Sociobiology

An international journal on social insects

RESEARCH ARTICLE - ANTS

How does landscape anthropization affect the myrmecofauna of urban forest fragments?

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Abstract

We evaluate whether landscape variables surrounding urban remnant forest fragments influence ant diversity and its components in urban areas. The study was conducted in six riparian forest fragments in midwestern Minas Gerais State, Brazil, by sampling epigaeic and arboreal ants. Arboreal ants respond to fragment isolation with changes in alpha, beta and gamma diversities. Isolation likely hinders dispersion and re-colonization such that the more isolated a fragment is, the less likely that new species arrive there. On other hand, epigaeic diversity did not show any response to variables of the surroundings or fragments, probably because natural periodic floods constitute a more severe disturbance for these ants. In addition, throughout the process of urbanization, anthropogenic improvements, such as paving, that prevent the natural percolation of water, increase the flooding of riparian soil. Arboreal ant species composition responds to percentage of urban area, fragment area and distance from the urban center, while epigaeic ants respond only to fragment area and percentage of urban area. We believe that even with the loss of species diversity and anthropogenic influences on fragments within urban centers, these areas are still important for species conservation. We also suggest the development of environmental protection projects for riparian areas within urban centers, including investments in ecological corridors connecting fragments and public policies seeking to preserve these areas.

Introduction

Currently there are few ecosystems that do not experience anthropic pressure (Barlow et al., 2012). These pressures are derived from the increasing human population and the consequent increase in urbanization, which leads to the reduction of green areas and biodiversity loss (Uno et al., 2010). Green areas in urban cities are generally restricted to street islands, tree lined streets, squares, home gardens, parks, and riparian forests (Loboda & De Angeles, 2005). Since they are denominated as Permanent Preservation Areas (PPA) by the Brazilian Forest Code (Law 12.651/2012), riparian forests are usually the largest, or the only remaining, green areas in cities.

From the social point of view, the presence of green areas improves quality of life because they are related to leisure, landscaping, and environmental preservation (Loboda & De Angeles, 2005), as well as human health (Thompson et al., 2012; Campos & Castro, 2017). In addition to social aspects, such areas have the potential to play a role in the conservation of biodiversity (Doody et al., 2009). Regarding birds and insects, urban green areas are important for provisioning shelter and different food resources, mostly for generalist species but also benefitting some specialist species that inhabit forest areas surrounding cities (Goddard et al., 2009), thus ensuring a varied species composition (Pacheco & Vasconcelos, 2012).

Among insects, ants represent a group of abundant, diversified organisms that can serve as bioindicators (Underwood et al., 2006; Philpott, 2010; Ribas et al., 2012), and which inhabit several strata including soil, litter, and trees. Ants of different strata have distinct responses to environmental

changes (Vargas et al., 2007; Schimdt & Solar, 2010; Neves et al., 2014). Moreover, ants are involved in several ecosystem functions, such as defense against herbivores (Lourenço et al., 2015), seed dispersal (Dominguez- Haydar & Ambrecht et al., 2011), and nutrient cycling (Souza-Souto et al., 2007). In this sense, the conservational status of an area may determine the number and identity of species inhabiting it. For example, Pacheco and Vasconcelos (2007) found that large public squares close to natural areas have higher ant species richness. Therefore, the area of a fragment, as well as its distance from the urban center, and the existence of natural vegetation in the surroundings, could be considered good predictors of the diversity of arthropods in urban areas (Egerer et al., 2017).

Urbanization and landscape metrics have been shown to influence arthropod communities (McKinney, 2008). Ortega and Meneses (2015) found that ant diversity is related to the level of impact, while Fattorini (2013) documented a rapid increase in the loss of tenebrionid beetles in an urban area. Jost (2010) points to the need for understanding distribution patterns in the geographic space that butterfly species inhabit because it can contribute to decision-making by environmental managers regarding land use and occupation in urban cities. Egerer et al. (2017) showed that an increase in percentage of urban area, a landscape metric, promoted an increase of invasive ant species, while Soga et al. (2012) reinforced the importance of fragment metrics by arguing that circularizing the shape of forest patches maximizes the core areas to preserve biodiversity in urban areas where small forest remnants dominate.

In this sense, understanding the spatial patterns of species richness is very important for the development of conservation strategies (Marques & Schoereder, 2013). On the other hand, the use of different parameters may lead to different results. In fact, in their review paper Ribas et al. (2012) noted that papers using ant species richness as an indicator parameter for disturbance concluded that the number of species can increase, decrease or remain unchanged. Thus,

the authors concluded, richness is not a good bioindicator parameter and suggested that species composition is the most suitable parameter for evaluating the effect of disturbance on ant communities. In a multi-taxa study, Kessler et al. (2009) also concluded that changes in species composition (referred to by them as beta diversity) are more consistent than changes in species richness (alpha diversity).

