Diversity of Epigeal Ants (Hymenoptera: Formicidae) in Urban Areas of Alto Tietê

by

D. R. de Souza[1]; S. G. dos Santos[1]; C. de B. Munhae[2] & M. S. de C. Morini[1]

ABSTRACT

The objective of this study was to conduct an inventory of the ant fauna, evaluating indicators of diversity, litter community composition and similarity among seven areas located around the city of Mogi das Cruzes (SP). In each area 20 pitfalls were distributed, which remained in the field for seven days. Four samplings were performed, two in the rainy season and two during dry season. In total there were 92 recorded species, 36 genera, 19 tribes and seven subfamilies. The most frequent species belong to the genera *Pheidole* and *Camponotus*, both common in the Neotropics. Differences were observed in species composition with the formation of two groups, one under the influence of the Atlantic Forest and other in the urban region. Only one exotic species, *Paratrechina longicornis,* was recorded. The results indicate the importance of the forest surrounding the city to maintain the biological diversity of ant communities.

Keywords: anthropization, communities, Atlantic Forest, exotic ants, Serra do Itapeti

INTRODUCTION

Urban ecosystems are characterized as spatially heterogeneous and temporally dynamic sites, being usually recognized as areas under deep and constant human activities (McIntyre *et al.* 2001). These sites are effectively synonymous of disorder and reduction of biological diversity (Murphy 1988; McIntyre *et al.* 2001; Yamaguchi 2004; 2005). They are very similar all over the world in relation to the structure and function and differ only on the geographic location and size (Savard *et al.* 2000).

[1]Universidade de Mogi das Cruzes, Núcleo de Ciências Ambientais, Laboratório de Mirmecologia. Av. Dr. Cândido Xavier de Almeida Souza n. 200. 08780-911. Mogi das Cruzes, SP, Brasil.
[2]Universidade Estadual Paulista, Instituto de Biologia, Centro de Estudos de Insetos Sociais. Avenida 24 n. 1515. 13506-725. Rio Claro, SP, Brasil.
Corresponding author. E-mail: morini@umc.br

Some cities still have areas of native vegetation that represent important refuges for plants and animals (Rodrigues *et al.* 1993). This is the case with the city of Mogi das Cruzes, located in the Alto Tietê River Basin and Protected by the Watershed Law (Law N^0 9.866). The region is composed of the main Atlantic Forest remnants in the southeastern Brazil and at the same time it has an expressive population and industrial development (Candido *et al.* 2010).

Ants are among the most abundant insects in urban environments (McIntyre *et al.* 2001; Holway *et al.* 2002; López-Moreno *et al.* 2003). The high diversity, numerical dominance and biomass in almost all habitats, ease of sampling and species identification, the presence of stationary nests, which allows the re-sampling over time (Alonso & Agosti 2000) make ants good indicators of biological diversity in urban areas (Arcila *et al.* 2003). These insects also play critical functions for ecosystems, such as cycling of nutrients (Hölldobler & Wilson 1990; Folgarait 1998; Sanders & Van Veen 2011) and interaction with other organisms (Schultz & McGlynn 2000).

Whereas the first step towards the conservation of certain areas or their use in a sustainable way are studies on biological diversity (Scott *et al.* 1987) and the importance of Formicidae ecosystems, this paper aims at presenting a list of species and descriptively assessing richness, diversity and similarity of communities around the city of Mogi das Cruzes. The urban area in this city grows around the Serra do Itapeti, which is a remnant of Atlantic forest with high biodiversity (Morini & Miranda 2011) and its conservation is of paramount importance.

MATERIALS AND METHODS

Samplings were made around the city of Mogi das Cruzes (S 23°52' 22"; W 46°18' 55" / 742 m), which is located in the eastern region of São Paulo city with 721 km^2. Seven sampling areas were delimited along a transect, whose ends are located in an urban park (Parque Leon Feffer) and a Conservation Unit (Parque Natural Municipal Francisco Affonso de Mello) (Table 1). In all areas, samplings were performed at sites under anthropogenic influence.

Four samplings were carried out in each area, two in the rainy season and two in the dry season (Minuzzi *et al.* 2007). Ants were collected with pitfall

Table 1. Characterization of sampling sites in the city of Mogi das Cruzes (SP).

