

## Diversity and Guilds of Ants in Different Land-Use Systems in Rio de Janeiro State, Brazil

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### ABSTRACT

This study aimed to evaluate the ant fauna in three different land-use systems: pasture, eucalyptus plantation and secondary forest, in southeastern Brazil. The ant fauna was collected with standardized pitfall traps. Forty-seven ant species were collected, belonging to 24 genera and six subfamilies. The total ant species richness was significantly higher in secondary forest (29 species) and eucalyptus plantation (25 species) when compared to the pasture (17 species), with no significant difference between the secondary forest and eucalyptus plantation. The species composition differed significantly between the three land-use systems. The frequency distributions of ant guilds in eucalyptus plantation and secondary forest differed significantly from the frequency in the pasture. The results demonstrated the importance of natural forests for the conservation of biological diversity of the Atlantic Forest, but they also indicated that eucalyptus plantations, with native understory plants, can harbor considerable ant diversity.

**Keywords:** biodiversity, *Corymbia*, Formicidae, seasonal forest.

## 1. INTRODUCTION AND OBJECTIVES

The Atlantic Forest is considered one of the most important biomes in the world due to its high diversity and endemism of plants and animals (Joly et al., 2014). Hence, its protection is especially relevant for the conservation of biodiversity (Myers et al., 2000). In the past centuries, indiscriminate exploitations of natural resources by different land-use regimes and successive economic cycles changed the natural landscape and put at risk the biome's biological diversity (Ribeiro et al., 2011; Silvério Neto et al., 2015).

The state of Rio de Janeiro, southeastern Brazil, has some remaining Atlantic Forest areas distributed in small and isolated fragments (Silvério Neto et al., 2015). Semi-deciduous seasonal forests figure among the vegetation types of this biome that were most reduced and degraded by human activities, and thus, their biodiversity is severely threatened (Brasil, 2007; Ribeiro et al., 2011). Several areas naturally covered by semi-deciduous seasonal forests were converted to urban areas, pastures, commercial forests, and agroecosystems (Brasil, 2007; Ribeiro et al., 2011), which caused habitat loss and simplification (Martins et al., 2011). It is worth mentioning that a reduction in environmental heterogeneity decreases the diversity of the ecological niches, and, consequently, biodiversity loss (Braga et al., 2010; Estrada et al., 2014; Oliveira et al., 2014). However, the replacement of natural ecosystems with other land-use systems does not mean that the environment becomes completely inhospitable to biodiversity (DaRocha et al., 2016; Santos et al., 2015), since it is possible to conciliate agriculture, livestock farming, and forest production with the conservation of at least part of the biodiversity (Dias et al., 2008).

Therefore, assessing the contribution of environments with different land-use systems for biodiversity conservation is important. In terrestrial ecosystems, the ant fauna deserves special attention due to its ecological importance, broad geographic distribution, high species richness, abundance and biomass, collection easiness, and sensitivity to environmental change (Agosti et al., 2000; Gomes et al., 2012; Ribas et al., 2012). Anthropogenic actions influence the ant fauna because they change biotic and abiotic factors in ecosystems, such as

air temperature, leaf litter abundance and plant diversity (Almeida et al., 2007; Estrada et al., 2014; Gomes et al., 2013). Accordingly, ant communities are frequently used as bioindicators of biodiversity and environmental quality in terrestrial ecosystems (Braga et al., 2010; Pereira et al., 2007; Ribas et al., 2012). In this sense, studies indicate that ant species richness and diversity decrease with the reduction of the structural complexity of ecosystems (Gomes et al., 2013; Martins et al., 2011).

In addition to assessing the taxonomic diversity, it is important to analyze the composition of ant guilds, as they are related to different ecological functions (Boscardin et al., 2014; Macedo et al., 2011). Ant guilds are influenced by environmental impacts, which can compromise their functions in ecosystems and the environmental quality (Boscardin et al., 2014; Kwon et al., 2014; Macedo et al., 2011); however, few studies have evaluated ant guilds in different land-use systems, including in the Atlantic Forest dominium.

