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Original Article

Canopy ants on the briefly deciduous tree (*Elateriospermum tapos* Blume) in a tropical rainforest, southern Thailand

Sopark Jantarit*, Suparoek Wattanasit and Sunthorn Sotthibandhu

Department of Biology, Faculty of Science,
Prince of Songkla University, Hat Yai, Songkhla, 90112 Thailand.

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Abstract

A year-round investigation of the ant species present in the canopies of the briefly deciduous tree, *Elateriospermum tapos* Blume was conducted in the tropical rainforest at Khao Nan National Park (KNNP), Nakhon Si Thammarat Province, Southern Thailand during May 2006-March 2007. Three permanent plots of 50x50 m^2 were established 500 m apart. In each plot a single plant was randomly selected for fogging at bimonthly intervals. A total of 3,285 individual ants were identified and belonged to 5 subfamilies 31 genera and 123 morphospecies. Ants in the subfamily Myrmicinae were the most dominant species followed by Formicinae, Dolichoderinae, Pseudomyrmicinae and Ponerinae, respectively. In terms of abundance and number of species, the top four genera were *Crematogaster, Camponotus*, *Polyrhachis* and *Pheidole*, whereas *Camponotus(Karavaievia)* sp.2, *Technomyrmex* sp.1, *Oecophylla smaragdina* (Fabricius), *Crematogaster (Crematogaster)* sp.7, and *Camponotus (Karavaievia)cf. dolichoderoides* were dominant in the numbers of individuals. When *E. tapos* species shed their leaves briefly around February-March, the species richness of canopy ants (P>0.05) did not significantly change. Explanations for this finding are discussed.

Keywords: canopy ants, deciduous tree, *Elateriospermum tapos*, tropical rainforest

1. Introduction

Tropical rainforests have an abundance of habitats that have created the most remarkable biodiversity of organisms in the world (Whitmore, 1990). Forest canopies play a key role in many ecosystems on earth and have been recognized as a habitat reservoir for genetically diverse organisms, particularly those in the arthropod group (Erwin 1983; Basset *et al*., 2003). Tropical rainforests are dominated by evergreen vegetation and consequently tropical deciduous vegetation in the rainforests has always received less attention (Whitmore, 1990). However, tropical deciduous trees are of immense value because of their very important ecosystems, diversity and richness of endemic species (Castaño-Meneses and Palacios-Vargas, 2003). With regard to *Elateriospermum tapos* Blume, this is one deciduous tree that is commonly found in South-East Asian tropical rainforests (Whitmore 1972, Yong and Salimon, 2006). *E. tapos* is widely distributed in Peninsular Thailand and throughout Malaysia. It is a member of the Euphorbiaceace family and can be classified into the subfamily of the Crotonoideae and Elateriospermeae tribe. *E. tapos* is a monoecious canopy tree that responds to a deciduous life-cycle in the short period of the dry season. Mature trees shed leaves annually around February-March (Whitmore 1972; Osada *et al*. 2002). This species is dominant in the Khao Nan National Park (KNNP), Nakhon Si Thammarat Province, Southern Thailand. In general, tropical deciduous trees shed their leaves during periods of low moisture availability and high evaporative demand (Gove *et al*, 2005). Hence, a variation in the leaf life-cycle, say when *E. tapos* sheds its leaves at different times, is expected to be associated with changes in environmental factors, for instance temperature and humidity, and cause changes to the diversity of arthropods, particularly canopy ant species. Ants

