

Abundances of three spider (Araneae) species in native and managed ecosystems in Rio Grande do Sul State, Brazil

Abundância de três espécies de aranhas (Araneae) em ecossistemas nativos e manejados no Rio Grande do Sul, Brasil

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Abstract

We assessed the abundance patterns of three theridiid species: *Hetschkia gracilis* (Keyserling 1886); *Phycosoma altum* (Keyserling 1886); and *Thwaitesia affinis* O. P.-Cambridge, 1882 in four habitats: Araucaria Forest (native forest) and plantations of *A. angustifolia*, *Pinus* spp., and *Eucalyptus* spp. in Floresta Nacional de São Francisco de Paula Reserve, southern Brazil. The plantation stands in the study system are managed by the selective cutting of adult trees, allowing longer rotation intervals. We collected spiders in 2003 and 2004 by beating the vegetation inside three replicates of each forest type. We performed a permanova to test whether there were differences on species abundances between habitats. We tested the influence of the stand sizes, distance between stands, and vegetation cover composition on each spider species abundance. Stands with higher vegetation cover of bushes and vines presented higher abundances of *Hetschkia gracilis* and *Thwaitesia affinis*. *Phycosoma altum* abundance did not respond to any explanatory variables. Results highlighted the importance of alternative management of plantation stands to enhance and maintain the understory vegetation diversity, which in turn support the spider populations.

Key words: Araucaria Forest, Habitat structure, *Pinus* plantation, *Eucalyptus* plantation, Forest management.

Resumo

Os padrões de abundância de três espécies de Theridiidae - *Hetschkia gracilis*, *Phycosoma altum* e *Thwaitesia affinis* foram analisados em quatro habitats florestais: Floresta com Araucária, plantação de Araucária, plantação de *Pinus* e plantação de *Eucalyptus* na Floresta Nacional de São Francisco de Paula, sul do Brasil. O manejo florestal aplicado na área de estudo consiste no corte seletivo e no longo período de rotação. As coletas foram realizadas com guarda-chuva entomológico entre 2003 e 2004 em três repetições de cada tipo florestal. Diferenças nas abundâncias entre os habitats foram avaliadas através de permanova. Para testar a influência do tamanho dos talhões, da distância entre eles e da composição da cobertura vegetal sobre as abundâncias das três espécies, utilizou-se regressão múltipla. As abundâncias de *Hetschkia gracilis* e de *Thwaitesia affinis* estiveram diretamente correlacionadas com a presença de lianas e arbustos, enquanto a de *Phycosoma altum* não respondeu a nenhuma variável explicativa. Os resultados realçam a importância do manejo alternativo realizado nesta Floresta Nacional para o incremento e a manutenção da diversidade da vegetação do sub-bosque, o que proporciona estrutura para sustentar as populações de aranhas.

Palavras-chave: Floresta com Araucária, Estrutura de habitat, Plantação de *Pinus*, Plantação de *Eucalyptus*, Manejo florestal.

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Introduction

Forest ecosystems worldwide were transformed by human activities. In temperate and subtropical regions, large areas are still suffering heavy exploitation. The environmental mosaic composed of patches of distinct forest composition and/or structure creates a range of habitat conditions suited to the colonization and establishment of animal populations (Lindenmayer and Franklin, 2002). Thus, relating human influence on managed forests to patterns of animal abundance is one of the key issues for managing diversity (Ernault *et al.*, 2003).

