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SPECIES DIVERSITY AND ABUNDANCE OF ANTS IN LOWLAND TROPICAL RAIN FOREST OF BALA FOREST, NARATHIWAT PROVINCE, SOUTHERN PENINSULAR THAILAND

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ABSTRACT

Studies on the species diversity and abundance of ants in Bala forest at Hala-Bala Wildlife Sanctuary, Southern Peninsular Thailand, were conducted in lowland tropical rain forest. Ants were collected every 2 months by 4 methods: leaf litter sifting, hand collecting, honey bait traps and soil sampling, between March 2001 to March 2002. Eight subfamilies, 63 genera and 255 species of ants were identified. Species richness, abundance and species composition varied with season and collection method. The highest number of species (133) was found in January 2002. It was also discovered that the combination of 4 methods yielded higher numbers of species, genera and subfamilies than the use of any one method. The highest number of genera and species was found in Myrmicinae (26 genera 104 species), followed by Ponerinae (16 genera 74 species) and Formicinae (12 genera 47 species). The genus *Pheidole* had the highest number of species (25), followed by *Pachycondyla* (15), *Hypoponera* (13), *Cerapachys* (12) and *Camponotus* (11). Species diversity and abundance of ants are rather high in the lowland tropical rain forest. A combination of sampling methods is recommended for inventories of ant communities, and comparisons between different microhabitats as well as for long-term monitoring, providing useful data in biodiversity and conservation studies in tropical rain forests.

Key words: abundance, ants, Bala forest, diversity, Hala-Bala Wildlife Sanctuary, lowland tropical rain forest, Southern Peninsular Thailand

INTRODUCTION

Ants (Formicidae, Hymenoptera) are eusocial insects which have been evolving successfully since the Cretaceous Period. Around 10,000 species have been described belonging to 296 genera and 16 subfamilies (BOLTON, 1994). They are abundantly found in almost every habitat throughout the world. However, the number of species still remaining to be discovered and described is many times higher (HÖLLDOBLER & WILSON, 1990).

Ants are important ecologically because they function at many levels in an ecosystem, as predators, prey and scavengers, and they have diverse associations with plants such as protectors, seed dispersers, pollinators, and sometimes even herbivores (BRONSTEIN, 1998).

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Many species participate in symbioses with plants and other animals, particularly arthropods (SCHULTZ & MCGLYNN, 2000). Many ant species are highly sensitive to microclimate and habitat structure and thus respond rapidly to environmental change (ALONSO *ET AL.*, 2000; ANDERSON, 1990; KING *ET AL.*, 1998). For example, in Australia, ants have been used extensively as bioindicators (ANDERSON, 1997) in relation to minesite restoration (MAJER *ET AL.*, 1984) and other disturbances such as fire grazing and logging (ANDERSON, 1991; YORK, 1994).

Lowland forest habitats tend to have the most abundant and diverse flora and fauna. Tropical continental forests have the greatest recorded species diversity of ants (HÖLLDOBLER & WILSON, 1990). In Malaysia, 20 m^2 of litter and rotting logs contained 104 ant species representing 41 ant genera (AGOSTI *ET AL.*, 1994). In Peruvian tropical lowland forest, 128 species (48 genera) were found in approximately 5 hectares of forest, and 43 species (26 genera) in a single tree (TOBIN, 1994; WILSON, 1987). Rainforest is being lost at a rate of approximately 1.2% per year in Asia (WHITMORE, 1997). In Thailand, forest cover has been reduced from 53% of the country (BHUMIBAMON, 1986) to about 22.8% or 111,010 km^2 (FAO, 1997), due both to habitat destruction and habitat disturbance. In the lowlands, the natural forest cover has almost completely vanished and has been replaced by rubber, fruit and oil palm plantations, while the remaining forests have been fragmented and degraded (GRAHAM & ROUND, 1994). Peninsular Thailand is a region of high national conservation significance because it contains all of Thailand's remaining lowland rain forests, the most biologically diverse and threatened of forest types in Southeast Asia (SODHI *ET AL.*, 2004). Less than 20% of the Thai Peninsula remains under forest cover (COLLINS *ET AL.*, 1991). Little is known about status and detailed ecology of forest ants in Thailand, therefore a basic knowledge of local patterns of ant diversity will assist in biodiversity and conservation planning.