Therefore, we aimed to evaluate whether landscape metrics influence ant diversity (richness and composition) of forest fragments in urban areas. We also sought to understand whether this influence differs among different spatial scales (alpha, beta and gamma diversities). We investigated the hypothesis that fragments that are larger, more distant from the urban center, less isolated and with a smaller percentage of urban area and more forest cover in the surrounding area will have a greater number of ant species and dissimilar ant species composition.

Material and Methods

Study area

We conducted the study during the rainy season, from February to April, in six riparian forest fragments in the urban area of Divinópolis, midwestern Minas Gerais State, Brazil (20º 8'21" S and 44º 53'17" W). The municipality has an area of 716 km^2 and the urban area consists of 192 km^2 with approximately 228 thousand inhabitants (IBGE, 2014). The original vegetation is predominantly Cerrado (Brazilian savanna) and the climate is temperate humid with a dry winter and hot summer, according to Köppen's index. The rainiest months are from December to March whereas the driest are from April to November. The municipality is crossed by the Itapecerica and Pará rivers; the first is the major source of water for the population and passes through the city for part of its 18 km length. Four of the six fragments sampled in this study, are on the banks of the Itapecerica river, while the other two are on the banks of the Pará river (Table 1).

Table 1. Description of studied urban fragments of riparian forest in the municipality of Divinópolis, Minas Gerais, Brazil. The fragment F1 is the closest to the urban center whereas F6 is the farthest.

Fragment	Arboreal ant richness	Epigaeic ant richness	River	Riverbank	Coordinates	Extension
F1	12	03	Itapecerica	Left	20°08'30.2" S 44°53'00.6" W	600m length 180 m width
F2	10	12	Itapecerica	Right	20°08'05.8" S 44°52'51.4" W	190 m length 130 m width
F3	12	08	Itapecerica	Right	20°07'49.7" S 44°52'52.4" W	180 m length 60 m width
F4	08	05	Itapecerica	Right	20°11'32.5" S 44°53'36.9" W	1000 m length 620 m width
F5	05	15	Pará	Left	20°06'36.34" S 44°50'01.80" W	300 m length 410 m width
F6	12	08	Pará	Right	20°07'51.20" S 44°52'53.98" W	600 m length 800 m width

Sampling Design

Since some of the studied remnants were very small, we used a 50-m transect, inserted perpendicular to the riverbank and at least 50 m from the fragment edge, to sample ants. For each transect, we established five sampling points 10 m apart from each other, with the first being 10 m from the riverbank. At every sampling point we collected ants in two strata (arboreal and epigaeic) by using pitfall traps (Bestelmeyer et al., 2000; Ribas et al., 2003), since this method is very common in bioindicator studies (Ribas et al., 2012). Pitfalls were made with plastic containers (10 cm high and 20 cm in diameter), containing sardine and honey as bait. The traps were kept in the field for 48 hours, after which the material was collected, sorted, mounted, identified to the level of genus using the key provided by Bolton (1994) up dated by the key of Baccaro et al. (2015), and separated to morphospecies by comparison with the reference collection of Laboratório de Ecologia de Comunidades de Formigas of the Universidade Federal de Viçosa.

In order to calculate landscape metrics, we used a land use map based on cartographic data from the Terra Class Cerrado Project, under the responsibility of the Instituto Nacional de Pesquisas Espaciais (INPE). For each fragment we calculated dits area and then arbitrarily defined the urban center as the intersection of the two main streets of the business center (Avenida Primeiro de Junho and Rua Goiás, 20°08'50.30''S; 44°53'17.43''W), to measure the distance from the edge of the analyzed fragments to the urban center. Distance from the nearest fragment, which we considered as an isolation metric, was calculated from the Euclidian distance from the edge of each analyzed fragment to the edge of the next nearest fragment. The percentage of urban area and the percentage of forest cover in the surrounding area we calculated for a 500-m buffer from the fragment centroid. These metrics were calculated in ArcGIS 10.2 with softwares V-LATE and Patch Grid.

Statistical analyses

We carried out analyses of diversity and composition separately for each stratum (arboreal and epigaeic). Species richness was estimated by the jackknife technique of the vegan package (Oksanen et al., 2007) in R-project software ver. 3.3.2. We determined gamma diversity as the total number of species collected per fragment, alpha diversity as the mean number of species collected by pitfall traps within each fragment, and the beta diversity as the difference between alpha and gamma diversities (Magurran, 2004).

