A 15-year post evaluation of the fire effects on ant community in an area of Amazonian forest

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ABSTRACT. A 15-year post evaluation of the fire effects on ant community in an area of Amazonian forest. Fire represents an important disturbance to ant communities in areas of fire regime. Otherwise, little is known about the effects of fire on ant communities in areas of non-fire regimes, such as in the Amazonian region. We evaluated the long-term effect of fire on ant species richness in a rain forest (Bacaba Plateau) burned 15-years ago and compare our data with the data of primary unburned forest. A total of 85 ant species distributed in 21 genera and 14 tribes were collected; among them, 72 and 44 species were found on the litter and vegetation, respectively. The fire damaged forest studied supports an intermediate richness of ants when compared to a primary unburned rain forest in the same region. A comparative analysis of ant species richness showed that the Bacaba Plateau presented a different ant fauna when compared with the primary unburned forests, suggesting that fire can alter ant species composition. Although, our results cannot be conclusive on the effects of fire on ant community, they represent a pioneer data on human induced fire in tropical rain forests.

KEYWORDS. Amazon; Brazil; community structure; rain forest; species richness.

RESUMO. Uma avaliação após 15 anos do efeito do fogo sobre a comunidade de formiga em uma área de floresta amazônica. O fogo representa uma importante perturbação para a comunidade de formigas em áreas de regime de fogo. No entanto, pouco se conhece sobre os efeitos do fogo na comunidade de formiga em áreas de não-regime, tal como a região da Amazônia. Nós analisamos o efeito de longo prazo do fogo sobre a riqueza de formiga numa floresta tropical queimada 15 anos atrás e comparamos nossos dados, com os de uma floresta primária não-queimada. Foram coletadas um total de 85 espécies de formigas distribuídas em 21 gêneros e 14 tribos, dentre eles 72 e 44 espécies foram encontradas na liteira e vegetação, respectivamente. Esta área de floresta queimada, com 85 espécies, pode suportar uma riqueza intermédia de formigas quando comparadas com uma floresta tropical primária não-queimada, com 29, 22 e 98 espécies na mesma região. Uma análise comparativa da riqueza de espécies de formigas mostrou que o platô Bacaba apresentou uma diferente fauna de formigas quando comparado com as florestas primárias não queimadas, sugerindo que o fogo pode alterar a composição das espécies. Embora, nossos resultados sobre os efeitos do fogo não sejam conclusivos, eles representam dados pioneiros sobre incêndios induzidos por humanos em floresta tropical.

PALAVRAS-CHAVE: Amazônia; Brasil; estrutura de comunidades; Floresta Tropical; Riqueza.

Anthropogenic fire provokes strong disturbances that change the structure of ant communities and influence the functioning of ecosystems (Floren *et al.* 2001). The effects of fire on insects and other arthropods can operate through a variety of mechanisms, and at different temporal and spatial scales. For instance, fire can have an immediate effect through direct mortality (Bock & Bock 1990), reducing species abundance (Andersen & Müller 2000; Sanders 2004) or on foraging activity (Araújo *et al.* 2004). Fire is considered an important disturbance on ant communities in areas of fire regime, such as savannas across the world (Andersen & Müller 2000; Hoffmann 2003; Parr *et al.* 2004).

The effects of fire on ant assemblages should be particular to each habitat. Ant species richness may be higher in unburned areas than in burned areas (e.g., York 2000), higher in burned areas than in unburned areas (e.g., Folgarait 1998), or show no effects (Hoffmann 2003; Parr *et al.* 2004). Fire effects on ant species community may depend on habitat type (e.g., Farji-Brener *et al.* 2002; Hoffmann 2003; Parr *et al.* 2004), on the structural complexity of the habitat (Ratchford *et al.* 2005), or even on the ant assemblage. Despite the increasing incidence of fires in tropical rain forests (areas of non-fire regimes) such as in the Brazilian Amazonia, little is known about the effects of habitat burning on ant communities in such habitats.

