Original Article

TEMPORAL DYNAMIC OF FORAGING OF EPIGEIC ANTS IN AN URBAN FOREST FRAGMENT

DINÂMICA TEMPORAL DO FORRAGEAMENTO DE FORMIGAS EPIGÉICAS EM UM FRAGMENTO FLORESTAL URBANO

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ABSTRACT: The present study aimed to investigate the foraging dynamic of an ant community in an urban semideciduous mesophitic forest. A total of 4,297 individuals, distributed in 23 species, seven genera and four subfamilies were sampled in January, April, July and October of 2010. Four ant species guilds were found: leaf cutters, soil-dominant omnivores, soil and vegetation opportunists and large-sized epigaeic predators. There were no significant differences in total of species richness and abundance of individuals in samples among the months evaluated. However, there was a clear substitution (turnover) of species over the months. Nine species were sampled exclusively in the rainy period and five species were present only during the dry period. Thus, the species turnover over the months support the hypothesis that ant communities present a temporal dynamics in their foraging activities even in an urban forest fragment. In general, the abundance of ants foraging on soil was greatest during the months with greater rainfall. However, two species belonging to the guild of opportunistic ants from soil and vegetation doubled the number of foraging individuals in period during the months with less precipitation. These findings support that ant communities, independent of isolation and environment (urban or natural), have temporal dynamics that arise from factors relating to the biology and behavior of the group.

KEYWORDS: Ant guilds. Cerrado. Fragmentation. Species richness.

INTRODUCTION

Ants constitute one of the most successful groups of insects (HÖLLDOBLER; WILSON, 1990). They are ubiquitous and diverse and their abundance has been widely recognized (ALONSO; AGOSTI, 2000; RICO-GRAY; OLIVEIRA, 2007). In tropical ecosystems, ants represent up to 80 % of animal biomass (ANDERSEN, 2000; DAVIDSON et al., 2003), and they are an example of successful colonizers of terrestrial environments (FITTKAU; KLINGE, 1973; STRINGER et al., 2009). This success may be related to their great ability to cooperate in the exploitation of natural resources, as hunters, herbivores or detritivores, and their capacity to establish symbiotic relationship with other organisms such as plants (JOLIVET, 1996; GIANOLI et al., 2008), bacteria and fungous (MUELLER et al., 2005), and other arthropods (see RICO-GRAY; OLIVEIRA, 2007). Thus, ants interact with the community in a general way, influencing the population dynamics of a great number of organisms that live there (FOLGARAIT, 1998; RICO-GRAY; OLIVEIRA, 2007).

Due to the wide variety of functions that ants play, the composition and abundance of their assembly are associated with floristic and climatic characteristics of each region (HÖLLDOBLER; WILSON, 1990), as well as environmental disturbances (CERDÁ et al., 2002; ANDERSEN et al., 2002; BRÜHL et al., 2003), which make them good bioindicators of environmental monitoring (ALONSO, 2000; ANDERSEN, 2000; SCHMIDT et al., 2013). According to Delabie and Fowler (1993), striking factors of ant communities, like structure and temporal dynamics of foraging may be influenced by modifications of environment structure, and, therefore, provide important information about conservation of a determined area. In this sense, studies have been searching to understand the impacts caused by the simplification of natural ecosystems through ant community analyses (MAJER, 1996; ANDERSEN, 2000; BROWN JR., 2000), including studies about the impact of urbanization on both structure and functioning communities (LÓPEZ-MORENO et al., 2003).

Ants present a variety of strategies and places for foraging, which makes it possible to separate them into functional groups (SILVESTRE et al., 2003). In general, the activity of food search by ants can be classified by foraging stratum, naming species that forage over the soil and litter as epigeic, those that forage on vegetation as arboreal,

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and those that forage in the subsoil as hypogeic. In addition, there is an ant species classification according to the hierarchy of resource dominance (ant mosaic – LESTON, 1978). Each species is associated with a foraging stratum, and their individuals possess a search-for-food area that is around the nest (TRANIELLO, 1989; BELCHIOR et al., 2012). However, according to Traniello (1989), the variation in food availability relating to seasonal factors can alter the path and the distance of ants' search for food. Beside this, the richness and abundance of a species that forage in a specific stratum may also vary. This high sensibility of ants to the environmental characteristics highlights the importance of this group for testing hypotheses about species richness (e.g. KASPARI et al., 2003) and community dynamics (BRONSTEIN, 1998; GOTELLI; ELLISON, 2002; RICO-GRAY; OLIVEIRA, 2007).

