**Universidade de Aveiro**
**2016**
Departamento de Biologia

**João Ricardo Lavoura Puga**

# Influência da aplicação de *mulching* no restabelecimento das comunidades de invertebrados do solo em áreas ardidas

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Ecologia Aplicada, realizada sob a orientação científica da Doutora Ana Catarina Bastos, Investigadora em Pós-Doutoramento do CESAM e Departamento de Biologia da Universidade de Aveiro, e sob a co-orientação científica do Doutor Nelson José Cabaços Abrantes, Investigador Auxiliar do CESAM e Departamento de Ambiente e Ordenamento da Universidade de Aveiro, e do Doutor Jan Jacob Keizer, Investigador Auxiliar do CESAM e Departamento de Ambiente e Ordenamento da Universidade de Aveiro.

**Esta Tese foi desenvolvida no âmbito do projecto europeu:**

"RECARE – Preventing and Remediating degradation of soils in Europe through Land Care" (no. 603498)

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**palavras-chave** effects of mulching, wildfires, ground-dwelling arthropods

**resumo**

Nas últimas décadas Portugal tem sido um dos países da bacia mediterrânica mais afectado pelos incêndios. Um número crescente de estudos em todo o mundo têm vindo a ser realizados no sentido de melhor compreender os efeitos directos e indirectos do fogo e assim encontrar melhores estratégias de gestão e mitigação dos ecossistemas afectados pelos incêndios. O uso de *mulching* é actualmente utilizado para proteger os solos da erosão depois de um incêndio. No entanto, os efeitos do *mulching* sobre as comunidades de invertebrados do solo são pouco conhecidos. Actualmente é reconhecido o papel fundamental que as comunidades de invertebrados do solo desempenham na recuperação da maioria dos ecossistemas. Este estudo procura compreender os efeitos da utilização de um tipo específico de *mulching* (casca e desperdícios de eucalipto) na recuperação das comunidades de invertebrados do solo, uma vez que esta técnica é comummente utilizada como medida de mitigação após um incêndio. Este estudo foi realizado numa plantação de eucalipto no centro-norte de Portugal, que anteriormente havia ardido e na qual foi aplicado o *mulching* após o incêndio. Os resultados deste estudo mostram comunidades de invertebrados do solo semelhantes entre os locais tratados e não tratados e entre posições ao longo da encosta. Em geral, não foram encontradas relações significativas entre as variáveis ambientais estudadas e a comunidade de invertebrados do solo. Foi encontrado um elevado nível de homogeneidade entre as classes de cobertura do solo definidas e a composição da comunidade de invertebrados do solo nas áreas tratada e não tratada. As ordens Hymenoptera e Collembola foram as mais abundantes, estando associadas maioritariamente a famílias de hábitos omnívoros e microbianos e as ordens Coleoptera e Araneae apresentaram a maior riqueza de morfo-espécies, sendo na sua maioria formada por famílias de predadores terrestres. A análise da função ecológica de cada família, sugere que a grande disponibilidade de matéria orgânica no solo pode influenciar a abundância de formigas e colêmbolos, e fomentar uma maior diversidade de predadores terrestres.No global, a utilização de *mulching* não parece afectar a recuperação das comunidades de invertebrados do solo, após um período pós-fogo prolongado. Porém, os resultados deste estudo sugerem que o *mulching* poderá afectar alguns grupos de invertebrados, durante o período inicial após a sua aplicação na área ardida.

**keywords**

effects of mulching, wildfires, ground-dwelling arthropods

## abstract

In the past decades Portugal has been one of the Mediterranean countries most affected by wildfires. In order to find better fire mitigation strategies for ecosystem recovery and land management a crescent number of studies all over the world have been conducted. The use of mulch is currently used to protect soils from erosion after a fire. However, the effects of mulching in communities such as ground-dwelling arthropods have been neglected. Hence, this study aimed to contribute to a better understanding of the long-term effects of chopped eucalypt bark mulch on the recovery of ground-dwelling arthropod communities five years after the wildfire and the respective mulching application. This study was conducted in a burnt Eucalyptus plantation located in north-central of Portugal, which was mulched immediately after the fire. The results of this study showed that five years after the wildfire and the mulching application the ground-dwelling arthropod communities are similar between mulched and untreated sites and among positions along the slope. In general, no significant relations were found between environmental variables and the ground-dwelling arthropod community. A high homogeneity of ground cover classes and ground-dwelling arthropod communities' composition was obtained for both treatments. The most abundant orders were Hymenoptera and Collembola, associated with omnivore and microbial feeders that seem to be beneficiated by the high availability of litter. Coleoptera and Araneae had the higher richness of morphospecies, being mostly compodes by ground predatory families. Analysis of ecological function suggests that the high availability of litter could be an important and selective factor for the current ground-dwelling arthropod community in the study area. Globally it seems that the effects of mulching on the recovery of ground-dwelling arthropod communities in Eucalyptus plantations are diluted in a long-term after fire. However these findings do not discard potential short-term effects of mulching on particular groups of arthropods during the early period after its application on the burnt area, which are still ignored.

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## 1. Introduction

Wildfires despite being important natural events are becoming a major problem to the sustainability of Mediterranean ecosystems, mainly due to human land uses and its interaction with climacteric changes and unadjusted forest management (Pausas *et al*., 2008). Currently the recurrence of fires in the Mediterranean Basin is one of the most important problems related to fire in Europe (Malak, 2015). Portugal shows an increase in the number and area scorched by fires, and in the recurrence of fires (Gonçalves *et al*., 2011), that is not likely to decrease in the future. Every year, Portuguese forests and their associated ecosystems are ravaged by wildfires. In the last decade, the wildfires resulted in an average burnt area of 140 000 ha/year (ICNF, 2014).

Wildfires affect each ecosystem directly and indirectly, through physical, chemical, and biological changes, sometimes with permanent effects (Certini, 2005). In fact, wildfires represent a major disturbance to ecological systems (Bowman *et al*., 2013), affecting both fauna and flora (e.g. mortality, decrease of diversity, community alterations) (Brown & Smith, 2000; Smith, 2000; Jhariya & Raj, 2014)

Notwithstanding its great impacts on ecosystems, most of the study effort about wildfires in the Mediterranean basin has been focusing on its effects on geomorphological and hydrological processes (Neary *et al*., 2005, Keizer *et al*., 2008, Shakesby, 2011) and in interactions between fire and vegetation dynamics (Thonicke *et al*., 2001, Moreira *et al*., 2010), so that better solutions and mitigation measures can be adopted to forest and fire management. In this context, recent studies related to wildfires issues show that the use of mulch after wildfires reduces peak flows and post-fire erosion, contributing to the reduction of the negative effects of wildfires (Bautista *et al*., 1996; Badía & Martí, 2000; Wagenbrenner *et al*., 2006; Prats *et al*., 2015). Actually, since 1900 mulching has been adopted in several studies, especially for agricultural applications, increasing soil microbial activity, improving nutrient balance, reducing nitrogen content, reducing soil erosion, conserving soil moisture, moderating soil temperature and improving infiltration of water (Gill *et al*., 2011; Chalker-Scott, 2007; Westerman & Bicudo, 2005; Altieri & Nichols, 2003). Chopped eucalypt bark mulch was found to be highly effective in reducing post-fire runoff on eucalypt plantations (Prats *et al*., 2012, 2014), but little is known about its effects in the soil fauna.

Soil invertebrates are critical components of forest ecosystems, as they act as predators and prey, contributing to nutrient cycling and decomposition (García-Domínguez *et al*., 2010).

Wildfires can affect structural elements in the ecosystems on which ground-dwelling invertebrates are heavily dependent, which potentially makes these animals especially sensitive to management strategies. Several studies have studied the effects of wildfires on different arthropod groups, showing different responses regarding specific *taxa* and/or ecosystems (e.g. high resilience, slight short-term changes, decline of some groups, increase in biodiversity (Apigian *et al*., 2006; Baker *et al*., 2004; Collet, 2003), but the effects of mulches on soil arthropods living on the soil surface have been generally neglected (Gill *et al*., 2011), especially on soils affected by wildfires, despite being known that mulching constituents are likely to influence soil microhabitats, and therefore the composition of the soil-inhabiting arthropod community (Addison *et al*., 2013).

Hence the present study focuses on the long-term impact of mulching on ground-dwelling arthropods of a previously burnt eucalypt plantation in order to understand the potentially effects of this type of treatment in this specific community.

The raised questions within this study were:

a. Is the composition and diversity of ground-dwelling arthropod communities conditioned by the application of chopped eucalypt bark mulch on previously burnt eucalypt plantations when comparing to non-treated soils.
b. Is the position throughout the slope – bottom, middle, top – a discriminant factor on the composition and diversity of ground-dwelling arthropods in both treated and non-treated burnt soils.

## 2. Materials and methods

### *2.1 Site description*

The present study was conducted in a planted forest area located in north-central Portugal (Ermida, Sever do Vouga municipality: 40º44´05´´N, 8º21´18´´W) (Figure 1). The selected area was burnt by a wildfire on 26th July 2010, consuming approximately 300 ha, predominantly covered by eucalypt (*Eucalyptus globulus* Labill.) and maritime pine (*Pinus pinaster* Ait.) plantations (AFN, 2012). Previous studies in the area, based on the remaining tree stumps after the wildfire, showed that a plantation of eucalypt (*Eucalyptus globulus*) has been harvested every 7 - 14 years, for paper pulp production, during approximately the last 30 years within the study area (Prats *et al*., 2015). According to the soil severity index of Vega *et al*. (2013), the estimated soil burn severity for most of the area was moderate and higher at the base of the slope where logs had been cut and piled up before the wildfire (Prats *et al*., 2015).

