

## ECOLOGY, BEHAVIOR AND BIONOMICS

### What is the Effect of Soil Use on Ant Communities?

FERNANDO A. SCHMIDT<sup>1</sup> AND ELENA DIEHL<sup>1,2</sup>

<sup>1</sup>Lab. de Insetos Sociais, Univ. do Vale do Rio dos Sinos – UNISINOS, C. postal 275, 93001-970 São Leopoldo, RS  
schmidt.fa@gmail.com

<sup>2</sup>PPG em Biologia: Diversidade e Manejo de Vida Silvestre – UNISINOS; elena.diehl@pesquisador.cnpq.br

*Neotropical Entomology* 37(4):381-388 (2008)

#### Qual é o Efeito do Uso do Solo sobre as Comunidades de Formigas?

**RESUMO** - Estudos sobre as comunidades de formigas em agroecossistemas têm contribuído para o conhecimento do efeito das práticas agrícolas sobre as comunidades biológicas. O objetivo deste trabalho foi avaliar o efeito do uso do solo nas comunidades de formigas. Foi testada a hipótese de que há um decréscimo na riqueza de espécies de formigas e uma mudança na composição de espécies em habitats com uso mais intenso do solo. As formigas foram amostradas com iscas de sardinhas, armadilhas subterrâneas e por coleta direta em quatro habitats com diferentes usos do solo (mata secundária, início de sucessão vegetal, reflorestamento com *Acacia* e cultivo misto). A riqueza não diminuiu com a intensidade de uso do solo. Na área em início de sucessão vegetal, o número de espécies coletadas por iscas de sardinha foi significativamente diferente do obtido pelas armadilhas subterrâneas. A composição de espécies teve uma pronunciada variação, sendo que a fauna de formigas epigéica e hipogéica do habitat com maior intensidade de uso do solo (cultivo misto) mostrou baixa similaridade com as comunidades de formigas dos outros três habitats. As espécies predadoras restringiram-se aos habitats com baixa intensidade de uso do solo (mata secundária e sucessão vegetal). Assim, a composição de espécies refletiu melhor as mudanças funcionais nas comunidades de formigas ao uso do solo do que a riqueza de espécies. Os resultados podem ajudar a escolher o componente das comunidades de formigas mais adequado e que melhor corresponde à resposta da biodiversidade aos impactos causados pelas atividades agrícolas.

**PALAVRAS-CHAVE:** Agroecossistema, biodiversidade, bioindicador, monitoramento ambiental, Formicidae

**ABSTRACT** - Studies on ant communities in agroecosystems have contributed to the knowledge of the effect of agricultural activities on biological communities. The aim of this study is to explain the effect of soil use on ant communities. We tested the hypothesis that there was a decrease in ant species richness and a change in the species composition at habitats with more intense soil use. We collected ants using sardine baits, subterranean traps and direct sampling at four habitats with different soil use (secondary forest, *Acacia* forestry, initial stage of succession and mixed crops). The ant species richness did not decrease with intensity of soil use. In successional habitat the species numbers collected using sardine baits and subterranean traps were significantly different. Species composition of communities had a pronounced variation, with the epigaic and hypogaic ant faunas of the habitat with high intense soil use (mixed crops) had low similarity with ant communities of the three other habitats. The predator species were restricted to habitats with low intensity of soil use. Then, species composition could better reflect the functional changes on ant communities than species richness. Our data can help to choose the component of ant community that better reflect the response of biodiversity to agricultural impacts.

**KEY WORDS:** Agroecosystem, biodiversity, bio-indicator, environmental monitoring, Formicidae

The intensive exploitation of natural resources affects integrity of biodiversity and changes the structure of the biological communities (Wilson 1997, Altieri *et al.* 2003). Agriculture is one of the main agents of changes in biodiversity and fragmentation of ecosystems (Benhin 2006). It changes the local landscape, the composition

and the structure of biological communities, especially through the introduction of exotic species, and exclusion of native species. The insects represent the largest part of live fauna and play essential roles in the dynamics of ecosystem processes (Folgarait 1998, Thomazini & Thomazini 2000, Samways 2005). Furthermore, insect fauna has an important

role in integrated pest management programs (Altieri *et al.* 2003). Thus, methods to evaluate the impacts of agricultural activities on biodiversity, especially on insect fauna, are extremely useful.

Among the insects, ants are an abundant group (Wilson 1971) and consist of more than 11,800 described species (Agosti & Johnson 2005). Moreover, ants, bees, wasps and termite comprise 75% of the total insect biomass (Hölldobler & Wilson 1990). Ants have a wide geographic distribution, and local communities are affected by several factors. Among these factors are the physical and chemical characteristics of the soil. For example, the number of ant species in dry soils is small (Kusnezov 1957). Moreover, in sites with pronounced variation of humidity during the year, species richness is smaller during the dry season (Bestelmeyer & Wiens 1996).