In general, food production varies with seasonal rainy patterns in tropical environments. The plant resource consumers, including ants, track this production in space and time, adjusting their foraging activities with food availability (e.g. CARROLL; JANZEN, 1973; POL et al., 2011; BELCHIOR et al., 2012). In the Brazilian savannah (Cerrado), precipitation is seasonally discontinuous and yields high temporal heterogeneity in food production, primarily of vegetal origins (FRANCO, 2002). This scenario can significantly affect both patterns of foraging and feeding of Cerrado insects, including ants, during the whole year (YAMAMOTO; DEL-CLARO, 2008; MARQUES; DEL-CLARO, 2010; BELCHIOR et al., 2012).

An examination of foraging patterns in a whole year allows narrowing the range of factors affecting the activity levels in assemblages of ants (HANN; WHEELER, 2002). In this sense, this study aimed to evaluate the dynamics of epigeic ant community foraging in an urban forest fragment looking for changes in foraging patterns due to temporal variations. The hypothesis is that ant communities vary throughout the year in relation to abundance of individuals, richness and composition of species. Besides, it is expected a turnover of species over the months and that in periods with lower precipitation occur a greater number of species due to decrease of food availability and the intensification of foraging activity.

MATERIAL AND METHODS

The present study was carried out in Parque Municipal Bosque John Kennedy (PMBJK), a municipal park located in the urban perimeter of Araguari city (48°11'19" W and 18°38'35" S) in the state of Minas Gerais, Brazil. The park area of 11.2 ha is occupied by a primary and secondary semideciduous mesophitic forest with trees up to 25 m high. Its vegetal community is similar to the native reserves of the region; that is, it possesses closed areas, with high trees and a dense canopy, next to gaps that are forming and in a recovering phase. Despite being an urban forest subjected to anthropic actions, according to Araújo et al., (1997), and Souza and Araújo (2005), the PMBJK still retains a high natural floristic diversity. As shown in Fig. 1, the study region presents two distinct periods: a rainy period with high temperatures (January, February, and October to December) and another period that is drier with low temperatures (March to September).

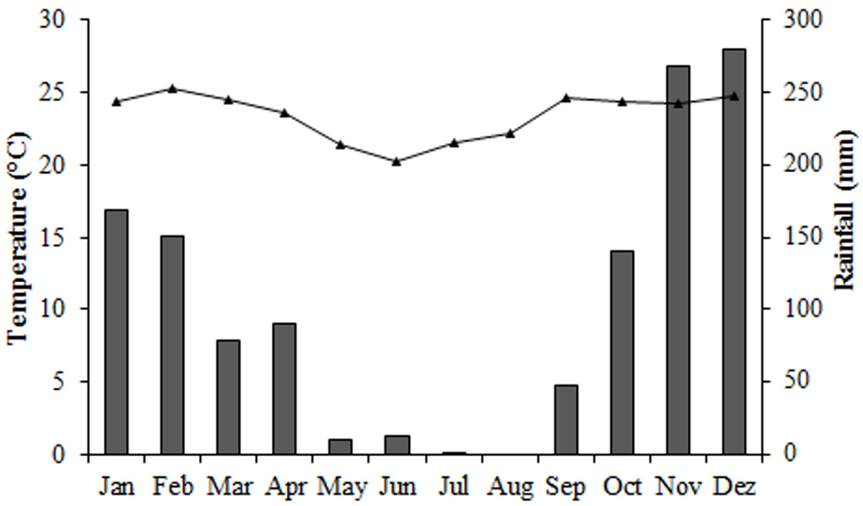

Figure 1. Mean temperature (°C) in bar and monthly precipitation (mm) in line during 2010, from the nearest city of Araguari, Minas Gerais, Brazil.