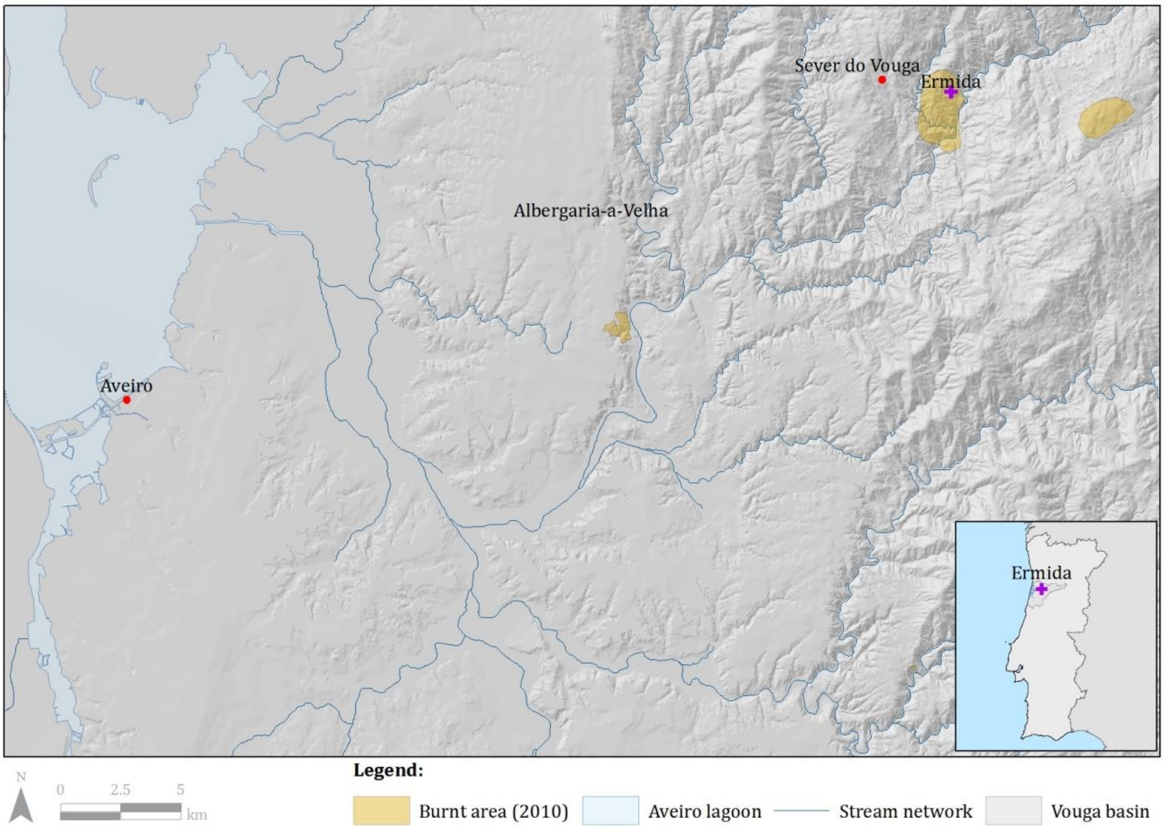

**Figure 1.** Location of the study area.

According to Köppen classification, the study area is humid mesothermal with an average annual rainfall (2005 - 2015) of 1343 mm. Over the past 30 years, the mean annual temperature varied between 12 and 19ºC (SNIRH, 2015). The soil at the study site is pre-Ordovician schist (Ferreira de Brum, 1978), despite its insertion in the Miniense Subsector, normally dominated by granites (Costa *et al.*, 1998). The climax vegetation of this region consists of mesotemperate and termotemperate oak forests of *Rusco aculeati-Quercetum roboris quercetosum suberis* that survive in small threatened forest pockets surrounded by the pine and eucalypt plantations (Costa *et al.*, 1998). The understorey is more resilient to human management and it is normally composed by mixed shrublands of *Erica*, *Cytisus* and *Ulex* (Costa *et al.*, 1998).

### *2.2 Field methods*

Immediately after the fire, a field experiment was carried-out in a burnt slope to assess the effects of residue mulch on runoff and soil erosion. This study was conducted under the framework of the FIRECNUTS project (PTDC/AGRCFL/104559/2008).

The experimental design consisted of 6 slope-scale silt fence plots (SF), 40 x 3 m each, along the slope. The slope (about 25° of inclination) was facing SW and located 200 m above sea. Chopped eucalypt bark mulch at 12 t/ha was added as treatment to 3 of the SF (hereafter designated Mulched) while the remaining half SF were left untreated and used as control (hereafter designed as Untreated) (Figure 2).

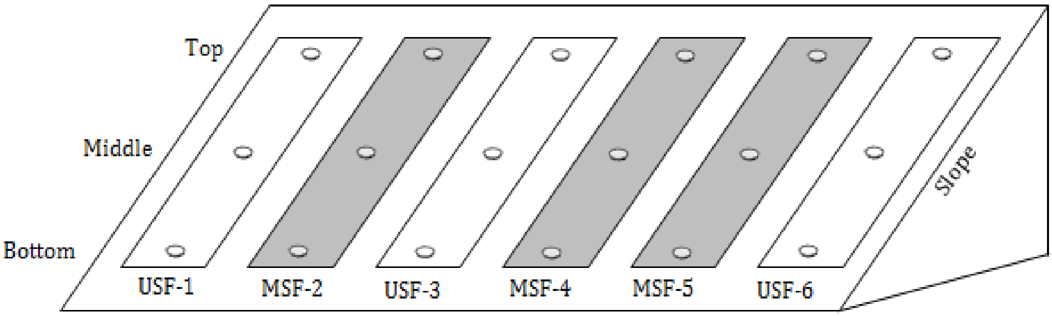

**Figure 2.** Experimental design of the slope-scale silt fence plots in the study area and the pitfall traps (circles). (U – untreated; M – mulched; SF – slope-scale silt fence plots).

Prats *et al*. (2015) determined that the soils of the study area on the lower half of the slope have high stone content and sandy-loam texture corresponding to Humic Cambisols. Those on the upper half of the slope are stony soils with low percentage of organic matter thus being Umbric Leptosols. Information related to soil moisture was collected from a Hobo Inc. automatic tipping-bucket rain gauge previously installed in the study area.

In order to understand the potential influence of mulching over time after the wildfire on the ground-dwelling arthropod community, a biological survey was carried out 5 years after the fire occurrence (June 2015). The survey consisted of 18 pitfalls traps that were equally distributed accordingly to the treatment type (untreated and mulched) and position throughout the slope (bottom, middle, top). Hence, 3 pitfalls were linearly placed on the ground along each SF at a distance of approximately 15 m of each other (Figure 2).

Pitfall traps are commonly used for the collection of soil invertebrates, being an efficient and inexpensive approach to collect ground-dwelling fauna, despite the known disadvantages of the technique (Spence & Niemelä, 1994). This trapping method has been found to provide reasonable activity-density estimates for groups such as carabid beetles (Baars, 1979), spiders and ants (Wang *et al*., 2001). The traps consisted of 8,5 cm width and 12 cm height plastic bottom bottles containing a small amount of ethanol 70% and a few drops of glycerine both used as preserving agents and a drop of detergent to break the ionic tension at the top of the solution, ensuring that the invertebrates would remain on the trap. Three pitfalls were linearly placed on the ground along each SF at a distance of approximately 15 m of each other during 7 days. After one week, the samples were collected and placed in vials with ethanol 70% with a few drops of glycerine until laboratory processing.

Parallel to the biological sampling, ground cover was assessed in each SF according to five cover categories: stones, ashes, bare soil, litter (includes mulch) and vegetation. On each SF a 1 x 1 m grid was randomly assigned on three positions within each SF (upper, middle and bottom) on which each cover category was assigned on a 10 cm grid. Hence, for each position the plot-wise cover values were calculated as averages over the entire grid (n=100).

Likewise, soil samples were randomly collected on three sites within each SF (upper, middle and bottom) following a three equally-spaced point transect along the SF. Only topsoil samples (0-2 cm depth) were collected since moderate wildfires affect mainly the upper 2 cm of soil (Badía *et al*., 2014; Badía-Villas *et al*., 2014).

### 2.3 Laboratory analysis

All the collected invertebrates were identified to order and family level using standard taxonomic keys (Harde & Severa, 1984; Goulet & Huber, 1993; Roberts, 1995; Barrientos, 1998; Czechowski *et al*., 2002). Despite the considerable identification effort, only the order level was used to describe the results related to abundance, due to a very low number of individuals of several identified families within each order. However, richness and richness dependent analyses were always calculated considering the number of identified families within each order.

Acari, Diptera and Lepidoptera were excluded from this study due to the limitations of the adopted collection method. Pitfall traps tend to attract only part of the community within each of the referred groups, which normally can incur in biased analysis of the data. Larvae identification was also not considered. Each individual was identified using a stereoscopic magnifier.

In the laboratory, the soil samples collected were analysed for organic matter content (OM%) by loss on ignition (ASTM, 1987). After air dried, each soil sample was sieved with a 2 mm net and 5 g of each sample was dried at 105ºC in a muffle during approximately 6 hours. Samples were then transferred to a muffle furnace and heated to 550ºC for at least six hours and then put in a desiccator to a temperature at which they can be safely handled, then weighted. The weight loss when the samples are dried at 105 ºC (wet weight - dry weight) represents the amount of pore-water held within the sample and the weight loss between 105 and 550ºC as a percentage of the total original dry sample weight is the OM%.

### 2.4 Data analysis

All the statistical analysis has been performed using SPSS 13.0 and Microsoft Excel 2010.

As mentioned before, family level was used to calculate ground-dwelling arthropod community structural parameters: total abundance, richness, Shannon-Weiner diversity index ($H'$),

$$H' = -\sum_{i=1}^{S} p_i ln(p_i)$$

where $p_i$ = fraction of the entire population made up of families $i$; $S$ = numbers of families encountered; $\sum$ = sum from family 1 to family $S$, and Pielou evenness index ($J'$),

$$J' = \frac{H'}{H'_{max}}$$

where $H'$ = Shannon-Weiner diversity index; $H'_{max}$ = Shannon-Weiner diversity index maximum value obtained, both accordingly to the position on the slope and typology of treatment on each SF.

