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Original Paper

Fern and lycophytes of the Taquari River riparian forests at different stages of succession

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Abstract

Riparian forests are important biodiversity corridors among groups. Such forests were greatly altered or suppressed in the state of Rio Grande do Sul. This study investigates the variation of species richness and distribution of ferns and lycophytes of eighteen study areas at different stages of succession in riparian forests of the Taquari River region. Fern and lycophyte samples were collected using the pathway methodology along the Taquari River during two years. The richness was compared at the different succession stages (advanced remnant formations, intermediate and initial) through analysis of variance and a randomized test, in which about 22 species were recorded: 19 species were at the advanced stage of succession, nine species were at the intermediate stage and seven species were at the initial stage of succession. The average richness was significantly higher in areas at advanced stage of succession. The high value of common species found at intermediate stages highlights the importance of preserving riparian forests at all stages of succession in the Taquari River as alternative for preserving the local biodiversity.

Key words: conservation, disturb, environment, pteridophytes, species richness, Subtropical Atlantic Forest.

Resumo

As matas ripárias são importantes corredores de biodiversidade entre os grupos. Essas florestas foram muito alteradas ou suprimidas no estado do Rio Grande do Sul. Este estudo investiga a variação da riqueza de espécies e distribuição de samambaias e licófitas de dezoito áreas de estudo em diferentes estágios de sucessão em matas ripárias da região do rio Taquari. Amostras de samambaias e licófitas foram coletadas utilizando a metodologia de caminhamento ao longo do rio Taquari durante dois anos. A riqueza foi comparada nos diferentes estágios de sucessão (formações remanescentes avançadas, intermediárias e iniciais) por meio de análise de variância e um teste randomizado, no qual foram registradas cerca de 22 espécies: 19 espécies estavam em estágio avançado de sucessão, nove espécies estavam no estágio intermediário e sete espécies estavam em estágio inicial de sucessão. A riqueza média foi significativamente maior nas áreas em estágio avançado de sucessão. O alto valor das espécies comuns encontradas nos estágios intermediários destaca a importância da preservação das matas ripárias em todos os estágios de sucessão do rio Taquari como alternativa para preservação da biodiversidade local.

Palavras-chave: conservação, distúrbio, meio ambiente, Mata Atlântica Subtropical, pteridófitas, riqueza de espécies, Mata Atlântica Subtropical.

Introduction

Riparian forests are vegetation around watercourses such as rivers, lakes, springs, and streams. They play an important role in protecting and maintaining riverbeds and local biodiversity (Chaves 2009), functioning as biological corridors and maintaining water quality in rivers. For the protection of watercourses, such forests act as intermediary between agricultural areas and aquatic environments by reducing negative impacts on

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the fauna and flora. Furthermore, they contribute to maintenance of soil porosity by favoring the infiltration of rainwater and the groundwater supply (Pessoa *et al*. 2000).

Despite its recognized importance in urbanized areas (Dias *et al.* 2014), riparian forests are negatively affected mainly by human occupation in the vicinity of such environments (Martins 2007). In rural areas, degradation is mainly due to a disordered agricultural expansion (Rodrigues & Gandolfi 2000). Riparian forests are systems particularly fragile to erosion, watercourse sedimentation and other impacts caused by humans mainly for being located at the bottom of valleys (Van Den Berg & Oliveira-Filho 2000). Those sites have the most fertile soils, thus, being preferred for agriculture development and making riparian forests potentially more threatened (Mencacci & Schlittler 1992; Van Den Berg & Oliveira-Filho 2000).

Studies on riparian forests have pointed out heterogeneous characteristics in their structure, composition, and dynamics (Ribeiro-Filho *et al.* 2009) related to several factors, such as edaphic and topographic variations, surrounding vegetation, history of disturbances, among others, which define differentiated ecological conditions (Durigan *et al.* 2000). Considering Brazilian rainforests, several studies have shown that the local distribution and diversity of ferns and lycophytes may be associated with several factors, including structural changes to the forest (Paciencia & Prado 2004, 2005; Nóbrega *et al.* 2011), and microclimatic (Paciencia & Prado 2004; Rodrigues *et al.* 2004) or edaphic-topographic features (Costa *et al.* 2005; Zuquim *et al.* 2007, 2009; Nóbrega *et al.* 2011; Nervo *et al*. 2019). According to Weigand *et al*. (2019), the richness of ferns and lycophytes is most strongly impacted at plot level or sampling point by local environmental factors.

Despite the taxonomic advance regarding this group in Rio Grande do Sul (*e.g.*, Sehnem 1967a, b, c, d, 1968a, b, 1970a, b, 1971, 1972, 1974, 1978, 1979a, b, c, d, e, f, g, 1984; Nervo & Windisch 2010, among others), fern and lycophyte species in riparian forests are not completely known. Few studies have contributed to their understanding (Diesel & Siqueira 1991; Mallmann & Schmitt 2014). There is a lack of floristic and ecological studies evaluating their composition. Moreover, surveys of local fern and lycophyte flora in forest fragments at different stages of succession may provide important information on environmental ecosystems conditions and help with conservation and exploitation of natural resources in such locations (Gonzatti 2018).

In this study, we performed a floristic fern and lycophyte survey in eighteen fragments of riparian forests of the Taquari River, Rio Grande do Sul state (RS), Brazil, which belongs to the Taquari-Antas river basin. In addition, we analyzed the relations between species composition and different stages of succession. Our hypothesis is that the species composition change between successional stages and areas at advanced stages of succession have greater richness of ferns and lycophytes. Thus, upon verifying the composition of species at different stages of succession, this study seeks to answer the following questions: (1) what is the composition of ferns and lycophytes in Taquari River riparian forests? (2) How does species richness of riparian forests vary at different stages of succession? (3) Are there species restricted to particular stages? (4) How do floristic similarities vary at different stages of succession?

