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Seasonality of Epigaeic Ant Communities in a Brazilian Atlantic Rainforest

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Abstract

In this study we assessed the leaf-litter ant community in the Cicuta Forest, a semi-deciduous forest located in the state of Rio de Janeiro, southeastern Brazil. Specifically, we tested the following hypotheses: (1) ant richness and diversity are higher in the rainy season, due to higher resource availability and better temperature and humidity conditions; and that (2) the structure of the ant community is influenced by climate seasonality. We collected 83 ant species of 35 genera and eight subfamilies. In total, 64 species were collected in the dry season and 73 species in the rainy season. Based on rarefaction curves with confidence intervals, we observed that species richness in the dry and rainy seasons did not differ significantly from each other. Shannon diversity did not differ significantly ($t = -1.20$; $P = 0.23$) between the dry (3.43) and rainy seasons (3.52). We did not observe a significant effect of climate seasonality neither on ant species composition, richness, and diversity, nor on community structure. These results may be explained by the degree of isolation and degradation of this forest remnant. In short, our study contributes to knowledge on how seasonal variations affects ant communities.

Introduction

Ants are extremely abundant and diverse in tropical rainforests (Hölldobler & Wilson, 1990; Ward, 2000; Lach et al., 2010). Previous studies showed that ant diversity is influenced by several biotic factors, such as plant richness and density (Gomes et al., 2010a; Tews et al., 2004), as well as by abiotic factors, such as leaf litter depth (Nakamura et al., 2003; Vargas et al., 2007), temperature (Almeida et al., 2007), rainfall (Kaspari, 2000; Speight et al., 2008), and physical and chemical properties of the soil (Gomes et al., 2010b). Moreover, due to the high spatial abundance of ants in tropical environments, they play several ecological roles (Hölldobler & Wilson, 1990).

In the soil-litter interface, ants also are related with essential ecological processes, such as decomposition of organic matter, soil aeration, seed dispersal, and population control of other arthropods (Hölldobler & Wilson, 1990; Folgarait, 1998; Passos & Oliveira, 2004; Dattilo et al., 2009).

The structure of ant assemblages varies in time and space, following environmental heterogeneity (Lassau & Hochuli, 2004; Jankowski et al., 2009). It is well known that variations in rainfall intensity affect temperature and humidity, and so influence ecosystem productivity (Kaspari, 2001). Therefore, rainfall seasonality is expected to lead to variations in the activity, abundance, and species richness and composition of ants (Coelho & Ribeiro, 2006; Almeida et al., 2007; Castro et al., 2012). Indeed, rainfall may affect ant assemblages in two ways, by altering microclimate at a local scale or ecosystem productivity at a regional scale (Castilho et al., 2011; Castro et al., 2012).

On the other hand, seasonal variations may not affect ant richness and composition due to environmental simplification and changes in habitat structure, either at a local or at a regional scale, which makes these variations less pronounced (Vasconcelos & Laurance, 2005; Silva et al., 2011).

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For example, Castro et al., (2012) did not observe variations in the structure of ant assemblages in an impacted area, but only between different areas. In this study, we assessed temporal variations in ant assemblages that live in the soil-litter interface in the Cicuta Forest. This area is a rainforest remnant located in an urban matrix in southeastern Brazil. Specifically, we hypothesized that, due to higher resource availability and better temperature and humidity conditions during the warm and rainy season, ant richness and composition should differ between dry and rainy seasons.

Material and Methods

Study area

The Cicuta Forest has 125.14 ha and is located within the municipalities of Volta Redonda and Barra Mansa, in the southern region of Rio de Janeiro State, southeastern Brazil. In the 18th and 19th centuries this region was economically very important due to coffee production (Dean, 1996). Classified as an area of relevant ecological interest, according to the Brazilian environmental law, the reserve was created by the CONAMA resolution #05 of June 5th, 1984 and by the Decree #90,792 of January 9th, 1985. The local vegetation is classified as submontane semi-deciduous seasonal forest (IBGE, 1992). The surrounding landscape is classified as an urban matrix, with small forest fragments at different successional stages, *Eucalyptus* plantations, and mainly pastures.

The altitude ranges between 300 and 500 m a.s.l. (Monsores et al., 1982) and the climate is Cwa (dry winter and warm and rainy summer) in Koeppen classification. The average annual rainfall is 1,300mm; February is the warmest month (24ºC) and July is the coldest (17ºC). The local geomorphology is characterized by flattened hilly terraces, isolated structural hills, and dissected tablet-shaped terraces. The Red-Yellow Podzolic soil, whose constitution may facilitate the occurrence of erosion, predominates in the region (Brasil, 1983; Dias et al., 2001). The Cicuta Forest, which is considered an important Atlantic Forest remnant, harbors large tree species such as jequitibá (*Cariniana estrellensis*), chichá (*Sterculia chicha*) and figueira branca (*Ficus guaranítica*).