In order to determine if landscape variables were correlated we used Pearson correlation for normally distributed variables (distance of urban center, percentage of forest cover and percentage of urban area) and Spearman correlation for non-normally distributed variables (fragment area and isolation). For correlated variables (>70%), the variable with the greater biological significance to the aim of the study was retained while the others were excluded from the analyses. We tested for correlations between explanatory variables related to fragments (area and isolation) and among those related to the surroundings (distance of urban center, percentage of forest cover and percentage of urban area) separately.

We tested the hypothesis that landscape metrics influence ant diversity by constructing generalized linear models (GLMs) using landscape metrics as explanatory variables. Since we did not have enough degrees of freedom to test all variables in the same model, we constructed two models, separating explanatory variables that related to fragments (area and isolation) from those related to the surroundings (distance of urban center, percentage of forest cover and percentage of urban area). Because different groups of ants may exhibit distinct responses to different environmental factors, the analyses were carried out separately for epigaeic and arboreal ants. Thus, alpha, beta, and gamma diversities of each stratum were considered separately as response variables. We tested for normality and corrected distributions when necessary. These analyses were performed with R software (R Development Core Team, 2014).

To investigate whether there were differences in myrmecofauna composition in relation to the landscape metrics, again using fragment variables and surrounding variables separately, we conducted a multivariate analysis based on the distance based linear models (DISTLM). We used the composition of each fragment as the response variable. Tests were performed using the Jaccard similarity index with 999 permutations, adjusted to the matrices of presence and absence. This analysis was done in the software Primer v6 (Clark & Gorley, 2006).
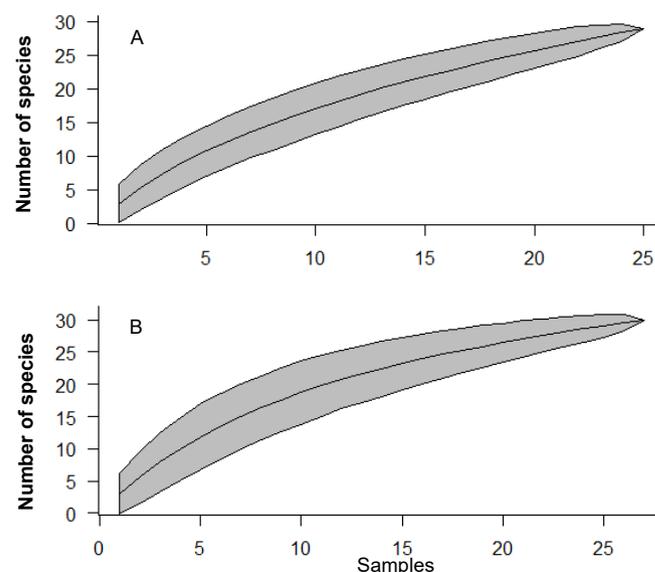
Fig 1. Accumulation of ant species collected in urban fragments of riparian forest: A) arboreal ants; B) epigaeic ants.

Table 2. Ant species sampled in each of six urban fragments of riparian forest. The letter "A" refers to ants sampled in the arboreal stratum whereas the letter "E" refers to ants collected in the epigaeic stratum.