The subtropical humid forest of the upland landscape of southern Brazil is dominated by *Araucaria angustifolia* (Bertol.) Kuntze (Araucariaceae) and is part of the Atlantic Forest biome (*lato sensu*). Thus, it is considered a global biodiversity hotspot for conservation priorities (Myers *et al.*, 2000). However, from the beginning of European colonization of the region in the 1850's, the Araucaria Forest suffered heavy timber exploitation, as well as habitat loss due to agricultural expansion, in particular cattle grazing. These practices caused the degradation of about 86% of the natural landscape. In the 1960's, large scale reforestation began, mainly with *Eucalyptus* (Myrtaceae), *Pinus* (Pinaceae), and *Acacia* (Mimosaceae) species (IBDF, 1983). This practice persists until today, creating a heterogeneous landscape mosaic. Spiders are widespread intermediate-level predators and their distribution and occurrence are strongly influenced by habitat structure (Uetz, 1991). Spider abundance can be positively correlated with vegetation diversity, which provides a range of attachment points to webs (Baldissera *et al.*, 2004) and influences the prey availability. In managed areas, spider assemblages can show different patterns of distribution and occurrence, suggesting differential response to structural changes imposed by human activities (Cattin *et al.*, 2003).

There are numerous papers dealing with spiders in the context of forest management. Impacts and management actions on forest systems range from various types of timber harvesting, wildfire, prescribed burning, attack by insect pests, and forest fragmentation (e.g., Docherty and Leather, 1997; Harris *et al.*, 2003; Abbott *et al.*, 2003; Brennan *et al.*, 2006; Chen and Tso, 2004; Baldissera *et al.*, 2008). The conversion of native forests into tree plantations can potentially affect the distribution and occurrence of spiders. Causal effects of vegetation structure (Robinson, 1981; Scheidler, 1990; Uetz, 1991; Wise, 1993; Buddle *et al.*, 2000; Baldissera *et al.*, 2004; Horvath *et al.*, 2005; Baldissera *et al.*, 2008) and landscape variables (Bonte *et al.*, 2004; Rego *et al.*, 2007) on spider abundances were inferred in various studies. Web spiders are thought to have the strongest relationship with physical structures because of the requirement for web attachment sites (Uetz, 1991). The time since isolation, the distance between adjacent original remnants, and the degree of connectivity between them are all important determinants of the biotic response to fragmentation (Saunders *et al.*, 1991). Individual spider species can present differential responses to habitat changes following forest management regimes (Ewers and Didham, 2006). Therefore, knowledge of spider species abundance patterns, such as habitat preferences and spatial distribution, in managed and native forests is vital for integrating diversity conservation into future planning and management of forest ecosystems.

Our objective was to assess the abundance patterns of *Hetschkia gracilis* (Keyserling 1886), *Phycosoma altum* (Keyserling 1886), and *Thwaitesia affinis* O.P. - Cambridge, 1882 in the understory of an Araucaria Forest and three managed forest habitats: Araucaria plantation, *Eucalyptus* plantation, and *Pinus* plantation. These species were chosen because they performed three of the most abundant

species found in the region. We also tested the influence of within- and between-stand factors that potentially can explain individual species abundances: size of stands, mean distance between stands, and composition of vegetation cover. Following previous results on this forest system (Baldissera *et al.*, 2008) we hypothesized to find the vegetation cover composition as the best predictor of species abundances. It is the first attempt to assess patterns of response of the three species in forested systems.

Material and Methods

Study area

We carried out the study in the National Forest of São Francisco de Paula (29°23'S; 50°23'W), in the highlands of the state of Rio Grande do Sul, in southern Brazil (study area 845 m - 916 m a.s.l). Brazilian government established the reserve in 1945 and it encompasses an area of 1,600 ha. Araucaria Forest forms the matrix, i.e., the dominant patch type in the region and plantations of two exotic commercial woody species are embedded in the Araucaria Forest: *Pinus* spp. and *Eucalyptus* spp., as well as plantations of *Araucaria angustifolia* (Figure 1). The area represents a subtropical region of mid-latitude climatic conditions with no dry seasons. Mean rainfall was 2,235 mm year⁻¹ evenly distributed along the year and minimum and maximum temperatures were 4.5°C and 29°C, respectively, during the study years of 2003 and 2004. Contrary to usual management practices throughout the region, the plantation stands are managed by the selective cutting of adult trees, allowing longer rotation intervals, which creates conditions for understory vegetation establishment and persistence. Plantations present a canopy composed mainly by the tree of interest for timber and the understories are denser and composed mainly by bushes and vines. Therefore, the