The objective of the present study was to compare the ant fauna and their guilds in different land-use systems in the Atlantic Forest. Hence, the following hypotheses were tested: 1) the land-use system influences the richness and diversity of ants, being smaller in habitats with lower environmental heterogeneity; 2) the land-use system affects the composition and guilds of the ant fauna; and 3) air temperature and leaf litter are important environmental variables in the ant fauna structuring.

## 2. MATERIALS AND METHODS

### 2.1. Study area

Our study was carried out in the municipality of Sapucaia, state of Rio de Janeiro, Brazil, which has an area of 541.181 km<sup>2</sup> and an altitude of 221 m a.s.l (IBGE, 2016). The climate is predominantly semi-humid hot and sub-hot (IBGE, 2002). Winter is the season with the lowest rainfall and the mean annual rainfall is 1,181 mm (IBGE, 2002; Inea, 2014). The average temperature varies from 20 °C to 24 °C (Napoleão, 2011). Inserted within the Atlantic Forest, Sapucaia shows urban areas, crop areas, eucalyptus plantations, pastures, and semi-deciduous seasonal forest fragments (IBGE, 2016) and the forest cover

of the region is mostly composed of small fragments in different stages of regeneration (Silvério Neto et al., 2015).

We chose three areas for the study: a fragment of a second-growth forest with an area of 8.3 ha (22°3'29.75" S and 42°59'2.28" W), a bovine pasture with 6.9 ha (22°3'44.39" S and 42°59'5.56" W), and a plantation of lemon eucalyptus (*Corymbia citriodora* (Hook)) with 9.6 ha (22°3'52.28" S and 42°58'54.60" W). According to the characteristics predicted in the Conama Resolution (1994), the secondary forest was at an intermediate regeneration stage. Its physiognomy was dominated by trees and shrubs, with average circumference at the breast height (CBH) of 31 cm, average height of 4.95 m, approximately 20 years old, with predomination of woody lianas. The bovine pasture was covered by grasses of the species *Brachiaria brizantha* (Hochst ex A. Rich) (palisade grass), with the presence of shrubs, with CBH below 0.15 cm, such as the species *Baccharis dracunculifolia* DC and *Blainvillea* sp., as well as a few trees. The eucalyptus plantation was approximately 10 years old, and part of the planted trees had already been cut down and harvested. The eucalyptus trees showed an average height of 11.80 m and an average CBH of 72 cm. We observed that several areas of the eucalyptus plantation showed a developed understory with native species and a remarkable leaf litter layer.

## 2.2. Sampling

Ant collection was carried out in May 2015 in four 300-m<sup>2</sup> plots (30 m × 10 m) at 30 m away from one another, in the center of each land-use system. Six pitfall traps containing 100 ml of alcohol 70% were set up inside the perimeter of each plot at 10-m intervals, which remained active for 48 h. After this period, the contents of traps were removed and placed in labeled polyethylene containers with alcohol 70%. The containers were taken to the laboratory, where the material was sorted. Ants were dry-fixed and identified to the genus level with the taxonomic key proposed by Baccaro et al. (2015) and to the species with specific keys for the species of each genus and comparisons with previously identified individuals. Our reference collection is the Coleção Entomológica Costa Lima at Universidade Federal Rural do Rio de Janeiro (Agosti et al., 2000).

The classification of ants in guilds followed Delabie et al. (2000), Silvestre & Silva (2001), Groc et al. (2014), and Pereira et al. (2016). The following guilds were used: (1) arboreal omnivorous; (2) leafcutters; (3) fungus-growers (except leafcutter); (4) soil or litter dominants; (5) soil or litter dominant true omnivorous; (6) litter omnivores and scavengers; (7) soil cryptic predators; and (8) litter generalist predators. For the ants that were not identified to the species level, the classification was based on information available for the genus (Delabie et al., 2000; Groc et al., 2014; Silvestre & Silva, 2001). We chose to allocate the leafcutters ants in a different guild from other fungus-growers, due to the significant differences in behavior and resource use (Silvestre & Silva, 2001).