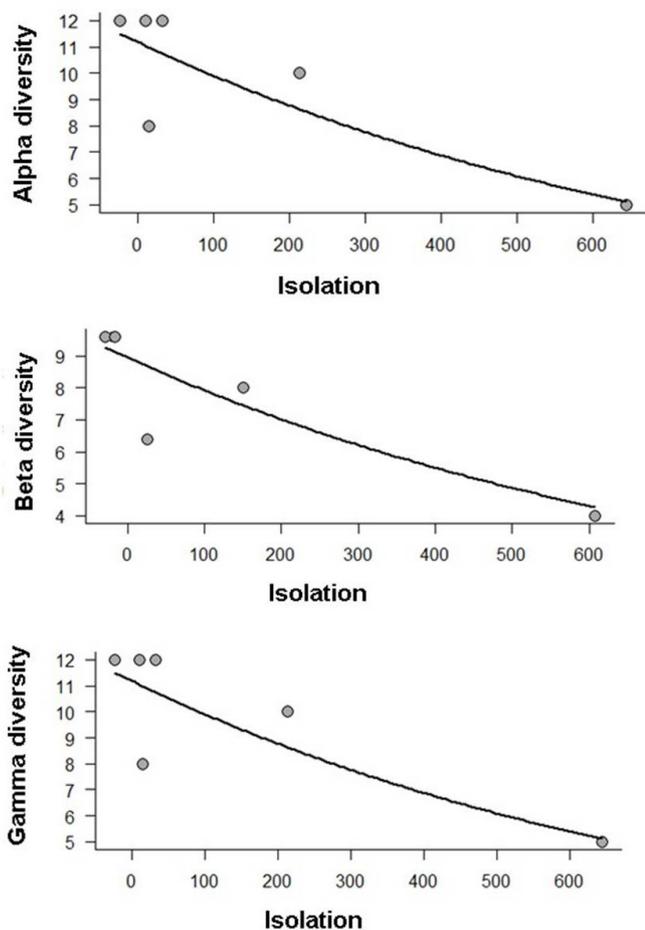| Species	F1	F2	F3	F4	F5	F6
Atta sexdens (Linnaeus, 1758)				A	A	
Brachymyrmex sp. 1					E	
Camponotus agra (Smith, 1858)				A		
Camponotus atriceps (Smith, F., 1858)			A	A	A	A
Camponotus crassus (Mayr, 1862)	A			A		
Camponotus melanoticus (Emery, 1894)						A
Camponotus rufipes (Fabricius, 1775)	A					
Camponotus sericeiventris (Guérin-Méneville, 1838)			A		A	
Camponotus (Tanaemyrmex) sp. 1						A
Camponotus sp.						E
Camponotus sp. 1						A
Camponotus sp. 2		A	A			A
Camponotus sp. 6		A				A
Carebara sp.		E				
Cephalotes pusillus (Klug, 1824)	A	A	A	A		
Cephalotes sp. 1					E	
Cephalotes sp. 3		A	A			
Crematogaster acuta (Fabricius, 1804)	A	A, E	A		E	
Crematogaster sp. 2			A			A
Crematogaster sp. 4	A	A	A			
Crematogaster sp. 7		E	E	E		
Crematogaster sp. 8			E			
Dolichoderus validus (Kempf, 1959)		A		A		A
Ectatomma edentatum (Roger, 1863)						E
Hypoponera sp. 1			A			
Hypoponera sp. 2		E				
Hypoponera sp. 9		E	E	E	E	
Labidus coecus (Latreille, 1802)				E		
Leptogenys sp. 1				E		
Linepithema sp.					E	
Linepithema sp. 1				A		
Megalomyrmex modestus (Emery, 1896)					E	
Mycocepurus sp.						E
Neivamyrmex planidorsus (Emery, 1906)			E			
Nesomyrmex sp. 1						A
Nylanderia sp. 1		A, E	A, E		E	A
Octostruma balzani (Emery, 1894)		E	E			
Odontomachus bauri (Emery, 1892)					E	
Odontomachus meinerti (Forel, 1905)		E			E	
Pachycondyla vilosa (Fabricius, 1804)	A					
Pheidole gertrudae (Forel, 1886)					E	
Pheidole radoszkowiskii (Mayr, 1884)					E	E
Pheidole sp. 1	A	A				
Pheidole sp. 8			E		E	
Pheidole sp. 16		E	E		E	E
Procryptocerus sp. 1			A			A
Pseudomyrmex sp. 12		A				
Solenopsis sp. 2	A, E	E		A, E	A, E	E
Strumygenys sp.	E					
Strumygenys sp. 1		E				
Strumygenys sp. 2						E
Wasmannia auropunctata (Roger, 1863)	A, E	A, E	E		A, E	E
Wasmannia sp. 1	A					
Wasmannia sp. 2	A					
Wasmannia sp. 3			A			A
Total arboreal species	**11**	**11**	**12**	**8**	**5**	**12**
Total epigaeic species	**3**	**12**	**9**	**5**	**15**	**8**

Results

We collected 55 species belonging to six subfamilies. Twenty-six species were collected only in the arboreal stratum, 25 species were collected exclusively in the epigaeic stratum, and four species were common to both strata (Table 2). Our samples represented 72.3% and 65.4% of the total number of species estimated by the jackknife technique for the arboreal and epigaeic ant faunas, respectively (Figure 1).

Percentage of urban area and percentage of forest cover were correlated (Table 3); therefore, we opted to retain only percentage of urban area since we were interested in

the impacts generated by anthropization. None of the other variables were correlated (Table 3).

With respect to the variables related to fragments (fragment area and isolation), the diversities of the arboreal stratum (alpha, beta and gamma) were not influenced by fragment area (Table 4) but were negatively influenced by isolation (Figure 2). The variables related to the surroundings (percentage of urban area and distance of urban center) did not have an influence on arboreal ant diversity (alpha, beta and gamma) (Table 4). For the epigaeic stratum, none of the explanatory variables, either related to fragments or to surroundings, influenced alpha, beta and gamma diversities (Table 4).

Table 3. Correlation between landscape metrics. Bold values indicate significant correlations.

