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Vascular epiphytes of the Atlantic Forest in the Sinos River basin, state of Rio Grande do Sul, Brazil: richness, floristic composition and community structure

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Abstract

The Atlantic Forest, which has a vast epiphytic richness, is a priority area for preservation, listed as one of the five most important world hotspots. Vascular epiphyte richness, composition and community structure were studied in two fragments, one of the ombrophilous (29°43'42"S and 50°22'00"W) and the other of the seasonal (29°40'54"S and 51°06'56"W) forest, both belonging to the Atlantic Forest biome in the Sinos River basin, Rio Grande do Sul, Brazil. In each fragment, 40 trees, divided into four ecological zones, were analyzed. In each zone, the occurrence of the species was recorded, and the importance value of each species was calculated according to the frequency of phorophytes and intervals, and cover scores. The Shannon index was calculated for the two communities. In the fragment of the ombrophilous forest (F1), 30 epiphytic species were recorded, and in the seasonal forest (F2), 25. The highest importance value was found for *Microgramma squamulosa* (Kaulf.) de la Sota in both fragments. The diversity indexes for F1 (H'=2.72) and F2 (H'=2.55) were similar and reflected the subtropical location of the areas. The decrease in mean richness in both fragments in zone 3 (internal crown) to zone 4 (external crown) may be associated with time and space availability for epiphyte occupation and microclimate variations. Exclusive species were found in the areas, which suggest that a greater number of preserved fragments may result in a greater number of preserved epiphytic species in the Sinos River basin.

Keywords: vertical distribution, epiphytism, phytosociology, floristic diagnostic, southern Brazil.

Epífitos vasculares em Floresta Atlântica da bacia do Rio dos Sinos, estado do Rio Grande do Sul, Brasil: riqueza, composição florística e estrutura comunitária

Resumo

A Floresta Atlântica apresenta uma grande riqueza de epífitos e é considerada uma área prioritária para preservação listada entre os cinco mais importantes *hotspots* mundiais. A riqueza, a composição e a estrutura comunitária de epífitos vasculares foram estudadas em um fragmento de floresta ombrófila (29°43'42"S e 50°22'00"O) e outro de floresta estacional (29°40'54"S e 51°06'56"O), ambos pertencentes ao Bioma Floresta Atlântica, na bacia do Rio dos Sinos, Rio Grande do Sul, Brasil. Em cada fragmento foram analisadas 40 árvores divididas em quatro zonas ecológicas. Em cada zona, foi registrada a ocorrência das espécies e o valor de importância de cada uma delas foi calculado a partir da frequência nos forófitos e nos intervalos e das notas de cobertura. O índice de Shannon foi aplicado para as duas comunidades. No fragmento de floresta ombrófila (F1) foram registradas 30 e no de floresta estacional (F2) 25 espécies epifíticas. O maior valor de importância foi observado para *Microgramma squamulosa* (Kaulf.) de la Sota, em ambos os fragmentos. Os índices de diversidade para o F1 (H'=2,72) e o F2 (H'=2,55) foram próximos e refletem a posição geográfica mais subtropical das áreas. A diminuição na riqueza média em ambos os fragmentos da zona 3 (copa interna) para a zona 4 (copa externa) pode estar relacionada com a disponibilidade de tempo e de espaço para a ocupação de epífitos e com variações microclimáticas. Considerando que as áreas apresentaram espécies exclusivas, ficou evidenciado que um maior número de fragmentos conservados conduzirá à manutenção de um maior número de espécies epifíticas na bacia do Rio dos Sinos.

Palavras-chave: distribuição vertical, epifitismo, fitossociologia, diagnóstico florístico, sul do Brasil.

1. Introduction

Epiphytes account for a substantial part of forest diversity and up to 10% (Kress, 1986) to 50% (Kersten and Silva, 2005) of all vascular plants in tropical forests. The Atlantic Forest, listed as one of the five most important world hotspots, has 20,000 species of vascular plants (Myers et al. 2000), and 3,000 to 4,000 of them are epiphytic (Kersten, 2010). In the state of Rio Grande do Sul, Brazil, the Atlantic Forest has been reduced to only 7.48% of its original area (Fundação SOS Mata Atlântica and INPE, 2011), and ombrophilous and seasonal forests are found in some of the phytoecological regions of this biome.

