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Lycophytes and ferns composition of Atlantic Forest conservation units in western Paraná with comparisons to other areas in southern Brazil

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ABSTRACT

This study surveyed lycophyte and fern species in four forest fragments in western Paraná, Brazil, and compared them to 15 other fragments with different plant formations from the Atlantic Forest biome in southern Brazil. In total, five lycophyte species (in two families and two genera) and 98 species and two varieties of ferns (in 16 families and 38 genera) were registered in the four fragments. The most represented families were Pteridaceae (23 spp.), Polypodiaceae (18 spp.), Aspleniaceae (13 spp.), and Thelypteridaceae (11 spp.). *Asplenium* (12 spp.), *Thelypteris* (10 spp.), and *Blechnum* (seven spp.) were among the most represented genera. The occurrence of *Dicksonia sellowiana* was noteworthy because it was associated with seasonal semideciduous forest and is threatened in Brazil. Similarity among areas was determined by a cluster analysis (UPGMA and Sørensen's index) and the relation between similarity and geographic distance was determined through Matel's analysis. The analyses revealed greater similarity among the four study areas and, for these areas as a whole, greater similarity to fragments in Rio Grande do Sul, which is evidence that these areas have similar environmental conditions.

Keywords: *Araucaria* forest, pteridophytes, semideciduous forest, similarity, species richness

Introduction

Lycophytes and ferns are represented by about 13,600 species. The distribution of these groups follows a pattern known as the latitudinal gradient of diversity, where in both hemispheres, from poles to equator, the number of species per unit area increases more than 30 times (Moran 2008). However, pteridophyte richness is not regular, and around 75% of this group occurs in tropical and subtropical humid regions (Tryon & Tryon 1982).

The Atlantic Forest is one of the 34 global "hotspots" of biodiversity (Mittermeier *et al.* 2004), is the second largest tropical forest in the Americas, and originally extended continuously along the Brazilian coast, to eastern Paraguay and northeastern Argentina at its southern limit (SOS Mata Atlântica 2015). In Brazil, it is regarded as one of the richest biomes in plant diversity where there are 15,782 species, of which 7,155 are endemic (Stehmann *et al.* 2009). Out of the total number of species in the Atlantic Forest, 840 are lycophytes and ferns (Salino & Almeida 2009).

The high environmental diversity of the Atlantic Forest is thought to be the cause of the species richness, diversity, and high degree of endemism in this biome (Silva & Casteleti 2005). Latitude varies significantly along the Atlantic Forest, which, unlike other tropical forests, stretches more than 27 degrees. Elevation is also an important factor, which ranges from sea level to 2,700 m (Rizzini 1992). In addition, there is longitudinal variation, where inland forests differ significantly from those near the coast; the more inland the forests are, the more seasonal they become (Oliveira-Filho & Fontes 2000).

Species composition varies widely because of environmental diversity. MacArthur & Wilson (1967) pointed out that geographical proximity influences floristic similarity and, according to Oliveira-Filho & Fontes (2000), different forest formations in the Atlantic Forest have different plant species compositions. Thus, for biodiversity conservation purposes, the Atlantic Forest cannot be addressed as a homogeneous unit and there is a need to take into account the various forest types found in this biome. As defined by Veloso *et al.* (1991), this biome has the following plant formations: rainforest, *Araucaria* forest, semideciduous forest and deciduous forest, as well as associated ecosystems, such as mangroves, *restinga*, high

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altitude grasslands, inland swamps, and forest enclaves in the Northeast Region.

In Paraná, the remaining Atlantic Forest is restricted to a few publicly and privately protected areas, such as Parque Nacional do Iguaçu, Parque Nacional de Ilha Grande, Parque Estadual São Camilo, Parque Estadual da Cabeça do Cachorro, Parque Estadual do Rio Guarani, and the private nature reserve Fazenda Santa Maria. Most of these areas are included in the Iguaçu-Paraná Biodiversity Corridor, located in the Iguaçu and Paraná III river basins (Tossulino *et al.* 2007).

The aim of this study was to survey the ferns and lycophytes in Parque Estadual Cabeça do Cachorro (PECC), Parque Estadual do Rio Guarani (PERG), Parque Nacional do Iguaçu (PNI) and Fazenda Santa Maria (FSM), and to analyze the floristic similarity among these four areas and other areas of Atlantic Forest in southeastern and southern Brazil. This study considers the hypothesis that areas with similar forest formations have a similar floristic composition, regardless of their geographical proximity (MacArthur & Wilson 1967; Oliveira Filho & Fontes 2000).

Material and methods

Study areas

The study was conducted in four protected areas (Fig. 1). In these regions the climate is characterized as mesothermal humid subtropical, which is CFA in Köppen's classification (Köppen 1931), with an average annual temperature of 21ºC. Summers have an average temperature of over 22ºC and winters have an average below 18ºC. Rainfall is well distributed throughout the year, decreasing slightly in the winter, and annual rainfall is around 1,800 mm (IAPAR 2015). Soils are predominantly dark red, purple, and dark brown latosols, with a deep profile and high fertility (Larach *et al.* 1984).