Sampling

For sampling ants we used pitfall traps at three equidistant sites, 500 m apart from one another. At each site, we placed 20 pitfalls at every 10 m in four parallel transects. Pitfall traps were made of 500-mL plastic cups (8 cm diameter) containing approximately 150 ml of ethanol 70% as preservative fluid, which remained in the field for seven days. During the exposure period, the traps were constantly checked so that they always contained the preservative fluid. We repeated sampling four times: two times in the rainy season and two times in the dry season (June 2001 - dry season, March - rainy season and June - dry season in 2002, and March 2003- rainy season).

Data analysis

We used the Mao Tau moment-based rarefaction (Gotelli & Colwell, 2001) to build rarefaction curves of ant species for the dry and rainy seasons. In spite of our sampling effort, this technique eliminates the need for replicates, as it allows a direct comparison of richness between seasons of the year (Colwell et al., 2004). In addition, we used the first order Jackknife non-parametric species richness estimator for extrapolating species richness in the study area. Both analyses (rarefaction and richness estimation) were made in EstimateS 7.5.2 (Colwell, 2005). We calculated the Shannon diversity index (H') for each season (winter and summer) and compared them with a t test in PAST (Hammer et al., 2001).

We also tested for a turnover in the composition of dominant ant species between the dry and rainy seasons. We considered dominant the species that were present in more than 25% of the samples.

To summarize the structure of the ant community in dry and rainy seasons, we ordered the samples with non-metric multidimensional scaling (NMDS). This type of ordination is one of the most robust, as it summarizes more information in fewer axes compared with other techniques (Legendre & Legendre, 1998). The NMDS was performed based on a distance matrix calculated with the Bray-Curtis dissimilarity index. Next, we tested for differences in ant species composition between samples collected in the dry and rainy seasons, using a permutation test (10,000 permutations) based on an analysis of similarities (ANOSIM) (Clarke, 1993). Both the ordination and similarity analysis were performed in R 2.13.1 (R Development Core Team). In order to not overestimate the ant species with more efficient systems for recruiting and / or those whose colonies are closer to the bait (Gotelli et al. 2011), all analyses used in this study were calculated based on the frequency of species occurrence in the pitfall traps and not based on the number of workers.

Results

We collected 83 ant species of 35 genera and eight subfamilies (Table 1). The subfamily Myrmicinae had the largest number of species (42 - 51%), followed by Formicinae (17 - 20%), Ponerinae (12 - 14%), and Ecitoninae (5 - 6%). In total, 64 species were collected in the dry season and 73 in the rainy season.

Although the rarefaction curves evidenced a fast increase in the number of species in both seasons (dry and rainy), no curve reached an asymptote. This suggests that more species could have been added with a larger sampling effort or with the addition of other sampling methods (Figure 1). According to the Jackknife 1 richness estimator, the sampling efficiency was 71.2 % in the dry season (observed richness: 64 species; estimated richness: 89.7 species) and 73.9 % in the rainy season (observed richness: 73 species; estimated richness: 98.78

species). Diversity (H’) was 3.43 in the dry season and 3.52 in the rainy season, which did not differ significantly from each other (t = -1.20; *P* = 0.23).

Although some species occurred only in one season, the structure of the ant assemblage did not differ between the dry and rainy seasons (Figure 2) (NMDS followed by ANOSIM: r = 0.048; P < 0.001). In addition, we observed that 10 species (15.6 %) were particularly dominant in the dry season and only five species (6.8 %) in the rainy season. We recorded 27 (33%) rare species (Table 1).

Table 1 - List of species by subfamilies sampled in two different periods (dry and wet) in Cicuta Forest, Volta Redonda, Rio de Janeiro.