Area	Location	Sampling Site characteristics
PLF-Parque Leon Feffer	S 23°31'37.56"; W 46°13'45.28"	It is an urban park, whose vegetation is found in different degrees of regeneration
CEC- Centro Esportivo Colégio Joana D'arc	S 23°31'19.36"; W 46°13'14"	Presence of grasses and a few tree species
PNJ - Parque Nagib Najar	S 23°31'17"; W 46°13'01"	It is an urban park, whose vegetation is at various stages of regeneration
AUI – Urbanized area I	S 23°30'49.24"; W 46'12'52.10"	It is a country club, near a forest area; presence of grasses
AUII – Urbanized area II	S 23°30'37.22"; W 46°12'32.22"	Area near a highway; presence of grasses
AP – Private Area	S 23°30'10.97"; W 46°11'55.55"	Little native vegetation, presence of grasses and exotic species
PNMFAM - Parque Natural Municipal Francisco Affonso de Mello	S 23°29'17"; W 46°11'43"	It is a Conservation Unit, consisting of secondary vegetation of Atlantic Forest at advanced stages of regeneration

(N = 20), distributed every 20 m (Baccaro *et al.* 2011). Traps remained in field for seven days.

The material was initially classified into subfamilies according to the proposal from Bolton (2003), identified at the level of genus and named according to Bolton (1994), Baroni-Urbani & De Andrade (2007) and Lapolla *et al.* (2010) and subsequently named into morphospecies comparing specimens with those from the Formicidae collection of Alto Tietê. The taxa numbering sequence is according to this collection. The species were identified by comparison with specimens deposited in the Zoology Museum, University of São Paulo (MZUSP). Vouchers were deposited at the University of Mogi das Cruzes (SP).

Richness was defined as the number of species and the abundance as the number of individuals of each species collected. The relative frequency of occurrence was based on the presence and absence data. We calculated the estimated richness (Chao 2) and compared between different sampling areas using the Kruskal-Wallis test; the diversity indices of Shannon-Wiener (H') and evenness (E). Patterns of species composition and community structure were compared between sampling sites through ordination analysis (non-metric multidimensional scaling - NMDS). A similarity dendrogram was constructed using Bray-Curtis as dissimilarity measure for the analysis of clusters formed by the complete connection method. The sotfware R (Oksanen *et al.* 2009), EstimateS version 8.2 (Colwell 2009), Biostat (Ayres *et al.* 2007) and DivEs (Rodrigues 2005) were used for analyses.

RESULTS AND DISCUSSION

The extensive inventory of epigaeic ant communities in areas surrounding the city of Mogi das Cruzes showed similar diversity in fauna and composed of 92 species, 36 genera, 19 tribes and seven subfamilies (Table 2). Myrmicinae was the richest subfamily. The total richness recorded has been possibly influenced by the Atlantic Forest surrounding the city (Oliveira & Campos-Farinha 2005).

The richest genera were *Pheidole* and *Camponotus* with total of 24 and 14 species, respectively. These genera are characterized by high species richness and abundance in different environments, being common in the neotropical region (Ward 2000). Species such as *Linepithema neotropicum* Wild and *Gnamptogenys striatula* Mayr, common in the study sites, are found in the litter of the Atlantic Forest in region (Morini *et al.* 2012).

The species accumulation curves indicated a plateau, indicating that the sampling effort was enough to sample the species from localities (Figure 1). Among all sampling areas, the estimated richness is significantly different (Kruskal-Wallis = 57.8806, df = 6, $p < 0.01$), and average richness ranged from 12 to 15 species (Table 3). The lowest number of species was recorded in locations near the urban area or areas with high human interference, such as urban parks; the Urbanized Area I is an exception in this case.

The Urbanized Area around I is composed of Atlantic Forest vegetation that may be providing increased flow of species among locations. The communities' analysis confirms this observation once there was the formation of two groups (Figures 2 and 3). One composed of areas that are closer to the urban area of the city of Mogi das Cruzes, being directly susceptible to the effects of urbanization, such as Parque Leon Feffer, Sports Center Joana D'Arc, Parque Nagib Najar and Urbanized Area II. The other consists of areas that still have Atlantic Forest vegetation or are close to or within the Conservation Unit, ie. the Urbanized Area I, and Parque Municipal Francisco Affonso de Mello. The areas forming the first group share 21 species while those of the

Table 2. Relative frequency of occurrence (FRO) and abundance (FRA) according to the taxa and sampling sites located in the city of Mogi das Cruzes (SP).