Landscape variables	p value	R value
Fragment area x Isolation	0.9493	-0.033
% Urban area x % Forest cover	**0.0156**	-0.896
% Urban area x Distance of urban center	0,0817	-0.756
% Forest cover x Distance of urban center	0.1866	0.622

Of the variables linked to fragments, the composition of arboreal ants was influenced by fragment area ($p = 0.011$), which explained 7% of the variation. Of the variables related to the surroundings, two influenced the composition of arboreal ants, the percentage of urban area ($p = 0.015$) and the distance of urban center ($p = 0.045$), with each explaining 6% of the variation. Epigaeic ant species composition was influenced by fragment area ($p = 0.044$; 6%) and percentage of urban area ($p = 0.017$; 7%).

Discussion

Fragment isolation (distance from nearest fragment) was found to influence ant richness (diversity alpha, beta and gamma) of forest fragments in the studied urban area, and this influence is similar regard less of the spatial scale analyzed, but dependent on the stratum. Arboreal ants were found to be responsive to the isolation of fragments while epigaeic ant diversity was not influenced by any variable. Composition of arboreal ants was affected by fragment area, percentage of urban area and distance of urban center, while composition of epigaeic ants was responsive only to fragment area and percentage of urban area.

Fig 2. Relationship between isolation (calculated from Euclidian distance from the edge of each analyzed fragment to the nearest fragment edge) and diversity of arboreal ants. Alpha diversity: $F_{(1,3)}= 6.339$; $p = 0.004$. Beta diversity: $F_{(1,3)}= 6.340$; $p = 0.004$. Gamma diversity: $F_{(1,3)}= 6.339$; $p = 0.004$.

Table 4. Influence of landscape metrics (F-values) on alpha, beta and gamma ant diversity. Values with * are significant $p > 0.05$.

	Arboreal stratum			Epigaeic stratum		
	Alpha	Beta	Gamma	Alpha	Beta	Gamma
Fragment area	2.949	2.949	2.949	2.1990	1.1729	1.4681
Isolation	66.339*	66.340*	66.340*	3.0088	3.6639	4.1293
% of urban area	0.4836	0.4836	0.4836	0.0964	0.0023	0.0063
Distance of urban center	0.5558	0.5558	0.5558	0.6833	1.7221	1.4176

Our findings support that arboreal ants are more responsive to landscape metrics than epigaiec ants, indicating that they are more affected by this anthropic impact, probably because vegetation suppression is one of the first actions of the process of urbanization. Yasuda and Koike (2009) observed that host tree species richness was an important factor in determining the abundance of ants and other arthropods. Our results confirm the importance of this stratum, which can serve as shelter and a source of food, and contribute to the maintenance of favorable environments for ants (Estrada et al., 2014). However, the only landscape metric that affected arboreal ant richness in the present study was fragment isolation, which was calculated as the distance from nearest fragment.

Our observation that arboreal ant diversity decreased with increased fragment isolation was also observed by Badano et al. (2005). Likewise, Pacheco and Vasconcelos (2005) observed that natural areas with native vegetation in the proximity of urban parks can be important for the species diversity therein. A hypothesis that may explain the reduced species richness of the arboreal stratum in more isolated fragments is the difficulty of dispersion and re-colonization, since new species are less likely to arrive to more isolated fragments (Lucey et al., 2013; MacArthur & Wilson, 1967). We also observed that the effect of isolation was independent of spatial scale. Epperson (2010) reported that such spatial scales are correlated, that is, the effect caused on a smaller scale may be reflected on a larger scale, which we believe to have been the case in our study. Over the long term, urbanization can affect, and contribute more and more to, this scenario of isolated fragments having reduced diversity.

It is noteworthy that the diversity of epigaeic ants was not influenced by any landscape metric. Ives et al. (2013), and Egerer et al. (2017) suggest that epigaeic ants respond more to local conditions and factors, such as interactions, rather than to landscape metrics. Gomes et al. (2010) and Forgs et al. (2015) also did not find a relationship between ant richness and abundance and a highly urbanized area, or percentage of the surrounding vegetation. Likewise, Gomes et al. (2010) did not find a relationship between leaf litter ant richness and fragment area, which they attributed to the very small corporal size of ants and, thus, the lack of a need for a large area to nest and to obtain alimentary resources. Nevertheless, a possible explanation is that, for riparian soil ants, another factor may be more important, such as flooding. Natural floods of riparian forest areas are in fact a sever source of disturbance and can be worsened by urbanization and improvements for the human population, especially paving. Pavement prevents the natural percolation of water into the soil, thus forcing the water to reach rivers more rapidly and, consequently, increasing the frequency and intensity of flooding (Soares et al., 2013). Flooded and humid soils make it difficult for ants to establish colonies, which may be masking the effects of the variables tested in the riparian areas of the present study. This strong disturbance can also explain the reduced richness of ant species if we compare to epigaeic with

arboreal strata. In this context, Campos et al. (2008) found more species on the soil than in trees, even when using fewer traps on the soil than in arboreal stratum, unlike our study where we did not find higher richness on the soil in comparison to the trees when using a similar trapping effort in both strata.

