Comunicata Scientiae 4(2): 186-194, 2013

Original Article

Assessment of ant communities in secondary forest in the eastern Amazon

Ana Yoshi Harada[1], Paulo Roberto Silva Farias[2], Letícia de Fátima Campos Lopes[2], Anderson Gonçalves da Silva[3*], Alessandra Daniele de Sousa Brandão[2]

[1]Research Coordination Zoology, Goeldi Museum, Belém, PA, Brazil
[2]Institute of Agricultural Sciences, Federal Rural University of Amazonia, Belém, PA, Brazil
[3]Federal Rural University of Amazonia, Belém, PA, Brazil
* Corresponding author, e-mail: agroanderson.silva@yahoo.com.br

Abstract

Ant communities were assessed in plots fertilized with nitrogen and phosphorus in an area of secondary forest in the Eastern Amazon. Collections were made from April to September 2004, using the mini-Winkler extractor method. A total of 4893 ant individuals were obtained distributed in three subfamilies, 22 genera and 82 species. The most frequent species were *Wasmannia auropunctata* (100%), *Pyramica* sp1 and *Solenopsis* sp1 (75%). The Shannon diversity index showed low values, the Jaccard index presented dissimilarity, the equitability index showed that the distribution of the abundance of individuals was not homogeneous and the species richness also presented low values. There was variation in the composition of the ant fauna in soils fertilized with N, N + P and P. The study corroborated other research in degraded areas, showing that the species composition is modified compared to more complex environments.

Keywords: ant, composition, secondary forest, nutrients

Avaliação das comunidades de formigas em floresta secundária na Amazônia Oriental

Resumo

Avaliaram-se comunidades de formigas, em parcelas fertilizadas com nitrogênio e fósforo em uma área de floresta secundária na Amazônia Oriental. As coletas ocorreram durante os meses de abril e setembro de 2004, utilizando-se o método de extrator de mini-Winkler. Foram obtidos 4893 indivíduos de formigas distribuídos em três subfamílias, 22 gêneros e 82 espécies. As espécies mais freqüentes foram *Wasmannia auropunctata* (100%), *Pyramica* sp1 e *Solenopsis* sp1 (75%). O índice de diversidade de Shannon apontou baixos valores, o índice de Jaccard apresentou dissimilaridade, no índice de Equitabilidade verificou-se que a distribuição da abundância dos indivíduos não foi homogênea e a Riqueza de Espécies também apresentou baixos valores. Houve variação na composição da fauna de formigas em solos fertilizados com N, N + P e P. O estudo corrobora com outras pesquisas em áreas degradadas, mostrando que a composição de espécies é modificada quando comparadas com ambientes mais complexos.

Palavra-chave: Formigas, composição, floresta secundária, nutrientes

Received: 07 August 2012
Accepted: 27 November 2012

Introduction

Tropical forests occupy about 7% of the land surface and are home to more than 50% of all known species on the planet (Ewers & Laurance, 2006). Of this amount, the Brazilian Amazon contains about 40% (Kirby et al., 2006). It is estimated that 62% of the deforested areas in the Eastern Amazon are destined for livestock undertakings, where about 25 million hectares of pasture have been implanted. Of this total, it is calculated that half is degraded or in the process of degradation (Wright et al., 1992; Dias-Filho, 2007). After use for livestock raising, pastures are abandoned and go through successive stages of secondary forest. In these locations the records show slow forest recovery, resulting in a smaller evotranspiration from the ecosystem, net loss of carbon into the atmosphere, greater fire frequency and possible loss of biological diversity (Vitousek, 1994).

Degraded forest recovery is hindered by the strong disturbance and breakdown of the efficient nutrient cycling mechanisms of the forest so that these elements are lost through burning, lixiviation and soil erosion. However, is little is known about nutrient cycling during the successional stages of forests degraded by pasture, which eliminates the certainty in predicting the special-temporal variations in carbon kidnapping, greenhouse gas production and the nutrient loss to river waters (Davidson et al., 2004).

In an endeavor to understand the nutrient cycling process during the successional stages of the tropical secondary forests, the role of the limitation exercised by nitrogen and phosphorus availability was assessed on the plant biomass accumulation and recovery of the biogeochemical cycles.

As tropical secondary forest maintenance depends on the action of several organisms, ants (Hymenoptera: Formicidae) were selected because of their importance in this process. The ant is a dominant animal in most of the earth ecosystems, and one of the largest groups of social insects, widely distributed geographically, and they are found from temperate regions to the equator, on all the oceanic islands and are more abundant in locations with tropical climate (Wilson, 1987). These insects are represented by 27 subfamilies, 365 genera and more than 12,000 species (Bolton 2003; Agosti & Johnson, 2009), and it is estimated that there are from 3000 to 8000 species for the neotropical region (Fowler et al., 1991).

