Soil invertebrates in southern Brazilian *Araucaria* forest – grassland mosaic: differences between disturbed and undisturbed areas

André Frainer[1,2] & Marcelo M. Duarte[1]

1. Seção de Conservação e Manejo, Museu de Ciências Naturais, Fundação Zoobotânica do Rio Grande do Sul. Av. Salvador França 1427, 90690-000 Porto Alegre, RS, Brazil. (marcelo@fzb.rs.gov.br)
2. Current address: Department of Ecology and Environmental Science, Umeå University, SE-901 87 Umeå, Sweden. (andre.barbosa@emg.umu.se)

ABSTRACT. Soil invertebrate distribution in *Araucaria* forest, grassland and edge habitats was studied in both disturbed and undisturbed areas in southern Brazil. Mean-density and taxa compositions were verified. Invertebrate densities differed between grassland and the other two habitats in the undisturbed area but not across the disturbed one. At the disturbed area taxa differed between the grassland and the other two habitats. The undisturbed area, on the other hand, presented taxa differences only between the grassland and the forest habitats. Acari, Arachnida and Collembola were the most sensitive taxa for detecting differences across habitats in both areas. At the disturbed area, these taxa presented densities lowering from the forest to the grassland. At the undisturbed area the same taxa increased from the forest to the grassland. Coleoptera and Formicidae (Insecta) presented no difference between habitats at the studied taxonomic level.

KEYWORDS. *Araucaria* forest, forest edge, grasslands, Acari, Collembola.

RESUMO. Invertebrados de solo no mosaico floresta com *Araucaria* – campos no sul do Brasil: diferenças entre áreas impactadas e não impactadas. A distribuição dos invertebrados de solo entre os em ambientes de floresta com *Araucaria*, borda-de-mata e campo, foi analisada em duas áreas no sul do Brasil: uma reserva ecológica e uma propriedade agrícola. A densidade média e a composição dos principais taxa foram verificadas. A densidade total de invertebrados diferiu entre o campo e os outros dois hábitats na área protegida, mas não na fazenda. A composição dos taxa diferiu entre o hábitat de campo e os outros dois habitats na fazenda, e entre o campo e a mata com *Araucaria* na área protegida. Acari, Arachnida e Collembola foram os grupos que mais apresentaram diferenças entre os diferentes habitats. Na área alterada (fazenda), esses grupos apresentaram diminuição na densidade na direção da floresta com Araucária para o campo, enquanto que na área protegida suas densidades foram maiores no campo do que na floresta com Araucária. Coleoptera e Formicidae (Insecta) não apresentaram diferenças significativas no nível taxonômico estudado.

PALAVRAS-CHAVE. Borda campo-floresta, Campos, floresta com *Araucaria*, Acari, Collembola.

The importance of edge influence to forest interior has been broadly studied for several animal and plant groups (Bell & Donnelly, 2007; Harper *et al.*, 2005; Laurance *et al*., 2002; Wilkin *et al*., 2007). Edges may act as barriers between the forest interior to the unstable external environment for some species (Wilkin *et al*., 2007) or as a novel habitat for other species (Harper *et al*., 2005). Thus, the way an edge is structured may reflect on the way invertebrates respond to its disturbance. Edge effect and its consequences to the forest interior will also depend on the quality of the surrounding environment, whether it is an agricultural field or a recovering grassland field in initial forest succession (Laurance *et al*., 2002).

Disturbed areas as grasslands in farming systems may present biological diversity deficits due to unfavorable microclimatic conditions for the soil invertebrates community (Laurance *et al*., 2002) and for shortening the available time for populations to grow (Sgardelis & Usher, 1994). Disturbances such as livestock grazing and absence of vegetal shelter may cause these systems to have low superficial water contention and an increase in soil temperature (Adejuyigbe *et al.*, 1999). For this reason, farming systems that lack senescent shrubs (i.e., with low superficial organic matter input), present their soil fauna basically structured on the rhyzosphere (Garret *et al.*, 2001). Seasonal variation on soil use in agricultural areas, e.g. before and after crop planting, can also affect invertebrates composition (Rodrigues *et al*., 2008).