Three replicates were used for position and treatment along each of the six SF's. Correlations between each variable were analysed using Pearson's correlation. A similar procedure was adopted to analyse the relations between treatment and position with OM and ground cover. A two-way ANOVA was used to test statistical significant differences between treatments (mulched *vs* untreated) and position (bottom *vs* middle *vs* top), as well as their interaction, using both richness and abundance of the ground-dwelling arthropod community.

Specific differences between factors were detected *a posteriori* using the Shapiro-Wilk multiple comparison test. Differences were considered significant at a $p<0.05$. Normality and homogeneity of variances of data were confirmed by the Shapiro-Wilk test and the Levene median test, respectively. When normality and homogeneity of variances were not achieved, data were transformed as neperian logarithm (Ln).

Pearson's correlation was also used to analyse relations between the ecological feeding function of each family for each treatment and position on the slope.

Accumulated proportional abundance was determined for order taxon and ecological feeding function regarding untreated and mulched SF's and also the pitfall position on the slope.

## 3. Results

### *3.1 Environmental variables analysis*

Ground cover and OM content in soil samples were analysed on each SF along the slope. Ground cover results were similar for mulched and untreated SF's for every tested position, being litter the ground cover class with higher cover percentage (Table 1). Minor differences were observed regarding understory and stone content on mulched and untreated SF's. OM content was approximately 10% higher on mulched SF's, but within treatment is identical for each position.

**Table 1.** Mean and standard deviation of percentage of OM and ground cover for each untreated and mulched SF, according to the position of the pitfalls in the slope.

| **Environmental variables (%)** | **Untreated**<br>**Bottom** | <br>**Middle** | <br>**Top** | **Mulched**<br>**Bottom** | <br>**Middle** | <br>**Top** |
|---|---|---|---|---|---|---|
| Organic matter | 27.62 ± 9.67 | 23.47 ± 5.71 | 23.57 ± 13.85 | 38.14 ± 5.00 | 34.36 ± 9.18 | 34.32 ± 12.41 |
| Stones | 7.33 ± 4.50 | 8.00 ± 9.20 | 6.00 ± 3.56 | 3.00 ± 0.82 | 10.67 ± 6.85 | 3.33 ± 2.49 |
| Bare soil | 12.33 ± 5.79 | 11.67 ± 4.64 | 15.00 ± 8.49 | 12.67 ± 4.50 | 5.33 ± 2.05 | 14.67 ± 8.18 |
| Ashes | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 1.00 ± 1.41 | 1.00 ± 1.41 |
| Litter | 56.00 ± 7.79 | 65.67 ± 15.33 | 55.00 ± 5.35 | 57.33 ± 9.46 | 64.67 ± 16.50 | 74.33 ± 10.34 |
| Understorey | 24.33 ± 17.33 | 14.67 ± 10.78 | 24.00 ± 15.58 | 27.00 ± 12.03 | 18.33 ± 10.37 | 6.67 ± 3.40 |

The two-way ANOVA showed statistical differences between the percentage of bare soil and treatment (P=0.04) (Table 2). For the others tested environmental variables no significant differences were found ($p<0.05$).

**Table 2.** Two-way ANOVA summary relative to the percentage of each environmental variable at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top). Statistical significant relations in bold type. (*df* – degrees of freedom; MS – mean squares; *F* – F test; *P* – *p* value)

| Environmental variables (%) | Source of variation | *df* | MS | *F* | *P* |
|---|---|---|---|---|---|
| OM | Treatment | 1 | 96.37 | 0.58 | 0.46 |
| | Position | 2 | 31.19 | 0.19 | 0.83 |
| | Treatment x Position | 2 | 78.02 | 0.47 | 0.64 |
| Stones | Treatment | 1 | 16.06 | 0.39 | 0.55 |
| | Position | 2 | 39.39 | 0.95 | 0.41 |
| | Treatment x Position | 2 | 25.72 | 0.62 | 0.55 |
| Bare soil | **Treatment** | **1** | **168.06** | **5.24** | **0.04** |
| | Position | 2 | 61.56 | 1.92 | 0.19 |
| | Treatment x Position | 2 | 81.56 | 2.54 | 0.12 |
| Ashes | Treatment | 1 | 2.00 | 2.00 | 0.18 |
| | Position | 2 | 0.50 | 0.50 | 0.62 |
| | Treatment x Position | 2 | 0.50 | 0.50 | 0.62 |
| Litter | Treatment | 1 | 84.50 | 0.37 | 0.55 |
| | Position | 2 | 136.50 | 0.60 | 0.56 |
| | Treatment x Position | 2 | 70.17 | 0.31 | 0.74 |
| Understorey | Treatment | 1 | 280.06 | 1.13 | 0.29 |
| | Position | 2 | 192.17 | 0.84 | 0.46 |
| | Treatment x Position | 2 | 103.72 | 0.45 | 0.65 |

Results showed that 5 years after the fire, ground cover showed similar results for all of the selected classes for each treatment and along the slope (Figure 3). Litter was the dominant cover on both treatments, while ashes only have been found on the mulched SF's. Stones showed smaller cover percentages when comparing with litter and understory, while bare soil covers about 15% of the ground in the untreated SF's and between 5 to 15% in the mulched SF's. With exception of the understory that showed the highest values on the bottom of each slope for both treatments, no clear patterns were observed for the others ground cover classes.

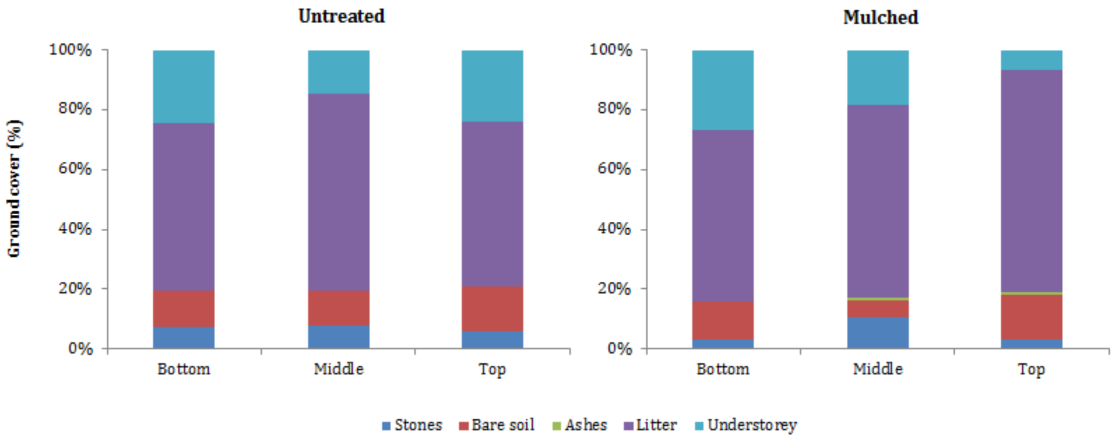

**Figure 3.** Ground cover distribution according to treatment type and position along each SF.

### *3.2 Community analysis*

A total of 519 ground-dwelling invertebrates were captured, covering 40 families within 13 orders (see full family table on Appendix 1). Similar values of abundance and richness were obtained for treatment and position along the slope (Figure 4). Abundance of some orders can be high, but for most *taxa* the abundance values were low, corresponding to the information given by the values of richness, which is on average inferior to 10 (Figure 4). The obtained values for Shannon-Weiner diversity index and Pielou evenness index support these results, showing almost no differences in the ground-dwelling arthropod community, between treatment and position along the slope (Figure 5), meaning that the ground-dwelling arthropod community is similar and not much diverse.

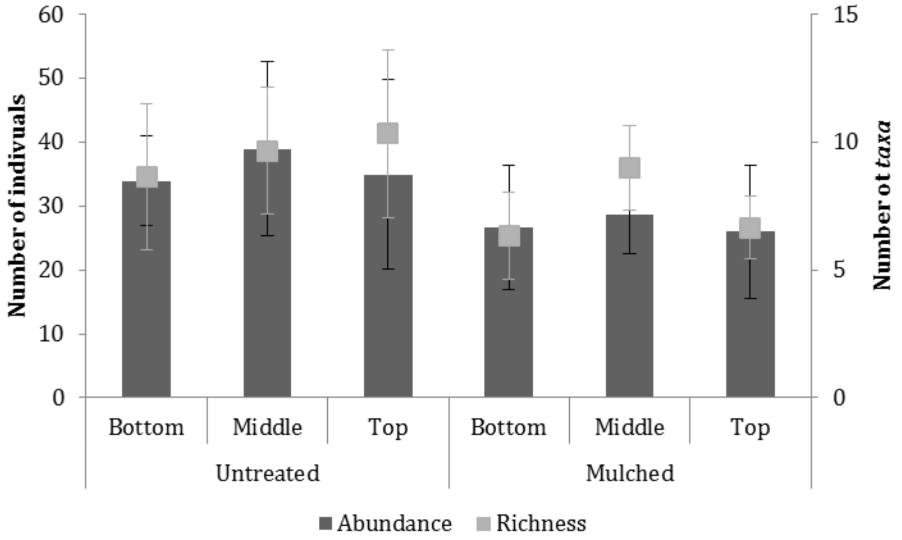

**Figure 4.** Mean and standard deviation for abundance and richness of the ground-dwelling arthropod community, according to treatment and position on the slope.