Materials and Methods

Study area

This study was conducted on the banks of the Taquari River, which belongs to the Taquari-Antas River basin (BHRTA). It is located in the Northeast Region of the state of Rio Grande do Sul between the municipalities of Muçum and Taquari (Fig. 1). We selected eighteen study areas at different stages of ecological succession according to the Classification of the National Environment Council (CONAMA) (Brasil 1994): six areas were at an initial stage of forest succession (INI), measuring between 20 and 25 meters wide and 100 and 200 meters long, with a history of less than three-year use by agropastoral activities, and considered the most disturbed areas in our study. Six areas were at an intermediate stage of succession (INT), with 10 and 20 meters wide and 280 and 860 meters long, and other six areas at a late (advanced) stage of succession (LAT), measuring 70 and 150 meters wide and 280 and 1,000 meters long. The study area is inside the Atlantic Forest biome, and the vegetational type is Deciduous Seasonal Forests. The soil is characterized by a complex association of Eutrophic Litholic soils (IBGE 2017). According to the Köppen classification, the regional climate is humid subtropical (Cfa) (Alvares *et al*. 2013). The region's annual rainfall is about 1,300–1,400 mm, and the average annual temperature is 19–20 °C (66 to 68 °F), varying between the warmest and the coldest months (see details in Tab. 1).

Data collection

The floristic survey was performed through unsystematic hiking in the areas (Filgueiras *et al.* 1994). All ferns and lycophytes were sampled from October 2012 to December 2014. Species identification was carried out using specialized bibliography, through expert consultation and comparison with herbaria species. The material was deposited at the HVAT Herbarium of the Museum of Natural Sciences of the Universidade do Vale do Taquari - Univates. Families and genera were classified according to PPG I (2016), and we chose to follow the International Plant Name Index (IPNI). In each study area, all species of fern and lycophyte were estimated considering three habits and based on the occupied substrate (by Nervo *et al*. 2016): terrestrial (species with roots in the soil), rupicolous (species that grow in rocks) and epiphytes (species that grow on tree trunks up to 2 meters), as it was performed by Tuomisto & Ruokolainen (1994).

To identify differences between species richness for each successional stage of the riparian forest, richness data were compared between the three successional stages by analysis of variance (ANOVA) with a permutation testing (Pillar & Orlóci 1996). To evaluate habitat specificity, we compared common and exclusive species at different areas of different successional stages (INI, INT and LAT) using Venn diagram (Oliveros 2007). We considered common species those occurring in two or more fragments with different successional stages, and as exclusive species those occurring only one type of successional fragment of different stages forest. Differences in species composition among sites were tested using Non-metric multidimensional scaling (NMDS), with Bray-Curtis index as distance measure. The similarity of floristic composition at different successional stages was analyzed by the Sørensen Index of Similarity. The composition similarity of ferns and lycophytes on each study area was compared by the Bray-Curtis index using the Ward method. Values of co-phenetic relationship of the cluster above 0.7 were adopted as satisfactory correspondence