Undisturbed areas, on the other hand, present more stable environments with higher litter input, which firstly allow an increase in invertebrates diversity (Liiri *et al*., 2002) and secondly the structuring of a detritus-feeding invertebrate assemblage on the litter surface (Beare *et al.*, 1995; Butcher *et al.*, 1971; Cragg & Bardgett, 2001; Lavelle *et al.*, 1995; Seadsted, 1984). Increase of plant shelter and of litter input has positive consequences on the fauna diversity both in the forest interior and on grassland fields.

Although it iswell known that invertebrates present different ecological responses between disturbed and undisturbed areas (e.g., Laurence *et al*., 2002; Sgardelis & Usher, 1994) and between disturbed and undisturbed areas (e.g., Didham & Lawton, 1999; Aviron *et al*., 2005), few studies have addressed this question to southern Brazilian *Araucaria* forest - grassland mosaic. In this work, we aimed to verify whether soil invertebrate composition would differ between forest, edge and grassland habitats in two areas with contrasting environmental status: a farming property and an undisturbed biological reserve.

MATERIAL AND METHODS

To study natural and disturbed forest, edge and grassland habitats, were selected two areas within the naturally existing *Araucaria* forest and grassland mosaic, in southern Brazilian highlands (OLIVEIRA & PILLAR, 2004). The undisturbed area is a Biological Reserve called "Estação Ecológica de Aracuri (EEA)" (28°13'S, 51°10'W) and the disturbed one is a farming property located within 13 Km from the EEA (28°20'S, 51°04'W). The EEA was created on a former agricultural property, approximately thirty years ago. Since then, no human disturbances such as livestock grazing or crop plantations have been conducted. The disturbed area, on the other hand, has kept the agricultural activities as the seasonal soybean, wheat, and corn plantation on the grassland fields and livestock grazing on both the grasslands and forest interior, which is disturbed by cattle grazing and footing as well (e.g., ABENSPERG-TRAUN *et al*., 1996; SAMPAIO & GUARINO, 2007).

In all habitats, nine core soil samples of 7.0 cm diameter and 6.0 cm depth were taken in June, 2001. Edge samples were taken within five meters from the forest border. Both forest and grassland samples were taken at 100 meters distance from the edge, towards the forest interior and the open grassland fields, respectively. Soil samples were preserved in previously tagged plastic bags and transported to the laboratory for analysis. Fauna soil samples were processed in modified Berlese-Tullgren extractors for seven days (DUARTE & BECKER, 2000). Soil invertebrates were identified following DINDAL (1990).

Comparison of soil fauna composition between habitats was performed after a Bray-Curtis dissimilarity test. A MANOVA was performed to compare faunal densities between all sampled areas. Later, a one-way ANOVA was conducted for each invertebrate group, separately, to compare differences between habitats and between the disturbed and undisturbed area. Data was log(x+1) transformed to satisfy parametric assumptions. All statistical analyses were conducted on MULTIV software (version 2.3.21 Copyright © PILLAR, 2006).

RESULTS

A total of 10,317 organisms was identified as belonging to several terrestrial groups: Acari, Arachnida (Araneae and Pseudoscorpionida), Collembola, Protura, Diplura, Insecta (Coleoptera, Hymenoptera, Thysanoptera, Dermaptera, Diptera), and Myriapoda (Diplopoda and Pauropoda) (Fig. 1). For clarification, in this study, non-insects Protura and Diplura and insects Thysanoptera, Dermaptera and Diptera are simply referred to as "others", due to the small number of individuals that these groups presented in this study. Diplopoda and Pauropoda are referred to as "Myriapoda".

Acari was the most abundant group in both the disturbed and the undisturbed areas and in all habitats. At the undisturbed area, Acari represented 74 % of the total fauna in the forest habitat (27,745.7 ind.m^{-2}), 79 % in the edge habitat (44,905.7 ind.m^{-2}) and 73 % in the grassland habitat (51,252.5 ind.m^{-2}). At the disturbed area, Acari represented 89 % in the forest habitat (48,025.7 ind.m^{-2}), 85 % in the edge habitat (55,120 ind.m^{-2}) and 62 % in the grassland habitat (18,373.3 ind.m^{-2}). Collembola was the second most abundant taxa found in this study, reaching, at the undisturbed area, 16 % of total fauna in the forest habitat (6,054.3 ind.m^{-2}), 12 % in the edge habitat (7,280 ind.m^{-2}) and 16 % in the grassland habitat (11,180 ind.m^{-2}). At the disturbed area this taxa represented 10 % in the forest habitat (5,831.4 ind.m^{-2}), 5 % in the edge habitat (3,045.7 ind.m^{-2}) and 7 % in the grassland habitat (2,080 ind.m^{-2}). The other taxa presented around 10 % of the total soil fauna in each area, most of which were Formicidae (Hymenoptera).