The Amazonian forest is known for its high diversity of ant species (Wilson 1987; Ward 2000; Floren & Linsenmair 2005). A summary of major published surveys of ant communities in the Brazilian Amazonia shows a range of ant species richness varying from 30 up to 520 species (Majer & Delabie 1994). Benson & Harada (1988) suggested that the high diversity of Amazonian ant community is due to the high abundance of nesting sites in the leaf litter, dead wood and trees, and absence of density-limiting climatic factors. Therefore, one might postulate that burning might have a strong effect by eliminating and/or disrupting nesting sites in this non-fire regime region as habitat recovery should be slower compared to fire prone vegetation (e.g., savannas). Otherwise, in spite of the Amazonian ant fauna to be particularly interesting and speciose, we were unable to locate any study on the fire effects on ants in this broad region.

We had a unique opportunity to study the ant diversity in an area of forest that have been burned and is currently in regeneration on the Bacaba Plateau, Porto Trombetas, Pará, Brazil. The study area was burned 15 years ago, and hence we attempted to evaluate the long-term effect of fire on ant species richness. Furthermore, we compare our data with the data of primary non burned forest obtained by Oliveira & Della Lucia (1992) and Majer & Delabie (1994) in adjacent native areas of the same region.

MATERIALS AND METHODS

Study location. The area surveyed has 205ha and is located in the Platô Bacaba, Saracá - Taqüera National Forest - IBAMA, 65km northwest of the town of Oriximiná and 30km south of the Trombetas River in western Pará State, Brazil (1° 77'S 56° 37'W). The vegetation is evergreen equatorial moist forest. The forests occupying the upland mesas and surrounding slopes of the plateau have an average canopy height of 20 – 35m, with emergent trees up to 45m (Parrotta *et al.* 1997; Parrotta & Knowles 1999, 2001). According to the residents of the Sapucuá Lake and proved by local evidences (trunks with fire signs), the plateau was burnt early in the year of 1990. Remote sensing images of the Landsat 7 satellite indicate that, in 1999, an area of 111ha (54.0%) of the Bacaba plateau was represented by primary vegetation, 65ha (31.7%) of secondary forest, while the remaining 29ha (14.3%) was represented by vegetation strongly altered by fire (sampled area).

Sampling and treatment of the biological material. Samples of ants were done between 08:00-11:00h and 13:00-17:00h in August 2004 (wet season) and November 2004 (dry season). Transects of one hundred meters to sample ants (AST) were arbitrarily set on each study site (n=24) per season in the plateau Bacaba (totaling 48 sites during the year). Twenty tuna baits were placed at ten meters intervals along each transect, with ten tuna baits placed on the low-vegetation (up to two meters) and other ten on the litter. Baits were revisited two hours later and the ants feeding on them were collected (see Romero & Jaffé 1989; Bestelmeyer *et al.* 2000). Whenever possible, ants were identified at the species level and species nomenclature follows Bolton (1995). To actualize the information given in the Table II, the species nomenclature also follows the appropriate publications (MacKay 1993; Bolton 1995, 2000, 2003; Fernandez 2002, 2004). Voucher specimens are deposited in the Myrmecology Laboratory at the Center for Cocoa Research (CEPLAC).

Data analysis and comparison of our data with available information. We used Chi-square for comparison of ant diversity between the litter and low vegetation (Zar 1999). Although it should be reminded that the data of ants on native forest were obtained from the same region but from studies done several years ago (Oliveira & Della Lucia 1992, Majer & Delabie 1994), this study represents a first tentative to compare the long-term effect of burning on Amazonian Basin ant species. We used Cluster Analysis (Single Linkage - Euclidean distances) to estimate the similarity between assembly of ant genera in burned and unburned forests (StatSoft Statistica 6.0 StatSoft 2001). The dendrogram is the result of a cluster analysis of a matrix of Euclidean distances between forests constructed on the basis of the presence or absence of ant genera from Oliveira & Della Lucia (1992), Majer & Delabie (1994), and for this study.

RESULTS

A total of 85 ant species distributed in 21 genera and 14 tribes were collected (Table I) in this study. *Pheidole* and *Crematogaster* were the most speciose genera with 28, and 13 species, respectively. Six sub-families were sampled: Myrmicinae (56 species), Formicinae (10 species), Dolichoderinae (nine species), Ectatomminae (five species), Ponerinae (four species), and Paraponerinae (one species) (Table I).