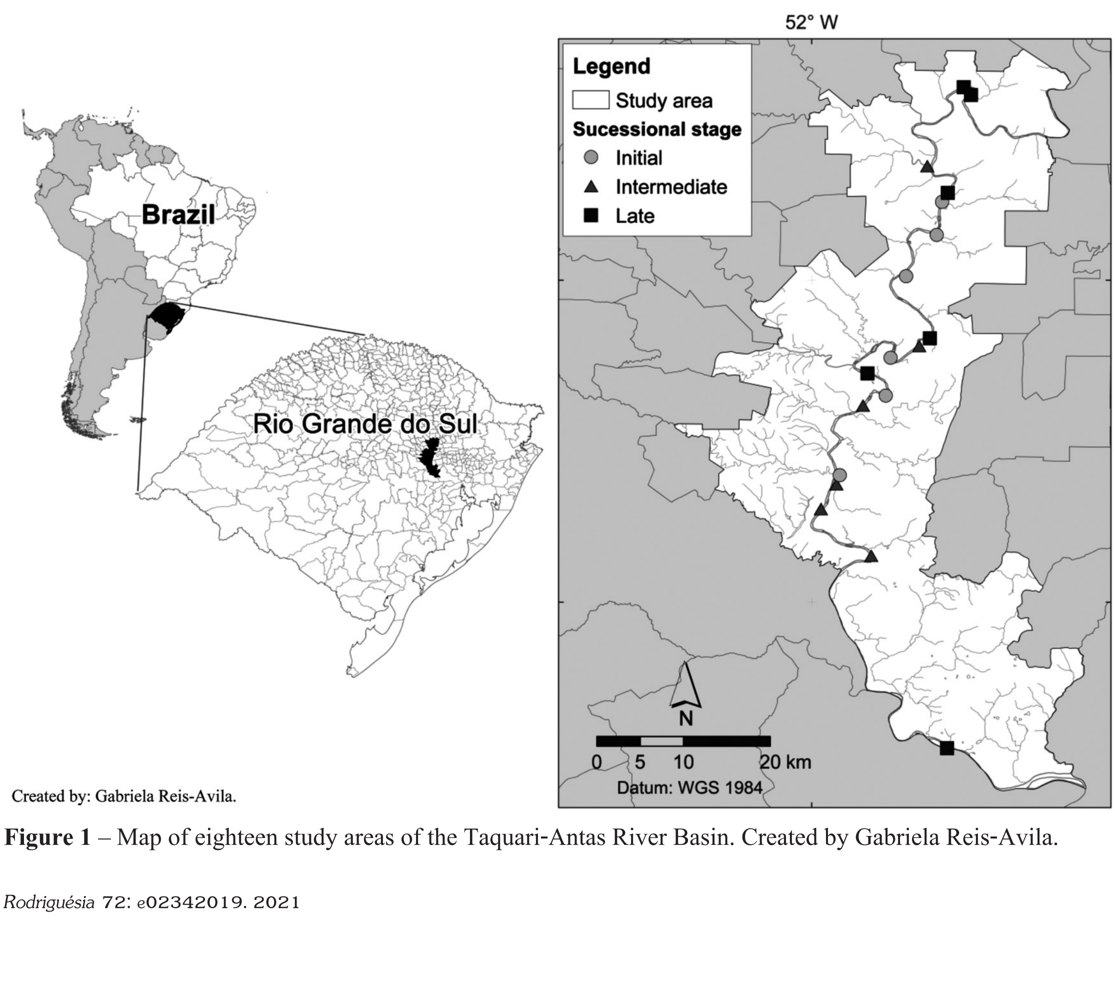

Figure 1 – Map of eighteen study areas of the Taquari-Antas River Basin. Created by Gabriela Reis-Avila.

Table 1 – Characteristics of the different study sites in remnants of the Taquari-Antas River Basin in Rio Grande do Sul state, Brazil, in three forest sucession – INI = initial stage of forest succession; INT = intermediate stage of forest succession; LAT = late stage of forest succession. AP = Annual Precipitation; MAT = Mean Annual Temperature.

Area	Municipality	Forest sucession	Coordinates	AP (mm)	MAT (Celsius)
1	Arroio do Meio	INI	-29º24'48''S, -51º55'06''W	1334	19.9
2	Bom Retiro do Sul	INT	-29º37'07''S, -51º56'18''W	1316	19.7
3	Colinas	LAT	-29º23'36''S, -51º52'39''W	1334	19.9
4	Colinas	INT	-29º24'05''S, -51º53'19''W	1334	19.9
5	Cruzeiro do Sul	INT	-29º31'59''S, -51º58'57''W	1315	19.8
6	Encantado	INT	-29º12'54''S, -51º52'49''W	1386	19.8
7	Encantado	INI	-29º16'51''S, -51º52'13''W	1386	19.8
8	Estrela	INT	-29º32'32''S, -51º58'27''W	1329	19.8
9	Estrela	INI	-29º32'32''S, -51º58'48''W	1329	19.8
10	Lajeado	LAT	-29º25'47''S, -51º56'32''W	1329	19.8
11	Lajeado	INI	-29º27'09''S, -51º55'24''W	1329	19.8
12	Lajeado	INT	-29º27'47''S, -51º56'49''W	1329	19.8
13	Muçum	LAT	-29º07'59''S, -51º50'32''W	1400	19.8
14	Roca Sales	INI	-29º15'08''S, -51º51'54''W	1370	19.8
15	Roca Sales	LAT	-29º14'34''S, -51º51'31''W	1370	19.8
16	Roca Sales	LAT	-29º14'53''S, -51º83'57''W	1370	19.8
17	Roca Sales	INI	-29º19'44''S, -51º54'08''W	1370	19.8
18	Taquari	LAT	-29º49'04''S, -51º51'34''W	1330	19.5

indicator (Visnadi & Vital 2001). The analyses were performed using the MULTIV (Pillar 1997), Paleontological Statistic (PAST) (Hammer *et al.* 2003), and the R software (R Development Core Team 2013).

Results

We sampled 22 species were sampled in the riparian forests of the Taquari River. They belong to eight families and thirteen genera (Tab. 2). The most representative family was Pteridaceae (seven species), followed by Aspleniaceae (four species), and Thelypteridaceae and Polypodiaceae (three species, each family). Among the less representative families, Anemiaceae stands out with two species, followed by Blechnaceae, Lomariopsidaceae. And in the lycophytes, Selaginellaceae stands out with a single species. The four most representative families corresponded to 77% of sampled species.

Nine species were found in both terrestrial and rupicolous habitats (Tab. 2). According to the Species List of the Brazilian Flora, 21 species recorded are native (Flora do Brasil 2020, under construction). The only species regarded as non-native, naturalized and sub-spontaneous was *Macrothelypteris torresiana*, which belongs to the family Thelypteridaceae (Tab. 2) (Flora do Brasil 2020, under construction).

The remnants at the advanced succession stage showed the greatest species richness (19), followed by the remnants at the intermediate successional stage (nine species) and at the initial stage (seven species) (Tab. 2).

The average species richness was significantly different (Q = 59.11; p = 0.03) between the stages of succession. Formations at the advanced (late) stage showed significantly higher average richness (5.6 species) than those at the early stage of

Table 2 – Fern and lycophyte species occurring in Taquari-Antas River drainage base, with indication of – ST = substrat types; e = epiphyte; r = rupicolous; t = terrestrial; INI = initial stage of forest succession; INT = intermediate stage of forest succession; LAT = late stage of forest succession; HVAT = voucher number.

Family / Species	**ST**	**INI**	**INT**	**LAT**	**HVAT**
Anemiaceae					
Anemia phyllitidis (L.) Sw.	t/r	X	X	X	4755
Anemia tomentosa var. *anthriscifolia* (Schard.) Mickel	t		X		4756
Aspleniaceae					
Asplenium brasiliense Raddi	t/r			X	4957
Asplenium inaequilaterale Feé	t/r			X	4773
Asplenium sellowianum C.Presl	t			X	4737
Asplenium ulbrichtii Rosenst.	t/r			X	4759
Blechnaceae					
Blechnum auriculatum Cav.	t		X	X	4854
Lomariopsidaceae					
Nephrolepis cordifolia (L.) C.Presl	t		X		4734
Polypodiaceae					
Campyloneurum nitidum C.Presl	t			X	5052
Microgramma squamulosa (Kaulf.) de la Sota	e/t		X		5047
Microgramma vacciniifolia (Langsd. & Fisch.) Copel.	e/t			X	5046
Pteridaceae					
Adiantum digitatum C.Presl	t			X	4726
Adiantum raddianum C.Presl	t/r	X	X	X	4758
Doryopteris concolor (Langsd. & Fisch.) Kuhn & Decken	t/r		X	X	4740
Doryopteris nobilis (T.Moore) C.Chr.	t			X	4958
Doryopteris pentagona Pic.Serm.	t/r	X	X	X	4741
Doryopteris cf. triphylla (Lam.) Christ	t/r			X	4959
Pteris brasiliensis Raddi	t	X		X	4742
Selaginellaceae					
Selaginella muscosa Spring	t	X	X	X	4960
Thelypteridaceae					
Macrothelypteris torresiana (Gaudich.) Ching	t/r	X		X	4735
Christella hispidula (Decne.) Holttum	t			X	4743
Goniopteris riograndensis (Lindm.) Ching	t	X		X	4731