In sampled months (January, April, July and October of 2010), 50 pitfall traps were distributed in 10 parallel rows, distant at least 50 m from each other. In each row, traps were separated 10 m from each other. In all sampled period, the rows were randomly distributed throughout the area of the PMBJK. In order to achieve the study's goals, all traps were placed at the same points in the four samplings. The traps consisted of a plastic pot of a volume of 1 L and diameter of 15 cm filled with 200 ml of alcohol to 70 %, 5 ml formol to 10 % and liquid detergent (added to break the surface tension of the solution). Each trap was covered with a plastic cover located 7 cm above the pot edge and sustained by wooden sticks. After 5 days of permanence in the field, the traps were removed and the material was sorted in Petri dishes with the aid of a stereo microscope. Then, the ants were identified using keys of Bolton (2003) and after separated by guilds according to the methodology for Cerrado species by Silvestre et al., (2003). After these proceedings, specimens were deposited in the reference collection of the Laboratório de Zoobotânica da Universidade Presidente Antônio Carlos (UNIPAC), Campus Araguari, Minas Gerais, Brazil. Climatic data (temperature and precipitation) were obtained in the climatology station nearest the study area, in Universidade Federal de Uberlândia, in Uberlândia, Minas Gerais, located 30 km from the PMBJK.

The pitfall traps method was chosen due to their efficiency for capturing ants are rarely sampled through traditional methods of active search. In addition, these traps allow uniform sampling of individuals that forage during day and night. As the objective of this study was not to measure the ant diversity of fragment, but the temporal variation of foraging in one local inside of the fragment, the collection method using pitfall traps was sufficient.

EstimateS software version 8.2 (COLWELL, 2013) was used to generate species accumulation curves in terms of the sampling effort employed. The estimated species richness was calculated for each area using the Jackknife 2 index. This index is based on the numbers of species that occur only once in a sample and those occurring twice. In order to analyze the data, each sample corresponded to a row including five traps, totaling 40 samples evaluated to the end of the study period. Analysis of variance (ANOVA) for repeated measures was used to compare both individual abundance and species richness among the four months. The analysis was carried out using the Systat 13.0 program. A log(x+0.5) transformation was first applied to the data of ant abundance to normalize the data. In addition, to verify the similarity among the months sampled the Bray-Curtis index was used, starting from a matrix of individual abundance for each ant species using the program BioDiversity Professional version 2.

RESULTS

A total of 4,297 individuals were sampled, belonging to 23 ant species, seven genera, and four subfamilies (Table 1). Analyze of the accumulated richness curves (observed and estimated) indicated that sampling of the ant fauna was achieved in the second evaluation (Figure 2). This result proves that the sampling effort was satisfactory and the variations in the occurrence of species found among the months evaluated in this study are due to the temporal variation in foraging species.

Table 1. Abundance and relative frequency (% in parentheses) of ant species found in trimonthly samples evaluated in the Bosque Municipal de Araguari, MG, Brazil. The letter in "Guild" column mean: (*lc*) leaf cutters, (*so*) soil-dominant omnivores, (*svo*) soil and vegetation opportunists, and (*lep*) large-sized epigeic predators.

Subfamily/Species	Guild	January	April	July	October	Total
Ponerinae						
Odontomachus chelifer (Latreille, 1802)	*lep*	96(14.30)	32(8.33)	4(5.55)	8(5.88)	**140(8.20)**
Odontomachus meinerti Forel, 1905	*lep*	-	-	20(5.55)	-	**20(1.64)**
Pachycondyla verenae Forel, 1922	*lep*	57(7.14)	25(8.33)	16(11.12)	-	**98(6.56)**
Pachychondyla (gp. *harpax*) sp 1	*lep*	2(7.14)	-	-	-	**2(1.64)**
Pachychondyla (gp. *harpax*) sp 2	*lep*	122(14.30)	36(8.33)	13(5.55)	14(5.88)	**185(8.20)**
Ectatomminae						
Ectatomma lugens Emery, 1894	*lep*	-	-	-	4(11.78)	**4(3.28)**
Gnamptogenys sp 1	*lep*	-	-	-	3(5.88)	**3(1.64)**