Thus, studies on these communities are very relevant because they portray the transitory or permanent situation of the habitat assessed, emphasizing its conservation or degradation, frequently associated to the soil use by man (Spellerberg, 1993), impacts of forestry practices, success in ecological recovery, comparison of different management tools, impact of disturbances on conservation areas and assessment of the biological diversity (Oliveira & Brandão, 1991).

Considering the importance of the ant communities and their role in maintaining and recovering degraded areas, the objective of this study was to assess ant communities in plots fertilized with nitrogen and phosphorus in an area of secondary forest in the Eastern Amazon.

Material and Methods

Study area

The study was carried out on the Vitória Farm located at 6.5 km northwest of the city of Paragominas, Pará (02°59` S and 47°31` W), in the Eastern Amazon, Brazil. The plant cover is the wet tropical forest type with 50 to 118 m in height. The climate is hot and wet, with 1700 mm mean annual rainfall, characterized by a period with much rain, from January to May, and a period with little rain, from June to December.

The fertilization experiment was set up in a *Panicum maximum* (Jacq) 7.25 ha pasture. The area presented a rotational pasture regimen in 1984. At the start of the experiment there was some grass, herbs and bush cover and the vegetation was dominated by trees, that had an average of 2 cm DBH (Diameter Breast Height), with 11.4 cm maximum diameter and 7.5 m maximum height. The fertilization was applied in November 1999 (in the dry season), January 2000 (start of the wet season) and in February 2001.

Four treatments were carried out using 20 x 20m plots with three replications in each. The treatments used were: 1-without fertilization (control); 2-nitrogen (N): 100 kg/ha; 3-phosphorus (P) 50 kg/ha and 4-nitrogen+ phosphorus (N+ P), using the same rates.

The ants were collected in April (wet season) and September (dry season) in 2004 in the 12 plots. Twenty-five points were installed with 2 x 2 m spacing in the sample areas.

In the collection period, three points per plot were sampled, totaling 36 samples per collection. At each sample point a standardized 50 x 50 cm area of litter was removed using the mini-Winkler extractor (Bestelmeyer et al., 2000). The material remained in the mini-Winkler extractor for 48 hours so that the ants could migrate to a flask collector containing 70% alcohol.

The ants were identified using specific keys and compared with material deposited in the Invertibrate Collection at the Emílio Goeldi Paraense Museum (MPEG).

The relative frequency of occurrence was calculated individually for the species in each sampling per plot. Species were considered rare that had a relative frequency of less than 25%. The convergence or divergence between the composition and the sampled fauna among the plots was assessed by the Jaccard similarity index, defined by the following formula: S_j = a/ a+b+c, where S_j= Jaccard coefficient; a= number of species in the plot a; b= number of species in plot b; c= number of species common to both the plots.

The ant diversity was measured by the Shannon-Wiener index (Shannon & Weaver, 1949). This index is appropriate to test random samples of species of a community or sub community of interest, using the following equation

$$H' = -\sum p_i \, \text{Log} \, p_i \qquad (1)$$

Where: p_i is the proportion of the species in relation to the total number of specimens found in the surveys.

The Equitability index refers to the distribution of the individuals among the species, and is proportional to the diversity and inversely proportional to dominance. The Equitability or Equity measurement compares the Shannon-Weiner diversity with the distribution of the species observed that maximizes the diversity. This index is obtained by the equation: J = H'/H_{max}, where: H' is the Shannon-Wiener index and H_{max} is given by the following expression: H_{max} = Log s, where s is the number of species sampled. Two important points were considered before using this index: 1) all the samples were from the same environment and, 2) the sampling was sufficient to count samples of all the species.

Results and Discussion

A total of 4893 ant specimens were collected belonging to three subfamilies, 22 genera and 80 species. The most frequent species in the plots in April 2004 were *Wasmannia auropunctata* (Roger) (100%), *Pyramica* sp.1, *Solenopsis* sp.1 (75%), *Paratrechina* sp.7 (67%) and *Paratrechina* sp.6 (50%). The following species were most frequent in September 2004: *W. auropunctata* (100%), *Solenopsis* sp.1 (75%) and *Pyramica* sp.3 (58%), showing the high frequency of species from the Myrmicinae subfamily, a successful group ecologically, because they are extremely adaptable to the most varied ecological niches. These results corroborated the statements by Fowler et al. (1991), that the structural complexity of the habitats presumably provides a wide availability of food resources and nesting locations.