Subfamilies/Species	Sampling sites													
	PLF		CEC		PNJ		AUI		AUII		AP		PNMFAM	
	FRO	FRA	FRO	FRA	FRO	FRA	FRO	FRA	FRO	FRA	FRO	FRA	FRO	FRA
DOLICHODERINAE														
Dorymyrmex sp.1	1.32	0.35	2.75	1.93	1.72	0.06	0.36	0.56	5.33	3.26	0.35	0.45	0.38	0.01
Linepithema neotropicum Wild, 2007	5.28	4.13	3.44	1.32	6.01	1.84	5.73	9.61	5.33	3.57	6.71	18.28	5.32	3.94
ECITONINAE														
Labidus praedador (Smith F., 1858)	0.33	0.01	3.44	25.42	-	-	3.22	1.84	-	-	2.12	10.15	2.66	25.46
Labidus coecus (Latreille, 1802)	0.33	0.01	-	-	-	-	-	-	-	-	-	-	0.38	0.01
ECTATOMMINAE														
Ectatomma brunneum (Smith F., 1858)	-	-	2.75	0.12	-	-	2.51	0.67	1.00	0.31	0.35	0.04	-	-
Ectatomma edendatum Roger, 1863	0.33	0.01	1.37	0.10	0.43	0.05	1.07	0.24	0.66	0.03	-	-	-	-
Gnamptogenys striatula (Mayr, 1884)	5.61	3.49	1.03	0.03	2.15	0.44	6.09	9.90	1.66	0.45	4.24	3.99	7.60	12.21
Gnamptogenys sp.4	-	-	0.69	0.02	-	-	-	-	0.33	0.01	-	-	-	-
Thypholomyrmex rogenhoferi (Majer, 1862)	-	-	-	-	-	-	0.36	0.02	-	-	-	-	-	-
FORMICINAE														
Brachymyrmex heeri Forel, 1874	0.66	0.04	-	-	0.43	0.01	1.80	0.13	0.33	0.01	0.35	0.01	2.28	0.76
Brachymyrmex pictus Mayr, 1887	3.63	0.82	-	-	1.29	0.14	0.72	0.38	-	-	1.77	0.16	1.90	0.12
Brachymyrmex incisus Forel, 1912	6.60	7.07	6.87	15.16	8.15	8.76	5.01	2.60	4.66	3.35	4.95	1.98	3.04	4.74
Camponotus rufipes (Fabricius, 1775)	6.60	7.15	6.18	1.69	7.73	2.97	6.10	8.61	4.33	1.04	5.65	3.08	4.56	3.77

Camponotus (*Myrmaphaenus*) sp.2	0.99	0.03	2.06	0.08	1.29	0.08	2.87	0.40	2.00	0.45	1.06	0.10	1.14	0.37
Camponotus sericeiventris (Guérin-Méneville, 1838)	-	-	2.06	0.49	-	-	-	-	-	-	-	-	-	-
Camponotus (*Taenamyrmex)*	0.66	0.02	0.69	0.10	-	-	2.51	0.40	0.66	0.03	-	-	0.38	0.03
Camponotus (Myrmaphaenus) novogranadensis	1.32	0.15	0.69	0.02	3.00	0.20	0.36	0.02	2.00	0.12	0.70	0.04	0.76	0.01
Camponotus sp.7	0.33	0.01	0.34	0.02	-	-	0.36	0.04	1.66	0.18	-	-	-	-
Camponotus sp.8	5.94	1.53	5.50	1.32	3.43	0.66	3.59	0.69	5.00	0.61	2.83	0.34	1.90	0.31
Camponotus sp.9	0.33	0.01	-	-	-	-	-	-	1.33	0.15	-	-	0.38	0.03
Camponotus sp.10	0.33	0.01	-	-	-	-	-	-	-	-	-	-	0.76	0.03
Camponotus sp.11	-	-	0.34	0.02	-	-	0.72	0.11	2.66	0.45	2.47	0.21	1.52	0.15
Camponotus sp.12	-	-	-	-	-	-	0.36	0.02	-	-	-	-	-	-
Campontotus sp.13	-	-	-	-	-	-	-	-	-	-	-	-	0.76	0.08
Campontotus sp.16	-	-	-	-	0.86	0.03	0.36	0.02	-	-	-	-	-	-
Campontotus sp.18	-	-	-	-	-	-	-	-	0.33	0.01	-	-	-	-
Myrmelachista catharinae Mayr, 1887	-	-	-	-	-	-	-	-	-	-	-	-	0.38	0.01
Myrmelachista ruszkii Forel, 1903	-	-	-	-	-	-	0.36	0.02	-	-	1.06	0.05	-	-
Myrmelachista sp.4	-	-	-	-	-	-	0.36	0.04	-	-	-	-	-	-
Nylanderia fulva (Mayr, 1862)	4.95	4.27	5.50	4.52	8.58	42.93	0.72	0.04	4.66	7.98	1.41	0.14	2.66	1.32
Paratrechina longicornis (Latreille, 1802)	-	-	-	-	-	-	-	-	1.33	0.11	-	-	2.28	0.88
MYRMICINAE														
Acromyrmex crassispinus (Forel, 1909)	5.28	0.58	0.69	0.02	-	-	-	-	2.00	0.20	0.71	1.54	-	-
Acromyrmex disciger Mayr, 1887	-	-	0.34	0.01	-	-	-	-	0.33	0.01	0.35	0.01	-	-
Apterostigma sp.1	-	-	0.69	0.02	-	-	0.36	0.02	0.33	0.01	-	-	-	-