Myrmicinae						
Pheidole megacephala (Fabricius, 1793)	*so*	-	24(8.33)	-	-	**24(1.64)**
Pheidole longicornis Emery, 1888	*so*	-	-	-	31(5.88)	**31(1.64)**
Pheidole sp 1	*so*	-	-	1(5.55)	-	**1(1.64)**
Pheidole sp 2	*so*	55(7.14)	17(8.33)	41(5.55)	20(5.88)	**133(6.56)**
Pheidole sp 3	*so*	-	-	178(5.55)	-	**178(1.64)**
Pheidole sp 4	*so*	-	-	40(5.55)	-	**40(1.64)**
Pheidole sp 5	*so*	7(7.14)	-	-	-	**7(1.64)**
Pheidole sp 6	*so*	-	-	-	2(5.88)	**2(1.64)**
Pheidole sp 7	*so*	-	-	-	63(5.88)	**63(1.64)**
Acromyrmex sp 1	*lc*	213(7.14)	16(8.33)	105(5.55)	135(5.88)	**469(6.56)**
Formicinae						
Camponotus sericeiventris (Guérin-Méneville, 1838)	*svo*	68(7.14)	9(8.33)	22(11.12)	6(5.88)	**105(8.20)**
Camponotus lespesii Forel, 1886	*svo*	6(7.14)	7(8.33)	9(11.12)	1(5.88)	**23(8.20)**
Camponotus crassus Mayr, 1862	*svo*	31(7.14)	217(16.68)	188(11.12)	86(11.78)	**522(11.48)**
Camponotus gp. *bidens* Mayr, 1970	*svo*	-	-	-	7(5.88)	**7(1.64)**
Camponotus sp 1	*svo*	264(7.14)	1069(16.68)	747(11.12)	2(5.88)	**2082(9.84)**
Camponotus sp 2	*svo*	6(7.14)	-	-	152(5.88)	**158(3.28)**
Total abundance		**838**	**1420**	**1384**	**526**	**4,297**

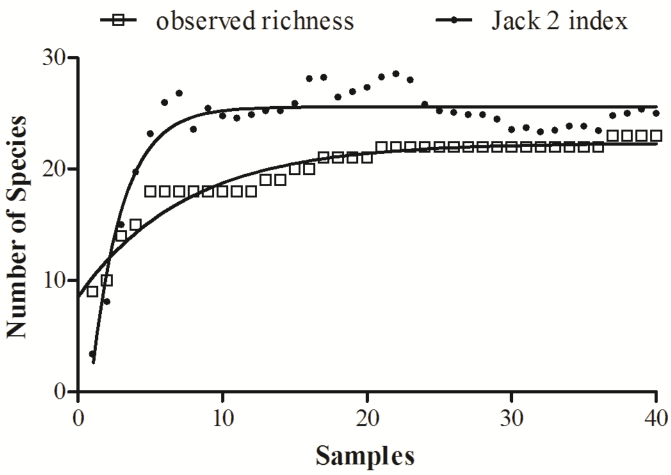

Figure 2. Observed richness and estimated richness (Jack 2 index) of ant species found in forty samples evaluated in January, April, July and October of 2010 in the Bosque Municipal de Araguari, MG, Brazil.

Out of the 15 guilds of ant species described by Silvestre et al., (2003) for the Cerrado Biome, four were found in this study: leaf cutters (*Acromyrmex* sp), soil-dominant omnivores (*Pheidole* spp), soil and vegetation opportunists (*Camponotus* spp), and large-sized epigeic predators (genera species of *Odontomachus*, *Pachycondyla*, *Ectatomma*, and *Gnamptogenys*) (Table 1).