In this paper species richness, species abundance and species composition of ants in lowland tropical rain forest were examined, using four sampling methods, which were designed to collect ants from different strata of the forest including lower vegetation, litter and soil (HASHIMOTO *ET AL.*, 2001), and provide unbiased representation of local ant communities.

STUDY AREA

The Bala forest is part of Hala-Bala Wildlife Sanctuary in Narathiwat Province, on the Thai–Malaysia border (5° 37' N, 101° 08' E). The Bala forest is 111.5 km^2 in area and is isolated from other forests by agricultural lands on the Thai side of the border. It ranges in elevation from 50 to 960 m above mean sea level (msl). It is classified by WHITMORE (1990) as Indo-Malayan rain forest. During the fieldwork (March 2001 to March 2002) rainfall was > 4,700 mm (rainfall data from the Waeng District meteorological station approximately 10 km from the Bala forest). This study was conducted in lowland forest below 200 m msl and the ants were collected every 2 months at 3 stations.

METHODS

Sampling Methods

Three stations were established and at each, one transect (180 m long) was set and subdivided into 3 60-m sampling sections. Each section was sampled by different methods (modified from YAMANE & HASHIMOTO, 1999). The methods involved the following procedures:

Leaf litter sifting (LL): Leaf litter was gathered up, sifted and sorted on a pan and ants were collected from it. Such sampling was repeated for 30 minutes per sampling section.

Hand collecting (HC): Ants were picked up using forceps from the lower vegetation and rotten logs. This procedure was carried out for 30 minutes per sampling section.

Honey bait traps (HB): Fifteen bait traps with 50% honey solution were set on the forest floor at 4-m intervals along the transect in each sampling section. The bait traps were set for 30 minutes and the ants attracted to the bait traps were collected using forceps.

Soil sampling (SS): Five soil samples were taken, each 20 x 20 x 10 cm, at 12-m intervals along the transect in each sampling section. The soil samples were sifted using a sieve and pan, and the ants were collected using forceps.

Identification

BOLTON (1994, 1994a, 1995b), DORROW & KOHOUT (1995), EGUCHI (2001), HÖLLDOBLER & WILSON (1990) and HUNG (1967) were referred to for ant identification. Species-level identifications were based only on morphological characters of the workers and confirmed using the reference collection at the Ant Museum of Kasetsart University, Bangkok. Also, *Polyrhachis* species were confirmed by Dr. Rudolf J. Kohout from Queensland Museum, Australia.

Data Analysis

The species composition for different sampling methods was assessed using a qualitative index based on presence or absence data. Similarity of samples was measured using the Sorensen index (C_S) (MAGURRAN, 1988).

RESULTS

Species Richness and Abundance of Ants

The total number of ant species collected per 2 months for different sampling methods and combination of 4 methods is shown in Figure 1. The 4 sampling methods yielded a total of 255 ant species. The highest number of species was found in January 2002 (133 species) and the lowest in May 2001 (85 species). In terms of the number of species collected by each method, leaf litter sifting was consistently more efficient than the other methods throughout the year. The number of species peaked in September 2001 (61 species), and