Parque Estadual Cabeça do Cachorro (PECC), located at 24°54'47"S/53°54'35"W, is 60.98 ha and 371 m above sea level (IAP 2006). Fazenda Santa Maria (FSM), located at 25°29'47"S/54°21'47"W, is 250 ha and 292 m above sea level. Parque Nacional do Iguaçu (PNI), located between 25°05'S/25°41'W and 53°40'S/54°38'W, is the largest fragment with an area of 185,262.5 ha and has an elevation ranging from 100 to 600 m (IBAMA 1999). Parque Estadual do Rio Guarani (PERG), located between 25°05'S/25°41'W and 53°40'S/54°38'W, is 2,235 ha and 300 to 400 m above sea level (IAP 2002).

The dominant vegetation in the four areas is semideciduous forest; however, in Parque Nacional do Iguaçu there is also a portion that is predominantly transitional vegetation between semideciduous forest and *Araucaria* forest (Roderjan *et al.* 2002; IBGE 2012).

Floristic survey

The floristic survey was conducted between August 2010 and September 2013. In Parque Estadual Cabeça do Cachorro and RPPN Fazenda Santa Maria, the existing trails were surveyed, totaling about 3.5 Km in each area. For the Parque Nacional do Iguaçu, 20 trails were surveyed, totaling about 50 km. In Parque Estadual do Rio Guarani, seven

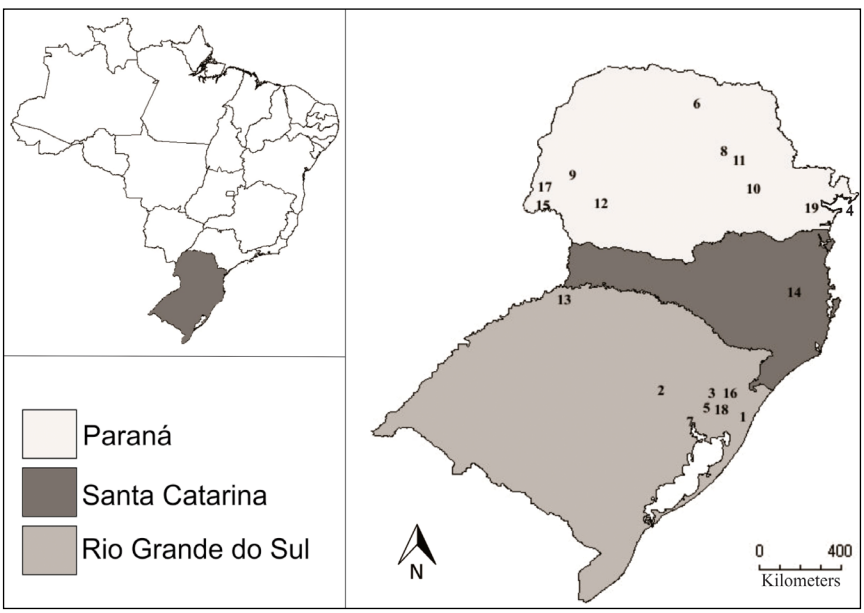

Figure 1. Locations of study areas and areas selected for the similarity analysis. **1. MB**: Área de Proteção Ambiental Morro da Borússia; **2. RVT**: Remnants from Vale do Taquari; **3. FLONAC**: Floresta Nacional de Canela; **4. IM**: Ilha do Mel; **5. LPV**: Location Picada Verão; **6. MG:** Mata do Godoy; **7. ME**: Morro da Extrema; **8. PEcK**: Parque Ecológico Klabin; **9. PECC**: Parque Estadual Cabeça do Cachorro; **10. PEVV**: Parque Estadual Vila Velha; **11. PEG**: Parque Estadual Guartelá; **12. PERG**: Parque Estadual Rio Guarani; **13. PET**: Parque Estadual Turvo; **14. PNSI**: Parque Nacional Serra de Itajaí; **15. PNI**: Parque Nacional Iguaçu; **16. MR**: Parque Natural Municipal da Ronda; **17. FSM**: Fazenda Santa Maria; **18. SFP**: Mata de São Francisco de Paula; **19. SMPr**: Serra do Mar Paranaense.

trails were surveyed, totaling about 17 km. Sampling was done in an unsystematic way in order to go through all of the vegetation types. Information regarding the habitat and habit of collected plants was recorded.

The plants were collected and processed according to standard techniques for lycophytes and ferns (Bridson & Forman 1998) and the specimens were archived at UNOP (Universidade do Oeste do Paraná) and BHCB (Thiers 2015). Additional specimens from BHCB and MBM (Thiers 2015) were included in the study.

Species were identified using the literature and herbarium specimens. For lycophytes, the classification system proposed by Kramer & Green (1990), with modifications by Øllgaard (2012), was used. The classification of ferns was based on Smith *et al.* (2006), with modifications by Rothfels *et al.* (2012) for Woodsiaceae. Author names of taxa were abbreviated according to the International Plant Names Index (IPNI) (Brummit & Powell 1992).