General mean density analysis showed no difference within the undisturbed habitats ($p > 0.05$) but a difference between the grassland and the other two habitats at the disturbed area ($p < 0.05$; Fig. 2) was found. Bray-Curtis dissimilarity test of community composition between areas and between habitats showed a similar result. Taxa composition differed between the disturbed habitats, being the grassland different from the other two (forest and edge). At the undisturbed area, forest and grassland presented differences between each other, but none of these two habitats presented differences towards the edge habitat (Tab. I).

Invertebrates main groups' density analyses showed other differences among forest-edge-grassland habitats. Acari, Collembola, Arachnida, and Myriapoda were the most sensitive taxonomic groups presenting differences in density between sites (Figs. 3-8). At the undisturbed area, most invertebrates presented an increase in their density values towards the grasslands while the forest habitat showed lower density values. At the disturbed area, invertebrates presented in general an opposite distribution, with lower values in the grasslands and higher values either in the forest or in the edge, depending on the taxa.

Table I. Soil invertebrate composition dissimilarity after Bray-Curtis test. Samples were taken in forest, edge and grassland habitats in both disturbed and undisturbed areas, in southern Brazil, within the *Araucaria* forest - grasslands mosaic ($p < 0.05$). n.s. = not-statistically significant.

Area	Habitats	Forest	Edge	Grassland
Undisturbed	Forest	0		
	Edge	n.s.	0	
	Grassland	0.0202	n.s.	0
Disturbed	Forest	0		
	Edge	n.s.	0	
	Grassland	0.0003	0.0012	0

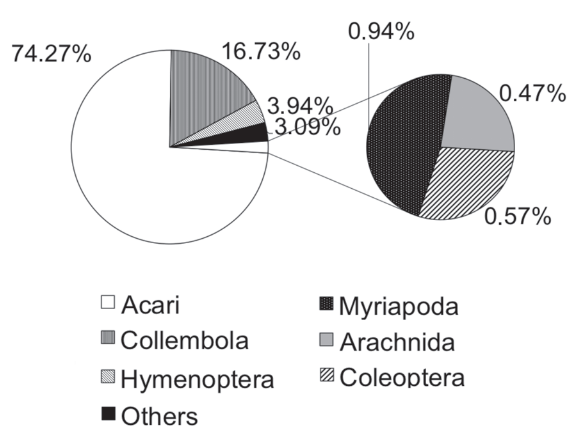

Figure 1. General composition of soil invertebrates community sampled in forest, edge and grassland habitats in both disturbed and undisturbed areas. *Araucaria* forest - grassland mosaic, southern Brazil.

More specifically, at the undisturbed area Acari presented higher densities in the grassland than in the other habitats, although not statistically significant. At the disturbed area, on the other hand, Acari presented statistically significant lower densities in the grassland than in the other two habitats (Fig. 3).