Atta sexdens (Forel, 1908)	-	-	3.09	0.72	3.43	0.97	5.38	4.51	-	-	2.12	0.44	1.52	0.39
Cephalotes pussilus v. *brevispinosus*	-	-	-	-	1.72	0.53	0.72	0.71	-	-	-	-	0.38	0.01
Crematogaster (*Orthocrema*) sp.1	-	-	-	-	-	-	0.36	0.13	-	-	-	-	1.90	0.39
Crematogaster sp.2	0.33	0.05	0.34	0.01	0.86	0.02	2.15	1.22	-	-	-	-	0.76	0.12
Crematogaster sp.3	0.66	0.01	0.34	0.10	0.43	0.03	-	-	2.66	1.25	-	-	-	-
Crematogaster sp.7	0.99	1.01	0.34	0.16	1.29	0.49	1.43	0.44	-	-	0.35	0.01	-	-
Cyphomyrmex sp.7	0.33	0.01	-	-	-	-	-	-	-	-	-	-	-	-
Hylomyrma reitteri (Mayr, 1887)	-	-	-	-	-	-	-	-	0.33	0.03	-	-	0.38	0.01
Leptothorax sp.1	-	-	-	-	-	-	0.36	0.04	-	-			-	-
Megalomyrmex sp.4	-	-	-	-	-	-	-	-	-	-	1.06	0.05	0.76	0.07
Mycetarotes parallelus Emery, 1905	-	-	0.69	0.03	-	-	-	-	0.33	0.01	-	-	-	-
Mycetosoritis sp.1	2.64	0.15	0.34	0.01	2.15	0.11	0.36	0.02	1.00	0.08	1.06	0.12	-	-
Oxypoecus sp.2	0.66	0.07	5.15	7.92	-	-	0.72	0.58	-	-	4.59	11.87	3.42	6.33
Pheidole sp.1	-	-	2.75	1.35	1.29	0.02	-	-	0.66	1.30	2.47	0.33	-	-
Pheidole sp.3	1.98	0.13	6.18	3.40	0.43	0.05	3.22	0.93	1.66	0.52	2.83	6.25	0.76	0.26
Pheidole sp.4	5.94	23.10	2.06	1.97	4.72	1.88	2.87	7.28	6.33	29.13	2.83	3.08	2.28	6.58
Pheidole sp.6	0.66	1.80	-	-	1.29	0.09	1.43	0.24	3.66	2.82	-	-	2.28	1.14
Pheidole sp.7	0.33	0.07	-	-	0.86	0.87	-	-	-	-	-	-	-	-
Pheidole sp.9	-	-	-	-	0.43	0.31	0.36	0.04	-	-	-	-	0.38	0.03
Pheidole sp.13	-	-	-	-	-	-	-	-	-	-	0.71	0.09	1.14	0.17
Pheidole sp.14	-	-	-	-	-	-	-	-	-	-	0.35	0.08	1.52	0.64
Pheidole sp.15	0.33	0.05	-	-	-	-	-	-	-	-	-	-	0.38	0.03

