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Original Article

# Phytosociological contrast of ferns and lycophytes from forest fragments with different surroundings matrices in southern Brazil

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(With 2 figures)

## Abstract

Forest edges typically exhibit higher luminosity and lower humidity than the forest interior, resulting in an abiotic gradient. However, the degree of abiotic difference can be affected from the type of the matrix, influencing the selection of species. We compared the floristic and phytosociological structure of understory communities of ferns and lycophytes of the edge and interior of three forest sites influenced by different types of surrounding matrices (natural field, *Pinus* plantation, and cultivation of crops). In the region of Araucaria Forest, in Rio Grande do Sul, Brazil, twelve 10 × 10 m plots were selected at the edge and interior of each site, totaling 72 plots and to evaluate the phytosociological contrast, using as a parameter coverage and species richness per plot to evaluate this contrast. We recorded a total of 38 species in the studied areas, distributed in 15 families. The results show that the edge effect acts at different intensities in the analyzed sites. In the site with unnatural matrix, the composition was more homogeneous both in the edges and in the interiors and presented lower richness, showing a more pronounced and deep impact. Already in the site with natural matrix surroundings, although the border also presents low richness, the interior was about 3x richer. Based on our results, we concluded that fern conservation efforts should focus on fragments of Araucaria Forest inserted in the natural field, because the conversion of natural field into *Pinus* planting and cultivation of crops decreases ferns species both in the edges and forest interiors of the studied fragments, besides altering the phytosociological structure leading the communities to simplification.

*Keywords:* araucaria forest, community structure, edge effects, fragmentation, pteridophytes, richness.

# Contraste fitossociológico de samambaias e licófitas de fragmentos florestais com diferentes matrizes de entorno no sul do Brasil

## Resumo

Bordas florestais tipicamente exibem maior luminosidade e menor umidade que o interior florestal, resultando em um gradiente abiótico. Entretanto, o grau de diferença abiótica pode ser afetado a partir do tipo da matriz, influenciando a seleção de espécies. Comparamos a composição florística e a estrutura fitossociológica das comunidades de samambaias e licófitas na borda e interior de três sítios influenciados por diferentes matrizes (campo natural, plantio de *Pinus* e cultivo de olerícolas). Na região de Floresta com Araucária no Rio Grande do Sul, Brasil, foram sorteadas doze parcelas de 10 × 10 m na borda e no interior de cada sítio, totalizando 72 parcelas para avaliar o contraste fitossociológico, utilizando como parâmetro cobertura e riqueza das espécies por parcela para avaliar esse contraste. Registramos um total de 38 espécies nas áreas estudadas, distribuídas em 15 famílias. Os resultados mostraram que o efeito de borda atua em intensidades distintas nos sítios analisados. Nos sítios com matriz antropizada, a composição foi mais homogênea tanto nas bordas, quanto nos interiores e apresentou menor riqueza, demonstrando impacto mais pronunciado e profundo. Já no sítio com matriz de entorno natural, apesar da borda também apresentar baixa riqueza, o interior foi cerca de 3x mais rico. Sugerimos que os esforços de conservação de samambaias e licófitas em fragmentos com araucária, devem se concentrar em sítios inseridos em campo natural, pois, a conversão destes em plantio de *Pinus* e cultivo de olerícolas, diminui a diversidade dessas plantas, tanto nas bordas quanto nos interiores da floresta, além de alterar a estrutura fitossociológica levando as comunidades à simplificação.

*Palavras-chave:* floresta com araucária, estrutura comunitária, efeito de borda, fragmentação, pteridófitas, riqueza.

## 1. Introduction

One of the major threats to biodiversity in forests is fragmentation by anthropogenic origin (Laurance and Bierregaard, 1997). Besides being rapidly destroyed, the forests that once occupied large areas, are now divided in small patches often surrounded by non-original matrices (Harper et al., 2005). Haddad et al. (2015) revealed that approximately 20% of the world's remaining forest area comprise edges (<100 m). The reduction of forest areas decreases the environmental heterogeneity and increases the area exposed to edge effects (Fahrig, 2003).

The forest edges composition may vary according to the type of matrix (Silva and Schmitt, 2015; Silva et al., 2017). The different responses are crucial because they can promote variability in forest edges and interiors. Edges can affect microclimate by modifying both the air and soil temperature, light availability, soil moisture and wind speed (Heithecker and Halpern, 2007; Marchand and Houle, 2006). Bergeron and Pellerin (2014) showed a strong species–area relationship that was influenced by surrounding land use, and conclude that fern richness decreased due increasing proportions of residential areas and urban heat islands in comparison to low urban influence.

According to Kupfer et al. (2006) the matrices' composition not only serve as a barrier, but also as a habitat within a landscape. In this sense, the natural matrices are recognized as being habitats more heterogeneous than anthropic matrices.