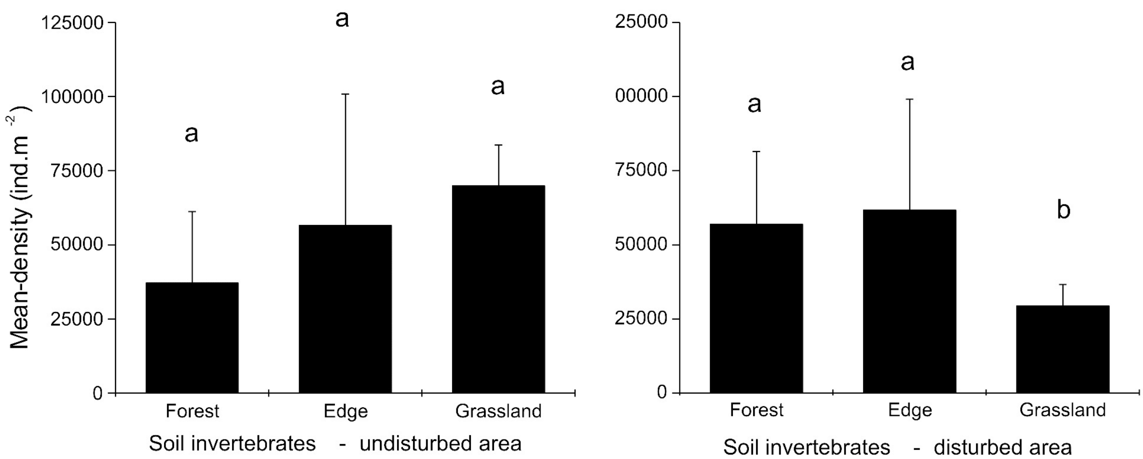

Figure 2. Soil invertebrates density (± standard deviation) for undisturbed (left panel) and disturbed (right panel) areas in the *Araucaria* forest - grassland mosaic, southern Brazil. Different letters indicate significant statistical difference ($p < 0.05$).

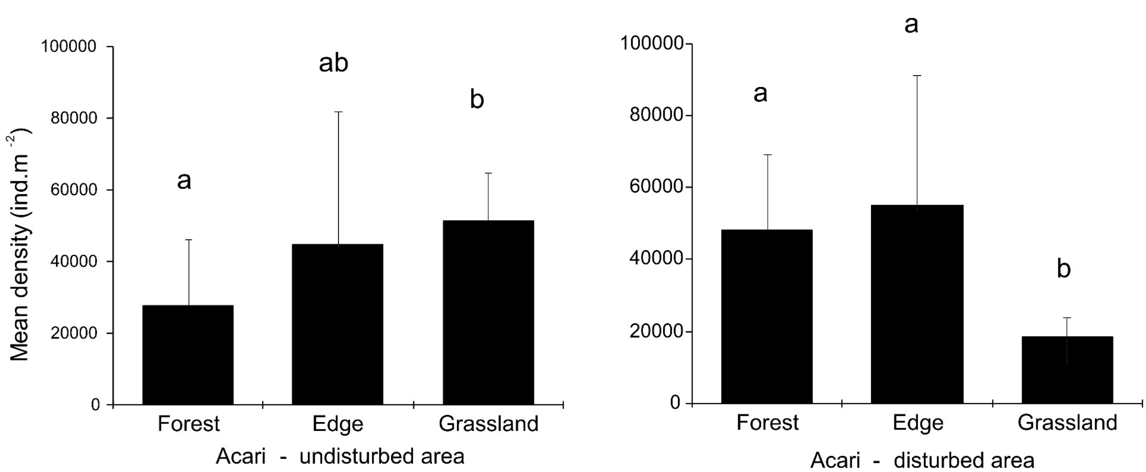

Figure 3. Acari, Collembola and Arachnida densities (± standard deviation) for undisturbed and disturbed areas in the *Araucaria* forest - grassland mosaic, southern Brazil. Different letters indicate significant statistical differences ($p < 0.05$).

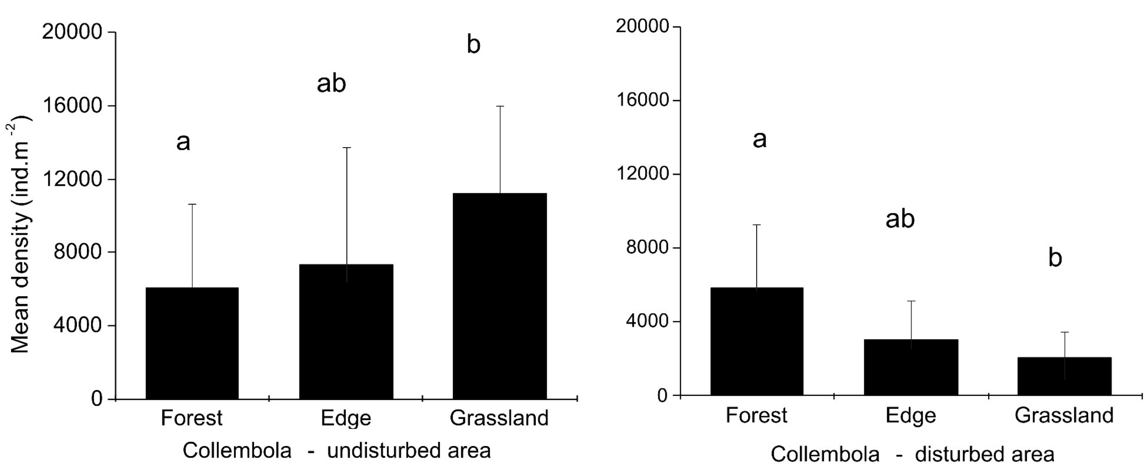

Figure 4. Formicidae, Coleoptera and Myriapoda densities (± standard deviation) for undisturbed and disturbed areas in the *Araucaria* forest - grassland mosaic, southern Brazil. Different letters indicate significant statistical differences ($p < 0.05$).