Ant litter collection rendered a total of 72 ants species distributed into 20 genera (Table I). *Pheidole* (24 species) and *Crematogaster* (10 species) were the most species rich genera. Five sub-families were sampled in the litter: Myrmicinae (48 species), Formicinae (eight species), Dolichoderinae (eight species), Ectatomminae (five species), Ponerinae (two species), and Paraponerinae (one species). Forty-one species were exclusively found in the litter.

A total of 44 ants species in 16 genera, were collected on the vegetation (Table I). *Pheidole* and *Crematogaster* were represented by eight species each. Five sub-families were sampled on the vegetation: Myrmicinae (25 species), Dolichoderinae (seven species), Formicinae (six species), Ponerinae (four species), and Ectatomminae (two species). Thirteen ant species were found exclusively on the vegetation.

The richness of ants in the litter (72 species) was higher than on the vegetation (44 species) (*Chi-square* = 21.152, df = 1, $p<0.001$). A comparative analysis of ant species richness of the burned forest in the Bacaba Plateau and unburned forests (Saracá and Castanhal Plateaus- Oliveira & Della Lucia 1992; Planalto Plateau - Majer & Delabie 1994) revealed two distinct groups. The primary forests, Saracá and Castanhal, showed similar ant assemblages (Fig. 1) while the secondary forest in the Bacaba Plateau presented a totally different ant assemblage when compared to the primary forests. The data also indicated that the ant fauna was relatively heterogeneous although it was collected with different methods in a same region of Trombetas.

Table I. Check-list of ant fauna of litter and low vegetation sampled in a burned area of Bacaba Plateau, Porto Trombetas, Pará, Brazil.