Epiphytism has an important ecological function in forest communities and participates in the preservation of biological diversity by providing nutritional resources and specialized microenvironments for the fauna in the crown and by participating in nutrient cycling mechanisms; it is, therefore, considered as a local biodiversity amplifier (Nadkarni, 1984; Gentry and Dodson, 1987; Lugo and Scatena, 1992; Waechter, 1992; Rocha et al., 2004). Knowledge on vascular epiphyte composition and community structure has been used to define quality and environmental characteristics (Krömer et al., 2007). Epiphytic plants have been used to classify the successive regeneration stages of plant formations in the Atlantic Forest of Rio Grande do Sul, according to the CONAMA Resolution no. 33/94 (Brasil, 2012).

The spatial distribution of richness and the composition of the epiphytic flora may be affected by several factors at different scales and directions, such as the regional mosaic of plant types, the vertical profile of the forests, the characteristics of phorophytes and the climate conditions inside the forest (Gentry and Dodson, 1987; Nieder et al., 1997; Schmitt and Windisch, 2005; 2010; Waechter, 2006). Some of the microclimate factors that may affect vertical distribution are humidity, which tends to decrease from the ground to the apex, and luminosity, which increases in the same direction (Lüttge, 1989; Ter Steege and Cornelissen, 1989).

In general, epiphytes are extremely diversified and profuse in dense ombrophilous forests when compared with deciduous and semi-deciduous seasonal forests (Rambo, 1954; Klein, 1975; Roderjan et al., 2002), a similar distribution to that of fern richness (Sehnem, 1977; 1979). In the southern region of Brazil, studies have been conducted with different vegetation types, including coastal plains (Waechter, 1986; 1992; 1998; Kersten and Silva, 2001; Gonçalves and Waechter, 2003; Staudt et al., 2012; Becker et al., 2013), semi-deciduous (Aguiar et al., 1981; Borgo et al., 2002; Dettke et al., 2008) and deciduous (Rogalski and Zanin, 2003) seasonal forests, dense (Blum et al., 2011) and mixed (Borgo and Silva, 2003; Hefler and Faustioni, 2004; Schmitt et al., 2005; Brustulin and Schmitt, 2008; Buzatto et al., 2008; Bonnet et al., 2009; Kersten and Kuniyoshi, 2009; Kersten et al., 2009) ombrophilous forests, riparian forests (Giongo and Waechter, 2004) and areas of transition from semi-deciduous seasonal to mixed ombrophilous forests (Bonnet et al., 2010, 2011).

Among the studies that compared the epiphytism in different areas, Barthlott et al. (2001) analysed secondary and primary vegetations in a humid Montana forest in Venezuela. Flores-Palacios and García-Franco (2008) compared the relationship between tree size and species richness in forest and pastureland trees. Krömer et al. (2007) studied the vertical stratification in a submontane and montane forest of the Bolivian Andes. In Brazil, Menini-Neto et al. (2009) analysed the angiosperm epiphytes in forest fragments in southeastern Minas Gerais. Bataghin et al. (2010) compared the distribution of epiphytes in three sites with different degrees of disturbance in a semi-deciduous seasonal forest in the Floresta Nacional de Ipanema, in the state of São Paulo. In the state of Paraná, Kersten and Kuniyoshi (2009) evaluated epiphyte composition and distribution in eight areas of the mixed ombrophilous forest of the Alto Iguaçu river basin. In the same forest type, Bonnet et al. (2009) evaluated the vascular epiphyte diversity in four sites from the Corredor Araucária, relating it to factors of environmental degradation and forest characteristics. Bonnet et al. (2010) analysed three sections of riparian vegetation in the Tibagi River to evaluate the composition, distribution and association with environmental factors in each area. The present study evaluated the richness, composition and community structure of vascular epiphytes in two fragments in the upper and lower sections of the Sinos River basin, belonging to ombrophilous and semi-deciduous forests, respectively.

2. Material and Methods

2.1. Study area

This study was conducted in two secondary forest fragments located in the Sinos River basin in the state of Rio Grande do Sul, Brazil: (a) fragment 1 (F1) was in the upper section of the basin, in a rural area, next to the source of the Sinos River, in the municipality of Caraá (29°43’42”S and 50°22’00”W; 408.1 m alt.); 60 ha of predominantly dense ombrophilous forest with some remaining mixed ombrophilous forest; (b) fragment 2 (F2) was in the lower section of the basin, in the municipality of Novo Hamburgo (29°40’54”S and 51°06’56”W; 16.4 m alt.), in the Henrique Luís Roessler park, formally declared a Preservation Area in 2009, in the category of Relevant Area of Ecological Interest. This park is in the urban area of the town and has an area of 54.4 ha of fields and forests (Rosa, 2010) classified as lowlands semi-deciduous seasonal forest (Teixeira et al., 1986). The climate in the region of the two fragments is *Cfa* according to the Köppen classification: temperate with rainfall regularly distributed over the year; and temperature of the hottest month higher than 22 °C (Moreno, 1961). In Caraá (F1), rainfall is about 1,600 mm per year (Brigada Militar de Caraá, 2012); in the weather station close to F2, in the city of Campo Bom (29°41’S; 51°03’W; 25.8 m alt.), rainfall is about 1,500 mm per year.

