ANTS (HYMENOPTERA: FORMICIDAE) AS BIOINDICATORS OF LAND RESTORATION IN A BRAZILIAN ATLANTIC FOREST FRAGMENT

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INTRODUCTION

1 - Introduction

Over half a century of exploitation, the Atlantic forest went through a process of environmental degradation that resulted from severe anthropic impacts. It has experienced a reduction of up to 90% in its natural area, followed by an incredible drop of species diversity (21). Currently, the Atlantic Forest is considered a hotspot, a priority area for conservation, due to its high degree of endemism and to the severity of its environmental impacts, still in acceleration (17).

Contrary to this trail of destruction, there have been several projects aiming at the recovery of the Atlantic Forest. These efforts are directed, basically, upon two work fronts: environmental awareness and reforestation (20, 11). The latter consists of replanting native species in degraded areas in order to recompose the original diversity of the Atlantic Forest. Those efforts are presently well - known, having achieved significant success in several ecosystems (29). However, there is a great need for monitoring the diversity of species throughout the regeneration process. In face of the impossibility of evaluating all the ecosystem, specific taxa have been used, known as bioindicators (4).

Ants, in comparative terms, are especially appropriate bioindicators since they present high abundance of individuals and high global and local species richness; besides presenting specialized niches, wide geographic distribution and being easily sampled and sorted bymorph - species, they are also sensitive to environmental changes (14, 25). Several local - scale studies of ant communities have shown to be valuable tools for evaluating the environmental conditions of forests, savannas and post - fire areas, as well as patterns of land use (15, 6, 27, 10). Moreover, (25) suggest that ant species richness is potentially useful to assess the biodiversity of invertebrates as a whole. Accordingly, ground ant communities are the best bioindicators for plants and butterflies in forests of Venezuela (19, see also 1).In this study we provide data from the ant fauna in the restored Atlantic forest.

OBJECTIVES

The main goal of our study was to test the hypothesis that the ant fauna is closely related the structural complexity of the habit. Thus, we expect great ant species richness in the older, more structurally complex fragments.

MATERIAL AND METHODS

2 - Material and Methods

2.1-Sampling and processing of the collected material

This study was carried out between May 12th and May 15th, 2004 in the Bulcão Farm, coordinates 41^{0}04'20.3"W, 19^{0}30'08.1"S", located in the province of Aimorés, in the Vale do Rio Doce region, Minas Gerais state.

Eighteen sites, from three different successional stages, were sampled : I) four of early stage (3 - 5 years), represented by abandoned pastures with *Brachiaria sp.* (Poaceae) and sparse trees; II) seven of intermediate stage (10 - 15 years), with dense brushwood; III) seven of intermediate stage (10 - 15 years) under *Myracrodruon urundeuva* Allen (Anacardiaceae) dominance. In each site, a 100 - meter long transect was randomly positioned, along which 20 Sardine baits - ten on the soil and ten on the vegetation (around 1m above ground) - were simultaneously placed every 10 meters (see 22). All the ants around the baits were manually collected after one hour. The sampling was carried out

during the daytime from 8am to 5pm. The "sardine bait" method is frequently used for sampling both soil and vegetation ants, as it is cheap, simple and expedient. However, due to the method's selectivity to certain ant species, the species richness is underestimated (3).
For instance, some canopy ants and other restricted - habit species, were not sampled. All the sampled ants were packed in a 2 liters plastic bag, taken to the lab for triage, fixed in 70% alcohol and sorted into morph - species. The ants were identified in the Myrmecology Laboratory at the Research Center of Cacau. Since the data did not present normality, the richness differences between successional stages were tested using the Kruskal - Wallis test, whereas the T - Test paired was used to compare ground and above - ground species richness (30).