Air temperature was measured with a digital thermometer placed beside each pitfall. Soil cover by leaf litter was also obtained close to each pitfall, with a 2,500-cm<sup>2</sup> gridded square, with 100 cm<sup>2</sup> divisions placed on the soil to estimate the percentage of the area of the square covered by leaf litter.

## 2.3. Data analysis

For data analysis, we built species accumulation curves using the Mao Tau method, with the data obtained in each pitfall trap to analyze the total ant species richness in different land-use systems. The total ant species richness was significantly different between land-use systems when the 95% confidence intervals did not overlap (Gomes et al., 2013). To test the normality of the data we used the Lilliefors test. We used the Ancova with the data of each plot to compare the average richness and the average diversity (Shannon index, using natural log – ln) (dependent variables) in land-use systems (factor) and assess the effect of air temperature and leaf litter cover (covariates), followed by Tukey tests. The arcsine square root transformation was utilized for leaf litter cover data normalization. We also obtained the estimated species richness (Chao 2). We assessed the similarity of the ant fauna among land-use systems with the non-metric multidimensional scaling (NMDS) using the Jaccard similarity index and Anosim to determine significance (e.g. Gomes et al., 2013). The temperature and litter leaf cover were incorporated into the analysis, yielding vectors representing the correlation between these environmental variables and the NMDS scores in the

PAST program (version 2.17) (Hammer et al., 2001). The chi-square test ( $\chi^2$ ) was used to compare frequency of ant species richness per guilds between land-use systems (e.g. Pereira et al., 2016).

### 3. RESULTS

We collected 47 ant species of 24 genera and six subfamilies (Table 1). Myrmicinae was the subfamily with the largest number of species (26), followed by Formicinae (six). *Pheidole* was the genus with the largest number of species (six), followed by *Camponotus*, *Ectatomma*, and *Solenopsis*, all with four species.

The secondary forest showed the highest values of richness, diversity, evenness and estimated richness, followed by the eucalyptus plantation, and pasture (Table 2). The cumulative species richness

was significantly higher on the secondary forest and eucalyptus plantation than in the pasture (Figure 1). However, there was no significant difference between the secondary forest and eucalyptus plantation. We observed that the species accumulation curves did not reach the asymptote.

The type of land-use influenced the ant species richness (Ancova;  $F_{2,12} = 5.52$ ;  $p = 0.04$ ; Figure 2), in contrast to temperature (Ancova;  $F_{1,12} = 2.59$ ;  $p = 0.15$ ; Figure 3) and leaf litter (Ancova;  $F_{1,12} = 0.80$ ;  $p = 0.40$ ; Figure 3). Likewise, the land-use system affected species diversity (Ancova;  $F_{2,12} = 7.02$ ;  $p = 0.02$ ; Figure 4), unlike temperature (Ancova;  $F_{1,12} = 2.84$ ;  $p = 0.14$ ; Figure 5) and leaf litter cover (Ancova;  $F_{1,12} = 0.44$ ;  $p = 0.53$ ; Figure 5). The average richness and diversity were significantly higher on the secondary forest and eucalyptus plantation compared to pasture.

**Table 1.** Frequency (number of pitfall traps) and guilds of ant species in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil.

Subfamilies/Species	Land-use systems			Guilds
	Pasture	Eucalyptus plantation	Secondary forest	
<b>Dolichoderinae</b>				
<i>Dorymyrmex</i> sp.1	1	-	-	LOS
<i>Linepithema</i> sp.1	-	5	4	LOS
<b>Ectatomminae</b>				
<i>Ectatomma edentatum</i> Roger, 1863	19	4	1	SLD
<i>Ectatomma brunneum</i> F. Smith, 1858	1	12	-	SLD
<i>Ectatomma permagnum</i> Forel, 1908	-	2	11	SLD
<i>Ectatomma tuberculatum</i> Olivier, 1792	-	-	4	SLD
<i>Gnamptogenys</i> sp.1	1	-	-	LGP
<b>Formicinae</b>				
<i>Brachymyrmex</i> sp.1	9	9	-	SLO
<i>Brachymyrmex</i> sp.2	-	1	3	SLO
<i>Camponotus rufipes</i> Fabricius, 1775	17	2	-	SLO
<i>Camponotus</i> sp.1	-	3	2	SLO
<i>Camponotus</i> sp.2	-	-	1	SLO
<i>Camponotus</i> sp.3	-	-	1	SLO
<i>Nylanderia</i> sp.1	-	1	-	SLO
<b>Myrmicinae</b>				
<i>Acromyrmex</i> sp.1	1	-	-	LC
<i>Atta sexdens rubropilosa</i> Forel, 1908	2	14	7	LC
<i>Cephalotes pusillus</i> (Klug, 1824)	1	-	-	AO
<i>Crematogaster</i> sp.1	2	-	-	AO
<i>Cyphomyrmex</i> sp.1	1	-	-	FG