Similarity

The list of lycophyte and fern species in the sampled areas (Parque Estadual Cabeça do Cachorro, Fazenda Santa Maria, Parque Nacional do Iguaçu, and Parque Estadual do Rio Guarani) was compared to 15 other, previously published lists (Tab. 1) for Atlantic Forest areas in southern Brazil (Fig. 1).

To compare the floristic similarity, we constructed a presence/absence matrix of species (Tabs. 1-2). A cluster analysis was performed with this matrix, which resulted in a dendrogram, by using the algorithm unweighted pair-group method using arithmetic averages (UPGMA) and Sørensen's index (Bray-Curtis) (Gotelli & Ellison 2011). To assess the deformation degree caused by the dendrogram construction, the cophenetic correlation coefficient was calculated (Hammer & Harper 2006). Analyses were conducted using the software *Palaeontological Statistics* (PAST) (Hammer *et al.* 2001).

To test the hypothesis that closer areas are more similar regarding their composition, Mantel's test was chosen because it is a test where the predictor variable is space, measured as geographical distance (Hammer & Harper 2006).

Results and Discussion

Floristic survey

In the four protected areas surveyed, 105 taxa (103 species and two varieties) were recorded. Of these, five species are lycophytes and 98 species and two varieties are ferns. The lycophytes are represented by two families, Selaginellaceae and Lycopodiaceae, each with one genus (Tab. 2). The ferns are distributed among 16 families and 38 genera (Tab. 2).

Table 1. List of the 19 locations included in the floristic similarity analysis of lycophytes and ferns. **Location:** APA: Environmental Protection Area; PR: Paraná; RPPN: Private nature reserve; RS: Rio Grande do Sul; SC: Santa Catarina. **Vegetation:** NG: natural grasslands; GF: General Fields; CF: Campestral Formations; DF: Deciduous Forest; SF: Semideciduous Forest; AF: *Araucaria* forest; GFo: Gallery Forest; RA: Rainforest; RES: Restinga; Sub: Submontane.

Code	Location	State	Area (ha)	Elevation (m)	Vegetation	N of species	Reference
1	APA Morro da Borussia (MB)	RS	7	50 - 398	RA/Sub	53	Santos & Windisch 2008
2	Remnants from "Vale do Taquari" (RVT)	RS	90 and 160	500 - 600	DF	56	Lehn *et al.* 2009
3	Floresta Nacional de Canela (FLONAC)	RS	517.7	770	AF	58	Schmitt *et al.* 2006
4	Ilha do Mel (IM)	PR	3	0 - 148	CF/RES/RA	114	Salino *et al.* 2005
5	Location Picada Verão (LPV)	RS	-	220 - 250	SF/Sub	77	Junior & Rörig 2001
6	Mata do Godoy (MG)	PR	690	690	SF	40	Rosseto & Vieira 2013
7	Morro da Extrema (ME)	RS	1	255	RA	45	Senna & Kazmirczak 1997
8	Parque Ecológico Klabin (PEcK)	PR	11,196	885	SF/AF/NG	121	Sakagami 2006
9	Parque Estadual Cabeça do Cachorro (PECC)	PR	60.98	370	SF	38	Present study
10	Parque Estadual Vila Velha (PEVV)	PR	3,803.28	800 – 1,100	AF/NG	151	Schwartsburd & Labiak 2007
11	Parque Estadual do Guartelá (PEG)	PR	798.97	770 – 1,100	GF/GFo	164	Michelon & Labiak 2013
12	Parque Estadual do Rio Guarani (PERG)	PR	2	300 - 400	SF	61	Present study
13	Parque Estadual do Turvo (PET)	RS	18	100 - 400	SF	66	Brack *et al.* 1985
14	Parque Nacional Serra de Itajaí (PNSI)	SC	57	150 - 940	RA	185	Gasper & Sevegnani 2011
15	Parque Nacional do Iguaçu (PNI)	PR	185, 262.5	200 - 600	SSF / AF	101	Present study
16	Parque Natural Municipal da Ronda (MR)	RS	1	870	AF	42	Blume *et al.* 2010
17	RPPN Fazenda Santa Maria (FSM)	PR	250	292	SSF	40	Present study
18	São Francisco de Paula (SFP)	RS	400	941	AF	41	Senna & Waechter 1997
19	Serra do Mar Paranaense (SMPr)	PR	1,800	0 - 1889	RA/RES	166	Paciencia 2008

Table 2. List of lycophyte and ferns species that occur in four protect areas in western Paraná. Voucher: ML: Mayara Lautert; PHL: Paulo Henrique Labiak; RSV: Raquel Stauffer Viveros. Habit: Ep: Epiphyte; Ru: Rupicolous; Sc: scandent; Tr: Terrestrial. Area sampled: 1. Parque Estadual Cabeça do Cachorro; 2. Fazenda Santa Maria; 3. Parque Nacional do Iguaçu; 4. Parque Estadual do Rio Guarani. • Species collected exclusively in semideciduous forest; * Species collected exclusively in *Araucaria* forest.