Pheidole sp.16	-	-	3.43	2.76	-	-	-	-	0.33	0.01	1.41	0.07	0.38	0.03
Pheidole sp.17	1.98	1.49	1.72	0.49	3.00	0.50	2.15	6.19	3.33	4.36	0.35	0.03	1.14	0.65
Pheidole sp.18	-	-	-	-	-	-	-	-	0.18	0.03	-	-	-	-
Pheidole sp.20	0.66	0.48	-	-	-	-	0.36	0.04	-	-	0.35	0.11	0.38	0.31
Pheidole sp.22	-	-	0.34	0.08	-	-	1.07	0.07	0.22	0.05	0.71	0.27	-	-
Pheidole sp.23	-	-	1.03	0.15	-	-	-	-	-	-	0.35	0.40	-	-
Pheidole sp.24	1.98	0.56	1.03	0.18	-	-	1.07	0.33	1.00	1.51	1.41	2.85	1.14	0.11
Pheidole sp.26	-	-	-	-	-	-	-	-	-	-	-	-	0.38	0.25
Pheidole sp.28	0.99	0.46	0.34	0.02	-	-	-	-	-	-	2.47	2.19	1.90	4.11
Pheidole sp.30	1.32	0.66	2.75	2.06	-	-	0.72	0.31	-	-	3.89	6.00	1.14	4.30
Pheidole sp.36	3.96	4.88	3.78	8.47	2.15	4.76	0.72	0.84	2.33	2.16	2.83	8.18	-	-
Pheidole sp.38	3.63	8.37	2.75	0.80	2.15	0.92	3.22	3.37	3.66	2.16	0.71	0.14	0.38	0.14
Pheidole sp.39	-	-	-	-	-	-	-	-	-	-	-	-	0.38	1.10
Pheidole sp.43	-	-	-	-	-	-	-	-	0.66	0.99	-	-	-	-
Pheidole sp.46	-	-	-	-	-	-	-	-	0.33	0.04	-	-	-	-
Pogonomyrmex abdominalis Santschi, 1929	-	-	-	-	-	-	-	-	2.66	0.69	-	-	-	-
Procryptocerus gr. pr. *Schmalzi*	-	-	-	-	-	-	0.36	0.02	-	-	-	-	-	-
Solenopsis saevissima (Smith, 1855)	5.61	19.64	5.15	12.95	8.58	18.86	7.17	18.52	4.33	7.47	4.95	6.76	4.56	8.23
Solenopsis sp.2	2.31	0.66	2.75	3.63	4.29	1.43	5.02	5.26	3.00	1.73	3.53	3.42	6.08	5.10
Solenopsis sp.3	1.32	2.15	-	-	5.58	4.94	0.72	10.32	1.00	0.77	1.41	2.05	3.04	0.24
Strumygenys schmalzi Emery, 1906	1.32	0.04	-	-	0.43	0.01	0.72	0.04	0.66	0.03	-	-	-	-
Trachymyrmex gr. *Septentrionales*	-	-	-	-							0.35	0.01	-	-

Wasmannia sp.3	2.31	0.13	1.03	0.08	4.31	4.63	0.72	0.20	3.00	18.72	2.12	1.36	1.52	0.39
PONERINAE														
Anochetus altisquamis (Mayr, 1887)	-	-	-	-	-	-	0.36	0.02	-	-	0.71	0.01	0.38	0.01
Hypoponera sp.1	-	-	0.69	0.02	-	-	0.72	0.04	-	-	0.35	0.01	-	-
Hypoponera sp.8	0.33	0.01	-	-	-	-	0.36	0.09	0.33	0.06	-	-	1.52	0.04
Hypoponera sp.9	-	-	-	-	-	-	-	-	-	-	-	-	0.38	0.03
Leptogenys sp.3	-	-	-	-	-	-	-	-	-	-	-	-	0.76	0.03
Odontomachus affinis Guérin-Méneville, 1844	-	-	0.34	0.01	-	-	1.07	0.13	-	-	1.06	0.22	1.52	0.15
Odontomachus meinerti Forel, 1905	-	-	-	-	-	-	-	-	-	-	0.71	0.04	0.76	0.03
Odontomachus chelifer (Latreille, 1802)	-	-	1.37	0.04	0.43	0.01	1.07	0.11	-	-	7.07	1.87	6.08	2.27
Pachycondyla striata Smith, 1858	6.60	4.39	2.75	0.15	4.72	0.41	6.09	1.38	4.66	1.11	6.01	0.91	6.84	1.86
Pachycondyla harpax (Fabricius, 1804)	-	-	-	-	0.43	0.01	-	-	-	-	-	-	-	-
PSEUDOMYRMECINAE														
Pseudomyrmex gracilis (Fabricius, 1804)	-	-	-	-	-	-	0.72	0.09	1.33	0.11	1.77	0.10	0.38	0.07
Pseudomyrmex pallidus (Smith, 1855)	-	-	-	-	-	-	0.36	0.02	-	-	-	-	-	-
Pseudomyrmex phyllophilus (Smith, 1858)	-	-	-	-	-	-	-	-	2.00	0.40	-	-	-	-
Partial Abundance	10.305		9.217		8.360		4.504		6.467		7.259		7.188	
Partial Richness	44		46		36		56		49		49		56	
Total Abundance							53.300							
Total Richness							92							
Shannon Diversity	3.31		3.48		3.21		3.54		3.58		3.50		3.62	
Evenness	0.88		0.91		0.89		0.88		0.92		0.90		0.90	