The way and intensity of soil use can also change the richness and composition of the ant fauna. Thus, habitats with disturbed soils, that had humidity or mineral concentration modified by cultivating or mining activities are likely to differ from undisturbed habitats with respect to ant species richness and composition (Majer 1983, Andersen 1997, Diehl *et al.* 2004). Moreover, environments at different succession stages can also host different ant communities. Habitats at the initial stage of succession harbour ant communities with low number of species and only few species dominate the habitat. Habitats at advanced successional stages with more microhabitats allow the establishment of more species and decrease the dominance of some ant species (Fowler *et al.* 1991, Vasconcelos 1999, Silva *et al.* 2007). Nevertheless, according to Dauber & Wolters (2005), at initial succession stages there is an increase in ant species richness that is not necessarily related to the increase of the structure complexity and richness of vegetation.

Research on ants has shown that it is possible to relate the presence or absence of ant species with structure complexity and stage of habitat conservation or restoration (Hoffmann & Andersen 2003, Ribas *et al.* 2003, Underwood & Fisher 2006). Thus, studies of ant communities in agroecosystems have contributed to the knowledge of the influence of agriculture activities on natural environments (Castro & Queiroz 1987, Lobry de Bruyn 1999, Fernandes *et al.* 2000). Studies of ant communities in agroecosystems have also helped to identify ant species with potential for biological control in several types of crops (Castro & Queiroz 1987, Carroll & Rish 1990, Fernandes *et al.* 1994). Furthermore, several authors consider ants as ecosystem engineers, because ants respond to changes in physical and chemical properties of the soil, increasing its drainage, aeration and nutrient quantity, which contribute to agricultural practices of low ecological impact (Brussaard *et al.* 1997, Folgarait 1998, Lobry de Bruyn 1999).

Ants have high sensibility to environmental changes and are easily sampled (Silva & Brandão 1999, Underwood & Fisher 2006) making these insects useful to evaluate the impacts of agriculture on natural environments. Therefore, our aim is to explain the effect of different soil uses on ant communities. We tested the hypotheses that there was a decrease in ant species richness and a change in the species composition at habitats with more intense soil use.

## Material and Methods

**Study area.** In the state of Rio Grande do Sul, south of Brazil, there are two main distinct agroecosystems. The southern part of the state is characterized by large areas with pasture. In the north and northeast, familiar agriculture at small properties are more common (Brose 1999). Agriculture and pasture occupy about 72% of surface of the state (Secretaria do Meio Ambiente do Rio Grande do Sul 2002).

We carried out the study in Rolante City (29°36'32.2"S; 50°31'39.1"W; altitude 370 m) in December, 2003. The climate of the region is subtropical (Cfb) according to the Köppen classification. Teixeira *et al.* (1986) reported that the pristine vegetation of the region consisted of a transition area among three forest formations: semideciduous stationary rainforest; forests dominated by *Araucaria angustifolia* (Bertol.) (Kuntze) and Atlantic coastal rain forest.

The studied area was a farm of 30 ha, consisting of a mixed landscape with different kinds of environments: crop areas, pastures, forestry and native forest remnants at different stages of succession.

**Sampling design.** We collected ants at four habitats types: (1) Secondary forest (10 ha, preserved area) consisting of forest remnants with sporadic wood extraction activities; (2) a site at the initial stage of succession (3 ha, five-years old) with *Baccharis dracunculifolia* (DC) as the main plant species, a characteristic species of the initial stage of succession; (3) *Acacia* forestry (10 ha, 10-years old) with *Acacia mearnsii* (De Wild) and a well-developed herb-stratum; (4) mixed crops (3 ha, 20-years old) with different kinds of crops (corn, cassava and several vegetables) during the year.

In each habitat, we collected ants using three sampling methods: sardine baits, subterranean traps and direct sampling. Sardine baits and subterranean trapping were disposed along two parallel transects of 100 m, 50 m apart from each other. Each transect had ten sampling units, 10 m apart. Each sampling unit consisted of one sardine bait and one subterranean trap. Then, in each habit there were 20 sardine baits and 20 subterranean traps. Sardine baits consisted of a portion (1 cm<sup>3</sup>) of sardine with vegetable oil on a filter paper (9 cm<sup>2</sup>), which remained in the field for 1h. The subterranean traps (Silvestre, R. personal communication) consisted of small plastic pots (3.3 cm diameter, 5.0 cm height) with small holes in the lateral side. Each pot was baited with a portion (1 cm<sup>3</sup>) of sardine with vegetable oil. The traps were placed at 20 cm depth in the soil for 48h. Direct sampling consisted of manual collection of ants during 1h between each two transects / transect.

**Identification of ant species.** We sorted and identified the collected ants to genera with the help of the identification key of Bolton (1994), and we adopted the subfamily classification suggested by Bolton (2003). Species identification was carried out according to the Formicidae reference collection of the Laboratory of Social Insects – UNISINOS, where all voucher specimens were deposited. The occurrence of ant species was confirmed with the catalogues of Kempf (1972) and Brandão (1991).