2.2. Sampling

In both fragments, at least 40 phorophytes of arboreal angiosperms, measuring at least 10 cm in diameter at breast height (CBH) were selected for the study of the epiphytic community using the centered quadrant method (Cottam and Curtis, 1956). Sampling points were defined at 20 m intervals along a 200 m transect. The trees were divided according to Braun-Blanquet (1979) into four ecological zones: (1) lower bole, (2) upper bole or transition from upper bole to internal crown, (3) internal crown, and (4) external crown.

2.3. Floristic inventory

The floristic inventory was made during bimonthly visits in 2010 and 2011 by means of direct observation of the plants in the epiphytic environment or by using a combination of phorophyte climbing and observation from a distance with binoculars (BUSHNELL® - 96m AT 1000M). Representative fertile specimens were collected, labelled and classified according to the technique described by Guedes-Bruni et al. (2002). Species were identified according to the taxonomic literature, comparisons with botanical collections in herbaria, or consultations with specialists. Angiosperms were classified according to the APG III system (APG, 2009), and the ferns, according to Smith et al. (2006; 2008). Voucher material was deposited in the *Herbarium* Anchieta (PACA) in São Leopoldo, Brazil. Species were classified according to the type of association with phorophytes in the ecological categories described by Benzing (1995): holoepiphytes do not have any relation with the ground, as they complete all their life cycle in the epiphytic environment, and may be habitual, accidental or facultative; hemiepiphytes have a relationship with the ground, which may be primary, when their growth begins in the phorophyte, or secondary, when their growth begins in the ground. Floristic similarity between the two epiphyte communities was calculated using the Jaccard index based on a matrix of presence and absence of species.

2.4. Richness

For both fragments, a rarefaction curve was obtained (Gotelli and Colwell, 2001) to evaluate the association between the increase of specific richness and the number of phorophyte samples, at 95% confidence intervals and using the EstimateS 7.5 software. The curve stabilisation was considered an asymptote. The number of species for the total sample was estimated with the same software and 50 random repeated sampling with the Jackknife 1 nonparametric estimator, which uses data about species presence or absence.

The normal distribution of data about richness was evaluated using the Shapiro-Wilk test using the SPSS 20.0 program. Differences between the richness of the zones in each fragment were evaluated using the Kruskal-Wallis test followed by the Student-Newman-Keuls test, at 5% probability. Mean richness values between fragments were compared using the Mann-Whitney test, and the level of significance was set at 5%.

2.5. Phytosociological parameters

Absolute and relative frequencies of species per phorophyte and zone were calculated using the method described by Waechter (1998). For each species, a cover score was assigned to the corresponding zone according to the scale described by Kersten and Kunyioshi (2006): (1) very small and isolated individuals; (3) few small individuals or one larger individual; (5) medium-sized individuals or many small individuals; (7) large individuals or many medium-sized individuals; and (10) very large individuals or many large individuals. The sum of cover scores per zone was used to calculate relative cover for each species. The importance value was the mean of the sum of relative frequencies in the phorophytes and in the zones, and of the relative cover. Specific diversity was determined by the Shannon index (H'), using the natural logarithm of frequency data; equability was determined according to the Pielou index (J') (Magurran, 1988).

3. Results

3.1. Floristic inventory

In F1, there were 30 species distributed into 15 genera and four families, and in F2, 25 species in 19 genera and eight families (Table 1). The three richest families in both fragments were Polypodiaceae, Orchidaceae and Bromeliaceae. Aspleniaceae, Blechnaceae and Pteridaceae had only one species each. Besides *Pleopeltis* Humb. & Bonpl. ex Willd. in F1, *Tillandsia* L. was the richest genus in both fragments. A total of eight genera had only one species. The analysis of ecological category revealed that habitual holoepiphytes were predominant, with 97.56% (39 species) of the total number of species. *Asplenium claussenii* and *Blechnum binervatum* were the only species classified as accidental holoepiphytes and secondary hemiepiphytes, both found only in F2. Of all the species found in the two fragments, 15 were common to both fragments, 15 were exclusive of F1, and 10, of F2. The similarity between F1 and F2 was low, and the Jaccard index was 0.38.