The Atlantic Forest is the second largest tropical rainforest in the American continent. In the past, it covered about 1.5 million km$^2$ with 92% of this area in Brazil (Galindo-Leal and Câmara, 2003; Fundação SOS Mata Atlântica, 2017). Currently, only 8.5% of the remaining Atlantic forest area has more than 100ha of the original forest indicating its degree of fragmentation (Fundação SOS Mata Atlântica, 2017). Among the phytophysiognomies of the Atlantic Forest, the Araucaria Forest is situated in the south and southeast of Brazil and characterized by the presence of *Araucaria angustifolia* (Bertol.) Kuntze, with subtropical climate and regular rainfall throughout the year. This phytophysiognomy is extremely fragmented, with a distribution area conditioned to 3% of its original surface (Fundação SOS Mata Atlântica, 2017).

Ferns and lycophytes are important indicators of environmental quality because they are sensitive to changes in abiotic factors (Ferrer-Castan and Vetaas, 2005; Silva et al., 2018; Silva and Schmitt, 2015), as demonstrated from environmental disturbances such as increased edge areas (Paciencia and Prado, 2004, 2005; Silva et al., 2011; Pereira et al., 2014; Silva and Schmitt, 2015). Thus, ferns and lycophytes can be an accurate tool to test the effects of fragmentation and loss of habitats, as well as the edge effects. Changes in abiotic factors, as humidity and shading conditions, may lead to the substitution of more sensitive by the species tolerant to the impacts caused by this process, resulting in the impoverishment and the decharacterization of the local native flora (Pereira et al., 2014).

The present study aims to compare the floristic composition between communities of ferns and lycophytes of the edge and interior in three fragments with different matrices, as well as to verify their phytosociological structure. The hypothesis of this study was: communities of ferns and lycophytes in fragments of forest with Araucaria suffer floristic and phytosociological simplification by the artificial edge effect when compared to natural matrices.

## 2. Material and Methods

### 2.1. Study area

The study was developed at the phytoecological unit denominated Araucaria Forest, Rio Grande do Sul, Brazil, whose characteristic elements are *Araucaria angustifolia* (Bertol.) Kuntze and natural fields (Teixeira and Moura Neto, 1986). According to the classification of Köppen-Geiger, the climate is type Cfb (Peel et al., 2007). The average annual temperature is 14.5 °C, and precipitation around 2.000mm (according to the data obtained from the weather station Davis Vantage pro-2, installed near to study area). The soil is classified as humose aluminous cambisol (Streck et al., 2008).

### 2.2. Data collection

We selected three forest sites under influence of different types of vegetation in the matrix: (1) natural field site - **NFS**: 29° 07' 58"S and 50° 06' 43"W 1032 m a.s.l. (approx. 245ha); (2) *Pinus* plantation site - **PPS**: 29° 28' 31"S and 50° 20' 59"W 925 m a.s.l.; (3) cultivation of crops site - **CCS**: 29° 28' 44"S and 50° 21' 30"W 906 m a.s.l. (both 2 and 3 share the same fragment, approx. 105ha). At each site, we draw two parallel transects of 500 m length. The first transect was at 5 m and the second transect at 100 m distance from a forest edge. Along each transect, we randomly selected 12 points, which were at least 10 m apart. It was established a total of 24 plots of 10 × 10 m. Therefore, we sampled a total of 72 plots (3 sites x 12 replicates x 2 conditions: forest edge and interior).

In each plot, we recorded the composition and richness of terrestrial ferns and lycophytes. Species were identified using specialized bibliography, comparisons with herbarium vouchers and supporting specialists. We followed the taxonomic classification of families and genera of PPG I (2016). Fertile specimens were collected and deposited in the *Herbarium* Anchieta (PACA), at the Universidade do Vale do Rio dos Sinos, São Leopoldo, Rio Grande do Sul, Brazil.

The phytosociological parameters were based on the absolute and relative coverage data, as well as absolute and relative frequency to obtain the Importance Value – IV, an indicator of the most important species within the community which resulted from the means of the relative coverage and frequency of each species (adaptation by Mueller-Dombois and Ellenberg, 1974). The coverage was determined according to the scale proposed by Braun-Blanquet (1979).

*2.3. Data analyses*

From a presence/absence matrix, we performed the Principal Coordinates Analysis (PCoA) to visualize the floristic dissimilarity among sampling sites using Euclidian similarity index. The floristic similarity between edge and interior sites was obtained using Sørensen–Dice index, providing a dendrogram from the UPGMA method, with ferns and lycophytes and another with ferns only. The analyses were performed using software Paleontological Statistics Package for Education and Data Analysis - PAST version 3.0 (Hammer et al., 2001).

## 3. Results

We recorded a total of 38 species in the studied areas, of which only two were lycophytes, distributed in 15 families.

NFS site: the edge of this site registered 11 species, the most important of this environment was *Dicksonia sellowiana* (IV=39.03 %), followed by *Macrothelypteris torresiana* (IV=18.42 %) (Table 1). In the interior plots, 28 species were recorded and *D. sellowiana* was again the species with the highest importance value (40.04 %), followed by *Dennstaedtia globulifera* (IV= 21.75 %) occurring in 83 % and 100 % of the plots (Table 2).