**Statistical analyses.** The analyses were carried out with data from sardine baits and subterranean traps at each habitat. We analysed the response of ant species richness to intensity of soil use by two methods: calculating the mean species richness per sample, and estimating species richness in each habitat. The first method compared the local species richness at the samples in each habitat. The other compared the total species richness among the habitats.

In the analysis of mean species richness per sample we compared the species richness (response variable) in each habitat type sampled by each sampling method and the interaction between these variables (explanatory variables) by ANOVA using Poisson errors distribution. The analysis was carried out using the R software (R Development Core Team 2005), followed by residual analysis to check for the suitability of the model and error distribution.

The estimated species richness was calculated using Chao 2 estimator of the EstimateS program (Colwell 1997). We used 95% confidence intervals.

The data from direct samples were used only to complement the ant community composition data obtained by sardine baits and subterranean traps. To compare the similarity in species composition in the different habitats the Sørensen similarity coefficient followed by cluster analyses with Euclidean distance was used in the Krebs/Win 0.9 program (Krebs 1997).

## Results and Discussion

We sampled 35 species from 17 genera and seven subfamilies. The more speciose subfamily was Myrmicinae (20 species), followed by Formicinae (six species), Dolichoderinae and Ponerinae, each one with three species. Ecitoninae, Ectatomminae and Pseudomyrmecinae each contained only one species (Table 1).

In subtropical regions the number of ant species tends to be lower than in tropical zones, and the variation in species richness among habitats with different structural complexities is small (Kusnezov 1957, Benson & Harada 1988). Our data are in agreement with other studies on ant species richness in environments that differ at structural complexity such as primary and secondary native forests (Diehl *et al.* 2005a), eucalyptus forestry (Fonseca & Diehl 2004), restinga (Sacchett & Diehl 2004, Diehl *et al.* 2005b), copper mines (Diehl *et al.* 2004) and urban areas (Haubert *et al.* 1998) in the State of Rio Grande do Sul.

The mean species richness per sample varied according to sampling method ( $F_{1,155} = 12.13$ ,  $P < 0.001$ ), but not to habitat type ( $F_{3,156} = 0.70$ ,  $P = 0.55$ ). The interaction term was significant ( $F_{3,152} = 5.79$ ,  $P < 0.001$ ), with the mean species richness higher in sardine baits than in subterranean traps in initial succession and mixed crops habitats. However, there was no significant difference between the sampling methods in secondary forest and *Acacia* forestry environments (Fig. 1).

There were no significant differences in estimated species richness from sardine baits among the habitats (Fig. 2). Nonetheless, in subterranean traps, *Acacia* forestry and

mixed crops environments have higher estimated species richness than secondary forest and initial succession habitats (Fig. 3).

The two analyses (mean species richness per sample and estimated species richness) showed that ant species richness did not decrease in habitats with more intense soil use. However, in the habitats of *Acacia* forestry and mixed crops, some species of *Camponotus*, *Dorymyrmex* and *Hylomyrma* were collected (Table 1), that had been reported by Brown Jr. (2000) as generalist genera. Opportunist species as *Linepithema* sp. increase at low to moderate levels of disturbance owing to their preference for more open habitats (Underwood & Fisher 2006). According to these authors, the more specialized groups such as cryptic and specialized predators are often absent following ecological disturbance. We collected specialist ant species only in habitats with a lower intensity of soil use. In particular, predator species such as *Gnamptogenys moelleri* (Forel), *Odontomachus chelifer* (Latreille) and *Pachycondyla striata* (Smith) were restricted to secondary forest and initial succession habitats.

Considering epigaeic ants, those sampled by sardine baits, the initial succession habitat may accumulate specialists from the secondary forest and generalist species from the more disturbed habitats (*Acacia* forestry and mixed crops). This may occur due to the spatial distribution of these habitats (Roth *et al.* 1994, Underwood & Fisher 2006) since the initial succession in the local of this study was between secondary forest and the other habitats. This hypothesis may be inferred observing Figs. 1 and 2, which show a trend towards higher species richness in the initial succession habitat. It was reported that at initial successional stages of an disturbed environment there is an increase in ant species richness (Dauber & Wolters 2005). However, the relationship between ant species richness and composition in a fragmented landscape is a complex trade off, which shape, edge and spatial distribution of the areas sampled could have different influences (Sobrinho *et al.* 2003, Sobrinho & Schoereder 2007). Then, our hypotheses just represent a suggestion to the pattern observed.

Analysing hypogaeic ants, we hypothesize that habitat disturbance may be responsible by the observed results. There is smaller mean species richness in the more disturbed habitats than in the secondary forest (Fig. 1) and higher estimated species richness in the disturbed habitats (Fig. 3), as reported by some authors (Andersen 1997, Lobry de Bruyn 1999, Vargas *et al.* 2007). This may be caused if some opportunist ants, like *Linepithema*, colonize local habitats in the disturbed environments and prevent them of being colonized by other species (Hoffmann & Andersen 2003). Moreover, each of these local habitats may be colonized by a different set of species causing a higher local turnover of species in disturbed habitats than in secondary forest (Underwood & Fisher 2006).