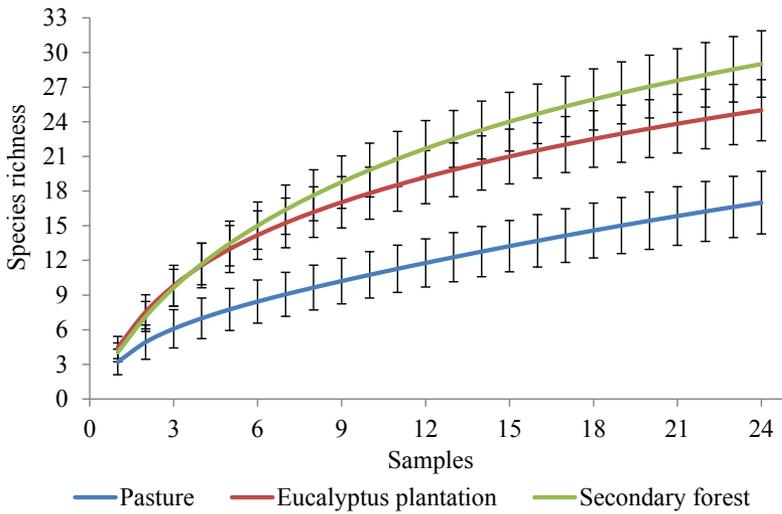
Table 1. Continued...

Subfamilies/Species	Land-use systems			Guilds
	Pasture	Eucalyptus plantation	Secondary forest	
<b>Myrmicinae</b>				
<i>Cyphomyrmex</i> sp.2	-	1	-	FG
<i>Mycocepurus goeldii</i> (Forel, 1893)	-	2	-	FG
<i>Mycocepurus smithii</i> (Forel, 1893)	-	2	4	FG
<i>Pheidole</i> prox. <i>fallax</i> Mayr, 1870	1	10	1	LOS
<i>Pheidole radoszkowskii</i> Mayr, 1884	-	7	-	LOS
<i>Pheidole</i> sp.1	7	4	9	LOS
<i>Pheidole</i> sp.2	2	12	8	LOS
<i>Pheidole</i> sp.3	-	7	1	LOS
<i>Pheidole</i> sp.4	-	-	2	LOS
<i>Sericomyrmex</i> sp.1	-	-	1	FG
<i>Sericomyrmex</i> sp.2	-	-	3	FG
<i>Solenopsis</i> sp.1	1	-	-	LOS
<i>Solenopsis</i> sp.2	-	1	-	LOS
<i>Solenopsis</i> sp.3	-	1	2	LOS
<i>Solenopsis</i> sp.4	-	-	4	LOS
<i>Trachymyrmex</i> sp.1	-	-	1	FG
<i>Trachymyrmex</i> sp.2	-	-	1	FG
<i>Tranopelta gilva</i> Mayr, 1866	-	-	1	SCP
<i>Wasmannia auropunctata</i> (Roger, 1863)	10	3	1	SLO
<i>Wasmannia</i> sp.1	-	1	1	SLO
<i>Wasmannia</i> sp.2	-	-	2	SLO
<b>Ponerinae</b>				
<i>Anochetus</i> sp.1	1	-	-	LGP
<i>Neoponera verena</i> (Forel, 1922)	-	1	-	LGP
<i>Odontomachus chelifer</i> Latreille, 1802	-	1	13	SLD
<i>Odontomachus</i> sp.1	-	-	2	SLD
<i>Pachycondyla lenis</i> Kempf, 1961	-	-	3	LGP
<i>Pachycondyla striata</i> Smith, F., 1858	-	-	3	LGP
<b>Pseudomyrmecinae</b>				
<i>Pseudomyrmex termitarius</i> Smith, F., 1855	-	1	-	LOS