PPS site: in the edge, 14 species were inventoried. The most important species was *Lastreopsis amplissima* (VI=40.48 %), followed by *D. sellowiana* (VI=23.36 %) (Table 3) occurring in 100 % and 75 % of the plots respectively. In the interior site, 16 species were recorded. The same previous species were recorded with similar IV (42.33 % and 20.24 %, respectively), both occurring in 100 % of the plots (Table 4).

CCS site: At the forest edge, 14 species and 12 genera were recorded. The most important species was *L. amplissima* (VI=58.39 %), followed by *D. sellowiana*

**Table 1.** Interior of NFS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dicksoniaceae | *Dicksonia sellowiana* Hook | 10 | 83.3 | 12.9 | 307.3 | 67.0 | 40.0 |
| Dennstaedtiaceae | *Dennstaedtia globulifera* (Poir.) Hieron. | 12 | 100.0 | 15.5 | 127.8 | 27.9 | 21.7 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 6 | 50.0 | 7.7 | 1.9 | 0.4 | 4.1 |
| Thelypteridaceae | *Amauropelta recumbens* (Rosenst.) Salino & T.E.Almeida | 5 | 41.6 | 6.4 | 5.3 | 1.1 | 3.8 |
| Hymenophyllaceae | *Crepidomanes pyxidiferum* (L.) Dubuisson & Ebihara | 5 | 41.6 | 6.4 | 1.1 | 0.2 | 3.3 |
| Dryopteridaceae | *Elaphoglossum sellowianum* (Klotzsch ex Kuhn) T. Moore | 4 | 33.3 | 5.1 | 0.4 | - | 2.6 |
| Dennstaedtiaceae | *Histiopteris incisa* (Thunb.) J.Sm. | 3 | 25.0 | 3.9 | 5.0 | 1.0 | 2.5 |
| Hymenophyllaceae | *Polyphlebium angustatum* (Carmich.) Ebihara & Dubuisson | 3 | 25.0 | 3.9 | 0.7 | 0.1 | 2.0 |
| Aspleniaceae | *Asplenium gastonis* Fée | 3 | 25.0 | 3.9 | - | - | 1.9 |
| Thelypteridaceae | *Amauropelta stierii* (Rosenst.) Salino & T.E.Almeida | 2 | 16.6 | 2.6 | 1.1 | 0.2 | 1.4 |
| Athyriaceae | *Deparia petersenii* (Kunze) M.Kato | 2 | 16.6 | 2.6 | 0.9 | 0.2 | 1.4 |
| Polypodiaceae | *Serpocaulon catharinae* (Langsd. & Fisch.) A.R.Sm. | 2 | 16.6 | 2.6 | 0.3 | - | 1.3 |
| Thelyoteridaceae | *Amauropelta retusa* (Sw.) Pic.Serm. | 2 | 16.6 | 2.6 | 0.2 | - | 1.3 |
| Polypodiaceae | *Pleopeltis hirsutissima* (Raddi) de la Sota | 2 | 16.6 | 2.6 | 0.1 | - | 1.3 |
| Hymenophyllaceae | *Didymoglossum ovale* E.Fourn. | 2 | 16.6 | 2.6 | - | - | 1.3 |
| Polypodiaceae | *Microgramma squamulosa (*Kaulf.) de la Sota | 2 | 16.6 | 2.6 | - | - | 1.3 |
| Cyatheaceae | *Cyathea atrovirens* (Langsd. & Fisch.) Domin | 1 | 8.3 | 1.3 | 2.0 | 0.4 | 0.8 |
| Selaginellaceae | *Selaginella muscosa* Spring | 1 | 8.3 | 1.3 | 2.0 | 0.4 | 0.8 |
| Dryopteridaceae | *Polysticum platylepis* Fée | 1 | 8.3 | 1.3 | 1.1 | 0.2 | 0.7 |
| Aspleniaceae | *Asplenium serra* Langsd. & Fisch. | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Polypodiaceae | *Pecluma pectinatiformis* (Lindm.) M.G.Price | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Ophioglossaceae | *Botrypus virginianus* (L.) Michx. | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Blechnaceae | *Blechnum austrobrasilianum* de la Sota | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Pteridaceae | *Vittaria lineata* (L.) Sm. | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Polypodiaceae | *Pecluma sicca* (Lindm.) M.G.Price | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Aspleniaceae | *Asplenium harpeodes* Kunze | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Polypodiaceae | *Pecluma recurvata* (Kaulf.) M.G.Price | 1 | 8.3 | 1.3 | - | - | 0.6 |
| Polypodiaceae | *Pleopeltis pleopeltidis* (Fée) de la Sota | 1 | 8.3 | 1.3 | - | - | 0.6 |

Phytosociological parameters of fern and lycophyte species: NP = Number of plots that the specie occurred; AF% = Absolute Frequency; RF% = Relative frequency; AC% = Absolute Coverage; RC% = relative coverage; IV% = Importance value; - = ≤ 0.09.