The compositions of arboreal and epigaeic ants were little affected by landscape metrics, only fragment area and percentage of urban area, plus distance from the urban center for arboreal ants. Urban area surrounding fragments indicates the loss of natural habitat and is probably related to the homogenization of the environment, which previously supported a composition of specialized and demanding species. With the alteration and degradation of the environment only the most tolerant species remain, such as opportunistic and less demanding generalists, or even the replacement of native with exotic species (Egerer et al., 2017). Since fragments with a higher percentage of urban area in the surroundings are more subject to anthropic impacts, such as pollution, a large influx of people frequenting the interior of these fragments trampling the soil and/or the discarding of solid residues in the areas, they may experience unfavorable impacts on species that depend on a more preserved environment. In addition, larger areas may possess greater environmental complexity (i.e. more heterogeneous environments), as well as distinct tree species that support a greater diversity of ant species that utilize and exploit their resources (Estrada et al., 2014). In contrast, more homogeneous environments will have less diversity of resources and, consequently, fewer species that exploit them. Once the landscape changes, the natural environment is re-characterized and the loss and/or substitution of species are inevitable results. This is also true for the direct interference of human actions in the living areas of these species.

Beyond the different responses of ants to the environmental parameters tested in the present study, we note that only four species occur in both epigaeic and arboreal strata, evidencing the importance of sampling more than one stratum in ecological studies using ant assemblages as models in riparian areas since structuring can be influenced in different ways. Species that forage and inhabit different stratum have different habits and behaviors and can respond in different ways to environmental changes. For example, Canedo et al. (2016), found the dynamics of a hypogaeic ant assemblage to respond differently to fire disturbance.

We believe that even with the loss of species diversity and anthropogenic disturbances of fragments within urban centers, these areas are still important areas for species conservation. This is particularly true because they connect forest remnants outside (downstream and upstream) of urban centers, and isolation, as evidenced by our data, is an important parameter for the richness of arboreal ants. With regard to the management of urban forest areas, we found that the most important variable was fragment isolation. In order for fragments to obtain greater ant richness, greater flow of species and increased colonization of areas, it is necessary to invest in ecological corridors and

the reforestation and recovery of green urban areas, because the greater the isolation of an area, the lower the richness of arboreal ant species. In addition, we suggest that urban centers develop environmental protection projects for riparian forests, such as investing in connecting fragments and instituting public policies that seek to conserve these areas.

Acknowledgements

References

Baccaro et al., (2015). Guia para os gêneros de formigas do Brasil. Manaus: Editora INPA, p.388

Badano E.I.; Regidor, H.A.; Núñez, H.A.; Acosta, R.; Gianoli, E. (2005). Species richness and structure of ant communities in a dynamic archipelago: effects of island area and age. Journal of Biogeography, 32: 221-227. doi: 10.1111/j.1365-2699.2004.01174.x

Barlow, J.; Gardner, T.A.; Lees, A.C.; Parry, L. and Peres, C.A. (2012). How pristine are tropical forests? An ecological perspective on the pre-Columbian human foot print in Amazonia and implications for contemporary conservation. Biological Conservation, 151: 45-49.

Bestelmeyer, B.T. et al. (2000). Field techniques for the study of ground- living ants: An overview, description and evaluation, p.122-144. In Agosti, D. et al. *Ants: standard methods for measuring and monitoring biodiversity.* Smithsonian Institution Press, Washington, p.280

Bolton, B. (1994). Identification guide to the ant genera of the world. Cambridge: Editora Harvard University Press, p. 200

Campos, R. I.; Lopes, C. T.; Magalhães, W. C.; & Vasconcelos, H. L. (2008). Estratificação vertical de formigas em Cerrado *strictu sensu* no Parque Estadual da Serra de Caldas Novas, Goiás, Brasil. Iheringia, Série Zoologia, 98: 311-316.

Campos, R. B. F.& Castro J.M. (2017). Áreas verdes: Espaços urbanos negligenciados impactando a saúde. Saúde & Transformação Social, 8: 106-116.

Canedo-Júnior.E.O; Cuissi, R. G. ; Curi, N. H. A. ; Demetrio, G. R. ; Lasmar, C. J. ; Malves, K. ; and Ribas, C. R. .(2016). Can anthropic fires affect epigaeic and hypogaeic Cerrado ant (Hymenoptera: Formicidae) communities in the same way? Revista de Biologia Tropical, 64: 95-104.