Taxon	Habit	Voucher	Area sampled			
			1	2	3	4
ANEMIACEAE						
Anemia raddiana Link •	Tr/Ru	ML 326			X	
Anemia phyllitidis (L.) Sw.	Tr	ML 72	X	X	X	X
ASPLENIACEAE						
Asplenium abscissum Willd. •	Tr/Ep	ML 267			X	X
Asplenium auriculatum Sw. •	Ep	PHL 3760			X	
Asplenium brasiliense Sw. •	Tr/Ep	ML 312	X	X	X	X
Asplenium claussenii Hieron. •	Tr	ML 69	X	X	X	X
Asplenium gastonis Fée	Ep	ML 231	X	X	X	X
Asplenium inaequilaterale Willd.	Tr/Ru	ML 298		X	X	X
Asplenium kunzeanum Klotzsch ex Rosenst. •	Tr	ML 370			X	
Asplenium mucronatum C.Presl •	Ep	ML 302		X		
Asplenium pulchellum Raddi •	Tr	ML 318			X	X
Asplenium scandicinum Kaulf.	Ep	ML 144	X	X	X	X
Asplenium serratum L. •	Tr/Ep	ML 33	X	X	X	X
Asplenium stuebelianum Hieron. •	Tr/Ep	RSV 137			X	X
Hymenasplenium triquetrum (N. Murak. & R. C. Moran) L. Regalado & Prada •	Ru	ML374			X	
ATHYRIACEAE						
Deparia pertersenii (Kunze) M.Kato*	Tr	ML 286			X	
Diplazium ambiguum Raddi	Tr	ML 266			X	X
Diplazium cristatum (Desr. in Lam.) Alston	Tr	ML 130	X	X	X	X
Diplazium herbaceum Fée •	Tr	ML 306			X	X
Diplazium lindbergii (Mett.) Christ	Tr	ML 288			X	X
BLECHNACEAE						
Blechnum acutum (Desv.) Mett.	Tr/Ep	ML 118	X	X	X	X
Blechnum austrobrasilianum de la Sota	Tr	ML 264			X	X
Blechnum brasiliense Desv. •	Tr	ML 307	X	X	X	X
Blechnum gracile Kaulf.	Tr	ML 156		X	X	X
Blechnum lanceola Sw.	Tr	ML 163			X	X
Blechnum occidentale L. •	Tr	ML 373		X	X	X
Blechnum polypodioides Raddi	Tr	PHL 3737			X	
CYATHEACEAE						
Alsophila setosa Kaulf.	Tr	ML 31	X	X	X	X
Cyathea atrovirens (Langsd. & Fisch.) Domin •	Tr	RSV 172			X	
Cyathea phalerata Mart.	Tr	ML 280			X	X
DENNSTAEDTIACEAE						
Dennstaedtia cicutaria (Sw.) T. Moore •	Tr	ML 101				X
Dennstaedtia dissecta T. Moore •	Tr	ML 172			X	X
Dennstaedtia globulifera (Poir.) Hieron.	Tr	ML 315	X	X	X	X
Hypolepis stolonifera Fée *	Tr	ML 292			X	
DICKSONIACEAE						
Dicksonia sellowiana Hook.	Tr	ML 289			X	X

Continues.

Table 2. Continuation.