*Corresponding author.
Email address: fugthong_dajj@yahoo.com

have long been known to dominate the arthropod communities in tropical forest canopies both in terms of biomass and the diversity of individuals (Erwin 1983; Hölldobler and Wilson, 1990; Tobin, 1995; Floren and Linsenmair, 1999). They are a major component of tropical rainforests and play an important role in any functional ecosystem (Hölldobler and Wilson, 1990; Tobin, 1995). Ants are valuable bio-indicators because they are common and abundant, have a high species richness, are easily sampled, occupy higher trophic levels, and can be successfully used to evaluate biotic responses to environmental change (Majer, 1983; Carroll and Risch, 1990; Andersen, 2000). Such changes have been known to impact the species richness and species composition of arthropod assemblages (Kaspari, 1993; Lawton *et al.*, 1998; Andersen, 2000). As a consequence, canopy ants respond to physical factors e.g. moisture and temperature gradients, and host conditions, that depend on the ants tolerance to heat, desiccation, and host biochemistry that can be related to ant foraging activity (Coley and Aide, 1991; Kaspari, 1993; Basset, 1996; Schowalter and Lowman, 1999; Andersen, 2000; Hahn and Wheeler 2002). Any large-scale disturbances to the forests appear to have the greatest effect on ant diversity and abundance (Kaspari, 1993; Lawton *et al.*, 1998; Floren & Linsenmair, 1999; Andersen, 2000). The tree foliage also plays a key role for canopy ants by providing structures for nesting ants, reducing desiccation, water loss, increasing local moisture and bringing about greater activity of the ants. Likewise, it can protect ants from predators, and acts as a buffer to climatic extremes, wind and rainstorms (Hölldobler and Wilson, 1990). As *E. tapos* sheds its leaves annually, it appears to respond to drier conditions and the changes of the environmental surroundings at that time. As a result, the loss of leaves is expected to affect either the species richness or the composition of ant communities even though arboreal ants have an ability to withstand desiccation stress (Hood and Tschinkel, 1990). Thus, an understanding of the ants that make up the species richness and composition of the canopy ants in the tree crowns of briefly deciduous trees has implications for forest managers and conservation biology. On the basis of this information, the aim of this work was to determine the species richness and composition of the canopy ants especially during the brief period when the leaves are lost at KNNP and to determine whether the composition of canopy ants changes during this time.

2. Materials and Methods

2.1 Study sites

This study was carried out in the tropical lowland rainforest of Khao-Nan National Park (KNNP), Nakhon Si Thammarat Province, Southern Thailand, (8°41'N-8°58'N, 99°30'E-99°99'E) at Pra forest. The KNNP is a part of the Nakhon Si Thammarat mountain range (Figure 1). It is a complex mountain ridge with a high diversity of floral and faunal species. The Park covers 436 Km^2 and elevations range from 80-1,438 meters above sea level (Wittaya, 2000). The regional climate is relatively constant and can be divided into 2 distinct seasons: wet and dry. The rainy season can be divided into the main rainy season from November-January and a lesser one from May-October, whereas the dry season is around February-April. The level of rainfall fluctuates between 2000-3500 mm (the Meteorological Department of Nakhon Si Thammarat Province, unpublished data). In addition, Pra forest has a long recorded history and many briefly deciduous *E tapos* trees. (Wittaya, 2000).

2.2 Sampling procedure

Communities of Pra forest, *E. tapos* trees were selected for the sampling of ants at KNNP during May 2006-March 2007. Three permanent plots of 50x50 m^2 were selected at least 500m apart. Then a single tree of 30-40 m height was selected in each plot for canopy fogging. The