The guild with the highest abundance of individuals was soil and vegetation opportunists, with six species and 2,897 individuals (Figure 3). The soil-dominant omnivore guild, represented by the *Pheidole* genus, was the second most abundant, with 479 individuals distributed in nine species. These two guilds/genera together encompassed about 78.4 % of all the individuals collected. Both leaf cutters and large soil predators were also abundant; 469 and 452 individuals were found foraging through the year distributed in one and seven species, respectively.

April and July presented a great abundance of individuals foraging, however, there was no significant difference among all months analyzed (F = 1.484; df = 39; p = 0.241). A similar result was observed with species richness in samples. Great values were observed in July and October but there was no significant difference among the months evaluated (F = 0.450; df = 39; p = 0.718). October presented the highest total species richness of foraging ants (15 species), followed by July and January and April (see Table 1). However, despite having no difference in richness and abundance of individuals in samples among the months, there was a clear substitution (turnover) of species over the months. Considering the 23 species collected, nine were exclusive in sampling of raining period and five species were present only during the dry period.

Based on Fig. 4A, it is evident that there was a variation in foraging activities by all ant guilds found in the traps. Only 34 % of the species (eight species) were found in the four months (Table 1). The soil and vegetation opportunist guild was the most abundant group in the four samplings, constituting more than 60 % of all individuals collected in both April and July. The turnover of individuals of different guilds/species foraging in the different months resulted in a similar richness of species within all samplings (Fig. 4B). This result is evidenced in Fig. 5. In this same figure it is also possible verify a greater similarity between the months of April and July (dry period) and a greater difference between October and the other months sampled.

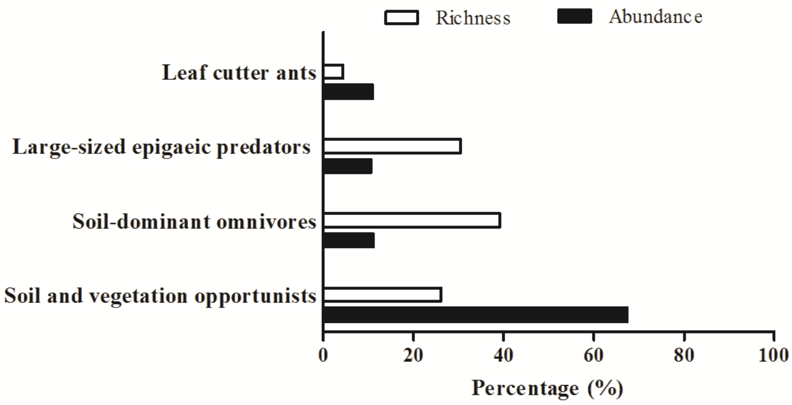

Figure 3. Total percentage of individual abundance and species richness of four ant guilds found from January to October in 2010, in Bosque John Kennedy, Araguari, Minas Gerais, Brazil.

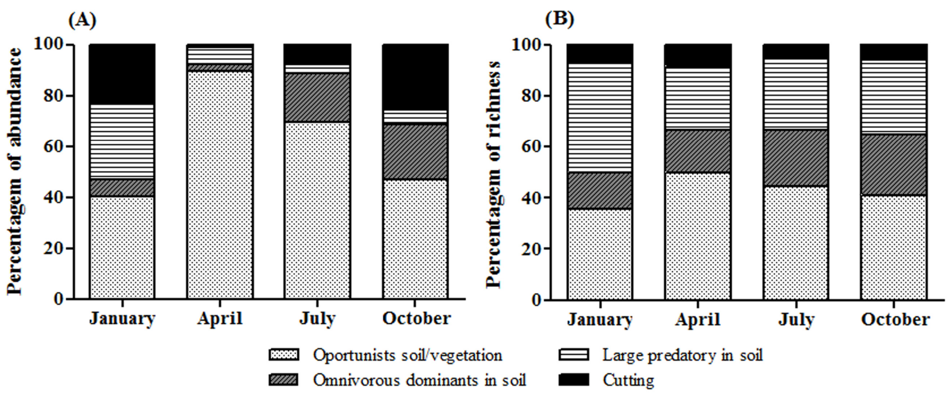

Figure 4. Percentage of individual abundance (A) and species richness (B) of four ant guilds found during samplings carried out in 2010, in Bosque John Kennedy, Araguari, Minas Gerais, Brazil.