3.2. Richness

The rarefaction curve based on the number of sampling units in both areas was not an asymptote (Figure 1). The richness estimator (Jackknife 1) showed that there might be even more species, and that 32.9 were estimated for F1 and 29.9 for F2. Mean total richness in F1 was 6.5 ± 2.7 species per tree, and a minimum of two and maximum of 13 species per phorophyte were recorded. In F2, mean total richness was 6.0 ± 2.1 species per tree, and a minimum of three and maximum of 11 species per phorophyte were recorded. Statistical analyses showed that means were not significantly different ($U = 710.00$; $P = 0.386$). In F1, phorophyte zone 2 had the highest mean richness without, however, being significantly different from zone 1. The highest richness means in F2 were recorded in the intermediate phorophyte zones (2 and 3). The comparison of the two areas revealed that mean richness recorded in zone 1 of the trees in F1 was

Table 1. Families and species of vascular epiphytes recorded in fragments 1 and 2, located in the upper and lower sections of the Sinos River basin. (HAB – habitual holoepiphyte; SHE = secondary hemiepiphyte; ACC = accidental holoepiphyte).

Family/species	Fragment		Ecological category
	1	2	
ASPLENIACEAE			
Asplenium claussenii Hieron.		X	ACC
BLECHNACEAE			
Blechnum binervatum (Poir.) C.V. Morton & Lellinger		X	SHE
BROMELIACEAE			
Aechmea calyculata (E. Morren) Baker		X	HAB
Billbergia nutans H.H. Wendl. ex Regel		X	HAB
Tillandsia aeranthos (Loisel.) L.B. Sm.	X	X	HAB
Tillandsia gardneri Lindl.	X		HAB
Tillandsia geminiflora Brongn.	X	X	HAB
Tillandsia recurvata (L.) L.	X	X	HAB
Tillandsia tenuifolia L.	X		HAB
Vriesea sp.	X	X	HAB
Vriesea gigantea Gaudich.	X		HAB
Vriesea rodigasiana E. Morren		X	HAB
Vriesea vagans (L.B. Sm.) L.B. Sm.	X		HAB
CACTACEAE			
Lepismium cruciforme (Vell.) Miq.		X	HAB
Rhipsalis teres (Vell.) Steud.		X	HAB
ORCHIDACEAE			HAB
Acianthera hygrophila (Barb. Rodr.) Pridgeon & M.W. Chase	X		HAB
Acianthera saurocephala (Lodd.) Pridgeon & M.W. Chase	X		HAB
Acianthera sonderana (Rchb. f.) Pridgeon & M.W. Chase	X		HAB
Baptistonia cornigera (Lindl.) Chiron & V.P.Castro	X		HAB
Brasiliorchis sp.	X		HAB
Campylocentrum aromaticum Barb. Rodr.		X	HAB
Cattleya intermedia Grah.	X		HAB
Coppensia flexuosa (Sims) Campacci	X	X	HAB
Isochilus linearis (Jacq.) R. Br.	X		HAB
Lophiaris pumila (Lindl.) Braem	X	X	HAB
Pabstiella mirabilis (Schltr.) Brieger & Senghas	X	X	HAB
Polystachya estrellensis Rchb. f.	X	X	HAB
PIPERACEAE			
Peperomia sp.		X	HAB
Peperomia tetraphylla (G. Forst.) Hook. & Arn.	X	X	HAB
PTERIDACEAE			
Vittaria lineata (L.) Sm.		X	HAB
POLYPODIACEAE			
Campyloneurum austrobrasilianum (Alston) de la Sota	X		HAB
Campyloneurum nitidum (Kaulf.) C. Presl	X	X	HAB
Microgramma squamulosa (Kaulf.) de la Sota	X	X	HAB
Microgramma vacciniifolia (Langsd. & Fisch.) Copel.	X	X	HAB
Pecluma recurvata (Kaulf.) M.G. Price	X		HAB
Pleopeltis astrolepis (Liebm.) E. Fourn.	X		HAB
Pleopeltis hirsutissima (Raddi) de la Sota	X	X	HAB
Pleopeltis pleopeltidis (Fée) de la Sota	X	X	HAB
Pleopeltis pleopeltifolia (Raddi) Alston	X	X	HAB
Pleopeltis polypodioides (L.) Andrews & Windham	X		HAB

higher than in the same zone of the phorophytes in F2, and the opposite was found in zones 3 and 4. In F1 and F2, zone 2 had statistically equivalent mean values of epiphytic species (Table 2).