succession (1.66 species). In turn, formations at the intermediate sucessional stage showed average richness similar to those in the other areas.

Four species of those recorded occurred at all stages of succession (*Adiantum raddianum*, *Anemia phyllitidis*, *Doryopteris pentagona*, *Selaginella muscosa*), while 13 species were unique only to one type of area (Fig. 2). Formations at the late successional stage had the highest number of exclusive species (ten) (Tab. 2), followed by those

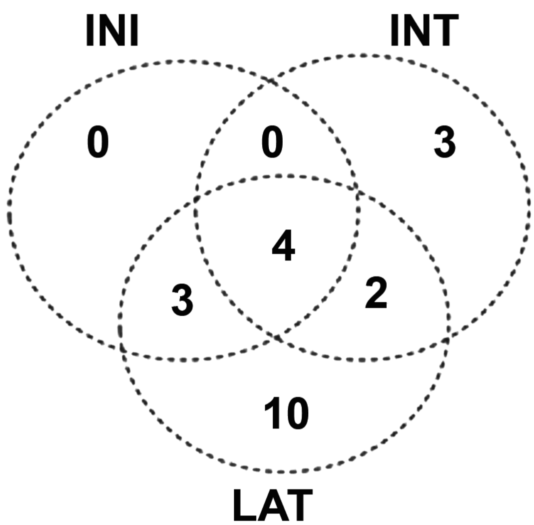

Figure 2 – Venn diagram – number of shared and exclusive species among the three succession stages. Succession stages: INI = initial stage of forest succession; INT = intermediate stage of forest succession; LAT = late stage of forest succession.

areas at intermediate stage of succession (three species). No exclusive species was recorded in areas at the initial successional stage. Riparian forests at late and initial succession stages were more similar in terms of floristic composition than those at intermediate succession areas, as evidenced by the Sørensen Index mean value calculated for all pairs of areas (Tab. 3).

The Non-metric multidimensional scaling ordination (NMDS, Fig. 3) using species composition did not indicate a clear separation among the three forest successional stages in remnants of the Taquari-Antas River basin (co-phenetic relationship > 0.9). This result was also observed for floristic similarity (Bray-Curtis index) shown in Figure 4, using the composition of each study areas. The areas 8, 11, 12 e 17 formed an external group in the analysis. The study areas numbered two and six showed a hundred percent in the floristic similarity. The lowest floristic similarity was in the study area number one.

Discussion

The number of recorded species for the region studied agrees with that generally found in riparian forests in the Atlantic Forest (Diesel & Siqueira 1991; Mallmann & Schmitt 2014; Padoin *et al.* 2015). When compared to the other studies of Rio Grande do Sul state, the total richness of ferns and lycophytes found in the Taquari River riparian forests (22 species) is similar as that recorded by Diesel & Siqueira (1991) in the Sinos River riparian forests (24 species), and lower than that found by Mallmann & Schmitt (2014) in three fragments of the Cadeia River riparian forest (with 0.3 ha sampled), *i.e.*, forty species.

The high species richness observed in Pteridaceae corroborates that observed by Gonzatti *et al.* (2014), who evaluated the deciduous forests remnants of the state of Rio Grande do Sul, Brazil. The vast area for occurrence of this family as an element for greater floristic richness is contradictory if compared to other studies surveying seasonal stationary or rain forests, in which Polypodiaceae was the richest family (Steffens & Windisch 2007; Santos & Windisch 2008; Nervo 2012). *Doryopteris* J.Sm. was the genus with the highest richness recorded, *i.e.*, four species. The high number of species of *Doryopteris* in the study region draws attention to the presence of potentially suitable environments for the development of this genus.

We observed a significant tendency of high species richness at more advanced stages of plant succession. The highest and most significant average species richness was observed in the

Table 3 – Floristic similarity of ferns and lycophytes in three formations forest in different sucession stage in the remnants of the Taquari-Antas River Basin, in Rio Grande do Sul state, Brazil, indicated by the Sørensen Index. INI = initial stage of forest succession; INT = intermediate stage of forest succession; LAT = late stage of forest succession; IHM = internal heterogeneity measure (= Sørensen index calculated for all pairs of areas within one formation).

	*IHM	INI	INT	LAT
INI	0.318	1	0.5	0.538
INT	0.409	0.5	1	0.428
LAT	0.863	0.538	0.428	1

late succession stage. According to Custódio *et al.* (2015), late forests generally have wider and more intact margins. Thus, the continuous flows of streams make margins safe by increasing the diversity of habitats with appropriate conditions for establishment of different fern and lycophyte species. As stated by Miguez *et al.* (2013), the increase in environmental heterogeneity favors the increased diversity of fern and lycophyte species. Such formations generally have greater diversity in soil drainage capacity, a thicker surface (concentration of sand in the soil), and higher contents of organic carbon and nitrogen (Galindo 2008).