**Table 2.** Edge of NFS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dicksoniaceae | *Dicksonia sellowiana* Hook | 4 | 33.3 | 13.3 | 34.4 | 64.7 | 39.0 |
| Thelypteridaceae | *Macrothelypteris torresiana* (Gaudich.) Ching | 6 | 50.0 | 20.0 | 8.9 | 16.8 | 18.4 |
| Thelypteridaceae | *Amauropelta recumbens* (Rosenst.) Salino & T.E.Almeida | 3 | 25.0 | 10.0 | 3.7 | 7.0 | 8.5 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 4 | 33.3 | 13.3 | 0.5 | 1.1 | 7.2 |
| Polypodiaceae | *Pleopeltis hirsutissima* (Raddi) de la Sota | 4 | 33.3 | 13.3 | 0.1 | 0.2 | 6.7 |
| Drypoteridaceae | *Polystichum platylepis* Fée | 2 | 16.6 | 6.6 | 3.6 | 6.8 | 6.7 |
| Polypodiaceae | *Serpocaulon catharinae* (Langsd. & Fisch.) A.R.Sm. | 3 | 25.0 | 10.0 | 0.1 | 0.3 | 5.1 |
| Blechnaceae | *Lomaria spannagelii* (Rosenst.) Gasper & V.A.O. Dittrich | 1 | 8.3 | 3.3 | 1.0 | 1.9 | 2.6 |
| Blechnaceae | *Blechnum austrobrasilianum* de la Sota | 1 | 8.3 | 3.3 | 0.2 | 0.4 | 1.9 |
| Athyriaceae | *Deparia petersenii* (Kunze) M.Kato | 1 | 8.3 | 3.3 | 0.2 | 0.4 | 1.8 |
| Blechnaceae | *Lomaridium plumieri* (Desv.) C. Presl | 1 | 8.3 | 3.3 | - | - | 1.7 |

Phytosociological parameters of fern species: NP = Number of plots with species presence; AF% = Absolute Frequency; RF% = Relative frequency; AC% = Absolute Coverage; RC% = relative coverage; IV% = Importance value; - = ≤ 0.9.

**Table 3.** Edge of PPS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dryopteridaceae | *Lastreopsis amplissima* (C.Presl) Tindale | 12 | 100.0 | 20.3 | 139.4 | 60.6 | 40.4 |
| Dicksoniaceae | *Dicksonia sellowiana* Hook. | 9 | 75.0 | 15.2 | 72.3 | 31.4 | 23.3 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 6 | 50.0 | 10.1 | 9.0 | 3.9 | 7.0 |
| Aspleniaceae | *Asplenium claussenii* Hieron. | 6 | 50.0 | 10.1 | 0.2 | 0.1 | 5.1 |
| Aspleniaceae | *Asplenium harpeodes* Kunze | 5 | 41.6 | 8.4 | 3.7 | 1.6 | 5.0 |
| Cyatheaceae | *Cyathea atrovirens* (Langsd. & Fisch.) Domin | 4 | 33.3 | 6.7 | 2.9 | 1.2 | 4.0 |
| Dennstaedtiaceae | *Dennstaedtia globulifera* (Poir.) Hieron. | 4 | 33.3 | 6.7 | - | - | 3.4 |
| Polypodiaceae | *Pecluma recurvata* (Kaulf.) M.G.Price | 3 | 25.0 | 5.0 | 0.5 | 0.2 | 2.6 |
| Aspleniaceae | *Asplenium maritianum* C.Chr. | 2 | 16.6 | 3.3 | 0.6 | 0.3 | 1.8 |
| Athyriaceae | *Deparia petersenii* (Kunze) M.Kato | 2 | 16.6 | 3.3 | 0.5 | 0.2 | 1.8 |
| Polypodiaceae | *Campyloneurum nitidum (*Kaulf.) C.Presl | 2 | 16.6 | 3.3 | 0.3 | 0.1 | 1.7 |
| Aspleniaceae | *Asplenium gastonis* Fée | 2 | 16.6 | 3.3 | - | - | 1.7 |
| Blechnaceae | *Neoblechnum brasiliense* (Desv.) Gasper & V.A.O. Dittrich | 1 | 8.3 | 1.6 | - | - | 0.8 |
| Thelypteridaceae | *Amauropelta retusa* (Sw.) Pic.Serm. | 1 | 8.3 | 1.6 | - | - | 0.8 |

Phytosociological parameters of fern species: NP = Number of plots with species presence; AF% = Absolute Frequency; RF% = Relative frequency; AC% = Absolute Coverage; RC% = relative coverage; IV%: Importance value; - = ≤ 0.9.

(VI=9.88 %) occurring in 100 % and 75 % of the plots respectively (Table 5). In the interior of the fragment 14 species and 12 genera were registered. The species that presented the highest VIs were *L. amplissima* (56.39 %), *Selaginella muscosa* (10.70 %.) and *Lomaridium plumieri*, occurring in 100 %, 67 % and 58 % of the plots respectively (Table 6). In both environments, the richness was 13 families.

The forest edge and interior in PPS and CCS sites showed high index of similarity (< 70 %, Figure 1A). Differently, NFS site had a similarity about 35 % between forest edge and interior (Figure 1A). In the dendrogram formed by ferns only (Figure 1B), it indicates that, the exclusion of the group of the lycophytes further accentuates the differences mainly between the NFS site with respect to the other sites.

