



## Original article

## Edge effects on epigeic ant assemblages in a grassland–forest mosaic in southern Brazil

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## ABSTRACT

This study analyzed the influence of vegetation structure variation along a natural vegetation mosaic formed by *Araucaria* forest and *Campos* grassland in the southern Brazilian highlands, on the species richness and composition of epigeic ants. The study site consisted of two different grassland–forest ecotones, where 76 pitfall traps were installed. We estimated the area covered by canopy vegetation by hemispherical photographs, and the structure of the understory vegetation by counting the number of vegetation touches, using a graduated stick. We collected 31 species or morphospecies of epigeic ants belonging to 17 genera and 6 subfamilies. Cluster analysis defined three habitat groups (grassland, edge, and forest) with different ant species composition as revealed by ordination analysis. The highest richness was observed at the forest edge, and decreased towards the grassland and the forest interior. Variation in the richness and composition of epigeic ant species was significantly explained by the factor of distance from the forest. The relationship between species richness and understory density was negative. On the other hand, species composition of epigeic ant assemblages was significantly explained by canopy cover. This finding indicates that the ecological responses of ant assemblages resulted predominantly from edge effects mediated by changes in vegetation structure.

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## 1. Introduction

Edge effects result from the interplay between two spatially contiguous ecosystems (Murcia, 1995). Edges usually exhibit features of both contiguous ecosystems, merged with particular microhabitat conditions generated by the contact between distinct environments (Risser, 1995). Edges often show increased biodiversity levels and complexity of vegetation structure (Murcia, 1995; Risser, 1995), which influences both vertebrate (Stevens and Husband, 1998) and invertebrate assemblage patterns (Majer et al., 1997).

Insect assemblages are very important components of biodiversity, because they accumulate considerable biomass and show high species richness. Furthermore, insects play central roles in ecosystem functioning (Erwin, 1991; Folgarait, 1998). For these reasons, insects are valuable ecological indicators of edge effects in natural mosaic landscapes. Among insects, ants can be considered as terrestrial ecosystem engineers, because they are capable of modifying habitats and regulating resource distribution to other organisms (Jones et al., 1994). Many studies have used ants as

bioindicators of ecological processes (Culver and Beattie, 1983; Majer, 1983; Andersen and Sparling, 1997) in some cases, ant functional groups have been identified (Andersen, 1995; King et al., 1998; Hoffmann and Andersen, 2003; Stephens and Wagner, 2006), making possible comparisons among ant communities across biogeographical zones (Hoffmann and Andersen, 2003).

Edges influence ant assemblage patterns, because variation in vegetation structure creates environmental gradients that affect ant activities such as nesting and foraging (Basu, 1997). For this reason, habitats with different degrees of complexity tend to show ant assemblages with distinct species compositions (Lassau and Hochuli, 2004). Nonetheless, Andersen (2008) has argued that habitat characteristics may not explain all the variation in richness and composition in ant assemblages. Other factors such as dispersal limitation could also be involved in the formation of ant assemblages across landscapes. Thus, analyses of species–habitat relationships should take into account between-site variation in species distribution, to avoid confounding effects of habitat on ant assemblages with spatial dispersal limitation.

Although forests with *Araucaria angustifolia* (Araucariaceae) constitute the main forest type on the highland plateau in southern Brazil at altitudes above 500 m a.s.l. (Duarte and Dillenburg, 2000), data about the ant fauna of Brazilian *Araucaria* forests are scarce (but see Ketterl et al., 2003; Silva and Silvestre, 2004; Diehl et al., 2005).

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*Araucaria* forests in southern Brazil often form mosaics with *Campos*, which is a native grassland vegetation (Rambo, 1994; Duarte et al., 2002). Our main goal in this study was to analyze the influence of edge effects on species richness and composition of epigeic ant assemblages occurring in a natural vegetation mosaic formed by *Araucaria* forest and *Campos* grassland in southern Brazilian highlands. Then, we discuss the suitability of ants for the conservation of ecological processes in forest–grassland mosaics.

## 2. Materials and methods

### 2.1. Study site

The study was conducted at 29°28'S and 50°13'W, in the Pró-Mata Research and Nature Conservation Center (CPCN Pró-Mata). The Center covers an area of 4500 ha and is located in São Francisco de Paula, state of Rio Grande do Sul, southern Brazil. The regional climate is classified according to Köppen's system as Cfb (Moreno, 1961), which is subtropical (C) and rainy, with precipitation uniformly distributed throughout the year (f), and warm summers (b). The annual mean temperature is ca. 15.1 °C (Hijmans et al., 2005), with freezing temperatures occurring from April to November (Backes, 1999). The annual mean rainfall is 2086 mm, equally distributed throughout the year (Hijmans et al., 2005).