Wasmannia auropunctata was the species with greatest relative frequency (Table 1); this ant was observed nesting in the litter and in the surface soil layers. Delabie & Fowler (1995) reported that this species is highly competitive, opportunistic and invasive and spreads when the environment is subject to any stress or modification for agricultural or forestry purposes or other anthropic actions. Vasconcelos et al. (2000) also detected high frequency of this species (100%) when using the same plot dimensions (20 x 20 m) in abandoned pasture in the Brazilian Central Eastern Amazon.

This species occurred throughout the study area (Table 1), according to McGlynn (1999) and Wetterer & Porter (2003) it is present in almost all the tropical regions of the planet, especially in in island environments, damaging native communities and is also an agricultural pest. This is explained by its facility to adapt to environmental variations that make this species one of the most competitive and aggressive ecologically in all the Neotropical region and in the environments where it was introduced.

Table 1. Relative frequency of ant species and morphospecies per collection season. Paragominas County, Pará State, Brazil.

Subfamily	Species	Season	
		Wet	Dry
Ponerinae	*Anochetus mayri* Emery 1884	17	25
Ponerinae	*Anochetus* sp.2	8	-
Formicinae	*Brachymyrmex* sp.5	8	-
Formicinae	*Brachymyrmex* sp.1	8	8
Formicinae	*Brachymyrmex* sp.2	25	17
Formicinae	*Brachymyrmex* sp.3	8	-
Formicinae	*Camponotus senex* (Smith)	-	8
Myrmicinae	*Carebara* sp.1	8	25
Myrmicinae	*Carebara* sp.2	8	-
Myrmicinae	*Carebara* sp.3	8	17
Myrmicinae	*Carebara* sp.4	8	-
Myrmicinae	*Crematogaster* sp.4	8	-
Myrmicinae	*Crematogaster* sp.1	-	17
Myrmicinae	*Crematogaster* sp.2	-	17
Myrmicinae	*Crematogaster* sp.3	8	-
Myrmicinae	*Cyphomyrmex* sp.1	8	-
Myrmicinae	*Cyphomyrmex* sp.2	8	17
Myrmicinae	*Cyphomyrmex* sp.3	-	17
Myrmicinae	*Cyphomyrmex* sp.4	8	-
Myrmicinae	*Cyphomyrmex* sp.5	8	-
Ponerinae	*Discothyrea* sp.3	42	-
Ponerinae	*Discothyrea* sp.1	17	-
Ponerinae	*Discothyrea* sp.2	-	8
Ponerinae	*Ectatomma tuberculatum* (Olivier)	-	8
Ponerinae	*Hypoponera* sp.1	-	33
Ponerinae	*Hypoponera* sp.2	8	42
Ponerinae	*Hypoponera* sp.3	-	8
Ponerinae	*Hypoponera* sp.4	17	17
Ponerinae	*Hypoponera* sp.5	-	8
Ponerinae	*Hypoponera* sp.6	8	8
Ponerinae	*Hypoponera* sp.7	17	-
Ponerinae	*Hypoponera* sp.9	8	-
Myrmicinae	*Leptothorax* sp.1	8	25
Myrmicinae	*Mycocepurus smithii* Forel, 1893	33	25
Myrmicinae	*Mycocepurus* sp.1	8	-
Myrmicinae	*Mycocepurus* sp.2	17	-
Myrmicinae	*Mycocepurus* sp.3	-	8
Formicinae	*Myrmelachista* sp.1	-	8
Ponerinae	*Odontomachus bauri* Emery	8	-
Ponerinae	*Pachycondyla constricta* Mayr, 1884	-	8
Ponerinae	*Pachycondyla harpax* Fabricius, 1804	17	-
Formicinae	*Paratrechina* sp.9	25	-
Formicinae	*Paratrechina* sp.1	33	8
Formicinae	*Paratrechina* sp.10	17	-
Formicinae	*Paratrechina* sp.2	8	8
Formicinae	*Paratrechina* sp.3	33	33
Formicinae	*Paratrechina* sp.5	17	-
Formicinae	*Paratrechina* sp.6	50	17
Formicinae	*Paratrechina* sp.7	67	25
Formicinae	*Paratrechina* sp.8	17	8
Myrmicinae	*Pheidole* sp.1	8	-
Myrmicinae	*Pheidole* sp.10	8	-
Myrmicinae	*Pheidole* sp.11	8	-
Myrmicinae	*Pheidole* sp.2	33	-
Myrmicinae	*Pheidole* sp.3	33	25
Myrmicinae	*Pheidole* sp.4	8	-