The PCoA separated the plots from NFS site on edge and interior showing that the species composition between the areas is quite heterogeneous due to the sharing of only eight species of the 31 species found for this site. The proximity and overlapping of some interior plots revealed a greater floristic homogeneity in the area, while the dispersion of the edge plots demonstrates a greater dissimilarity (Figure 2A). For the PPS site, the differentiation of the plots between the environments of edge and interior was less evident (Figure 2B). The separation of the plots between edge and interior of the CCS site was even less evident than at the previous site demonstrating greater floristic homogeneity among the environment. In comparison among the edge plots, high dispersion occurred indicating

**Table 4.** Interior of PPS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dryopteridaceae | *Lastreopsis amplissima* (C.Presl) Tindale | 12 | 100.0 | 17.6 | 427.0 | 67.0 | 42.3 |
| Dicksoniaceae | *Dicksonia sellowiana* Hook | 12 | 100.0 | 17.6 | 146.7 | 23.0 | 20.3 |
| Blechnaceae | *Lomaridium plumieri* (Desv.) C. Presl | 8 | 66.6 | 11.7 | 44.5 | 7.0 | 9.3 |
| Thelypteridaceae | *Amauropelta retusa* (Sw.) Pic.Serm. | 10 | 83.3 | 14.7 | 7.3 | 1.1 | 7.9 |
| Dennstaedtiaceae | *Dennstaedtia globulifera* (Poir.) Hieron | 6 | 50.0 | 8.8 | 1.6 | 0.2 | 4.5 |
| Aspleniaceae | *Asplenium maritianum* C.Chr | 5 | 41.6 | 7.3 | 1.9 | 0.3 | 3.8 |
| Aspleniaceae | *Asplenium harpeodes* Kunze | 3 | 25.0 | 4.4 | 3.0 | 0.4 | 2.4 |
| Aspleniaceae | *Asplenium claussenii* Hieron. | 2 | 16.6 | 2.9 | 1.4 | 0.2 | 1.5 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 2 | 16.6 | 2.9 | 0.5 | - | 1.5 |
| Athyriaceae | *Deparia petersenii* (Kunze) M.Kato | 2 | 16.6 | 2.9 | 0.2 | - | 1.4 |
| Cyatheaceae | *Cyathea atrovirens* (Langsd. & Fisch.) Domin | 1 | 8.3 | 1.4 | 1.0 | 0.1 | 0.8 |
| Dryopteridaceae | *Polystichum platylepis* Fée | 1 | 8.3 | 1.4 | 1.0 | 0.1 | 0.8 |
| Thelypteridaceae | *Amauropelta stierii* (Rosenst.) Salino & T.E.Almeida | 1 | 8.3 | 1.4 | 0.5 | - | 0.7 |
| Polypodiaceae | *Microgramma squamulosa* (Kaulf.) de la Sota | 1 | 8.3 | 1.4 | - | - | 0.7 |
| Selaginellaceae | *Selaginella muscosa* Spring | 1 | 8.3 | 1.4 | - | - | 0.7 |
| Thelypteridaceae | *Amauropelta recumbens* (Rosenst.) Salino & T.E.Almeida | 1 | 8.3 | 1.4 | - | - | 0.7 |

Phytosociological parameters of fern and lycophyte species: NP = Number of plots with species presence; AF% = Absolute Frequency; RF% = Relative frequency; AC% = Absolute Coverage; RC% = relative coverage; IV% = Importance value; - = ≤ 0.09.

**Table 5.** Edge of CCS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dryopteridaceae | *Lastreopsis amplissima* (C.Presl) Tindale | 12 | 100.0 | 24.0 | 985 | 92.7 | 58.3 |
| Dicksoniaceae | *Dicksonia sellowiana* Hook | 9 | 75.0 | 18.0 | 18.6 | 1.7 | 9.8 |
| Blechnaceae | *Lomaridium plumieri* (Desv.) C. Presl | 5 | 41.6 | 10.0 | 3.0 | 0.2 | 5.1 |
| Selaginellaceae | *Selaginella muscosa* Spring | 4 | 33.3 | 8.0 | 11.4 | 1.0 | 4.5 |
| Aspleniaceae | *Asplenium maritianum C.Chr* | 4 | 33.3 | 8.0 | 0.2 | - | 4.0 |
| Dryopteridaceae | *Elaphoglossum sellowianum* (Klotzsch ex Kuhn) T. Moore | 4 | 33.3 | 8.0 | 0.1 | - | 4.0 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 3 | 25.0 | 6.0 | 14 | 1.3 | 3.6 |
| Lycopodiaceae | *Diphasiastrum thyoides* (Willd) Holub | 1 | 8.3 | 2.0 | 28.7 | 2.7 | 2.3 |
| Thelypteridaceae | *Amauropelta retusa* (Sw.) Pic.Serm. | 2 | 16.6 | 4.0 | 0.1 | - | 2.0 |
| Thelypteridaceae | *Amauropelta recumbens* (Rosenst.) Salino & T.E.Almeida | 2 | 16.6 | 4.0 | - | - | 2.0 |
| Dennstaedtiaceae | *Dennstaedtia globulifera* (Poir.) Hieron | 1 | 8.3 | 2.0 | - | - | 1.0 |
| Hymenophyllaceae | *Polyphlebium angustatum* (Carmich.) Ebihara & Dubuisson | 1 | 8.3 | 2.0 | - | - | 1.0 |
| Polypodiaceae | *Pecluma recurvata (*Kaulf.) M.G.Price | 1 | 8.3 | 2.0 | - | - | 1.0 |
| Polypodiaceae | *Pecluma sicca* (Lindm.) M.G.Price | 1 | 8.3 | 2.0 | - | - | 1.0 |