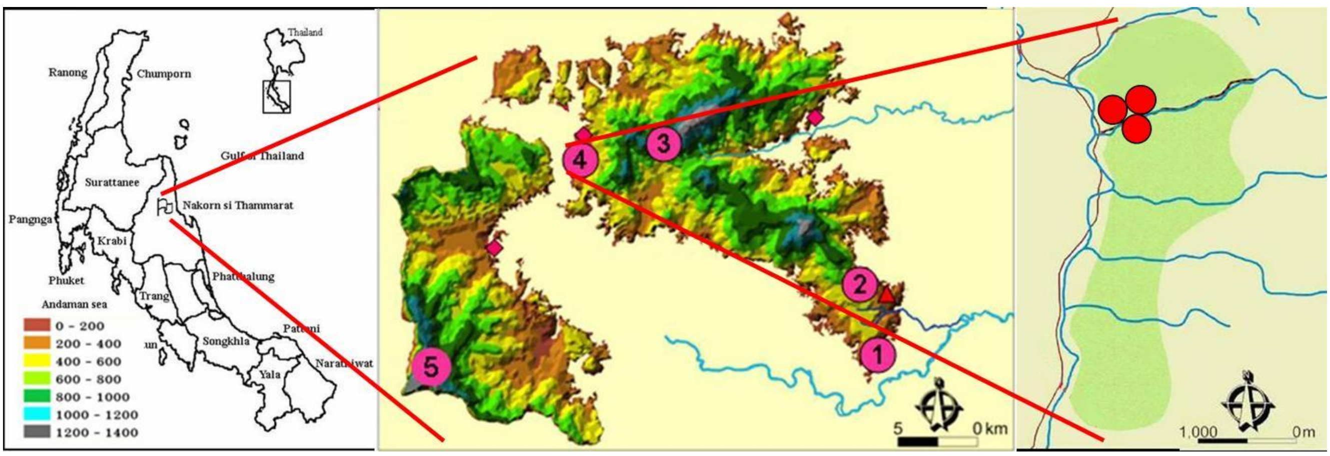

Figure 1. Study site at Khao Nan National Park consisting of five field stations. The number four is the Pra forest and the red circles are permanent plots.

canopy fogging was conducted bimonthly. Thus, a total of 18 trees were sampled during the period of study.

A synthetic pyrethroid insecticide diluted with diesel oil (1:49) was sprayed into the tree canopy into ten quadrate-shaped areas (1x1 m each) with a cylinder containing 70% ethanol suspended underneath the tree canopy to collect ants and other organisms. The fogging technique, using the fogging equipment SWINFOG® model SN 50, was carried out in the early morning around 0600 hours in order to avoid strong winds and sunlight. Fogging took 20 minutes for each tree and specimens were collected 2 hours afterwards. All of the specimens were preserved in 70% ethanol immediately and kept for sorting at the entomology laboratory of the Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai campus.

2.3 Identification and classification

All specimens were identified to genus level using the key of Bolton (1994) and Hölldobler and Wilson (1990) based on the external morphological characteristics of the worker class.

2.4 Statistical analysis

Species richness was estimated using the EstimateS software version 7.51, (see Colwell and Coddington, 1994 and Colwell, 2005).

Species accumulation curves were computed to analyze whether the sampling efforts were adequate to represent the local ant communities by the first order jackknife non-parametric estimator. The Jackknife1 was calculated as shortcuts to extrapolate from the species number observed to the true number present because this estimator was the most precise and least biased. All calculations were randomized 50 times. The Jackknife1 is calculated as: $S_{est}=S_{obs}+R(n-1/n)$, where S_{est} is the estimated total number of species, S_{obs} is the observed number of species, R is the number of species that occur in only one sample (singletons), and n is the number of specimens.

In addition, to determine whether there were differences in species richness at different times during the period when *E. tapos* shed its leaves, comparison were made with the period when leaves persisted. Analysis of variance (one-way ANOVA) was applied to compare between mean numbers of species in the top four genera together with overall species and time using STATISTIX for Windows.

3. Results

3.1 Community composition and abundance of ant fauna

The canopy ants detected on the briefly deciduous tree belonged to five subfamilies, 31 genera and 123 morphospecies. The most dominant subfamilies were the Myrmicinae 49.2% (61 species), followed by Formicinae 32.3% (40 species), Dolichoderinae 12.9% (16 species), Pseudomyrmicinae 3.2% (4 species) and Ponerinae 2.4% (3 species) respectively (Table 1).

In terms of the abundance of genera and species, the

Table1. Distribution of genera and species numbers of the canopy ant on the briefly deciduous tree. Numbers of individuals are given in brackets.

Subfamily	genera	species/individuals	Subfamily	genera	species /individuals
Myrmicinae			Formicinae		
Cardiocondyla	1	9	*Camponotus*	19	1,231
Cataulacus	1	1	*Echinopla*	1	1
Crematogaster	26	630	*Myrmoter*	1	3
Dilobocondyla	1	1	*Oecophylla*	1	273
Lordomyrma	1	1	*Paratrechina*	2	7
Meranoplus	1	8	*Philidris*	1	15
Monomorium	8	44	*Prenolepis*	1	1
Oligomyrmex	2	121	*Polyrhachis*	13	41
Paratopula	1	1	*Plagiolepis*	1	7
Pheidole	10	52	Dolichoderinae		
Pheidolegeton	1	1	*Dolichoderus*	3	5
Rhopathromastix	1	118	*Technomyrmex*	5	55
Strumigenys	1	2	*Tapinoma*	8	387
Tetramorium	2	26	Pseudomyrmicinae		
Vombrisidris	3	1	*Tetraponera*	4	160
Vollenhovia	1	20	Ponerinae		
			Platythyrea	2	2
			Pachycondylla	1	1

top four genera were the *Crematogaster* (26 species), *Camponotus* (19 species), *Polyrhachis* (13 species) and *Pheidole* (10 species), whereas the remaining genera were comprised of 1-8 species. (Table 1).