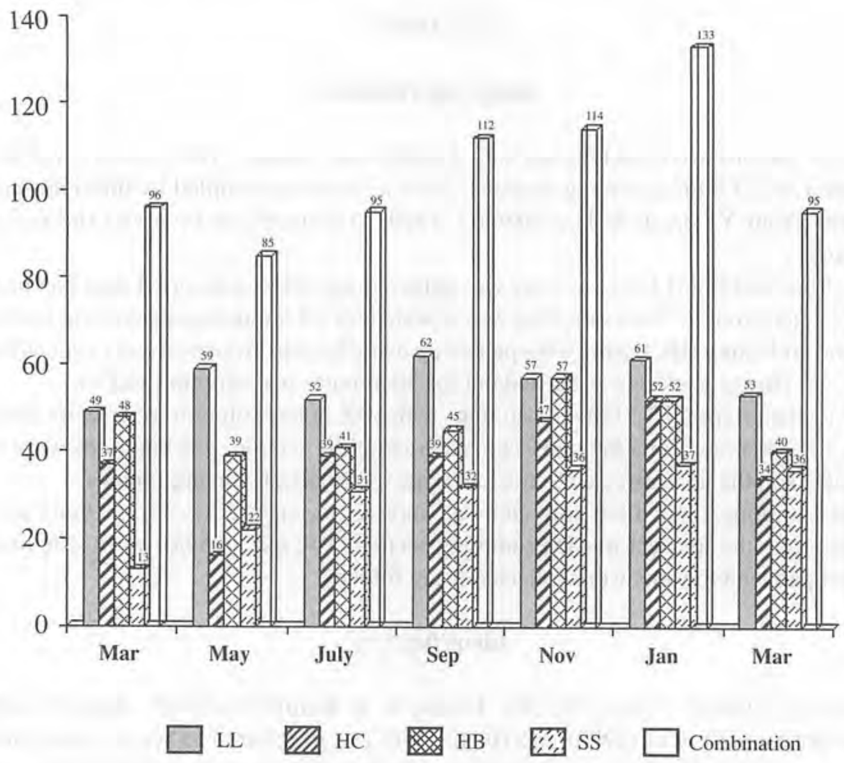

Figure 1. Total number of ant species collected by each method and combination of 4 methods during March 2001 to March 2002.

Table 1. Proportion of ant species and genera belonging to different subfamilies in the four sampling methods, LL, leaf litter sifting; HC, hand collecting; HB, honey bait traps; SS, soil sampling.

Subfamilies	LL		HC		HB		SS	
	Number		Number		Number		Number	
	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.	Gen.	Sp.
1. Aenictinae	1	4	1	1	1	1	-	-
2. Cerapachyinae	1	8	1	3	-	-	1	2
3. Dolichoderinae	3	6	4	7	2	4	3	4
4. Formicinae	6	17	9	28	9	18	7	15
5. Leptanillinae	-	-	-	-	1	1	1	1
6. Myrmicinae	20	69	19	47	17	57	15	43
7. Ponerinae	13	35	11	28	13	38	8	21
8. Pseudomyrmecinae	-	-	1	2	-	-	1	1
Total	44	139	46	116	43	119	36	87
(Unique)	(4)	(48)	(7)	(52)	(2)	(30)	(1)	(10)

bottomed in March 2001 (49 species). Honey bait traps recorded peak in the number of species in November 2001 (57 species), equaling the leaf litter sifting results.

The number of species collected by each method is shown in Table 1. Leaf litter sifting provided the largest total number of species (139), followed by honey bait traps (119), hand collecting (116) and soil sampling (87). Hand collecting provided the largest number of genera (46), followed by leaf litter sifting (44), honey bait traps (43) and soil sampling (36). In terms of the number of species collected in one sample by each method, hand collecting recorded the largest number of species (52), followed by leaf litter sifting (48), honey bait traps (30) and soil sampling (10).

Taxonomic Composition of Ants

A total of 255 ant species belonging to 63 genera and 8 subfamilies was obtained by the combination of the 4 sampling methods. The highest numbers of genera and subfamilies (49 genera and 8 subfamilies) were found in September 2001, while the lowest numbers of genera and subfamilies were found in May 2001 and March 2002 (38 genera and 5 subfamilies).

The distribution of species in the different subfamilies showed a dominance of Myrmicinae with 104 species (40.8%), followed by Ponerinae with 74 species (29.0%) and Formicinae with 47 (18.4%) species. In the Cerapachyinae and Dolichoderinae, 12 (4.7%) and 8 (3.1%) species were found, respectively. Five species (2.0%) found were in the Aenictinae. The proportion of species in the Pseudomyrmecinae and Leptanillinae subfamilies was the smallest (2.0% each).

Almost half of the genera, (26 genera or 41%) are members of the subfamily Myrmicinae. Sixteen genera (25%) belonged to the Ponerinae and 12 (19%) to the Formicinae. Dolichoderinae was represented by 4 genera (6%), Leptanillinae by 2 genera (3%). Aenictinae, Cerapachyinae, and Pseudomyrmecinae were represented by one genus each (2%).