RESULTS AND DISCUSSION

3-Results and Discussion
Thirty - three ant species were sampled over the three different succession stages in Bulcão Farm, with 21, 30 and 23 species found, respectively, in the early, intermediate and intermediate under *M. urundeuva* dominance stages. Some species occurred only in a single succession stage: *Atta sexdens rubropilosa* Forel, *Camponotus melanoticus* Emery and *Wasmannia rochai* Forel only occurred in the early stage; *Brachymyrmex sp.1, Brachymyrmex sp.2, Crematogaster erecta* Mayr, *Pheidole diligens* Smith, *Pseudomyrmex oculatus* Fr. Smith, *Pseudomyrmex schuppi* Forel, and *Wasmannia auropunctata* Roger only in the intermediate stage; and, *Cardiocondyla obscurior* Wheeler, *Pogonomyrmex naegelii* Forel and *Pseudomyrmex gracilis* Fabricius occurred exclusively in the intermediate stage under *M. urundeuva* dominance. Sixteen species occurred simultaneously in all the succession stages. Four subfamilies were registered in the three succession stages: the Myrmicinae prevailed, representing 48% of the sampled species, whereas Fomicinae (30%), Pseudomyrmecinae (15%) and Ectatomminae (6%) occurred in a lower frequency. There were no significant differences in species richness between the succession stages (Kruskal - Wallis H = 2.39; p = 0.30). The ground richness of ant species was 1.6 times higher than the above - ground (T - Test = 2,16, p = 0,04).
The overall ant species richness estimated for Bulcão Farm was considered low compared to the diversity parameters of the Atlantic Forest, which holds one of the most diverse ant populations in the world (5, 7, 9, 13, 24). Other studies carried out in tropical and subtropical areas observed ant communities of 300 - 500 species (25). Even in studies of disturbed or under - rehabilitation areas, using similar methodologies, the ant species richness found was higher than the one found in the present study. In Eucalyptus plantation and in a secondary Atlantic Forest, (26) observed a total of 64 species of ants. In rehabilitation areas of Amazonian Forest, (23) found a total of 85 ant species.
The main factors behind ant diversity are the variety of nest sites, the amount of available food, foraging area and interspecific competition (2, 18, 25). The specialization to nidification sites plays a key role in ant species diversity. In the tropics, dead trunks and fallen branches on the ground are very suitable nesting sites, allowing the ant fauna to diverge and specialize to the different substrates. Contrarily, in temperate regions, the ground is the only safe place for most colonies to stand over the winter, excepting a few species that build their nests in living trees. Such diversity patterns can be extrapolated to the present study. In this hypothesis, deforesting action reduces the number of niches, through the destruction of nidification sites, such as trunks, and by reducing food resources, like extra - floral nectaries and associations with Hemipterans.
The difference in ant richness between the different succession stages was not statistically significant. We believe that the higher environmental heterogeneity of the intermediate succession stages was not sufficient to cause differences in the ant species richness. However, a study of similar focus in the same area, but using insect galls as bioindicators (see 16), did find significant differences in gall species richness between the three succession stages. (16) verified that in the intermediate stage under *Myracrodruon urundeuva* dominance, the richness of galling insects was lower than in the intermediate stage. The authors even argue that the alelochemical effects of *Myracrodruon urundeuva* probably impeded the establishment of other plants, reducing the complexity and creating a negative impact on the associated herbivores. In this study, as we have not found significant differences in the ant species richness between the areas, we refute (16) hypothesis. However, those methods of baiting and manual collecting might not have been sufficient to reveal the ant richness of the studied areas. Comparing 17 collecting methods, (8) concluded that a single method is unsatisfactory for sampling the ant richness of one region, which requires a combination of methods. Winkler extractor and pitfall traps are the most efficient methods and most indicated for the general collecting protocols.

CONCLUSION

4-Conclusion
Some studies suggest the use of different bioindicators for assessing and monitoring degraded or under restoration areas, since different taxa can lead to contradictory results (28). The richest areas can vary according to the analyzed (25). The fact that we found results contradicting those found by (16) for gall insects., in the same region, reinforces the need for using different taxa for assessing and monitoring purposes, since each one should reflect different ecological connectivities (12).