The numbers of individuals and the proportion of the species that were dominant in the tree crown were *Camponotus(Karavaievia)* sp.2 (22%), *Technomyrmex* sp.1 (9%), *Oecophylla smaragdina* (Fabricius) (8%), *Crematogaster (Crematogaster)* sp.7 (6%), and *Camponotus (Karavaievia)cf. dolichoderoides* (5%).

3.2 Species richness on briefly deciduous trees

Overall, on the 18 trees fogged, we identified 123 morphospecies and 3,285 individuals. A species accumulation curve of the canopy ants using the jackknife estimator is shown in Figure 2. The observed curve and the curve for the jackknife estimate continues to rise with increasing sample size and indicated slightly asymptotic graphs (lack of convergence between the observed and estimated species richness curve). The species accumulation curve showed that the numbers of species recorded was likely to be a considerable underestimate of the real numbers. A measurement of the sample efficiency of the number of species of sampled ants (S_{obs}) as a proportion of the estimated number of species was calculated. It was estimated that there was an extrapolated maximum of 188 species but the number of species of sampled ants (S_{obs}) was only 123 species. The estimator expected 65 more ant species than those recorded from the fogging sample. As a result, the observed ant species represented at most 65% of the total species pool. As a consequence of a large number of species being found only once (32 singletons), the calculated estimate of undetected species is a rather high figure.

3.3 Effect of Leave shedding of canopy

Overall, the species collected were very similar at all collecting times, even when the plants changed their leaves (Figure 3) so leaf fall seemed to have no significant influence on the majority of the canopy ant species. There were also no significant differences between the times that plants shed their leaves and the time that they were clothed with leaves (F=1.17, P>0.05) (Table 2). The top four dominant genera were *Polyrhachis*, *Camponotus*, *Crematogaster*, and *Pheidole*. An analysis of variance (one-way ANOVA) showed no significant difference in the mean species number of these genera (P>0.05) (Table 2).

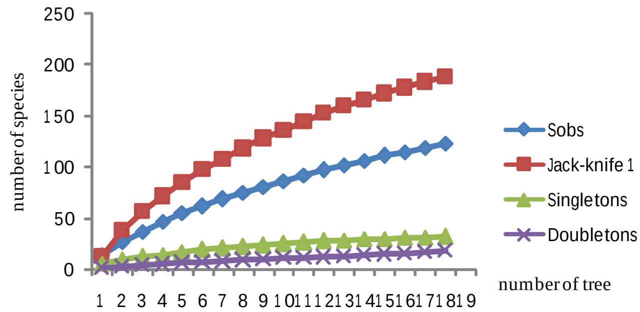

Figure 2. Species accumulation curves of observed and estimated ant species richness on the briefly deciduous canopy in KNNP from18 series of collections.
Note: S_{obs} = observed species richness
Jackknife1 = nonparametric estimator of species richness.

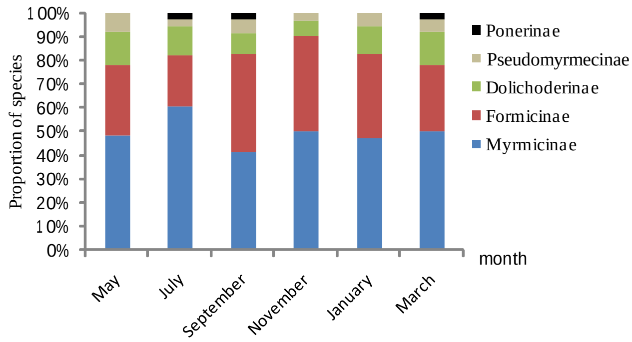

Figure 3. The proportion, at each sampling time, of the number of subfamily species.

Table 2. Mean (±SE) species number of ants in the top four genera as well as the analysis of variance (one-way ANOVA) showing the F-value and the significant difference level (P>0.05) of the mean number of species at KNNP during May 06 - March 07 (degree of freedom = 5).

