



ANT COMMUNITY RESPONSE TO A SUCCESSIONAL GRADIENT

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INTRODUCTION

Several pristine areas, most of them tropical forests, have been disturbed and changed by human activities. After a time of use or disturbance, in these areas, a natural forest restoration process begins resulting in secondary forest formations. Together with the process of vegetation restoration, the return of animal species may also occur. Thus, secondary forests at different restoration time may represent a successional gradient of animal community (Dunn, 2004).

Among animals, the ants are highly abundant, diverse and have a wide geographic distribution, although together with termites represent only 2% of the global insects species, they comprise more than half of the total insect biomass (Wilson & Hölldobler, 2005). Thus, many studies have used ants as models in ecological studies.

Ants have been suggested to assess the response of animal biodiversity to forest restoration after different disturbances. Overall, the response of ant communities was evaluated by the variation of diversity measures such as species richness, species composition, species abundance and diversity indexes among habitats at different successional or restoration time (Underwood & Fisher, 2006).

However, among the studies about the response of ant communities to successional time, it seems difficult to determine a clear pattern of the diversity measures (Underwood & Fisher, 2006). The variable response of ants to restoration could be related to the ant microhabitat sampled (Bihn 2008). Nevertheless, few studies try to explain the response of diversity measures to forest restoration, linking the patterns of ant communities with the variations of environmental factors inherent to the forest restoration process, which could improve an intricate understanding of the response of ant communities to the ecological process studied.

OBJECTIVES

We aimed to verify the response of ant communities to succession time in an intricate way by a vertical ant sampling design and explanatory hypotheses that intend to understand the ecological mechanisms involved in the response of these insect communities to vegetation restoration. Then, two assumptions related to different diversity measures were verified: (i) the response of ant species richness overall and in each particular microhabitat increase along a successional gradient; and (ii) the response of ant equitability overall and in each particular microhabitat increase along a successional gradient. We tested the following hypotheses to explain the possible changes on the diversity measures in each microhabitat: (a) in a successional gradient there is an increase in resources and modifications of conditions that support the changes in ant diversity measures; (b) in a successional gradient there is an increase of the structural and resource heterogeneity that represent a complementary way to support the changes in ant diversity measures.

MATERIAL AND METHODS

Study area

We carried out the study in Viçosa, Minas Gerais state in the south - eastern Brazil. The forests of the region are described as semideciduous seasonal rainforest, a forest formation of Atlantic Rain Forest biome.

The pristine forest covered a great extension of Viçosa region, but the agricultural and pastures development, and urbanization process fragmented the vegetation, resulting in a landscape with crop areas, pasture, forestry and native forest remnants, particularly restricted to hilltops. From the 1960s onwards the agriculture declined in the region and several forest areas restored into secondary forests (Sevilha *et al.*, 001).

Sampling ants

We sampled ants at eight habitats at different restoration time, a pasture in use (0 year) and seven forest remnants ranging from 7 to 120 restoration - years representing a successional gradient. In each habitat, we sampled ants at three microhabitats (arboreal, epigaeic and hypogaeic) using baited (sardine and honey) pitfall traps.

The epigaeic pitfall traps were placed in the soil surface in the way that the opening of plastic recipient was at the level of soil surface. The arboreal pitfall traps were tied at ca 1.3 m high to the trunks of trees. The hypogaeic pitfall traps were placed at 20 cm depth in the soil and had some adaptations: (i) the plastic recipient were closed with a lid, to avoid being filled with soil; (ii) to allow the ants to access the trap four radial holes (1 cm diameter) were made in the plastic recipient; (iii) a string with a colored ribbon was tied to find where the hypogaeic pitfall was buried.

In each habitat, we set the pitfall traps in ten sampling units along a 100 m transect, with a distance between the sampling units of 10 m. Each sampling units had three pitfall traps, one per microhabitat, except in pasture habitat that did not have trees to tie the arboreal pitfall traps. Then in pasture habitat we set 20 pitfall traps, in the total, and in each forest habitats, 30 pitfall traps. The pitfall traps remained in the field for 48 hours. Moreover, e sorted and identified the collected ant specimen at species and morpho - species levels.