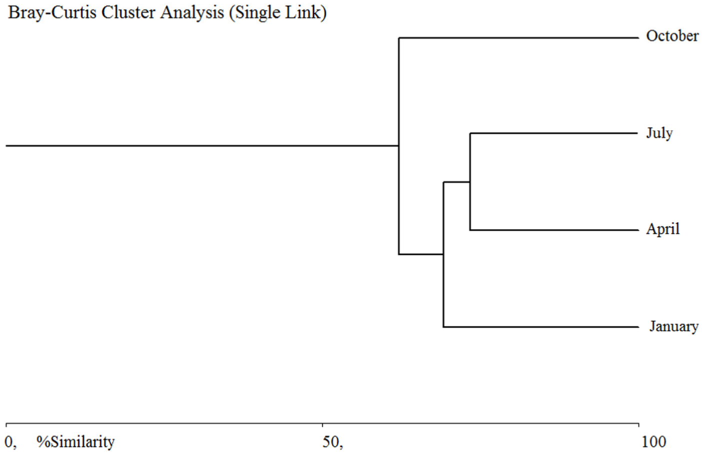

Figure 5. Ant community similarity (Bray-Curtis index) among evaluations (months) carried out in 2010, in Bosque John Kennedy, Araguari, Minas Gerais, Brazil.

DISCUSSION

The data obtained in the present study support the initial hypothesis that ant communities show temporal variation in foraging, represented by variation in abundance of individuals of each species and by substitution (turnover) of species over the months. This turnover of species among the months resulted in lack of significant difference in total of species richness and abundance of individuals and a variation in similarity of ant fauna among the months.

Ants of the soil and vegetation opportunists guild were the most frequent in the present study. These guilds have species with a large number of individuals in the nests, massive recruitment to collect food, and display high aggressive behavior, to inhibit the foraging of other species (SILVESTRE; SILVA, 2001). Further, some *Camponotus* species possess several adaptations for both soil and vegetation and establish mutualistic associations with plants, hemipterans and lepidopterans (OLIVEIRA; BRANDÃO, 1991; BRANDÃO et al., 2000) resulting in the success of the group in diverse environments.

The soil-dominant omnivore guild, represented by the *Pheidole* genus in this study, was the most abundant in number of species. According to Bolton (1995), *Pheidole* is between the 10 richer genera in number of Formicidae species. This high species richness added to the fact that the nests have many individuals, make this genus ubiquitous in natural or disturbed environments (see ANDERSEN, 2000; BROWN Jr., 2000; WARD, 2000; LANGE et al., 2008).

The great species number and low abundance found in the present study for the large-sized epigeic predator guild could be related to foraging strategy, since they have solitary foraging and nests with few individuals (SILVA; BRANDÃO, 1999; SILVESTRE, et al., 2003; VIEIRA et al., 2007). These findings, in turn, reduce the chance of finding them, compared with ant colonies with many individuals and massive foraging.

The leaf cutter ant guild was represented by one species in this study, but its abundance was similar to both the soil-dominant omnivore and large-sized epigeic predator guild. Species of leaf cutter ants are exclusive to neotropical regions and their importance in these areas has been largely documented in agroecosystems where they result in great economic losses (BOARETO; FORTI, 1997; BURRATO et al., 2012). In natural environments, the leaf cutters also cause significant damage to plant communities, although, due to the presence of natural enemies, this damage is not so harmful to the whole community (BRAGANÇA et al., 2009).