REFERENCES

5-References
1. Andersen, A. N. Insight using ants as bioindicators: multiscale issues in an ant community ecology. Conservation Ecology 1: 1, 1997.
2. Benson, W. W. & A. Y. Harada. Local diversity of tropical and temperate ant faunas (Hymenoptera, Formicidae). Acta Amazonica 18: 275 - 289, 1998.
3. Bestelmeyer, B. T. & J. A. Wiens. The effects of land use on the structure of ground foraging ant communities in the

Argentine Chaco. Ecological Applications 6: 1225 - 1240, 1996.

4. Brown, K. S.. Conservation of Neotropical environments: insects as indicators. In: Collins, N.M. & J.A. Thomas (Eds.) The conservation of insects and their habitats. New York, Academic, pp. 350 - 404, 1991.

5. Carvalho, K. S., A. L. B. Souza, M. S. Pereira, C. P. Sampaio & J. H. C. Delabie. Comunidade de formigas epígeas no ecótono Mata de Cipó, Domínio da Mata Atlântica, BA, Brasil. Acta Biologica Leopoldensia 26: 249 - 257, 2004.

6. Carvalho, K. S. & H. L. Vasconcelos. Forest fragmentation in Central Amazônia and its effects on litter - dwelling ants. Biological Conservation 91: 151 - 157, 1999.

7. Conceição, E. S., A. O. Costa Neto, F. P. Andrade, I. C. Nascimento, L. C. B. Martins, B. N. Brito, L. F. Mendes & J. H. C. Delabie. Assembléias de Formicidae da serapilheira como bioindicadores da conservação de remanescentes de Mata Atlântica no extremo sul do estado da Bahia. Sitientibus. Série Ciências Biológicas 6: 296 - 305, 2006.

8. Delabie, J. H. C. B. L. Fisher, J. D. Majer & I. W. Wright. Sampling effort and choice of methods. Pp.145 - 154 In: Agosti, D., J. D. Majer, L. E. Alonso & T. R. Schultz (eds.) Ants standard methods for measuring and monitoring biodiversity. Washington, Smithsonian Institution Press, 2000.

9. Delabie, J. H. C., B. Jahyny, I. C. Nascimento, C. S. F. Mariano, S. Lacau, S. Campiolo, S. Philpott & M. Leponce. Contribution of cocoa plantations to the conservation of native ants (Insecta: Hymenoptera: Formicidae) with a special emphasis on the Atlantic Forest fauna of southern Bahia, Brazil. Biodiversity and Conservation 16: 2359 - 2384, 2007.

10. Delabie, J.H.C.; V.R.L.M. Paim; I.C. Nascimento; S. Campiolo & C.S.F. Mariano. As formigas como indicadores biológicos do impacto humano em manguezais da costa sudeste da Bahia. Neotropical Entomology 35: 602 - 615, 2006.

11. Ferretti, A. R. & R. M. Britez. Ecological restoration, carbon sequestration and biodiversity conservation: The experience of the Society for Wildlife Research and Environmental Education (SPVS) in the Atlantic rain forest of southern Brazil. Journal for Nature Conservation 14: 249—259, 2006.

12. Lawton, J. H., D. E. Bignell, B. Bolton, G. F. Bloemers, P. Eggleton, P. M. Hammond, M. Honda, R. D. Holt, T. B. Larsen, N. A. Mawdsley, N. E. Stock, D. S. Srivastava & A. D. Watt. Biodiversity inventories, indicator taxa and effects of habitat modification in tropical forest. Nature 391: 72 - 76, 1998.

13. Macedo, L. P. M., E. Berti Filho & J. H. C. Delabie. Diversidade de formigas edáficas (Hymenoptera: Formicidae) associadas a *Euterpe edulis* von Martius (Arecaceae), em diferentes formações vegetais do bioma Mata Atlântica em São Paulo, Brasil. Revista de Agricultura 81: 55 - 70, 2006.