Sampling explanatory variables

In each sampling unit we collected data that were used as surrogates of resources and conditions of the three ant microhabitats. The collected data were specific for each microhabitat and are explained in the following topics.

Arboreal variables

Surrogate of resources: The number of trees with trunk circumference equal or higher than 15 cm at 1.3 m high in a rectangle (area = 10 m²) around each sampling unit. *Surrogate of conditions:* The percentage of vegetation cover present in a digital picture took at 1.3 m high next the tree where the arboreal pitfall was tied. The percentage of vegetation cover was analyzed with Gap Light Analyzer software (GLA).

Epigaeic variables

Surrogate of resources: The litter depth measured right beside the pitfall, using a digital caliper. *Surrogate of conditions:* The percentage of vegetation cover present in a digital picture took at the soil surface level and beside the site where the epigaeic pitfall was set.

Hypogaeic variables

Surrogate of resources: The percentage of organic matter present in a soil sample collected beside the site where the hypogaeic pitfall was set. *Surrogate of conditions:* The soil density present in a soil sample collected by the methodology of undisturbed samples with metal core of known volume (116.60 cm³).

Statistical analyses

The overall analysis of diversity measures were done to verify if a general pattern could be accessed with ants from all microhabitats. Independent to match this general pattern, ant communities of each microhabitat could present a

particular response pattern of diversity measures which requires explanatory hypothesis that reflect the single causal relationships of each microhabitat.

Thus, species richness was analyzed in the following ways: (a) overall species richness, the accumulated number of species sampled in all microhabitats; (b) species richness in each microhabitat, the accumulated number of species sampled in each particular microhabitat (arboreal, epigaeic and hypogaeic). The equitability was computed by the Shannon - Wiener Index of Equitability EH, with $EH = H'/H'max$ where $H' = - \sum (\pi_i) / \log \pi_i$ and $H'max = \log S$. The frequency of species i in a sample is π_i . The overall and in each microhabitat equitability was analyzed in the same way of species richness.

Analyses of the assumptions

To test the assumption (i) that the response of ant species richness, overall and at the three microhabitats (arboreal, epigaeic and hypogaeic) to a successional gradient is different, we carried out statistical models in which ant species richness was the response variable, and restoration time, was the explanatory variables. We also included in the models the area of the fragment as co - explanatory variable, because this factor has a strong and positive influence on ant species richness. The models were analyzed by analysis of co - variance with Poisson error distribution.

The test of assumption (ii) that the response of ant equitability (overall and in each particular microhabitat) is different from each other in a successional gradient we carried out a statistical models in the same way of assumption (i), using equitability as the response variable. The models were analyzed by simple linear regression.

Hypotheses analyses

To accept the hypotheses that resource and conditions influenced ant communities along a restoration gradient, the ants must respond to the surrogates of resources and conditions and these must respond to restoration time. These two analyses were carried out separately. The variables sampled (surrogates of resources and conditions) in each microhabitat were used both as averages within each sampled area, as well their coefficient of variations (CV), which indicate the heterogeneity of resources and conditions.

The relationships between the sampled variables, both averages and CVs, with restoration time were analyzed using simple linear regression, using normal errors, when the response variable was averages and Binomial errors, when CVs the response variable. The relationship between diversity measures (species richness and equitability) and surrogates of resources and conditions were analyzed through multiple linear regressions. The models had species richness and equitability as response variables and surrogates of resources and conditions as explanatory variables and the interactions between the variables were included in the models. The models were carried out separately in each microhabitat and analyzed with Poisson errors, when species richness was the response variable and with normal errors, when equitability was the response variable.

RESULTS AND DISCUSSION

We did not find a significant relationship between overall ant species richness and restoration time ($x_2 = 10.92$; $p = 0.34$) and in any of the species richness of particular microhabitats (arboreal, $x_2 = 18.72$; $p = 0.77$, epigaeic, $x_2 = 7.99$; $p = 0.57$, hypogaecic, $x_2 = 4.44$; $p = 0.41$). Moreover, the hypogaecic ant equitability was the only to have a significant and positive relationship with restoration time ($F_{1,5} = 35.37$; $p = 0.001$).