Myrmicinae	*Pheidole* sp.5	-	8
Myrmicinae	*Pheidole* sp.7	8	-
Myrmicinae	*Pheidole* sp.8	25	-
Myrmicinae	*Pheidole* sp.9	17	8
Myrmicinae	*Pseudomyrmex* sp.1	8	-
Myrmicinae	*Pyramica* sp.1	75	33
Myrmicinae	*Pyramica* sp.2	42	-
Myrmicinae	*Pyramica* sp.3	33	58
Myrmicinae	*Rogeria* sp.1	42	-
Myrmicinae	*Rogeria* sp.2	8	8
Myrmicinae	*Rogeria* sp.3	-	8
Myrmicinae	*Rogeria* sp.4	17	25
Myrmicinae	*Rogeria* sp.5	17	8
Myrmicinae	*Rogeria* sp.6	8	-
Myrmicinae	*Solenopsis* sp.1	75	75
Myrmicinae	*Solenopsis* sp.2	17	-
Myrmicinae	*Solenopsis* sp.3	8	8
Myrmicinae	*Solenopsis virulens* (Smith)	8	-
Myrmicinae	*Strumigenys* sp.1	-	8
Myrmicinae	*Strumigenys* sp.2	-	8
Myrmicinae	*Strumigenys* sp.3	17	-
Myrmicinae	*Strumigenys trudifera* Kempf & Brown	8	-
Myrmicinae	*Wasmannia auropunctata* Emery, 1894	100	100
Myrmicinae	*Wasmannia rochai* Forel, 1912	-	8

The second most frequent species was *Solenopsis* sp.1 (Table 1), that is typical of altered areas. These results are in line with those by Ramos et al. (2003) who stated that most of the species of this genus contribute substantially to the forest recovery process, in agricultural and/or native environments. According to Delabie & Fowler (1995), they can withstand long periods of food scarcity and compete with other ants species or animal groups because they have an efficient mass recruitment strategy. According to Bueno & Campos-Farinha (1999) the *Solenopsis* genus is very abundant and dominant in the Neotropical region, is widely distributed geographically and some species are native to South America. They are generally small, monomorphic or polymorphic and nest in the litter and the surface soil layers. According to Marinho et al. (2002), this genus is outstanding because of its aggressive use of resources and ability to withstand long periods of food scarcity, and most of the species are omnivorous.

The third most frequent species was *Pyramica* sp. that belongs to a very abundant genus in tropical forests (Longino, 2006). Some species of this genus nest in the litter and underneath tree trunks and are Collembola predators and can affect waste-feeding populations because of their feeding habits (Deyrup & Trager, 1984).

These species were probably present because of alterations in the ecological niche. Alteration by fire and pasture may have increased the foraging territory for some species and/or decreased competition with the other species that use the same resources. This explains the dominance of *W. auropunctata* that according to Wetterer & Porter (2003) and Longino & Fernández (2007) is a generalist, invading species with a great capacity to adapt.

The occurrence of more rare species (46 species) than abundant species (17 species) in the wet season (April) than in the dry season (September) with 30 rare species and 14 abundant species (Table 1), in areas altered by fire and pasture with fertilization process, shows that locations where the limiting factors act intensively along with interspecific competition, the diversity tends to decrease, that is, the number of more common species increases (greater number of individuals) and the rarer species decrease. Vasconcelos et al. (2000) and Kalif et al. (2001) found that degraded areas abandoned by agriculture, livestock raising or lumber extraction undergo a gradual regeneration process of the vegetation and ant fauna. Especially, the areas degraded by pasture recover more slowly than those degraded for other reasons. But this factor can also be related to others, such as the land use history that explains the non-recovery of the original composition of the ant community.

The Jaccard similarity coefficients resulted in low values, for the two periods studied and in September the Jaccard means were greater (0.35 and 0.36). The coefficients indicated that the plots analyzed sheltered two different communities (Figure 1). These results show an alteration in the communities because of the period studied.