3.3. Phytosociological parameters

Microgramma squamulosa had the highest importance value (IV) in both fragments and accounted for 87.5% of the phorophytes in F1 and 80.0% in F2. In F1, the second most important species was *Pleopeltis pleopeltifolia* (11.65%), and in F2, *Campyloneurum nitidum* (15.74%), which accounted for 62.5% and 82.5% of the phorophytes, respectively (Tables 3 and 4). In F1, *Microgramma vacciniifolia*, *Cattleya intermedia* and *Lophiaris pumila* were recorded in only one phorophyte and had, consequently, the lowest importance value (Table 3). In F2, *Billbergia nutans*, *Vriesea rodigasiana*, *Blechnum binervatum* and *Pleopeltis hirsutissima* were also found in only one phorophyte and had the lowest importance value (Table 4). The Shannon diversity indices (H') estimated for F1 and F2 were 2.72 and 2.55, and the equability indices (J) were 0.80 and 0.79.

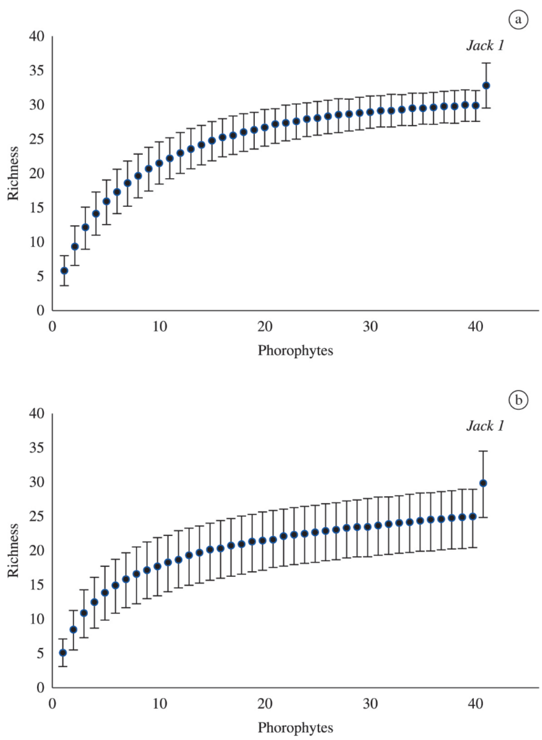

Figure 1. Rarefaction curves and vascular epiphytic richness estimate (Jackknife 1) in fragments of the Atlantic Forest in the (a) upper (F1) and (b) lower (F2) sections of the Sinos River basin, in the state of Rio Grande do Sul, Brazil. Bars indicate confidence interval.

4. Discussion

The area where the dense ombrophilous forest (F1) was predominant had a higher specific richness than the semi-deciduous seasonal forest (F2). The lower epiphytic richness of seasonal forests when compared with ombrophilous forests has already been described by other authors in the southern region of Brazil (Aguiar et al., 1981; Waechter, 1998; Borgo et al., 2002; Borgo and Silva, 2003). The specific richness in F1 was lower than that found by Blum et al. (2011) who recorded 278 species in 6.3 ha of ombrophilous forest which characterize a primary forest with little disturbance (Blum, 2006). The specific richness in F2 was greater than that found in other studies also conducted in the semi-deciduous seasonal forest. Aguiar et al. (1981) recorded 19 species in 37 phorophytes; Dettke et al. (2008), 22 species in 90 phorophytes; and Bataghin et al. (2010), 21 species in 270 phorophytes. Only Borgo et al. (2002) recorded a richer epiphytic flora (32 species), but based on the observation of 2,895 trees.

The families with the highest number of species in this study (Orchidaceae, Bromeliaceae and Polypodiaceae) are also the richest worldwide (Madison, 1977; Kress, 1986; Benzing, 1990), in neotropical regions (Gentry and Dodson, 1987) and in Brazil (Kersten, 2010). Other inventories of vascular epiphytes conducted in the Brazilian states of Rio Grande do Sul (Waechter, 1986, 1998; Gonçalves and Waechter, 2003; Rogalski and Zanin, 2003; Buzatto et al., 2008; Staudt et al., 2012) and of Paraná (Kersten and Silva, 2001; Borgo and Silva, 2003; Hefler and Faustioni, 2004; Dettke et al., 2008; Kersten et al., 2009; Bonnet et al., 2010; 2011; Blum et al., 2011) showed that these families have a great specific richness.

There was a concentration of vascular epiphyte species in few families, as found by Madison (1977), Kress (1986), Gentry and Dodson (1987) and Kersten (2010). According to

Table 2. Mean vascular epiphytic richness in the different phorophyte zones in a fragment of the Atlantic Forest of the upper (F1) and lower (F2) sections of the Sinos River basin, in the state of Rio Grande do Sul, Brazil.