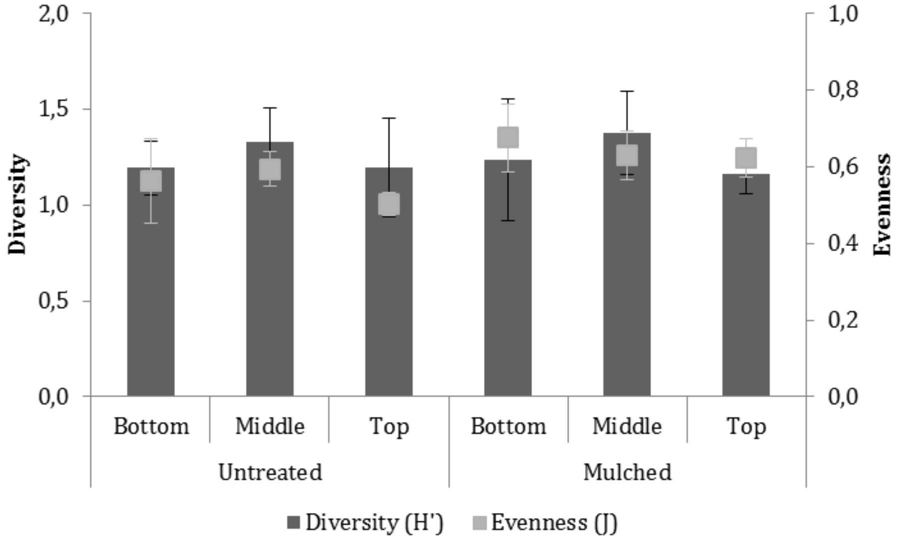

**Figure 5.** Mean and standard deviation for diversity and evenness of the ground-dwelling arthropod community, according to treatment and position on the slope.

The results regarding a two-way ANOVA test show no significant relations between the position on the slope and treatment with total abundance, total richness, total diversity and total evenness (Table 3).

**Table 3.** Two-way ANOVA summary regarding total abundance, richness, diversity and evenness of ground-dwelling arthropod community at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top). (*df* – degrees of freedom; MS – mean squares; *F* – F test; *P* – *p* value)

| **Variable** | **Source of variation** | **Abundance** | | | |
|---|---|---|---|---|---|
| | | ***df*** | **MS** | ***F*** | ***P*** |
| Total Abundance | Treatment | 1 | 346.72 | 2.34 | 0.15 |
| | Position | 2 | 2.17 | 0.01 | 0.99 |
| | Treatment x Position | 2 | 1.06 | 0.01 | 0.99 |
| Total Richness | Treatment | 1 | 22.22 | 3.45 | 0.09 |
| | Position | 2 | 5.06 | 0.78 | 0.48 |
| | Treatment x Position | 2 | 3.39 | 0.53 | 0.60 |
| Total Diversity (H') | Treatment | 1 | 0.00 | 0.02 | 0.88 |
| | Position | 2 | 0.02 | 0.11 | 0.90 |
| | Treatment x Position | 2 | 0.03 | 0,18 | 0.84 |
| Total Evenness (J) | Treatment | 1 | 0.04 | 0.14 | 0.72 |
| | Position | 2 | 0.03 | 0.11 | 0.90 |
| | Treatment x Position | 2 | 0.04 | 0.19 | 0.83 |

Hymenoptera and Collembola were the orders with the greatest abundance on both untreated and mulched SF's and also along all the positions in the slope (Table 4). There are several orders such as Dictioptera, Isopoda, Chilopoda and Psocoptera for which the number of collected specimens was very low, being its contribution to both abundance and richness quite residual.

**Table 4.** Mean and standard deviation of abundance within each order at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top).

| **Order** | **Abundance** | | | | | |
|---|---|---|---|---|---|---|
| | **Untreated** | | | **Mulched** | | |
| | **Bottom** | **Middle** | **Top** | **Bottom** | **Middle** | **Top** |
| Collembola | 6.67 ± 5.19 | 13.33 ± 10.12 | 5.67 ± 5.19 | 9.00 ± 5.72 | 8.00 ± 4.97 | 5.33 ± 3.30 |
| Hemiptera | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.67 ± 0.47 | 0.67 ± 0.47 | 0.67 ± 0.47 | 0.67 ± 0.47 |
| Thysanura | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Dictioptera | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.00 ± 0.00 |
| Isopoda | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Coleoptera | 2.67 ± 0.47 | 9.00 ± 7.07 | 4.00 ± 0.82 | 4.33 ± 4.19 | 5.33 ± 1.70 | 4.00 ± 0.82 |
| Hymenoptera | 17.33 ± 7.04 | 10.33 ± 0.94 | 20.67 ± 6.65 | 9.00 ± 1.41 | 8.67 ± 2.62 | 13.70 ± 5.31 |
| Chilopoda | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Thysanoptera | 0.33 ± 0.47 | 0.67 ± 0.94 | 0.33 ± 0.47 | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Pseudoscorpionida | 0.00 ± 0.00 | 0.67 ± 0.94 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.67 ± 0.94 | 0.00 ± 0.00 |
| Psocoptera | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Araneae | 5.67 ± 5.25 | 4.00 ± 0.82 | 2.33 ± 1.89 | 2.00 ± 2.16 | 5.00 ± 2.16 | 2.33 ± 1.70 |
| Opiliones | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |

Coleoptera and Araneae were the orders with the higher number of families when considering all of the individuals identified in this study (Appendix 1), contributing largely to the total richness of the ground-dwelling arthropod community of the study area. When comparing treatments and positions along the slope it was found that Hymenoptera and Araneae were the orders with the greatest richness in almost every position of the untreated SF's, while in the mulched SF's in addition to Hymenoptera and Araneae also Coleoptera had similar values of richness for every tested position (Table 5).

**Table 5.** Mean and standard deviation of richness within each order at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top).

| | **Richness** | | | | | |
|---|---|---|---|---|---|---|
| **Order** | **Untreated** | | | **Mulched** | | |
| | **Bottom** | **Middle** | **Top** | **Bottom** | **Middle** | **Top** |
| Collembola | 1.00 ± 0.00 | 1.00 ± 0.00 | 1.00 ± 0.00 | 1.33 ± 0.47 | 1.33 ± 0.47 | 1.00 ± 0.00 |
| Hemiptera | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.67 ± 0.47 | 0.67 ± 0.47 | 0.67 ± 0.47 | 0.67 ± 0.47 |
| Thysanura | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Dictioptera | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.00 ± 0.00 |
| Isopoda | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Coleoptera | 1.33 ± 0.47 | 3.00 ± 0.82 | 2.33 ± 0.47 | 0.67 ± 0.47 | 2.33 ± 0.94 | 1.33 ± 0.47 |
| Hymenoptera | 2.00 ± 0.82 | 1.67 ± 0.47 | 3.00 ± 0.82 | 1.33 ± 0.47 | 2.00 ± 0.00 | 2.33 ± 0.47 |
| Chilopoda | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Thysanoptera | 0.33 ± 0.47 | 0.33 ± 0.47 | 0.17 ± 0.37 | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Pseudoscorpionida | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.67 ± 0.94 | 0.00 ± 0.00 |
| Psocoptera | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 | 0.00 ± 0.00 |
| Araneae | 2.67 ± 1.70 | 2.33 ± 0.47 | 1.67 ± 0.94 | 0.67 ± 0.47 | 1.67 ± 0.47 | 1.33 ± 1.25 |
| Opiliones | 0.33 ± 0.47 | 0.00 ± 0.00 | 0.33 ± 0.47 | 0.67 ± 0.47 | 0.00 ± 0.00 | 0.00 ± 0.00 |

Pearson correlation was used to find possible relations between each order and each studied environmental variable, given the abundance and richness (Table 6). According to the analysis, there were found relations between ashes (%) and Collembola, ashes (%) and Psocoptera, and between stones (%) and Pseudoscorpionida. Since in the first case the percentage of ashes in the study area was almost 0%, and in the second case the abundance of Pseudoscorpionida was limited to 4 specimens belonging to 2 families, these results must be ignored to avoid misleading conclusions.

**Table 6.** Pearson correlations summary between environmental variables and each order, for both richness and abundance. Statistical significant relations in bold type. (Z – Z score; sig. – significance)