14. Majer, J. D.. Ants: bioindicators of mine site rehabilitation, land use and land conservation. Envinmental Management 7: 375:383, 1983.

15. Majer, J. D.. Ant recolonization of rehabilitated bauxite mines at Trombetas, Pará, Brazil. Journal of Tropical Ecology 12: 257 - 273, 1996.

16. Moreira, R. G., G. W. Fernandes, E. D. A. Almada & J. C. Santos. Galling insects as bioindicators of land restoration in an area of Brazilian Atlantic Forest. Lundiana 8: 107 - 112, 2007.

17. Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. A. B. Fonseca & J. Kent. Biodiversity hotspots for conservation priorities. Nature 403: 853 - 858, 2000.

18. Oliveira, M. A., T. M. C. Della Lucia, M. S. Araújo & A. P. Cruz. A fauna de formigas em povoamentos de eucalipto e mata nativa no estado do Amapá. Acta Amazonica 25: 117 - 126, 1995.

19. Osborn, F; W, Goitia, M. Cabrera & K. Jaffé. Ants, plants and butterflies as diversity indicators: Comparisons between at six forest sites in Venezuela. Studies of Neotropical Fauna and Environment 34: 59 - 64, 1999.

20. Padua, S. M. Conservation Awareness through an environmental - education program in the Atlantic Forest of Brazil. Environmental Conservation 21:145 - 151, 1994.

21. Ranta, P., T. Blom, J. Niemelä, E. Joensuu & M. Siitonen. The fragmented Atlantic rain forest of Brazil: size, shape and distribution of forest fragments. Biodiversity and Conservation 7: 385 - 403, 1998.

22. Romero, H. & K. Jaffé. A comparison of methods for sampling ants (Hymenoptera, Formicidae) in savannas. Biotropica 21: 348–325, 1989.

23. Santos, C. S., J. H. C. Delabie & G. W. Fernandes. A 15 - year post evaluation of the fire effects on ant community in an area of Amazonian forest. Revista Brasileira de Entomologia 52: 82 - 87, 2008.

24. Santos, M. S., J. N. C. Louzada, N. S. Dias, R. Z. Bonetti Filho, J. H. C. Delabie & I. C. Nascimento. Riqueza de formigas (Hymenoptera, Formicidae) da serapilheira em fragmentos de floresta semidecídua da Mata Atlântica na região do Alto do Rio Grande, MG, Brasil. Iheringia 96: 95 - 101, 2006.

25. Silva, R. R. & C. R. F. Brandão. Formigas (Hymenoptera: Formicidae) como indicadores da qualidade ambiental e da biodiversidade de outros invertebrados terrestres. Biotemas 12: 55 - 73, 1999.

26. Soares, S. M., C. G. S. Marinho & T. M. C. Della Lucia. Riqueza de espécies de formigas edáficas em plantação de eucalipto e em mata secundária nativa. Revista Brasileira de Zoologia 15: 889 - 898, 1998.

27. Vasconcelos, H. L., K. S. Carvalho & J. H. C. Delabie. Landscape modifications and ant communities. Pp. 199 - 206, 2001 In: Bierregaard Junior, R. O., C. Gascon, T. Lovejoy, E. (eds.). Lessons from Amazonia: the ecology and conservation of fragmented forest. New Haven, Yale University Press.

28. Weaver, J. C.. Indicator species and scale of observation. Conservation Biology 9: 939 - 942, 1995.

29. Young, T. P., D. A. Petersen & J. J. Clary. The ecology of restoration: historical links, emerging issues and unexplored realms. Ecology Letters 8: 662–673, 2005.

30. Zar J.H.. Biostatistical Analysis. 4th edn. Prentice - Hall, Englewood Cliffs, New Jersey, 929p, 1996.