Fragment	Zone 1 (mean ± SD)	Zone 2 (mean ± SD)	Zone 3 (mean ± SD)	Zone 4 (mean ± SD)	H	*P*
F1	2.30 ± 1.67 ab A	3.40 ± 2.11 a A	1.92 ± 1.79 b B	0.45 ± 1.26 c B	51.7174	< 0.001
F2	1.17 ± 1.03 b B	2.90 ± 1.97 a A	2.85 ± 1.39 a A	1.97 ± 1.92 b A	32.8759	< 0.001
U	482.00	705.50	496.00	315.50		
P	0.002	0.363	0.003	< 0.001		

H = Kruskal-Wallis test; U = Mann-Whitney test; *P* = probability; SD = standard deviation. Means with different lower case letters in the same line are significantly different by the Student-Newman-Keuls test at 5% probability. Means with different upper case letters in the same column are significantly different by the Mann-Whitney test at 5% probability.

Table 3. Community structure of vascular epiphytes in fragment 1 in decreasing order of importance value (IV). (np= number of phorophytes with species; nz= number of zones with species; AFf = absolute frequency of species on phorophytes; RFf = relative frequency of species on phorophytes; AFz = absolute frequency of species on zones; RFz = relative frequency of species on zones; ADo = absolute dominance of species (sum of coverage grades); RDo = relative dominance of species).

Species	np	nz	AFf	RFf	AFz	RFz	ADo	RDo	IV
Microgramma squamulosa	35	58	87.5	14.58	36.25	16.76	195	24.59	18.65
Pleopeltis pleopeltifolia	25	43	62.5	10.42	26.87	12.43	96	12.11	11.65
Pleopeltis pleopeltidis	28	36	70	11.67	22.5	10.40	76	9.58	10.55
Vriesea gigantea	11	22	27.5	4.58	13.75	6.36	86	10.84	7.26
Tillandsia aeranthos	14	24	35	5.83	15	6.94	50	6.31	6.36
Tillandsia gardneri	15	21	37.5	6.25	13.12	6.07	37	4.67	5.66
Tillandsia geminiflora	11	14	27.5	4.58	8.75	4.05	21	2.65	3.76
Campyloneurum nitidum	12	13	30	5.00	8.12	3.76	19	2.40	3.72
C. austrobrasilianum	10	14	25	4.17	8.75	4.05	14	1.77	3.33
Polystachya estrellensis	10	12	25	4.17	7.5	3.47	16	2.02	3.22
Pleopeltis hirsutissima	9	10	22.5	3.75	6.25	2.89	18	2.27	2.97
Coppensia flexuosa	5	8	12.5	2.08	5	2.31	16	2.02	2.14
Tillandsia tenuifolia	4	6	10	1.67	3.75	1.73	18	2.27	1.89
Isochilus linearis	4	6	10	1.67	3.75	1.73	18	2.27	1.89
Tillandsia recurvata	5	7	12.5	2.08	4.37	2.02	11	1.39	1.83
Baptistonia cornigera	5	5	12.5	2.08	3.12	1.45	11	1.39	1.64
Acianthera saurocephala	3	8	7.5	1.25	5	2.31	8	1.01	1.52
Peperomia tetraphylla	5	5	12.5	2.08	3.12	1.45	7	0.88	1.47
Acianthera sonderana	4	4	10	1.67	2.5	1.16	8	1.01	1.28
Pleopeltis astrolepis	4	4	10	1.67	2.5	1.16	8	1.01	1.28
Pleopeltis polypodioides	3	4	7.5	1.25	2.5	1.16	8	1.01	1.14
Vriesea sp.	3	3	7.5	1.25	1.87	0.87	9	1.13	1.08
Vriesea vagans	3	3	7.5	1.25	1.87	0.87	9	1.13	1.08
Acianthera hygrophila	2	3	5	0.83	1.87	0.87	11	1.39	1.03
Pabstiella mirabilis	3	4	7.5	1.25	2.5	1.16	4	0.50	0.97
Brasiliorchis sp.	2	3	5	0.83	1.87	0.87	7	0.88	0.86
Pecluma recurvata	2	2	5	0.83	1.25	0.58	2	0.25	0.55
Microgramma vacciniifolia	1	2	2.5	0.42	1.25	0.58	4	0.50	0.50
Cattleya intermedia	1	1	2.5	0.42	0.625	0.29	3	0.38	0.36
Lophiaris pumila	1	1	2.5	0.42	0.625	0.29	3	0.38	0.36

Gentry and Dodson (1987), a small number of families may also reflect the specialization of some of these families in the environments under study. This trend in the distribution of species was also found in other inventories of epiphytic communities conducted in southern and southeastern Brazil (Waechter, 1986; 1992; 1998; Kersten and Silva, 2001, Borgo et al., 2002; Borgo and Silva, 2003; Gonçalves and Waechter, 2003; Rogalski and Zanin, 2003; Hefler and Faustioni, 2004; Buzatto et al., 2008; Dettke et al., 2008; Menini-Neto et al., 2009; Mania and Monteiro, 2010; Staudt et al., 2012). The three richest families accounted for 82.5% of the recorded species. According to Kersten (2010), 91% of the species in Brazil are part of the 10 richest families, and in the case of the 20 richest families, this percentage may reach 98% of the total species recorded. The success of these three families in the epiphytic environment is associated with several adaptations to drought resistance and water saving (Staudt et al., 2012).