greater dissimilarity between them. This result can also be reported in the interior plots (Figure 2C).

## 4. Discussion

The results showed distinct intensities of the edge effect under analyzed sites, considering the phytosociological aspects of ferns and lycophytes as a parameter. According to Laurance and Bierregaard (1997), the matrix composition can influence the edge effects because of the differences in physical and biotic changes of the fragments. The greatest richness found in the interior of the NFS site and it was twice the number of species found in the interiors of the other sites analyzed indicating that areas surrounded by matrices of natural vegetation in forest with Araucaria phytophysiognomy present greater richness than areas surrounded by non-original matrices, indicating that the edge effect is attenuated in the natural environment. Bergeron and Pellerin (2014) demonstrated a decrease in fern species richness influenced by an anthropized matrix.

From the phytosociological data, it was verified that 18 species occurred in only one or two plots from the

**Table 6.** Interior of CCS.

| Family | Species | NP | AF% | RF% | AC% | RC% | IV% |
|---|---|---|---|---|---|---|---|
| Dryopteridaceae | *Lastreopsis amplíssima* (C.Presl) Tindale | 12 | 100.0 | 24.4 | 710 | 88.2 | 56.3 |
| Selaginellaceae | *Selaginella muscosa* Spring | 8 | 66.6 | 16.3 | 40.8 | 5.0 | 10.7 |
| Blechnaceae | *Lomaridium plumieri* (Desv.) C. Presl | 7 | 58.3 | 14.2 | 7.8 | 0.9 | 7.6 |
| Thelypteridaceae | *Amauropelta recumbens* (Rosenst.) Salino & T.E.Almeida | 5 | 41.6 | 10.2 | 2.9 | 0.3 | 5.2 |
| Thelypteridaceae | *Amauropelta retusa* (Sw.) Pic.Serm. | 5 | 41.6 | 10.2 | 2.3 | 0.2 | 5.2 |
| Dicksoniaceae | *Dicksonia sellowiana* Hook | 4 | 33.3 | 8.1 | 10.7 | 1.3 | 4.7 |
| Osmundaceae | *Osmunda regalis* L. | 1 | 8.3 | 2.0 | 13 | 1.6 | 1.8 |
| Dryopteridaceae | *Elaphoglossum sellowianum* (Klotzsch ex Kuhn) T. Moore | 1 | 8.3 | 2.0 | 6 | 0.7 | 1.3 |
| Dryopteridaceae | *Ruhmora adiantiformis* (G.Forst.) Ching | 1 | 8.3 | 2.0 | 5.2 | 0.6 | 1.3 |
| Aspleniaceae | *Asplenium serra* Langsd. & Fisch a | 1 | 8.3 | 2.0 | 4 | 0.5 | 1.2 |
| Polypodiaceae | *Pecluma recurvata* (Kaulf.) M.G.Price | 1 | 8.3 | 2.0 | 1 | 0.1 | 1.0 |
| Dennstaedtiaceae | *Dennstaedtia globulifera* (Poir.) Hieron | 1 | 8.3 | 2.0 | 0.2 | - | 1.0 |
| Cyatheaceae | *Cyathea atrovirens* (Langsd. & Fisch.) Domin | 1 | 8.3 | 2.0 | - | - | 1.0 |
| Athyriaceae | *Deparia petersenii* (Kunze) M.Kato | 1 | 8.3 | 2.0 | - | - | 1.0 |

Phytosociological parameters of fern and lycophyte species: NP = Number of plots that the specie occurred; AF% = Absolute Frequency; RF% = Relative frequency; AC% = Absolute Coverage; RC% = relative coverage; IV% = Importance value; - = ≤ 0.09.