Table 3. Average number of species per sample and richness estimates of epigaeic ants collected around the city of Mogi das Cruzes (SP).

Area	Average number of species (± sd)	Observed number of species	Richness estimate
PLF	15 (±1.84)	44	51.46
CEC	15 (±3.78)	46	51.34
PNJ	12 (±2.94)	36	42.65
AUI	14 (±3.05)	56	67.28
AUII	15 (±2.25)	49	59.45
AP	14 (±3.30)	49	55.53
PNMFAM	13 (±4.51)	56	70.36

second group share 32 species. The high exchange rate of species between areas near the Atlantic Forest suggests the importance of preserving these sites for conservation of the regional ant fauna in the Serra do Itapeti and at the same time, they can act as buffer areas for the Conservation Unit.

Taxa with specialized morphology and biology (Brandão *et al.* 2009) were observed in the areas under the influence of the Atlantic Forest, such

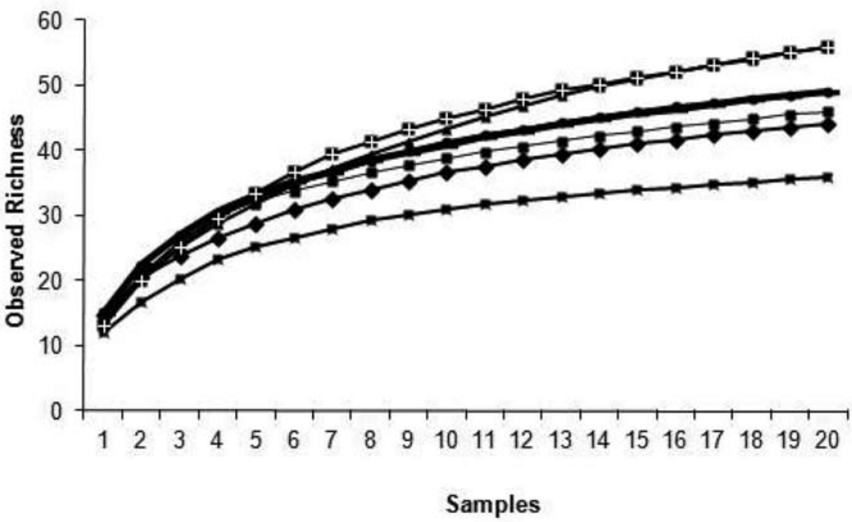

Fig. 1. Accumulation curves of epigaeic ant species sampled around the city of Mogi das Cruzes (SP). ( ) PLF; ( ) CEC; ( ) AUI; ( ) PNJ; ( ) AUII; ( ) AP; ( ) PNMFAM.

as the Urbanized Area I, Private Area and the Parque Natural Municipal Francisco Affonso de Mello; especially Ectatomminae and Ponerinae species. *Myrmelachista*, which is exclusively arboreal (Longino 2006) since most of its species nests in cavities of tree trunks and branches of living trees (Stout 1979; Brown 2000; Longino 2006; Edwards *et al*. 2009), was found only in sites in contact with forest areas. Only one exotic species, (*Paratrechina longicornis* Latreille) was recorded, including in the Conservation Unit. This species and *P. megacephala* Fabricius are present in the central region of Mogi das