Similar effects were observed for Collembola (Fig. 4). Arachnida presented higher densities in the undisturbed grassland while the lowest numbers were verified at the disturbed grassland (Fig. 5). Formicidae showed an increase in density towards grasslands in both disturbed and undisturbed areas, although this tendency was not

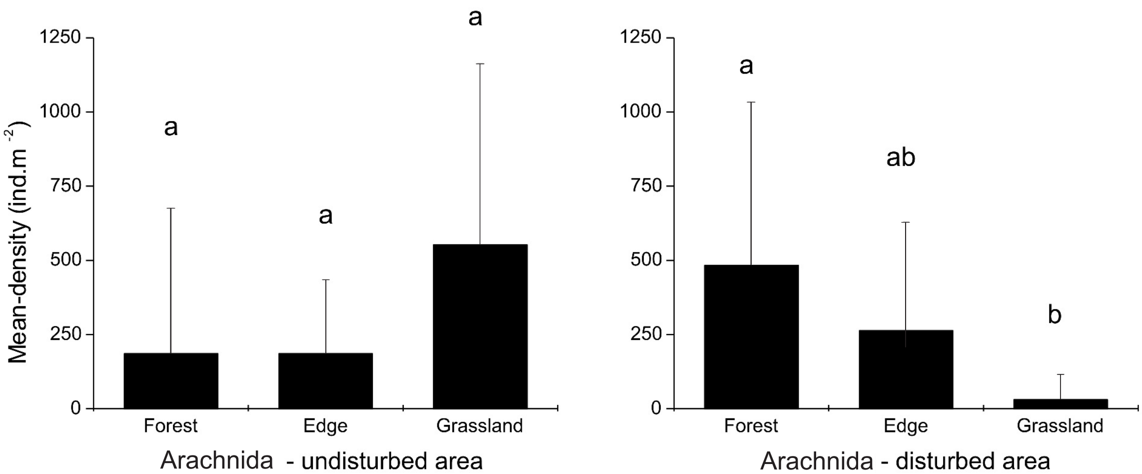

Figure 5. Arachnida (Araneae and Pseudoscorpionida) densities for undisturbed (on the left) and disturbed (on the right) areas. Different letters indicate significant statistical differences ($p < 0.05$).

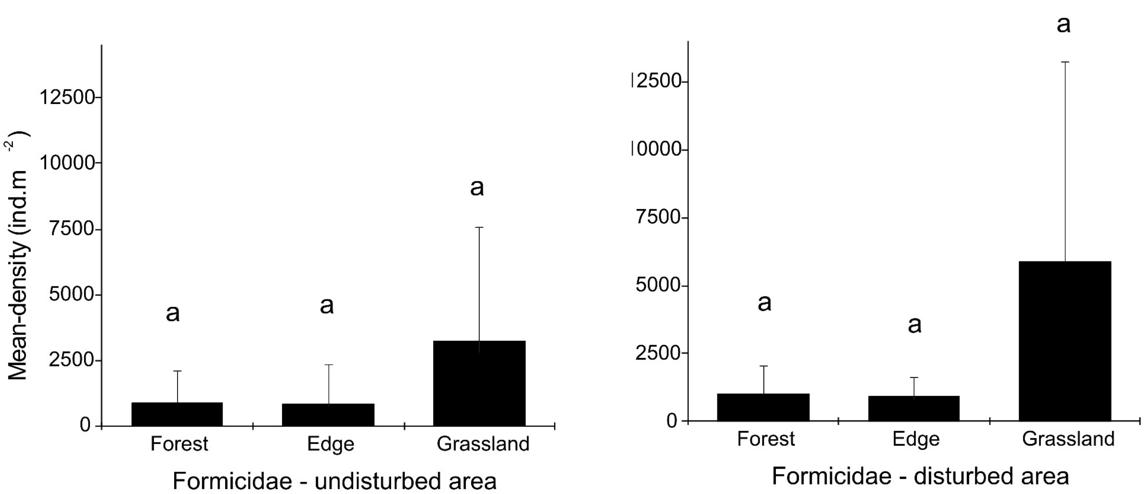

Figure 6. Formicidae densities for undisturbed (left column) and disturbed (right column) areas. Different letters indicate significant statistical differences ($p < 0.05$).