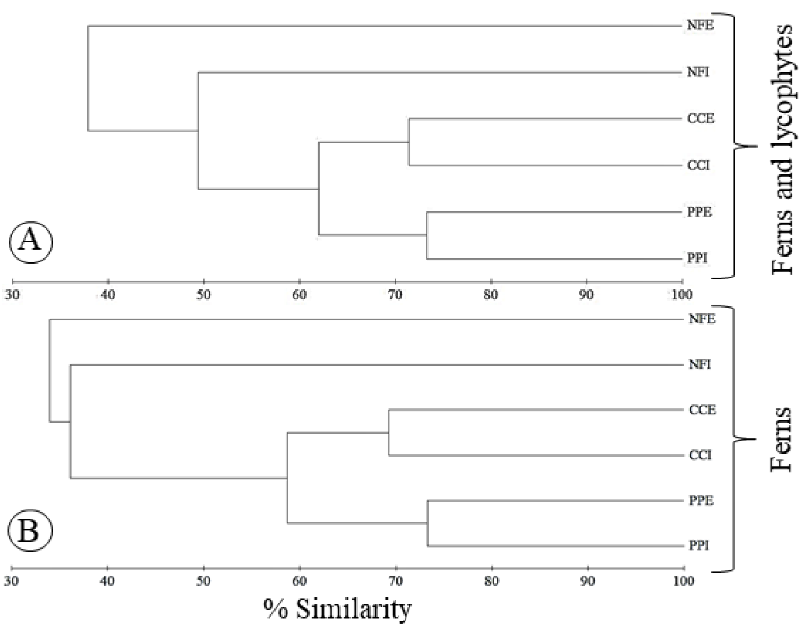


**Figure 1.** Dendrogram of floristic similarity generated by the UPGMA method using the Sorensen-Dice coefficient. NFE = edge of natural field site; NFI = interior of natural field site; CCE = edge of cultivation of crops site; CCI = interior of cultivation of crops site; PPE = edge of pine plantation site; PPI = interior of pine plantation site. (A) Dendrogram with Ferns and lycophytes; (B) Dendrogram with ferns only.

interior of the NFS site. In the other edges and interiors investigated, the richness never reached more than half (9) of that value. This finding indicates that the ferns and lycophytes community of NFS interior site has a less homogenous distribution when compared to other environments and presents a larger number of rare and less abundant species. According to Nee et al. (1991), rich assemblages are characterized by rare species. The presence of a few lycophytes was expected, since the terrestrial species of this group in the Araucaria Forest are less frequent compared to the ferns (JBRJ, 2017).

Hymenophyllaceae occurred mainly in the interior of NFS. A study developed by Paciencia and Prado (2005) indicated a prevalence of species of this family in