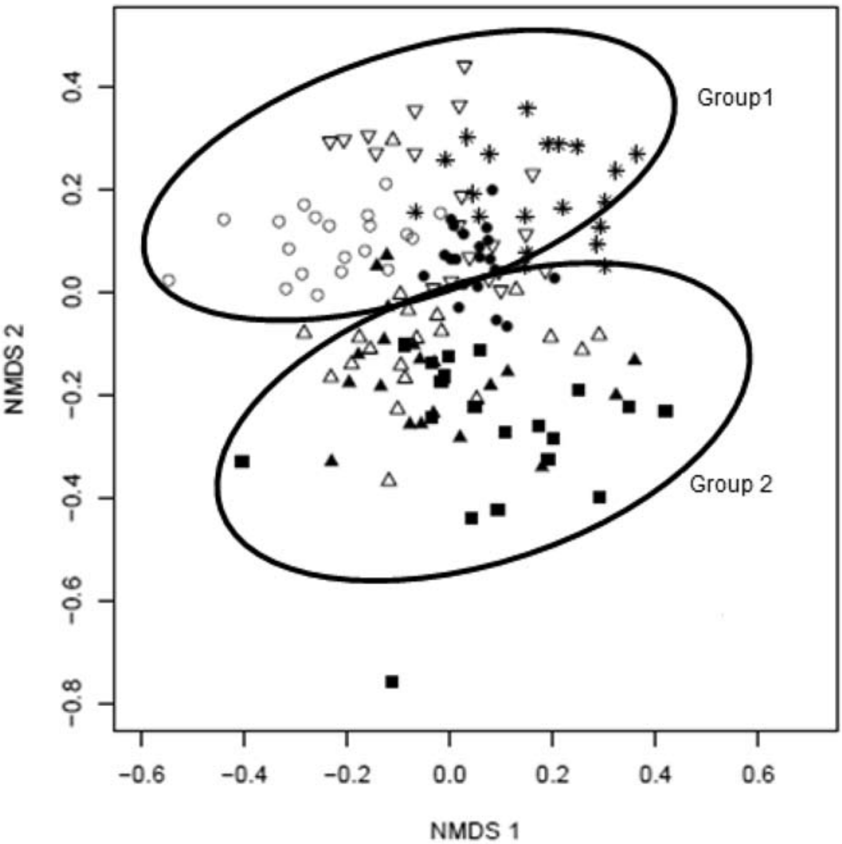

Fig. 2. Non-metric multidimensional scaling (NMDS) comparing epigaeic ant communities sampled around the city of Mogi das Cruzes (SP). (Stress = 27.71) - (●) PLF; (○) CEC; (△) PNJ (▽) AUI; (✱) AUII; (▲) AP; (■) PNMFAM.

Cruzes and neighborhoods built in the vicinity of the Serra do Itapeti (Kamura *et al.* 2007; Munhae *et al.* 2009; Souza *et al.* 2012). However, exhaustive inventories of litter in places sheltered from the Serra do Itapeti have registered exotic species (Morini *et al.* 2012; Suguituru *et al.* in preparation). The absence of these species is important for maintaining the biodiversity of Serra do Itapeti since they have potential to reduce native fauna (Nafus 1993; Harris & Barker 2007; Vanderwoude *et al.* 2000; Hoffmann 2010). However, it is necessary to monitor the populations of *P. longicornis*, as the species is already in areas of the Parque Natural Municipal Francisco Affonso de Mello where population's visit is constant. This conservation area is the largest one of Serra do Itapeti under legal protection (Law N°. 6220 of 29.12.2008), being very rich in fauna and flora (Morini & Miranda, 2012), although located in the metropolitan area of São Paulo city.

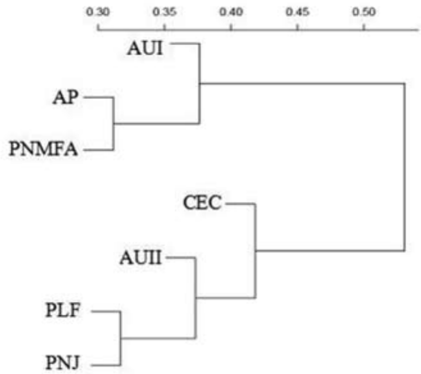

Fig. 3. Dendrogram of Bray-Curtis dissimilarity based on the composition of epigaeic ant species collected around the city of Mogi das Cruzes (SP).

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