The higher estimated species richness collected in subterranean traps in the secondary forest than in the initial succession could be caused by a rehabilitation of ant species composition after agricultural activities by the decrease of generalist ant species. However, to have a better understanding of these environmental changes we should

Table 1. Ants collected at four habitats with distinct soil use in Rolante, State of Rio Grande do Sul, in the south of Brazil. SF = secondary forest; IS = initial succession site; AF = *Acacia* forestry; MC = mixed crops. 1 = direct sampling; 2 = sardine baits; 3 = subterranean traps.

Taxa	SF	IS	AF	MC
<b>Dolichoderinae</b>				
<i>Dorymyrmex</i> sp.				2
<i>Dorymyrmex</i> sp.1				2
<i>Linepithema</i> sp.	2	2	2; 3	2; 3
<b>Ecitoninae</b>				
<i>Labidus praedator</i> (Smith)	2; 3			
<b>Ectatomminae</b>				
<i>Gnamptogenys moelleri</i> (Forel)	2	1		
<b>Formicinae</b>				
<i>Brachymyrmex</i> sp.2		2		
<i>Camponotus (Myrmaphaenus) fastigatus</i> Roger	2	2	2	2
<i>Camponotus rufipes</i> (Fabricius)			2	1
<i>Camponotus</i> sp.11	1			
<i>Paratrechina</i> sp.		2; 3	2	
<i>Paratrechina</i> sp.1			1	
<b>Myrmicinae</b>				
<i>Acromyrmex lundii</i> (Guérin)	1			
<i>Crematogaster (Orthocrema) quadriformis</i> Roger	1	2		2
<i>Hylomyrma</i> sp.1				2
<i>Pheidole</i> gr. <i>fallax</i> Mayr		2	2	2
<i>Pheidole fimbriata</i> Roger	2	2	2	
<i>Pheidole</i> sp.2				3
<i>Pheidole</i> sp.3			3	1
<i>Pheidole</i> sp.5				2
<i>Pheidole</i> sp.6	2	2	2	
<i>Pheidole</i> sp.7			2	2
<i>Pheidole</i> sp.10			3	
<i>Pheidole</i> sp.14		3		
<i>Pheidole</i> sp.17	3	3	3	3
<i>Pheidole</i> sp.22				2
<i>Pheidole</i> sp.23	3		3	
<i>Solenopsis invicta</i> Buren				2; 3
<i>Solenopsis (Diplorhoptrum)</i> sp.	2; 3	2; 3	2; 3	
<i>Solenopsis</i> sp.3	3			
<i>Solenopsis</i> sp.4	3		3	
<i>Wasmannia</i> sp.1		2		2
<b>Ponerinae</b>				
<i>Hypoponera foreli</i> (Mayr)	1		2	
<i>Odontomachus chelifer</i> (Latreille)	2	2		
<i>Pachycondyla striata</i> (Smith)	2	2		
<b>Pseudomyrmecinae</b>				
<i>Pseudomyrmex</i> sp.4		2	2	
Total species richness	17	16	17	16



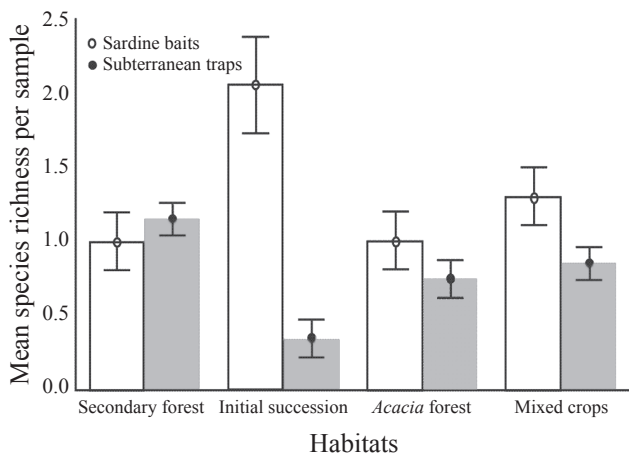


Fig. 1. Mean species richness per sample in sardine baits and subterranean traps at four habitats with distinct soil use. Bars = standard errors.

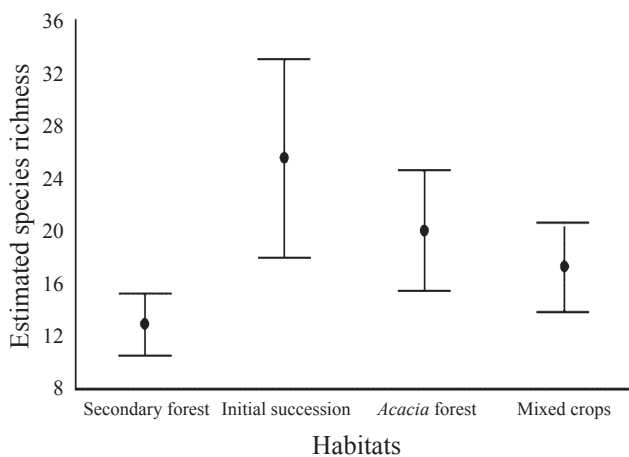


Fig. 2. Estimated species richness at four habitats with distinct soil use using sardine baits. Bars = standard errors.