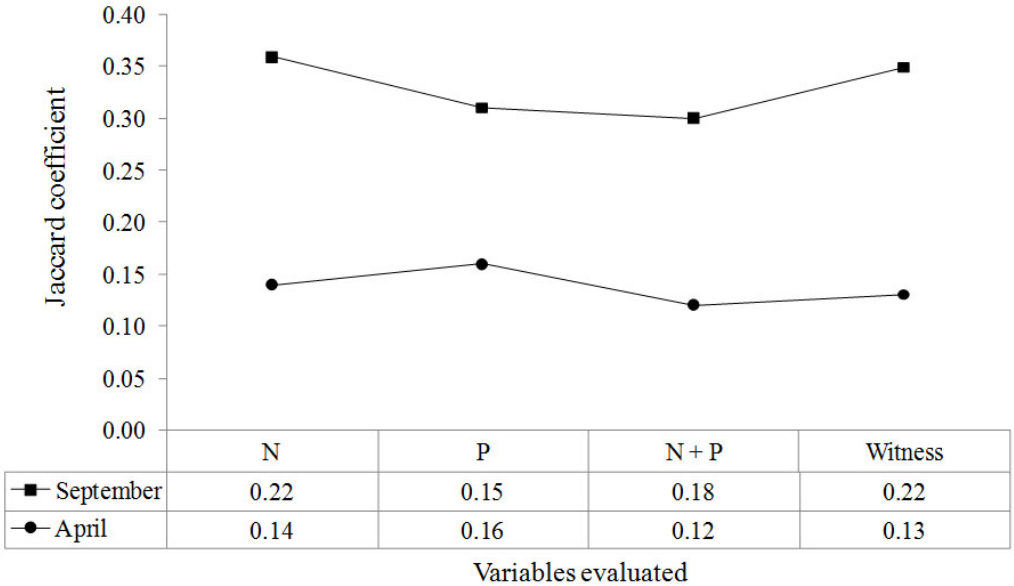


Figure 1. Jaccard coefficient of the ant samples in the plots to april and september 2004 in Paragominas County, Pará State, Brazil.

In April the plots fertilized with phosphorus reached the highest diversity means (H' = 1.61), compared to the plots fertilized with nitrogen (H' = 1.33), nitrogen and phosphorus (H' = 1.22) and the control plots (H' = 1.04). In September the ant diversity was smaller and the control plots (H' = 1.42) and those treated with phosphorus (H' = 1.41) (Figure 2) were outstanding.

The ant diversity, according to the results of the Shannon Index (Figure 2), was low and the fertilized plots were different between each other and in relation to the control plots. The ecological conditions encountered in the study area involving different habitats caused variation in the ant fauna composition. The structural differences observed in the study areas due to the fertilization process used were the quantity litter, climate, vegetation, etc., that contributed to the variation in the ant diversity among the fertilized and control plots.

The low genera and species richness observed was certainly related to the degree of degradation of the studied area. According to Fowler et al. (1991), ant diversity increases in function of the structural complexity of the environment and is modified in function of several factors. Because the studied area was a degraded environment, the fertilization process may have affected the ant community, contributing to the increase in species in the location, a fact that was also observed in studies by Pereira et al. (2007) in the Atlantic rainforest. Another factor to consider is the low fertility of the soil in the Eastern Amazon that, according to Fittkau & Klinge (1973), can reflect in low primary productivity and poor litter quality, the habitats used by an enormous variety of ant species.

The variation in the diversity among the fertilized plots taking into consideration the Shannon index (Figure 2) showed higher means for the plots treated with P (1.61) and lower for the control (1.04) in April. The inverse occurred in September when the highest means were found in the control plot (1.42) and decreased for that of P (1.41) and N+P (0.81). Generally, the fertilized plots presented a greater number of species, this was probably related to the increase in the plant complexity (bushes, herbs and grasses) with the increase in the biomass and vegetation structure in function of fertilization. On the other hand, Sternberg et al. (2007) showed that plants close to nests of *Atta columbica* (Guerin-Meneville) and *Atta laevigatta* (Smiyth) fertilized with N presented high calcium concentration and concluded that these ants may play an important role in the transport, redistribution and concentration of critical micronutrients in savannas and neo tropical forests.

The Equitability index, that estimates the species distribution in the sample, verifying the homogeneity of the numerical occurrence, indicated that the abundance distribution of the individuals was not homogeneous for the two collection dates (Figure 3).