Clarke, K.R.; Gorley, R.N. (2006). Primer v6: user manual/ tutorial. Plymouth: Plymouth Marine Laboratory.

Código florestal (2012). Lei 12.651/2012

Dominguez-Haydar, Y. & Armbrecht, I. (2011). Response of Ants and Their Seed Removal in Rehabilitation Areas and Forests at El Cerrejon Coal Mini in Colombia. The Journal of the Society for Ecological Restoration, 19: 178-184.

Doody, B.J.; Sullivan, J.J.; Meurk, C. D.; Stewart, G. H.; Perkins, H. C.(2009). Urban realities: the contribution of residential gardens to the conservation of urban forest remnants. Biodiversity Conservation, 19: 1385-1400. doi: 10.1007/s10531-009-9768-2

Egerer, M.H.;Arel, C.; Otoshi, M.D.; Quistberg, R.D.; Bichier, P. and Philpott, S. M. (2017). Urban arthropods respond variably to changes in landscape context and spatial scale. Journal of Urban Ecology, 3: 1-10. doi: 10.1093/jue/jux001

Epperson, B.K. (2010). Spatial correlations at different spatial scales are themselves highly correlated in isolation by distance processes. Molecular Ecology, 10: 845-853. doi: 10.1111/j.1755-0998.2010.02886.x

Estrada, M.A; Coriolano, R.E.; Santos, N.T.; Caixeiro, L.R.; Vargas, A.B & Almeida, F.S. (2014). Influência de áreas verdes sobre a mirmecofauna. Floresta e Ambiente, 21: 162-169.

Fattorini, S. (2013). Faunistic knowledge and insect species loss in an urban area: the tenebrionid beetles of Rome. Journal of Insect Conservation, 17: 637-643.

Forgs, M.G.I. et al (2015). Multi-taxonomic diversity patterns in a neotropical green city: a rapid biological assessment. Urban Ecosystems, 18: 633-647.

Goddard, M.A.; Dougill, A.J.; Benton, T.G. (2009). Scaling up from gardens: biodiversity conservation in urban environments. Trends in Ecology and Evolution, 25: 90-98.

Gomes J.P.; Iannuzzi I.; and Leal I.R. (2010). Resposta da comunidade de formigas aos atributos dos fragmentos e da vegetação em uma paisagem da floresta atlântica nordestina. Neotropical Entomology, 39: 898-905.

IBGE - Instituto Brasileiro de Geografia e Estatística. Available in http://www.ibge.gov.br/home/estatistica/ populacao/censo2010/MG2010 access in 15/03/2015

Ives, C. D., Hose, G. C., Nipperess, D. A., & Taylor, M. P. (2011). The influence of riparian corridor width on ant and plant assemblages in northern Sydney. Australia. Urban Ecosystems, 14: 1-16.

Ives, C.D.; Taylor, M. P.; Nipperess, D.A.; Hose, G.C. (2013). Effect of catchment urbanization on ant diversity in remnant riparian corridors. Landscape and Urban Planning, 110: 155-163.

Jost, L.; DeVries, P.; Walla, T.; Greeney, H.; Chao, A.; Ricotta, C. (2010). Partitioning diversity for conservation

analyses. Journal of Conservation Biogeography, 16: 65-76.

Kessler, M., Abrahamczyk, S., Bos, M., Buchori, D., Putra, D. D., Gradstein, S. R., & Saleh, S. (2009). Alpha and beta diversity of plants and animals along a tropical land–use gradient. Ecological Applications, 19: 2142-2156.

Loboda, C.R. & e De Angeles, B. L.D. (2005). Áreas verdes públicas urbanas: conceitos, usos e funções. Ambiência, 1: 125-139.

Lourenço, G.M.; Campos, R.B.F and Ribeiro, S.P. (2015). Spatial distribution of insect guilds in a tropical montane rain forest: effects of canopy structure and numerically dominant ants. Arthropod-Plant Interactions, 9: 163-174.

Lucey, J.M et al. (2014). Tropical forest fragments contribute to species richness in adjacent oil palm plantations. Biological Conservation, 169: 268-276 doi: 10.1016/j.biocon.2013.11.014

MacArthur, R.H. & Wilson, E.O. (1967). The theory of island of biogeograph. University Press, Princeton.