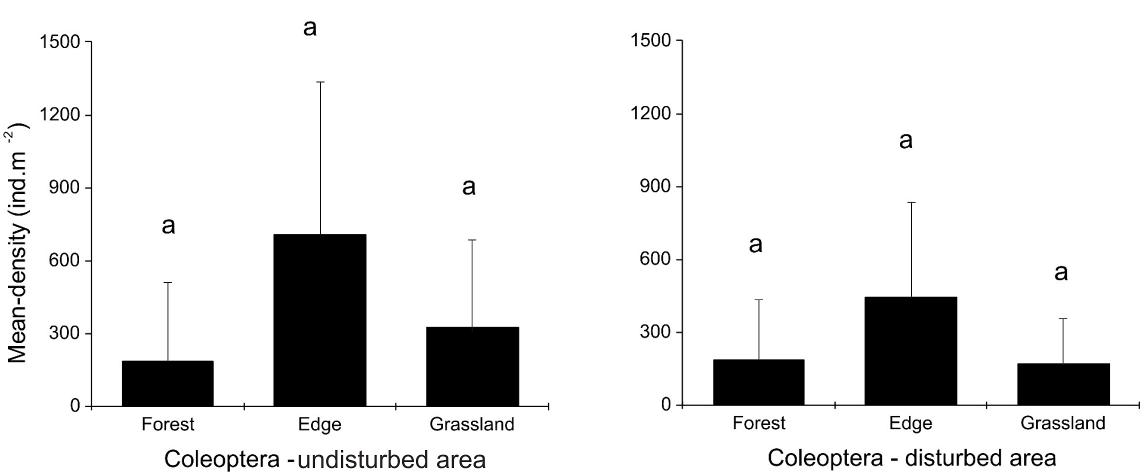

Figure 7. Coleoptera densities for undisturbed (on the left) and disturbed (on the right) areas. Different letters indicate significant statistical differences ($p < 0.05$).

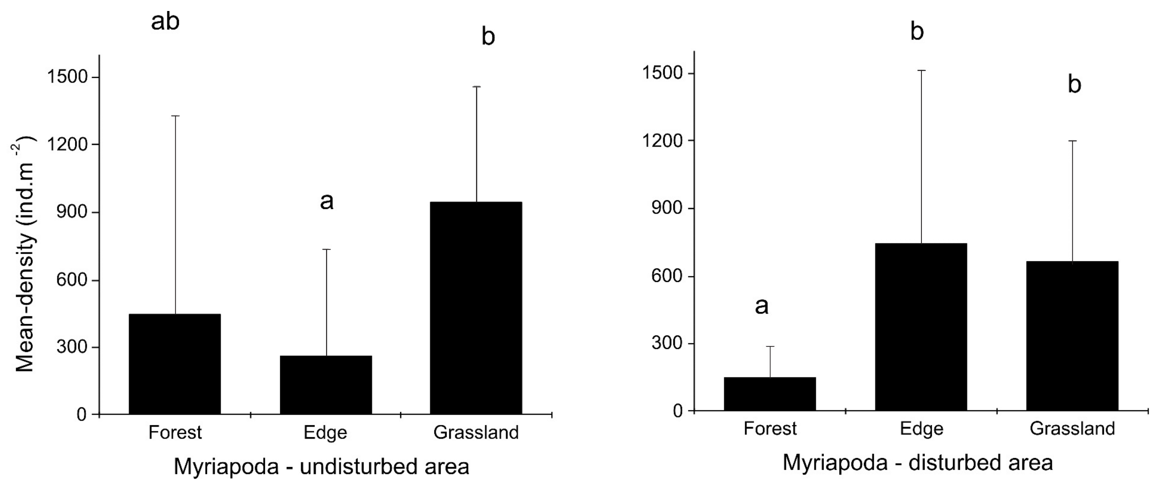

Figure 8. Myriapoda densities for undisturbed (on the left) and disturbed (on the right) areas. Different letters indicate significant statistical differences ($p < 0.05$).

statistically significant (Fig. 6). No significant difference was detected for Coleoptera between any area nor any habitat. However, this group presented higher densities in the edge than in the other two habitats in both the disturbed and the undisturbed areas (Fig. 7). Myriapoda showed higher densities in the undisturbed grassland habitat and in the disturbed grassland and edge habitats (Fig. 8).