Subfamilies/Species	**Sampling period**		**Functional groups**
	Dry	**Wet**	
Dolichoderinae	14	2	
Linepithema sp. 1		1	omn
Linepithema sp. 2	14	1	omn
Ecitoninae	32	12	
Eciton cf. *vagans* Olivier		3	arm
Labidus praedator (Fr. Smith)	28	8	arm
Neivamyrmex sp. 1	2	1	arm
Neivamyrmex sp. 2	1		arm
Neivamyrmex sp. 3	1		arm
Ectatomminae	11	2	
Ectatomma edentatum Roger	7	1	lit-dom
Gnamptogenys minuta (Emery)	1	1	gen-pred
Gnamptogenys sp. 3	3		gen-pred
Formicinae	43	43	
Acropyga sp. 1	1	1	sub
Brachymyrmex sp. 1	1	11	omn
Brachymyrmex sp. 2	5	2	omn
Brachymyrmex sp. 3	5	2	omn
Brachymyrmex sp. 4	4	1	omn
Brachymyrmex sp. 5		1	omn
Camponotus crassus Mayr		1	omn
Camponotus sericeiventris Guérin	1	1	omn
Camponotus sp. 1	5	5	omn
Camponotus sp. 2	1	3	omn
Camponotus sp. 3		1	omn
Camponotus sp. 4	16	11	omn
Camponotus sp. 5		1	omn
Camponotus sp. 6	1	1	omn
Camponotus sp. 7	1		omn
Camponotus sp. 8	1		omn
Nylanderia sp. 1	1	1	omn
Heteroponerinae		1	
Heteroponera sp. 1		1	gen-pred
Myrmicinae	263	291	
Acanthognathus brevicornis Smith	6	2	lit-pred
Acromyrmex sp. 1	5	11	fung
Apterostigma gr. *pilosum*	5	2	fung
Atta sp. 1		1	fung
Carebara urichi (Wheeler)	3	1	omn
Cephalotes pallens (Klug)		1	omn
Crematogaster sp. 1		2	omn
Crematogaster sp. 2	1	2	omn
Cyphomyrmex sp. 2	1	7	fung
Cyphomyrmex sp. 3		1	fung
Cyphomyrmex sp. 4	1		fung
Hylomyrma balzani (Emery)	4	4	lit-pred
Leptothorax sp. 1	1	2	lit-pred
Megalomyrmex sp. 1	6	6	lit-pred
Mycetarotes carinatus Mahyé-Nunes		3	fung
Octostruma sp. 1	3	7	omn
Pheidole gertrudae Forel		1	omn
Pheidole sp. 1	1	16	omn
Pheidole sp. 10	1	3	omn
Pheidole sp. 11	2	3	omn
Pheidole sp. 2	23	21	omn
Pheidole sp. 3	14	13	omn
Pheidole sp. 4	24	40	omn
Pheidole sp. 5	15	10	omn
Pheidole sp. 6	28	11	omn
Pheidole sp. 7	21	16	omn
Pheidole sp. 8	17	7	omn
Pheidole sp. 9		1	omn
Procryptocerus sp. 1	1		omn
Solenopsis sp. 1	1	4	lit-omn
Solenopsis sp. 2	24	40	lit-omn
Solenopsis sp. 3	39	19	lit-omn
Solenopsis sp. 4	4	10	lit-omn
Solenopsis sp. 5		2	lit-omn
Solenopsis sp. 6		2	lit-omn
Solenopsis sp. 7	1	7	lit-omn
Strumigenys apretiata	3	5	lit-pred
Strumigenys sp. 1	2	3	lit-pred
Strumigenys sp. 2	4	3	lit-pred
Strumigenys sp. 3	1		lit-pred
Strumigenys sp. 4	1		lit-pred
Trachymyrmex sp. 1		2	fung
Ponerinae	116	110	
Hypoponera sp. 1	3	8	gen-pred
Hypoponera sp. 2		1	gen-pred
Hypoponera sp. 3	6	2	gen-pred
Hypoponera sp. 4	8	1	gen-pred
Leptogenys sp. 1	1	1	lit-pred
Leptogenys sp. 2		1	lit-pred
Odontomachus chelifer (Latreille)	7	8	gen-pred
Odontomachus meinerti Forel	22	20	gen-pred
Pachycondyla harpax (Fabricius)	26	15	gen-pred
Pachycondyla sp. 1	1		gen-pred
Pachycondyla sp. 2	3	1	gen-pred
Pachycondyla striata Fr. Smith	39	52	gen-pred
Pseudomyrmecinae	1	2	
Pseudomyrmex sp. 1	1	2	omn
Total Richness	64	73	

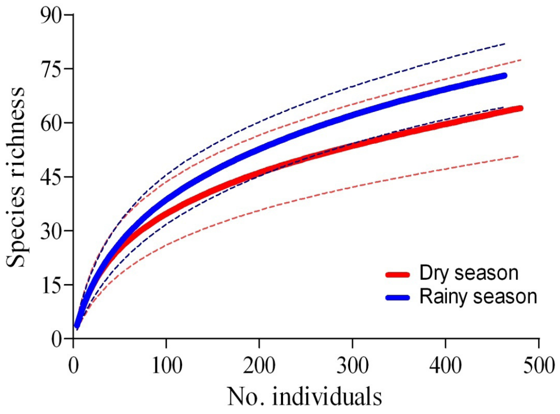

Fig 1. Rarefaction curves of ant species richness (Mao Tao) for dry and wet seasons based on the number of individuals collected. The thinner lines represent the confidence interval of 95%.