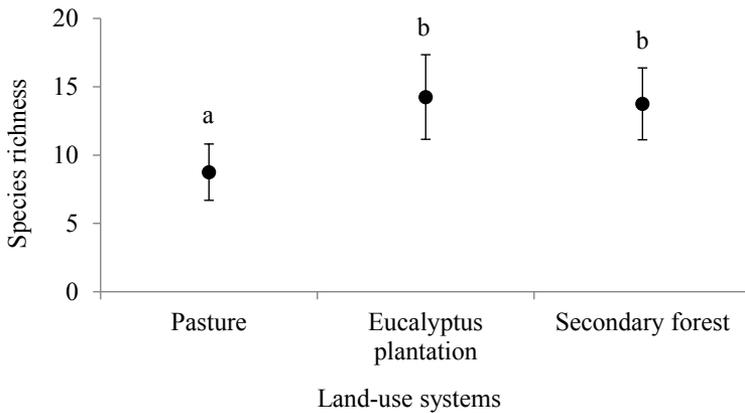
AO: arboreal omnivorous; LC: leafcutters; FG: fungus-growers; SLD: soil or litter dominants; SLO: soil or litter dominant true omnivorous; LOS: litter omnivores and scavengers; SCP: soil cryptic predators; LGP: litter generalist predators.

Table 2. Ant species richness, diversity of Shannon ( $H'$ ), equitability and estimated richness (Chao 2) in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil.

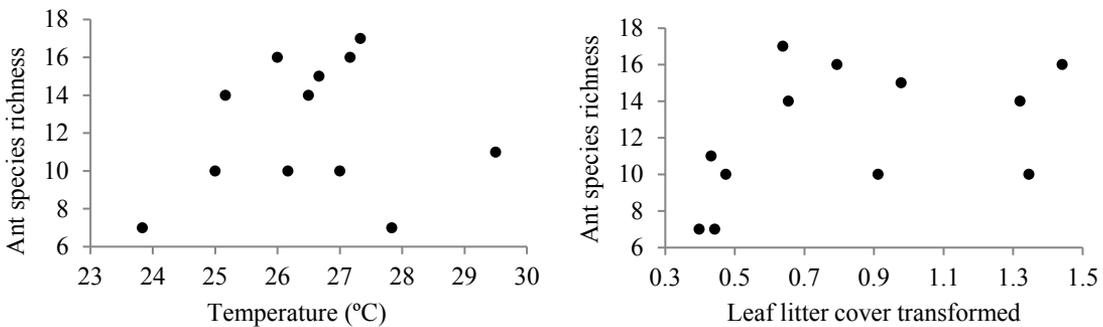
Variables	Land-use systems		
	Pasture	Eucalyptus plantation	Secondary forest
Richness	17	25	29
Diversity ( $H'$ )	2.21	2.82	3.01
Equitability	0.53	0.67	0.70
Estimated richness (Chao 2)	25.63	31.90	37.78