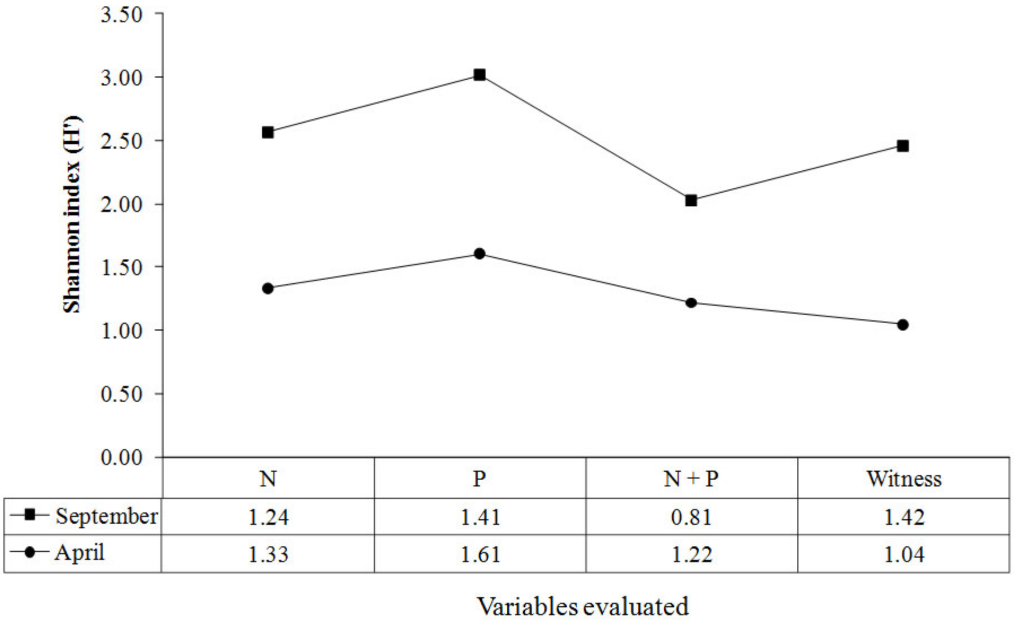


Figure 2. Shannon diversity Index of the ant samples in the plots for april and september 2004 in Paragominas County, Pará State, Brazil.

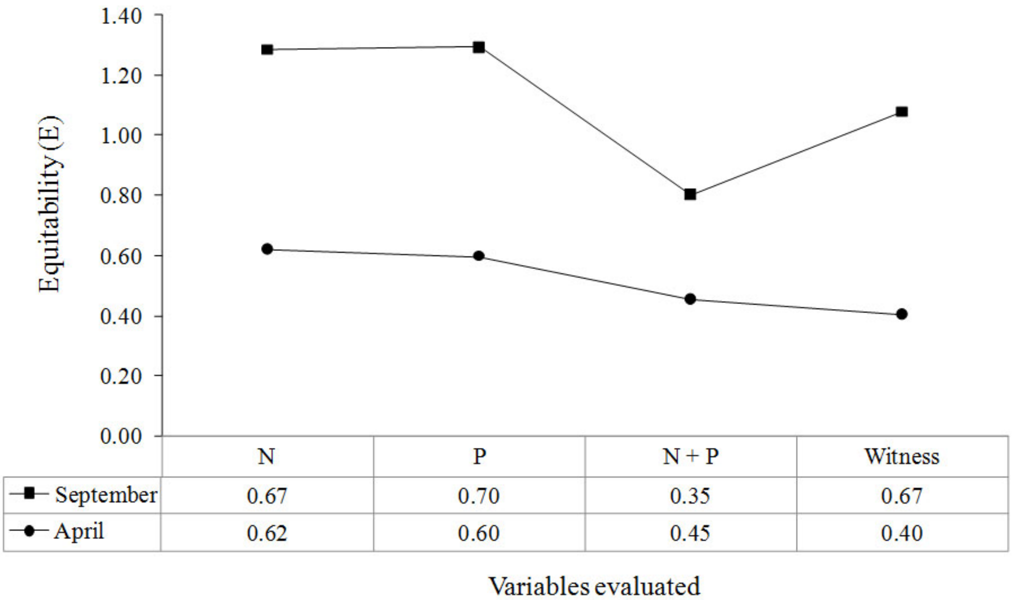
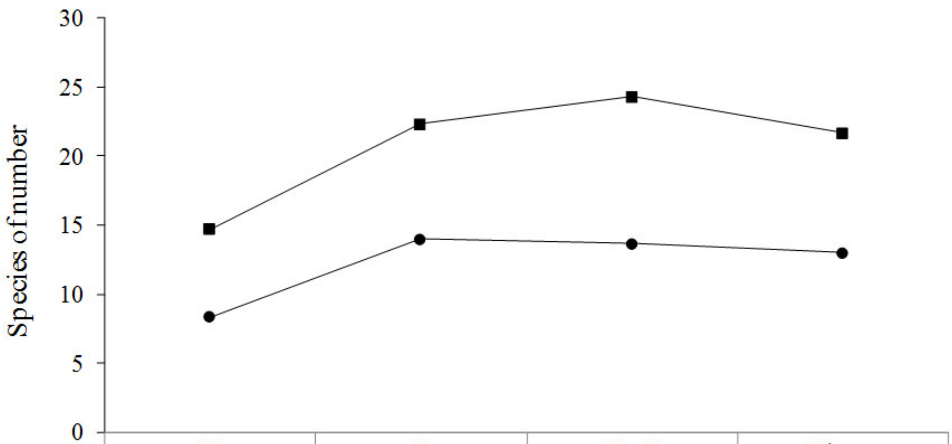