Proportion of Species and Genera of Different Subfamilies Caught by the Four Sampling Methods

Of the 8 subfamilies, Myrmicinae, Ponerinae and Formicinae were dominant in terms of number of species. Although these subfamilies were collected by all sampling methods, the proportions varied among sampling methods (Table 1). Species of Myrmicinae and Ponerinae were captured most frequently by leaf litter sifting (38 species) and honey bait traps (69 species), while species of Formicinae were captured most frequently by hand collecting (28 species). For the soil sampling method, Myrmicinae was the dominant subfamily (43 species).

Proportion of Species of Different Genera Caught by the Four Sampling Methods

The ranking of ant genera by the number of species and the proportion of the total number of species is shown in Table 2. The five most species-rich genera were *Pheidole* (25 species or 9.8%), *Pachycondyla* (15 species or 5.5%), *Hypoponera* (13 species or 5.1%), *Cerapachys* (12 species or 4.7%) and *Camponotus* (11 species or 4.3%). Twenty-five genera were found with only 1 species, 9 with 2 and 6 with 3 species.

Table 2. Ranking of ant genera sampled by the all four sampling methods, according to the number of species included and the proportion of the total number of species.

Rank	Genera	No. of species	Proportion (%)	Rank	Genera	No. of species	Proportion (%)
1	*Pheidole*	25	9.80	14	*Aphaenogaster*	2	0.78
2	*Pachycondyla*	15	5.55	14	*Dacetinops*	2	0.78
3	*Hypoponera*	13	5.10	14	*Dilobocondyla*	2	0.78
4	Cerapachys	12	4.71	14	*Pyramica*	2	0.78
5	*Camponotus*	11	4.31	14	*Cryptopone*	2	0.78
6	*Polyrhachis*	10	3.92	14	*Diacamma*	2	0.78
6	*Oligomyrmex*	10	3.92	15	*Dolichoderus*	1	0.39
7	*Acropyga*	9	3.53	15	*Philidris*	1	0.39
7	*Tetramorium*	9	3.53	15	*Tapinoma*	1	0.39
8	*Crematogaster*	8	3.14	15	*Anoplolepis*	1	0.39
8	*Leptogenys*	8	3.14	15	*Cladomyrma*	1	0.39
9	*Vollenhovia*	7	2.74	15	*Euprenolepis*	1	0.39
9	*Ponera*	7	2.74	15	*Oecophylla*	1	0.39
10	*Strumigenys*	6	2.35	15	*Prenolepis*	1	0.39
11	*Aenictus*	5	1.96	15	*Leptanilla*	1	0.39
11	*Technomyrmex*	5	1.96	15	*Protanilla*	1	0.39
11	*Paratrechina*	5	1.96	15	*Cataulacus*	1	0.39
11	*Monomorium*	5	1.96	15	*Calyptomyrmex*	1	0.39
11	*Myrmecina*	5	1.96	15	*Cardiocondyla*	1	0.39
11	*Amblyopone*	5	1.96	15	*Lophomyrmex*	1	0.39
11	*Anochetus*	5	1.96	15	*Mayriella*	1	0.39
11	*Platythyrea*	5	1.96	15	*Meranoplus*	1	0.39
12	*Gnamptogenys*	4	1.57	15	*Proatta*	1	0.39
13	*Pseudolasius*	3	1.18	15	*Recurvidris*	1	0.39
13	*Lordomyrma*	3	1.18	15	*Rhoptromyrmex*	1	0.39
13	*Pheidologeton*	3	1.18	15	*Solenopsis*	1	0.39
13	*Pristomyrmex*	3	1.18	15	*Centromyrmex*	1	0.39
13	*Odontomachus*	3	1.18	15	*Discothyrea*	1	0.39
13	*Tetraponera*	3	1.18	15	*Emeryopone*	1	0.39
14	*Echinopla*	2	0.78	15	*Mystrium*	1	0.39
14	*Myrmoteras*	2	0.78	15	*Odontoponera*	1	0.39
14	*Acanthomyrmex*	2	0.78				

Table 3. Similarity of ant species in the four sampling methods.

Method	Hand collecting	Honey bait traps	Soil sampling
Leaf litter sifting	0.35	0.56	0.54
Hand collecting	-	0.38	0.42
Honey bait traps	-	-	0.58

The proportion of species belonging to genera varied among sampling methods. Although species of *Pheidole* were sampled the most by all methods, *Cerapachys* and *Tetramorium* (8 species or 6%) were the second most abundant in leaf litter sifting while *Camponotus* and *Polyrhachis* (9 species or 8%) were the second most abundant in hand collecting. In honey bait traps, *Oligomyrmex, Hypoponera* and *Pachycondyla* (8 species or 7%) were the second most abundant genera, while *Pachycondyla* (7 species or 8%) were the second most abundant in soil sampling.