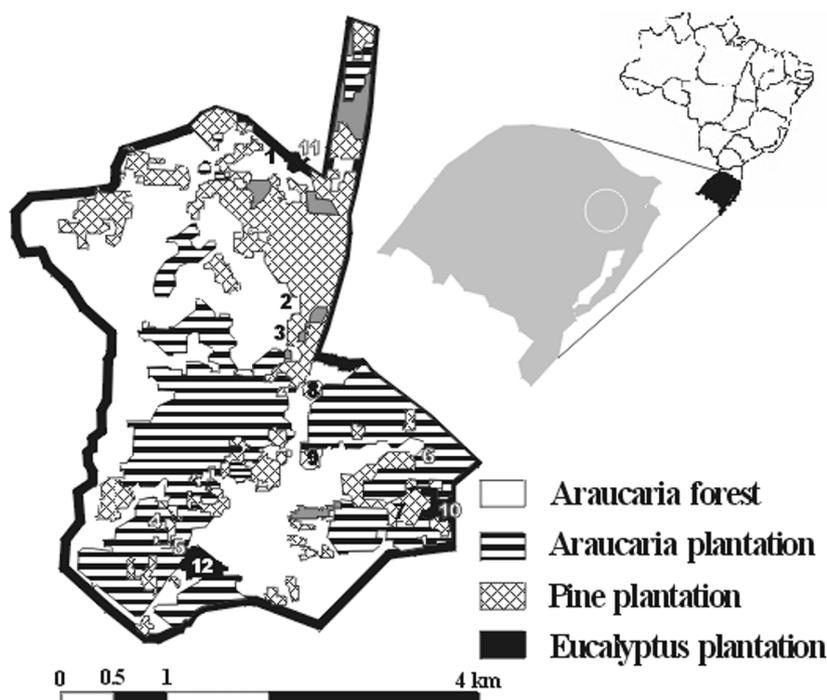


Figure 1. Landscape mosaic of Floresta Nacional de São Francisco de Paula in southern Brazil. Numbers in the map indicate the 12 patches sampled in the study. Grey represents building areas.

majority of plantation stands presents denser understory vegetation.

Sampling design

The study sites encompassed three stands of each plantation forest and three areas of Araucaria Forest (total of 12 stands). The plantation stands varied in age from 11 years (*Eucalyptus* plantation) to 58 years (*Araucaria* plantations), considering the year of 2003 when sampling began. Mean stand areas varied from 34 ha (Araucaria Forest) to 7 ha (*Eucalyptus* plantation) (Table 1). We established inside each stand two 50 m² permanent plots. Along a centralized 100 m long transect, we sorted two points out of 50. From these points, two 25 × 2 m² plots were established perpendicularly to the main transect. We calculated the geographical location of each stand utilizing a manual GPS device. Afterwards, we calculated the distance between each stand and the average distance between the other 11

stands (edge to edge distance) in order to check whether the distance could influence species abundance patterns (see Table 1).

Spider collections

We made the samplings during dry days by beating all the vegetation with a 1 m long stick at heights between 1 m and 2.5 m inside each plot. We did surveys during three field trips in April to May, July to August and December to January during 2003; and also April to May, July to August and October to November during 2004, to include the four main seasons. During each field trip, we surveyed one stand (two plots) of each one of the four vegetation types (total of four stands per field trip). We struck all parts of the vegetation inside each plot including tree branches, leaves, vines, bushes, ferns, and grasses. We collected the fallen vegetation with a 1 m² canvas sheet held horizontally below the vegetation and placed it inside a plas-

tic bag. We inspected the vegetation in the laboratory, where we selected the spider species by hand and stored them in 70% ethanol. Voucher species were deposited in the arachnological collection of the Instituto Butantan, in the state of São Paulo, Brazil.