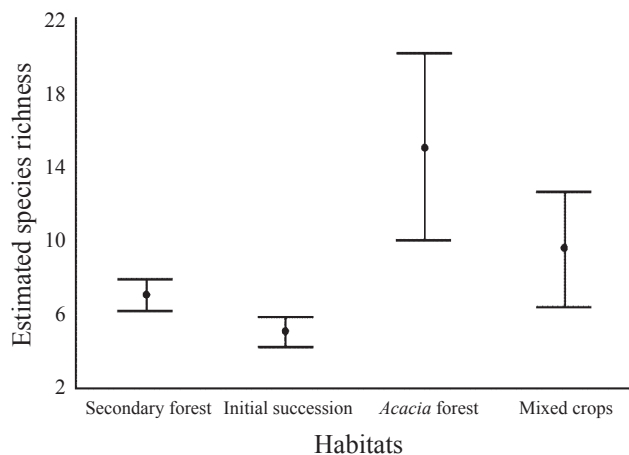


Fig. 3. Estimated species richness at four habitats with distinct soil use using subterranean traps. Bars = standard errors.

compare the response of generalist and specialist ant species to the effects of human disturbance (Sobrinho *et al.* 2003).

Cluster analysis revealed two distinct groups: a group of epigeaic ants consisting of the ants collected with the sardine baits at the soil surface; and a group of hypogaeic ants consisting of the ants collected using subterranean traps (Fig. 4). In both groups, the ant community of the mixed crops had a lower similarity compared to the other ant communities. For the other three habitats, the similarity among the ant communities of the epigeaic group was higher than that of the hypogaeic group (Fig. 4). These data show that agricultural practices have a strong effect on ant species composition and agree with other studies that observed a changing in ant species abundance, frequency and dominance after agriculture activities (Fernandes *et al.* 2000) and different ant composition in natural and crops areas (Castro & Queiroz 1987).

Differences in ant species composition collected with different sampling methods show the necessity of surveys comprising more than one sampling method, in order to better understand the ecological characteristics of local ant fauna (Romero & Jaffe 1989, Parr & Chown 2001, Underwood & Fisher 2006). The cluster analysis with data of sardine baits and subterranean traps revealed two distinct groups of ants (epigeaic and hypogaeic), in agreement with studies of ant fauna in the Atlantic rain forest and the Amazon rain forest. In these two forests a pronounced partitioning between the ant fauna was observed, as well as low similarity on species composition and large differences in the number of species between epigeaic ants collected at the soil surface and hypogaeic ants collected in the subterranean strata (Fowler & Delabie 1995, Fowler *et al.* 2000, Silva & Silvestre 2004).

Furthermore, the presence of seven species of the genus *Pheidole* in the crop habitat could have a beneficial effect. Many *Pheidole* species are predators of eggs and immature stages of insects and have been reported as efficient agents for biological control of pests in several crops (Way & Khoo 1992, Fernandes *et al.* 1994). However, the presence of *Solenopsis invicta* (Bruen) in agroecosystems has been reported as dubious, because this ant is an important predator of pests, but also has harmful effects on populations of natural enemies of several insect pests (Way & Khoo 1992). These fire ant species can increase the abundance of aphids through mutualistic relationships, which can cause severe crop damage (Eubanks 2001, Kaplan & Eubanks 2002).

Therefore, it is difficult to have a clear understanding of the effects that an environmental disturbance could have on ant communities, because the response of species richness and species composition could be different (Dunn 2004, Ottonetti 2006). Ant species, species groups and functional groups all show variable responses to environmental disturbance according to the habitat, intensity of the disturbance or time since the disturbance (Hoffmann & Andersen 2003). However, in our study, both epigeaic and hypogaeic groups species richness showed no change with soil use, but species composition had a pronounced variation in the two ant groups.

In conclusion, the soil use affects species composition more than it affects species richness. Thus, species composition could better reflect the functional changes on