Taxon	Habit	Voucher	Area sampled			
			1	2	3	4
DRYOPTERIDACEAE						
Ctenitis submarginalis (Langsd. & Fisch.) Ching	Tr	ML 147	X	X	X	X
Didymochlaena truncatula (Sw.) J. Sm.	Tr	ML 68	X	X	X	X
Lastreopsis effusa (Sw.) Tindale	Tr	ML 81	X	X	X	X
Megalastrum connexum (Kaulf.) A. R. Sm. & R. C. Moran	Tr	ML 316	X	X	X	X
Megalastrum umbrinum (C.Chr.) A.R. Sm. & R. C. Moran	Tr	ML 263			X	
Polystichum platylepis Fée *	Tr	ML 290			X	
HYMENOPHYLLACEAE						
Didymoglossum krausii (Hook. & Grev.) C.Presl	Ru	ML 252			X	X
Polyphlebium angustatum (Carmich.) Ebihara & Dubuisson	Ep	ML 238		X	X	X
Polyphlebium diaphanum (Kunth) Ebihara & Dubuisson	Ru/Ep	ML 37		X	X	X
Vandenbochia collariata (Bosch) Ebihara & Dubuisson	Ep/Ru	ML 372				X
LOMARIOPSIDACEAE						
Nephrolepis cordifolia (L.) C. Presl •	Ep/Tr	RSV 124			X	
LYCOPODIACEAE						
Phlegmariurus mandiocanus (Raddi) B. Øllg.	Ep	ML 141			X	
LYGODIACEAE						
Lygodium volubile Sw. •	Sc	ML 186			X	
OSMUNDACEAE						
Osmunda regalis L.	Tr	ML 276			X	X
POLYPODIACEAE						
Campyloneurum austrobrasilianum (Alston) de la Sota •	Ep	ML 103				X
Campyloneurum minus Fée •	Ep	RSV 255			X	
Campyloneurum nitidum (Kaulf.) C. Presl	Ep	ML 80	X	X	X	X
Microgramma lindbergii (Mett.) de la Sota •	Ep	ML 257			X	
Microgramma squamulosa (Kaulf.) de la Sota	Ep	ML 53	X	X	X	X
Microgramma vacciniifolia (Langsd. & Fisch.) Copel. •	Ep	RSV 224			X	
Niphidium crassifolium (L.) Lellinger	Ep	ML 138			X	X
Pecluma filicula (Kaulf.) M.G.Price	Ep	ML 304		X	X	X
Pecluma pectinatiformis (Lindm.) M. G. Price	Ep	ML 42			X	X
Pecluma robusta (Fée) M.Kessler & A. R. Sm. •	Tr/Ep	ML 308		X	X	
Pecluma sicca (Lindm.) M. G. Price	Ep	ML 135	X	X	X	X
Pecluma singeri (de la Sota) M. G. Price	Ep	ML 314	X	X	X	X
Pecluma truncorum (Lindm.) M. G. Price	Ep	ML 25	X	X	X	X
Pleopeltis astrolepis (Liebm.) E. Fourn. •	Ep	ML 328			X	
Pleopeltis hirsutissima (Raddi) de la Sota	Ep	ML 43	X	X	X	X
Pleopeltis minima (Bory) J. Prado & R. Y. Hirai	Ep	ML 177	X	X	X	X
Pleopeltis pleopeltifolia (Raddi) Alston.	Ep	ML 71	X	X	X	X
Serpocaulon vacillans (Link) A. R. Sm.*	Tr	ML 152			X	
PTERIDACEAE						
Adiantopsis chlorophylla (Sw.) Fée *	Tr	ML 282			X	
Adiantopsis perfasciculata Sehnem *	Tr	ML 341			X	
Adiantopsis radiata (L.) Fée	Tr	ML 70	X	X	X	X

Continues.

Table 2. Continuation.

Taxon	Habit	Voucher	Area sampled			
			1	2	3	4
Adiantum incertum Lindm. •	Tr	ML 260			X	
Adiantum obliquum Willd. •	Tr	RSV 152			X	
Adiantum pseudotinctum Hieron.	Tr	ML 84	X	X	X	X
Adiantum raddianum C. Presl	Tr	ML 83	X	X	X	X
Adiantum tetraphyllum Willd. •	Tr	ML 334			X	
Doryopteris concolor (Langsd. & Fisch.) J. Sm.	Tr	ML 57	X	X	X	X
Doryopteris majestosa Yesilyurt	Tr	ML 66	X	X	X	X
Doryopteris pentagona Pic. Serm	Tr	ML 65	X	X	X	
Hemionitis tomentosa (Lam.) Raddi	Tr	ML 325			X	
Pityrogramma calomelanos (L.) Link *var. calomelanos**	Tr	ML 278			X	
Pityrogramma calomelanos var. *aureoflava* (Hook.) Weath. ex Bailey *	Tr	ML 279			X	
Pityrogramma chaerophylla (Desv.) Link •	Tr/Ep	PHL 3799			X	
Pteris brasiliensis Raddi	Tr	RSV 177			X	
Pteris deflexa Link •	Tr	ML 82	X		X	
Pteris denticulata Sw.	Ru	ML 67	X	X	X	
Pteris lechleri Mett.	Tr	ML 63			X	X
Pteris vittata L. •	Ru	ML 179			X	
Vittaria graminifolia Kaulf. •	Ep	ML 305		X		
Vittaria lineata (L.) Sm.*	Ep	ML 44			X	
SELAGINELLACEAE						
Selaginella marginata (Humb. & Bonpl. ex Willd.) Spring •	Tr/Ru	ML 363			X	
Selaginella microphylla (Kunth) Spring •	Tr/Ru	ML 140			X	X
Selaginella muscosa Spring	Tr	ML 361			X	X
Selaginella sulcata (Desv. ex Poir.) Spring	Tr	ML 58	X	X	X	X
TECTARIACEAE						
Tectaria incisa Cav. •	Tr	ML 358			X	
THELYPTERIDACEAE						
Macrothelypteris torresiana (Gaudich.) Ching	Tr	ML 241			X	X
Thelypteris abbiattiae C. F. Reed •	Tr	ML 77	X		X	
Thelypteris amambayensis (Christ) Ponce*	Tr	RSV 217			X	
Thelypteris dentata (Forssk.) E. P. St. John •	Tr	ML 256	X		X	X
Thelypteris hispidula (Decne.) C. F. Reed •	Tr	ML 258			X	X
Thelypteris interrupta (Willd.) K. Iwats.*	Tr	ML 281			X	
Thelypteris recumbens (Rosenst.) C. F. Reed	Tr	ML 335			X	X
Thelypteris riograndensis (Lindm.) C. F. Reed	Tr	ML 291			X	X
Thelypteris rivularioides (Fée) Abbiatti *	Tr	ML 277			X	
Thelypteris scabra (C.Presl) Lellinger	Tr	ML 22	X	X	X	X
Thelypteris serrata (Cav.) Alston	Tr	ML 182			X	