Additionally, it is well known that ferns can persist and compete for nutrients on sites with varying fertility (Nervo *et al*. 2019). This behavior can drive the variation among species and help to determine how species are distributed across landscapes (Callaway 2007; Grime 2002; Nervo *et al*. 2019). Furthermore, one study by Hack *et al.* (2005) indicated that areas at advanced (or late) stage of succession usually have a uniform distribution of individuals in a specific occurrence.

Most species (60%) had a restrict ecological range (Fig. 2). They were observed in only one type of successional stage or one study area (for example, *Doryopteris nobilis* was present in only one late formation area), while some species (18%) occurred in more than one stage of succession with wide distribution. In contrast, the predominance of some species extensively throughout the studied areas, such as *Anemia phyllitidis* (occurring in 50% of the surveyed areas), *Adiantum raddianum* (34%), *Doryopteris pentagona* and *Selaginella muscosa* (both with a 28% occurrence), corroborate the results of Nervo *et al.* (2010), who recognized them as species of wide distribution in the state of Rio Grande do Sul with tolerance to several different environments (Nervo *et al.* 2016).

According to Michelon & Labiak (2012), *Anemia phyllitidis* can be found inside forest formations whose substrate is earthy and rupicolous, being common in riparian forest areas of the Iapó River in Paraná. Mynssen & Windish (2004), studying forests in the Atlantic Forest of Rio de Janeiro, stated that the *A. phyllitidis* growth may be related to shaded environments or to greater exposure to sunlight, facilitating a widespread occurrence. In a study conducted by Schwartsburd & Labiak (2007), the authors recorded *A. phyllitidis* inside an Araucaria Forest, riparian forests and silviculture (*Pinus sp.* and *Eucalyptus sp.*) in Paraná. In this study, *Adiantum raddianum* was

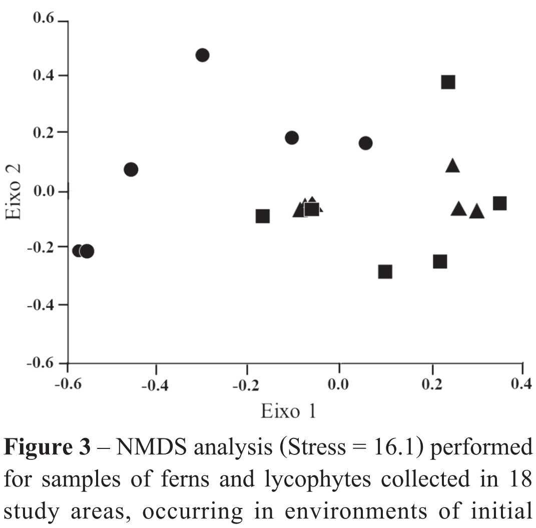

Figure 3 – NMDS analysis (Stress = 16.1) performed for samples of ferns and lycophytes collected in 18 study areas, occurring in environments of initial succession (circle) and intermediate succession (triangle) and late succession (square) in riparian forests of the river Taquari region, Rio Grande do Sul, Brazil.

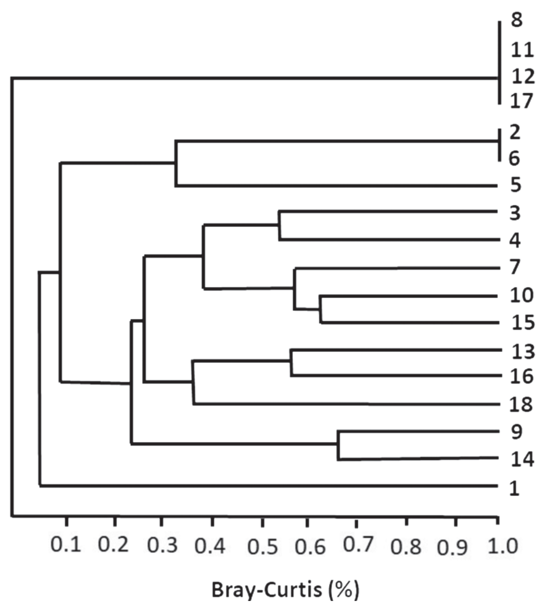

Figure 4 – Similarity dendrogram by the UPGMA algorithm, based on the Bray-Curtis Index (group co-phenetic correlation > 0.9) for the species of ferns and lycophytes sampled in 18 study areas, occurring in the environments of initial stage of forest succession (1 to 6); intermediate stage of succession (7 to 12) and late stage of succession (13 to 18) in riparian forests of the Taquari River region, Rio Grande do Sul, Brazil.

observed on a rupicolous soil substrate. According to Michelon & Labiak (2012), *A. raddianum* inhabits rocks alongside waterfalls and waterways within gallery forests. *Doryopteris pentagona* is often reported as terrestrial species within forest formations and anthropogenic environments (Michelon & Labiak 2012; Nervo *et al.* 2010). The frequent recording of *Selaginella muscosa* in the study areas may be related to the presence of humid and shaded environments (Mynssen & Windisch 2004) and the desiccation-tolerant ability of this species (Mehltreter *et al.* 2010). In addition, *Selaginella*, *Adiantum* and *Anemia* species have wide ecological and geographic distribution (Gonzatti *et al.* 2014), justifying the occurrence of species of genera in all areas.

Unlike expected, the NMDS calculated for all study remnants showed no distinct pattern among the three forest successional stages. This result is also supported by the those of floristic similarity (Bray-Curtis index) shown in by Figure 4. The species present at the initial stage of forest succession share their occurrence with remnants of at the intermediate and late stages of succession. Initial and late stages are more similar according to species composition than to intermediate stages (Tab. 3). Therefore, not only late stages are important for species conservation, but also intermediate stages, which present a similar richness as late stages, but a more dissimilar species composition compared to initial stages. For ferns and lycophytes, the degradation of riparian forests and the changes in springs and watercourses caused by human activities are among the main threats.