Vegetation measurements

We surveyed the vegetation by taking 50 point measurements of vegetation cover at horizontal 1 m intervals and between 1 m and 2.5 m height. Each measurement consisted of counting the number of vegetation touches to a 2.5 m stick. For each measurement, we divided the touches into five vegetation life forms: trees (any individual woody plant higher than 2.5 m), bushes (woody plants between 1 m and 2.5 m in height), vines (both woody and herbaceous), ferns, and grasses. We made the measurements in winter 2003 and summer 2004, and the two values correlated well (Pearson's $r = 0.891$; Bonferroni probability < 0.001), therefore we averaged the two values to estimate the vegetation cover density.

Statistics

We performed a PCoA ordination analysis to characterize the stands in relation to the vegetation life forms. We utilized the Euclidean distance dissimilarity matrix based on the matrix of the five vegetation life forms in each stand. Euclidean distance is a valid basis for comparing sites based on environmental descriptors (Legendre and Legendre, 1998). Vegetation touch data was square-rooted prior to PCoA analysis because grass abundance presented many null values. We used the software Multiv v. 2.63b to assess the variation in the vectors of abundances of each spider population in the vegetation types by a one-way permanova (1000 iterations), based on a Euclidean distance dissimilarity matrix between forest stands. Multiv utilizes randomization

Table 1. Characteristics of 12 stands of four vegetation types in southern Brazil: mean elevation (averaged from the two sampling unit measurements), year of formation (for AF stands, it is the year of Reserve formation). AF = Araucaria Forest; AP = *Araucaria* plantation; PP = *Pinus* plantation; EP = *Eucalyptus* plantation. See text for detailed description.

Stand	Elevation (m.a.s.l.)	Year	~Area (ha)	Distance (m)
AF1	875	-	50	3355
AF2	916	-	28	2069
AF3	872	-	24	1936
AP1	867	1959	23	2121
AP2	864	1947	9	2292
AP3	862	1947	9	2390
PP1	885	1965	9.5	2064
PP2	876	1972	4.5	1748
PP3	905	1968	9	1716
EP1	885	1972	4	2374
EP2	909	1994	2	2968
EP3	875	1988	15	2621

tests to compare groups of sampling units based on a sum of squares between groups as test criterion (Pillar and Orlóci, 1996). The results are interpreted similarly to the ones in an analysis of variance table.

We carried out a backward stepwise multiple regression analysis to verify spider species responses to environmental variables with each species abundance separately as dependent variables and (i) the first axis of PCoA ordination analysis, (ii) the sizes of stands and (iii) the distance of each stand from the averaged distance of the other eleven stands as independent variables. Independent variables were removed from the full models at the 0.05 significance level. We utilized a square root transformation on *P. altum* data prior to regression analysis to meet normality assumptions. All regression residuals were normally distributed (Kolmogorov-Smirnov one sample test).

Additionally, because the age influence may be confounded with understory vegetation composition, we tested for an age influence on spider population abundance patterns by fitting the interaction between PCoA axis 1 scores and the stand ages using a General Linear Model. Ordination was performed on Multiv v 2.63b

(Pillar, 2006). Regressions and GLMs were performed on Systat 11 (SYSTAT, 2004).

Results

The resulting PCoA first axis explained 67.99% of vegetation variation (Fig. 2), while axis two explained 18.35%. Vines and bushes showed higher negative correlations with first ordination axis (Figure 2), while the grass touch type was the only positively correlated with the first axis. Therefore, the first axis showed a gradient of transition from the stands with higher values of grasses (right-hand), mainly the *Eucalyptus*, to the stands with no grasses at all (left-hand) – the *Pinus* and *Araucaria* plantation stands. The second axis roughly separated the Araucaria Forest stands at the bottom, which showed higher values of trees. We did not detect influences of the interaction between age and vegetation on spider population abundances (*H. gracilis*: $t=0.293$, $P=0.718$; *P. altum*: $t=0.293$, $P=0.294$; *T. affinis*: $t=0.293$; $P=0.571$). Therefore, the age of stands did not influence the responses of spider populations.