The predominance of habitual holoepiphytes over the other categories has also been observed by Aguiar et al. (1981), Waechter (1986; 1998); Kersten and Silva (2001; 2002); Borgo et al. (2002); Borgo and Silva (2003); Gonçalves and Waechter (2003); Rogalski and Zanin (2003), Giongo and Waechter (2004); Kersten and Kunyioshi (2006) and Schmitt and Windisch (2010). Habitual holoepiphytes had more specialized and diversified vegetative adaptations, which favoured a more generalized distribution of forest formations (Fraga et al., 2008).

The inventory of all species in an area is virtually impossible (Santos, 2004). The richness estimator indicated that 91% and 83% of the total richness was sampled in F1 and F2. These estimates are not precise previews of the actual number of species, but they indicate minimum expected values (Colwell et al., 2004) in the epiphytic communities in both fragments.

Microgramma squamulosa (Polypodiaceae) had the highest importance value in both fragments, in the same way

Table 4. Community structure of vascular epiphytes in fragment 2 in decreasing order of importance value (IV). (np= number of phorophytes with species; nz= number of zones with species; AFf = absolute frequency of species on phorophytes; RFf = relative frequency of species on phorophytes; AFz = absolute frequency of species on zones; RFz = relative frequency of species on zones; Ado = absolute dominance of species (sum of coverage grades); RDo = relative dominance of species).

Species	np	nz	AFf	RFf	AFz	RFz	ADo	RDo	IV
Microgramma squamulosa	32	61	80.0	13.62	38.13	17.43	211	21.21	17.42
Campyloneurum nitidum	33	63	82.5	14.04	39.38	18.00	151	15.18	15.74
Peperomia sp.	19	35	47.5	8.09	21.88	10.00	123	12.36	10.15
Rhipsalis teres	21	27	52.5	8.94	16.88	7.71	107	10.75	9.13
Pleopeltis pleopeltifolia	16	22	40.0	6.81	13.75	6.29	70	7.04	6.71
Coppensia flexuosa	14	18	35.0	5.96	11.25	5.14	58	5.83	5.64
Tillandsia aeranthos	14	18	35.0	5.96	11.25	5.14	34	3.42	4.84
Tillandsia geminiflora	12	16	30.0	5.11	10.00	4.57	43	4.32	4.67
Peperomia tetraphylla	15	17	37.5	6.38	10.63	4.86	22	2.21	4.48
Pleopeltis pleopeltidis	8	12	20.0	3.40	7.50	3.43	30	3.02	3.28
Pabstiella mirabilis	10	11	25.0	4.26	6.88	3.14	13	1.31	2.90
Vriesea sp.	5	6	12.5	2.13	3.75	1.71	22	2.21	2.02
Microgramma vacciniifolia	4	7	10.0	1.70	4.38	2.00	21	2.11	1.94
Campylocentrum aromaticum	5	6	12.5	2.13	3.75	1.71	16	1.61	1.82
Polystachya estrellensis	4	6	10.0	1.70	3.75	1.71	17	1.71	1.71
Aechmea calyculata	3	4	7.5	1.28	2.50	1.14	13	1.31	1.24
Vittaria lineata	4	5	10.0	1.70	3.13	1.43	5	0.50	1.21
Tillandsia recurvata	4	4	10.0	1.70	2.50	1.14	7	0.70	1.18
Oncidium pumilum	4	4	10.0	1.70	2.50	1.14	4	0.40	1.08
Lepismium cruciforme	2	2	5.0	0.85	1.25	0.57	8	0.80	0.74
Asplenium claussenii	2	2	5.0	0.85	1.25	0.57	4	0.40	0.61
Billbergia nutans	1	1	2.5	0.43	0.63	0.29	7	0.70	0.47
Vriesea rodigasiana	1	1	2.5	0.43	0.63	0.29	3	0.30	0.34
Blechnum binervatum	1	1	2.5	0.43	0.63	0.29	3	0.30	0.34
Pleopeltis hirsutissima	1	1	2.5	0.43	0.63	0.29	3	0.30	0.34

as found in studies conducted by Kersten and Silva (2001), Kersten and Kuniyoshi (2009) and Geraldino et al. (2010). This species has been described as a pioneer (Kersten and Silva, 2001; Geraldino et al., 2010), which confirms the secondary character of the fragments under analysis. *Microgramma squamulosa* is found in not very dense primary and secondary forests, over isolated trees, even in parks, as well as on stone walls (Sehnem, 1970), which confirms its high plasticity and adaptation to different environments. It extends over boles and branches and takes up large areas, which is the reason why it has small individuals and reptant growth.