Similarity of Ant Species Caught by Different Sampling Methods

The similarity analysis of species collected by the four sampling methods is shown in Table 3. Honey bait traps and soil sampling were the closest ($C_S = 0.58$), followed by honey bait traps and leaf litter sifting ($C_S = 0.56$) and soil sampling and leaf litter sifting ($C_S = 0.54$). Leaf litter sifting and hand collecting were farthest apart ($C_S = 0.35$).

DISCUSSION

Species Richness, Abundance and Composition of the Ant Community

The results from this study show that species diversity of ants is high in the lowland tropical rain forest, equivalent to 3% of the number of ant species that have been described in the world (BOLTON, 1995a), or about 26–32% of the total number of ant species in Thailand (WIWATWITAYA, 2003). The diversity of the aboreal ants might have been underestimated in this study because sampling was restricted to hand collecting. Many studies have shown that a combination of sampling methods yields higher numbers of ant species than the use of a single method, and each method is adept at collecting different ant species (BRÜHL *ET AL.*, 1998; HASHIMOTO *ET AL.*, 2001; ROMEO & JAFFE, 1998; YAMANE & HASHIMOTO, 1999). The similarity analysis of species collected by the four sampling methods showed a low level of similarity between methods. This suggests that each of the four methods collected different components of the ant community. This pattern is similar to studies of ant communities in tropical rain forest of Sabah, Borneo (HASHIMOTO *ET AL.*, 2001). In tropical rain forest, strong partitioning of the ants among the different strata has been reported (BRÜHL *ET AL.*, 1998). Therefore, a combination of sampling methods is recommended for inventories of the ant community, comparisons between different microhabitats as well as for long-term monitoring.

Analysis of species diversity is difficult for social insects, especially ants, because the number of individuals collected does not necessarily reflect the relative abundance of species, which is need for diversity indices (BESTELMEYER *ET AL.*, 2000: LONGINO, 2000). This is due to the fact that some ant species with large colony size may recruit many workers to a bait or send a lot of workers out foraging while other ant species forage singly (HÖLLDOBLER & WILSON, 1990: SHATTUCK, 1999). Abundance of ants would best be measured as the number of colonies per species in an area, but this is difficult to do in practice (BESTELMEYER *ET AL.*, 2000: LONGINO, 2000). Therefore, the frequency of collection, measured as the number of baits, or traps in which species are present is often used as the measure of relative abundance of ants as suggested by BESTELMEYER *ET AL.* (2000), HASHIMOTO *ET AL.* (2001) and LONGINO (2000). This measure would be suitable for estimating how abundant ant species are, since the probability of collecting foraging workers is not based upon colony size of forager density but base upon the occurrence of ant species over the area.

Most species of Myrmicinae and Ponerinae were found in the leaf litter layer, as expected from previous studies (ANDERSON & MAJER, 1991; BELSHAW & BOLTON, 1994; BRÜHL *ET AL.*, 1998; LEVINGS, 1983). Formicinae are distributed mainly in the lower vegetation and in rotten logs, but they do also occur in the leaf litter layer and soil. A higher proportion of Formicinae were found in Sabah, Borneo (BRÜHL *ET AL.*, 1998; ITINO & YAMANE, 1994) where they were found mainly in the canopy and lower vegetation. The proportion of Formicinae was lower in this study because sampling focused only on the lower vegetation and the hand collecting method was applied to only a few trees.

In this study, Dolichoderinae and Pseudomyrmecinae species were mainly found in the lower vegetation and their range distribution is mostly in the canopy (BRÜHL *ET AL.*, 1998; FLOREN & LINSENMAIR, 1997). A single species of Pseudomyrmecinae was found in the soil because some species will occasionally forage on the ground around the base of trees or shrubs (SHATTUCK, 1999).

Army ants (Aenictinae and Dorylinae) are a predatory group and have highly aggregated distributions. Their colonies are nomadic and very large, with between 60,000 and 20,000,000 workers in many species (HÖLLDOBLER & WILSON, 1990). They are represented in this study by a single genus and 5 species of Aenictinae.