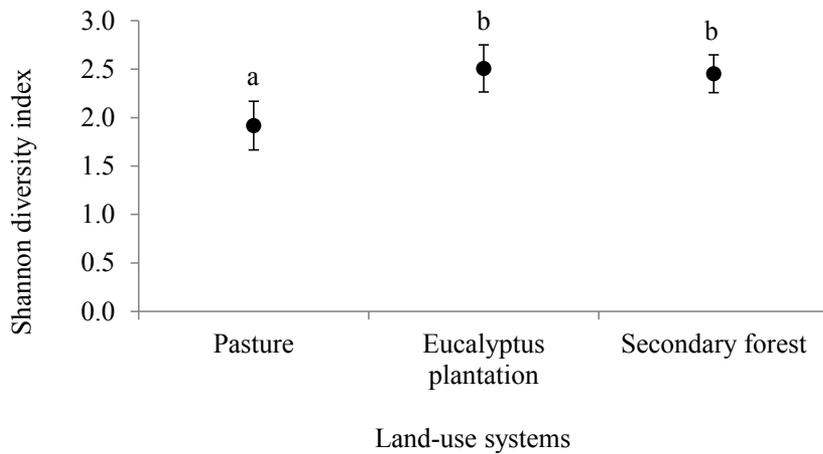
**Figure 1.** Species accumulation curves (Mao Tau method) with 95% confidence interval for the ant fauna collected in different land-use systems, in the municipality of Sapucaia, Rio de Janeiro, Brazil



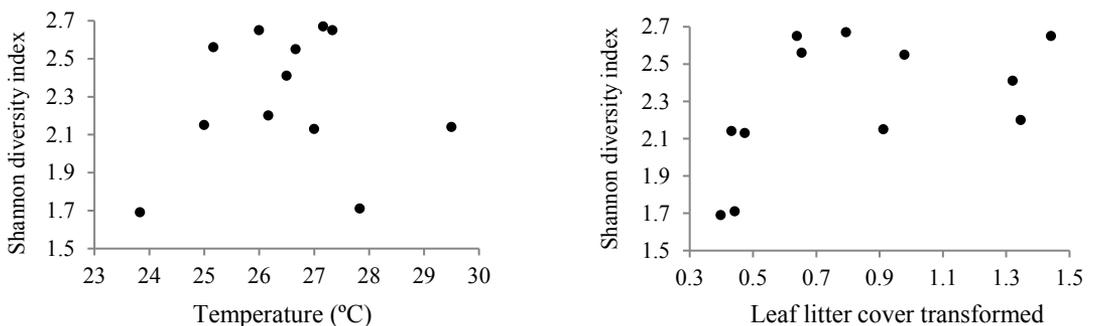
**Figure 2.** Average species richness ( $\pm$  Standard Deviation) for the ant fauna collected in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil. Different letters indicate significant difference between the land-use systems ( $p \leq 0.05$ ).



**Figure 3.** Relationship between ant species richness and temperature ( $F_{1,12} = 2.59$ ;  $p = 0.15$ ) and leaf litter cover ( $F_{1,12} = 0.80$ ;  $p = 0.40$ ) in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil.



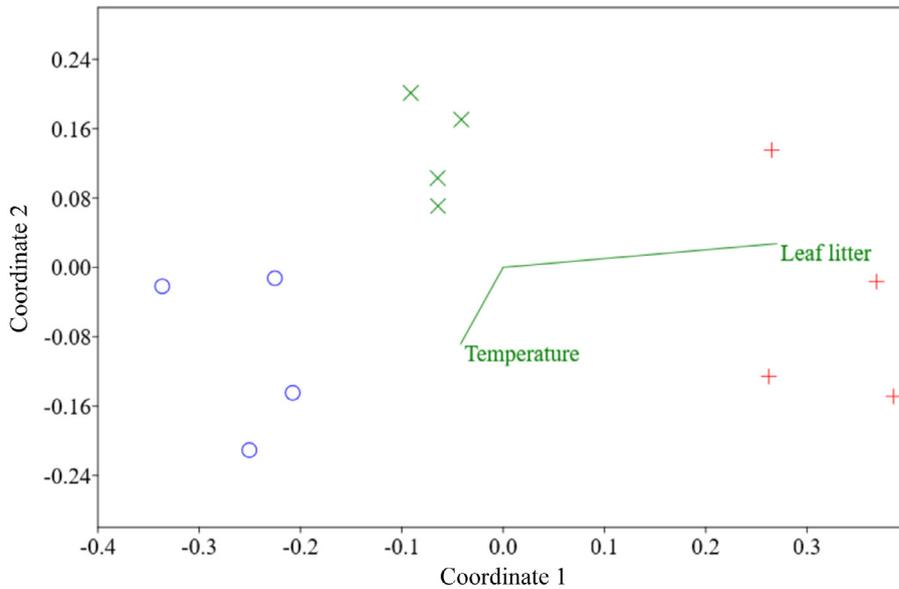
**Figure 4.** Average Shannon diversity index (± Standard Deviation) for the ant fauna collected in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil. Different letters indicate significant difference between the land-use systems ( $p \leq 0.05$ ).