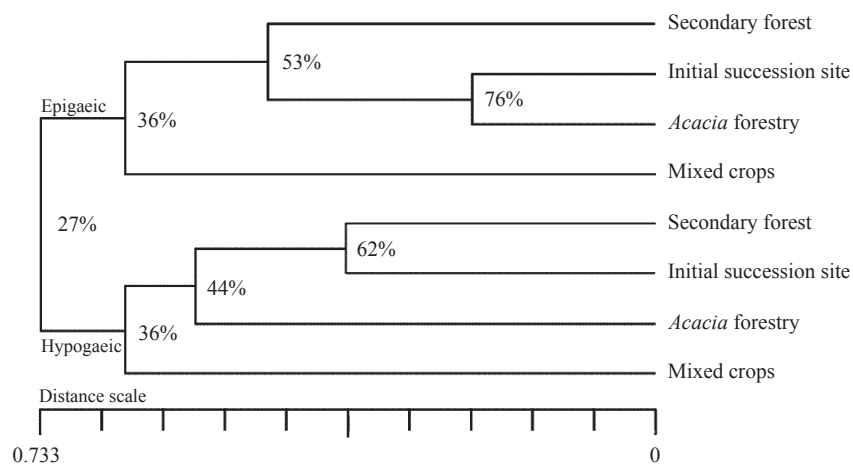


Fig. 4. Cluster analysis of ant communities at four habitats with distinct soil use. Percentages indicate Sørensen similarity.

the structure of ant communities than species richness, and could be more useful in environmental monitoring that use ant community to evaluate the effects of agricultural activities on biodiversity. However, more research is needed on the mechanisms that link the occurrence of determined ant species with ecological conditions of the environment and human disturbance.

### Acknowledgments

Thanks to José da Silva, for allowing to use his farm as study area, to Osmar Schmidt, for help in the fieldwork, to colleagues of Laboratory of Social Insects, for helping to identify the ant species. Thanks to Carla R. Ribas, Daniela F. Florencio and Ricardo R. Solar, for helping with statistical analyses and figures. To Arne Janssen (Visiting Teacher, scholarship Professor Visitante Estrangeiro from CAPES, Brazil) for English review. To José H. Schoereder and Carla R. Ribas, for critical reading of previous versions. To two anonymous reviewers for insightful comments to the first version. We also thank to CNPq, FAPERGS and UNISINOS for financial support and grants.

### References

- Agosti, D. & N.F. Johnson. 2005. Antbase. World wide electronic publication. antbase.org. (<http://www.antbase.org>) (Acessado em 08/12/2005).
- Altieri, M.A., E.N. Silva & C.I. Nicholls. 2003. O papel da biodiversidade no manejo de pragas. *Holos*, Ribeirão Preto, 226p.
- Andersen, A.N. 1997. Using ants as bioindicators: Multiscale issues in ant community ecology. In: *Conserv. Ecol.* 1 [online]. (<http://www.consecol.org/vol1/iss / art8>) (Acessado em 28/06/2005).
- Armbrecht, I., L. Rivera & I. Perfecto. 2005. Reduced diversity and complexity in the leaf-litter ant assemblage of Colombian coffee plantations. *Conserv. Biol.* 19: 897-907.
- Benhin, J.K.A. 2006. Agricultural and deforestation in the tropics: A critical theoretical and empirical review. *Ambio*. 35: 9-16.
- Benson, W. & A.Y. Harada. 1988. Local diversity of tropical and temperature ant faunas (Hymenoptera, Formicidae). *Acta Amazonica* 18: 275-289.
- Bestelmeyer, B.T. & J.A. Wiens. 1996. The effects of land use on the structure of ground-foraging ant communities in the Argentine chaco. *Ecol. Appl.* 6: 1225-1240.
- Bolton, B. 1994. Identification guide to the ant genera of the world. Harvard University Press, Cambridge, 201p.
- Bolton, B. 2003. Synopsis and classification of Formicidae. The American Entomological Institute, Gainesville, 370p.
- Brandão, C.R.F. 1991. Adendos ao catálogo abreviado das formigas da região Neotropical (Hymenoptera: Formicidae). *Rev. Bras. Entomol.* 35: 319-412.
- Brose, M. 1999. Agricultura familiar, desenvolvimento local e políticas públicas. EDUNISC, Santa Cruz do Sul.
- Brown Jr., W.L. 2000. Diversity of ants, p. 45-79. In D. Agosti, J.D. Majer, L.E. Alonso & T.R. Schultz (eds), *Ants: Standard methods for measuring and monitoring biodiversity*. Smithsonian Institution Press, Washington and London, 280p.
- Brussaard, L., V.M. Behan-Pelletier, D.E. Bignell, V.K. Brown, W. Didden, P. Folgarait, C. Fragoso, D.W. Freckman, V.S.R. Vadakattu, T. Hattori, D.L. Hawksworth, C. Klopatek, P. Lavelle, D.W. Malloch, J. Ruseck, B. Söderström, J.M. Tiedje & R.A. Virginia. 1997. Biodiversity and ecosystem function in soil. *Ambio* 26: 563-570.
- Castro, A.G. & M.V.B. Queiroz. 1987. Estrutura e organização de uma comunidade de formigas em agroecossistema neotropical. *An. Soc. Entomol. Brasil* 16: 363-375.
- Carroll, C.R. & S. Risch. 1990. An evaluation of ants as possible candidates for biological control in tropical annual agroecosystems, p.30-46. In S.R. Gliessman (ed), *Agroecology: Researching the ecological basis for sustainable agriculture*. Springer-Verlag, New York, 380p.