Genera/month	*Polyrhachis*	*Camponotus*	*Crematogaster*	*Pheidole*	Overall species
May	2.66±0.41	2.00±0.00	2.66±0.48	2.00±0.47	20.33±9.02
July	0.66±0.36	1.66±0.36	3.00±0.47	0.66±0.25	14.00±3.61
September	1.00±0.43	2.66±0.41	3.00±0.33	0.33±0.25	12.33±6.35
November	1.33±0.25	2.00±0.33	2.33±0.41	1.00±0.44	11.33±3.21
January	1.00±0.33	2.00±0.00	3.00±0.44	0.33±0.25	13.00±2.65
March	0	3.00±0.00	3.33±0.41	0.33±0.25	16.33±2.89
F-value	1.77	0.97	0.13	0.93	1.17
P-value	0.19	0.47	0.98	0.49	0.37

4. Discussion

4.1 Species richness and composition of canopy ants

In the present study the total number of ant species detected (123) on briefly deciduous trees is similar to or slightly lower than found in the habitats of evergreen trees in other tropical rainforests. For example, 118 species were found in the canopy of Ton-nga Chang Wildlife Sanctuary, Southern Thailand (Tongjerm *et al*., 2005), 135 species in the canopy of a Peruvian Amazon rainforest (Wilson, 1987), 91 species from an Australian rainforest (Majer *et al*., 2001), 161 species in Budongo Forest, Uganda (Schulz and Wagner, 2002), 97 species in Southern Cameroon (Watt *et al*., 2002), and 169 species in a lowland evergreen rainforest, Sabah, Malaysia (Widodo *et al*., 2004) etc. We suggest that the Pra forest habitats are complex in terms of forest structure even though *E. tapos* predominates in this area. The mature trees were around 30-45 meters tall and supported a large number of epiphyte species, each with its own microclimate. Many other plant species can grow in the same area and the plant community is diverse (field survey). Humidity is always high (e” 90%) and this is significantly correlated with the foraging activity of the ants (Hahn and Wheeler, 2002). The mature leaves of *E. tapos* provide extrafloral nectaries by secretions from dot glands that support visiting ant species (Fiala and Maschwitz, 1992). The variability of foliage resulting from the annual shedding of leaves attracts many arthropod visitors to utilize this habitat depending on their particular niche. In addition canopy ants scavenge and hunt prey on a variety of food items especially insect corpses and they serve as successful farmers by feeding some homopteran or lepidopteran larvae for honeydew sources (Tobin, 1995; Vasconcelos and Davidson, 2000; Wagner and Kay, 2002; Heil and Mckey, 2003). As a result, these trees can provide a highly heterogeneous resource and variety of habitats that will encourage many ant species to explore the tree crown. The presence of this high number of ant species could have community consequences with co-evolutionary dynamics resulting in consolidation of some degree of ant-plant specialization interactions, but in this case we have not detected any such specific relationship between ant species and this plant. Nevertheless, because more than one hundred species of ants are supported on the *E. tapos* canopies this may have implications in that the briefly deciduous forest could provide hotspot areas with completely suitable structural feature for ants that are different from those already known. So, these results from the briefly deciduous tree should be applied to develop strategies for conservation of biological diversity and management practices.

The incompleteness of the species collected is also indicated by the first order jackknife non-parametric estimate of 188 species, which suggests that more than sixty-five species have yet to be found. The rarity of species is mainly due to the presence of a high number of singletons (32 species), while the more abundant species were collected in sufficient numbers. Schulz and Wagner (2002) have reported that the large numbers of singletons may be unique species that are not typical arboreal ants but perhaps be ground-nesting ants that forage temporarily on the tree crown. *Pheidole* is among top four genera and this genus is a ground dewelling ant in this study, thus this finding can support the previous study. These large numbers of unique species are one important reason for the species accumulative curve not to be an asymptotic graph. Another reason could be that there were insufficient numbers of sample trees. In this study we only sampled 18 trees and this is probably not enough to provide an adequate representative sample. It probably does not cover all types of *E. tapos* communities at Pra forest study site. Besides, Longino *et al.* (2002) also point out that a single method is not enough to confirm insect inventories. So a combination of the choice of method used and using large samples is important to finally confirm the species richness (Watanasit, 2003).