Seven species were observed at initial successional stages (Tab. 2). In our study, we observed that these species develop in environments strongly disturbed by human action. *Anemia phyllitidis*, *Doryopteris pentagona*, and *Macrothelypteris torresiana* are species with ruderal behavior, and quick to establish themselves in anthropized environments. *Adiatum raddianum*, *Goniopteris riograndensis*, *Pteris brasiliensis* and *Selaginella muscosa* were observed distributed close to the water streams, in places with higher soil moisture. None of them occurred exclusively in this formation. According to Walker & Sharpe (2010), ferns and lycophytes are sensitive to changes in environment, which affects their establishment, growth and reproduction in certain areas (Walker & Sharpe 2010). Most species are water-dependent for requiring high moisture level to grow and reproduce (Barrington 1993). Therefore, the recent disturbances in such initial succession areas may have considerably changed the structure of initial succession fragments, to which few species have specific adaptations to establish themselves in the environment.

We must also consider the natural disturbance of the areas at initial succession, since water disturbance remains as a factor, considering that the study areas are riverbanks. Comparisons of floristic similarities among formations, as valued by the Sørensen Index (initial *versus* intermediate, initial *versus* late, intermediate *versus* late), evidenced a moderate floristic similarity (Tab. 2). The floristic proximity observed between late and early succession formations (54%) is related to the common distribution of three species (*Macrothelypteris torresiana*, *Pteris brasiliensis* and *Christella hispidula*), which have a wide distribution in Rio Grande do Sul (Lorscheitter *et al.* 2001; Nervo *et al.* 2010). These species, which have greater survival adaptability, establish themselves at initial successional formation and may remain for years within the community, forming extensive populations and contributing to the process of secondary and late succession. On the other hand, the presence of alien species (*Macrothelypteris torresiana*) can be a negative indicator of competition and replacement of native species.

Knowledge of biodiversity in degraded fostered areas by floristic inventories provides key information for advanced studies in taxonomy, ecology, phytogeography, conservation, and reforestation of degraded areas (Souza *et al.* 2009; Nervo 2012). For the group of ferns and lycophytes, the degradation of riparian forests and changes in springs and watercourses caused by human activities are among the main threats. It is worth mentioning that areas at late stage of succession have more than three times as many exclusive species as those at initial successional stages. Thus, the importance of preserving riparian forests of the Taquari River becomes evident for also preserving the local biodiversity.

Continuous government actions that act in synergy with scientific actions are essencial to improve biodiversity knowledge, to promote conservation, and control biodiversity loss (Dias 2017; BFG 2018).

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References

Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM & Sparovek G (2013) Köppen's climate classification map for Brazil. Meteorologische Zeitschrift 22: 711-728. DOI: <https://doi.org/10.1127/0941-2948/2013/0507>

Barrington DS (1993) Ecological and historical factors in fern biogeography. Journal of Biogeography 20: 275-279. DOI: <http://dx.doi.org/10.2307/2845635>.

BFG - The Brazil Flora Group (2018) Brazilian Flora 2020: innovation and collaboration to meet Target 1 of the Global Strategy for Plant Conservation (GSPC). Rodriguésia 69: 1513-1527.

Brasil (1994) Estágios sucessionais da vegetação da Mata Atlântica - Resolução CONAMA n° 4 de 1994. Available at <http://www.mma.gov.br/port/conama/legiabre.cfm?codlegi=174>. Access on 08 March 2017.

Callaway RM (2007) Positive interactions and interdependence in plant communities. Springer, Dordrecht. 404p.

Chaves A (2009) Importância da Mata Ciliar (legislação) na proteção dos cursos hídricos, alternativas para sua viabilização em pequenas propriedades rurais. Available at <http://www.sertao.ifrs.edu.br/site/midias/arquivos/20091114104033296revisao_m...pdf>. Access on 13 June 2017.

Costa FR, Magnusson WE & Luizao RC (2005) Mesoscale distribution patterns of Amazonian understorey herbs in relation to topography, soil and watersheds. Journal of Ecology 93: 863-878. DOI: <http://dx.doi.org/10.1111/j.1365-2745.2005.01020.x>

Custódio ST, Kreutz C & Filho FPA (2015) Influência de assentamento rural sobre a comunidade de samambaias e licófitas em Água Boa - MT. Pesquisas, Botânica 68: 381-393.

Dias B (2017) Biodiversidade, por que importa! Cause Magazine 5: 94-100. Available at <https://www.cause-magazine.com/conteudo/2017/8/15/biodiversidade-por-que-importa->. Access on 28 June 2021.

Dias RM, Salvador NNB & Branco MBC (2014) Identificação dos níveis de degradação de matas ripárias com o uso de SIG. Floresta e Ambiente 21: 150-161.

Diesel S & Siqueira JC (1991) Estudo fitossociológico herbáceo/arbustivo da mata ripária da bacia hidrográfica do Rio dos Sinos, Rio Grande do Sul. Pesquisas, Botânica 42: 205-257.

Durigan G, Rodrigues RR & Schiavini I (2000) A heterogeneidade ambiental definindo a metodologia de amostragem da floresta ciliar. *In:* Rodrigues RR & Leitão Filho HF (eds.) Matas ciliares: conservação e recuperação. EDUSP, São Paulo. Pp. 159-167.

Filgueiras TS, Nogueira PE, Brochado AL & Guala GF (1994) Caminhamento: um método expedito para levantamentos florísticos qualitativos. Cadernos de Geociências 12: 39-43.

Flora do Brasil 2020 em construção (2017) Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Available at <http://floradobrasil.jbrj.gov.br>. Access on 14 April 2017.

Galindo ICL (2008) Relação solo-vegetação em áreas sob processo de desertificação no estado de Pernambuco. Tese de Doutorado. Universidade Federal de Pernambuco, Recife. Pp. 255.