| | Order | Pearson | OM | Stones | Bare soil | Ashes | Litter | Understorey |
|---|---|---|---|---|---|---|---|---|
| **Abundance** | Collembola | Z | 0.43 | 0.25 | -0.38 | **0.61** | -0.05 | 0.09 |
| | | sig. | 0.07 | 0.32 | 0.12 | **0.01** | 0.84 | 0.74 |
| | Hemiptera | Z | -0.04 | -0.05 | -0.11 | 0.00 | -0.09 | 0.24 |
| | | sig. | 0.88 | 0.31 | 0.68 | 1.00 | 0.73 | 0.34 |
| | Thysanura | Z | 0.07 | -0.19 | -0.29 | 0.24 | -0.14 | 0.33 |
| | | sig. | 0.78 | 0.45 | 0.24 | 0.35 | 0.59 | 0.18 |
| | Dictioptera | Z | -0.03 | -0.22 | -0.25 | -0.09 | 0.38 | -0.14 |
| | | sig. | 0.91 | 0.38 | 0.32 | 0.74 | 0.12 | 0.58 |
| | Isopoda | Z | -0.24 | 0.36 | 0.03 | 0.44 | 0.12 | -0.30 |
| | | sig. | 0.34 | 0.14 | 0.91 | 0.07 | 0.65 | 0.22 |
| | Coleoptera | Z | -0.24 | 0.39 | 0.23 | -0.03 | -0.05 | -0.23 |
| | | sig. | 0.34 | 0.11 | 0.36 | 0.89 | 0.85 | 0.37 |
| | Hymenoptera | Z | 0.15 | -0.23 | -0.08 | 0.40 | 0.43 | -0.29 |
| | | sig. | 0.57 | 0.36 | 0.76 | 0.11 | 0.08 | 0.24 |
| | Chilopoda | Z | -0.24 | -0.08 | -0.20 | -0.13 | -0.18 | 0.31 |
| | | sig. | 0.34 | 0.75 | 0.42 | 0.62 | 0.48 | 0.22 |
| | Thysanoptera | Z | -0.25 | 0.43 | 0.17 | -0.20 | -0.44 | 0.16 |
| | | sig. | 0.32 | 0.08 | 0.49 | 0.42 | 0.07 | 0.52 |
| | Pseudoscorpionida | Z | -0.20 | **0.72** | 0.06 | -0.13 | -0.43 | 0.08 |
| | | sig. | 0.43 | **0.00** | 0.83 | 0.62 | 0.08 | 0.74 |
| | Psocoptera | Z | 0.36 | 0.35 | -0.32 | **0.69** | 0.11 | -0.14 |
| | | sig. | 0.14 | 0.15 | 0.20 | **0.00** | 0.68 | 0.58 |
| | Aranea | Z | 0.39 | 0.05 | -0.36 | 0.11 | 0.11 | 0.04 |
| | | sig. | 0.11 | 0.86 | 0.14 | 0.67 | 0.66 | 0.86 |
| | Opiliones | Z | -0.15 | 0.01 | 0.20 | -0.19 | -0.11 | 0.01 |
| | | sig. | 0.56 | 0.97 | 0.43 | 0.45 | 0.67 | 0.96 |
| **Richness** | Collembola | Z | 0.04 | -0.26 | 0.00 | -0.13 | 0.23 | -0.10 |
| | | sig. | 0.89 | 0.30 | 0.99 | 0.62 | 0.35 | 0.68 |
| | Hemiptera | Z | -0.04 | -0.25 | -0.11 | 0.00 | -0.09 | 0.24 |
| | | sig. | 0.88 | 0.31 | 0.68 | 1.00 | 0.73 | 0.34 |
| | Thysanura | Z | -0.07 | -0.19 | -0.29 | 0.24 | -0.14 | 0.33 |
| | | sig. | 0.78 | 0.45 | 0.24 | 0.35 | 0.59 | 0.18 |
| | Dictioptera | Z | -0.03 | -0.22 | -0.25 | -0.09 | 0.38 | -0.14 |
| | | sig. | 0.91 | 0.38 | 0.32 | 0.74 | 0.12 | 0.58 |
| | Isopoda | Z | -0.24 | 0.36 | 0.03 | 0.44 | 0.12 | -0.30 |
| | | sig. | 0.34 | 0.14 | 0.91 | 0.07 | 0.65 | 0.22 |
| | Coleoptera | Z | -0.13 | 0.23 | -0.27 | 0.41 | 0.33 | -0.31 |
| | | sig. | 0.61 | 0.36 | 0.29 | 0.09 | 0.18 | 0.22 |
| | Hymenoptera | Z | -0.22 | 0.12 | 0.06 | 0.43 | 0.33 | -0.42 |
| | | sig. | 0.38 | 0.65 | 0.80 | 0.08 | 0.18 | 0.09 |
| | Chilopoda | Z | -0.24 | -0.08 | -0.20 | -0.13 | -0.18 | 0.31 |
| | | sig. | 0.34 | 0.75 | 0.42 | 0.62 | 0.48 | 0.22 |
| | Thysanoptera | Z | -0.22 | 0.25 | 0.11 | 0.22 | -0.44 | 0.27 |
| | | sig. | 0.39 | 0.32 | 0.65 | 0.38 | 0.07 | 0.27 |
| | Pseudoscorpionida | Z | -0.16 | **0.63** | -0.03 | -0.12 | -0.43 | 0.16 |
| | | sig. | 0.53 | **0.01** | 0.91 | 0.64 | 0.08 | 0.53 |
| | Psocoptera | Z | 0.36 | 0.35 | -0.32 | **0.69** | 0.11 | -0.14 |
| | | sig. | 0.14 | 0.15 | 0.20 | **0.00** | 0.68 | 0.58 |
| | Aranea | Z | 0.44 | 0.05 | -0.41 | 0.23 | 0.24 | -0.06 |
| | | sig. | 0.07 | 0.86 | 0.09 | 0.36 | 0.35 | 0.81 |
| | Opiliones | Z | -0.15 | 0.01 | 0.20 | -0.19 | -0.11 | 0.01 |
| | | sig. | 0.56 | 0.97 | 0.43 | 0.45 | 0.67 | 0.96 |

A two-way ANOVA was also used to test the influence and potential interaction of treatment and position along the slope regarding the richness and abundance of each order (Table 7). Significant differences were observed for the Coleoptera richness's ($p=0.01$) according the position on the slope and for the abundance of Hymenoptera abundance's ($p=0.04$) between mulched and untreated SFs. However, for the generality of the taxa, no significant differences were found among positions within the slope or between treatments, either for abundance and richness.

**Table 7.** Two-way ANOVA summary regarding the abundance and richness of each order and total abundance and richness at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top). Statistical significant relations in bold type. (*df* – degrees of freedom; MS – mean squares; *F* – F test; *P* – *p* value)

| **Order** | **Source of variation** | **Abundance** | | | | **Richness** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***df*** | **MS** | ***F*** | ***P*** | ***df*** | **MS** | ***F*** | ***P*** |
| Collembola | Treatment | 1 | 5.56 | 0.10 | 0.76 | 1 | 0.22 | 2.00 | 0.18 |
| | Position | 2 | 40.17 | 0.71 | 0.51 | 2 | 0.06 | 0.50 | 0.62 |
| | Treatment x Position | 2 | 22.72 | 0.40 | 0.68 | 2 | 0.06 | 0.50 | 0.62 |
| Hemiptera | Treatment | 1 | 0.50 | 1.80 | 0.21 | 1 | 0.50 | 1.80 | 0.21 |
| | Position | 2 | 0.17 | 0.60 | 0.56 | 2 | 0.17 | 0.60 | 0.56 |
| | Treatment x Position | 2 | 0.17 | 0.60 | 0.56 | 2 | 0.17 | 0.60 | 0.56 |
| Thysanura | Treatment | 1 | 0.22 | 1.33 | 0.27 | 1 | 0.22 | 1.33 | 0.27 |
| | Position | 2 | 0.39 | 2.33 | 0.14 | 2 | 0.39 | 2.33 | 0.14 |
| | Treatment x Position | 2 | 0.06 | 0.33 | 0.72 | 2 | 0.06 | 0.33 | 0.72 |
| Dictioptera | Treatment | 1 | 0.06 | 1.00 | 0.34 | 1 | 0.06 | 1.00 | 0.34 |
| | Position | 2 | 0.06 | 1.00 | 0.40 | 2 | 0.06 | 1.00 | 0.40 |
| | Treatment x Position | 2 | 0.06 | 1.00 | 0.40 | 2 | 0.06 | 1.00 | 0.40 |
| Isopoda | Treatment | 1 | 0.22 | 2.00 | 0.18 | 1 | 0.22 | 2.00 | 0.18 |
| | Position | 2 | 0.06 | 0.50 | 0.62 | 2 | 0.06 | 0.50 | 0.62 |
| | Treatment x Position | 2 | 0.06 | 0.50 | 0.62 | 2 | 0.06 | 0.50 | 0.62 |
| Coleoptera | Treatment | 1 | 0.06 | 0.01 | 0.94 | 1 | 2.72 | 4.46 | 0.06 |
| | **Position** | 2 | 4.22 | 0.46 | 0.64 | **2** | **4.17** | **6.82** | **0.01** |
| | Treatment x Position | 2 | 6.22 | 0.68 | 0.52 | 2 | 0.06 | 0.09 | 0.91 |
| Hymenoptera | **Treatment** | **1** | **156.06** | **5.24** | **0.04** | 1 | 0.50 | 1.00 | 0.34 |
| | Position | 2 | 80.72 | 2.71 | 0.11 | 2 | 1.72 | 3.44 | 0.07 |
| | Treatment x Position | 2 | 17.39 | 0.58 | 0.57 | 2 | 0.50 | 1.00 | 0.40 |
| Chilopoda | Treatment | 1 | 0.22 | 2.00 | 0.18 | 1 | 0.22 | 2.00 | 0.18 |
| | Position | 2 | 0.06 | 0.50 | 0.62 | 2 | 0.06 | 0.50 | 0.62 |
| | Treatment x Position | 2 | 0.06 | 0.50 | 0.62 | 2 | 0.06 | 0.50 | 0.62 |
| Thysanoptera | Treatment | 1 | 0.22 | 0.57 | 0.46 | 1 | 0.06 | 0.25 | 0.63 |
| | Position | 2 | 0.17 | 0.43 | 0.66 | 2 | 0.22 | 1.00 | 0.40 |
| | Treatment x Position | 2 | 0.39 | 1.00 | 0.40 | 2 | 0.22 | 1.00 | 0.40 |
| Pseudoscorpionida | Treatment | 1 | 0.00 | 0.00 | 1.00 | 1 | 0.06 | 0.20 | 0.66 |
| | Position | 2 | 0.89 | 2.00 | 0.18 | 2 | 0.50 | 1.80 | 0.21 |
| | Treatment x Position | 2 | 0.00 | 0.00 | 1.00 | 2 | 0.06 | 0.20 | 0.82 |
| Psocoptera | Treatment | 1 | 0.06 | 1.00 | 0.34 | 1 | 0.06 | 1.00 | 0.34 |
| | Position | 2 | 0.06 | 1.00 | 0.40 | 2 | 0.06 | 1.00 | 0.40 |
| | Treatment x Position | 2 | 0.06 | 1.00 | 0.40 | 2 | 0.06 | 1.00 | 0.40 |
| Araneae | Treatment | 1 | 5.56 | 0.64 | 0.44 | 1 | 4.50 | 3.00 | 0.11 |
| | Position | 2 | 6.17 | 0.71 | 0.51 | 2 | 0.39 | 0.26 | 0.78 |
| | Treatment x Position | 2 | 11.72 | 1.34 | 0.30 | 2 | 1.17 | 0.78 | 0.48 |
| Opiliones | Treatment | 1 | 0.00 | 0.00 | 1.00 | 1 | 0.00 | 0.00 | 1.00 |
| | Position | 2 | 0.39 | 2.33 | 0.14 | 2 | 0.39 | 2.33 | 0.14 |
| | Treatment x Position | 2 | 0.17 | 1.00 | 0.40 | 2 | 0.17 | 1.00 | 0.40 |

Relative abundance was also calculated for each order regarding treatment and position along the slope (Figure 6). Hymenoptera and Collembola were by far the dominant taxa on both treatments and along the slope. Araneae and Coleoptera, despite less abundant than Hymenoptera and Collembola, still have a high contribution within the ground-dwelling arthropod community. , The remaining orders contribute with less than 10% for the total community. On both treatments, 80% of the abundance is distributed among 4 families of 3 orders (Collembola: Entomobryidae; Coleoptera: Staphylinidae; Hymenoptera: Myrmicinae and Formicinae), corresponding the remaining 20% to the other families.