Among the surrogates of resources and conditions, only three had a significant increase along the successional gradient: average tree density ($F_{1,6} = 12.74$; $p = 0.01$; $r_2 = 0.67$), CV of tree density ($F_{1,6} = 7.77$; $p = 0.03$; $r_2 = 0.56$) and CV of soil density ($F_{1,6} = 9.05$; $p = 0.02$; $r_2 = 0.60$). The epigaeic and hypogaecic ant species richness did not have any significant relationship with the surrogates of resources and conditions of these microhabitats. Arboreal ant species richness had a significant relationship with heterogeneity of resources and conditions (CV of tree density and CV of vegetation cover respectively), and with the interaction between them ($x_2 = 4.24$; $gl = 4$; $p = 0.03$). Moreover, hypogaecic ant equitability had a positive significant relationship with average organic matter ($F_{1,6} = 9.07$; $p = 0.02$).

The non - significant relationship between ant species richness and restoration time in overall and in any of the microhabitats, confirmed the findings of several authors (e.g. Ottonetti *et al.*, 2006). Nevertheless, the surrogates of resources and conditions, with the exception of tree average density and CV of vegetation cover (both from arboreal microhabitat), also did not have a significant change along the habitats at different restoration time. Then, if the described relationship between ant species richness and environmental factors holds true (Ribas *et al.*, 2003) we could expect that if most of the surrogates of resources and conditions did not change with restoration time, the ant species richness consequently would not change along the successional gradient.

Another plausible hypothesis for the non - significant relationship between species richness and restoration time in our study is that in Viçosa region there is a great amount of forest remnants (Sevilha *et al.*, 2001) that host high ant species richness (Ribas *et al.*, 2005) and may represent a source of re - colonization to areas in initial stages of succession. Due to the short distances among the forest remnants, the ant species re - colonization process may be rapid in disturbed areas and differences on ant species richness among forests remnants at different restoration times could be realized immediately after the disturbance event and would be more noticeable in small spatial and temporal scales (Campos *et al.*, 2007).

The significant relationship between arboreal ant species richness with heterogeneity of resources and conditions (CV of tree density and CV of vegetation cover) and with the interaction between them could improve the understanding about useful estimates of heterogeneity of resources and conditions related with the structure of arboreal ant communities reported in recently studies (Ribas *et al.*, 2003 a and Ribas and Schoederer 2007). These authors have reported the effect of heterogeneity of tree density, and our

study increased these findings by adding the effect of heterogeneity in vegetation cover.

The fact that just hypogaecic ant equitability responded to the successional gradient means that ants with hypogaecic life style could be more sensitive to perturbation events and require a longer restoration time than ants with others life styles (epigaeic and arboreal). Despite that, hypogaecic ant species richness did not change along the successional gradient, but equitability significantly increased. This could mean that a species turnover happened along the gradient that keep the species number constant, but ant species frequency of each community at different restoration time were not the same along this gradient. This hypothesis is confirmed with the observed frequency of occurrence of *Linepithema aztecoides* Wild 2007, which had high occurrence at the beginning of the gradient and decreased from the middle to the end, where all species share almost the same values of frequency. *L. aztecoides* is described as a species that lives in open environments, which is the situation of the two initial levels of our successional gradient, a pasture without trees and a forest in restoration process at seven years age. Thus, it is possible to affirm that along the successional gradient hypogaecic resources and conditions could be improved or changed allowing a more uniform ant species frequency. However, any surrogates of resources and conditions had significant relationships with restoration time. Then, the positive significant relationship between hypogaecic equitability and average organic matter does not represent a causal explanation to the pattern of hypogaecic equitability along the successional gradient. Nevertheless, the relationship between hypogaecic ant equitability and organic matter may be an independent pattern that requires its own hypothesis to report the ecological mechanisms behind it.

CONCLUSION

Our data are relevant to the study of the response of ant communities to successional gradient, because the use of different diversity measures allows the understanding of the distinct ecological processes involved on the structure of communities along the gradient. Moreover, our findings point that the response of ant communities to restoration time could not occur at the local scale, but factors that act at the landscape and regional scales could affect this ecological processes, although the evidence of this influence could be dependent on ant microhabitats sampled and measures of diversity.

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