- Colwell, R.K. 1997. EstimateS: statistical estimation of species richness and shared species from samples. (<http://viceroy.eeb.uconn.edu/estimate>) (Acessado em 15/01/ 2005).
- Dauber J. & V. Wolters. 2005. Colonization of temperate grassland by ants. *Basic Appl. Ecol.* 6: 83-91.
- Diehl, E., C.E.D. Sanhudo & Ed. Diehl-Fleig. 2004. Ground-dwelling ant fauna of sites with soil high level of copper. *Bras. J. Biol.* 64: 33-39.
- Diehl, E., D.F. Florencio, F.A. Schmidt & L.V.A. Menzel. 2005a. Riqueza e composição das comunidades de formigas e térmitas na Floresta Nacional de São Francisco de Paula (FLONA-SFP), RS. *Acta Biol. Leopoldensia* 27: 99-106.
- Diehl, E., F. Sacchett & E.Z. de Albuquerque. 2005b. Riqueza de formigas de solo na Praia da Pedreira, Parque Estadual de Itapuã, Viamão, RS, Brasil. *Rev. Bras. Entomol.* 49: 552-556.
- Dunn, R.R. 2004. Recovery of faunal communities during tropical forest regeneration. *Conserv. Biol.* 18: 302-309.
- Eubanks, M.D. 2001. Estimates of the direct and indirect effects of red imported fire ants on biological control in field crops. *Biol. Control* 21: 35-43.
- Fernandes, W.D. & M.C.A. Cruz, O. Faccenda & T.O. Valente. 2000. Impacto de herbicidas em uma guilda de formigas predadoras. *Rev. Bras. Herb.* 1: 225-231.
- Fernandes, W.D. & P.S. Oliveira, S.L. Carvalho & M.E. Habib. 1994. *Pheidole* ants as potential biological control agents of the boll weevil, *Anthonomus grandis* (Col., Curculionidae) in Southeast Brazil. *J. Appl. Entomol.* 118: 437-441.
- Folgarait, P.F. 1998. Ant biodiversity and its relationship to ecosystem function: A review. *Biodivers. Conserv.* 7: 1221-1244.
- Fonseca, R.C. & E. Diehl. 2004. Riqueza de formigas (Hymenoptera, Formicidae) epigéicas em povoamentos de *Eucalyptus* spp. (Myrtaceae) de diferentes idades no Rio Grande do Sul, Brasil. *Rev. Bras. Entomol.* 48: 95-100.
- Fowler, H.G., L.C. Forti, C.R.F. Brandão & J.H.C. Delabie. 1991. Ecologia nutricional de formigas, p.131-223. In A.R. Panizzi & J.R.P. Parra (eds), *Ecologia nutricional de insetos e suas implicações no manejo de pragas*. Manole, São Paulo, 359p.
- Fowler, H.G. & J.H.C. Delabie. 1995. Resource partitioning among epigaeic and hypogaeic ants (Hymenoptera: Formicidae) of a Brazilian cocoa plantation. *Ecol. Austral* 5: 117-124.
- Fowler, H.G., J.H.C. Delabie & P.R.S. Moutinho. 2000. Hypogaeic and epigaeic ant (Hymenoptera: Formicidae) assemblages of Atlantic coastal and dry mature and secondary Amazon forest in Brazil: continuums or communities. *Trop. Ecol.* 41: 73-80.
- Haubert F., E. Diehl & A. Mayhé-Nunes. 1998. Mirmecofauna de solo do município de São Leopoldo, RS: Levantamento preliminar. *Acta Biol. Leopoldensia* 20: 103-108.
- Hoffmann, B.D. & A.N. Andersen. 2003. Responses of ants to disturbance in Australia, with particular reference to functional groups. *Austral Ecol.* 28: 444-464.
- Hölldobler, B. & E.O. Wilson. 1990. *The ants*. Belknap Press of Harvard University Press, Cambridge, 732p.
- Kaplan, I. & M.D. Eubanks. 2002. Disruption of cotton aphid (Homoptera: Aphididae) – natural enemy dynamics by red imported fire ants (Hymenoptera: Formicidae). *Environ. Entomol.* 31: 1175-1183.
- Kempf, W.W. 1972. Catálogo abreviado das formigas da região Neotropical (Hymenoptera: Formicidae). *Stud. Entomol.* 15: 3-344.
- Krebs, C.J. 1997. *Ecological methodology*. Version 0.9. ([www.http://gause/biology/ualberta.ca/pub/jbrzusto/krebs](http://www.http://gause/biology/ualberta.ca/pub/jbrzusto/krebs)) (Acessado em 20/06/2005).
- Kusnezov, N. 1957. Numbers of species of ants in faunae of different latitudes. *Evaluation* 11: 298-299.
- Lobry de Bruyn, L.A. 1999. Ants as bioindicators of soil function in rural environments. *Agric. Ecosyst. Environ.* 74: 425-441
- Majer, J.D. 1985. Utilizing economically beneficial ants, p.290-313. In S.B. Vinson (ed.), *Economic Impact and control of social insects*. Praeger, New York, 432p.
- Marques, G.D.V. & K. Del Claro. 2006. The ant fauna in a Cerrado area: The influence of vegetation structure and seasonality (Hymenoptera: Formicidae). *Sociobiology* 47: 235-252.
- Ottonetti, L., L. Tucci & G. Santini. 2006. Recolonization patterns of ants in a rehabilitated lignite mine in Central Italy: Potential for the use of Mediterranean ants as indicators of restoration processes. *Restor. Ecol.* 14: 60-66.
- Parr, C.L. & S.L. Chown. 2001. Inventory and bioindicator sampling: Testing pitfall and winkler methods with ants in a South African savanna. *J. Insect Conser.* 5: 27-36.
- R Development Core Team 2005. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. (<http://www.R-project.org>) (Acessado em 13/09/2006).
- Ribas, C.R., J.H. Schoereder, M. Pic & S.M. Soares. 2003. Tree heterogeneity, resource availability, and larger scale processes regulating arboreal ant species richness. *Austral Ecol.* 28: 305-314.
- Romero, H. & K. Jaffe. 1989. A comparison of methods for sampling ants (Hymenoptera, Formicidae) in savannas. *Biotropica* 21: 325-348.
- Roth, D.S., I. Perfecto & B. Rathcke. 1994. The effects of management systems on ground-foraging ant diversity in Costa Rica. *Ecol. Applic.* 4: 423-436.
- Sacchett, F. & E. Diehl. E. 2004. Comunidades de formigas de solo no Morro da Grota, Parque Estadual de Itapuã, RS. *Acta Biologica Leopoldensia* 26: 79-92.
- Samways, M.J. 2005. *Insect diversity conservation*. Cambridge University Press, New York, 342p.
- Secretaria do Meio Ambiente do Rio Grande do Sul (SEMA-RS). 2002. Cobertura florestal. Inventário florestal. (<http://www.sema.rs.gov.br/sema/html/cobflinve2.htm>) (Acessado em 08/03/2005).