Considering the ant community, there is no doubt that the subfamily Myrmicinae is dominant in this study followed by Formicinae and Dolichoderinae because these subfamilies have a worldwide distribution in both terrestrial and arboreal ant assemblages (Hölldobler and Wilson, 1990; Bolton, 1995; Shattuck, 1999). With regard to genera, the four most common genera, namely *Crematogaster, Camponotus, Polyrhachis* and *Pheidole* are found most frequently on the briefly deciduous tree *E. topos*. Many species of *Crematogaster, Camponotus* and *Polyrhachis* are a truly arboreal group with an established colony on the tree crown and some also have a great foraging activity on the canopy but their nests are on the terrestrial level (Shattuck, 1999). In contrast, *Pheidole* is a genus that has been detected in hyperdiverse habitats including both arboreal and terrestrial and is frequently preferentially sampled by fogging. The canopy is able to sustain leaf litter and humus used by some species of *Phiedole* as an important source to support their nests that are mainly on the ground, but ants of this taxa frequently enter the tree crown and sometimes in large numbers (Hahn and Wheeler, 2002; Schulz and Wagner, 2002; Ribas *et al*., 2003; Schonberg *et al*., 2004).

Concerning the abundance of individual of species, the result showed that *Camponotus(Karavaievia)* sp.2, *Technomyrmex* sp.1, *Oecophylla smaragdina* (Fabricius), *Crematogaster(Crematogaster)* sp.7, *Camponotus (Karavaievia) cf. dolichoderoides* are most frequently found dwelling on the briefly deciduous canopy. Both *Camponotus (Karavaievia)* sp.2 and *Camponotus (Karavaievia) cf. dolichoderoides* are the most abundant species on *E. tapos* canopies (907 individuals ≈27%). Surprisingly, in the findings of Dumpert (1985), Dumpert and colleagues (1989, 1995, 2006), they pointed out that only one colony of *Karavaievia* or a few pavilions could be found in Peninsular Malaysia and also that they did not exist on plants that shed their foliage in rainforest. Those conclusions contrast with our study. It is possible the variety of habitat in the crown of the deciduous *E. tapos* provides a lot of niches that support

Karavaievia colonies better than other known species. Concerning *Oecophylla smaragdina* (Fabricius) is also a species with a well known arboreal life style. This species has widely available nesting sites, most frequently found in the openings of the canopy and has a great ability to produce many colonies in the same tree (Hölldobler and Wilson, 1978). We know nothing about the ecological information for *Technomyrmex* sp.1 and *Crematogaster(Crematogaster)* sp. 7, which are also a highly abundant and frequent species on *E. tapos*. We suggest that both species may favor an open habitat and may prefer a variable leaf canopy as found in this plant species.

4.2 Effect of leave fall on ant community

The ant species found in this tree when it has dropped its leaves are similar to when the tree has persistent leaves. There is some evidence to explain this phenomenon. *E. topos* shed their leaves between February-March and there is very little influence on the diversity of the canopy ants. After dropping their leaves, the plant produces flowers and new leaves with liquid sugar near by. Many studies show that flowering events provide an important food resource for the canopy ants which their abundance and diversity are associated with the reproductive structures and flowers of the plants (Rico-Gray, 1993; Rico-Gray *et al.*, 1998; Wagner and Kay, 2002; Heil and Mckey, 2003). Fiala and Linsenmair (1995). Consequently, canopy ants appear to exploit the carbohydrates, produced by the plant, as their main food source (Tobin, 1995). Now, host plants directly produce food rewards for attracting ants to protect themselves (Wagner and Kay, 2002; Heil and Mckey, 2003). So, the plentiful supply of food made available during flowering and the secretion of sugar fluids by young leaves allows much ant activity on the canopy even though plants have dropped their leave. Furthermore, Hahn and Wheeler (2002) found that arboreal ants could increase their activity on tree crowns even when the desiccation risk is high. In this case, pay off from environmental constraint is less than food resources for the canopy ants. Hood and Tshchinkel (1990) shows that arboreal ants can resist desiccation stress more effectively than the terrestrial ants. They have evolved more effective epicuticular lipid waterproofing and thicker waxy cuticles to prevent desiccation. As a consequence the briefly deciduous life-cycle of *E. tapos* appears to have little impact on the composition of the canopy ants.

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