Gonzatti F (2018) Checklist of ferns and lycophytes in a remnant of Atlantic Forest in the state of Rio Grande do Sul, Brazil. Rodriguésia 69: 1893-1908. DOI: <https://doi.org/10.1590/2175-7860201869425>

Gonzatti F, Valduga E, Wasum RA & Scur L (2014) Florística e aspectos ecológicos de samambaias e licófitas em remanescentes de matas estacionais deciduais da serra gaúcha, Rio Grande do Sul, Brasil. Revista Brasileira de Biociências 12: 90-97.

Grime JP (2002) Plant strategies, vegetation processes, and ecosystem properties, 2nd ed. John Wiley & Sons, Chichester. 456p.

Hack C, Longhi SJ, Boligon AA, Murari AB & Pauleski DT (2005) Análise fitossociológica de um fragmento de Floresta Estacional Decidual no município de Jaguari, RS. Ciência Rural 35: 1083-1091.

Hammer O, Harper DAT & Ryan PD (2003) Past: Paleontological statistics software package for education and data analysis. Available at <https://palaeo-electronica.org/2001_1/past/intro.htm>. Access on 13 April 2017.

IBGE - Instituto Brasileiro de Geografia e Estatística (2017) Mapa exploratório de solos do Rio Grande do Sul. Available at <http://geoftp.ibge.gov.br/informacoes_ambientais/pedologia/mapas/>. Access on 23 June 2017.

Lorscheitter ML, Ashraf AR, Windisch PG & Mosbrugger V (2001) Pteridophyte spores of Rio Grande do Sul flora, Brazil. Part III. Palaeontographica 260: 1-165.

Mallmann IT & Schmitt JL (2014) Riqueza e composição florística da comunidade de samambaias na mata ciliar do Rio Cadeia, Rio Grande do Sul, Brasil. Ciência Florestal 24: 97-109.

Martins SV (2007) Recuperação de matas ciliares. 2ª ed. Vol. 1. Editora Aprenda Fácil, Viçosa. 255p.

Mehltreter K, Walker LR & Sharpe JM (2010) Fern Ecology. Published by Cambridge University Press, Cambridge. 444p.

Mencacci PC & Schlittler FHM (1992) Fitossociologia da vegetação arbórea da mata ciliar de Ribeirão Claro, município de Rio Claro, SP. Revista do Instituto Florestal 4: 245-251.

Michelon C & Labiak PH (2012) Samambaias e Licófitas do Parque Estadual do Guartelá, Paraná. Hoehnea 40: 191-204. DOI: <http://dx.doi.org/10.1590/S2236-89062013000200001>

Miguez FA, Kreutz C & Athayde Filho FP (2013) Samambaias e licófitas em quatro matas de galeria do município de Nova Xavantina, Mato Grosso, Brasil. Pesquisas, Botânica 64: 243-258.

Mynssen CM & Windisch PG (2004) Pteridófitas da Reserva Rio das Pedras, Mangaratiba, RJ, Brasil. Rodriguésia 55: 125-156.

Nervo MH (2012) Diagnóstico da composição florística e do efeito de borda sobre a comunidade de samambaias e licófitas em remanescente de Floresta Atlântica da Bacia do Rio dos Sinos, RS, Brasil [M.Sc. dissertation]. Universidade FEEVALE, Novo Hamburgo. Pp. 77.

Nervo MH & Windisch PG (2010) Ocorrência de *Pityrogramma trifoliata* (L.) R.M. Tryon (Pteridaceae) no estado do Rio Grande do Sul, Brasil. Iheringia, Série Botânica 65: 291-293.

Nervo MH, Windisch PG & Lorscheitter ML (2010) Representatividade da base amostral da pteridoflora do estado do Rio Grande do Sul (Brasil) e novos registros de distribuição. Pesquisas, Botânica 61: 245-258.

Nervo MH, Coelho FVS, Windisch PG & Overbeck GE (2016) Fern and lycophyte communities at contrasting altitudes in Brazil's subtropical Atlantic Rain Forest. Folia Geobotanica 51: 305-317.

Nervo MH, Andrade BO, Tornquist CG, Mazurana M, Windisch PG & Overbeck GE (2019) Distinct responses of terrestrial and epiphytic ferns and lycophytes along an elevational gradient in Southern Brazil. Journal of Vegetation Science 30: 55-64.

Nóbrega GA, Eisenlohr PV, Paciencia MLB, Prado J & Aidar MPM (2011) Ferns composition and diversity differ between Restinga and Lowland Rainforest areas in the Serra do Mar? Biota Neotropica 11: 153-164. DOI: <http://dx.doi.org/10.1590/S1676-06032011000200015>

Oliveros JC (2007) VENNY. An interactive tool for comparing lists with Venn Diagrams. Available at <http:/bioinfogp.cnb.csic.es/tools/venny/index.html>. Access on 22 March 2017.

Paciencia MLB & Prado J (2004) Efeitos de borda sobre a comunidade de pteridófitas na Mata Atlântica da região de Una, sul da Bahia, Brasil. Revista Brasileira Botânica 27: 641-653.

Paciencia MLB & Prado J (2005) Distribuição espacial da assembleia de pteridófitas em uma paisagem fragmentada de Mata Atlântica no sul da Bahia, Brasil. Hoehnea 32: 103-117.

Padoin TOH, Graeff V, Silva VL & Schmitt JL (2015) Florística e aspectos ecológicos das samambaias e licófitas da mata ciliar de um afluente do Rio Rolante no sul do Brasil. Pesquisas, Botânica 68: 335-348.

Pessoa MCPY, Ghini R, Marques JF, Skorupa LA, Brandão MSB, Castro VLS, Saito ML, Bettioland W & Ferraz JMG (2000) Modelo conceitual de indicadores de sustentabilidade para a Microbacia do Córrego Taquara Branca, Sumaré, SP. *In*: Marques JF, Skorupa LA & Ferraz JMG (eds.) Indicadores de Sustentabilidade em Agroecossistemas. Embrapa Meio Ambiente 2003, Jaguariúna. 281p.