**Figure 5.** Relationship between Shannon diversity index for the ant fauna and temperature ( $F_{1,12} = 2.84$ ;  $p = 0.14$ ) and leaf litter cover ( $F_{1,12} = 0.44$ ;  $p = 0.53$ ) in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil.

Eight species were found exclusively in the pasture, seven in the eucalyptus plantation and 14 species occurred exclusively in the secondary forest. Only six species occurred in all land-use systems. There was a significant difference in ant species composition between environments (Anosim;  $R = 0.93$ ;  $p < 0.01$ ; Figure 6). The pairwise comparison detected significant differences between pasture and eucalyptus plantation (Anosim;  $R = 0.95$ ;  $p = 0.03$ ), pasture and secondary forest (Anosim;  $R = 1.00$ ;  $p < 0.03$ ), and eucalyptus plantation and secondary forest (Anosim;  $R = 0.99$ ;  $p < 0.03$ ). Higher air temperatures were mainly related to the ant fauna composition in the pasture. On the other hand, higher values of leaf litter cover are mainly related to the ant community of the secondary forest.

The ant guilds with the largest number of species were litter omnivores and scavengers (13 species), followed by soil or litter dominant true omnivorous (10 species), and fungus-growers (8 species) (Table 1). In the pasture and secondary forest, we found seven guilds, whereas in the eucalyptus plantation we collected species of six guilds (Table 3). The frequency of ant species richness per guilds in the pasture differed significantly from those observed in the eucalyptus plantation ( $\chi^2 = 25.406$ ;  $p < 0.01$ ) and secondary forest ( $\chi^2 = 28.76$ ;  $p < 0.01$ ). In contrast, the frequency of ant species richness per guilds in the eucalyptus plantation and secondary forest did not differ significantly ( $\chi^2 = 6.633$ ;  $p = 0.36$ ).



**Figure 6.** Non-metric multidimensional scaling ordination (NMDS) for ants collected in pasture (O), eucalyptus plantation (x) and secondary forest (+), in the municipality of Sapucaia, Rio de Janeiro, Brazil, with Jaccard's similarity index (Stress = 0.075).

**Table 3.** Percentage of the number of species in each guild in different land-use systems in the municipality of Sapucaia, Rio de Janeiro, Brazil.

Guilds	Pasture	Eucalyptus plantation	Secondary forest	Total
Arboreal omnivorous	11.8	0.0	0.0	4.3
Leafcutters	5.9	12.0	17.2	17.0
Fungus-growers	11.8	4.0	3.4	4.3
Soil or litter dominants	11.8	16.0	17.2	12.8
Soil or litter dominant true omnivorous	17.6	28.0	24.1	21.3
Litter omnivores and scavengers	29.4	36.0	27.6	27.7
Soil cryptic predators	0.0	0.0	3.4	2.1
Litter generalist predators	11.8	4.0	6.9	10.6

#### 4. DISCUSSION

Native tropical forests usually present higher ant species richness and diversity when compared to pastures and eucalyptus plantations (Gomes et al., 2013; Martins et al., 2011; Soares et al., 2010). However, this pattern was not completely corroborated by the present study. In general, tropical forests have several vertical strata and higher species richness of plants than pastures and eucalyptus plantations, and so they have higher structural complexity (Gomes et al., 2013; Martins et al., 2011). In addition, high plant diversity

creates a heterogeneous leaf litter, which provides a greater diversity of sites for nesting and food for ants (Pereira et al., 2007). This explains the lower ant species richness and diversity in the pasture. On the other hand, the studied eucalyptus plantation has structural complexity similar to the secondary forest, due to the presence of a native understory and a thick layer of leaf litter. This structure provides a considerable number of niches and ant species richness and diversity, similar to the native forest in regeneration. Consonant results were observed in other studies (Braga et al., 2010; Cantarelli et al., 2015; Marinho et al., 2002).