The species with the second highest importance value in F1, *Pleopeltis pleopeltifolia* (Polypodiaceae), was also the second in the mixed ombrophilous forest (Kersten and Kuniyoshi, 2009) in the state of Paraná, as well as in the ecotone between the semi-deciduous seasonal and the mixed ombrophilous forests (Geraldino et al., 2010) in the same state. In the same way as in F2, *Campyloneurum nitidum* (Polypodiaceae) had the second highest importance value in the inventory conducted by Schneider and Schmitt (2011) in a semi-deciduous seasonal forest in the state of Rio Grande do Sul, but they considered only phorophytes of *Alsophila setosa* Kaulf. In these three Polypodiaceae species, adaptations such as frond trichomes (Müller et al., 1981), rhizome succulence (Waechter, 1992), poikilohydry (Benzing, 1990) and the higher sclerophylly index and stomatal density prevent dehydration (Rocha et al., 2013) and facilitate a greater occupation of phorophytes, increasing their importance in the organisation of the epiphytic community.

Diversity indices found in F1 and F2 were very similar, and mean total richness recorded in phorophytes was statistically equivalent. The values of the Shannon index in the fragments were close to those recorded by Waechter (1998) in Emboaba, in the city of Osório (2.99), and by Waechter (1992) in Taim, in the city of Rio Grande (2.89), in the coastal plains of Rio Grande do Sul, as well as by Kersten and Silva (2002) in a mixed ombrophilous forest (2.71) in the state of Paraná, Brazil. They were lower than the values found by Giongo and Waechter (2004) in riparian forests in Rio Grande do Sul (3.43), Kersten and Silva (2001) in Ilha do Mel (3.61), Kersten and Kunyioshi (2006) in a dense ombrophilous forest (4.07) and Geraldino et al. (2010) in a transition area between a mixed ombrophilous forest and a semi-deciduous seasonal forest (3.17) in the state of Paraná. The lower values found in this study, particularly in relation to other places in Paraná, reflect their geographic location, which was characteristically more subtropical in the areas under analysis. The high diversity and the richness of vascular epiphytes in the tropical regions visually decrease towards the south because of the lower temperatures and greater rainfall, as well as the variations in environmental conditions due to the topography (Waechter, 1992).

The trend towards an increase in mean richness from zone 1 to zone 2 in both fragments is associated with the fact that boles are areas that do not usually promote epiphyte colonisation because of their verticality (Bøgh, 1992), less luminosity (Parker, 1995) and exposure to the action of herbivorous animals (bovine cattle) that move around the trees (Gonçalves and Waechter, 2002), as well as to the extraction of ornamental epiphytic plants. Human action may be one of the determinant factors of differences in richness found in zone 1 in F1 when compared with F2. In F2, an urban park used for leisure, public visitation is intense, and epiphytes with any ornamental value may have been removed illegally from the tree boles. Epiphytes are usually more diversified in intermediate zones, where phorophyte structures provide the necessary space and support for epiphytic flora (Nieder et al., 1999), as seen in both areas under analysis, but more evident in F2. The decrease in mean richness in both fragments from zone 3 to zone 4 is associated with the fact that the latter is the most recent part of the tree and, consequently, it had the shortest time to receive epiphytes. Yeaton and Gladstone (1982) reported that substrate availability time is an important factor in the development of epiphytic plants in phorophytes. The external crown branches are thinner with smaller areas and less diversified structurally, which may result in a smaller number of species. In addition, in the external crown there is great microclimate variability characterised by long periods of low humidity, high temperatures and strong winds (Krömer et al., 2007).

Although both F1 and F2 belong to the Atlantic Forest Biome and had similar richness means and diversity indices, there were exclusive species in each area, which resulted in low similarity and revealed a characteristic floristic identity in each area. This low coefficient of similarity between epiphytic floras of the two study areas was expected due to environmental differences such as altitude and forest type. Regardless of the nature of the matrix, whether urban or rural, in which the fragments are located, all should be taken into consideration when defining handling and preservation procedures. Therefore, if more fragments are protected, a larger number of epiphytic species may be preserved in the Sinos River basin.

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