Of the four areas, the fragment with the largest number of species was Parque Nacional do Iguaçu (101 species), followed by Parque Estadual do Rio Guarani (60 species), the private nature reserve Fazenda Santa Maria (40 species), and Parque Estadual Cabeça do Cachorro (38 species) (Tab. 2). The species richness found in the four areas is similar to that reported in studies conducted in areas with the same vegetation type, especially in southern Brazil (Schmitt *et al.* 2006; Lehn *et al.* 2009).

The most representative families were Pteridaceae (22 taxa), Polypodiaceae (17), Aspleniaceae (13), and Thelypteridaceae (11). Together, these four families account for 61% of recorded taxa. Other floristic surveys in forest formations of the Atlantic Forest had similar results (Melo & Salino 2002; Santos & Windisch 2008; Salino & Almeida 2009).

Species-rich genera were *Asplenium* (12 species), *Thelypteris* (10), *Blechnum* (seven), and *Pecluma* (six). Higher diversity of these taxa corroborates results obtained by other

floristic surveys in forest formations in the Atlantic Forest (Melo & Salino 2002; Santos & Windisch 2008; Salino & Almeida 2009; Gasper *et al.* 2012). Together, these four genera represent 33% of the registered taxa. It was noted that 19 genera are represented by only one species and 15 are represented by a few species (from two to five) (Tab. 2).

Most of the registered species (about 60%) are widespread and have been recorded in other areas in Paraná (Dittrich *et al.* 2005; Salino *et al.* 2005; Sakagami 2006; Schwartsburd & Labiak 2007; Michelon & Labiak 2013). The remaining 42 species (40%) are restricted to particular vegetations. This is possibly due to the influence of environmental factors, such as soil type, physical structure, and microclimate, which usually affect species distributions (Zuquim *et al.* 2012). Of the four areas studied, PNI is the only fragment that has two forest formations, where 11 taxa (10.47%) were registered only in *Araucaria* forest and 31 species (28.57%) were collected only in semideciduous forest (Tab. 2).

Regarding geographical distribution, 76% of the taxa are well distributed in the Neotropics, 11% are Pantropical species and 13% are species restricted to Brazil: *Asplenium kunzeanum, A. pulchellum, Cyathea atrovirens, C. phalerata, Diplazium herbaceum, Hypolepis stolonifera, Megalastrum connexum, Pecluma sicca, P. truncorum, Pleopeltis pleopeltifolia, Polyphlebium diaphanum, Pityrogramma chaerophylla, Serpocaulon vacillans*, and *Thelypteris recumbens* (Tab. 2); the latter has a rather restricted distribution and is endemic to southern Brazil (Prado & Sylvestre 2015). There was a predominance of widely distributed species. Possibly, the absence of local endemic species is due to the location of the study areas because they are further inland and south, with a subtropical climate, which are characteristics that are not typical of endemism (Given 1993; Moran 2008).

Dicksonia sellowiana is a threatened species (Santiago *et al.* 2013) that usually occurs in association with *Araucaria* forest and rainforest at elevations between 600 and 2,200 m (Santiago *et al.* 2013). However, it may occur in deciduous forest (Gasper *et al.* 2011) and gallery forest (Salino & Viveros 2012). In this study this is species was observed both in *Araucaria* forest (PNI) and in semideciduous forest, noteworthy, its first record (PERG) between 300 and 400m altitudinal height.

Five species (*Macrothelypteris torresiana, Nephrolepis cordifolia, Thelypteris dentata, Pteris vittata*, and *Deparia petersenii*) found in the study areas (two species in PERG, one in PECC, and five in PNI) are exotic or naturalized (Moro *et al.* 2012), of extra-American origin, and occur spontaneously or sub-spontaneously in Brazil.

Adiantopsis perfasciculata and *Blechnum lanceola* are new records for the state of Paraná. *Adiantopsis perfasciculata* was cited only for Central Brazil, the state of Minas Gerais (Figueiredo & Salino 2005; Prado 2015) and, in the South Region, the states of Rio Grande do Sul and Santa Catarina (Sehnem 1972; Gasper *et al.* 2012). *Blechnum lanceola* was previously recorded for the Central, Southeast, and South regions of Brazil, but in the latter region it was only known from Rio Grande do Sul (Dittrich 2005; Dittrich & Salino 2015).