The mean abundance of all populations was higher in the *Pinus* plantation (Table 2). However, permanova

results did not show differences in the abundances of each one of the three species among the vegetation types (*H. gracilis*: $SS = 125.67$, $P = 0.565$; *P. altum*: $SS = 40.25$, $P = 0.398$; *T. affinis*: $SS = 24.33$, $P = 0.110$). *Phycosoma altum* abundance did not respond to any explanatory variables. *Hetschikia gracilis* ($r^2 = 0.692$; $F_{1,10} = 22.491$; $P = 0.001$; Figure 3) and *T. affinis* ($r^2 = 0.366$; $F_{1,10} = 5.776$; $P = 0.037$; Figure 4) abundances were positively correlated to the scores of the PCoA first axis, showing that stands presenting more vines and bushes had higher abundances of the two species.

Discussion

The best predictor of *H. gracilis* and *T. affinis* abundances was the composition of vegetation cover. Clearly, the species increased numbers in the stands presenting more vines and bushes: *Pinus* and *Araucaria* plantations. The higher abundance of vegetation structures per se could serve as suitable habitat influencing web-site selection; and the denser understory vegetation created by vines and bushes intercept the fallen needles of *Araucaria* and *Pinus*, augmenting the area of vegetation that could serve for web-site placement. Therefore, the abundances of the two populations on plantations were highly correlated to increased habitat complexity that increase the resources to construct their tridimensional webs and living leaves to construct retreats (Halaj *et al.*, 2000; Stiles and Coyle, 2001). Although we cannot draw conclusive explanations on the patterns found, because there is no data on the permanence of observed abundances over a long period, the interspersed pattern of plantations inside the Araucaria Forest matrix produces habitat diversifications maximizing spatial diversity, heterogeneity and connectivity. These characteristics were found to be more effective in managing spider and other taxa diversity and abundance in this same forested

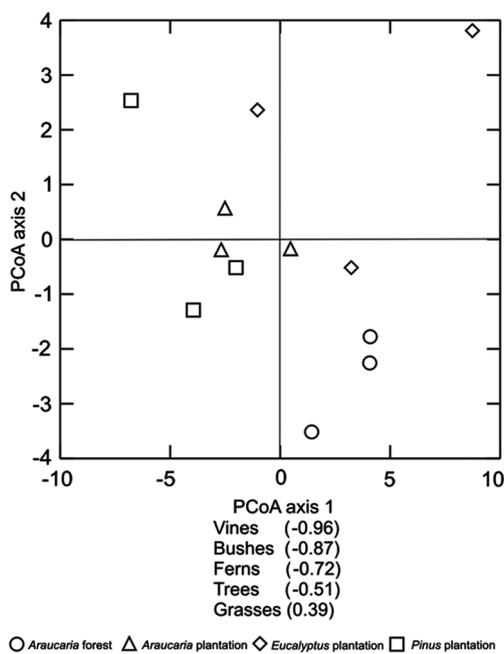


Figure 2. Scatterplot of the scores of the first and second PCoA axis based on vegetation life forms in an Araucaria Forest and three managed vegetation types in southern Brazil. Correlation coefficients between original descriptors and ordination axis 1 are shown on both sides of axis 1.

Table 2. Mean abundances (ind./100 m²) and standard errors of three theridiid species found in four habitats in southern Brazil. AF = Araucaria Forest; AP = Araucaria plantation; PP = Pinus plantation; EP = Eucalyptus plantation.

	AF	AP	PP	EP
<i>Hetschkia gracilis</i>	7±1	13.67±3.38	15.33±2.4	10±7.64
<i>Phycosoma altum</i>	0.33±0.33	1.14±0.59	2.1±0.68	1.46±0.78
<i>Thwaitesia affinis</i>	0.67±0.67	3.33±0.88	4.33±0.88	1.67±1.2