Sub-family / Tribes / Species	Litter*	Low vegetation*
Dolichoderinae		
Dolichoderini		
Azteca chartifex Forel, in Emery, 1896	1	1
Azteca instabilis (Smith, 1862)	1	1
Azteca sp. near *instabilis*	1	1
Dolichoderus attelaboides (Fabricius, 1775)	0	1
Dolichoderus bispinosus (Olivier, 1792)	1	1
Dolichoderus decollatus Smith, 1858	1	0
Dolichoderus bispinosus (Olivier, 1792)	1	1
Dorymyrmex pyramicus alticonis Forel, 1912	1	0
Dorymyrmex sp.	1	1
Ectatomminae		
Ectatommini		
Ectatomma brunneum Fr. Smith, 1858	1	1
Ectatomma lugens Emery, 1894	1	0
Ectatomma suzanae Almeida, 1986	1	0
Ectatomma tuberculatum (Olivier, 1791)	1	1
Gnamptogenys striatula Mayr, 1884	1	0
Formicinae		
Brachymyrmecini		
Brachymyrmex heeri Forel, 1874	1	0
Brachymyrmex sp.1	1	1
Brachymyrmex sp.2	1	1
Camponotini		
Camponotus crassus Mayr, 1862	0	1
Camponotus latangulus Roger, 1863	1	1
Camponotus rapax (Fabricius, 1804)	1	1
Lasiini		
Paratrechina fulva (Mayr, 1862)	0	1
Paratrechina sp.1	1	0
Paratrechina sp.2	1	0
Paratrechina sp.3	1	0
Myrmicinae		
Blepharidattini		
Blepharidatta brasiliensis Wheeler, 1915	1	0
Cephalotini		
Cephalotes atratus (Linnaeus, 1758)	1	1
Cephalotes opacus Santschi, 1920	1	1
Cephalotes placidus (Fr. Smith, 1860)	1	1
Cephalotes simillimus (Kempf, 1951)	1	0
Crematogastrini		
Crematogaster sp. near *acuta*	1	0
Crematogaster victima Fr. Smith, 1858	0	1
Crematogaster evallans Forel, 1907	1	1
Crematogaster limata Fr. Smith, 1858	1	1
Crematogaster longispina Emery, 1890	1	0
Crematogaster nigropilosa Mayr, 1870	0	1
Crematogaster wardi Longino, 2003	1	0
Crematogaster sp. near *limata*	0	1
Crematogaster sp.1 near *longispina*	1	1
Crematogaster sp.2 near *longispina*	1	1
Crematogaster sp.1 near *nigropilosa*	1	1
Crematogaster sp.2 near *nigropilosa*	1	0
Crematogaster sp.3 near *nigropilosa*	1	0
Dacetiti		
Daceton armigerum (Latreille, 1802)	0	1
Solenopsidini		
Megalomyrmex balzani Emery, 1894	1	0
Megalomyrmex emeryi Forel, 1904	1	0
Ochetomyrmecini		
Ochetomyrmex neopolitus Fernandez, 2003	1	1
Ochetomyrmex semipolitus Mayr, 1878	1	1
Pheidolini		
Pheidole bruesi Wheeler, 1911	1	0
Pheidole bufo Wilson, 2003	1	0
Pheidole deima Wilson, 2003	1	0
Pheidole fallax Mayr, 1870	1	0
Pheidole fimbriata Roger, 1863	1	0
Pheidole gauthieri Forel, 1901	1	0
Pheidole gigas Wilson, 2003	1	0
Pheidole puttemansi Forel, 1911	1	1
Pheidole radoszkowskii Mayr, 1883	1	1
Pheidole rogeri Emery, 1896	1	0
Pheidole stigma Wilson, 2003	1	0
Pheidole sp.	1	0
Pheidole sp. (gp. *scrobifera*?)	0	1
Pheidole sp. gp. *aberrans*	1	0
Pheidole sp. gp. *flavens*	1	0
Pheidole sp. gp. *tristis*	0	1
Pheidole sp. near *diana*	1	1
Pheidole sp. near *exquisita*	1	0
Pheidole sp.1 gp. *diligens*	1	0
Pheidole sp.2 gp. *diligens*	1	0
Pheidole sp.3 gp. *diligens*	1	0
Pheidole sp.4 gp. *diligens*	0	1
Pheidole sp.5 gp. *diligens*	1	0
Pheidole sp.6 gp. *diligens*	1	0
Pheidole sp.1 gp. *fallax*	0	1
Pheidole sp.2 gp. *fallax*	1	0
Pheidole sp.3 gp. *fallax*	1	1
Pheidole sp.4 gp. *fallax*	1	0
Solenopsidini		
Solenopsis geminata (Fabricius, 1804)	1	1
Solenopsis globularia (Smith, 1858)	1	0
Solenopsis sp.	1	1
Attini		
Trachymyrmex sp.	1	0
Blepharidattini		
Wasmannia auropunctata (Roger, 1863)	1	1
Paraponerinae		
Paraponerini		
Paraponera clavata (Fabricius, 1775)	1	0
Ponerinae		
Ponerini		
Odontomachus haematodus (Linnaeus, 1758)	1	1
Pachycondyla carinulata (Roger, 1861)	0	1
Pachycondyla harpax (Fabricius, 1804)	1	1
Pachycondyla unidentata (Mayr, 1862)	0	1
Total - 14 tribes - 85 species	72 species	44 species

Table II. Ant genera fauna sampled in a burned area of Bacaba Plateau and an unburned area of Planalto Forest (* see Majer & Delabie 1994) in Porto Trombetas, Pará, Brazil. The taxonomy used in Oliveira & Della Lucia (1992) and Majer & Delabie (1994) has been revised due to several nomenclatural changing at the generic level in the Formicidae family since this paper has been published (see MacKay 1993; Bolton 1995; 2000, 2003; Fernandez 2002, 2004)