Regarding growth form (Page 1979; Lellinger 2002), lycophytes and ferns are predominantly herbaceous. In this study, four species were arborescent (*Alsophila*, *Cyathea* [*Cyathea atrovirens* and *C. phalerata*], and *Dicksonia*) and one was subarborescent (*Blechnum brasiliense*). Regarding habit, 65 were classified as only terrestrial (62%), 21 as epiphytes (20%), four as rupicolous (3.8%), and one as scandent (0.95%). Eleven species (10.47%) had more than one growth habit (Tab. 2). The growth-form percentages are in accordance with the representativeness registered in other studies, such as Melo & Salino (2002) and Kersten (2010), for epiphytes in semideciduous forest.

Similarity

The cluster analysis (Fig. 2) showed high statistical significance and the cophenetic correlation coefficient was 0.8758, indicating that distortion between the similarity matrix and multidimensional space shown in the dendrogram was small (Hammer & Harper 2006).

The dendrogram shows the formation of two groups. A larger group (group I) comprises 10 areas in Paraná, including the studied areas, one area in Santa Catarina, and five areas in Rio Grande do Sul. The second group (group II) comprises two areas in Rio Grande do Sul (LPV and PET) and one in Paraná (MG) (Fig. 2).

According to Mantel's analysis, differences in floristic composition between selected areas are not related to geographical distance because the test showed that geographical distance between locations was negative and strongly insignificant ($p = 0.432$ [$p > 0.01$] and $r = 0.0579$).

The fragment São Francisco de Paula (SFP) does not occur with any other group, behaving as an outlier in the analysis. This fragment is located in an urban area in Rio Grande do Sul and more than half of the species from this survey (about 25) are different from those found in the studied areas.

Within group I, there are two subgroups (A and B). In subgroup A, the fragments PEcK (PR), PEVV (PR), PEG (PR), SMPr (PR), PNSI (SC) cluster on one branch and IM (PR) is alone on a separate branch.

Possible reasons why Ilha do Mel (PR) differs from the other areas are its location, elevation above sea level, due to the fact that it is an island (Tab. 1), and because it has a forest formation influenced by *restinga* (Dzwonko & Kornás 1994).

Branch A1 is a cluster of the areas PEcK (PR), PEVV (PR) and PEG (PR), which are about 65% similar in floristic composition (Fig. 2). These three locations share the same vegetation type (*Araucaria* forest and natural grasslands) (Tab. 1) and are geographically close, which suggests that both of these aspects are strong influences for this cluster.

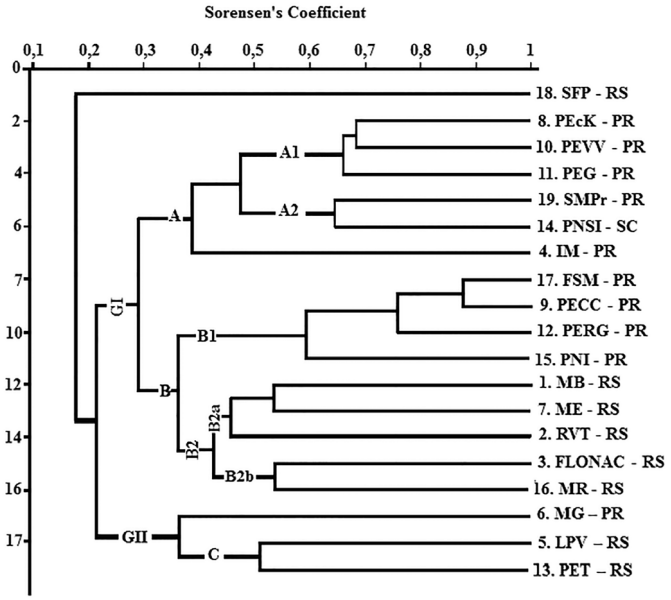

Figure 2. Similarity dendrogram of lycophyte and fern species among 19 Atlantic Forest areas in southern Brazil (using Sørensen's Index and UPGMA algorithm). **PR:** Paraná; **RS:** Rio Grande do Sul; **SC:** Santa Catarina. **1. MB**: Área de Proteção Ambiental Morro da Borússia; **2. RVT**: Remnants from Vale do Taquari; **3. FLONAC**: Floresta Nacional de Canela; **4. IM**: Ilha do Mel; **5. LPV**: Localidade Picada Verão; **6. MG:** Mata do Godoy; **7. ME**: Morro da Extrema; **8. PEcK**: Parque Ecológico Klabin; **9. PECC**: Parque Estadual Cabeça do Cachorro; **10. PEVV**: Parque Estadual Vila Velha; **11. PEG**: Parque Estadual Guartelá; **12. PERG**: Parque Estadual Rio Guarani; **13. PET**: Parque Estadual Turvo; **14. PNSI**: Parque Nacional Serra de Itajaí; **15. PNI**: Parque Nacional Iguaçu; **16. MR**: Parque Natural Municipal da Ronda; **17. FSM**: Fazenda Santa Maria; **18. SFP**: Mata de São Francisco de Paula; **19. SMPr**: Serra do Mar Paranaense.