- Silva, R.R. & C.R.F. Brandão. 1999. Formigas (Hymenoptera: Formicidae) como indicadores da qualidade ambiental e da biodiversidade de outros invertebrados terrestres. *Biotemas* 12: 55-73.
- Silva, R.R. & R. Silvestre. 2004. Riqueza da fauna de formigas (Hymenoptera: Formicidae) que habita as camadas superficiais do solo em Seara, Santa Catarina. *Pap. Avulsos Zool.* 44: 1-11.
- Silva, R.R. R.S.M. Feitosa & F. Eberhardt. 2007. Reduced ant diversity along a habitat regeneration gradient in the southern Brazilian Atlantic Forest. *For. Ecol. Manag.* 240: 61-69.
- Sobrinho, T.G., J.H. Schoereder, C.F. Sperber & M.S. Madureira. 2003. Does fragmentation alter species composition in ant communities (Hymenoptera: Formicidae)? *Sociobiology*. 42: 329-342.
- Sobrinho, T.G., J.H. Schoereder. 2007. Edge and shape effects on ant (Hymenoptera: Formicidae) species richness and composition in forest fragments. *Biodivers. Conserv.* 16:1459-1470.
- Teixeira, M.B., A.B. Coura Neto & U. Pastore. 1986. Vegetação, p.541-620. In IBGE (ed.), *Levantamento de recursos naturais*, v. 33. IBGE, Rio de Janeiro, 796p.
- Thomazini, M.J. & A.P.B.W. Thomazini. 2000. A fragmentação florestal e a diversidade de insetos nas florestas tropicais úmidas. Rio Branco, EMBRAPA Acre, 21p. (EMBRAPA Acre, 57).
- Underwood, E.C. & B.L. Fisher. 2006. The role of ants in conservation monitoring: If, when, and how. *Biol. Conserv.* 132: 166-182.
- Vargas, A.B., A.J. Mayhé-Nunes, J.M. Queiroz, G.O. Souza & E.F. Ramos E.F. 2007. Efeitos de fatores ambientais sobre a mirmecofauna em comunidade de Restinga no Rio de Janeiro, RJ. *Neotrop. Entomol.* 36: 28-37.
- Vasconcelos, H.L. 1999. Effects of forest disturbance on the structure of ground-foraging ant communities in central Amazonia. *Biodivers. Conserv.* 8: 409-420.
- Way, M.J. & K.C. Khoo. 1992. The role of ants in pest management. *Annu. Rev. Entomol.* 37: 479-503.
- Wilson, E.O. 1971. *The insect societies*. Belknap Press of Harvard University Press, Cambridge, 548p.
- Wilson, E.O. 1997. A situação atual da diversidade ecológica, p.3-24. In E.O. Wilson & F.M. Petter (eds), *Biodiversidade*. Nova Fronteira, Rio de Janeiro, 657p.

*Received 21/II/07. Accepted 18/IV/08.*

---