Bacaba Plateau (burned area)		Castanhal (unburned area)*		Saracá Plateau (unburned area)*		Planalto Forest (unburned area)**	
Method: tuna bait		*Method: baiting (tuna honey and cookie)*		*Method: baiting (tuna honey and cookie)*		*Several methods*	
This study		*Oliveira & Della Lucia (1992)*		*Oliveira & Della Lucia (1992)*		*Majer & Delabie (1994)*	
Genus	Number of species	Genus	Number of species	Genus	Number of species	Genus	Number of species
Pheidole	28	*Ectatomma*	5	*Ectatomma*	3	*Pheidole*	12
Crematogaster	13	*Pheidole*	4	*Gnamptogenys*	3	*Pachycondyla*	8
Cephalotes	4	*Paratrechina*	3	*Paratrechina*	3	*Camponotus*	7
Dolichoderus	4	*Gnamptogenys*	2	*Crematogaster*	2	*Hypoponera*	7
Ectatomma	4	*Crematogaster*	2	*Camponotus*	2	*Odontomachus*	5
Paratrechina	4	*Heteroponera*	1	*Odontomachus*	1	*Paratrechina*	5
Azteca	3	*Odontomachus*	1	*Leptogenys*	1	*Solenopsis*	5
Brachymyrmex	3	*Cephalotes*	1	*Pheidole*	1	*Crematogaster*	4
Camponotus	3	*Megalomyrmex*	1	*Megalomyrmex*	1	*Gnamptogenys*	4
Pachycondyla	3	*Monomorium*	1	*Mycocepurus*	1	*Strumigenys*	4
Solenopsis	3	*Mycocepurus*	1	*Cephalotes*	1	*Cyphomyrmex*	3
Dorymyrmex	2	*Pyramica*	1	*Neivamyrmex*	1	*Dolichoderus*	3
Megalomyrmex	2	*Solenopsis*	1	*Tapinoma*	1	*Rogeria*	3
Ochetomyrmex	2	*Cephalotes*	1	*Pseudomyrmex*	1	*Carebara*	3
Blepharidatta	1	*Neivamyrmex*	1			*Anochetus*	2
Daceton	1	*Tapinoma*	1			*Apterostigma*	2
Gnamptogenys	1	*Pseudomyrmex*	1			*Azteca*	2
Odontomachus	1	*Camponotus*	1			*Trachymyrmex*	2
Paraponera	1					*Acropyga*	1
Trachymyrmex	1					*Atta*	1
Wasmannia	1					*Blepharidatta*	1
						Brachymyrmex	1
						Carebarella	1
						Eciton	1
						Ectatomma	1
						Eurhopalothrix	1
						Gigantiops	1
						Labidus	1
						Lachnomyrmex	1
						Leptogenys	1
						Myrmicocrypta	1
						Ochetomyrmex	1
						Pyramica	1
						Pseudomyrmex	1
						Sericomyrmex	1
21 genera	85 species	18 genera	29 species	14 genera	22 species	35 genera	98 species

DISCUSSION

The ant species richness in the Bacaba Plateau may be considered similar to the ant species richness observed elsewhere in the Amazonian Basin. We recorded 85 ant species distributed within 21 genera (see Table I) while Vasconcelos & Delabie (2000) recorded 227 species of ants in the litter of fragmented areas near Manaus (Amazonas, Brazil) and Oliveira *et al.* (1995) found 107 species of ants in a primary forest in Amapa (Brazil). However, on a secondary and primary forest in Pará (Brazil), Fowler et al. (2000) recorded 48 and 31 species of ants, respectively. As the number of species observed is dependent on the collection effort and sampling method (Bestelmeyer *et al.* 2000), this information has limited value to generate conclusions about the areas that have been studied, mostly due to the several different methods of sampling that have been employed.

Compared with the study of Oliveira & Della Lucia (1992) carried out on two primary forests adjacent to the Bacaba Plateau, the richness of sites burned 15-years ago in the Bacaba Plateau was higher than in unburned primary forests. They found 29 ant species distributed within 18 genera in the Castanhal Forest, and 22 ant species distributed within 14 genera in the Saracá Plateau (see Table II). Oliveira & Della Lucia (1992) used baits made of a combination of tuna, honey and cookie crumbs while we used only tuna bait. Otherwise, our data indicate that burned forest areas may support a higher diversity of ants when compared to primary, unburned forests. Nevertheless, when our data are compared with the study of Majer & Delabie (1994) carried out on primary forest in the