Branch A2 consists of the fragments SMPr (PR) and PNSI (SC), which are about 62% similar and, although geographically more distant, share the same vegetation type (rainforest).

It is noteworthy that areas from subgroup A (PEcK, PEVV, PEG, SMPr, PNSI, IM) are the most representative in species number because they are located in the far eastern, coastal part of the country (mainly in Serra do Mar) that has unique features, such as the influence of humid winds coming from the ocean and heavy rainfall throughout the year (Pellegatti & Galvani 2010). According to Page (1979), environments with a higher occurrence of lycophytes and ferns are very humid and tropical, and have no dry periods throughout the year.

Subgroup B comprises nine fragments, FSM (PR), PECC (PR), PERG (PR), PNI (PR), MB (RS), ME (RS), RVT (RS), FLONAC (RS) and MR (RS), and two branches (B1 and B2).

Branch B1 is exclusively formed by the fragments of this study, FSM, PECC, PERG and PNI (Fig. 2). The fragments FSM and PECC have the highest similarity rate, with about 90% of the same species, and these two areas are 85% similar to the species from PERG (Fig. 2). The floristic composition of PNI is 60% similar to the other three areas combined (Fig. 2).

As found by Mantel's test and the similarity analysis, PNI differs the most for these fragments even though it is geographically closer to FSM (Fig. 1). This might be because PNI is large and has two forest formations. Thus, also in the four areas under study in western Paraná, the greatest similarity was found between fragments with the same forest formation. Additionally, other factors could influence this similarity, such as environmental heterogeneity (Jones *et al.* 2006; Gasper *et al.* 2012) and disturbance history (Jones *et al.* 2008; Nóbrega *et al.* 2011).

Branch B2 is exclusively formed by the fragments from Rio Grande do Sul (MB, ME, RVT, FLONAC, MR). These areas are mainly *Araucaria* forest, except for MB, which consists of rainforest, and RVT, which is deciduous forest. Branch B2 comprises two clusters (B2a and B2b), and branch B2a comprises MB, ME and RVT. The floras of fragments MB and ME are 54% similar and these fragments, when compared to the fragment RVT, are 45% similar; RVT is the least similar. Branch B2b comprises fragments FLONAC and MR, which are 54% similar (Fig. 2). The difference of these five fragments in relation to the other areas is evidence that they are grouped according to forest formation (*Araucaria* forest).

In the group II there is a union of fragments that only have semideciduous forest (MG, LPV and PET). Subgroup C is formed by the fragments LPV and PET, which are 50% similar, and fragment MG is further from the latter two, with about 35% similarity in its floristic composition.

The occurrence of 2 clusters with areas of semideciduous forest (GI and B1), in different branches, could be explained by how the data was collected during the studies of these areas. The studies related to the three areas of group GI were surveys of the entire vascular flora, not specifically lycophytes and ferns, which could have resulted in a sub-

sampling of the groups. This is an important bias to consider in relation to the composition of species lists.

Based on the hypothesis proposed, when analyzing the cluster of areas in this study with areas in Rio Grande do Sul (subgroup B), a possible explanation for the existence of similarity might be the influence of *Araucaria* forest on the species composition within the areas of this study, especially because western Paraná is a transition area between this forest formation and semideciduous forest. There could also be a relationship between the longitude and latitude of these areas, as found for continental inland forests compared to those close to the coast, because the more inland the forests are the more seasonal they become (Oliveira-Filho & Fontes 2000). Since humidity and temperature vary significantly relative to longitude and latitude, for the various phytophysiognomies in the Atlantic Forest, it is possible that areas located further west and further south are less influenced by humidity and have similar environmental conditions.

The results of this study support the hypothesis that areas with similar forest formations have a similar floristic composition, regardless of their geographical proximity. This is supported by evidence in subgroup A, where IM was the least similar fragment, which was mainly due to the presence of *restinga* in this area (Fig. 2). The hypothesis is also supported in subgroup B, where fragments FSM and PNI are geographically close (Fig. 1) but are only 60% similar in floristic composition (Fig. 2) because *Araucaria* forest occurs only in PNI.

The results of the similarity analysis reaffirm the fact that species composition is one of the determining factors in the plant community structure present in each forest type within a biome. Patterns found in this study were also found by Nóbrega *et al.* (2011), Souza *et al.* (2012), Salino *et al*. (2013), which supports the hypothesis in this work and the results in the dendrogram.

The remaining Atlantic Forest in western Paraná is known only from a few protected areas and there is a deficiency of pteridophyte studies for this region because the diversity of this group is concentrated in other areas of the state (Cislinski 1996; Dittrich *et al.*1999; Borgo & Silva 2003). The species richness of the four areas, here surveyed, is lower compared with eastern regions. This was expected, since the rainforests in the east are richer than seasonal forests. However, this study contributed to the knowledge of lycophytes and ferns because little is known, based on the literature and herbarium collections, about the occurrence and distribution of species of these plants in western Paraná. Therefore, these new data are important for the conservation and management of the remaining Atlantic Forest in Brazil.

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