Pillar VDP (1997) Multivariate exploratory analysis and randomization testing with MULTIV. Coenoses 2: 145-148.

Pillar VDP & Orlóci L (1996) On randomization testing in vegetation science: multifactor comparisons of relevé groups. Journal of Vegetation Science 7: 585-92.

PPG I (2016) The Pteridophyte Phylogeny Group. A community-derived classification for extant lycophytes and ferns. Institute of Botany, Chinese Academy of Sciences 54: 563-603.

R Core Team (2013) R: a language and environment for statistical computing. R Foundation for Statistical Computing, Vienna. Available at <http://www.r-project.org/>. Access on 14 April 2017.

Ribeiro-Filho AA, Funch LS & Rodal MJN (2009) Composição florística da Floresta Ciliar do Rio Mandassaia, Parque Nacional da Chapada Diamantina, Bahia, Brasil. Rodriguésia 60: 265-276.

Rodrigues RR & Gandolfi S (2000) Conceitos, tendências e ações para a recuperação de florestas ciliares. *In*: Rodrigues RR & Leitão Filho HF (eds.) Matas ciliares: conservação e recuperação. EDUSP/FAPESP, São Paulo. Pp. 235-247.

Rodrigues ST, Almeida SS, Andrade LHC, Barros ICL & Van Den Berg ME (2004) Composição florística e abundância de samambaias em três ambientes da bacia do Rio Guamá, Belém, Pará, Brasil. Acta Amazonica 34: 35-42.

Santos ACC & Windish PG (2008) Análise da Pteridoflora da área de proteção ambiental do Morro da Borússia (Osório-RS). Pesquisas, Botânica 59: 237-252.

Schwartsburd PB & Labiak PH (2007) Pteridófitas do Parque Estadual de Vila Velha, Ponta Grossa, Paraná, Brasil. Hoehnea 34: 159-209.

Sehnem A (1967a) Maratiáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 18p.

Sehnem A (1967b) Osmundáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 11p.

Sehnem A (1967c) Plagiogiriáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 7p.

Sehnem A (1967d) Vitariáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 18p.

Sehnem A (1968a) Aspleniáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 93p.

Sehnem A (1968b) Blecnáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 87p.

Sehnem A (1970a) Gleiqueniáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 35p.

Sehnem A (1970b) Polipodiáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 165p.

Sehnem A (1971) Himenofiláceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 93p.

Sehnem A (1972) Pteridáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 233p.

Sehnem A (1974) Esquizeáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 74p.

Sehnem A (1978) Ciateáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 112p.

Sehnem A (1979a) Aspidiáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 338p.

Sehnem A (1979b) Davaliáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 17p.

Sehnem A (1979c) Marsiliáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 8p.

Sehnem A (1979d) Ofioglossáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 15p.

Sehnem A (1979e) Parkeriáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 5p.

Sehnem A (1979f) Psilotáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 7p.

Sehnem A (1979g) Salviniáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 10p.

Sehnem A (1984). Eqüisetáceas. Flora Ilustrada Catarinense. Herbário Barbosa Rodrigues, Itajaí. 10p.

Souza ACR, Almeida Júnior EB & Zickel S (2009) Riqueza de espécies de sub-bosque em um fragmento florestal urbano, Pernambuco, Brasil. Biotemas 22: 57-66.

Steffens C & Windish PG (2007) Diversidade e formas de vida de pteridófitas no Morro da Harmonia em Teutônia - RS, Brasil. Pesquisas, Botânica 58: 375-382.

Tuomisto H & Ruokolainen K (1994) Distribution of Pteridophyta and Melastomataceae along an edaphic gradient in an Amazonian rain forest. Journal of Vegetation Science 5: 25-34.

Van Der Berg E & Oliveira-Filho AT (2000) Composição florística e estrutura fitossociológica de uma floresta ripária em Itutinga, MG e comparação com outras áreas. Revista Brasileira de Botânica 23: 231-253.

Visnadi SR & Vital DM (2001) Briófitas das Ilhas de Alcatrazes, do Bom Abrigo, da Casca e Castilho, estado de São Paulo, Brasil. Acta Botânica Brasílica 15: 255-270.

Walker LR & Sharpe JM (2010) Ferns, disturbance and succession. *In*: Mehltreter K, Walker LR & Sharpe JM (eds.) Fern ecology. Cambridge University Press, Cambridge. Pp. 177-219.

Weigand A, Abrahamczyk S, Aubin I, Bita-Nicolae C, Bruelheide H, Carvajal-Hernández CI, Cicuzza D, Costa LEN, Csiky J, Dengler J, Gasper AL, Guerin GR, Haider S, Hernández-Rojas A, Jandt U, Reyes-Chávez J, Lehnert M, Lenoir J, Moulatlet GM, Aros-Mualin D, Noben S, Olivares I, Quintanilla LG, Reich PB, Salazar L, Silva-Mijangos L, Tuomisto H, Weigelt P, Zuquim G, Kreft H & Kessler M (2019) Global fern and lycophyte richness explained: how regional and local factors shape plot richness. Journal of Biogeography 47: 59-71. DOI: <https://doi.org/10.1111/jbi.13782>.

Zuquim G, Costa FRC & Prado J (2007) Redução de esforço amostral *vs.* retenção de informação em inventários de samambaias na Amazônia Central. Biota Neotropica 7: 217-223.

Zuquim G, Costa FRC, Prado J & Braga-Neto R (2009) Distribution of Pteridophyte communities along environmental gradient in Central Amazonia, Brazil. Biodiversity and Conservation 18: 151-166. DOI: <http://dx.doi.org/10.1007/s10531-008-9464-7>.

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