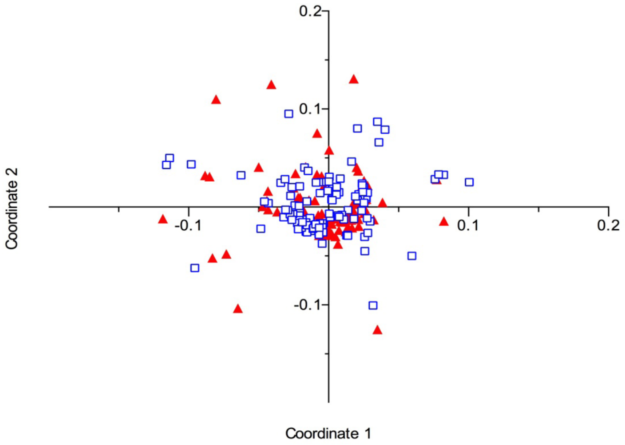

Fig 2. Non-metric multidimensional scaling (NMDS) composition of ants collected in dry (triangles) and rainy seasons (squares) between June 2001 and March 2003 in the hemlock forest, State of Rio de Janeiro, Brazil. This ordination analysis was calculated from Bray-Curtis dissimilarity index's (Stress = 0.615; Axis Axis 1 + 2 = 39.3% of explanation).

Discussion

Several studies have shown that abiotic factors, such as rainfall and temperature, are directly related to the availability of food and nesting sites for insects (Speight et al. 2008). These factors may also influence the foraging activity of ants (Levings, 1983; Almeida et al., 2007). Some previous studies carried out in semi-deciduous areas of the Brazilian Atlantic Forest pointed to an effect of climate seasonality on ant assemblages (Vargas et al., 2007; Castilho et al., 2011). In this study, despite the highest ant richness found in the rainy period, we did not observe an effect of climate seasonality on species richness, diversity, or assemblage structure. However, the expressive number of exclusive species and their frequency in each season suggest that some species may be influenced by seasonality.

Our results corroborate Castro et al., (2012) who also did not found a relationship between ant species richness and seasonality in a degraded area. The lack of correlation observed in the present study may be explained by environmental degradation, which makes the environments simpler (Vasconcelos et al., 2006; Sobrinho & Schoereder, 2007), and increases the competition and abundance of generalistic species (Schoereder et al., 2004). We observed the same pattern in the hypogaeic fauna, as also observed by Figueiredo et al., (2013).

The Cicuta Forest has faced different impacts throughout the years, such as fire, hunting, cattle farming, and logging, mainly in its surroundings, which influence vegetation structure. These impacts certainly restrict the occurrence of more demanding species and contribute to the dominance of a smaller number of generalist species. Currently access to the forest is prohibited, except for scientific research, in order to minimize human impacts and help its conservation. This forest remnant is extremely important to biodiversity maintenance in the region, mainly because it is located within an urban matrix. One example of its importance is the occurrence of a population of *Alouatta guariba clamitans* Cabrera, 1940 (red howler monkey), which may be considered one of the last populations in the Paraíba Valley (Alves & Zaú, 2005).

The ant richness found in the Cicuta Forest is high compared to other forest remnants (Veiga-Ferreira et al., 2005; Castro et al., 2012; Vargas et al., 2013). The assemblage composition of ants is highly generalist, but also we can found a high occurrence of rare species (33%). In addition, it is worth to mention the record of a well-documented pattern for tropical forest fragments with Myrmicinae, Formicinae, and Ponerinae as the subfamilies with highest diversity. The same is true for the genera *Pheidole*, *Camponotus*, and *Solenopsis*, which stood out as the most diverse (Ward, 2000 Ward, 2010; Castilho et al., 2011; Miranda et al., 2013; Dattilo et al., 2011).

However, subfamilies as Amblyoponinae, Cerapachyinae, and Proceratiinae, which are usually recorded in forests, were not represented. This has possibly happened due to the sampling technique used here (see Vargas et al., 2009), as most of their species present cryptic behavior, and reduced size and they rarely forage in the leaf litter (Hölldobler & Wilson, 1990; see Longino et al., 2002; Figueiredo et al., 2013).

Hence, biodiversity conservation in the Atlantic Forest is related to the maintenance of its forest remnants, even if they are relatively small. Therefore, the Cicuta Forest is important for the conservation of biodiversity in semi-deciduous seasonal forests, especially if we consider that variations in rainfall and temperature are important to regulate the ant community. In short, our study contributes to knowledge of how seasonal variations affects ant communities.

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