DISCUSSION

In this work we verified different responses of the soil invertebrates community related to habitat types and also to the environmental conditions presented in each habitat. According to Didham & Lawton (1999), forest habitats surrounded by grasslands that present shrubs and other high grasses are less suitable to the microclimatic changes occasioned by the edge effect than forest patches surrounded by pasture. This was the case for the Acari and Collembola groups at the undisturbed area which presented an increase in density from the forest interior to the shrub-sheltered grassland habitat. On the other hand, the disturbed area assessed in this work presented a decrease in Acari densities in the grassland when compared to its edge and forest habitat.

Agricultural activities on grasslands may alter not only the grassland fauna composition but also the fauna composition of nearby forest habitats. Schmidt & Barcellos (2007), for instance, studying another conservation unity in southern Brazil (Parque Estadual do Turvo, distant 300 Km from the protected area sampled in this work) found, in the forest habitats, Heteroptera species that are frequently associated to crops, suggesting an influence of adjacent agricultural fields on forest habitats.

In this work we noticed that, for the soil arthropod community structure, edge habitat acts as a border depending on the conditions outside the forest site. Regarding the main group found in this study - Acari - the relationship between undisturbed forest, grassland and edge habitats was more as a gradient, with densities increasing from the forest interior to the open grassland habitat. On the other hand, disturbed areas presented a decrease in Acari densities in the grassland, while most Acari were observed in the edge habitat.

A large number of Acari species is ecologically sensitive to environmental disturbances (Duarte, 2004; Parisi *et al.*, 2005; Sgardelis & Usher, 1994). In this work we found that higher Acari densities at the studied taxonomic group level were related to regenerating environmental conditions, (e.g., undisturbed grassland field and disturbed edge) but not to highly disturbed areas (disturbed grassland field). The same was observed for Collemboa. As Coleoptera showed no density difference between habitats, it is expected that identification to a lower taxonomic level could indicate differences between habitats, as some coleopterans are resistant to the disturbance while other families are highly sensitive to environmental alterations. According to Ronqui & Lopes (2006), there should be a predominance of Coleoptera detritivores in agricultural fields.

Ants seem to be resistant to disturbances, as attested by the higher densities of Formicidae found in the disturbed grassland habitat. Santos *et al.* (2006) also found that Formicidae did not respond to edge influence. In their work, ant richness was observed to be similar in different size forest patches that ranged from 3 to 45 ha. Dias *et al.* (2008), however, observed higher Formicidae richness in forest habitats than in edge and cattle grazing fields. Nevertheless, all habitats cited by Dias *et al.* (2008), presented higher richness than coffee agro-systems, for which the authors pointed the use of insecticides on coffee plantations as a possible reason for the observed decrease in ant richness. In any case, a more specific identification of Formicidae could demonstrate richness and diversity differences between our studied areas.

Besides the use of pesticides, the reasons for differences in abundance or densities across habitats between disturbed and undisturbed areas is mainly related to the availability of nutrients (Hemerik & Brussaard, 2002) and to the microclimatic changes (Carvalho & Vasconcelos, 1999; Didham & Lawton, 1999) occurred in the surrounding environment of the forest habitat. In the studied undisturbed area, edge did not promote a drastic invertebrate community change from the grassland to the forest interior. For this reason, few differences in invertebrates densities were found between the undisturbed habitats. The disturbed area, however, presents a highly impacted grassland field surrounding its forest habitat. This was proved by the highly unequal invertebrate composition between the grassland field and the edge and between the grassland field and the forest interior.

It is particularly important to know how faunal communities respond to environmental alterations on the Araucaria forest - grassland mosaic. This regions suffers an increse in land-use alterations, with both crop plantations and exotic forestry monocultures being rapidly expanded throughout southern Brazilian higlands. Also, identifications of lower taxonomic levels in Acari (e.g., oribatid mites), Collembola and Myriapoda could help to find groups that better respond to high environmental disturbances or that are mostly related to the different forest, edge and grassland habitats.

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