Figure 3. Equitability of the ant samples in the plots for april and september 2004 in Paragominas County, Pará State, Brazil.

In the plots studied in April, there were higher richness means for the areas fertilized with N + P (S = 14) and those fertilized with P (S = 14). The control plots came close to this value (S = 13), and only the plots fertilized with nitrogen presented lower values (S = 8). In September, the highest mean observed was in the plots fertilized with N + P (S = 11), that was similar to the control plots (S = 9). The other plots presented lower values, those fertilized with P (S = 8) and N (S = 6). This showed the ants´ preference for soils fertilized with N + P. The low richness values found were associated to the low structural complexity of the environment (Figure 4) and corroborated the hypothesis by Silveira Neto et al. (1976) that homogeneous environments are dominated by one or a few ant species, unlike heterogeneous environments, where the relative species dominance is low.

The results obtained in this study are in line with those reported by Davidson et al. (2004), in the same area, when the treatments with fertilization significantly influenced the increase in the biomass and vegetation structure. However, differences were not found in the composition and diversity of the ant community and other invertebrates among the same plots. Therefore, the response of the communities studies varied according to time and the fertilization processes. Thus other studies are suggested for a longer period to understand the complexity of the ant community structure.



	N	P	N + P	Witness
September	6	8	11	9
April	8	14	14	13

Variables evaluated

Figure 4. Richness of the ant samples in the plots for april and september 2004 in Paragominas County, Pará State, Brazil.

Conclusions

It was concluded that fertilization processes with N, P and N + P enable a modification in the mirmecofauna composition and vegetation growth, differentiating them from more complex environments, as in fertilized areas.

References

Agosti, D., Johnson, N. 2009. Actual list of the ants of the world. American Museum of Natural History. http://www.antbase.org/databases/ant_list.htm/<Access in 10 Feb. 2011>

Bestelmeyer, B.D., Agosti, L.E., Alonso, C.R.F., Brandão, W.L., Brown, Jr. J.H.C., Delabie, S.R. 2000. Field techniques for the study of ground-dwelling ants: an overview, description and evaluation. In: Agosti, D., Majer, J.D., Alonso, L.E., Schultz, T.R. (eds) *Ants: standard methods for measuring and monitoring biodiversity*. Smithsonian Institution Press, Washington, USA. p. 122-144

Bolton, B. 2003. Synopsis and classification of Formicidae. *Memoirs of the American Entomological Institute* 71: 1-370.

Bueno, O.C., Campos-Farinha, A.E.C. 1999. The Ants Home, p.135-180. In: Mariconi, F.A.M. (ed) Insects and other invaders of homes. FEALQ, Piracicaba, Brazil. 460p.

Davidson, E.A., Carvalho, C.J.R, Vieira, I.C.G., Figueiredo, R.O., Moutinho, P., Ishida, F.Y., Santos, M.T.P., Guerrero, J.B., Kalif, K., Sabá, R.T. 2004. Nitrogen and phosphorus limitation of biomass growth in a tropical secondary forest. *Ecological Applications* 4: 150-163.

Delabie, J.H.C., Fowler, H.G. 1995. Soil and litter cryptic ant assemblages of Bahian cocoa plantations. *Pedobiologia* 39: 423-433.

Deyrup, M., Trager, J. 1984. Strumigenys rogeri an Africa Dacetine ant new to the U.S (Hymenoptera: Formicidae). *Florida Entomologist* 67: 512-576.

Dias-Filho, M.B. 2007. *Degradação de pastagens*: processos, causas e estratégias de recuperação. 3. ed. Embrapa Amazônia Oriental, Belém, Brazil. 190p.

Ewers, R.M., Laurance, W.F. 2006. Scaledependent patterns of deforestation in the Brazilian Amazon. *Environmental Conservation* 33: 203-211.

Fittkau, E.J., Klinge, H. 1973. On biomass and trophic structure of the central amazonian rain forest ecosystem. *Biotropica* 5: 2-14.