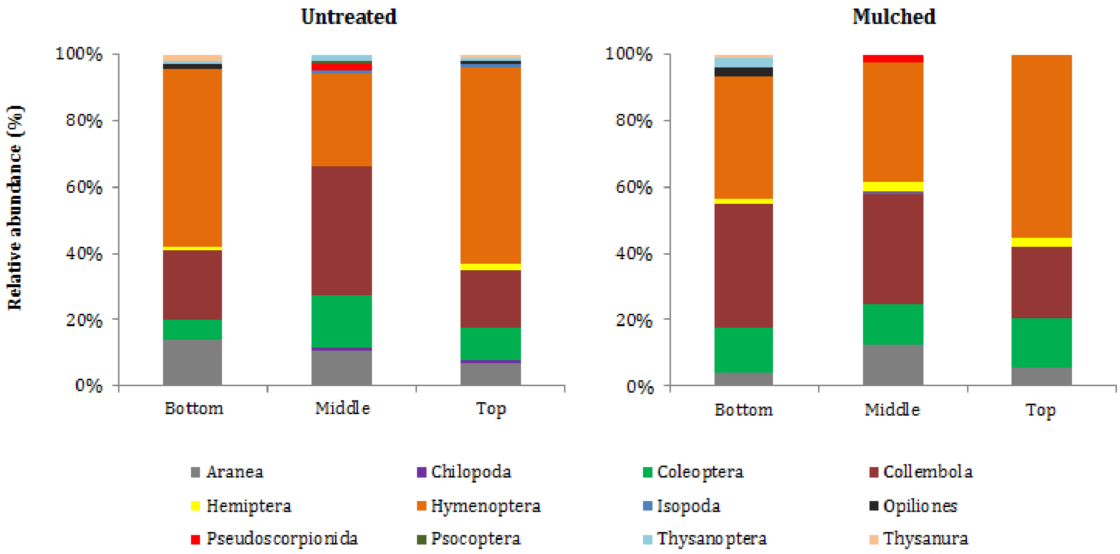

**Figure 6.** Relative abundance of each order according to treatment type and position along each SF.

### *3.3 Ecological function analysis*

All of the identified families were classified accordingly to their ecological function in 4 main classes (Appendix 1): microbial feeders, omnivores, plant feeders and predators. Omnivores were the most abundant on both untreated and mulched SF's and also in almost every tested position along the slope (Table 8), however the mean abundance values obtained for each of the tested classes are very identical despite de treatment or position along the slope, turning again on absence of statistical significant relations between the tested variables (p<0,05).

**Table 8.** Mean and standard deviation of abundance according to each defined ecological function within the ground-dwelling arthropod community for each untreated and mulched SF and to the position of the pitfalls in the slope.

| | **Abundance** | | | | | |
|---|---|---|---|---|---|---|
| **Ecological function** | **Untreated** | | | **Mulched** | | |
| | **Bottom** | **Middle** | **Top** | **Bottom** | **Middle** | **Top** |
| Microbial feeders | 6.67 ± 5.19 | 13.67 ± 10.21 | 5.67 ± 5.19 | 9.00 ± 5.72 | 8.00 ± 4.97 | 5.33 ± 3.30 |
| Omnivores | 17.67 ± 6.34 | 10.67 ± 0.94 | 20.33 ± 7.59 | 9.67 ± 0.47 | 9.67 ± 3.40 | 14.67 ± 3.30 |
| Plant Feeders | 1.00 ± 0.00 | 1.34 ± 0.94 | 1.33 ± 1.25 | 0.33 ± 0.47 | 1.00 ± 0.00 | 1.00 ± 0.00 |
| Predators | 7.67 ± 4.64 | 8.67 ± 3.77 | 6.33 ± 3.09 | 6.33 ± 4.19 | 7.67 ± 4.19 | 4.67 ± 3.30 |

Pearson correlations were also used to verify possible relations between ecological function and environmental variables, based on its abundance and richness (Table 9). Ashes were related with microbial feeders abundance (p = 0.01) and with plant feeders richness (p =0.00). On the other hand the abundance of omnivores seems to be related with the percentage of litter (p=0.05).

**Table 9.** Pearson correlations summary between environmental variables and ecological function, for both richness and abundance. Statistical significant relations in bold type. (Z – Z score; sig. – significance)

| | **Ecological function** | **Pearson** | **OM** | **Stones** | **Bare Soil** | **Ashes** | **Litter** | **Understorey** |
|---|---|---|---|---|---|---|---|---|
| **Abundance** | Microbial feeders | Z | 0.42 | 0.27 | -0.37 | **0.60** | -0.06 | 0.08 |
| | | sig. | 0.08 | 0.28 | 0.13 | **0.01** | 0.82 | 0.75 |
| | Omnivores | Z | 0.06 | -0.26 | -0.05 | 0.39 | **0.46** | -0.33 |
| | | sig. | 0.80 | 0.30 | 0.85 | 0.11 | **0.05** | 0.18 |
| | Plant feeders | Z | -0.05 | 0.34 | -0.22 | **0.71** | 0.27 | -0.34 |
| | | sig. | 0.85 | 0.17 | 0.38 | **0.00** | 0.28 | 0.17 |
| | Predators | Z | 0.20 | 0.15 | -0.16 | 0.05 | 0.00 | 0.01 |
| | | sig. | 0.42 | 0.56 | 0.51 | 0.84 | 0.99 | 0.97 |
| **Richness** | Microbial feeders | Z | -0.10 | 0.15 | 0.13 | -0.16 | 0.05 | -0.16 |
| | | sig. | 0.71 | 0.56 | 0.59 | 0.53 | 0.84 | 0.52 |
| | Omnivores | Z | -0.30 | -0.01 | -0.16 | 0.25 | 0.20 | -0.12 |
| | | sig. | 0.23 | 0.96 | 0.53 | 0.32 | 0.43 | 0.63 |
| | Plant feeders | Z | -0.05 | 0.34 | -0.22 | **0.71** | 0.27 | -0.34 |
| | | sig. | 0.85 | 0.17 | 0.38 | **0.00** | 0.28 | 0.17 |
| | Predators | Z | 0.18 | 0.17 | -0.42 | 0.24 | 0.09 | 0.03 |
| | | sig. | 0.46 | 0.49 | 0.09 | 0.35 | 0.73 | 0.91 |

Regarding the two-way ANOVA performed for the abundance and richness of the ground-dwelling arthropod community ecological function (Table 10), no statistical differences ($p<0.05$) were found among positions along the slope and between treatments.

**Table 10.** Two-way ANOVA summary regarding the abundance and richness of each functional group at different treatments (Untreated, Mulched) and positions (Bottom, Middle, Top). Statistical significant relations in bold type. (*df* – degrees of freedom; MS – mean squares; *F* – F test; *P* – *p* value)

| **Ecological function** | **Source of variation** | **Abundance** | | | | **Richness** | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | ***df*** | **MS** | ***F*** | ***P*** | ***df*** | **MS** | ***F*** | ***P*** |
| Microbial feeders | Treatment | 1 | 6.72 | 0.12 | 0.74 | 1 | 0.06 | 0.33 | 0.57 |
| | Position | 2 | 42.89 | 0.76 | 0.49 | 2 | 0.17 | 1.00 | 0.40 |
| | Treatment x Position | 2 | 24.89 | 0.44 | 0.65 | 2 | 0.06 | 0.33 | 0.72 |
| Omnivores | Treatment | 1 | 107.56 | 3.55 | 0.08 | 1 | 0.70 | 0.70 | 0.42 |
| | Position | 2 | 80.72 | 2.66 | 0.11 | 2 | 0.39 | 0.30 | 0.74 |
| | Treatment x Position | 2 | 19.06 | 0.63 | 0.55 | 2 | 0.83 | 0.83 | 0.46 |
| Plant feeders | Treatment | 1 | 0.89 | 1.33 | 0.27 | 1 | 0.89 | 1.33 | 0.27 |
| | Position | 2 | 0.50 | 0.75 | 0.49 | 2 | 0.50 | 0.75 | 0.49 |
| | Treatment x Position | 2 | 0.06 | 0.08 | 0.92 | 2 | 0.06 | 0.08 | 0.92 |
| Predators | Treatment | 1 | 8.00 | 0.35 | 0.57 | 1 | 12.50 | 4.33 | 0.06 |
| | Position | 2 | 10.72 | 0.47 | 0.64 | 2 | 1.06 | 0.37 | 0.70 |
| | Treatment x Position | 2 | 0.17 | 0.01 | 0.99 | 2 | 0.50 | 0.17 | 0.84 |

The analysis of the relative abundance of each functional group showed similar results for each treatment and along the slope (Figure 7). The proportion of each functional group is also identical for the untreated and mulched SF's, showing dominance of omnivores and plant feeders in the upper slope, higher abundance of microbial feeders and plant feeders in the middle slope and an increase of predators in the middle and bottom slopes.