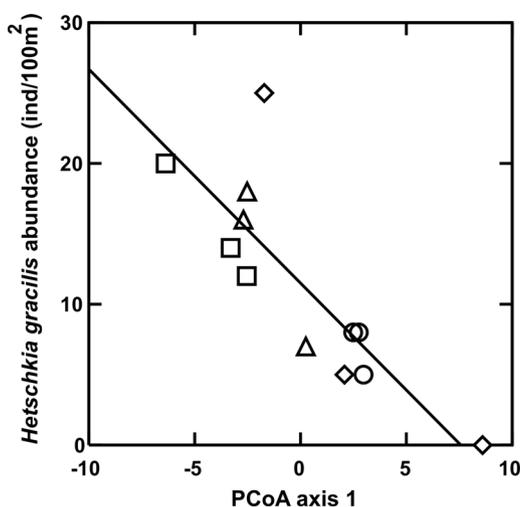


Figure 3. Relationship between *Hetschkia gracilis* abundance and PCoA first axis scores. Resulting model: *H. gracilis* abundance = 11.500 × -1.519axis1.

system and elsewhere (Samu *et al.*, 1999; Thorbek, 2003; Abbott *et al.*, 2003; Fonseca *et al.*, 2009). The selective cutting and long rotation periods of stands in this silviculture system allow the establishment and maintenance of understory diversity (Fonseca *et al.*, 2009), demonstrating that negative impacts of logging on invertebrates could be ephemeral depending on the intensity of disturbances (Abbott *et al.*, 2003).

The lack of between-habitat differences in spider population abundances may be reflecting the homogenization of stands resulting from the managing practices, which allow a connection between the understories of the different stands. The homogenization may enhance the tolerance of theridiid populations to the habitat alterations in the long run, because the increase of vegetation structures may provide more sites to web attachment, retreat construction and shelter from abiotic stressors (Wise, 1993). Aubert and Oliveira-Filho (1994) showed that the presence of native forest in the surroundings of managed *Pinus* and *Eucalyptus* stands coupled with a long-time period of rotation (16 years) allowed the understories of plantations to show a similar plant composition with the native areas. Typically, the rotation time employed in the classical rotation period for commercial tree monocultures is 7-10 years, which avoid the development of a dense understory. Indeed, some empirical studies indicate that understory diversity is the best predictor of the diversity of animals in monocultures (López and Moro, 1997; Humphrey *et al.*, 1999).

The methods utilized here were not the best to assess specific characteristics of the species and there is not bibliographic information about them either that could help us in this matter. Moreover, the possibility of finding spurious correlations is present in almost every mensurative experiment, because this kind of research is explorative in essence and rigorous control over confounding factors is difficult

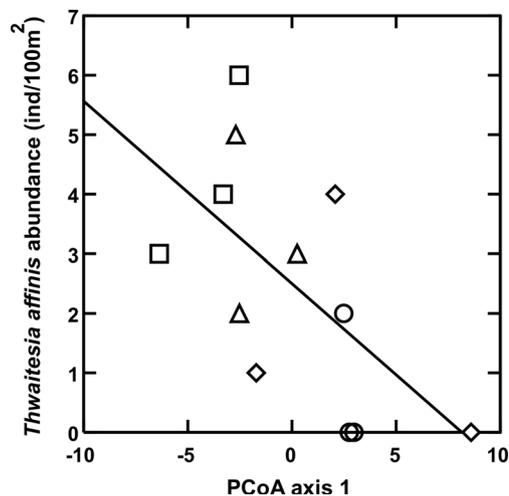


Figure 4. Relationship between *Thwaitesia affinis* abundance and PCoA first axis scores. Resulting model: *T. affinis* abundance = $-0.306 \times 2.5\text{axis}1$.

to achieve. However the effects found in the present study are well supported by theory (Rubinfeld, 2000) related to the response of spider diversity to variations on vegetation diversity and composition in various managed ecosystems around the world and in this same ecosystem (e.g. Brown *et al.*, 2003; Oxbridge *et al.*, 2005; Schmidt *et al.*, 2005; Baldissera *et al.*, 2008). Therefore, we believe our study can serve as a starting point to future research on spider populations in managed forest systems.

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