Cerapachyinae species of only one genus were found in the leaf litter, lower vegetation and rotten logs, but they also occurred in the soil samples. Species are known throughout the world in tropical and subtropical areas. Nests occur in a wide range of sites, most commonly directly in the soil with single, simple entrance holes or in rotten wood in the ground (SHATTUCK, 1999). Their workers are specialist predators of other ants, similar to army ants (BROWN, 2000; SHATTUCK, 1999).

Leptanillinae belonging to 2 genera and 2 species, *Leptanilla* sp. and *Protanilla* sp., were found in honey bait traps and soil sampling in this study. They are distributed in the Old World tropics and temperate zone, including Australia (BROWN, 2000; HÖLLDOBLER & WILSON, 1990). Some species are known to form colonies of several hundred workers in the soil, to be predacious on small arthropods and to forage largely or exclusively in the soil, and some species are known to be nomadic and forage using group-raiding, similar to army ants (SHATTUCK, 1999). They have remained a puzzle, because they are very rare locally and little is known about their taxonomy, biology and ecology.

Pheidole was the most species-rich genus with 25 species. This is the second largest genus of ants in the world and is particularly diverse in tropical rain forest (BROWN, 2000; EGUCHI, 2001). Most species were found in the soil and honey bait traps but they also occured in the leaf litter layer, lower vegetation and rotten logs. This is similar to other studies in which *Pheidole* species were found, mostly nesting in the soil. They can also make nests under rocks and a few species are known to occasionally nest aboreally or nest in rotten wood on the ground (BROWN, 2000; EGUCHI, 2001; SHATTUCK, 1999). A wide range of food is taken as these ants are general predators and scavengers. They also feed on seeds and many species are omnivorous (BROWN, 2000; SHATTUCK, 1999).

Pachycondyla with 15 species and *Hypoponera* with 13 species were found in the leaf litter layer, lower vegetation, rotten logs, soil sampling and honey bait traps. They are distributed worldwide in the tropics and subtropics (BROWN, 2000). *Pachycondyla* is a large and diverse group of ants. They nest in soil, under rocks, occasionally in lower vegetation, foraging on the ground and most are general predators or scavengers. Some are specialist predators on termites and harvest seeds (BROWN, 2000; HÖLLDOBLER & WILSON, 1990; SHATTUCK, 1999). *Hypoponera* can be found under rocks, other objects on the ground, in rotten wood and in leaf litter (BROWN, 2000; HÖLLDOBLER & WILSON, 1990; SHATTUCK, 1999). Their role is cryptic predators, foraging in leaf litter and some species are known to specialise on Collembola (SHATTUCK, 1999).

The fifth largest species-rich genus in this study is *Camponotus* with 11 species. Most species were found in the lower vegetation and rotten logs, but they also occurred in the leaf litter layer, soil sampling and honey bait traps. This is the largest genus in the world with 1,518 described species and subspecies (SHATTUCK, 1999). They are found on the ground or on lower vegetation and nests in dead wood, soil, between rocks, among the roots of plants and in twigs on standing shrubs or trees (BROWN, 2000; HÖLLDOBLER & WILSON, 1990; SHATTUCK, 1999). They are general scavengers and predators, including feeding on nectar and plant secretions (SHATTUCK, 1999).

The differences between the most species-rich genera might be related to different sampling efforts. In studies where the canopy was investigated (BRÜHL *ET AL.*, 1998; FLOREN & LINSENMAIR, 1997; YAMANE, 1997; YAMANE & NONA, 1994), *Camponotus* was the most species-rich genus. In this study, *Pheidole* was the dominant genus; this is similar to the ant communities in the Kimberly region of Australia (ANDERSON & MAJER, 1991) and ants in New Guinea rain forest (WILSON, 1959). It might be related to the previous studies that the leaf litter and soil of tropical rain forest were sampled more extensively than the other strata (lower vegetation and canopy).

To summarize the results, species diversity and abundance of ants are very high in lowland tropical rain forest and a combination of sampling methods is recommended for inventories of the ant community, comparisons between different microhabitats, as well as for long-term monitoring, providing useful data in biodiversity and conservation studies in tropical rain forest.

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