The study site consisted of ca. 78 ha *Campos* grassland surrounded by *Araucaria* forest, situated on a plateau at about 900 m a.s.l. *Araucaria* forest communities are characterized by the presence of woody species that are phytogeographically related to Austral–Antarctic and Andean floras (Rambo, 1951; Waechter, 2002). The most physiognomically important tree species is *A. angustifolia*. Some other typical species in these forests are *Podocarpus lambertii*, *Drimys brasiliensis*, *Dicksonia sellowiana*, and several species of Myrtaceae, Melastomataceae, and Lauraceae. Oliveira-Filho and Fontes (2000) recognized the Brazilian *Araucaria* forest as a particular type of Atlantic Forest. In the grassland, small forest nuclei, regionally called *capões*, are found, in different degrees of development (Duarte et al., 2006). Cattle grazing and burning practices were terminated in 1993, allowing increasing regeneration of the forest and more biomass accumulation and woody-plant establishment in the grassland (Oliveira and Pillar, 2004). These conditions generated a tall dense grassland matrix composed of caespitose grasses (*Andropogon lateralis*, up to 0.8 m high) and shrubs (*Baccharis uncinella*, *Calea phyllolepis*), which tend to suppress short grasses and other herbaceous species (Oliveira and Pillar, 2004).

### 2.2. Sampling methods

#### 2.2.1. Ant assemblages

Sampling was carried out in January 2006, in two different grassland–forest ecotone sites. In each site (at least 500 m distant from each other), two parallel, 180 m long transects were delimited, 20 m distant from each other. Transects were centralized in relation to the outermost forest tree/shrub with diameter at breast height >10 cm and whose crown was touching the continuous forest canopy. This point was assumed to represent the limit between grassland and forest (zero distance point). Nine sampling points were established at 10 m distance intervals starting from the edge, both in the direction of the grassland (negative distances), and in the direction of the forest (positive distances). Along each transect, one soil trap (300 mL) containing 70% ethanol mixed with detergent was installed at each sampling point (10 m distant from each other), totaling 76 sampling units. After 48 h of exposure, soil traps were collected (adapted from Agosti and Alonso, 2000). The collected material was identified at the genus level according to Palacio and Fernández (2003). All species and morphospecies were

identified by comparison with the specimens of Formicidae in the collection of the Laboratório de Insetos Sociais, UNISINOS, where all the collected specimens were deposited.

#### 2.2.2. Ant attributes

For each identified species, its foraging habit (carnivorous, granivorous, nectarivorous, omnivorous) and nesting site (epiphytes, hollow wood, litter, plant cavities, rocks, soil, trees) was categorized as nominal variables, according to information available in specialized literature (Takahashi-Del-Bianco et al., 1998; Holway et al., 2002; Rossi and Fowler, 2002; Kaufmann et al., 2003; Passos and Oliveira, 2003; Ramos et al., 2003; Schilman and Roces, 2003; Milesi and Casenave, 2004; Battirola et al., 2005; Harada, 2005; Longino, 2006; Marchioretto and Diehl, 2006; Weiser and Kaspari, 2006; Delabie et al., 2007; Longino and Fernández, 2007; Milks et al., 2007; Vieira et al., 2007; Brandt et al., 2009; Silva-Melo and Giannotti, 2010). For morphospecies we used available information encompassing the whole genus.

#### 2.2.3. Habitat variables

We evaluated the canopy vegetation cover by means of hemispherical photographs of the canopy (Frazer et al., 2001). Photographs were taken just above the soil traps, at ca. 1.5 m from the soil surface. The images were analyzed by using the software Gap Light Analyzer 2.0 (Frazer et al., 1999), and the proportion of sky area covered by vegetation (0–1) was obtained.

At each sampling point, the structure of the understory vegetation was characterized by counting the number of vegetation touches at each 10-cm interval from the ground up to 1.5 m above the sampling trap, using a graduated stick (Bibby et al., 1992; Baldissera et al., 2008). By doing so, we estimated the density of the understory vegetation as the total number of vegetation touches along the stick (number of touches m<sup>-1</sup>). Additionally, we calculated an index of understory homogeneity. For this, we generated a matrix describing the number of vegetation touches in each 10 cm interval (variables) at each sampling point. Whenever we found more than 10 vegetation touches per 10 cm interval, these were grouped in the same class. Thus, our data matrix contained ten variables (from 0 to 10 or more touches). We then computed a Shannon diversity index for each sampling point, which was taken as an index of understory height homogeneity. High Shannon index values indicated more vertically heterogeneous understories, while low values indicated more concentrated understories.

### 2.3. Data analyses

We used ANOVA with permutation tests (Pillar and Orlóci, 1996) to evaluate the effects of the factors 'site' and 'distance from forest edge', as well as the interaction between these two factors, on the number of ant species found in each soil trap. Prior to the analysis, we performed a logarithmic transformation on the number of ant species. To control for spatial autocorrelation within transects, permutations among sampling units were nested within transects; after nesting, transects were permuted between sites as bundles (see Pillar, 2006). We used MANOVA with permutation tests (Pillar and Orlóci, 1996) to evaluate the effects of the factors 'site' and 'distance from forest edge', as well as the interaction between those two factors, on the composition of epigeic ant assemblages found in each soil trap, described as a presence/absence data matrix. Prior to the analysis, variables (ant species) were centralized to control for species commonness/rarity in the sample, and sampling units (traps) were normalized (Legendre and Legendre, 1998). For MANOVA we used the same permutation design as in the previous ANOVA. In both analyses, Euclidean distances were used as the

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