Magurran, A.E. (2004). Measuring Biological Diversity. Blackwell Science Ltda, Oxford

Marques T. & Schoereder J.H. (2013). Ant diversity partitioning across spatial scales: Ecological processes and implications for conserving Tropical Dry Forests. Austral Ecology, 39: 72-82. doi: 10.1111/aec.12046

McKinney, M.L. (2008). Effects of urbanization on species richness: A review of plants and animals, Urban Ecosystems, 11: 161-176. doi: 10.1007/s11252-007-0045-4

Neves, F.S. et al., (2013). Ants of Three Adjacent Habitats of a Transition Region Between the Cerrado and Caatinga Biomes: The Effects of Heterogeneity and Variation in Canopy Cover. Neotropical Entomology, 42, 558-268. doi: 10.1007/s13744-013-0123-7

Oksanen, J. Kindt, R. Legendre, P. O'Hara, B. Henry H. Stevens, M. (2007). The Vegan Package. Available in: http://ftp.uni-bayreuth.de/math/statlib/R/CRAN/doc/packages/vegan.pdf

Ortega, M.R. and Meneses, G.C. (2015). Effects of urbanization on the diversity of ant assemblages in tropical dry forests, Mexico. Urban Ecosystems, 18: 1373-1388. doi 10.1007/s11252-015-0446-8

Pacheco; R. Vasconcelos, H. L. (2005). Conservação de invertebrados em áreas urbanas: um estudo de caso com formigas no Cerrado Brasileiro. In: XVII Simpósio de Mirmecologia, Campo Grande. p. 258-261

Pacheco, R.; Vasconcelos, H. L. (2007). Invertebrate conservation in urban areas: Ants in the Brazilian Cerrado. Landscape and Urban Planning, 81: 193-199.

Pacheco R., Vasconcelos H. L. (2012). Habitat diversity enhances ant diversity in a naturally heterogeneous Brazilian

landscape. Biodiversity and Conservation, 21: 797-809.

Philpott S.M.; Perfecto I.; Armbrecht, I. & Parr, C.L. (2010). Ant Diversity and Function in Disturbed and Changing Habitats. Chapter 8 Ant Ecology Oxford University

R Core Team (2014). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL http://www.R-project.org/

Ribas, C.R.; Campos, R.B.F.; Schimidt, F.A.; Solar, R.R.C. (2012). Ants as indicators in Brazil: a review with suggestions to improve the use of ants in environmental monitoring programs. Psyche: A jornal of Entomology, 1: 1-23.

Ribas, C. R.; Schoereder, J. H.; Pic, M; Soares, S. M. (2003). Tree heterogeneity, resource availability, and larger scale processes regulating arboreal ant species richness. Austral Ecology, 28: 305-314. doi: 10.1046/j.1442-9993.2003.01290.x

Schmidt, F.A. & Solar, R.R.C. (2010). Hypogeic pitfall traps: methodological advances and remarks to improve the sampling of a hidden ant fauna. Insectes Sociaux, 57: 261-266. doi: 10.1007/s00040-010-0078-1

Soares, S.A., Suarez, Y.R., Fernandes, W.D., Tenório, P.M.S., Delabie, J.H.C., Antonialli-Junior, W.F. (2013). Temporal variation in the composition of ant assemblages (Hymenoptera, Formicidae) on trees in the Pantanal floodplain, Mato Grosso do Sul, Brazil. Revista Brasileira de Entomologia, 57: 84-90.

Soga, M., Kanno, N., Yamaura, Y., & Koike, S. (2013). Patch size determines the strength of edge effects on carabid beetle assemblages in urban remnant forests. Journal of insect Conservation, 17: 421-428.

Souza-Souto,L.; Schoereder, J.H. and Schaefer, C.H.G.R, (2007). Leaf-cutting ants, seasonal burning and nutrient distribution in Cerrado vegetation. Austral Ecology, 32: 758-765.

Thompson, C.W; Roe, J.; Aspinall, P.; Mitchell, R.; Clow, A. & Miller, D. (2012). More green space is linked to less stress in deprived communities: Evidence from salivary cortisol patterns. Landscape and Urban Planning, 105: 221-229.

Underwood, E. C.; Fisher, B. L. (2006). The role of ants in conservation monitoring: If, when, and how. Biological Conservation, 132: 166-182.

Uno, S.; Cotton, J.; Philpott, S. M. (2010). Diversity, abundance, and species composition of ants in urban green spaces. Urban Ecosystems, 13: 425-441. doi: 10.1007/s11252-010-0136-5

Vargas A.B.; Mayhé-Nunes A.J.; Queiroz, J.M.; Souza G.O; Ramos, E.F. (2007). Efeitos de fatores ambientais sobre a mirmecofauna em comunidade de Restinga no Rio de Janeiro, RJ. Neotropical Entomology, 36: 28-37.

Yasuda M. & Koike (2009). The contribution of the bark of isolated trees as habitat for ants in an urban landscape. Landscape and Urban Planning, 92: 276-281.