Fowler, H.G., Forti, L.C., Brandão, C.R.F., Delabie, J.H.C., Vasconcelos, H.L. 1991. Nutritional ecology of ants, p.131-223. In: Panizzi, A.R., Parra, J.R.P. (eds). *Nutritional ecology of insects and its implications in pest management*. Manole, São Paulo, Brazil. 359p.

Kalif, K.A.B., Malcher, S.A.O., Ramos, C.A., Moutinho, P.R.S. 2001. The effect of logging on the ground-foraging ant community in Eastern Amazonia. *Studies on Neotropical Fauna and Environment 3*: 215–219.

Kirby, R.K., Laurance, W.S. Albernaz, A.K. Schroth, G., Fearnside, F.M., Bergen, S., Venticinque, E.M., Costa, C. 2006. *The future of deforestation in the Brazilian Amazon*. *Futures* 38: 432- 453.

Longino, J.T. 2006. New species and nomenclatural changes for the Costa Rican ant fauna (Hymenoptera: Formicidae). *Myrmecologische Nachrichten* 8: 131-143.

Longino, J.T., Fernández F.C. 2007. A taxonomic review of the genus *Wasmannia*. in: Snelling, R.R.; Fisher, B..; Ward, P.S. (ed.). *Advances in ant systematics (Hymenoptera: Formicidae): homage To, E.; Wilson, O. 50 years of contributions*. American Entomological Institute, Washington, USA. p. 271-289.

Marinho, C.G.S., Zanetti, R., Delabie, J.H.C., Schlindwein, M.N., Ramos, L.S. 2002. Ants diversity (Hymenoptera: Formicidae) of the Forest floor in the Eucalyptus (Myrtaceae) in the Cerrado ecosystems in Minas Gerais. *Neotropical Entomology* 31: 187-195.

McGlynn, T.P. 1999. The world wide transfer of ants: Geographical distribution and ecological invasions. *Journal of Biogeography* 26: 535- 548.

Oliveira, P.S., Brandão, C.R.F. 1991. The ant community associated with extrafloral nectaries in the Brazilian cerrados. In: Huxley, C.R.E., Cutler, D.F. (eds). *Ant-plant interactions*. Oxford University Press, Oxford, UK. p. 198-212.

Pereira, M.P.S., Queiroz, J.M., Valcarcel, R., Mayhé-Nunes, A.J. 2007. *Fauna de formigas como ferramenta para monitoramento de área de mineração reabilitada na ilha da madeira, Itaguaí, RJ. Ciência Florestal 17:* 197-204.

Ramos, L.S., Zanetti, R., Delabie, J.H.C., Lacau, S., Santos, M.F.S.S., Nascimento, I.C., Marinho, C.G.S. 2003. Ant communities (Hymenoptera: Formicidae) of litter in the "cerrado" stricto sensu "in Minas Gerais. *Lundiana* 4: 95-102.

Shannon, C.E., Weaver, W. 1949. *The mathematical theory of communications*. University of Illinois Press, Illinois, USA. 144p.

Silveira Neto, S., Nakano, O., Barbin, D., Villa Nova, N.A. 1976. *Manual de ecologia dos insetos*. Ceres, Piracicaba, Brazil. 419p.

Spellerberg, I.F. 1993. *Monitoring ecological change*. Cambridge University Press, Cambridge, UK. 334p.

Sternberg, L.S.H., Pinzon, M.C., Moreira, M.Z., Moutinho, P., Rojas, E.I., Here, E.A. 2007. Plants use macronutrientes accumulated in leaf-cutting ant nests. *Proceedings the Biologycal Society* 274: 311-321.

Vasconcelos, H.L.; Vilhena, J.M.S; Caliri, J.G.A. 2000. Responses of ants to selective logging of a central Amazonian forest. *Journal of Applied Ecology* 37: 508-515.

Vitousek, P.M. 1994. Beyond global warming: ecology and global change. *Ecology* 75: 1861-1876.

Wetterer, J.K. Porter, S.D. 2003. The little fire ant, *Wasmannia auropunctata*: distribution, impact, and control. *Sociobiology* 42:1-41.

Wilson, E.O. 1987. The arboreal ant fauna of Peruvian Amazon forest: first assensement. *Biotropica* 19: 245-251.

Wright, I., Gash, J., Rocha, H., Shuttleworth, W., Nobre, C., Maitelli, G., Zamporoni, C., Carvalho, P. 1992. Dry season micrometeorology of central Amazonian ranchland. *Journal of the Royal Meteorological Society* 118: 1083-1099.