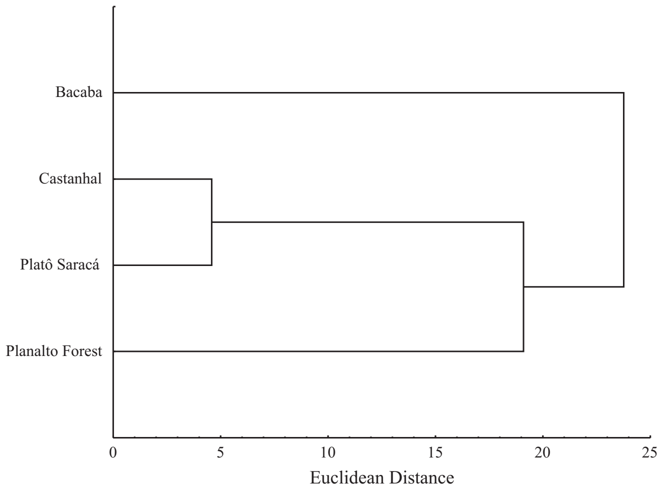

Fig. 1. Cluster analysis dendogram revealing a clear distinction in two groups ant assemblage genera, burned forest (Bacaba) and unburned forests (primary forests Saracá, Castanhal and Planalto Plateau), in Trombetas, Pará,

same region but on different plateaus, the ant richness found in our burned sites was smaller than in unburned forests. Majer & Delabie (1994) found 98 ant species distributed within 39 genera (see Table II). Otherwise, the same authors also used a combination of six different methods to sample ants.

Although the studies of Oliveira & Della Lucia (1992) and Majer & Delabie (1994) were not carried out exactly at the same place, actual comparisons suggest differences in the structure of ant assemblages. Only seven ant genera (*Camponotus*, *Crematogaster*, *Ectatomma*, *Gnamptogenys*, *Odontomachus*, *Paratrechina*, and *Pheidole*) were common in the three studies. Bacaba Plateau showed a different ant fauna when compared with the primary forest (Fig. 1), suggesting that fire altered the composition of species. Moreover, the differences of ant assemblages observed in our study with the two cited studies suggest that a great heterogeneity in ant composition may exist in the Amazonian forests as already suggested by Vasconcelos *et al.* (2003).

Ant diversity is strongly influenced by habitat structural complexity and type (Boomsma & Van loon 1982; Della Lucia *et al.* 1982; Morais & Benson 1988; Delabie *et al.* 1999; Floren *et al.* 2001; Marinho *et al.* 2002; Lassau & Hochuli 2004; Delabie *et al.* 2007). Despite the fact that no absolute argument is yet available, we can postulate that the structural complexity of the ant fauna of the Bacaba Plateau was strongly affected by the fire that occurred 15 years ago. For instance, in *Darlingtonia* fens, ant species richness was higher in burned sites than in unburned sites, while in the forest, ant species richness was lower in burned sites than unburned sites (Ratchford *et al.* 2005). Furthermore, nesting sites, shelter, and food sources (e.g., plants with extrafloral nectaries and associated hemipterans) are among the factors that strongly influence ant diversity (Rico-Gray 1996; Del-Claro & Oliveira 1999, 2000; Blüthgen *et al.* 2000). Farji-Brener *et al.* (2002) suggest that the effects of disturbances on ant assemblages depends both on habitat characteristics, which influence the extent of the changes induced by the disturbance, and on the regional context of the ant fauna, which influence the ability of the ants to deal with the post-disturbance conditions.

In spite of the large number of ants known in the Amazonian Basin and many studies on ant-plant interactions (e.g., Blüthgen *et al.* 2000), the knowledge of the role of fire in disturbing Amazonian ant communities may be considered rather rudimentary at present. Our results cannot be conclusive because other studies demonstrated that ant diversity can increase (e.g., Folgarait 1998), decrease (York 2000), or even remains unchanged after fire (e.g., Jackson & Fox 1996; Hoffmann 2003) and also due to the limitations of the sampling methods employed. However, they are important given the increasing threat of human induced fire in the region (see Secretariat of the Convention on Biological Diversity 2001 for details). Important questions should be addressed in a short future such as the succession of ant species after fire, species differential survival, and resilience (i.e., the rate of return to a pre-disturbance state) of ant communities in burned tropical forests. Where ants have had a long association with fire (i.e., savanna), they are likely to display considerable resistance and resilience to burning (Andersen & Müller 2000; Orgeas & Andersen 2001; Parr *et al.* 2004). Furthermore, as ants may have important direct and indirect effects on community structure and diversity, the role of fire in the species rich non fire regime Amazonian tropical rain forests is of much concern at several scales.

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