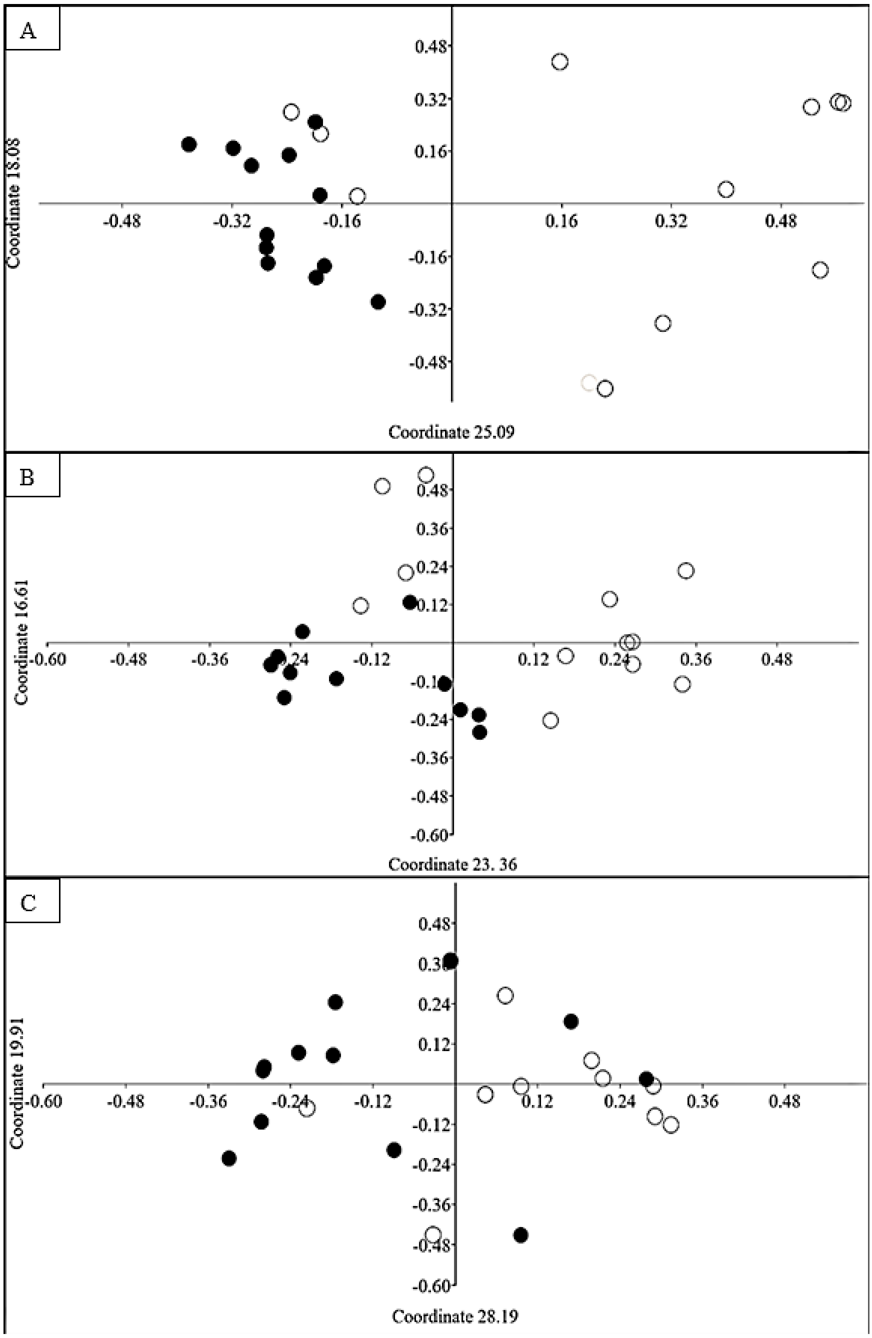


**Figure 2.** Principal coordinates analysis (PCoA) of sampled plots at the edge and in the interior of the NFS (A), PPS (B) and CCS (C) sites. Edge (○), Interior (●).

forest interior. Hymenophyllaceae have leaves with low saturation point, supporting high humidity levels and low luminosity (Benzing, 1987; Dubuisson et al., 2009; Windisch, 2015). On the other hand, the low saturation point renders them more susceptible to desiccation and high photosynthetically active radiation, which eventually becomes a limiting point to its occurrence in other sites. Another family that deserves attention and found inside of the NFS was Ophyoglossaceae, with the representative specie *Bothypus virginianus*, this fern is rarely found in Rio Grande do Sul (Lorscheitter et al., 1998) it is also on the red list of endangered species of Rio Grande do Sul, in the vulnerable category (Rio Grande do Sul, 2014), reinforcing the importance of this interior environment in keeping species with restricted distribution in the south of Brazil.

Nearly half of fern species habitually epiphytic occurred in the understory of the NFS interior site should be the result of the greater environmental heterogeneity in this site. According to Magurran (2004) different conditions and resources availability in natural environments favors a greater variety of habitats, reflecting the level of conservation of the place. Therefore, the ecosystem can support different species with different functional characteristics provide an increase in richness. In a natural environment matrix, the anthropic pressures are less impactful, which can contribute to the heterogeneity and the development of some epiphytic ferns in the understory of this interior site.

The forests edge in PPS site presented high floristic similarity when compared with their interior, the same can be applied to the CCS site indicating that environments surrounded by non-original matrices may cause a more pronounced edge effect than natural matrices and the edge effect reaches depths greater than 100 m. According to Brummitt et al. (2016), agriculture or monoculture matrices impact about 80 % of the ferns considered endangered in the world. These results indicate that edge effect in ferns may be more intense in sites inserted in fragments that present this type of surrounding matrix. The fragmentation tends to simplify ecosystems and decrease heterogeneity (Fahrig, 2003; Williams, 1964).

*Lastreopsis amplissima* was the species with the highest importance value in PPS and CCS (edge and interior), Blume et al. (2010) showed that this species presented the highest values of abundance among the ferns recorded in a forest fragment with araucaria, surrounded by a strongly anthropized matrix (Pine plantations urban influence) indicating that these species can be resilient to environments with impacted matrices such as those presented in this study.

In the case of *Dicksonia sellowiana*, the high IV suggests a high ecological amplitude, independent of the surround matrix (NFS; PPS) and habitat (edge or interior). Although this tree fern obtained high IV in PPS, this species presented values two to four times greater in the NFS both in the edge and in the interior, suggesting that this species has its distribution potential and reproductive success favored in a natural environment matrix when compared to artificial ones.

This species provides habitat to the establishment of epiphytes and hemiepiphytes (Becker et al., 2015; Negrão et al., 2017), moreover it also provides a great amount of organic matter to the soil (Fraga et al., 2008).

In the unnatural matrices sites, the presence of these two species together indicated percentages of IV always higher than 60 % in both edges and interiors. As a result, it can be inferred that these two ferns are resilient to artificial edges with anthropized environment matrices (PPS and CCS). Silva and Schmitt (2015) also verified this effect in ferns and showed that changes caused by forest edges eliminate species that are less tolerant to environmental change favoring the success of others that are adapted. Artificial edges can eliminate sensitive species but also be responsible for the addition of species tolerant to climatic conditions of the altered environment (Laurance et al., 1998).

Araucaria Forests and their surrounding natural fields have suffered direct anthropic pressures caused mainly by the transformation of their areas into pastures and agricultural land, commercial tree plantations and burning practices (Bittencourt and Sebbenn, 2007; Silva and Schmitt, 2015; Bilenca and Miñarro, 2004). This study verified that in spite of a decrease in the richness of the edge in the site connected to natural field, the interior of the same site presented high richness and in comparison to the other environments, it presented the best conditions for the development of ferns. The results demonstrated that the site with natural fields matrix was less affected by edge effects than forests with surrounding anthropized matrix. Based on these results, we conclude that fern conservation efforts should focus on fragments inserted in natural field because of the conversion of natural grassland into *Pinus* and farming fields leads to the loss of fern and lycophytes species both on the edge and in the forest interiors.

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