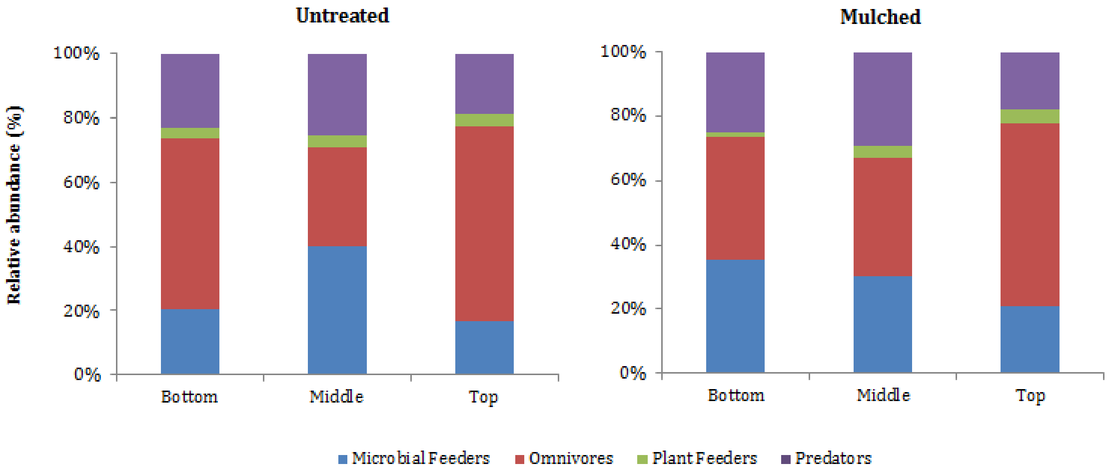

**Figure 7.** Relative abundance of each functional group according to treatment type and position along each SF.

## 4. Discussion

Wildfires promote physical, chemical and biological changes, affecting each ecosystem in ways that normally conduct to direct and indirect transformations over time (Bowman *et al.*, 2013). These modifications are usually related to the typology of the fire and the main characteristics of the affected ecosystem (Certini, 2005).

Although environmental changes related to direct effects of fire on invertebrate communities are still unclear, some research studies show that it may be attenuated on ground-dwelling arthropods due to their higher mobility and burrowing behaviours (Certini, 2005). In fact, according to García-Dominguez *et al.* (2010) the number of predators and omnivores increases during the following weeks after a fire, while herbivores tend to remain the same (McSorley, 1993). Other studies show negative response to fire by a decrease soil invertebrate diversity (Apigian *et al.*, 2006) or only relevant responses at short-term for some groups (Baker *et al.*, 2004). Indirect effects of fire over these communities include alteration of the soil microbial community composition and activity and changes in their physico-chemical environment conditions (Paul & Clark, 1996; Certini, 2005), affecting nutrient availability, and biotic sources for the re-colonization of most animal and plant communities (Tabatai, 1994; Hamman *et al.*, 2007). According to Certini (2005), one of the main fire induced changes on forest soils is related to the increase of organic carbon (in the form of organic matter) after a fire, due to the reintroduction of vegetation and to normally fast ecological successions. If fast ecological successions occur, more rapidly a new community tends to establish, despite changes on microbial biomass and community and a decrease in ground-dwelling invertebrate biomass and composition (Certini, 2005).

However there are some other variables to consider that also have an important role on the recovery of an ecosystem. Erosion can dictate how fast an ecosystem recovers after a fire, especially in slope areas where its effects are often more noticeable. Wildfires lead to increases in runoff and erosion rates, especially on one of the main forest types present in the study area of the present study -mono-specific plantations of eucalypt (Leighton-Boyce *et al.*, 2007; Ferreira *et al.*, 2008; Martins *et a*l., 2013; Prats *et al.*, 2015). Important nutrients contained in the plant biomass and in the litter and soil organic layers are more prone to be lost, impoverishing the soil, especially after rainfall events (Machado *et al.*, 2015), which can delay or inhibit the functional role of soil microorganisms (Hart *et al.*, 2005), reducing the extent of the ecosystem recovery. Moreover, the absence of management measures after a fire can constrain the richness and abundance of the ground-dwelling arthropod communities, which can be negatively affected by the indirect effects of fire, especially if litter mass reduction occurs (Certini, 2005). As reported by Collet *et al.*, (1993), soil moisture and nutrient availability seems to be important variables on *Eucalyptus* forests after a fire since it helps to the establishment of important invertebrate groups.

In order to prevent the accumulated negative post-fire effects, eucalypt bark mulch was added to the study area following the fire. It is know that the use of mulch decreases the effects of erosion over time, being especially helpful preventing soil erosion after the fire. The use of mulch increases the availability of organic matter and in this particular case (eucalypt bark mulch) its effects remain after a medium-to-long term, since it still could be found in the study area, almost 5 years after the fire. In fact, the results of the present study showed that the increment of available organic matter was approximately 10% higher on the mulched plots when compared with the untreated plots. Considering the position along the slope, it would be expected to find a higher percentage of organic matter on the bottom of the slope, especially on the mulched plots, due to particulate transport, despite the mitigated effect of the mulch layer. However there were almost no differences between the obtained values along the slope for both mulched and untreated plots, showing that the percentage of available organic matter at the topsoil surface were not dependent on the position along the slope.

Likewise, when comparing ground cover between treatments and positions along the slope, no differences were observed between them. In fact, 5 years after the fire occurrence most of the soil surface has been covered by litter, not because of a great increment of natural vegetation, but due to the re-sprout of the *Eucalyptus* trees after the fire, being the litter formed mostly by *Eucalyptus* leafs and bark. It is known that planted forests have a lower diversity of vegetal species when compared with natural habitats (Bremer & Farley, 2010). Normally these artificial planted forests provide refuge to common and resilient species, creating a simple ecosystem. It is also known that allelopathic substances can be found in some organic mulches, such as the *Eucalyptus* mulch, which can inhibit seed germination and growth of plants through the release of chemicals, especially dicot weed species and newly planted or shallowly rooted plants (Chalker-Scott, 2007). The small percentage of understory in the study area was mainly composed by few species of ferns and bushes, which can be related to negative effects of mulching at some extent, but mainly to the land management before the wildfire. According to Prats *et al.* (2015), the eucalypt plantation in the study area had been used for almost 30 years for paper pulp production, being harvested every 7 – 14 years. This type of management normally impoverishes the biodiversity of an area over time, which seems to have happened in this case. According to the obtained data, except for bare soil, 5 years after the fire the use of mulch does not seem to have a great influence on the ground cover when compared to the untreated SF's. The percentage of bare soil in the mulched SF's was lower than the untreated SF's, and despite the statistical significance (p =0.04) observed between treatments, it may be due to natural differences between each plot, associated to a bigger or smaller presence of stones. The use of mulch might be important during the early period after the fire, for the already stated reasons, but it seems that most of the recovery of a similar pre-fire ecosystem might be due to the resilience of the *Eucalyptus* to fire and to the management measures practiced in the area (Maia *et al*., 2014).

In general, ground-dwelling arthropods communities in the study area showed high homogeneity in terms of abundance, richness and diversity regarding mulched and untreated plots and the position along the slope. These findings are in line with other studies where the effect of mulch on ground-dwelling arthropod communities was tested. Addison *et al*. (2013) found that insect abundance was similar in control and mulched sites and Gill *et al*. (2011) found almost no differences on the abundance of most orders between woody mulch and control sites. In both studies, the most abundant orders were also Hymenoptera and Collembola (Gill *et al*., 2011; Addison *et al*., 2013), while Coleoptera and Araneae were the more diverse. A similar pattern was found in this study, with the same orders responding similarly. It is well documented that after a fire, abundance and especially diversity of Coleoptera and Araneae tend to increase (Buddle *et* al., 2006; Campbell *et al*., 2007; García-Domínguez *et al*., 2010; Elia *et al*., 2012). When comparing evenness, the results also showed a very similar community in both treatments and along the slope, where the dominant orders in the study area were Hymenoptera, especially ants (Myrmicinae and Formicinae) and Collembola (Entomobryidae). Despite the scarcity of scientific literature on the effects of mulching after a fire, Addison *et al.* (2013) refers that the use of mulching for other applications than post-fire mitigation, showed that some groups of invertebrates have the potential of being bio indicators (Hymenoptera, Collembola and Coleoptera) due to their abundance and also to their response to alterations in the habitat and soil quality and to land use.

Ants are normally resilient to fire, because typically only 2% of the population of a mature ant colony is active on the surface, so when fire breaks out, the majority of the colony survives (Matsuda *et al*., 2011). This makes ants prone to rapidly re-establish in a previous burnt-area, especially in an ant diversity propitious ecosystem such as *Eucalyptus* plantations (Zina *et al*., 2015), which may be one of the key factors for the relatively high abundance of ants. Other possibility for the recorded abundance of ants can be related to the proximity of colonies to the pitfalls, that can increase the number of captured individuals, although it is unlikely that this situation has occurred since in a similar study in the same geographical region the abundance of ants recorded was also high (Camarinha, 2012).

Collembola are typically very abundant on the soil surface, feeding mostly on fungus and decaying plants (Neher *et al*., 2012), being also high quality prey for spiders and ground beetles (Wise *et al*., 1999). These feeding habits of Collembola are favoured following a fire, when the availability of decaying plant matter increases, which can be amplified as a result of the eucalypt mulch application. However, the present results showed no statistical differences between the untreated SFs and the mulched SFs. In fact, since all treatments are located within a eucalypt stand, the production of litter by the *Eucalyptus* trees in the form of leafs and bark contributes to a high homogeneity between plots. This finding explains the higher percentage of litter in the study area compared to other cover classes and its similarity between treatments and position in the slope. . Notwithstanding a difference on the percentage of organic matter in the mulched SF's when compared to the untreated SF's, it was not enough to significantly separate treatments nor having any relation with the collembolans.