The use of other collection techniques and sampling in different vertical strata could provide the collection of more species of ants (Montine et al., 2014). Although the sampling effort was not enough to collect all ant species of the land-use systems, it is a common pattern in tropical ecosystems for the ant fauna and is related to the aggregated spatial distribution pattern of the species, the high diversity of the family Formicidae and the presence of rare species (Santos et al., 2006).

Despite the similarities in the structural complexity, the different conditions of each environment regarding biotic and abiotic factors were determinants for the structuring of the ant communities in the land-use systems. Some ant species present limitations to colonize simplified environments due to several factors, to include lack of food, nesting resources, abiotic conditions specificity and limited competition abilities (Martins et al., 2011). In contrast, invasive and generalist ant species with low ecological requirements may present greater competitive success in habitats with less structural complexity (Martins et al., 2011). In the present study the most frequent species in the pasture – *Ectatomma edentatum* Roger, 1863, *Camponotus rufipes* Fabricius, 1775 and *Wasmannia auropunctata* (Roger, 1863) are common in anthropized habitats (Almeida et al., 2007; Coriolano et al., 2014; Estrada et al., 2014; Iop et al., 2009). In addition, *W. auropunctata* is an invasive and generalist species with high reproductive and predatory capacity (Delabie, 1988). *Atta sexdens rubropilosa* Forel, 1908 was the most abundant in the eucalyptus plantation for using the leaves of this species for the cultivation of the fungus from which it feeds, being considered important pest of this tree (Zanetti et al., 2014). In the secondary forest, the most abundant species, *Odontomachus chelifer* Latreille, 1802, is a predator and an important seed disperser, being commonly collected in semi-deciduous seasonal forests, and rarely observed in highly anthropized habitats (Almeida et al., 2013). *Ectatomma permagnum* Forel, 1908 has already been collected in eucalyptus plantations and native forests (Soares et al., 2010).

One species that deserves attention is *Tranopelta gilva* Mayr, 1866, which is not commonly found in studies carried out in areas under the Atlantic Forest domain, maybe because it is not easily observed foraging on the surface (Baccaro et al., 2015). There is

scarce information about the biology of species of this genus, but it is known that they build their nests in the soil or leaf litter under barks of tree trunks in forests (Baccaro et al., 2015).

The number of ant guilds may be positively related to the complexity of the vegetative structure (Macedo et al., 2011), but this finding was not observed in this work since the pasture and the secondary forest presented the same number of guilds. On the other hand, the frequency of species richness in the guilds was influenced by the land-use systems. The vegetation structure of the native forest and the commercial forest provided guilds of ants with a relative number of ant species different from the pasture. This result reinforces the usefulness of ant guilds as indicators of environmental quality. It is worth mentioning that *Cephalotes pusillus* (Klug, 1824) and *Crematogaster* sp.1, the only species classified in the guild as “arboreal omnivorous”, were only recorded in the pasture. This fact could be due to the presence of trees and shrubs in the one studied. It is very likely that there are also arboreal ants in the eucalyptus plantation and secondary forest; however, the method used in this study aimed to sample epigeic ants and therefore did not allow the detection of arboreal ants.

## 5. CONCLUSIONS

The present study showed that ant communities could be used to assess the effects of land-use changes by providing subsidies for the use of ants as environmental indicators. In addition, it emphasizes the need for conservation of natural forests for protection of the biodiversity of Atlantic Forest. Even the secondary forest at an intermediate ecological succession stage can show a diverse fauna different from that of adjacent anthropized areas. However, our results also indicate that areas cultivated with forest species that allow a good development of an understory with native species can harbor considerable ant diversity.

## ACKNOWLEDGEMENTS

The authors are thankful to UFRRJ for a research fellowship granted to Laiz da Cunha Messias Honório Apolinário.

## SUBMISSION STATUS

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Received: 16 Nov., 2017

Accepted: 13 Dec., 2018

## CORRESPONDENCE TO

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