The major number of ants foraging during the months of low precipitation in the present study was influenced mainly by two species (*C. crassus* and *Camponotus* sp1). The other species that were found in the four samples had highest abundance in the months of rainy season (January and October). This results may be related to the foraging strategy of each species (PORTER; TSCHINKEL, 1987), to the physical barrier imposed by rain, to the efficiency of the pitfall trap during the rainy months, and to the variation of available resources (NUNES et al., 2011). According to Dos Santos et al., (2012), in the Cerrado biome, during the months with lowest precipitation, the availability and quality of food fall sharply, influencing populations directly, including some ant species (see COGNI; OLIVEIRA, 2004; YAMAMOTO; DEL-CLARO 2008). Consequently, some species that forage on soil and vegetation may intensify their patrolling on soil in searching for food when the resources in the vegetation are scarce. This pattern was evident in this study for *C. crassus* and *Camponotus* sp1. Other species, on the other hand, intensified their search for food during the rainy season, such as *Odontomachus chelifer, Pachycondyla verenae, Pachycondyla* sp2, *Acromyrmex* sp1, and *Camponotus sericeiventris*. Therefore, the hypothesis that the decrease in supply of resource intensifies the foraging for food was not evident for most of the ant community studied.

One factor, which was not evaluated in this study, but may have influenced the temporal dynamics of foraging ants, is the competitive hierarchy among ant species inside and outside of intra and inter-guilds. A possible evidence of this is the fact that species with massive recruitment usually dominate the resources, inhibiting the presence of other species (SILVESTRE, 2000; PARR; GIBB, 2010). As a result, for the ant community of the present study, the highest presence of the large-sized epigeic predator guild during the period of greatest rainfall may be the temporal reflex of this hierarchy competition by food resources. In other words, the guilds with massive recruitment (the soil and vegetation opportunist guild and soil-dominant omnivore guild) may inhibit foraging in the driest period of the year and reduce this dominance in the wettest periods.

Other factors influencing the foraging patterns of ant species are the reproductive period and size of the colony. Larger colonies with massive recruitment, as is the case of minor species, need constant food to maintain all individuals of the colony (TRANIELLO, 1989). Nevertheless, larger species with small colonies increase their foraging in the reproductive period, because the food demand is higher in this period (SILVESTRE, 2000). These characteristics would explain, in part, the foraging pattern observed in the present study, of species abundant in the driest period of the year, like *Pheidole* and *Camponotus*.

Thus, our initial hypothesis of a temporal dynamics in activity of ants was confirmed. However, the increase in search for food occurred during the rainy season, with an exception of two species of *Camponotus*. Our findings highlight that ant communities, independent of isolation and environment (urban or natural), have temporal dynamics that arise from factors relating to the biology and behavior of the group.

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RESUMO: O presente estudo teve como objetivo investigar a dinâmica temporal do forrageamento da comunidade de formigas de um fragmento de mata mesófila semidecídual urbana. Um total de 4.297 indivíduos, distribuídos em 23 espécies, sete gêneros e quatro subfamílias foram coletados nos meses de janeiro, abril, julho e outubro de 2010. Quatro guildas de espécies de formigas foram encontradas: Cortadeiras, Onívoras dominantes de solo, Oportunistas de solo e vegetação e Predadoras epigéicas grandes. Não houve diferenças significativas na riqueza de espécies e na abundância de indivíduos encontrados nas amostras entre os meses avaliados. Entretanto, houve uma clara substituição (*turnover*) de espécies ao longo dos meses. Nove espécies foram amostradas exclusivamente no período chuvoso e cinco espécies no período seco. Assim, a substituição das espécies ao longo dos meses reforça a hipótese de que comunidades de formigas apresentam uma dinâmica temporal em suas atividades de forrageamento mesmo em um fragmento florestal em área urbana. No geral, a abundância de formigas forrageando no solo foi maior durante os meses de maior pluviosidade. Entretanto, duas espécies da guilda de formigas oportunistas de solo e vegetação dobraram o número de indivíduos forrageando no período de menor precipitação. Estes resultados comprovam que as comunidades de formigas, independente do isolamento e ambiente (urbano ou natural), possuem uma dinâmica temporal na atividade de forrageamento que surgem a partir de fatores relacionados com a biologia e o comportamento de cada grupo e espécie.

PALAVARAS-CHAVE: Guildas de formigas. Cerrado. Fragmentação. Riqueza de espécies.

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