Coleoptera is an extremely diverse arthropod order, occurring in a high diversity of habitats and ecological niches (Harde & Severa, 1984). Hence, Coleoptera diversity by itself could explain the statistical significant relation observed between this order and the position along the slope. In fact, despite the similarity between treatments and a fairly degree of uniformity of ground cover, along a 40 m slope there still are a lot of niches that can be occupied by a high number of morphospecies of Coleoptera, increasing their diversity in the study area. By relating Coleoptera diversity with the ecological function of each identified family (Appendix 1), the previous assumption is clearly supported, showing the highest variety of established ecological functions within all the orders identified in this study. Also, the high abundance of Collembola can be a major factor for the abundance of Staphylinidae, a soil invertebrate predator family of Coleoptera (Harde & Severa, 1984), as collembolans are important prey for ground beetles (Wise *et al*., 1999).

Another highly diverse and abundant group found was the order Araneae. Spiders are predators and each family is normally associated with a particular feeding strategy and related to a particular type of prey and/or a specific habitat (Roberts, 1994). In the present study, almost every identified spider family was ground or ant hunters, being each one characterized by distinct hunting strategies. Considering the abundance of prey, especially ants and collembolans, this explains the establishment of a high number of ground-hunting spiders, thus contributing to a relevant diversity in the study area, regardless of any relation with treatment or position along the slope.

After a wildfire, the surviving and quickly immigrating species are the ones that have the greatest advantage in early stages of the succession (Moretti *et al*., 2006), and this can be related to their habits (e.g. burrowing, flying, diet, opportunist behaviour) but also with their existence in the surrounding long-unburnt areas and ability to colonize burnt areas. The orders with higher abundance within the study area have at least some of these characteristics, which can explain their overall higher contribution to the ground-dwelling arthropod community of the study area.

As regards the results obtained for the ecological function it appears that the ground-dwelling arthropod community in the study area has already reached a certain degree of stability. This assumption is corroborated by Camarinha (2012) that showed identical results regarding soil invertebrate communities in burnt and unburnt eucalypt plantations surveyed 5 years after the fire in Portugal. This author also found Hymenoptera, Collembola, Hymenoptera and Araneae as the more The results obtained for the ecological function and the contribution of each family for each designated function (Appendix 1) are very similar regardless of treatment or position along the slope. Moreover, the results also indicate that the community lacks of plant related families, which can be an expression of low percentage of understory vegetation, or as already abovementioned, a problem utterly associated with the reported lower biodiversity in *Eucalyptus* plantations (Bremer & Farley, 2010) with the management practices or with the fire history (Oliver *et al*., 2000). While being just an hypothesis, the results suggest that litter seems to be the main driver for the establishment of the ground-dwelling arthropod community, showing a high abundance of microbial feeders and omnivores that find resources in the organic matter formed by the litter, and a diverse predatory group specialized in preying mostly ants and ground arthropods. The same is valid even for unburnt *Eucalyptus* plantations (Camarinha, 2012).

According to Moreira *et al*. (2010), edaphic communities take up to 5 years to recover after a fire, despite a larger period of time could be required for a more well-established community (Buddle *et* al., 2006). Hence, and based on our findings, it seems reasonable to assume that 5 years since the wildfire the effects of the treatment on the ground-dwelling arthropod community are vestigial. However, despite this evidence, it seems plausible that mulching can have an important role for the ground-dwelling arthropod community during the short-medium term after the fire, but as the community recovers, its relevance most likely dilutes with time.

## 5. Conclusion

The present study showed that 5 years after the fire, a homogenous ground-dwelling arthropod community, dominated by Hymenoptera and Collembola, is present in both tested treatments (untreated and mulched SFs) and positions along the slope (bottom, middle and top). It also suggests that 5 years after the fire, chopped eucalypt bark mulch and position along the slope, seem to affect only a few orders belonging to the ground-dwelling arthropod community, despite the possibility of a more important role and/or influence on a higher range of arthropod groups during the early period after the fire. Finally, the present results suggest that the historicity and typology of management of the *Eucalyptus* plantations in the study area seem to be the major determinant factors for the diversity, abundance and ecological role of the ground-dwelling arthropod community.

## 6. Final considerations

The present study raised several questions that should be included in future research for a better understanding of the effects of position along the slope but especially about the effects of mulching on ground-dwelling arthropods communities on *Eucalyptus* plantations.

The necessity of focusing on similar studies immediately after a fire on these habitats seems essential to find more comprehensive ways to verify if mulching has any effect on the early stages of ecological succession. Also it seems fundamental that comparisons between untreated and mulched plots and long unburnt areas should be assessed, so that potential differences between communities should be correctly assigned to the effects of fire and/or the effects of mulching in a more clarifying way.

Further research on the effects of mulching in the ground-dwelling arthropod community should focus on some groups of invertebrates that have the potential of being bio indicators, because tendencies and responses to the use of mulch (Addison *et al*., 2013), namely Hymenoptera and Collembola, similar to the results presented in this study. One main advantage is the high abundance and normally lower diversity within these orders that can facilitate the range of the study in terms of lab work identification to genus or species. However, depending on further research, it might be needed to include other groups of invertebrates that may be utterly affected by the use of mulch.

Moreover, it is worth mentioning that some of the existing literature on this particular subject refers that the use of mulch can stimulate the appearance and/or posterior dominance of invasive species of invertebrates in the after fire community. Hence, this issue should not be neglected due to the fact that while mulch is used to mitigate the effects of post-fire erosion it can induce negative effects into the environment.

As a final consideration, it seems important to test the importance of a higher range of environmental variables that literature (Certini, 2005; Jhariya & Raj, 2014) knows or suspects to be of influence to the ground-dwelling arthropod communities before and after a fire (e.g. such as soil texture, bulk density, pH, porosity, nutrient availability, base saturation, quality of organic matter).

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# 9. Appendix

**Appendix 1.** Total abundance and ecological function of each identified family for each position along the SF's (Ecological function according to: 1 - Gill *et al*, 2011; 2 - Czechowski *et al.*, 2002; 3 - Neher & Barbercheck, 1998; 4 - Roberts, 1995; 5 - Bellman, 1994; 6 - Goulet & Huber, 1993; 7 - Barrientos, 1988; 8 - Hard & Severa, 1984).

| Order | Family | Ecological function | U-SF1 | | | M-SF2 | | | U-SF3 | | | M-SF4 | | | M-SF5 | | | U-SF6 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Bottom | Middle | Top | Bottom | Middle | Top | Bottom | Middle | Top | Bottom | Middle | Top | Bottom | Middle | Top | Bottom | Middle | Top |
| Collembola | Entomobryidae | Microbial Feeders $^{3,7}$ | 14 | 1 | 2 | 11 | 11 | 9 | 3 | 26 | 13 | 1 | 1 | 0 | 14 | 11 | 6 | 3 | 13 | 2 |
| Collembola | Sminthurinae | Microbial Feeders $^{1,3,7}$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Collembola | Neelidae | Microbial Feeders $^{3,7}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Collembola | Isotomidae | Microbial Feeders $^{1,3,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hemiptera | Piesmatidae | Plant Feeders $^{7}$ | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| Hemiptera | Aphidoidea | Plant Feeders $^{1,7}$ | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hemiptera | Psyllinea (subOrder) | Plant Feeders $^{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| Thysanura | Machilidae | Omnivores $^{7}$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| Dictioptera | Blattidae | Omnivores $^{7}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Isopoda | Eubelidae | Omnivores $^{5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Isopoda | Oniscoidea | Omnivores $^{5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Coleoptera | Staphylinidae | Predators $^{1,7,8}$ | 3 | 2 | 1 | 9 | 4 | 3 | 0 | 1 | 3 | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 7 | 2 |
| Coleoptera | Scarabidae | Omnivores $^{7,8}$ | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Histeridae | Predators $^{7,8}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 |
| Coleoptera | Pselaphidae | Predators $^{7,8}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Scolitidae | Plant Feeders $^{7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| Coleoptera | Silphidae | Omnivores $^{7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Elateridae | Plant Feeders $^{1,7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Coleoptera | Cusculionidae | Plant Feeders $^{7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Tenebrionidae | Omnivores $^{7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 4 | 1 | 0 | 0 | 0 | 0 | 0 |
| Coleoptera | Anthribidae | Microbial Feeders $^{7,8}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Hymenoptera | Myrmicinae | Omnivores $^{2,6,7}$ | 8 | 11 | 14 | 8 | 6 | 4 | 23 | 8 | 25 | 10 | 10 | 4 | 7 | 4 | 12 | 15 | 7 | 3 |
| Hymenoptera | Formicinea | Omnivores $^{2,6,7}$ | 0 | 0 | 1 | 0 | 4 | 10 | 1 | 2 | 3 | 0 | 1 | 3 | 0 | 1 | 7 | 3 | 1 | 10 |
| Hymenoptera | Ponerinae | Omnivores $^{2,6,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Hymenoptera | Vespoidea | Predators $^{2,6,7}$ | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 2 |
| Chilopoda | Scutigeromorpha (Order) | Predators $^{5,7}$ | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Thysanoptera | Thropidae | Omnivores $^{7}$ | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 2 | 1 |
| Pseudoscorpionida | Neobisiidae | Predators $^{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 2 | 0 |
| Pseudoscorpionida | Syarinidae | Predators $^{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 |
| Psocoptera | Psocomorpha (subOrder) | Plant Feeders $^{7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Gnaphosidae | Predators $^{4,5,7}$ | 1 | 0 | 0 | 0 | 3 | 1 | 2 | 3 | 2 | 0 | 0 | 0 | 2 | 2 | 1 | 1 | 2 | 0 |
| Araneae | Zodariidae | Predators $^{4,5,7}$ | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Theridiidae | Predators $^{4,5,7}$ | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Dysderidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Lycosidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| Araneae | Agelenidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| Araneae | Oonopidae | Predators $^{4,5,7}$ | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Araneidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Araneae | Linyphiidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 |
| Araneae | Salticidae | Predators $^{4,5,7}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Opiliones | Phalangiidae | Predators $^{5,7}$ | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |