Composition of Canopy Ants (Hymenoptera: Formicidae) in a Tropical Rainforest at Khao Nan National Park, Nakhon Si Thammarat Province

Sopark Jantarit

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Ecology (International Program)

Prince of Songkla University

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Author	Mr. Sopark Jantarit
Major Program	Ecology (International Program)

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ชื่อวิทยานิพนธ์ องค์ประกอบของมดบนเรือนยอดในป่าดิบชื้นของอุทยานแห่งชาติ
เขานัน จังหวัดนครศรีธรรมราช
ผู้เขียน นายโสภาค จันทฤทธิ์
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บทคัดย่อ

การศึกษาครั้งนี้ใช้ระยะเวลาหนึ่งปีในการศึกษาองค์ประกอบของมดบนเรือนยอดในป่าดิบชื้นของอุทยานแห่งชาติเขานัน จังหวัดนครศรีธรรมราช ระหว่างเดือนพฤษภาคม 2548 ถึงเดือนมีนาคม 2549 โดยใช้พื้นที่ศึกษา 2 พื้นที่ คือ บริเวณสำนักงานของตัวอุทยาน ซึ่งมีพืชไม่ผลัดใบเป็นพืชชนิดเด่น และบริเวณสถานีห้วยเลข ซึ่งมีต้นประ (*Elateriospermum tapos*) ซึ่งเป็นพืชผลัดใบเป็นพืชชนิดเด่น แต่ละพื้นที่ประกอบด้วยแปลงย่อยขนาด 50 X 50 เมตร จำนวน 3 แปลงย่อย แต่ละแปลงย่อยห่างกันประมาณ 500 เมตร การศึกษาครั้งนี้ใช้วิธีการพ่นหมอกควันของสารเคมี (fogging technique) ในการเก็บตัวอย่าง ในแต่ละแปลงย่อยจะสุ่มเลือกต้นไม้แปลงละ 1 ต้น ซึ่งจะทำการเก็บตัวอย่างทุกๆ 2 เดือน ผลการศึกษาพบมดทั้งหมด 16,884 ตัว จาก 7 วงศ์ย่อย 34 สกุล และ 205 ชนิด มดในวงศ์ย่อย Myrmicinae และวงศ์ย่อย Formicinae เป็นมดที่พบมากที่สุด ตามด้วยมดในวงศ์ย่อย Dolichoderinae, Pseudomyrmecinae, Ponerinae, Aenictinae และ Cerapachyinae ตามลำดับ ขณะที่มดในสกุล *Crematogaster, Camponotus, Polyrhachis* และ *Pheidole* และมดชนิด *Dolichoderus thoracicus, Oecophylla smaragdina, Dolichoderus* sp.4, *Dolichoderus* sp.5 และ *Crematogaster (Paracrema)* sp.2 เป็นมดที่มีความชุกชุมมากที่สุด ตามลำดับ

ผลของพื้นที่ศึกษากับองค์ประกอบของมด พบว่า จำนวนของชนิดของมดทั้ง 4 สกุลเด่น กับพื้นที่ศึกษาทั้งสองไม่มีความแตกต่างกันทางสถิติอย่างมีนัยสำคัญ (One-way ANOVA, $P>0.05$) ค่าดัชนีความหลากหลายและความเท่าเทียมของชนิดของมดทั้งสองพื้นที่ (Shannon-Wiener index และ evenness) พบว่าไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติด้วย (One-way ANOVA, $P>0.05$) แต่จำนวนตัวกลับพบว่ามีความแตกต่างกันอย่างมีนัยสำคัญทางสถิติ (One-way ANOVA, $P<0.05$)

ความสัมพันธ์ระหว่างปัจจัยทางกายภาพ (อุณหภูมิ ความชื้น และปริมาณน้ำฝน) ต่อมดชนิดพันธุ์เด่น โดยใช้การวิเคราะห์ความถดถอยเชิงพหุ ด้วยวิธี Stepwise ผลการศึกษาพบว่า ไม่มีปัจจัยใดรวมกันแล้วมีผลต่อมดบนเรือนยอด แต่พบว่าเฉพาะความชื้นมีความสัมพันธ์เชิงบวกและเชิงลบกับมดชนิด *Oecophylla smaragdina* ($R^2 = 0.236$, $P < 0.05$)

และ *Cataulacus granulatus* (R^2 = 0.355, $P < 0.05$) ตามลำดับ และเฉพาะปริมาณน้ำฝนมีความสัมพันธ์เชิงลบกับมดชนิด *Tetraponera* sp.1 (R^2 = 0.398, $P < 0.05$)

เมื่อพิจารณาเฉพาะต้นประซึ่งเป็นพืชที่ผลัดใบในช่วงเดือนกุมภาพันธ์ถึงเดือนมีนาคมพบว่าความหลากหลายของชนิดของมดในช่วงเวลาดังกล่าวเปรียบเทียบกับช่วงเวลาที่ต้นไม้ไม่ผลัดใบ ไม่มีความแตกต่างอย่างมีนัยสำคัญทางสถิติ (One-way ANOVA, P>0.05) สำหรับการอธิบายในผลการศึกษาทั้งหมดที่กล่าวมาข้างต้นได้ถูกอภิปรายไว้ในวิทยานิพนธ์อย่างละเอียดและสมบูรณ์แล้ว

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ABSTRACT

This study is on a year-round investigation of the composition of ant present in the canopies in the tropical rainforest at Khao Nan National Park (KNNP), Nakhon Si thammarat Province, of Southern Thailand during May 2006-March 2007. Two habitat types were chosen which located at the headquarters of KNNP represented by the evergreen tree and the Hui Lek station stood for the briefly deciduous tree. Each habitat contained three permanent plots of 50 X 50 m^2 that were established 500 m apart from each other. The chemical knockdown by fogging technique was applied to collect ant samples. Of each plot a single tree was selective sampling for fogging at bimonthly intervals. Sixteen thousand eight hundred and eighty four (16,884) individual ants were identified and belonged to 7 subfamilies 34 genera and 205 morphospecies. Ants in the subfamily Myrmicinae and Formicinae were the most dominant species followed by Dolichoderinae, Pseudomyrmecinae and Ponerinae, Aenictinae, and Cerapachyinae respectively. In terms of abundance and number of species, the top four genera were *Crematogaster, Camponotus, Polyrhachis*, and *Pheidole* whereas *Dolichoderus thoracicus, Oecophylla smaragdina, Dolichoderus* sp.4, *Dolichoderus* sp.5, and *Crematogaster (Paracrema)* sp.2 were dominant in the numbers of individuals.

With reference to the effect of study sites on ants, significant differences were not detectable between the two habitats based on number of species of top four genera (one-way ANOVA, P>0.05). Values for Shannon-Wiener index and evenness also did not differ significantly between two habitat types (one-way ANOVA, $P>0.05$) but number of individuals between both sites was statistical difference (one-way ANOVA, $P<0.05$).

The stepwise multiple regression analyses were used to find out the significant association between physical factors (temperature, humidity, and precipitation) and common ant species. The result showed that there was not physical factor combined affecting the common ant species. However, only humidity was positively and negatively associated with *Oecophylla smaragdina* ($R^2 = 0.236$, $P < 0.05$ and *Cataulacus granulatus* ($R^2 = 0.355$, $P < 0.05$) respectively. Only precipitation was negatively correlated with one species of *Tetraponera* sp.1 ($R^2 = 0.398$, $P < 0.05$).

When *E. tapos* species shed their leaves briefly around February to March, the species richness of canopy ants did not significantly change (one-way ANOVA, $P>0.05$). However, all explanations for those finding are discussed.

ACKNOWLEDGEMENTS

I especially would like to thank Assoc. Prof. Suparoek Watanasit and Assoc. Prof. Dr. Sunthorn Sotthibandhu, my principle advisor and co-advisor, who accepted me into their program a few years ago and for believing in what I could do. They have taught me how to be a better scientist and a better person. Their patience, kindness, constant guidance and unwavering support are highly appreciated.

I would also like to show my gratitude to the committee members, Assoc. Prof. Dr. Surakai Permkam and Assoc. Prof. Dr. Decha Wiwatwitaya, for their valuable time, advice, assistance, and kind words of encouragement.

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Finishing work on this particular project is a bitter-sweet experience. Much credit should go to several individuals who played significant roles in this thesis. To begin with, I would like to thank all of my colleagues, friends, and The Insect Unit for their assistance and encouragement. Also, for the generous support from the KNNP for permitting to collect the samples and the staffs for assistance with the fieldwork.

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Sopark Jantarit

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CHAPTER 1

INTRODUCTION

Tropical rainforests have the most remarkable biodiversity and abundance of terrestrial habitats for plants, animals and micro-organisms in the world (Whitmore, 1975; 1990). Forest canopies represent an important interface between the atmosphere and the biosphere and as a consequence they play a key role in many ecosystems around the world. They control energy flows, biogeochemical cycles and the dynamics of regional and global climates (Jacobs, 1988; Shukla *et al.*, 1990). Besides, forest canopies have also been recognized as a habitat reservoir for genetically diverse organisms, particularly those in the ant assemblages (Erwin 1983; Basset *et al.*, 2003). Ants are known to dominate the arthropod communities in tropical forest canopy/es both in terms of biomass and the diversity of individuals (Fittkau and Klinge 1973; Erwin 1983; Hölldobler and Wilson, 1990; Tobin, 1995). They are a major component of the rainforest and play an important role in the ecosystem by serving the food web and food chain, as pollinators, and seed dispersers (Hölldobler and Wilson, 1990; Wagner, 2000). Ants can protect their host plants against herbivores reflecting some degree of co-evolution with their host plants (Hölldobler and Wilson, 1990). Canopy ants also offer both direct and indirect benefits to human beings. The exploitation of canopy ants as food, a biological indicator for monitoring forest changes, and as biological control agents against herbivores in orchards, are all favorable traditions in Southern Asia and Australia (Way and Khoo, 1992; van Mele and Cuc, 2000; Andersen, 1997; Andersen *et al.*, 2002). On the basis of the aforementioned versatility the canopy ants are an interesting insect group which challenges a detailed investigation.

As mentioned by E.O. Wilson "*the canopy is the last biological frontier on the planet*" because it is difficult to reach and has been overlooked. Nowadays, however, investigation of canopy ants is a burgeoning and exciting field as evidenced by the ever increasing numbers of publications concentrating on these habitats (Nadkarni and Parker, 1994; Nadkarni *et al.*, 1996). Unfortunately, relatively little research on canopy ants have been done in Thailand. Therefore species richness and species compositions of canopy ants are ambiguous. Existing publications do not cover all types of habitats and the information is lacking in those studies already undertaken. Taking these points into consideration, it is well known that the tropical rainforest contains both evergreen and deciduous trees (Whitmore, 1990). However, most ant studies on the canopy have concentrated on the evergreen trees and the deciduous plants have not been considered. The gap of knowledge opens up an avenue for the comparative study of species richness and species composition of canopy ants in both evergreen and deciduous trees in the southern part of Thailand.

This present study was established to give some answers to the problems described above. In particular it begins to redress the lack of information on the ant fauna in Thailand with respect to the distinction between evergreen and deciduous trees. An understanding of the variables that determine species richness and composition of canopy ants in tree crowns not only provides an important data base but also has implications of considerable ecological value to forest managers and conservation biologists with respect to local and regional diversity.

Review of literature

1. TROPICAL RAINFOREST

Tropical rainforests generally locate around the equator from the tropic of Cancer (23.5° N latitude) in the north, to the tropic of Capricorn (23.5° S latitude) in the south. Tropical rainforests occupy in three major geographical areas around the world: Central America, West Africa and Madagascar, and Indo-Malayan. It is divided into tropical, subtropical, and temperate rainforest. The forest is usually tall, 30m or more, and contains mature trees of many different heights, and a large numerous plant species (Jacobs, 1988; Whitmore, 1990).

Rainforests now cover less than 6% of Earth's land surface. In this region, sunlight strikes earth at roughly a 90-degree angle resulting in intense solar energy. Because of their greater access to solar energy, tropical rainforests are usually warm where temperatures are at least 22 to 34 degrees Celsius all year round. Rainforests lie in the inter-tropical convergence zone where intense solar energy produces a convection zone of rising air that loses its moisture through frequent rainstorms. So, rainforests are characterized by a gigantic amount of rainfall that fluctuates at least 1,700 mm to over 10,000 mm of rain each year. In an average year the climate in a tropical rainforest is very humid, 60-80% daytime and 95-100% night time, because of all the rainfall. Hence, tropical rainforests could be defined by their wet (>100 mm rainfall) and dry seasons (<100 mm rainfall) (Jacobs, 1988; Whitmore, 1990).

An important of rainforests has been suggested for several values. To begin with, it is the most remarkable of biodiversity and abundance of habitats for plants, animals and micro-organisms in the world. As a consequence, rainforests are home to two-thirds of all the living on the planet. It has been estimated that many hundreds of millions of new species of plants, insects and microorganisms are still undiscovered. Secondly, it is a vital source of medicines. Today, less than 1% of the world's tropical forest plants have been tested for pharmaceutical properties, yet at least 25% of all modern drugs came originally from rainforests. Most were first discovered and used by indigenous peoples. Thirdly, rainforests offer a veritable bounty of foods. An estimated 75,000 edible plants found in nature, which are only 150 enter world commerce, and many of domestic animals have been developed from rainforest species. Finally, human beings depend on rainforests in numerous ways. There are 300 million indigenous people worldwide, and approximately 50 million of them live in tropical forests. They rely almost exclusively on the forests for their survival needs and non-material values (Jacobs, 1988; Whitmore, 1990).

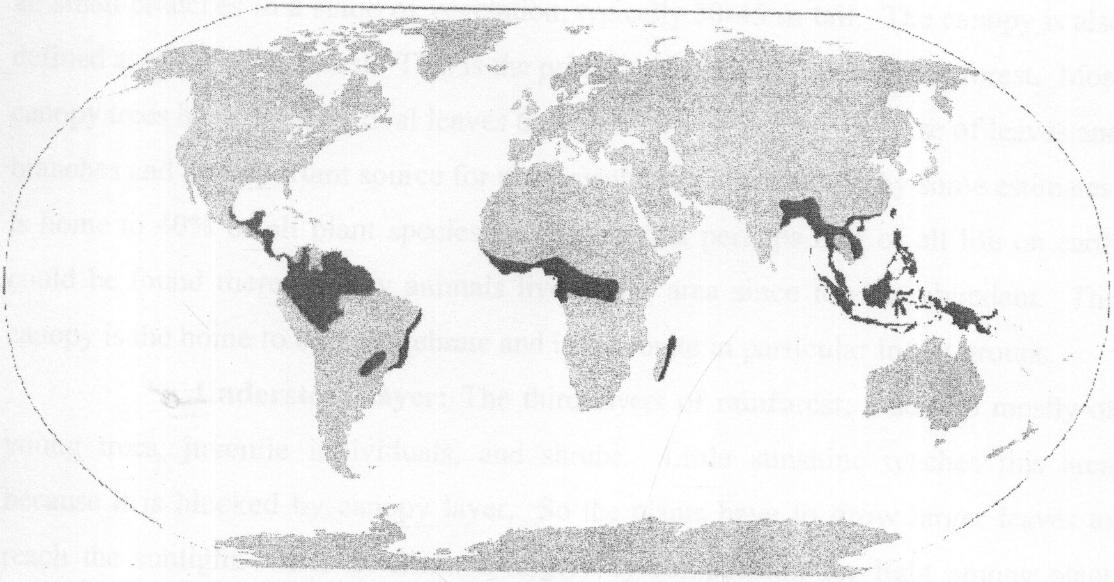


Figure 1. The tropical rainforest in the world. Source: Wikipedia, 2007

2. FOREST CANOPIES

The rainforests are vertical complexity and stratification which are better developed. The architecture of trees are distinctive itself which depend on their growth habit. As a result, the vertical stratification of the rainforest could be divided into four very distinct layers. These layers have been identified as the emergent, canopy, understory, and forest floor. The emergent and canopy layers make up the very top of rainforest and close to the sun. Below the canopy are the young trees and shrubs that make up the understory while the forest floor is the ground layer of rainforest. Each layer has its own unique plant and animal species interacting with the ecosystem around them.

Emergent layer: The tallest trees are the emergent, poke out above the green growth to reach the sun, towering around 45-55 m, a few species rarely to 60 m or 70 m tall. The trees are often evergreens, but some are deciduous. Sunlight is plentiful up here. Animals found are birds, butterflies and small monkeys live with bats, snakes and bugs.

Canopy layer: The canopy is the combination of all leaves, twigs, and all small branches in a stand of vegetation, typically 30-45 m tall. The canopy is also defined as the roof of forest. This is the primary and highest layer of the forest. Most canopy trees have smooth, oval leaves that come to a point. It is a maze of leaves and branches and an important source for photosynthesis. The canopy, by some estimates, is home to 40% of all plant species, suggesting that perhaps half of all life on earth could be found there. Many animals live in this area since food is abundant. The canopy is the home to both vertebrate and invertebrate in particular insect groups.

Understory layer: The third layers of rainforest, made up mostly of young trees, juvenile individuals, and shrubs. Little sunshine reaches this area because it is blocked by canopy layer. So the plants have to grow larger leaves to reach the sunlight. It is determined largely by competition for light among plant species. The plants in this area seldom grow to 12 feet. This layer is the home to birds, butterflies, frogs and snakes.

Forest floor: The ground layer of rainforest which is very dark. This is due to the layers above stopping the sunlight from entering the forest. It is estimated that only 2% of the sunlight actually reaches the floor. The soil on the floor is covered in a layer of leaves, twigs and dead plants, mushroom, decaying matter, which rot down quickly to provide nutrients for the plants. The leaf litter is alive with invertebrates and microorganisms, which quickly rot down this surface layer. Mosses and ferns grow on the forest floor where it is warm, damp and shady. The forest floor is home to some of the larger animals of the forest both invertebrate and vertebrate.

With respect to the forest canopies, it plays a key role in ecosystem processes, for instance, energy flows, and biogeochemical cycles. Forest canopies also both control regional climate and play an important role in regulating global climate (Jacobs, 1988; Shukla *et al.*, 1990). The forest canopies are the principal site of energy assimilation in primary production which interaction between a canopy and the surrounding atmosphere create local changes in the distribution and movement of abiotic factors such as air movement, gases, water vapor, temperature, humidity, precipitation, light and water cycle. It has been estimated that most photosynthetic activities in the biosphere occur in the canopy. Forest canopies also account for almost half of the carbon stored in terrestrial vegetation and fix more carbon per year than any other habitat (Malhi and Grace, 2000). Within canopy turbulence distributes heat and water vapor, with the result that canopies tend to be buffered against the more extreme temperature and humidity fluctuations in the air column above them (Parker, 1995). Light quality and quantity are closely related to canopy structure, more that 80% of the high energy shortwave radiation is typically absorbed by canopy leaves; the remainder is transmitted downward through the canopy or reflected back up whereas long wave radiation, in contrast, is nearly all transmitted or reflected (Parker, 1995).

What is more, the canopy is the richest region of the diverse rainforest. They are an important reservoir of genetic diversity that sustains countless species of animals and plants in particular epiphyte. The majority of them are undiscovered and potentially unexploited resources. An estimated 70-90 % of organism in the rainforest exists in the trees, above the shaded forest floor (Jacobs, 1988; Basset *et al.*, 2003). Forest canopies support about 40% of extant species (Novotny *et al.*, 2002), of which 10% are predicted to be canopy specialists (Hammond *et al.*, 1997). Abundance of leaves in the canopy provide energy in process of photosynthesis result in higher yield of leaves, flowers, fruits, and seeds which attract and support a wide diversity of animal life and ants as well (Whitmore, 1990). Indeed, ants have long been known to dominate the arthropod communities in tropical forest canopies both in terms of biomass and the diversity of individuals (Fittkau and Klinge 1973; Erwin 1983; Hölldobler and Wilson, 1990; Tobin, 1995; Floren and Linsenmair, 1999). They are a major component of tropical rainforest canopy and play an important role in functional ecosystem (Hölldobler and Wilson, 1990; Tobin, 1995) which will be defined in the item below.

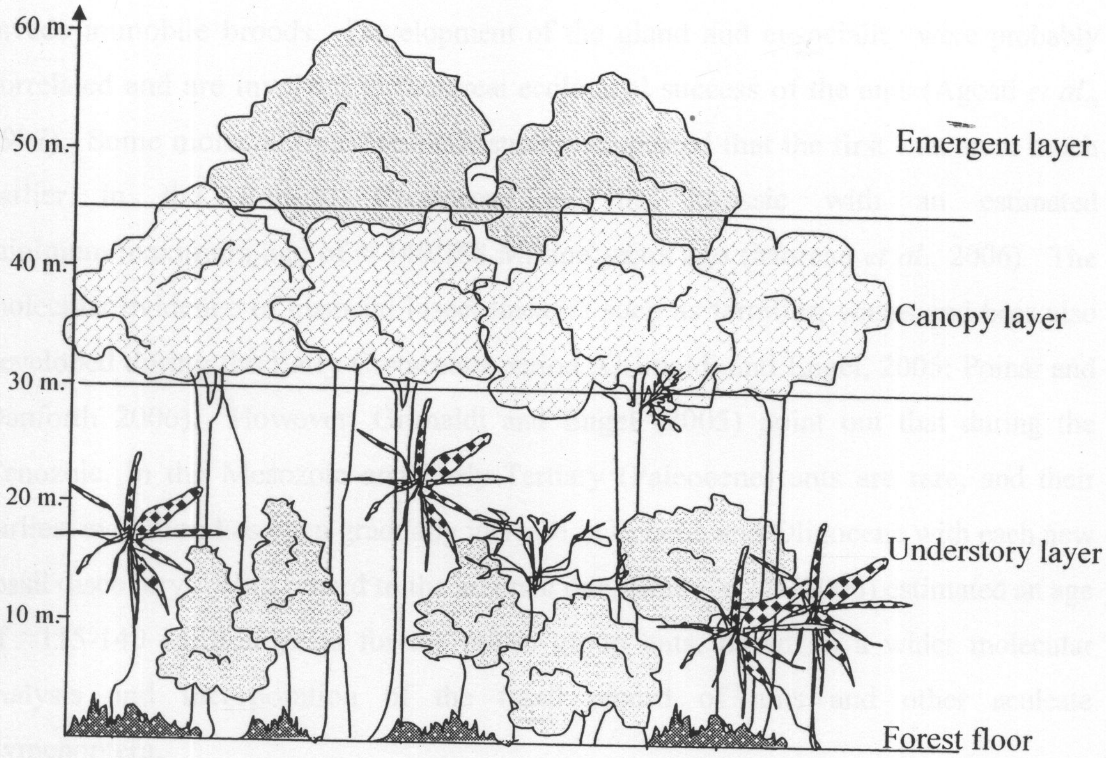


Figure 2. The vertical stratification in rainforest

3. BRIEFLY ON CANOPY ANTS BIOLOGY AND THEIR EVOLUTIONARY HISTORY

Ants are well-known eusocial insects belonging to a single family, the Formicidae, within the order Hymenoptera, the same with bees, and wasps. However, no consensus yet exists on the age estimate of the first Formicidae or on the origin of their eusociality. Fossil evidence in a piece of amber of truly primitive ants, for example, *Haidomyrmodes, Haidomyrmex, Sphecomyrma* and *Sphecomyrmodes*, allow the scientists to predict an origin of its. They suggested that ants have been evolved from the aculeate wasp which is based on morphological characters such as the overlapping of body between primitive ant and stinging wasp, having short mandible and metapleural gland, and the relative length of antennal segments (Grimaldi *et al.*, 1997). The metapleural gland is the only morphological trait unique within the Hymenoptera that distinguishes ants, and can be seen in most ants embedded in amber. This gland produces antibiotic-like substances, necessary to maintain nests underground or in humid pieces of wood, where bacteria and fungi would otherwise invade immobile broods. Development of the gland and eusociality were probably correlated and are involved in the great ecological success of the ants (Agosti *et al.*, 1997). Some molecular phylogenetic studies suggested that the first ants arose much earlier in the Earliest Cretaceous or the Jurassic with an estimated minimum/maximum age of ≈ 140/168 Million years ago (Moreau *et al.*, 2006). The molecular evidence of eusocial insect lineages such as termites, wasps and bees also developed during the Early Cretaceous period (Grimaldi and Engel, 2005; Poinar and Danforth 2006). However, Grimaldi and Engel (2005) point out that during the Cenozoic, in the Mesozoic and Early Tertiary (Paleocene) ants are rare, and their earliest evolution has been gradually increase in Eocene and Oligocene with each new fossil discovery. With regard to the arboreal one, Brady *et al.* (2006) estimated an age of ≈115-140 Million years for the crown group ants, based on a wider molecular analysis and incorporation of the fossil record of ants and other aculeate Hymenoptera.

Nevertheless, the distribution of ants to be arboreality suggests that it is related to the evolutionary history of ants. The fossil and molecular analysis assures that Ponerinae, Dolylinae, Aenictinae, and Cerapachyinae belong to the older groups whereas Myrmicinae, Formicinae, Dolichoderinae, and Pseudomyrmicinae are evolutionary younger groups (Brühl *et al.*, 1998). The older subfamilies are mainly found in the litter and soil which believe to be original habitat of ants while the younger one appear to arboreal life style. The colonization from ground to the tree crown have been suggested that (1) finding a new habitats and food sources (2) ecological niche expansion and (3) inter-specific competition are important parameters in structuring ant communities (Wilson, 1987; Kaspari, 2000). As a consequence, advance ants species appear to modify the characteristic to occupy the upper stratum. They exhibit numerous adaptations that promote an arboreal lifestyle, such as the difference in larger average size worker, modify 'sticky' tarsi that allow them to cling to surfaces (Yanoviak *et al.*, 2005). They also have evolved more effective epicuticular lipid waterproofing and thicker waxy cuticles to prevent desiccation stress on this habitat. Thus, they have ability to withstand desiccation stress than the terrestrial assemblage (Hood and Tschinkel, 1990) because the wide temperature fluctuations, drought, and the lower humidity are characteristic of forest canopy.

Canopy ants find appropriate nesting sites in tree crown in different ways. The nesting strategy of ants associated with host plant and their own unique character. The arboreal species utilize broadly structure as nesting sites for instance, hollow twigs or cavities in tree trucks (normally called "domatia"), carton nests, dwell in leaf litter and humus accumulated on branches, beneath the leave, or joining leaves together with silk pavilions using larval silk.

With reference to foraging activity, the terrestrial ants are mostly scavengers and predatory foraging behavior while the arboreal ants appear to exploit a wider range of food. Carbohydrate nutrients seem to be a main food source on the tree crown (Tobin, 1995). Arboreal ants are a great extent to utilize floral and extrafloral nectar, fruit sap, food bodies, seed, and in particular arthropod exudates. Hence, they seem to be a great farmer by feeding some homopterans or lepidopteran larvae to honeydew sources (Tobin, 1995; Wagner and Kay, 2002; Heil and Mckey, 2003). However, some arboreal ants could hunt prey both invertebrate and invertebrate (Hölldobler and Wilson, 1990)

The canopies of tropical rainforest and of tree crop plantation are occupied by a large group of ants which could be identified into: dominant, subdominant, and non-dominant ant species. To begin with, the dominant species are characterized by extremely population colonies (several hundred thousand to several million individuals, the ability to build large or polydomous nest and a highly developed intra-as well as interspecific territoriality. Secondly, the subdominant species is species that have less population colonies (up to a few thousand individuals) and generally depend on pre-existing botanical structure for nesting (hollow branches, rough bark, and epiphyte). Yet, there are able to defend territories in the same way as do dominant. Lastly, non-dominant ant species is species which have very less population and occur within or between the territories of dominant ants. Observation of scientists show that two or more species of ants were typically much more abundant than any other species and that the areas of activity of these 'dominant' ant species in the trees did not overlap. The patchwork distribution these ants formed was termed 'ant mosaic' (Leston, 1973). The ant mosaic is defined to ant species that is establishment and defense of mutually exclusive territories by aggressive and highly abundant dominant ant species together with positively and negatively associated subordinate ants and other arthropods (Room, 1971; Majer, 1972, 1976; Leston, 1973; Floren and Linsenmair; 2000). It is favorable found in agroecosystems and orchard plantation for instance, *Oecophylla, Crematogaster, Tetramorium,* and *Dolichoderus*. As a result, the competition among ants is typically for food resources and habitats. Consequently, it properly is the evolution of eusocial behaviour which Grimaldi and Agosti (2000) point out that 1). Eusociality vastly increases the efficiency of foraging and resource use, as well as defense (2), and it has been commonly invoked as the reason for the ecological dominance of ants, termites, and eusocial bees.

However, ant mosaic has been denied in lowland rainforest trees by Floren and Linsenmair (2000). The former authors investigated a highly diverse canopy fauna in a mature rainforest in Sabah, Borneo. They made extensive collections of arboreal ants from 19 individual *Aporusa* or *Xantophyllum* trees in the lower canopy using knockdown insecticide fogging. Their statistical analysis of the resulting data failed to significantly demonstrate effects of mutual exclusion between ant species (Floren and Linsenmair, 1997, 2000; Floren *et al.*, 2001). Aside from these analytical results, extensive observations in these relatively small crowns indicated that resource monopolization by dominant ants was uncommon on these trees (Floren and Linsenmair, 2000). Then, they concluded that the diverse and complex ant communities in rainforest canopies are more likely structured by stochastic processes rather than by competitive effects that are the heart of ant mosaic theory. Moreover, Ribas and Schoereder (2002) used a different statistical approach based on a 'checkerboardedness' index to reanalyze several previous studies on ant mosaics from plantations and secondary forests and failed to significantly confirm a structured distribution in most of these studies. They suggested that spatial distribution patterns may not be different from expectations based on null models and may not necessarily imply competition between these species (Blüthgen and Stork, 2007).

4. DIVERSITY OF ANTS IN TROPICAL FOREST CANOPY

Ants are ubiquitous and dominant feature of both terrestrial and tree crown. Since the 1970s, quantitative field studies have documented that ants constitute about 20 to 40% of the arthropod biomass in tropical rainforest canopies (Tobin, 1995). It also represents 15-20% of total animal biomass and plays an important role in many ecosystems (Hölldobler and Wilson, 1990). It is well known by the fact that there are 16 subfamily 296 genera and about 15,000 species in the world (Bolton, 1995), current day 12,264 species were identified (Agosti and Keller, 2008). However, the number of species is incredibly high which is still remaining to be discovered and described. Ants are a major component of tropical forests particularly the tree top. The canopies of tropical rainforest are recognized as habitats of arboreal ant enormous species richness in the world (Fittkau and Klinge 1973; Erwin 1983; Stork, 1991). It is best known the fact that, for example Wilson (1987) found 135 species on the canopy of Peruvian Amazon rainforest, Harada and Adis (1997) recorded 100 species in Brazil, Brühl *et al.*, (1998) exhibited 133 in the tree crown of Sabah, Borneo. Floren *et al.*, (2001) detected 273 species of arboreal ant in primary lowland canopy of Borneo, Schulz and Wagner (2002) showed 161 species of canopy ant in Budongo Forest, Uganda, Watt *et al.*, (2002) disclosed 97 species of canopy ant in Southern Cameroon, Tongjerm (2003) revealed 118 species in canopy of Ton-nga Chang Wildlife Sanctuary, Southern Thailand, Stuntz *et al.*, (2003) collected 91 species on epiphytes in Panama, Widodo *et al.*, (2004) found 169 species in lowland evergreen rainforest, Sabah, Malaysia etc.

With regard to the diversity of canopy ants to a single tree, inventories and surveys in lowland neotropical forests show that individual tree crowns frequently harbor more than 30 species of ants (Yanoviak *et al.*, 2007). It is illustrated by the fact that Wilson (1987) found 43 species from a single tree in Peru, Harada and Adis (1997) recorded 82 species from a single tree in Brazil, Floren and Linsenmair (2000) showed 61 species on a single tree and Schulz and Wagner (2002) detected 37 species on a single tree whereas on birch tree in Germany only two species of ants were found foraging in summer (T. Schmidt, cited by Brühl *et al.*, 1998). One large tree in Peru yielded 43 species of ants, equivalent to the entire British fauna (Wilson, 1987).

Consequently, it is obviously guarantee that the tropical forest canopies are the most richness of ant species in the world.

Nevertheless, Davidson *et al.*, (2003) explain the abundance of ants in lowland rainforest canopies by reviewing and proposing at least four untested and not mutually exclusive hypotheses. These hypotheses base on the idea that greatest animal biomass in rainforest must be the herbivores at the second level of the trophic pyramid. Firstly, certain insect herbivores (such as immobile Coccoidea, which are often tended by ants) might be far more abundant than currently estimated, because of under-sampling by canopy fogging and the failure of leaf-area removal measures to quantify their impact. Secondly, high turnover of arthropod herbivores might sustain a high standing biomass of ants and produce inverted pyramids of numbers and biomass. Thirdly, large populations of long-lived workers might be supported principally by abundant dietary carbohydrates and demand little protein. Lastly, ecologically dominant ant taxa might themselves feed as herbivores, deriving both carbohydrates and N from plant and insect exudates. Indeed, ants as herbivores are major players in the ecological dynamics of tropical rainforest trees and, thereby, in the balance of earth. “Little things” really do matter.

5. CANOPY ANT VALUE

Ants are a major component on canopies and play an important role in functional ecosystem. They are associated with a large group of animal, plant, and fungal species, ants have a significant impact at all tropic level. They serve as a prey for many native predatory enemies, such as reptiles or amphibians, bats, birds, and occasionally, people capture and kill or eat the flying males, females and eggs. In contrast, worldwide, ants are one of the most important predators on small invertebrates, including other insects, and even other ants. They also diet a variety of vertebrate, reptiles or amphibians, and bird which may hunt by workers. Ants also act as a scavenger. They are the garbage collectors of the rainforest ecologically useful.

However, being predatory behaviors on canopy, ants are often used as biological control agents of insect pests and fungal pathogens. A recent studies in agroecosystems found that generalist predators (single and multiple-species assemblages), controlled herbivore abundance (79% of studies) and reduced plant damage and increased plant yields (65% of studies) (Symondson *et al.*, 2002). Ants, in both natural and agricultural systems exhibit top-down effects by limiting herbivore communities and by increasing plant growth and reproduction (Schmitz *et al.*, 2000). Ants are biological control agents in agroecosystems and reduce undesirable pests by directly preying upon pests, by chemically deterring them and by causing pests to drop from the host plants that they are attacking (Way and Khoo, 1992). In addition, ants may indirectly reduce herbivore populations and also reduce fungal phytopathogens by removing spores (de la Fuente and Marquis, 1999) or by restricting interactions between plants and disease vectors (Leston, 1973; Khoo and Ho, 1992). Taking these point into utilization, using ant as a biological control agent against herbivores and fungi in agroecosystems and orchards plantation are favorable traditions in application (Way and Khoo, 1992; van Mele and Cuc, 2000; Andersen, 1997; Andersen *et al.*, 2002).

As a consequence, ants are also valuable biological indicator agents for monitoring forest changes. Owing to the fact that ants are commonly and extremely abundant and relatively high species richness. Also, there are many specialist species, occupy higher trophic levels, easily sampled and usually easily identified. Needless to say, they are rapidly responsive to changing environmental conditions (Majer, 1983; Carroll and Risch, 1990; Andersen, 2000). The use of ants as bio-indicators has now become worldwide in particular Australia (Andersen *et al.*, 2002). Indeed, ants are good bio-indicators which have been widely and successfully used to evaluate degree of disturbance, differences in environment features, biotic responses and help indicate ecosystem health (Majer, 1983; Andersen *et al.*, 2000).

On the other hand, ants commonly touch with bacteria and fungi which are generally found in rainforest where humidity is always high. Fortunately, an immune system by secreting antibiotics from the metapleural gland is efficiency. Hence, the idea that ant may control antimicrobials are of interest to the pharmaceutical industry is part of a small but significant shift towards ecologically driven bio-prospecting, which has been adopted by a few laboratories across the world (Beattie and Ehrlich, 2001; Coley *et al.*, 2003). Needless to say, ants as sources of pharmaceuticals are well worth further exploration.

Apart form being ecological interaction, biological control against herbivores, bio-indicator, and pharmaceutical medicine, lastly, the canopy ants is also full of protein nutrient. The exploitation of canopy ant's as edible foods is favorable in South-East Asia. For example the egg, pupa, and larva of waver ants *Oecophyla smaragdina* even reproductive caste can and are eaten by human. In fact, practically any insect can be eaten, and they provide an important source of protein, calories, vitamins such as vitamin B1 and B2, as well as minerals. Many native peoples indulge in this practice, scientifically called entomophagy. As humans are omniverous, ants are certainly something which is popular food items in the world.

Nowadays, however, canopy ants are becoming increasing and well-documented research. An investigation of canopy ants is a burgeoning and exciting field as evidenced by the ever increasing number of publications concentrating on these habitats (Nadkarni and Parker, 1994; Nadkarni *et al.*, 1996). They are a key insect in canopy not only richness and abundance but a valuable versatility of canopy ants is also widely accepted to understanding a detailed investigation.

6. HOST PLANT INHABITANCY

Interactions between organisms at adjacent trophic levels, such as dweller and hosts, occupy major roles in tropical forest ecosystems. Mutualistic interactions between plants and ants have been known for a long time particularly in tropical forest. Symbioses between ants and plants have contributed greatly to understanding of mutualism as a trade-off between the costs and benefits of an association between two organisms (Bronstein, 1998). The relationship between ant and host plant have been called "Myrmecophytes", which describe plants regularly inhabited by ants (Davidson and McKey, 1993). Ants normally participate in three kinds of mutualisms that are of key importance in determining, their impact on the structure of ecological communities.

To begin with, ants are the principal predators of arthropods in tropical forest (Novotny *et al.*, 1999; Floren *et al.*, 2002). As a consequence, they can protect their host plants and increase plant fitness by reducing damage caused by herbivores, pathogenic fungi, removal of vines, and providing nutrients (Benson, 1985; Davidson and McKey 1993; Fonseca, 1994; Federle *et al.,* 1998). Likewise, plants offer their structure for nesting ant, that is called "domatia" or shelter in leaf, and also offer energy and nutrients available to foraging ant partners. Host plants typically produce these rewards in both direct and indirect for canopy ants. Myrmecophilic plants directly produce food rewards such as extrafloral nectar (EFN), sugar sap, and food bodies and also can attracted indirectly the homopteran species, which is called trophobiosis (i.e. aphids, coccide pseusococcide, membracid, etc.).

Secondly, as a consequence, ants often utilize honeydew from phloem-feeding hemipterans (formerly known as 'Homoptera') such as aphids, membracids, scale insects and mealybugs. The carbohydrate-rich excretions of these 'trophobionts' provide ants with an energy-rich food source. Feeding by homopterans represents a drain on the plant's resources, and could represent a cost to the host plant (Nava-Camberos *et al.*, 2001; Smith and Schowalter, 2001).

Finally, however, associations between ants and their trophobionts can have widely varied effects on plants (Cushman and Addicott, 1991). In some cases, ant-tended trophobionts are probably the plant's principal herbivores or pests and the effect on the plant is negative. In a few cases, the ants may actually castrate their host plant, greatly reducing that plant's sexual reproductive capability (Yu and Pierce 1998; Stanton *et al.*, 1999). Furthermore, interaction between ants and host plants become to symbiosis that involved with community consequence and co-evolutionary history, for instance, *Pseudomymex* species with *Acacia* trees or *Crematogaster* species with *Magaranga* trees etc. (Hölldobler and Wilson 1990; Whitmore, 1990).

The abundance and diversity of ant–plant interactions is particularly notable in tropical habitats. Approximately one third of tropical woody dicots and herbaceous vines produce extrafloral nectar (EFN) and/or lipid-rich pearl bodies as "biotic defenses" to attract ants that defend vegetative and reproductive structures against herbivores (Davidson, *et al.*, 2003). For instance, associations with ants are now extremely widespread across plants, and EFN are found in at least 332 genera belonging to at least 93 angiosperm families (more than a quarter of all plant families), as well as in 11 genera of ferns (Koptur, 1992). Rico-Gray (1993) recorded a total of 312 ant–plant associations in one Mexican coastal site, whereas Fonseca and Ganade (1996) reported that myrmecophytic plants occur at a density of 377 plants/ha in the Amazonian rainforest. Thus, ant-plant interactions and the structure and functioning of tropical are a major necessary for food webs. The most important predators of arthropods in tropical forest canopies are largely sustained by an interlocking set of mutualisms. Without these mutualisms, food webs in tropical forest communities would probably be very different from those we know.

7. CANOPY ANTS AND ABIOTIC ENVIRONMENTAL CONDITION

According to my objective, here I only focus on the abiotic factor namely temperature, humidity and precipitation.

The environment of the canopy is very different from the environment of the other parts of the forest. Interactions between a canopy and the surrounding atmosphere create local changes in the distribution and movement of physical factors, notably air movement, gases, humidity, temperature, precipitation, and light. It has its own habitat characteristic which is called microclimate. Environmental factors in the canopy are unpredictable. As a result, within canopy, it commonly fluctuates in temperature, humidity, wind speeds and turbulence of airflow (Parker, 1995).

Temperature and humidity: In the rainforest, temperature and humidity is reverse variation (Parker, 1995). It can be clarified that if temperature increases, the humidity decreases. The canopy temperature was significantly correlated with the light intensity and air temperature (Parker, 1995). Consequently, more than 80% of solar radiation is typically absorbed by canopy leaves; the remainder is transmitted downward through the canopy or reflected back up (Parker, 1995). So, during the day time, the canopy is drier and hotter than other parts of the forest. Canopy tends to be buffered against the more extreme temperature and humidity fluctuations in the air column above them. The inner canopy is particular stable, while the outer canopy is a site of active heat exchanges. Also, the radiation absorption in the canopy is dependent on the distribution of leave. During day time the highest temperature is observed at the canopy which is different from the bottom to the top around 5 degree Celsius (Kruijt *et al.*, 2004). However, during midday, turbulence is effective in promoting transport in the canopy. Consequently, temperature and humidity gradients tend to be weak (Parker, 1995).

Microclimate, particularly humidity and temperature, has been identified as the main abiotic governing ant activity (Kaspari, 1993; Andersen, 2000; Kaspari and Weiser, 2000; Hahn and Wheeler, 2002). With regard to insect, their body temperature tends to be the same as ambient temperature but this does not mean that an insect's body temperature is always the same as that of the environment (Romoser and Stoffolano, 1994). So, the range of tolerable temperatures varies from species to species, within a species, and with the physiological state of an individual. The optimal temperature range for the most species is 22 to 38 degree Celsius (Romoser and Stoffolano, 1994). For ant, Kaspari *et al.*, (2000) found that the foraging activity of an average species peaks at 32.3 °C and ceases at 40.6 °C while Bestelmeyer (2000) show most active from 32 to 35 °C. The responses of ants to temperature variation are mediated by at least two well-documented mechanisms: 1) the direct effect of temperature on ant physiology and 2) the indirect effects of changes in competitive hierarchies among ant species (Bestelmeyer, 2000).

All the moisture factors are variation both temporally and spatially. For example, relative humidity varies with location, time of day or year, topography, vegetation, and so on, and commonly tends to be comparatively high during the night and lower during the day (Romoser and Stoffolano, 1994). So, tropical rainforest is very humid, around 60-80% daytime and 95-100% night time. However, it may also be different at different heights above the ground (Romoser and Stoffolano, 1994). Consequently, it can be said that the humidity in the canopy is obviously lower than the other part of forest. Extremes of environmental humidity content directly influence many of activity of insects, including feeding, reproduction, and development (Romoser and Stoffolano, 1994). An increasing in humidity often is associated with increased insect abundance and activity (Levings and Windsor 1996). For ant, it is widely accepted that humidity is positive significantly correlated with the foraging activity of the ants (Kaspari, 1993; Kaspari and Weiser, 2000; Hahn and Wheeler, 2002). In particular the terrestrial ants are mainly predatory behavior so moist litter may be more likely to release nutrients, and bolster populations of microbes and microfauna prey that form the base of the litter food web (Coleman and

Crossley, 1996; Levings and Windsor, 1996). However, in the canopy ecosystems, where high temperatures and low humidity creating gradients of desiccation risk are characterized, can shape activity in ants (Kaspari and Weiser, 2000). For example, some ants desiccate more quickly and are less active during the drier afternoon in one tropical forest (Kaspari, 1993, Kaspari and Weiser, 2000). Taking these points into consideration, humidity may be an important parameter to govern ant species in the canopy. But arboreal ants could increase their activity in tree crowns even when the desiccation risk is high (high temperature and low humidity) (Hahn and Wheeler, 2002). This may be the result of several physiological mechanisms utilized by arboreal ants to resist desiccation stress more effectively than terrestrial ants (Hood and Tschinkel, 1990).

Precipitation: In rainforest, there is no truly season. It is characterized by a gigantic amount of rainfall that fluctuates at least 1,700 mm to over 10,000 mm of rain each year. Of course, the canopy directly and hardly receives rainfall and acts as a buffer against rainstorm. The precipitation is intercepted, retained, and redistributed by the canopy which is suggested that between 10 and 30% of incident precipitation is intercepted and evaporated from the canopy (Parker, 1995). Water evaporates from the canopy or drips through or run down the stems to the forest floor (Parker, 1995). Accordingly, rainfall affects the abundance of many populations (Kaspari and Valone, 2002; Sanders and Gordon, 2004). For ant, rainfall plays a key role in regulating and reducing ant activity (Basu, 1997; Wirth and Leal, 2001). Heavy rainfall must surely be destructive to ant and probably led to high levels of mortality for many newly established colonies of some ant species (Sanders and Gordon, 2004). The effect of rainfall may be considered a type of disturbance that reduces ant activity (Wirth and Leal, 2001). Ant abundance is certainly linked to seasonal variations in rainfall, with some species being more abundance in the dry season, whereas others proliferate only during the rains (Höllkdobler and Wilson, 1978). Nevertheless, it has been shown that abundance and foraging efficiency of ants in tropical habitats is limited by the duration and timing of rainfall (Basu, 1997).

QUESTIONS

The research questions are:

1. What is the species composition of canopy ants in tropical lowland rainforest at Khao Nan National Park (KNNP), Nakhon Si Thammarat Province?
2. Is there any difference in species composition between canopy ants at the evergreen vegetation and the deciduous vegetation?
3. Do some physical factors affect species composition and abundance of canopy ants?

HYPOTHESES

It is hypothesized that:

1. The compositions of canopy ant species in two habitats (evergreen and deciduous trees) are different.
2. Physical factors: temperature (°C), humidity (%), precipitation (mm), affects species richness and abundance of canopy ant species composition.
3. In dry season, the deciduous trees will exert an effect on the dispersal of canopy ants.

OBJECTIVES

The objectives of this work are the followings:

1. To assess the species composition of canopy ants in tropical rainforest at KNNP, Nakhon Si Thammarat Province.
2. To compare the species composition of canopy ants between evergreen tree and deciduous tree at the KNNP.
3. To examine the effects of some physical factors on the species composition and abundance of canopy ants.

CHAPTER 2

MATERIALS AND METHODS

1) Study area

This study was carried out in the tropical lowland rainforest of Khao-Nan National Park (KNNP), Nakhon Si Thammarat Province, Southern Thailand. Its approximately location is between 8° 41' and 8° 58' N latitude and 99° 30' and 99° 99' E longitude. The KNNP is a part of the Nakhon Si Thammarat mountain range (Fig.3). The Park covers 436 km^2 (around 272,500 *rai*) and the elevation ranges from 80-1,438 meters above sea level (Wittaya, 2000). This Park is composed of the sub-districts of Krung Ching, Noppitam, Talingchun, Khaonoi, Theparat, Plian and the district of Thasalar and Sichol. The regional climate is relatively constant and can be divided into 2 distinct seasons: wet and dry. The rainy season could 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 per year (the Meteorology of Nakhon Si Thammarat Province, unpublished data). Most of the area has high humidity and heavy continuous rain so that the weather in this area is constant in temperature all year round. Most of the area is also the main source of the rivers in this area. It is a complex mountain ridge with a high diversity of floral and faunal species. About 90% of the area is a productive rainforest which has many valuable plants including both evergreen and deciduous trees. The dominant plant species include *Ficus* spp., *Caryota* spp., as well as members of the families Annonaceae, Myrtaceae, Sterculiaceae, Sapindaceae and Euphobiaceae (Wittaya, 2000). However, there is a special deciduous plant, called *Elateriospermum tapos* Blume, which has a deciduous life-cycle in the short period of the dry season. Mature trees shed leaves annually around February to March (Whitmore 1972; Osada *et al.*, 2002). *E. tapos* is rarely found growing in clusters, so its clusters in this area are unique for a rainforest (Wittaya, 2000). Also, the KNNP consists of 8 stations (Fig.3).

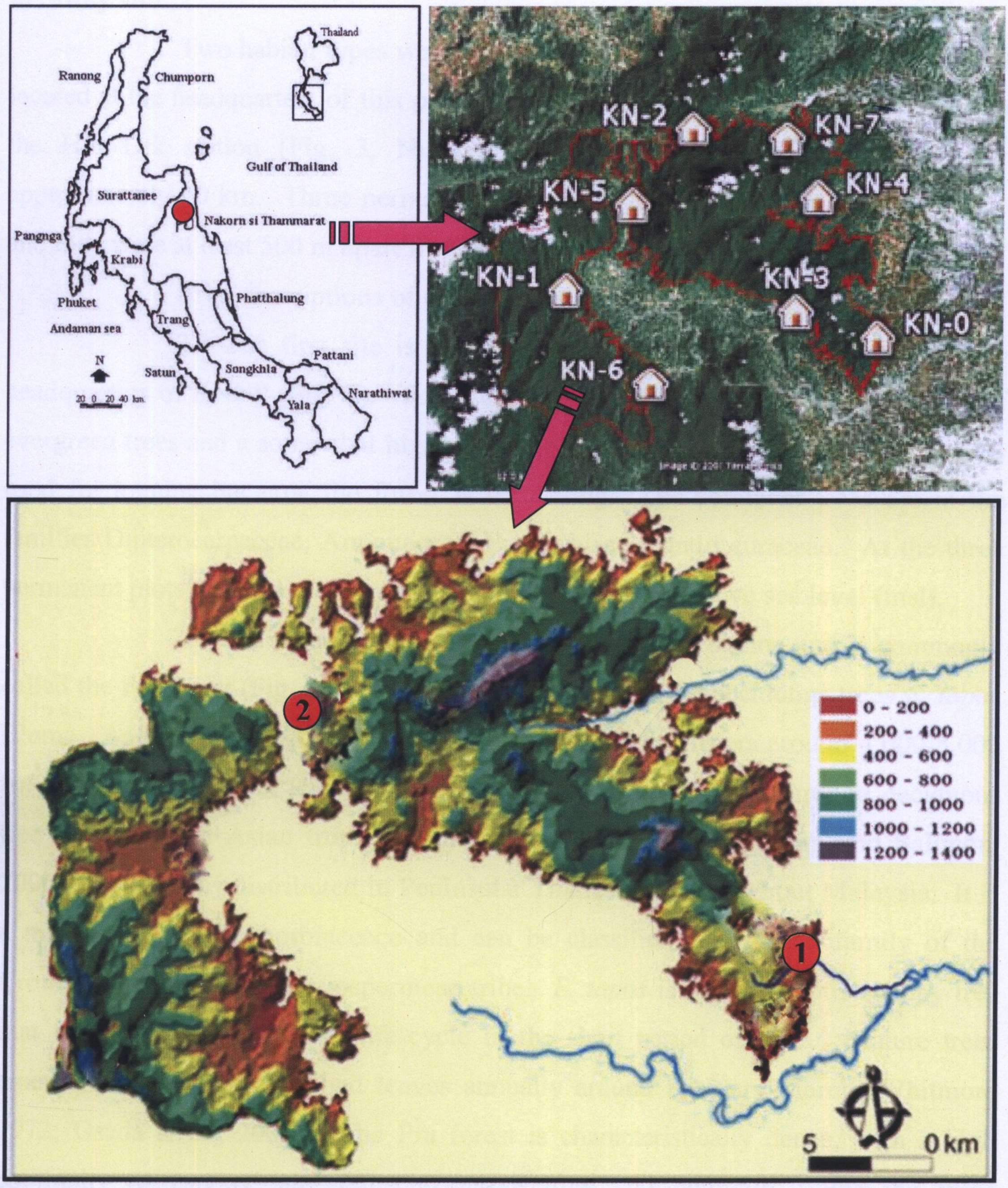


Figure 3. Study areas at Khao Nan National Park (KNNP), Nakhon Si Thammarat, Source: the BRT program, 2007 (personal information) and Pheera *et al*., 2008

Number 1 = Headquarters of this Park.

Number 2 = Hui Lek station.

2) Study site

Two habitat types were chosen for this investigation. The first site was located at the headquarters of this park (Fig. 3, Number 0) and the second site was at the Hui Lek station (Fig. 3, Number 5). Both study sites stayed apart for approximately 40 km. Three permanent plots of 50X50 m^2 were set up at each site and they were at least 500 m apart from each other.

Brief descriptions of each study site (Figs. 4, 5)

2.1 The first site is located in the tropical lowland rainforest at the headquarters of KNNP (Fig. 4). This site is characterized by a low density forest of evergreen trees and a somewhat high continuity of canopy. In the past, this area was used for logging but now the forest is recovering. The dominant trees are in the families Dipterocarpaceae, Annonaceae, Euphorbiaceae and Lauraceae. At the three permanent plots, the elevations range from 142-160 meters above sea level (msl).

2.2 The second site is located at the Hui Lek station and is commonly called the Pra forest (Fig. 5). This area is dominated by the deciduous trees *E. tapos* Blume. As mentioned above *E. tapos* is rarely found in clusters around 4,000-5,000 *rai* and is only found at Hui Lek station. *E. tapos* is however a common deciduous tree in South-East Asian tropical rainforests (Whitmore 1972, Yong and Salimon, 2006) and is widely distributed in Peninsular Thailand and throughout Malaysia. It is a member of the Euphorbiaceace and can be classified into the subfamily of the Crotonoideae and the Elateriospermeae tribe. *E. tapos* is a monoecious canopy tree that responds to a deciduous life-cycle in the short period of time. Mature trees emerge for 45 meter and shed leaves annually around February-March (Whitmore 1972; Osada *et al.*, 2002). The Pra forest is characteristically dense, with a high continuity of canopy, and constant temperature and humidity. For the three permanent plots, the elevations range from 251-289 meters above sea level (msl).

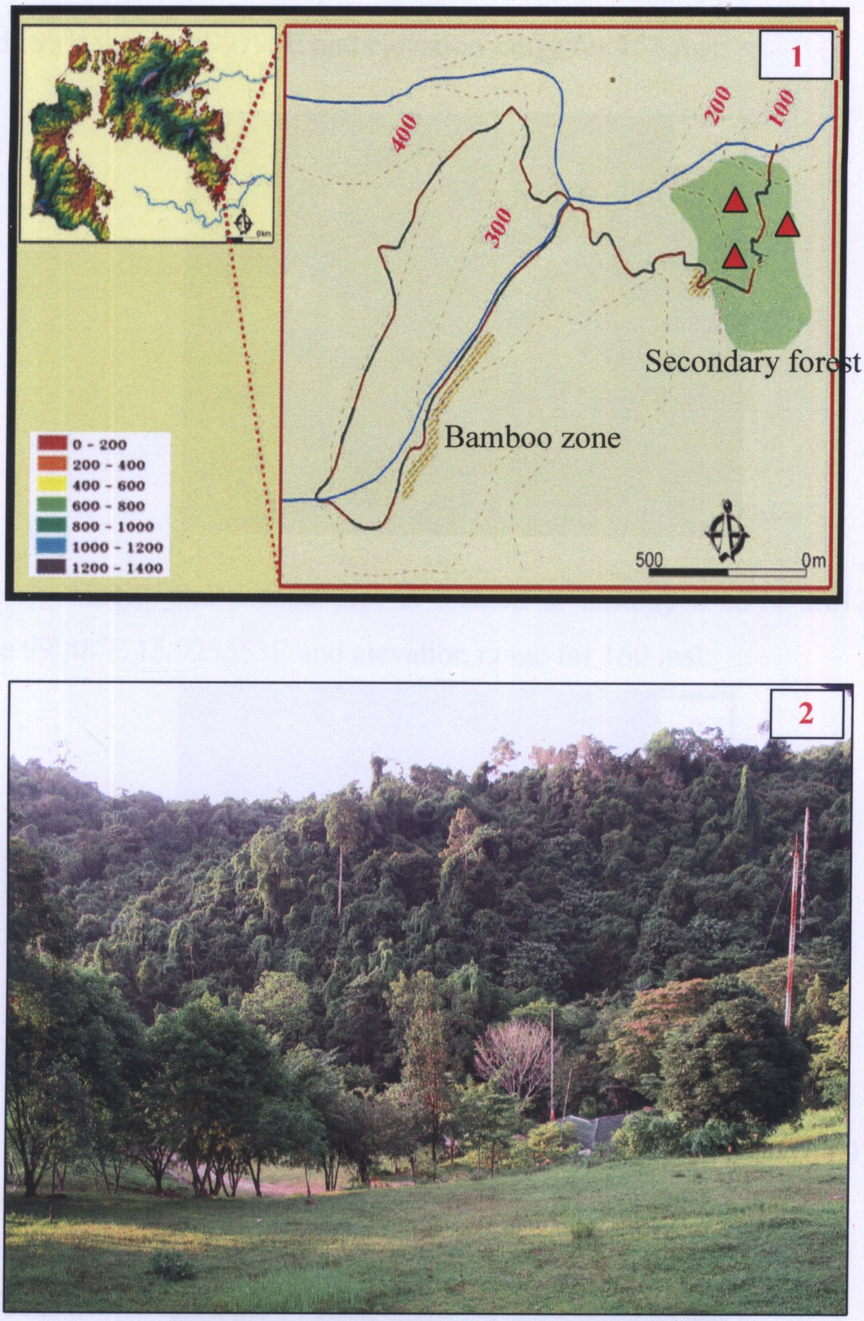


Figure 4. (1) The first habitat is located at the headquarters of KNNP (Source: the BRT program, 2007) and (▲) three permanent plots and (2) the characteristic of forest at the first site.

2.1.1 The first plot is located at latitude 8°46°N 0.756156N and longitude 99°48° E 11.699793E and elevation range for 153 msl.

2.1.2 The second plot is located at latitude 8°46°N 2.212468N and longitude 99°48°E 15.925553E and elevation range for 160 msl.

2.1.3 The third plot is located at latitude 8°46°N 1.039396N and longitude 99°48°E 16.315832E and elevation range for 142 msl.

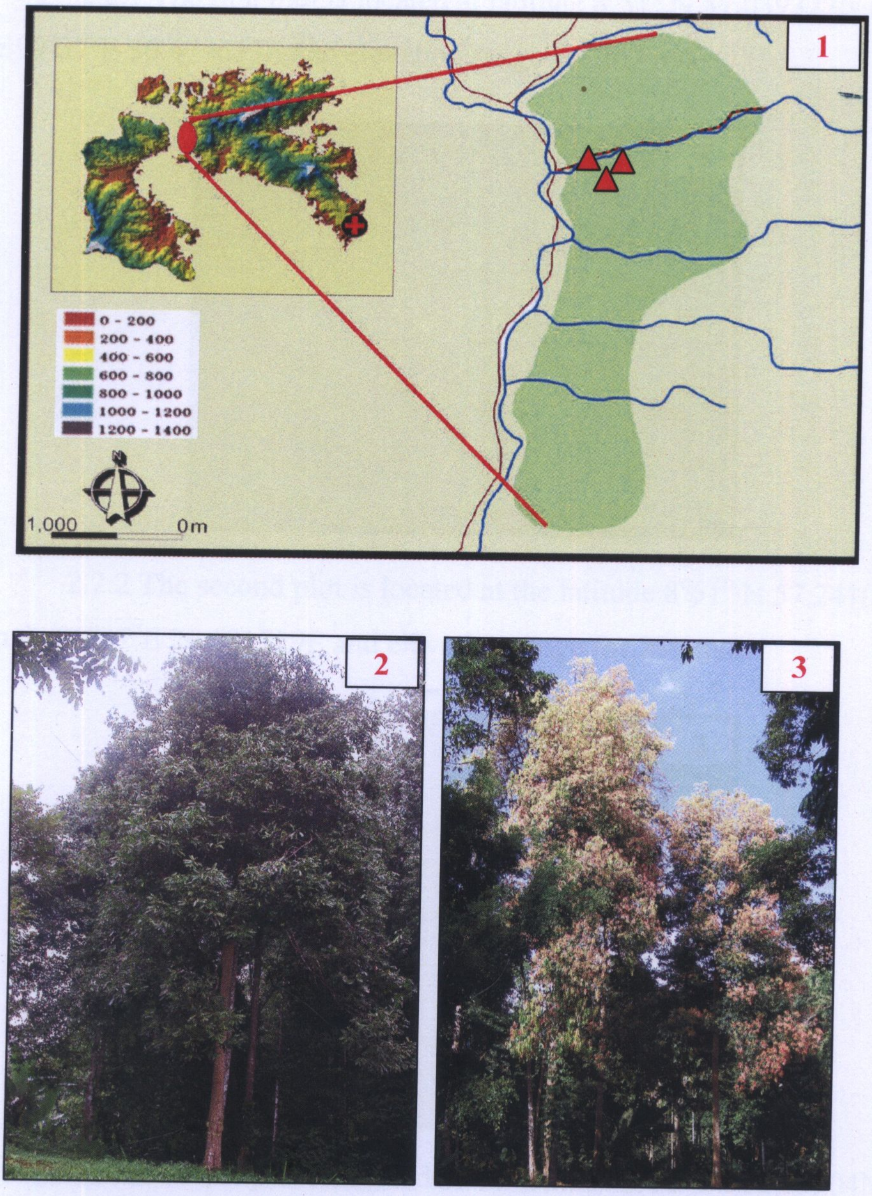
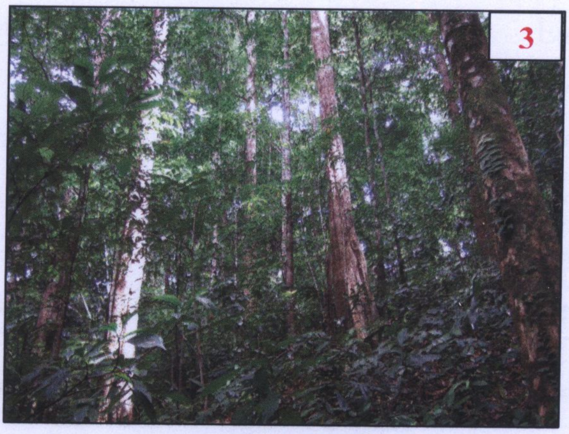


Figure 5. (1) The second habitat is located at the Hui Lek station (Source: the BRT program, 2007) and (▲) three permanent plots. The briefly deciduous tree, *E. tapos* (Blume) (2) when this plant is closed with leaves, and (3) when it shed its leaves and grows new leaves later around February to March.

2.2.1 The first plot is located at latitude 8°51° N 57.039322N and longitude 99°37°E 30.479633E and elevation range for 267 msl.

2.2.2 The second plot is located at the latitude 8°51° N 57.241049N and longitude 99°37°E 26.681729E and elevation range for 289 msl.

2.2.3 The third plot is located at the latitude 8°51° N57.569304N and logigtude 99°37°E 25.110595E and elevation range for 251 msl.



3) Duration of field work

Field work was conducted in the tropical lowland rainforest of KNNP, through one seasonal cycle from May 2006 to March 2007. Field research was performed at bimonthly intervals. Totally, 6 experiments were carried out: 11-16 May 2006, 09-14 July 2006, 10-15 September 2006, 12-17 November 2006, 14-19 January 2006 and 08-13 March 2007.

4) Sampling vegetation

From each of six permanent plots a single mature tree of 20-40 m. height was selective sampling for collecting ants. The tree was identified and the height measured. The average height of evergreen trees was 27.72 m whereas of the *E. tapos* it was 32.77 m. A flowering and fruiting tree was omitted from the study in order to avoid any contamination. The tree that was selected was not sampled again for the next study. As a result, 6 trees were fogged each time, 3 evergreen tree and 3 *E. tapos* trees. Totally, 36 trees were selected to assess canopy ants throughout the experiment: 18 evergreen trees and 18 deciduous ones. The list of all trees are presented in the Table 1 (a full species list is in Appendix 1).

Table 1. List of all selected trees from both habitat types.

Tree	Family	character	quantity
Syzygium cumini (L.) Skeels.	Myrtaceae	Evergreen	3
Bouea microphylla Griff.	Anacardiaceae	Evergreen	3
Castanopsis piriformis Hickel and A.Camus	Fagaceae	Evergreen	3
Pseuduvaria monticola J. Sinclair.	Annonanceae	Evergreen	2
Ryparosa javanica Bl.	Flacourticeae	Evergreen	2
Castanopsis javanica Blume.	Fagaceae	Evergreen	1
Chisocheton spp.	Meliaceae	Evergreen	1
Parashorea stellata Kurz.	Dipterocarpaceae	Evergreen	1
Baccaurea kunstleri King ex Gage.	Euphorbiaceae	Evergreen	1
Nephelium melliferum Gagnep.	Sapindaceae	Evergreen	1
Elateriospermum tapos Blume.	Euphorbiaceae	Deciduous	18
Total			36

5) Sampling procedure

Ants were collected using the canopy fogging technique because of its expediency, accuracy, and general nondestructive nature (Adis *et al.*, 1998). A synthetic pyrethroid insecticide diluted with diesel oil (ratio 1:49) was used to spray into the tree crown. The fogging technique used the fogging equipment iGEBA model TF 35. After the host tree in each plot was selected, ten quadrate-shaped areas (1x1 m each) with a cylinder containing 70% ethanol were set up and were suspended underneath the tree canopy as close as possible to support ants and other organisms (Fig. 6). The fogging machine was suspended into the canopy as closely as possible and was fogged (Fig. 6). It was carried out at around 0600 in the morning in order to avoid the effect of wind and sunlight on insecticide activity (Chey *et al.*, 1998; Floren *et al.*, 2001; Tovar-Sanchez *et al.*, 2003). Fogging took 20 minutes for each tree and samples were collected within 2 hours afterwards. In this study, one day was done only one tree fogged. Ants were removed from the quadrate using a hand-held modified vacuum technique. All of the samples were immediately preserved in 70% ethanol, labeled, and kept for sorting at the Department of Biology, Faculty of Science, Prince of Songkla University, Hat Yai.

Furthermore, some physical factors were recorded during the experiments. Temperature (°C) and relative humidity (%) were simultaneously measured using thermometer and hydrometer during collecting period. Also, precipitation (mm/month) was recorded from the weather station at both sites in order to assess a seasonal changes (dry and wet season) in KNPP.

6) Identification

In the laboratory, all samples were stored in bottles and vials containing 70% alcohol until they could be sorted and processed. Processed specimens were separated into similar taxa (i.e. order, family, or morphologically similar groups). Collected ants were cleaned and individually pinned, placed in vials or on mounting points with an identification label. They were dried and identified to the genus level using the key of Bolton (1994) and Hölldobler and Wilson (1990) based on the external morphological characteristics of the worker stage. They also identify and confirm to species level by Prof. Dr. Seiki Yamane (persernal communication). Once identified, a label with the order, family, and species names was included with each specimen. For each species at least 8 individuals were mounted. Voucher specimens will be deposited at Princess Maha Chakri Sirindthorn Natural History Museum, Faculty of Science, Prince of Songkla University, Hat Yai.

Figure 6. Ten quadrates were set up and moved to the canopy (1, 2) and (3) fogging technique by spraying the synthetic pyrethroid insecticide (4) the author with fogging equipment.

7) Statistical Analyses

Canopy ants were assessed using several different measurements.

7.1 Alpha diversity

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. Jackknife1 was calculated as a shortcut to extrapolate from the species number observed to the true number present. This estimator was the most precise and least biased and also provides a powerful approach for assessing alpha diversity. All calculations were randomized 100 times. Jackknife 1 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), where *n* is the number of samples.

Shannon-Wiener diversity index (*H'*) using Species Diversity and Richness software version 2.3 (Handerson and Seaby, 1998) was calculated to take into account richness and the proportion of each species within a local community. This index assumes that the area sampled contains an infinite number of individuals. The equation for *H'* is defined as: $H' = -sum\ (Pi\ natural\ log\ [Pi])$ where *Pi* is the proportion of individuals in species and '*i*' divided by the total number of ants from that site. Values can range from zero to the amount of species in the sample with higher numbers representing higher levels of diversity.

Species equitability or evenness (*J*) was computed for each site. Equitability (*J*) is calculated as $J = H/log(S)$ where S is the number of species in the sample. This method was used to assess the distribution of individuals of each species in the area sampled. Community structure was also examined further by Rank-abundance curves. The rank-abundance is useful as they provide a means for visually representing species richness and species evenness using Species Diversity and Richness software.

In addition to these measures, analysis of variance (one-way ANOVA) using mean difference between 2 populations was used to compare the habitat sites for significant differences in top four genera, species composition and abundance. Also, one-way ANOVA was used to test statistical difference between Shannon diversity index and Evenness each time compare with different habitats. Calculations were performed using SPSS for Windows version 16. All outcomes were plotted on a graphs and charts using Microsoft Office Excel 2007.

7.2 Influence of some physical factors

The effect of environmental parameters, such as temperature, humidity, and precipitation, on levels of individual abundance of ant species was investigated. The relationship of community composition to these potential co-variables was assessed by SPSS for window version 16. The stepwise multiple regression analyses were computed to find out the significant association between physical factors and common ant species. Data was log-transformed to meet the assumptions of normality. The level of significance had been determined to be at 0.05. Ecological factor were treated as the independent variables, and ant species were used as the dependent variable.

7.3 Effect of leave shedding in deciduous tree

In addition, it was important to determine whether there were differences in species richness at different times during the period when *E. tapos* shed its leaves, compared 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. Calculations were made using SPSS for Windows version 16.

CHAPTER 3

RESULTS

1) COMMUNITY COMPOSITION OF CANOPY ANTS

A year round investigation on ant species were collected both evergreen and briefly deciduous tree canopies. The chemical knockdown using fogging technique was carried out in tropical rainforest at KNNP. The result showed that ants belonged to 7 subfamilies 34 genera and 205 morphospecies which 16,884 individuals were identified (Table 2) (a full species list is in Appendix 1). The proportion of species in each subfamily was shown in Table 2. The majority of ant species was Myrmicinae (42%, 87 species) and Formicinae (42%, 86 species). The rest were Dolichoderinae (10%, 19 species), Pseudomyrmecinae (3%, 6 species), Ponerinae (1%, 3 species), Aenictinae (1%, 2 species) and Cerapachyinae (1%, 2 species) respectively.

The proportion of the top four genera were *Crematogaster* (39 species), *Camponotus* (39 species), and *Polyrhachis* (37 species) all of which were 18%, followed by *Pheidole* 6% (13 species) whereas the rest genera comprised of 1-8 species represented 35% of species sampled (Table 2).

With regard to the number of individuals and the proportion of the species, the top five species that were the most dominant in number of individuals were *Dolichoderus thoracicus* 18% (3,123 individuals), *Oecophylla smaragdina* 11% (1,806 individuals), *Dolichoderus* sp. 4 7% (1,098 individuals), *Dolichoderus* sp. 5 6% (1,065individuals), and *Crematogaster (Paracrema)* sp. 2 6% (1,019 individuals).

Table 2. Total of subfamily, genera, species, and number of individuals of the canopy ants at KNNP.

Subfamily	Genera	Number of species	Proportion in %	Number of individuals
Aenictinae				
	Aenictus	2	0.97	6
Cerapachyinae				
	Cerapachys	2	0.97	2
Dolichoderinae				
	Dolichoderus	8	3.90	5,361
	Tapinoma	6	2.92	91
	Technomyrmex	5	2.43	762
Formicinae				
	Camponotus	39	19.02	2,242
	Echinopla	3	1.46	24
	Myrmoteras	1	0.48	3
	Oecophylla	1	0.48	1086
	Paratrechina	2	0.97	80
	Philidris	1	0.48	230
	Plagiolepis	1	0.48	7
	Polyrhachis	37	18.04	737
	Prenolepis	1	0.48	43
Myrmicinae				
	Cardiocondyla	1	0.48	28
	Cataulacus	1	0.48	68
	Crematogaster	39	19.02	4,007
	Dilobocondyla	4	1.95	28
	Lordomyrma	1	0.48	1
	Meranoplus	1	0.48	112
	Monomorium	8	3.90	315
	Oligomyrmex	4	1.95	59
	Paratopula	1	0.48	7
	Pheidole	13	6.34	57
	Pheidologeton	1	0.48	1
	Rhopalomastix	1	0.48	121
	Solenopsis	1	0.48	1
	Strumigynys	2	0.97	4
	Tetramorium	4	1.95	178
	Vollenhovia	4	1.95	24
	Vombisidris	1	0.48	7
Pseudomymecinae				
	Tetraponera	6	2.92	468
Ponerinae				
	Pachycondyla	2	0.97	2
	Platythyrea	1	0.48	2
Total	34	205	100	16,884

2) EVERGREEN VS DECIDUOUS

2.1 Species composition

The ant community is slightly different in species composition in each habitat type. In evergreen canopies at the headquarters of KNNP, 7 subfamilies, 29 genera, and 144 morphospecies with 13,645 individuals were found. Likewise in briefly deciduous canopies at Hui Lek station 5 subfamilies 31 genera, 119 morphospecies with 3,285 individuals were identified.

The subfamily Formicinae (67 species) was the most predominant at headquarters followed by Myrmicinae (54 species), Dolichoderinae (12 species), Pseudomyrmecinae (6 species), Ponerinae (1 species), Aenictinae (2 species) and Cerapachyinae (2 species) respectively (Fig. 7). However, the subfamily Myrmicinae (61 species) was the most frequently found at Hui Lek station followed by Formicinae (40 species), Dolichoderinae (12 species), Pseudomyrmecinae (3 species) and Ponerinae (3 species) (Fig. 7) (Appendix 1).

The top four genera of both habitats are alike. At the headquarters *Polyrhachis* (30 species) was commonly found followed by *Camponotus* (29 species) *Crematogaster* (24 species) and *Pheidole* (5 species) while the Hui Lek station contained 26 species of *Crematogaster*, 19 species of *Camponotus*, 13 species of *Polyrhachis*, and 10 species of *Pheidole* (Fig. 8) (Appendix 1).

The most abundant species at headquarters were *Oecophylla smaragdina* (1,806 individuals), *Dolichoderus* sp.4 (1,098 individuals), *Dolichoderus* sp.5 (1,065 individuals) and *Crematogaster (Paracrema)* sp.2 (1,019 individuals). At Hui Lek station, *Camponotus (Karavaievia)* sp.2 (728 individuals), *Technomyrmex vitieusis* (283 individuals), *Oecophylla smaragdina* (273 individuals), and *Crematogaster (Crematogaster)* sp.7 (197 individuals) were most frequently found (Appendix 1).

However, out of the 205 morphospecies collected, only 58 species (28%) overlapped between 2 sites. While 86 species (42%) were found individually at headquarters only 61 species (30%) were discovered at Hui Lek station (Fig. 9) (a full species list is in Appendix 1).

What is more, the common ant species in both habitats were determined by frequency calculations. The results showed that most of species were found in fewer than 5 trees. At each habitat, at least ≥50% of the recorded species could be classified as common. The species that were encountered between 16-49% defined as intermediate species and species that were found less than <15% were determined as rare (Table 3). By this definition, the 12 common species on evergreen tree of the headquarters were *Polyrhachis(Myrmatopla)* sp.1, *Oecophylla smaragdina, Cataulacus granulate*, *Tetraponera attenuate*, *Camponotus (Colobosis) vitrius*, *Camponotus (Tanaemyrmex)* sp.1, *Dolichoderus thoracicus*, *Crematogaster (Crematogaster)* sp.2, *Polyrhachis (Myrmhopla)* sp.1, *Polyrhachis (Myrmhopla)* sp.9, *Cardiocondyla* sp.1, *Tetraponera* sp.1. Interestingly, only 2 species of *Tetraponera attenuate* and *Tetraponera* sp.1 were encountered as common species on the tree crown of briefly deciduous trees at Hui Lek station (Table 3).

2.2 Community structure

Out of the 36 trees fogged, the proportions of taxa within both habitats differed slightly. The mean number of the top four ant genera, included *Camponotus*, *Polyrhachis*, *Crematogaster*, *Pheidole*, and the mean number of ant species at both habitats are shown in Table 4. An analysis of variance (one-way ANOVA) indicated that there were not significant differences between study sites of the number of the top four species ($P>0.05$). The calculation of the indices of species diversity was performed using the values which depended upon levels of species richness and evenness. The Shannon-Weiner diversity index reveled that the species richness of both habitats were similar (Table 4). For the headquarters site, the Shannon-Wiener index came out to 3.10 and the Hui Lek station was 3.24. So, the Hui Lek station appeared to have higher richness than the headquarters. The different values of H' for the two communities reflects the differences in species evenness. The equitability or evenness index are relatively similar in value although the Hui Lek station seems to be a bit higher than the headquarters (evenness = 0.61 and 0.58 respectively) (Table 4). Values for Shannon-Wiener index and evenness, however, did not differ significantly between the two habitat types (one-way ANOVA, $P> 0.05$).

Species richness and equitability are important for assessing biodiversity. Therefore, the rank abundance curve was achieved using the relative abundances of different species in a sample (Fig. 10). The abundance of individuals at each habitat was obviously different. An average of individuals for each evergreen tree was 758.06±133.31. The maximum individual number per tree was 1,883 individuals while the minimum per tree was 201. An average individual for the briefly deciduous tree was a 179.94±43.20 individuals per tree. The maximum individual per tree was 782 and the minimum was only 11 individuals per tree. As a result, the headquarters had clearly higher abundance than the Hui Lek station and there was a statistical difference in number of individuals between both habitats ($P<0.05$) (Table 4). Rank abundance curves also showed that the common species were displayed on the left and the rare species were on the right. The curves of both habitats were similar. All curves appear to have a steep gradient indicating relatively low evenness as the high ranking species have much higher abundances than the low ranking species. The slopes of the rank abundance plots for the two habitats demonstrated similar levels of dominance, and all plots show a long tail of rare species (Fig. 10).

A species accumulation curve of the canopy ants was completed using the first order Jackknife estimator (Fig. 11). Asymptotes were not reached in the species accumulative curve for any of the totally species at KNNP and of the two habitats. For overall species at KNNP (Fig. 11a), 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. 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 310 species but the number of species of sampled ants (S_{obs}) was only 205 species. The estimator expected 100 more ant species than those recorded from the fogging sample. As a result, the observed ant species represented 66% of the total species pool. As a consequence of a large number of species being found only once (46 singletons) and twice (30 doubletons), the calculated estimate of undetected species is a rather high figure.

Likewise, an accumulation curve for the headquarters and ~~the~~ Hui Lek station are slightly asymptotic graphs as well. At the headquarters of KNNP (144 species) an extrapolated maximum of 217 species was computed while at Hui Lek station (119 species) it was 186 species. This estimator prophesied 73 and 67 more ant species than those recorded from the observed species respectively. Hence, the observed ant species represented mostly 66% and 64% of the total species pool respectively. Considering the number of singletons and doubletons, the observed number of species was high. Singletons contained 31 species at headquarters and 30 species at Hui Lek station and doubletons were 13 species at headquarters and 18 species at Hui Lek station (Figs. 11b. and 11c.)

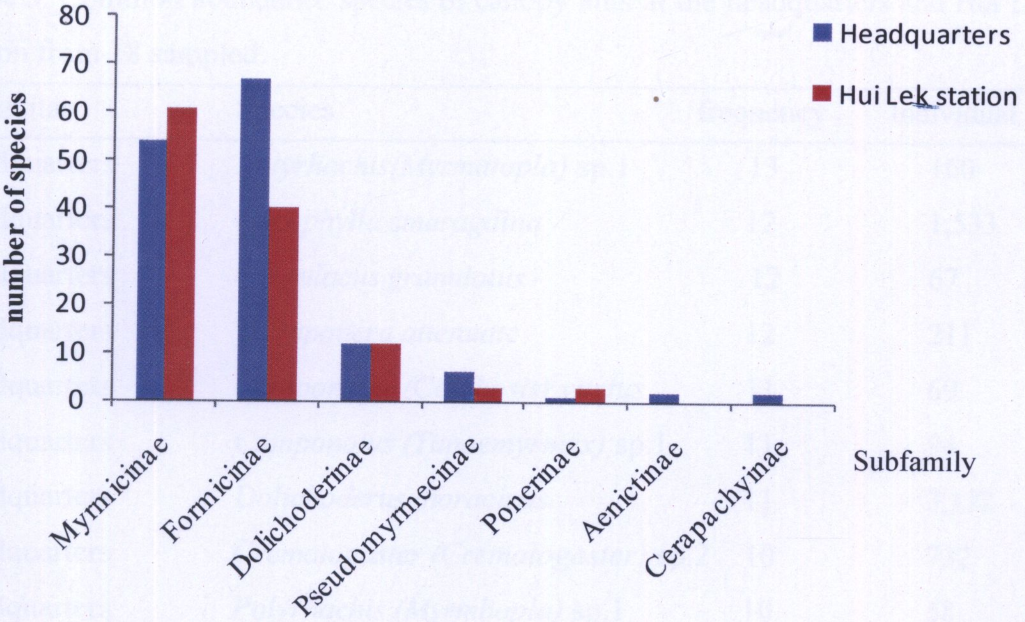


Figure 7. Proportion of the number of subfamily species in each habitat type

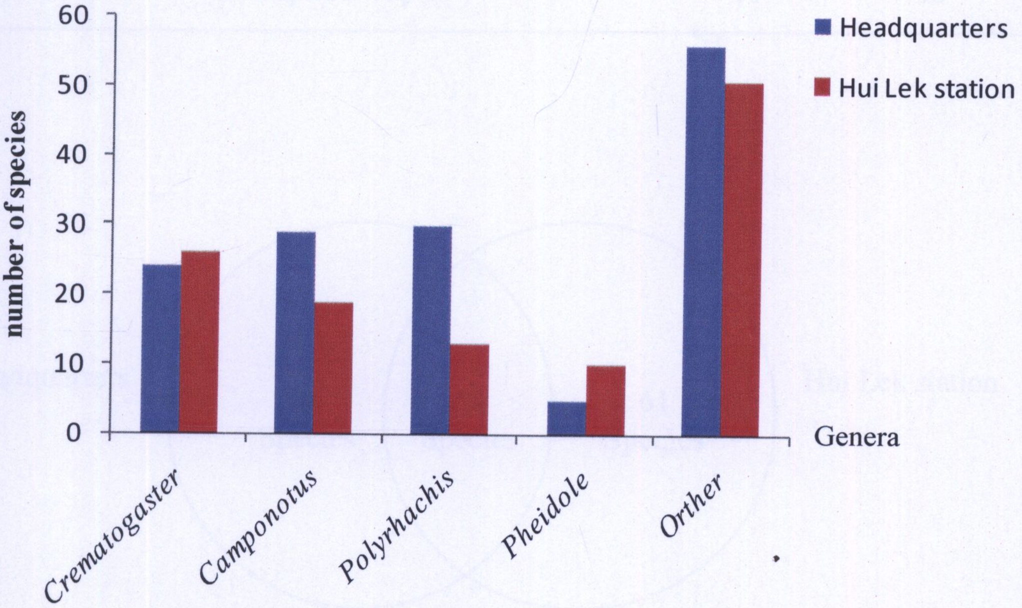


Figure 8. Proportion of the number of top four genera species in each habitat type

Table 3. Common abundance species of canopy ants at the headquarters and Hui Lek station from 18 sampled.

Habitat	Species	frequency	individual
Headquarters	*Polyrhachis(Myrmatopla)* sp.1	13	160
Headquarters	*Oecophylla smaragdina*	12	1,533
Headquarters	*Cataulacus granulatus*	12	67
Headquarters	*Tetraponera attenuate*	12	211
Headquarters	*Camponotus (Colobosis) vitrius*	11	69
Headquarters	*Camponotus (Tanaemyrmex)* sp.1	11	94
Headquarters	*Dolichoderus thoracicus*	11	3,122
Headquarters	*Crematogaster (Crematogaster)* sp.2	10	732
Headquarters	*Polyrhachis (Myrmhopla)* sp.1	10	58
Headquarters	*Polyrhachis (Myrmhopla)* sp.9	10	64
Headquarters	*Cardiocondyla* sp.1	9	19
Headquarters	*Tetraponera* sp.1	9	39
Hui Lek station	*Tetraponera attenuate*	11	121
Hui Lek station	*Tetraponera* sp.1	10	38

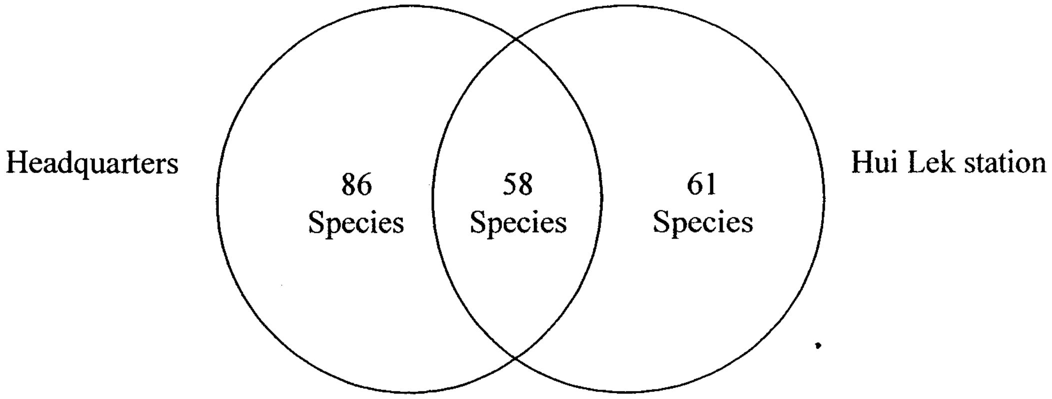


Figure 9. Species overlap among Headquarters and Hui Lek station from 36 trees of fogging sampling at KNNP.

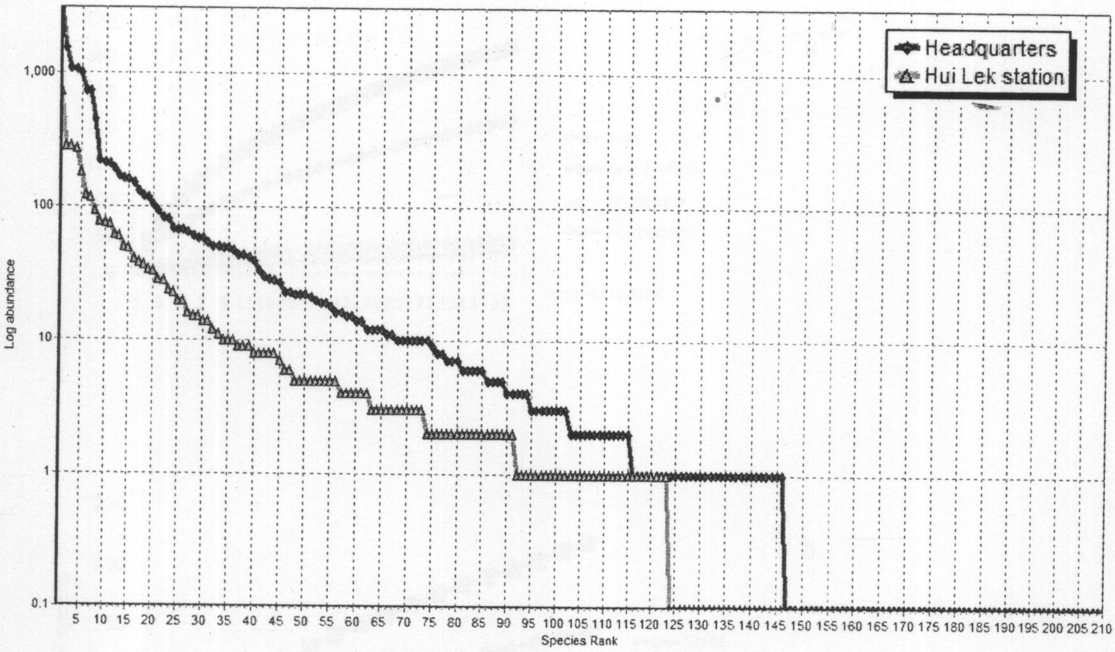


Figure 10. Species rank abundance distribution for the two habitat types.

Table 4. Analysis of variance (one-way ANOVA) shows the mean number of the top and other genera, number of species, number of individuals (±SE) as well as F and P value of two habitats at KNNP based on 36 tree fogged.

	Habitat		Value	
Parameter	Headquarter	Hui Lek station	F-value	P-value
Camponotus	3.06±0.49	2.78±0.38	0.20	0.66
Polyrhachis	3.50±0.62	2.44±0.55	1.62	0.21
Crematogaster	3.22±0.43	2.78±0.32	0.69	0.41
Pheidole	0.61±0.14	0.39±0.22	0.62	0.44
Other genera	8.89±1.20	8.11±0.80	0.29	0.59
No. of species	19.83±2.09	17.06±1.61	1.11	0.30
No. of individual	758.06±133.31	179.94±43.20	**17.02**	**0.00***
Shannon-Wiener index	3.10±0.15	3.24±0.29	0.11	0.74
Evenness	0.58±0.03	0.61±0.07	0.10	0.76

Note: * Significant at the 0.05 level

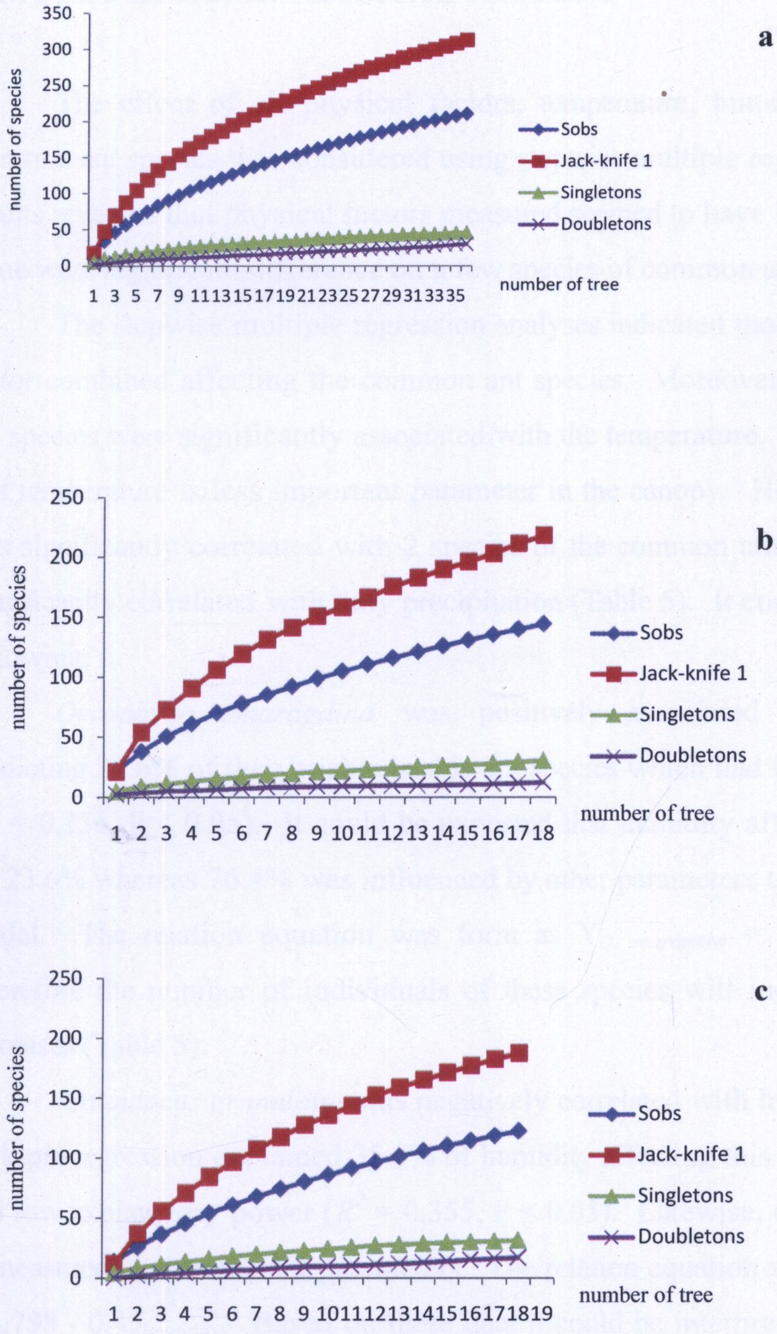


Figure 11. Species accumulation curves of observed and estimated ant species richness as well as singletons and doubletons at (a) total species at KNNP (b) headquarters and (c) Hui Lek station.

3) EFFECT OF SOME PHYSICAL FACTORS

The effect of all physical factors, temperature, humidity, precipitation, on common ant species was considered using stepwise multiple regression analyses. The results revealed that physical factors measured seemed to have less impact on ants and some were significant difference on a few species of common ant.

The stepwise multiple regression analyses indicated that there was no physical factor combined affecting the common ant species. Moreover, none of the common ant species were significantly associated with the temperature. It could be interpreted that temperature is less important parameter in the canopy. However, only humidity was significantly correlated with 2 species of the common ants and one species was significantly correlated with only precipitation (Table 5). It could be explained as the following:

Oecophylla smaragdina was positively associated with only humidity predicting 23.6% of the variable in this ant species which had low explanatory power ($R^2 = 0.236$, $P < 0.05$). It could be expected that humidity affecting this ant species for 23.6% whereas 76.4% was influenced by other parameters that did not exist in this model. The relation equation was form as $Y_{O.\ smaragdina} = -5.612 + 0.071_{\text{humidity}}$. Therefore the number of individuals of these species will increase if the humidity increases (Table 5).

Cataulacus granulatus was negatively correlated with humidity. The stepwise multiple regression explained 35.5% of humidity affecting this ant species which also had low explanatory power ($R^2 = 0.355$, $P < 0.05$). Likewise, 64.5% was affected by unmeasured environmental parameters. The relation equation was form as $Y_{C.\ granulatus} = 4.798 - 0.45_{\text{humidity}}$. Based on these data it could be interpreted that the number of individuals of this species will be higher if humidity is lower (Table 5).

Pecipitation was negatively correlated only with *Tetraponera* sp.1 suggesting 39.8% of rainfall in this ant species which had low explanatory power as well ($R^2 = 0.398$, $P < 0.05$) because 60.2% was influenced by unmeasured environmental parameters. The relation equation was form as $Y_{T.\ sp1} = 0.95 - 0.002_{\text{precipitation}}$. It also indicated that the number of individuals of this species will be higher if rainfall is lower (Table 5).

Table 5. Results of stepwise multiple regression analyses.

Dependent variable	Independent variable	Coefficient (b)	S.E. (b)	Beta	t	*P*	R^2	F	*P*
Polyrhachis(Myrmatopla) sp.1	-	ns	ns	ns	ns	ns	ns	ns	ns
Oecophylla smaragdina	Humidity	0.071	0.30	0.486	2.358	**0.030***	0.236	5.561	**0.030***
Cataulacus granulatus	Humidity	-0.45	0.018	-0.596	-2.459	**0.032***	0.355	6.045	**0.032***
Tetraponera attenuate	-	ns	ns	ns	ns	ns	ns	ns	ns
Camponotus(Colobosis) vitrius	-	ns	ns	ns	ns	ns	ns	ns	ns
Camponotus(Tanaemyrmex) sp.1	-	ns	ns	ns	ns	ns	ns	ns	ns
Dolichoderus thoracicus	-	ns	ns	ns	ns	ns	ns	ns	ns
*Crematogaster(Crematogaster)*sp.2	-	ns	ns	ns	ns	ns	ns	ns	ns
Polyrhachis(Myrmhopla) sp.1	-	ns	ns	ns	ns	ns	ns	ns	ns
Polyrhachis(Myrmhopla) sp.9	-	ns	ns	ns	ns	ns	ns	ns	ns
Cardiocondyla sp.1	-	ns	ns	ns	ns	ns	ns	ns	ns
Tetraponera sp.1	Precipitation	-0.002	0.001	-0.631	-3.355	**0.004***	0.398	11.257	**0.004***

Note: ns = non significant, * significant at the 0.05 level.

4) EFFECT OF LEAVE SHEDDING OF CANOPY ON ANT

E. tapos always dropped its leaves February to March. Overall, however, the species collected were very similar at all collecting times, even when the plants changed their leaves. 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 6). Regarding to the top four dominant genera (*Polyrhachis*, *Camponotus*, *Crematogaster*, and *Pheidole*), the analysis of variance (one-way ANOVA) also showed no significant difference in the mean species number of these genera (P>0.05) (Table 6).

Table 6. Mean (±SE) species number of ants in the top four genera and 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 2006 to March 2007.

Month/ Genera	*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

CHAPTER 4

DISSCUSSION

1) COMMUNITY COMPOSITION AND DIVERSITY OF CANOPY ANTS

1.1 Community composition.

In this study, 7 subfamilies, 34 genera, 205 morphospecies, and 16,884 individuals of ants were identified from the canopy trees at the KNNP. The subfamilies Myrmicinae, Formicinae, Dolichoderinae and Pseudomyrmecinae were the most abundant in the KNNP accounting for 97% or 198 species whereas the remaining subfamilies Ponerinae, Aenictinae and Cerapachyinae comprised of only 3% (7 species). It is not surprising that these subfamilies are dominant because they have a worldwide distribution in both terrestrial and, especially, arboreal ant assemblages (Hölldobler and Wilson, 1990; Bolton, 1995; Shattuck, 1999). The evolutionary history which Brühl *et al.* (1998) described using fossil and molecular analysis to establish that the Ponerinae, Dolylinae, Aenictinae, and Cerapachyinae belong to the older groups whereas Myrmicinae, Formicinae, Dolichoderinae, and Pseudomyrmicinae are evolutionarily younger groups is borne out in this study. The older subfamilies are mainly found in the terrestrial habitat which is believed to be the original habitat of ants while the younger ones appear to have the arboreal lifestyle. As a consequence, many species of these subfamilies are commonly found in the tree crown and canopy (Floren *et al.*, 2001; Schulz and Wagner, 2002; Watt *et al.*, 2002; Tongjerm, 2003; Widodo *et al.*, 2004). A few species of the rest of the subfamilies Ponerinae, Anictinae, and Cerapachyinae were also found in this study because they are mainly terrestrial ant assemblages. They are best regarded as largely predators known for their aggressiveness and ability to subdue prey (Majer *et al.*, 2001). Workers are generally foraging on the ground, and some specialize on a very limited range of prey but occasionally upon the trees. So, a few species of these subfamilies have the ability to search their food in the tree canopy or accidently travel in the canopy (Shattuck, 1999).

The top four genera at both sites in the tree canopy are *Crematogaster, Camponotus, Polyrhachis* and *Pheidole*. Owing to the fact that all genera belong to the evolutionarily younger groups well known to occupy the tree top. In particular *Crematogaster, Camponotus* and *Polyrhachis* are a truly arboreal groups with an established colony on the tree crown and some also have a great foraging activity in the canopy but their nests are on the terrestrial level (Shattuck, 1999; Floren *et al.*, 2001; Schulz and Wagner, 2002; Watt *et al.*, 2002; Tongjerm, 2003). Conversely, *Pheidole* is a genus that has been detected in hyperdiverse habitats including both arboreal and terrestrial and is frequently preferentially sampled by fogging. Because the canopy is able to sustain leaf litter and humus used by some species of *Pheidole* as an important source to support their nests that are mainly on the ground 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). Therefore, they are also commonly found in the tree tops and are frequently sampled by fogging as well (Floren *et al.*, 2001; Schulz and Wagner, 2002; Watt and *et al.*, 2002; Tongjerm, 2003; Widodo *et al.*, 2004). Moreover, some tree species sampled may not be a truly canopy because its height is less than 30 m. So, it may be an important reason that *Pheidole* could be able to travel or has an activity on that tree.

The results showed that *Dolichoderus thoracicus*, *Oecophylla smaragdina*, *Dolichoderus* sp.4, *Dolichoderus* sp.5, and *Crematogaster (Paracrema)* sp.2 have the highest number of individuals in this study. It could be interpreted by the fact that the canopies of tropical rainforest and of tree crop plantation are occupied by a large group of ants which could be identified into: dominant, subdominant, and non-dominant ant species (Davidson, *et al.*, 2007; Sanders, *et al.*, 2007). Firstly, the dominant species are characterized by extremely populated colonies, the ability to build large or polydomous nests and a highly developed intra-as well as interspecific territoriality. Secondly, the subdominant species is a species that have less populated colonies and generally depend on pre-existing botanical structure for nesting (hollow branches, rough bark, and epiphytes). Yet, they are able to defend territories in the same way as the dominant species do. Lastly, non-dominant ant species are much less populated and occur within or between the territories of dominant ants. Accordingly, the abundance in number of individuals of those species may be the dominant species in this Park. Tobin (1997) and Davidson *et al.* (2003) argue that tropical arboreal ants which are numerically or behaviorally dominant not only forage for carbohydrate-rich homopteran honeydew and plant exudates but also require substantial amounts of nitrogen-rich protein sources to promote colony growth and development. Particularly, *Dolichoderus* spp is commonly found in the canopies and a large number of individuals because these species tend to collect hemipteran honeydew and plant exudates as well. A species with a well known omnivore and arboreal lifestyle is *Oecophylla smaragdina* (Fabricius). It forms very large colonies with many satellites. This species has widely available nesting sites in the openings of the canopy and has a great ability to produce many colonies in the same tree (Hölldobler and Wilson, 1978). In the meanwhile, *Crematogaster* spp. is also well known as a major species found on trees in the rainforest and is known as a dominant species in the tree tops (Hölldobler and Wilson, 1990; Shattuck, 1999; Floren *et al.*, 2001; Schulz and Wagner, 2002; Watt and *et al.*, 2002; Tongjerm, 2003; Widodo *et al.*, 2004).

1.2 Why were so many ant species collected?

In the study, 205 morphospecies was the total number of ant species identified. An estimated 800-1,000 species of ant exists in Thailand (Jaitrong and Nabhitabhata, 2005) and around 500 species have been reported from Southern Thailand (Watanasit, unpublished data). Therefore, this study sustains about 20% of the ants in Thailand. Compared to other tropical rainforests, this shows that species numbers are similar or more abundant. For example, Floren *et al.*, (2001) detected 273 species of arboreal ants in Borneo, Malaysia; Schulz and Wagner (2002) showed 161 species of canopy ant in Budongo Forest, Uganda;Watt and *et al.*, (2002) disclosed 97 species of canopy ants in Southern Cameroon; Tongjerm (2003) reported 118 species in the canopy of Ton-nga Chang Wildlife Sanctuary, Southern Thailand; Stuntz *et al.*, (2003) collected 91 species from epiphytes in Panama; and Widodo *et al.*, (2004) found 169 species in lowland evergreen rainforest, Sabah, Malaysia. However, comparisons of data collected through different regions may be misleading because of collecting in different ways, times, asking different questions, and using different sampling methods.

The number of ant species in this study is higher than from the previous studies of Stuntz *et al*., (2003), Watt *et al*., (2002), Schulz and Wagner (2002) and Widodo *et al*., (2004) which were conducted only in evergreen trees, fogged only one plant species, and had fewer tree replications. For example Schulz and Wagner (2002) fogged 15 trees from 4 plant species; Watt *et al*., (2002) collected ants from 15 trees of one species of *T. Superba*. Stuntz *et al*. (2003) examined the influence of a the epiphyte assemblage of the tree crown on its ant fauna from 25 crowns of one species, *Annona glabra,* trees and Widodo *et al*., (2004) sampled nine trees of *Shorea parvifolia*. This study fogged 36 trees from 11 distinct plant species (Table 1). So, many different plant species and a larger number of replications yield a greater variety of that attract a greater diversity of ants than a few species of fogged trees. Tongjerm (2003) conducted his study in Southern Thailand as well, but he collected a lower number of species than this study. Interestingly, even though his study consisted of 14 plant species and 42 tree replications the number of species is still less than this study. The reason may involve the different types of habitat and tree species. This study was conducted using both evergreen and deciduous trees. Only deciduous tree canopies could support 119 species of ant which indicates it is a hotspot area for sustaining ant species. Tongjerm (2003) did not access deciduous trees. As a consequence, collecting over a large area sampling both evergreen and deciduous trees revealed more ant species than collecting on only in the evergreen trees.

Notwithstanding, the number of ant species in this study is lower than the study of Floren *et al*. (2001) which was carried out in a large area of both primary lowland forest and three disturbed forests 5, 15 and 40 years of age. Overall, 50 trees from 5 plant species were fogged. The number of species from the primary forest was 195 species and from the disturbed forest 78 species. Considering only the primary forest, it is a bit lower than this study because of number of trees fogged (19 trees) from 3 species of plants. Thus, a combination of many different tree species, different habitat structure, and using larger samples are important to increase the yield of species richness.

Moreover, as Ribas *et al.* (2003) pointed out, different tree species provide various foods and nesting resources to the ants. It is known that carbohydrate is a main food source in the tree crown for ants (Tobin, 1995). As a result, ants to a great extent utilize floral and extrafloral nectar, fruit sap, food bodies, and seeds from their host plants. They also obtain nutrients from arthropod exudates. Hence, they appear to be great farmers by feeding on some homopterans or lepidopteran larvae as honeydew sources (Tobin, 1995; Wagner and Kay, 2002; Heil and Mckey, 2003). Some canopy ants are also able to hunt prey, both vertebrate and invertebrates, whereas nesting sites are located in dead and living trees (Palmer *et al.*, 2000). Furthermore, canopy ants find appropriate nesting sites in tree crown in different ways. The nesting strategy of ants associates with host plants in unique ways. The arboreal species utilize broadly structures as nesting sites, for instance, hollow twigs or cavities in tree trunks (normally called "domatia"), or dwell in leaf litter and humus accumulated on branches, or underneath leaves (Tobin, 1995). Community heterogeneity, then, as estimated by tree species richness, may surely influence ant species richness. According to this study having more resource variety shelters more species which specialize using different resources and sites. More tree species offer more opportunities for such specialist species. An increase of tree species also represents higher resource availability to ants (Ribas *et al.*, 2003). Also, the more available resource, the less intra-interspecific competition the results may allow the coexistence of more ant species.

Why are there some unarboreal ant species in the canopy? For example, *Pachycondyla*, *Platythyrea*, *Cerapachys* and *Solenopsis* are not truly arboreal and are mostly found on the ground (Shattuck, 1999). Andersen and Yen (1992) observed that out of 44 ant species sampled in tree canopies in north-western Victoria, Australia, only two were truly arboreal. The reason is that the canopy has been utilized by ground-nesting ant species which is frequency of occurrence in the tree crown, allowing this study to identify more than two hundred species from two habitats.

2) EVERGREEN VS DECIDUOUS

2.1 Why is there no significant difference between the top four genera?

The effect of study site between evergreen and briefly deciduous trees was investigated comparing the top four genera of *Camponotus*, *Polyrhachis*, *Crematogaster* and *Pheidole*. An analysis of variance (one-way ANOVA) found that there were no differences between habitats with respect to the top four genera. As a result, there may be three possible hypotheses to explain this event.

Firstly, food resource hypothesis, it is known that ants are ubiquitous and species richness has been increased from the temperate zone to the tropics (Hölldobler and Wilson, 1990). Since tropical environments are more productive, they are able to support more ant species (Kaspari, 2000). In particular, arboreal nesting allows ants to be closer to the majority of a forest's productivity (Kaspari, 2000). As discussed above, all top four genera are an evolutionarily younger group by virtue of having a truly arboreal life style and worldwide distribution in tree tops (Hölldobler and Wilson, 1990; Brühl *et al.*, 1998; Shattuck, 1999). The truly arboreal ants have been known to feed on carbohydrate food source either directly form plant organs or indirectly from honeydew producing insect (Tobin, 1995). Therefore, resource availability is a major factor for these ant genera. Ribas *et al.* (2003) reported that food resources for ants are provided by several different tree species. Ten different plant species were sampled at the headquarters. One species of briefly deciduous trees, *E. tapos,* is also able to provide food supply for ants at the Hui Lek station which is complex in terms of forest structure even though *E. tapos* dominates this area. The mature trees of *E. tapos* are about 30-45 m in height and also they support a large number of epiphyte species. They play an important food resources as well as nesting sites to support many ants (Stuntz *et al.*, 2003). The mature leaves of *E. tapos* also provide extrafloral nectar by secretions from dot glands that support visiting ant species (Fiala and Maschwitz, 1992). It is a crucial energy source to attract ant to be diverse in this area. Moreover, the variability of foliage resulting from the annual shedding of leaves attracts many other arthropod visitors to utilize this habitat in their various niches. The canopy ants scavenge and hunt prey on a variety of food items especially insect corpses. They also feed on 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, this tree can provide a highly heterogeneous resource that will encourage the top four genera to explore the tree crown. Both habitat types are able to offer food resources for ants. Thus, in the vicinity of food supply of both habitats may support and nourish the top four genera in the same way leading to significant difference did not find.

Secondly, related to the first, is the adjacent habitat hypothesis. Because both habitats are closely located (40 km stays apart) ants may easily disperse to the nearby habitat. Cox *et al.* (1976) stated that the distribution of animals is related to their food and habitat niches. However, Kaspari (2000) can divide ant niches into 3 categories: food niche, nest niche and temporal niche. Due to the fact that ant species produce winged reproductive caste that participates in large scale nuptial flights followed by wide-ranging dispersal (Hölldobler and Wilson, 1990; Bourke and Franks, 1995; Shattuck, 1999) the nearby habitat niche can provide a food niche for those ants. As a consequence, the top four genera can distribute themselves to any habitat they need.

Thirdly, related to the second, is the microclimate scale hypothesis. Cox *et al.* (1976) point out that most species have specific distributions depending on their environment. There are certain characteristic species of ants found in different habitats but their habitats are more or less similar in microclimate (Hölldobler and Wilson, 1990; Han and Wheeler, 2002). Ribas and Schoereder (2006) studied arboreal ants in Brazil and found that if the environmental conditions around the tree sampled were similar, ant species were the same. In this study the physical conditions of temperature, humidity and precipitation at both study sites are similar. (Appendix 1). As a consequence, there are no climatic effects on diversity of top four genera of ants.

2.2 Species diversity and species composition

Species diversity is defined on the basis of two factors: (1) the number of species in the community, which is usually called species richness, and (2) the relative abundance of individuals among species, or species evenness (Molles, 2002). Therefore, species diversity of both habitat types is ascertained form the Shannon-Weiner index (*H'*) and Equitability (*J*). The results reveal that the Hui Lek station appears to be more diverse than the headquarters with respect to both species richness and community evenness but statistical analysis does not support this impression (Table 4).

The number of species between the two habitats is similar. The Headquarters has slightly more than the Hiu Lek station (146/123 species) but, interestingly, the alpha diversity of the Hui lek station appears to have both a greater richness and evenness than the Headquarters (Table 4). It can be explained based on information theory because this index is a measure of uncertainty (Smith and Smith, 2001). The higher value of *H'*, the greater is the uncertainty, or the probability that the next individual chosen at random from collection of species will not belong to the same species as the previous one. On the other hand, the lower the value of *H'*, the greater the probability that the next individual encountered will be the same species as the previous one (Smith and Smith, 2001). The different values of *H'* for the two communities then reflect the difference in species evenness (Molles, 2002). A community with many equally distributed species will exhibit high species diversity, whereas a community dominated by one or a few species will have low species diversity. As a result, the species rank abundance also confirms the distribution of individuals at the Hui Lek station is more equivalent than at Headquarters (Fig 10). Taking this point into account, the number of individuals at Headquarters is obviously more than at Hui Lek (Table 4) but the number of species is similar. It means that number of individuals of ants at Headquarters is not equally distributed because many individuals belong to the same species. On the other hand, the Hui Lek station has a more equal distribution of individuals than Headquarters because the distribution of individuals among the species is more even. As a consequence, the Hui Lek station community appears to have a greater alpha diversity than the Headquarters community.

This study shows that study site affects the number of individuals (one-way ANOVA, F = 17.02, P<0.05). Headquarters is more diverse in number of individuals than Hui Lek (Table 4). It may be that the difference in host plant species which provide different amounts of carbohydrate sources for canopy ants (Tobin, 1995; Ribas *et al.*, 2003). Moreover, several trees also provide a higher amount and variety of resources, food and nest sites (Fonseca and Ganade 1996; Yu and Davidson 1997; Oliveira and Pie 1998; Fonseca, 1999; Bluthgen *et al.*, 2000; Ribas *et al.*, 2003). As a consequence, the ten plant species at Headquarters may provide more food resources than one species at Hui Lek station.

With reference to the species accumulation curve, the results showed that it did not reach an asymptotic curve (Fig. 11). The incompleteness of the species collected is indicated by the first order Jackknife non-parametric. Overall, estimate of 310 species suggests that a hundred species were not collected. By extrapolation it appears that 73 and 67 more ant species should be detected at Headquarters and Hui Lek respectively (Fig. 11). The reason for the disparity is due to the presence of a high number of singletons (overall 46 species, 31 at headquarters and 30 at Hui lek stations). Lowton *et al.* (1998) point out that the arboreal and terrestrial ants can travel from the ground to the tree tops or from the canopy to the terrestrial habitat. Majer *et al.* (2001) and Schulz and Wagner (2002) have reported that large numbers of singletons is not typical for arboreal ants. They may be ground dwelling ant species and temporarily forage on the tree crown. Singletons species behave as tourists which travel along the canopy (Majer *et al.*, 2001; Stuntz *et al.*, 2003). Thus, richness estimates are highly influenced by rare species (Longino *et al.*, 2002). So the large number of unique species is one important reason for the species accumulative curve not to be asymptotic.

Species accumulation curves are used to analyze whether the sampling efforts were adequate to represent the local ant communities by extrapolating from the species number observed to the true number present (Floren *et al.*, 2001). From the results, it means that replications of this study may be insufficient in numbers of trees sampled because the graph shows that it would be increase higher in species number with a further sampling effort. Majer *et al*, (2001) also stated that there are cases in which species are abundant at the study site but are undersampled due to the inadequacy of the sampling methods. Therefore, it probably does not cover all types of KNNP since both communities resulting in the species accumulative curve did not reach an asymptotic graph.

Finally, the results for individual collection method reveal that a single method is not sufficient to confirm insect inventories. Most show high proportions of rare species and therefore species accumulation curves that do not show signs of approaching a plateau. The "uniques" and "duplicates" curves are either rising or flat, and richness estimates rise steeply and remain well above the observed species richness. Although insecticide fogging has been known to be the best way to collect canopy insects, it is limited for capturing cryptic ants in the hollows or the trunk-dwelling ants (Stork and Hammond, 1997). There is evidence from insecticide knockdown yields that there are many unknown numbers of singletons species (Stork, 1987; Majer *et al.*, 2001; Longino *et al.*, 2002; Schulz and Wagner., 2002; Stuntz *et al.*, 2003). Hence, a combination of methods may be able to capture the unique species in sufficient numbers in order to accomplish the important final goal of confirming the true species richness (Longino *et al.*, 2002; Watanasit, 2003).

3. EFFECT OF SOME PHYSICAL FACTORS

The association between physical factors (temperature, humidity and precipitation) and individual numbers of ant species is detected using the stepwise multiple regression analyses. The results showed that all combination of physical factors measured appeared to have no significant impact on canopy ants. None of the common ant species were significantly associated with the temperature. The reason for this may be that the environmental surrounding of the tree canopy always fluctuates and is unpredictable (Romoser and Stoffolano, 1994). They are oviously different in environmental factors when time is changed. Temeprature in the canopy is high in the day time and drop at the night. As temperature is unpredictable, then it may not affect canopy ant due to the fact that canopy ants are able to withstand the desiccation stress because of their physiological mechanisms (Hahn and Wheeler, 2002; Hood and Tschinkel, 1990). As a consequence, temperature seems to have no significantly impact on ant.

With regard to other factor (humidity and precipitation) affecting the ant species, the results showed that humidity and precipitation were associated with ants. Only humidity was correlated both positively and negatively with 2 species of *Oecophylla smaragdina* and *Cataulacus granulatus* repectively while only precipitation was positively associated with one species of *Tetraponera* sp.1. Although the significant differentces were found but it had low explanatory power when the R squar (coefficient of determination) was considered. R^2 is the value showing the influence of independent variables (physical factors) on the dependent variable (ant species). As a result, the explanatory power (R^2) of physical factors on ant is very low (23.6% in *Oecophylla smaragdina*, 35.5% in *Cataulacus granulatus* and 39.8% in *Tetraponera* sp.1). Hence, it could be explained that in 76.4%, 64.5% and 60.2% of those ant species respectively were influenced by other parameters that did not exist in this model. As a consequence, it could indicate that the physical factors measured in this study are not strong influence the canopy ants but the other factors should be taken into account. Wang *et al.* 2001 and Thompson and McLachlan, 2007 point out that canopy cover, light intensity, microclimate, vegetation structure, and forest community composition have been shown to be associated with changes in ant diversity and community composition. So, those environmental parameters may play an essential role in governing canopy ant. Other aspect that should mention in this study is that all of physical factors measured in this study are not too many fluctuations (appendix 1). So, it may be an important reason to be not significant difference with common ant species.

As a consequence, this study indicated that the physical factors, for instance temperature, humidity and precipitation, were not associated with canopy ant species. Though some significant differences are found but R^2 value has low explanatory power. Hence, other environment factors should be taken into consideration and would be benefit to the futher study.

4) EFFECT OF LEAVE SHEDDING OF CANOPY ON ANT

The *E. tapos* is a briefly deciduous plant that shed leave annually around February to March (Whitmore 1972; Osada *et al.*, 2002). The diversity of canopy ant species found in this tree is similar with leaves. An explanation is that *E. tapos* produces flowers simultaneously after they drop their leaves (field survey). Thus the flowering events provide some food resources for the canopy ants. Many studies show that ant 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) also indicated that the young leaves of mature *E. tapos* trees have glands that produce sugar in the secreted fluids. Consequently, canopy ants appear to exploit the carbohydrates, produced by the plant, as their main food source (Tobin, 1995). Host plants directly produce food rewards. For example floral or extrafloral nectar, sugar sap, are both food bodies for attracting ants to protect the plants from herbivores (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 leaves. Furthermore, Hahn and Wheeler (2002) found that arboreal ants could increase their activity in tree crowns even when the desiccation risk is high. Desiccation stress is in this case therefore probably of minor importance in regulating the activity of arboreal ants. This may be the result of several physiological mechanisms utilized by arboreal ants to resist desiccation stress more effectively than terrestrial ants (Hood and Tschinkel, 1990). In this case, they have evolved more effective epicuticular lipid waterproofing and thicker waxy cuticles to prevent desiccation (Hood and Tschinkel, 1990; Yanoviak *et al.*, 2005).

However the canopy ants adapt themselves to desiccation, deciduous situations are obviously distinct from those found with evergreens that are clothed with leaves all the year round and protect ants from heat indirectly. In deciduous trees when plants shed foliage this provides conditions for allowing direct drought, temperature fluctuations, and for lower humidity in the canopies. Thus, ants become more vulnerable and those activities may have a selective effect on ant composition

(Kaspari, 1993; Andersen, 2000). However, this is not the case of *E tapos*, because they produce flowers and new leaves simultaneously after dropping their leaves. As a consequence the briefly deciduous life-cycle of *E. tapos* appears to have little impact on the composition of the canopy ants.

CHAPTER 5

CONCLUSIONS

The tropical canopy at KNNP supports various habitats for ant assemblage. There are 16,884 individuals and 205 species have been identified both evergreen and deciduous trees, while Jackknife estimator expect more ant species have yet to be found. The majority of ant species are Myrmicinae and Formicinae whereas the rest are Dolichoderinae, Pseudomyrmecinae, Ponerinae, Aenictinae and Cerapachyinae. The top four genera are *Crematogaster, Camponotus, Polyrhachis,* and *Pheidole*. The most dominant in number of individuals are *Dolichoderus thoracicus, Oecophylla smaragdina, Dolichoderus* sp.4, *Dolichoderus* sp.5, and *Crematogaster (Paracrema).*

Effect of study sites (the Headquarters and the Hui Lek station) on the top four genera of *Camponotus*, *Polyrhachis*, *Crematogaster* and *Pheidole* is not detected (one-way ANOVA, P>0.05). The reasons may be that (1) the both habitats are able to provide food resource in the same way, (2) habitats are closely by each other, and (3) microclimate scale of both habitats are similar. The species richness at the evergreen and the deciduous tree are likely to be similar in supporting ant assemblage. Although there are different in community structure of habitat but ant composition are quit similar. The Shannon-Weiner index shows a bit different of the ant fauna but statistical difference are not detected (one-way ANOVA, P>0.05). Owing to the Hui Lek station is more equally individual distribution than the Headquarters. In terms of number of individual collected from both study sites, the Headquarters is more diverse in number of individual than the Hui Lek station (one-way ANOVA, P<0.05). It may be difference in host plant species providing different in variety of resources, food, and nest sites.

Consequently, it could indicate that the deciduous community is a very crucial habitat both in terms of species richness and species evenness because more than 123 species of ants are found on the *E. tapos* canopies. This is implications in that the briefly deciduous community is able to 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 stepwise multiple regression analyses of the physical factors (temperature, humidity and precipitation) were not associated with canopy ant species. Though some significant differences are found but R^2 value has low explanatory power. Hence, other environment factors should be taken into consideration and would be benefit to the futher study.

Shedding leaves shortly of *E. tapos* appears to have no significant impact on the composition of the canopy ants (one-way ANOVA, $P<0.05$)

PERSPECTIVES AND RECOMMENDATIONS

1. The presence of the high number of ant species could probably have involved in community consequences and co-evolutionary dynamics resulting in some degree of ant-plant specialization interactions. But in this case I have not detected any such specific relationship between ant species and this plant. So, this is an interesting question that is still needed and would benefit for the further study.

2. Other canopy habitats for example mangrove forest, beach forest, deciduous forest or even riparian tree etc. need to be examined in a similar manner to provide a wider picture of canopy ant assemblage.

3. A year-round investigation at bimonthly intervals may be insufficient. If field sampling is done at monthly interval, it will more understand a changing of canopy ant assemblage.

4. Terrestrial ants should be considered simultaneously to understand the distribution between the canopy and the ground assemblage. Thus, understanding the distribution between ground dwelling ant and canopy ants is interesting topic for further study

5. Apart from temperure, humidity and precipitation, other environmetal parameters should be taken into consideration for example canopy cover, light intensity, microclimate, vegetation structure, and forest community composition. It probably explains the wide picture of canopy ant that is affected by those physical factors.

6. Insecticide knockdown should be aware for conducting. Since environmental factors for instance wind velocity, effect of sunlight and rain etc. are important parameters to affect on insecticide fogging. Early morning around 6.00-7.00 am is suitable time for performing because this time wind is slightly and solar impact.

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Appendices

Appendix 1

Table 1. Canopy ant list at KNNP

Species	Habitat/number of individuals						
	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Polyrhachis(Campomyrma) sp.1	0	0	1	0	0	0	1
Polyrhachis(Campomyrma) sp.2	0	1	0	0	0	0	1
Polyrhachis(Campomyrma) sp.3	0	1	0	0	0	0	1
Polyrhachis(Cyrtomyrma) sp.1	2	0	0	0	0	0	2
Polyrhachis(Myrmhopla) sp.1	29	11	18	0	0	3	61
Polyrhachis(Myrmhopla) sp.2	9	0	1	0	0	0	10
Polyrhachis(Myrmhopla) sp.3	31	18	4	0	0	0	53
Polyrhachis(Myrmhopla) sp.4	4	0	0	0	0	0	4
Polyrhachis(Myrmhopla) sp.5	0	0	0	4	0	0	4
Polyrhachis(Myrmhopla) sp.6	0	0	0	1	1	3	5
Polyrhachis(Myrmhopla) sp.7	0	0	1	0	0	1	2
Polyrhachis(Myrmhopla) sp.8	2	0	7	0	0	0	9
Polyrhachis(Myrmhopla) sp.9	23	32	9	0	0	0	64
Polyrhachis(Myrmhopla) sp.10	1	0	0	0	0	0	1
Polyrhachis(Myrmhopla) sp.11	5	0	0	0	0	0	5
Polyrhachis(Myrmhopla) sp.12	10	0	0	0	0	0	10
Polyrhachis(Myrmhopla) sp.13	0	0	0	1	0	0	1
Polyrhachis(Myrmhopla) sp.14	1	0	0	0	0	0	1
Polyrhachis(Myrmhopla) sp.15	0	0	10	0	0	0	10
Polyrhachis(Myrmhopla) sp.16	0	0	4	0	0	0	4
Polyrhachis(Myrmatopla) sp.1	59	57	44	0	1	1	162
Polyrhachis(Myrmatopla) sp.2	41	41	0	0	0	0	82
Polyrhachis(Myrmatopla) sp.3	29	0	0	0	0	0	29
Polyrhachis(Myrmatopla) sp.4	2	0	0	0	0	0	2
Polyrhachis(Myrmatopa) sp.5	0	0	0	2	0	0	2
Polyrhachis(Myrmatopa) sp.6	0	0	0	0	1	0	1
Polyrhachis(Myrmatopla) sp.7	0	5	0	0	0	9	14
Polyrhachis(Myrmatopla) sp.8	0	0	0	0	5	0	5
Polyrhachis(Myrmatopla) sp.9	1	1	12	0	0	0	14
Polyrhachis(Myrmothrinax) sp.1	44	27	46	1	1	0	119
Polyrhachis(Myrmothrinax) sp.2	5	3	19	0	0	0	27
Polyrhachis(Myrmothrinax) sp.3	1	0	0	0	0	0	1
Polyrhachis(Myrma) sp.1	2	1	1	0	0	0	4
Polyrhachis(Myrma) sp.2	0	0	0	0	0	2	2
Polyrhachis(Myrma) sp.3	0	6	0	0	0	0	6
Polyrhachis(Polyrhachis) sp.1	0	0	8	0	0	3	11

Table 1. Canopy ant list at KNNP (continued)

Species	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Polyrhachis(Polyrhachis) sp.2	0	7	0	0	0	0	7
Camponotus sp.1	78	1	1	0	1	5	86
Camponotus sp.2	2	0	0	0	0	0	2
Camponotus sp.3	151	0	0	0	0	5	156
Camponotus sp.4	1	0	0	0	0	0	1
Camponotus sp.5	0	0	0	1	0	0	1
Camponotus(Colobobsis)leonardi	0	16	0	3	1	46	66
Camponotus(Colobosis) saundersi-group	0	0	0	13	0	3	16
Camponotus(Colobosis) vitrius	21	38	10	0	8	2	79
Camponotus(Colobosis) sp.1	0	2	0	0	0	0	2
Camponotus(Colobosis) sp.2	46	4	0	0	0	0	50
Camponotus(Colobosis) sp.3	1	0	0	0	0	0	1
Camponotus(Colobosis) sp.4	0	3	0	0	0	0	3
Camponotus(Colobosis) sp.5	0	0	0	2	0	0	2
Camponotus(Colobosis) sp.6	5	0	0	0	0	0	5
Camponotus(Colobosis) sp.7	4	0	0	0	0	0	4
Camponotus(Colobosis) sp.8	0	0	0	0	1	0	1
Camponotus(Colobosis) sp.9	0	2	0	0	0	0	2
Camponotus(Karavaievia) cf. dolichoderoides	0	0	11	0	179	0	190
Camponotus(Karavaievia) sp.1	0	0	0	0	0	3	3
Camponotus(Karavaievia) sp.2	0	0	0	0	0	728	728
Camponotus(Myrmamblys) sp.1	60	0	0	0	0	0	60
Camponotus(Myrmamblys) sp.2	0	0	0	1	0	0	1
Camponotus(Myrmamblys) sp.3	1	0	0	0	0	0	1
Camponotus(Myrmamblys) sp.4	1	0	0	0	0	0	1
Camponotus(Myrmamblys) sp.5	0	0	0	0	1	0	1
Camponotus(Myrmotarsus) rufifemur	10	0	0	5	0	0	15
Camponotus(Myrmotarsus) sp.1	10	7	2	0	0	0	19
Camponotus(Tanaemyrmex) cf.arrogans	0	4	0	0	0	0	4
Camponotus(Tanaemyrmex) sp.1	12	37	45	25	48	5	172
Camponotus(Tanaemyrmex) sp.2	14	17	16	15	5	0	67
Camponotus(Tanaemyrmex) sp.3	0	15	0	0	0	0	15
Camponotus(Tanaemyrmex) sp.4	0	1	0	0	0	0	1
Camponotus(Tanaemyrmex) sp.5	0	21	0	0	0	0	21
Camponotus(Tanaemyrmex) sp.6	2	0	0	0	0	0	2

Table 1. Canopy ant list at KNNP (continued)

Species	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Camponotus(Tanaemyrmex) sp.7	0	0	7	49	12	0	68
Camponotus(Tanaemyrmex) sp.8	0	0	0	0	0	62	62
Camponotus(Tanaemyrmex) sp.9	0	0	0	0	0	2	2
Camponotus(Tanaemyrmex) sp.10	163	0	0	0	0	0	163
Camponotus(Tanaemyrmex) sp.11	6	0	163	0	0	0	169
Echinopla striata	17	0	1	0	0	1	19
Echinopla sp.1	1	1	0	0	0	0	2
Echinopla sp.2	3	0	0	0	0	0	3
Myrmoteras sp.1	0	0	0	0	3	0	3
Oecophylla smaragdina	626	805	102	239	28	6	1806
Paratrechina sp.1	35	7	1	3	0	0	46
Paratrechina sp.2	0	20	0	14	0	0	34
Prenolepis sp.1	0	42	0	0	0	1	43
Philidris sp.1	215	0	0	8	5	2	230
Plagiolepis sp.1	0	0	0	6	1	0	7
Crematogaster(Crematogaster) sp.1	1	2	0	24	4	9	40
Crematogaster(Crematogaster) sp.2	329	384	19	8	14	12	766
Crematogaster(Crematogaster) sp.3	0	0	0	0	5	3	8
Crematogaster(Crematogaster) .sp4	1	0	0	0	0	0	1
Crematogaster(Crematogaster) sp.5	0	49	0	0	0	8	57
Crematogaster(Crematogaster) sp.6	0	0	5	0	197	86	288
Crematogaster(Crematogaster) sp.7	0	0	0	0	0	5	5
Crematogaster(Crematogaster) sp.8	0	0	0	0	5	0	5
Crematogaster(Crematogaster) sp.9	0	0	0	0	5	0	5
Crematogaster(Crematogaster) sp.10	0	0	0	0	0	2	2
Crematogaster(Crematogaster) sp.11	0	0	16	0	20	0	36
Crematogaster(Crematogaster) sp.12	0	0	0	1	0	0	1
Crematogaster(Crematogaster) sp.13	0	0	0	11	0	0	11
Crematogaster(Crematogaster) sp.14	0	0	0	1	0	0	1
Crematogaster(Crematogaster) sp.15	0	23	0	0	0	0	23
Crematogaster(Crematogaster) sp.16	0	2	0	0	0	0	2
Crematogaster(Crematogaster) sp.17	452	0	0	0	0	0	452
Crematogaster(Crematogaster) sp.18	0	0	0	1	0	0	1
Crematogaster(Crematogaster) sp.19	0	0	0	0	3	0	3
Crematogaster(Decacrema) sp.1	1	48	0	2	0	8	59
Crematogaster(Decacrema) sp.2	12	193	2	0	0	0	207
Crematogaster(Decacrema) sp.3	0	10	0	0	0	10	20

Table 1. Canopy ant list at KNNP (continued)

Species	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Crematogaster(Decacrema) sp.4	0	0	15	0	0	0	15
Crematogaster(Orthrocrema) sp.1	2	0	4	0	0	0	6
Crematogaster(Orthrocrema) sp.2	0	0	0	0	3	1	4
Crematogaster(Orthrocrema) sp.3	0	0	0	0	2	0	2
Crematogaster(Orthrocrema) sp.4	0	8	0	0	0	0	8
Crematogaster(Orthrocrema) sp.5	0	0	3	2	46	1	52
Crematogaster(Orthrocrema) sp.6	0	0	0	3	2	1	6
Crematogaster(Orthrocrema) sp.7	26	4	0	0	0	0	30
Crematogaster(Orthrocrema) sp.8	1	0	0	0	0	0	1
Crematogaster(Orthrocrema) sp.9	0	0	0	1	0	0	1
Crematogaster(Orthrocrema) sp.10	0	1	0	0	0	0	1
Crematogaster(Orthrocrema) sp.11	1	0	0	0	0	0	1
Crematogaster(Parecrema) sp.1	70	270	396	32	57	5	830
Crematogaster(Paracrema) sp.2	915	6	89	0	0	9	1019
Crematogaster(Paracrema) sp.3	0	0	0	23	0	0	23
Crematogaster(Parecrema) sp.4	0	0	0	0	3	0	3
Crematogaster(Physocrema) sp.1	5	0	7	0	0	0	12
Cardiocondyla sp.1	9	7	3	9	0	0	28
Cataulacus granulatus	7	52	8	1	0	0	68
Dilobocondyla sp.1	7	5	0	0	0	0	12
Dilobocondyla sp.2	0	1	1	0	0	0	2
Dolobocondyla sp.3	5	1	1	1	0	0	8
Dilobocondyla sp.4	6	0	0	0	0	0	6
Lordomyrma sp.1	0	0	0	0	1	0	1
Meranoplus castaneus	95	9	0	2	6	0	112
Monomorium floricola	1	9	0	3	0	0	13
Monomorium sp.1	9	12	22	15	7	6	71
Monomorium sp.2	27	6	34	3	2	0	72
Monomorium sp.3	23	0	0	1	1	0	25
Monomorium sp.4	33	0	17	13	32	29	124
Monomorium sp.5	0	0	0	1	0	1	2
Monomorium sp.6	1	0	0	1	0	3	5
Monomorium sp.7	0	0	0	0	3	0	3
Oligomyrmex sp.1	0	0	14	0	0	0	14
Oligomyrmex sp.2	0	0	0	22	19	0	41
Oligomyrmex sp.3	0	0	0	0	3	0	3
Oligomyrmex sp.4	1	0	0	0	0	0	1

Table 1. Canopy ant list at KNNP (continued)

Species	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Paratopula sp.1	0	1	5	1	0	0	7
Pheidole aristotelis	0	0	0	1	0	1	2
Phiedole longipes group	0	0	0	0	1	0	1
Pheidole sp.1	0	0	0	2	0	0	2
Pheidole sp.2	0	1	0	17	0	12	30
Pheidole sp.3	0	0	0	4	0	4	8
Pheidole sp.4	0	0	0	0	1	0	1
Pheidole sp.5	1	0	0	0	1	0	2
Pheidole sp.6	0	0	0	0	0	1	1
Pheidole sp.7	0	0	0	0	2	0	2
Pheidole sp.8	1	0	0	0	0	0	1
Pheidole sp.9	0	1	0	0	0	0	1
Pheidole sp.10	0	0	1	0	0	0	1
Pheidole sp.11	0	0	0	1	4	0	5
Pheidologeton sp.1	0	0	0	0	1	0	1
Rhopalomastix sp.1	3	0	0	0	61	57	121
Solenopsis sp.1	1	0	0	0	0	0	1
Strumigynys sp.1	1	0	0	0	0	0	1
Strumigenys sp.2	0	0	1	0	2	0	3
Tetramorium sp.1	2	17	3	2	0	22	46
Tetramorium sp.2	10	116	3	0	0	0	129
Tetramorium sp.3	0	0	0	2	0	0	2
Tetramorium sp.4	1	0	0	0	0	0	1
Vombisidris sp.1	3	1	2	1	0	0	7
Vollenhovia sp.1	0	3	0	5	2	7	17
Volenhovia sp.2	0	0	0	2	1	1	4
Volenhovia sp.3	0	0	0	1	0	1	2
Vollenhovia sp.4	1	0	0	0	0	0	1
Dolichoderus thoracicus	1485	1062	575	1	0	0	3123
Dolichoderus sp.1	0	0	0	0	1	0	1
Dolichoderus sp.2	1	1	0	0	0	0	2
Dolichoderus sp.3	11	0	0	0	0	0	11
Dolichoderus sp.4	831	182	85	0	0	0	1098
Dolichoderus sp.5	0	479	586	0	0	0	1065
Dolichoderus sp.6	0	0	0	0	0	3	3
Dilichoderus sp.7	0	0	58	0	0	0	58
Technomyrmex elatior	0	194	0	0	0	0	215

Table 1. Canopy ant list at KNNP (continued)

Species	Headquarters			Hui Lek station			
	plot1	plot2	plot3	plot4	plot5	plot6	Total
Technomyrmex vitieusis	89	2	29	244	5	34	424
Technomyrmex albipes	33	0	0	0	0	12	67
Technomyrmex difficilis	0	0	0	8	0	0	30
Technomyrmex textor	0	0	0	0	4	0	26
Tapinoma sp.1	2	2	6	6	8	1	25
Tapinoma sp.2	0	0	0	2	0	0	2
Tapinoma sp.3	3	2	7	16	0	17	45
Tapinoma sp.4	0	0	0	0	1	0	1
Tapinoma sp.5	0	0	2	0	0	0	2
Tapinoma sp.6	0	0	12	4	0	0	16
Tetraponera attenuate	78	44	99	45	49	27	342
Tertaponera pilosa	7	15	0	1	0	0	23
Tetraponera sp.1	18	18	3	8	11	19	77
Tetraponera sp.2	0	2	0	0	0	0	2
Tertaponera sp.3	10	10	2	0	0	0	22
Tertaponera sp.4	0	0	2	0	0	0	2
Platythyrea paralella	0	1	0	0	0	1	2
Pachycondyla sp.1	0	0	0	0	0	1	1
Pachycondyla sp.2	0	0	0	0	1	0	1
Aenictus laeviceps	3	0	0	0	0	0	3
Aenictus sp.1	0	3	0	0	0	0	3
Cerapachys sp.1	1	0	0	0	0	0	1
Cerapachys sp.2	1	0	0	0	0	0	1
Total	6,451	4,513	2,681	950	899	1,390	16,884

Table 2. Ant species list on briefly deciduous tree canopies of Pra forest at KNNP.

Subfamily	species	abundant
Formicinae	*Camponotus* sp.1	6
	Camponotus sp.3	5
	Camponotus sp.5	1
	Camponotus (Tanaemyrmex) sp.1	78
	Camponotus (Tanaemyrmex) sp.2	20
	Camponotus (Tanaemyrmex) sp.7	61
	Camponotus (Tanaemyrmex) sp.8	62
	Camponotus (Tanaemyrmex) sp.9	2
	Camponotus (Colobosis) saundersi group	16
	Camponotus (Colobobsis) leonardi	50
	Camponotus (Colobosis) vitrius	10
	Camponotus (Colobosis) sp.5	2
	Camponotus (Colobosis) sp.8	1
	Camponotus (Myrmotarsus) rufifemur	5
	Camponotus (Myrmamblys) sp.2	1
	Camponotus (Myrmamblys) sp.5	1
	Camponotus (Karavaievia).dolichoderoides	179
	Camponotus (Karavaievia) sp.1	3
	Camponotus (Karavaievia) sp.2	728
	Echinopla striata	1
	Myrmoteras sp.1	3
	Oecophylla smaragdina	273
	Paratrechina sp.1	3
	Paratrechina sp.2	14
	Philidris sp.1	15
	Plagiolepis sp.1	7
	Polyrhachis (Myrmhopla) sp.1	3
	Polyrhachis (Myrmhopla) sp.5	4
	Polyrhachis (Myrmhopla) sp.6	5
	Polyrhachis (Myrmhopla) sp.7	1
	Polyrhachis (Myrmhopla) sp.13	1
	Polyrhachis (Myrmatopla) sp.1	2
	Polyrhachis (Myrmatopa) sp.5	2
	Polyrhachis (Myrmatopa) sp.6	2
	Polyrhachis (Myrmatopla) sp.7	9
	Polyrhachis (Myrmatopla) sp.8	5
	Polyrhachis (Myrmothrinax) sp.1	2
	Polyrhachis (Polyrhachis) sp.1	3
	Polyrhachis (Myrma) sp.2	2
	Prenolepis sp.1	1
Myrmicinae	*Crematogaster (Crematogaster)* sp.1	37
	Crematogaster (Crematogaster) sp.2	34
	Crematogaster (Crematogaster) sp.3	8

Table 2. Ant species list on briefly deciduous tree canopies of Pra forest at KNNP (continued)

Subfamily	species	abundant
Myrmicinae	*Crematogaster (Crematogaster)* sp.5	8
	Crematogaster (Crematogaster) sp.6	86
	Crematogaster (Crematogaster) sp.7	197
	Crematogaster (Crematogaster) sp.8	5
	Crematogaster (Crematogaster) sp.9	5
	Crematogaster (Crematogaster) sp.10	2
	Crematogaster (Crematogaster) sp.11	20
	Crematogaster (Crematogaster) sp.12	1
	Crematogaster (Crematogaster) sp.13	11
	Crematogaster (Crematogaster) sp.14	1
	Crematogaster (Crematogaster) sp.18	1
	Crematogaster (Crematogaster) sp.19	3
	Crematogaster (Paracrema) sp.1	94
	Crematogaster (Parecrema) sp.2	9
	Crematogaster (Paracrema) sp.3	23
	Crematogaster (Parecrema) sp.4	3
	Crematogaster (Orthrocrema) sp.2	4
	Crematogaster (Orthrocrema) sp.3	2
	Crematogaster (Orthrocrema) sp.5	49
	Crematogaster (Orthrocrema) sp.6	6
	Crematogaster (Orthrocrema) sp.9	1
	Crematogaster (Decacrema) sp.1	10
	Crematogaster (Decacrema) sp.3	10
	Cardiocondyla sp.1	9
	Cataulacus granulatus	1
	Dolobocondyla sp.3	1
	Lordomyrma sp.1	1
	Monomorium floricola	3
	Monomorium sp.1	28
	Monomorium sp.2	5
	Monomorium sp.3	2
	Monomorium sp.4	74
	Monomorium sp.5	2
	Monomorium sp.6	4
	Monomorium sp.7	3
	Meranoplus castaneus	8
	Oligomyrmex sp.2	41
	Oligomyrmex sp.3	3
	Paratopula sp.1	1
	Pheidole aristotelis	2
	Phiedole longipes group	1

Table 2. Ant species list on briefly deciduous tree canopies of Pra forest at KNNP (continued)

Subfamily	species	abundant
Myrmicinae	*Pheidole* sp.1	2
	Pheidole sp.2	29
	Pheidole sp.3	8
	Pheidole sp.4	1
	Pheidole sp.5	1
	Pheidole sp.6	1
	Pheidole sp.7	2
	Pheidole sp.11	5
	Pheidolegeton sp.1	1
	Rhopalomastix sp.1	118
	Strumigenys sp.2	2
	Tetramorium sp.1	24
	Tetramorium sp.3	2
	Vollenhovia sp.1	14
	Volenhovia sp.2	4
	Volenhovia sp.3	2
	Vombisidris sp.1	1
Dolichoderinae	*Dolichoderus thoracicus*	1
	Dolichoderus sp.1	1
	Dolichoderus sp.6	3
	Tapinoma sp.1	15
	Tapinoma sp.2	2
	Tapinoma sp.3	33
	Tapinoma sp.4	1
	Tapinoma sp.6	4
	Technomyrmex vitieusis	283
	Technomyrmex albipes	39
	Technomyrmex difficilis	30
	Technomyrmex textor	26
Pseudomyrmicinae	*Tetraponera attenuate*	121
	Tertaponera pilosa	1
	Tetraponera sp.1	38
Ponerinae	*Pachycondyla* sp.2	1
	Pachycondyla sp.1	1
	Platythyrea paralella	1

Table 3. Ant species list on evergreen canopies of headquarters at KNNP.

Subfamily	species	abundant
Formicinae	*Camponotus* sp.1	80
	Camponotus sp.2	2
	Camponotus sp.3	151
	Camponotus sp.4	1
	Camponotus (Tanaemyrmex) cf. arrogans	4
	Camponotus (Tanaemyrmex) sp.1	102
	Camponotus (Tanaemyrmex) sp.2	47
	Camponotus (Tanaemyrmex) sp.3	15
	Camponotus (Tanaemyrmex) sp.4	1
	Camponotus (Tanaemyrmex) sp.5	21
	Camponotus (Tanaemyrmex) sp.6	2
	Camponotus (Tanaemyrmex) sp.7	7
	Camponotus (Tanaemyrmex) sp.10	163
	Camponotus (Tanaemyrmex) sp.11	169
	Camponotus (Colobosis) vitrius	69
	Camponotus (Colobobsis) leonardi	16
	Camponotus (Colobosis) sp.1	2
	Camponotus (Colobosis) sp.2	50
	Camponotus (Colobosis) sp.3	1
	Camponotus (Colobosis) sp.4	3
	Camponotus (Colobosis) sp.6	5
	Camponotus (Colobosis) sp.7	4
	Camponotus (Colobosis) sp.9	2
	Camponotus (Myrmamblys) sp.1	60
	Camponotus (Myrmamblys) sp.3	1
	Camponotus (Myrmamblys) sp.4	1
	Camponotus (Myrmotarsus) rufifemur	10
	Camponotus (Myrmotarsus) sp.1	19
	Camponotus (Karavaievia) dolichoderoides	1
	Echinopla striata	18
	Echinopla sp.1	2
	Echinopla sp.2	3
	Oecophylla smaragdina	1533
	Philidris sp.1	215
	Paratrechina sp.1	43
	Paratrechina sp.2	20
	Polyrhachis (Myrmhopla) sp.1	58
	Polyrhachis (Myrmhopla) sp.2	10
	Polyrhachis (Myrmhopla) sp.3	53
	Polyrhachis (Myrmhopla) sp.4	4
	Polyrhachis (Myrmhopla) sp.7	1
	Polyrhachis (Myrmhopla) sp.8	9
	Polyrhachis (Myrmhopla) sp.9	64

Table 3. Ant species list on evergreen canopies of headquarters at KNNP (continued).

Subfamily	species	abundant
Formicinae	*Polyrhachis (Myrmhopla)* sp.10	1
	Polyrhachis (Myrmhopla) sp.11	5
	Polyrhachis (Myrmhopla) sp.12	10
	Polyrhachis (Myrmhopla) sp.14	1
	Polyrhachis (Myrmhopla) sp.15	10
	Polyrhachis (Myrmhopla) sp.16	4
	Polyrhachis (Myrmatopla) sp.1	160
	Polyrhachis (Myrmatopla) sp.2	82
	Polyrhachis (Myrmatopla) sp.3	29
	Polyrhachis (Myrmatopla) sp.4	2
	Polyrhachis (Myrmatopla) sp.7	5
	Polyrhachis (Myrmatopla) sp.9	14
	Polyrhachis (Myrmothrinax) sp.1	117
	Polyrhachis (Myrmothrinax) sp.2	27
	Polyrhachis (Myrmothrinax) sp.3	1
	Polyrhachis (Myrma) sp.1	4
	Polyrhachis (Myrma) sp.3	6
	Polyrhachis (Campomyrma) sp.1	1
	Polyrhachis (Campomyrma) sp.2	1
	Polyrhachis (Campomyrma) sp.3	1
	Polyrhachis (Cyrtoyrma) sp.1	2
	Polyrhachis (Polyrhachis) sp.1	8
	Polyrhachis (Polyrhachis) sp.2	7
	Prenolepis sp.1	42
Myrmicinae	*Crematogaster (Orthrocrema)* sp.1	6
	Crematogaster (Orthrocrema) sp.4	8
	Crematogaster (Orthrocrema) sp.5	54
	Crematogaster (Orthrocrema) sp.7	30
	Crematogaster (Orthrocrema) sp.8	1
	Crematogaster (Orthrocrema) sp.1	1
	Crematogaster (Orthrocrema) sp.1	1
	Crematogaster (Parecrema) sp.1	369
	Crematogaster (Paracrema) sp.2	977
	Crematogaster (Decacrema) sp.1	31
	Crematogaster (Decacrema) sp.2	225
	Crematogaster (Decacrema) sp.3	10
	Crematogaster (Decacrema) sp.4	15
	Crematogaster (Crematogaster) sp.1	3
	Crematogaster (Crematogaster) sp.2	732
	Crematogaster (Crematogaster) sp.4	1
	Crematogaster (Crematogaster) sp.5	49
	Crematogaster (Crematogaster) sp.6	54
	Crematogaster (Crematogaster) sp.11	16

Table 3. Ant species list on evergreen canopies of headquarters at KNNP (continued).

Subfamily	species	abundant
Myrmicinae	*Crematogaster (Crematogaster)* sp.15	23
	Crematogaster (Crematogaster) sp.16	2
	Crematogaster (Crematogaster) sp.17	452
	Crematogaster (Physocrema) sp.1	12
	Crematogaster (Paracrema) sp.2	33
	Cardiocondyla sp.1	19
	Cataulacus granulatus	69
	Dilobocondyla sp.1	12
	Dilobocondyla sp.2	2
	Dilobocondyla sp.3	7
	Dilobocondyla sp.4	6
	Meranoplus castaneus	104
	Monomorium floricola	10
	Monomorium sp.1	43
	Monomorium sp.2	90
	Monomorium sp.4	50
	Monomorium sp.6	1
	Oligomyrmex sp.1	14
	Oligomyrmex sp.4	1
	Pheidole sp.2	1
	Pheidole sp.5	1
	Pheidole sp.8	1
	Pheidole sp.9	1
	Pheidole sp.10	1
	Paratopula sp.1	6
	Rhopalomastix sp.1	3
	Solenopsis sp.1	1
	Strumigynys sp.1	1
	Strumigenys sp.2	1
	Tetramorium sp.1	22
	Tetramorium sp.2	129
	Tetramorium sp.4	1
	Vombisidris sp.1	6
	Vollenhovia sp.1	3
	Vollenhovia sp.4	1
Dolichoderinae	*Dolichoderus thoracicus*	3122
	Dolichoderus sp.2	2
	Dolichoderus sp.3	11
	Dolichoderus sp.4	1098
	Dolichoderus sp.5	1065
	Dilichoderus sp.7	58
	Technomyrmex elatior	215
	Technomyrmex vitieusis	120

Table 3. Ant species list on evergreen canopies of headquarters at KNNP (continued).

Subfamily	species	abundant
Dolichoderinae	*Terchnomyrmex albipes*	40
	Tapinoma sp.1	10
	Tapinoma sp.3	12
	Tapinoma sp.5	2
	Tapinoma sp.6	12
Pseudomyrmicinae	*Tetraponera attenuate*	342
	Tertaponera pilosa	221
	Tetraponera sp.1	22
	Tetraponera sp.2	39
	Tertaponera sp.3	2
	Tertaponera sp.4	22
Ponerinae	*Platythyrea paralella*	2
Aenictinae	*Aenictus laeviceps*	3
	Aenictus sp.1	3
Cerapachyinae	*Cerapachys* sp.1	1
	Cerapachys sp.2	1

Table 4. Tree species list from both habitat types.

Time	Habitat	Tree species	Tree family	Height(m)
11/05/06	Headquarters	*Syzygium cumini* (L.) Skeels.	Myrtaceae	23
12/05/06	Headquarters	*Syzygium cumini* (L.) Skeels.	Myrtaceae	25
13/05/06	Headquarters	*Bouea microphylla* Griff.	Anacardiaceae	22
14/05/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
15/05/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
16/05/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
09/07/06	Headquarters	*Pseuduvaria monticola* J. Sinclair.	Annonaceae	25
10/07/06	Headquarters	*Bouea microphylla* Griff.	Anacardiaceae	22
11/07/06	Headquarters	*Baccaurea kunstleri* King ex Gage.	Euphorbiaceae	25
12/07/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
13/07/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
14/07/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	30
10/09/06	Headquarters	*Ryparosa javanica* Blume.	Flacourticeae	33
11/09/06	Headquarters	*Bouea microphylla* Griff.	Anacardiaceae	20
12/09/06	Headquarters	*Ryparosa javanica* Blume.	Flacourticeae	28
13/09/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
14/09/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	30
15/09/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
13/11/06	Headquarters	*Pseuduvaria monticola* J. Sinclair.	Annonaceae	30
14/11/06	Headquarters	*Castanopsis piriformis* Hickel&Camus.	Fagaceae	35
15/11/06	Headquarters	*Nephelium melliferum* Gagnep.	Sapindaceae	33
16/11/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
17/11/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
18/11/06	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
14/01/07	Headquarters	*Castanopsis piriformis* Hickel & Camus.	Fagaceae	30
15/01/07	Headquarters	*Castanopsis javanica* Blume.	Fagaceae	27
16/01/07	Headquarters	*Castanopsis piriformis* Hickel & Camus.	Fagaceae	28
17/01/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
18/01/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
19/01/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
08/03/07	Headquarters	*Syzygium cumini* (L.) Skeels.	Myrtaceae	28
09/03/07	Headquarters	*Parashorea stellata* Kurz.	Dipterocarpaceae	40
10/03/07	Headquarters	*Chisocheton* spp.	Meliaceae	30

Table 4. Tree species list from both habitat types (continued).

Time	Habitat	Tree species	Tree family	Height(m)
11/03/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	35
12/03/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40
13/03/07	Hui Lek	*Elateriospermum topos* Blume.	Euphorbiaceae	40

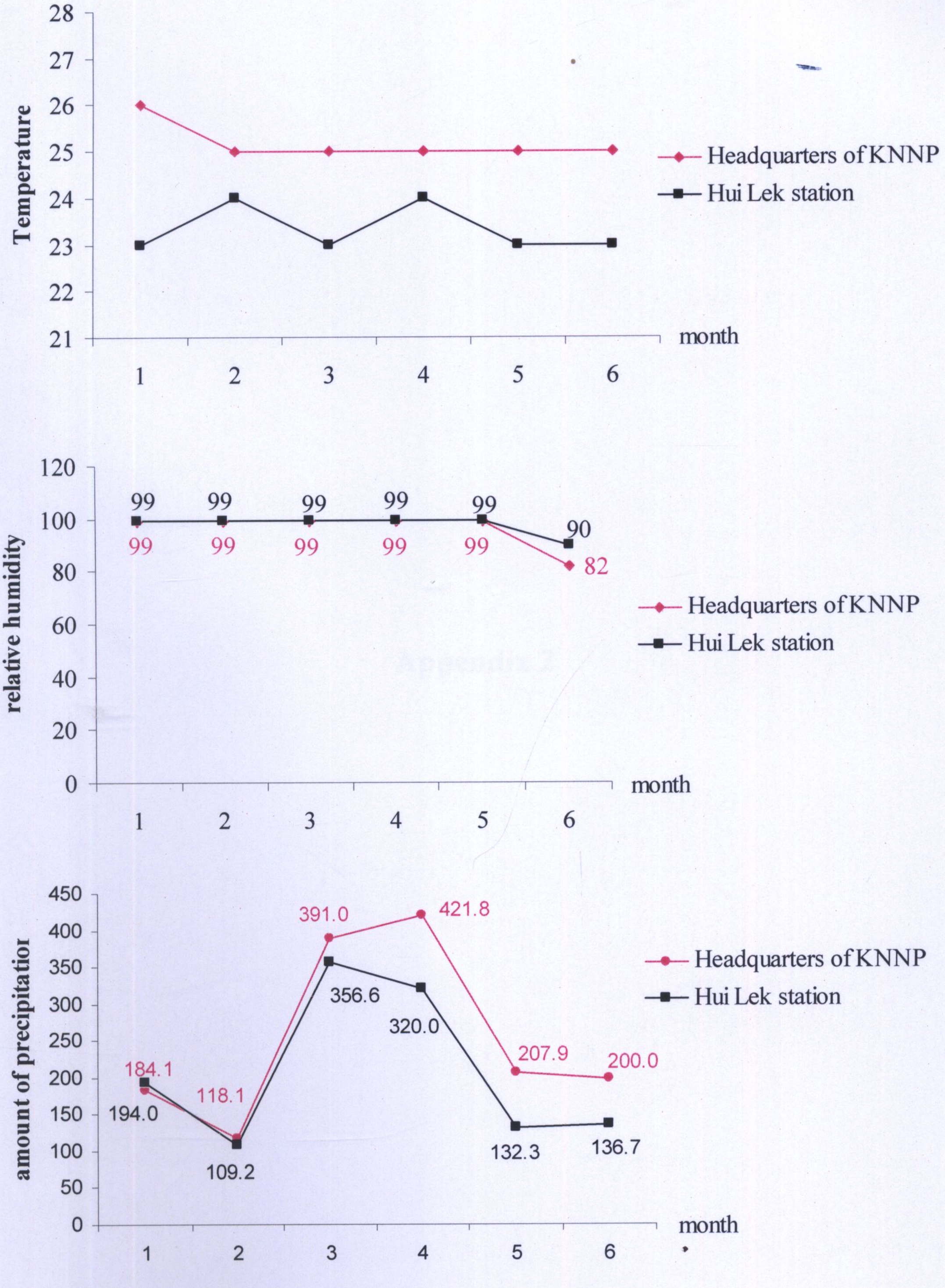
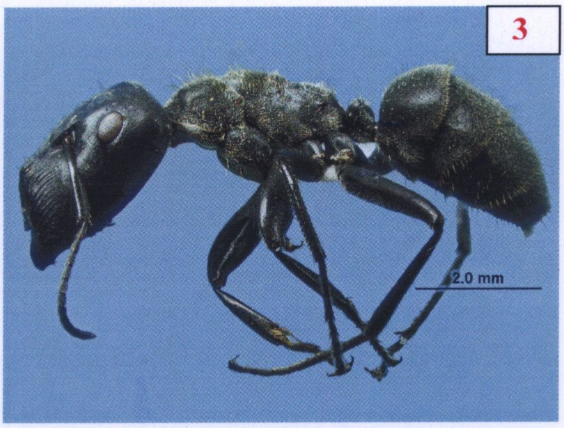
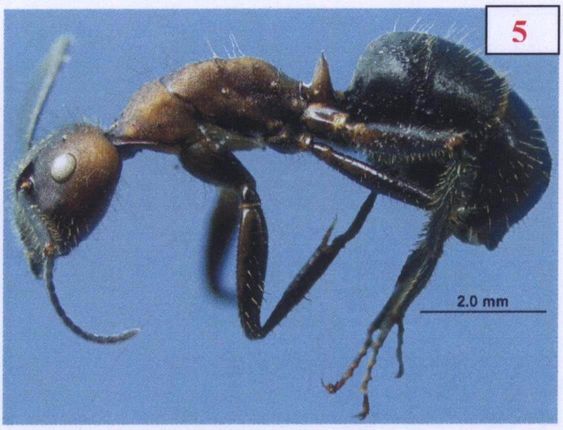
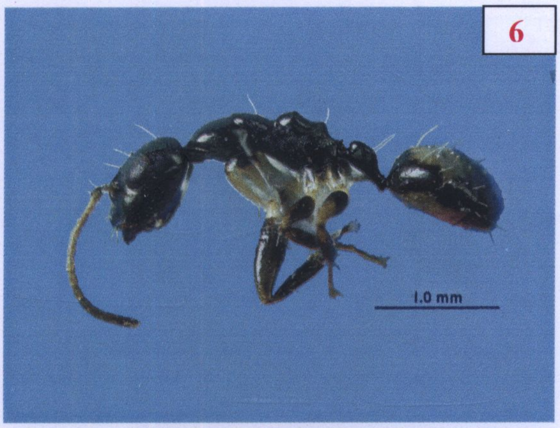


Figure 1. A year-round physical factor measured at headquarter (pink line) and Hui Lek station (black line) since May 2006-March 2007 (a) temperature (b) relative humidity and (c) precipitation.

Appendix 2







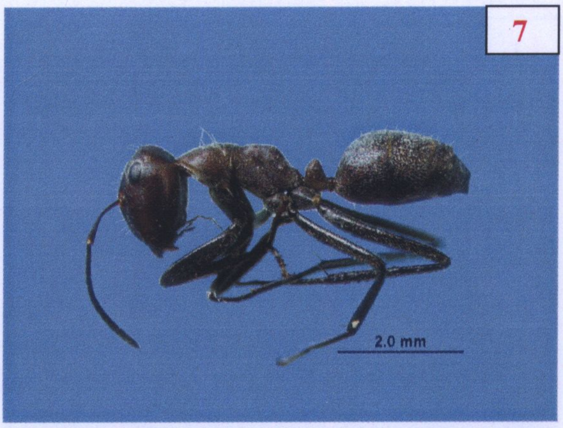


Figure 2. *Aenictus* sp.1

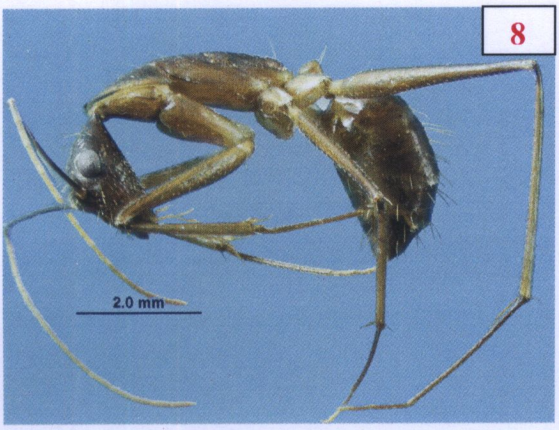
Figure 3. *Camponotus(Colobosis) leonardi* group sp.1

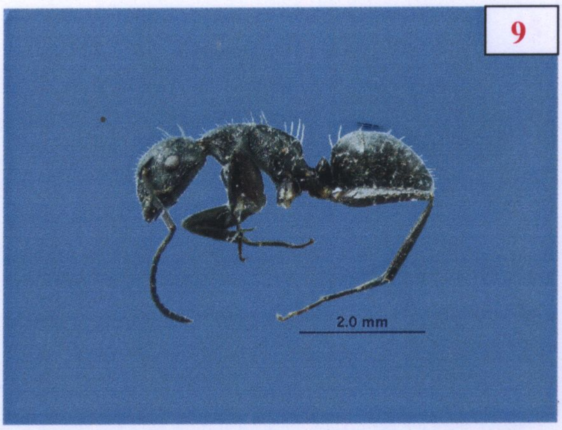
Figure 4. *Camponotus(Karavaievia) dolicoderiodes*

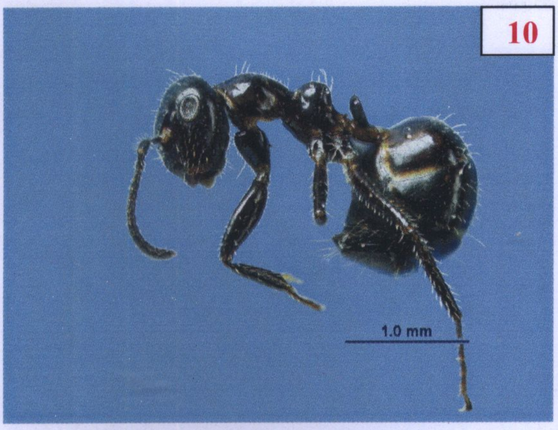
Figure 5. *Camponotus(Tanaemyrmex) arrogans*

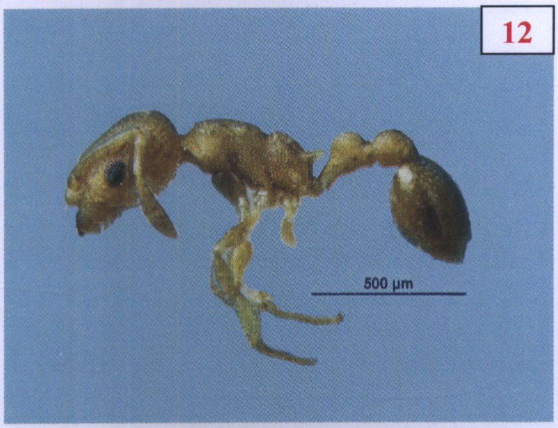
Figure 6. *Camponotus* sp.21

Figure 7. *Camponotus* sp.25









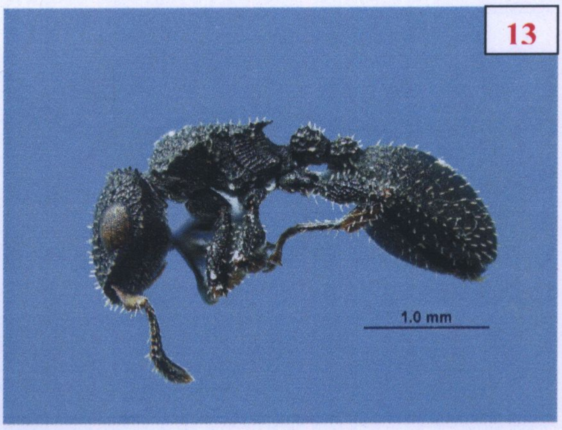


Figure 8. *Camponotus* sp.30

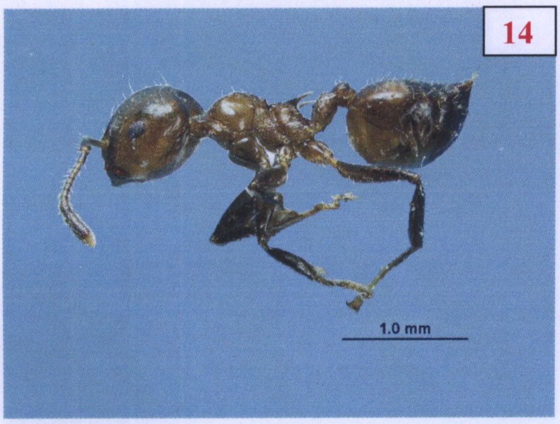
Figure 9. *Camponotus* sp.5

Figure 10. *Camponotus* sp.19

Figure 11. *Cerapachys* sp.1

Figure 12. *Cardiocondyla* sp.1

Figure 13. *Cataulacus granulatus*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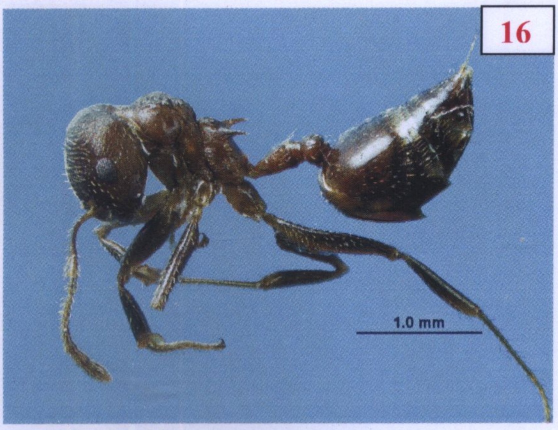
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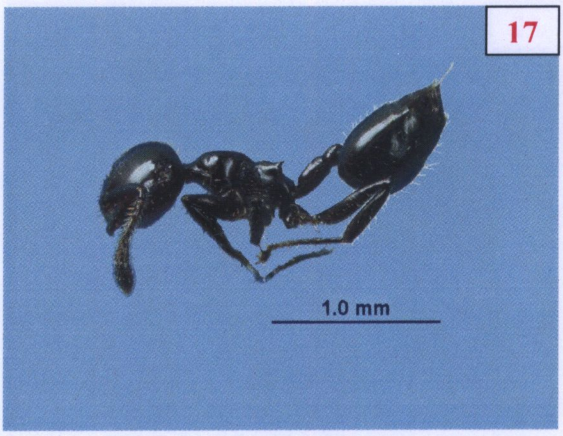
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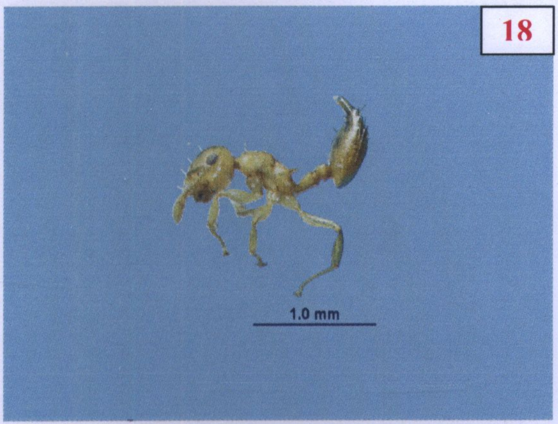
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Figure 14. *Crematogaster (Crematogaster)*sp.2

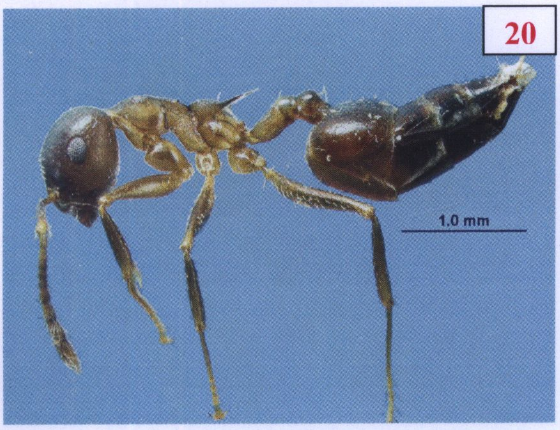
Figure 15. *Crematogaster (Crematogaster)* sp.7

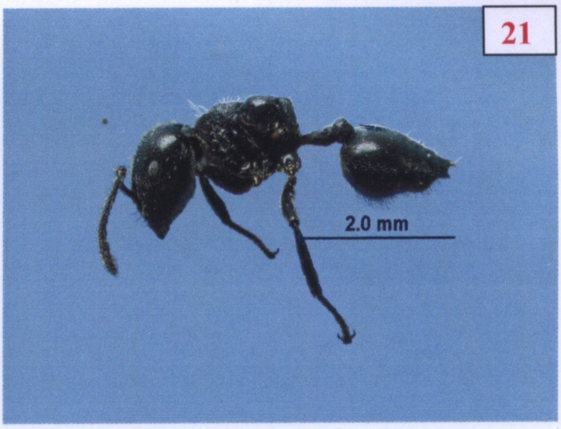
Figure 16. *Crematogaster(Crematogaster)* sp.13

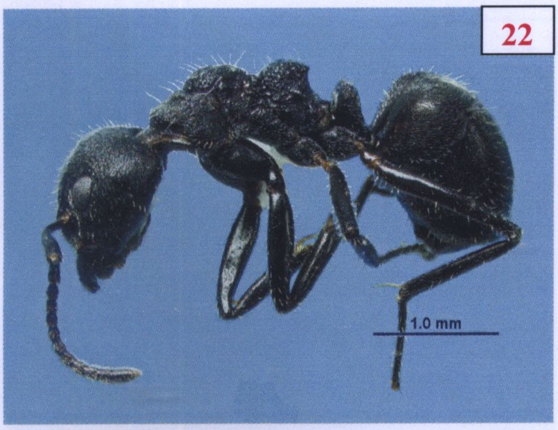
Figure 17. *Crematogaster(Decacrema)* sp.1

Figure 18. *Crematogaster(Othrocrema)* sp.3

Figure 19. *Crematogaster(Paracrema)* sp.2







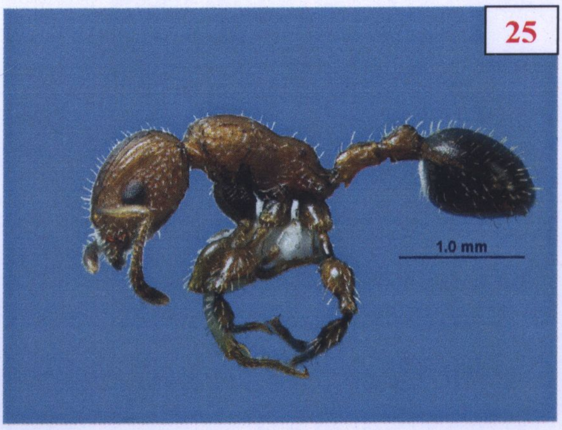


Figure 20. *Crematogaster(Paracrema)* sp.3

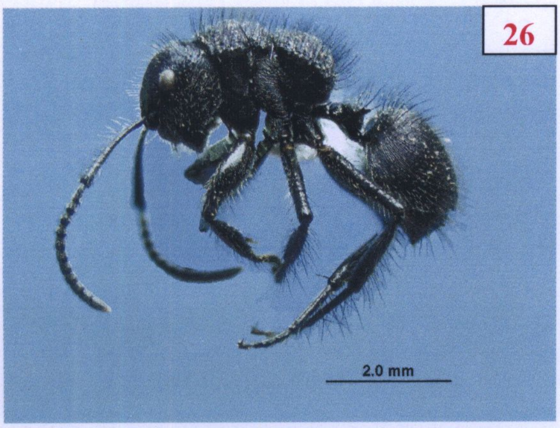
Figure 21. *Crematogaster(Physocrema)* sp.1

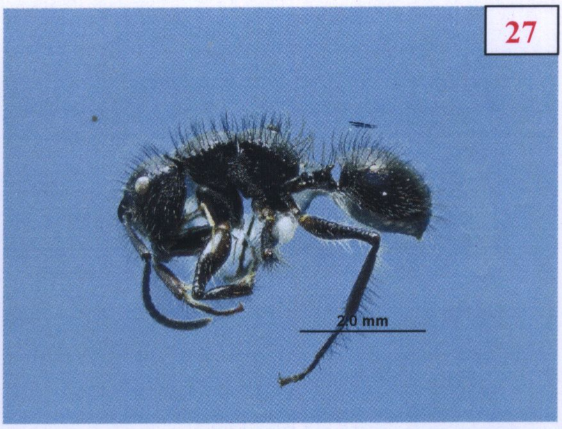
Figure 22. *Dolichoderus thoracicus*

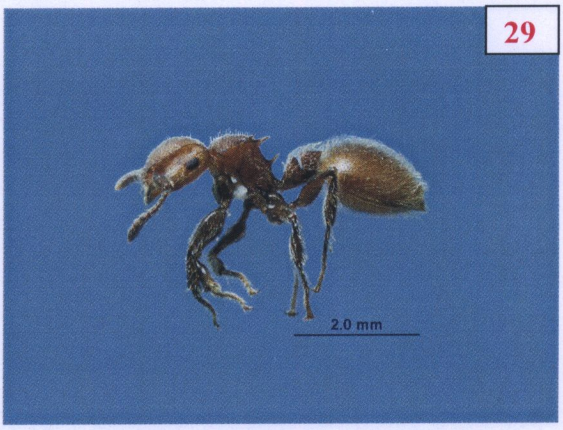
Figure 23. *Dolichoderus* sp.4

Figure 24. *Dolichoderus* sp.5

Figure 25. *Dilobocondyla* sp.1







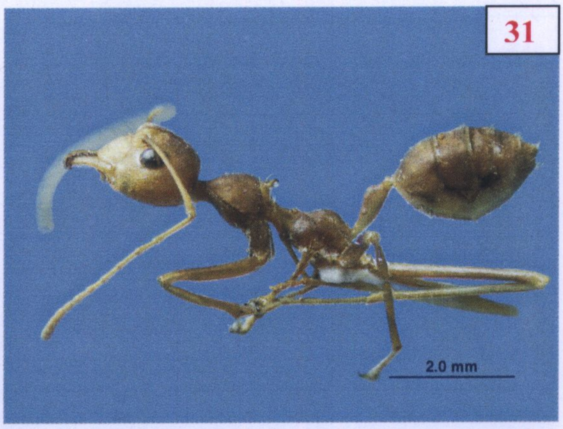


Figure 26. *Echinopla striata*

Figure 27. *Echinopla* sp.1

Figure 28. *Lodomyrma* sp.1

Figure 29. *Meranoplus castaneus*

Figure 30. *Monomorium* sp.2

Figure 31. *Oecophylla smaragdina*

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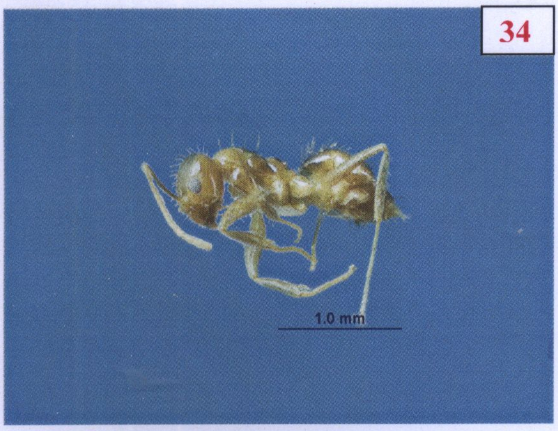

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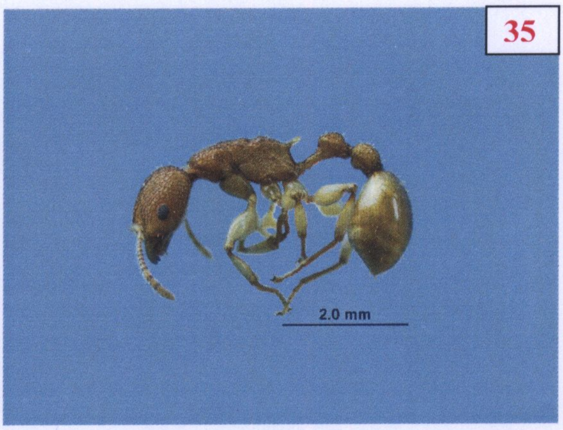

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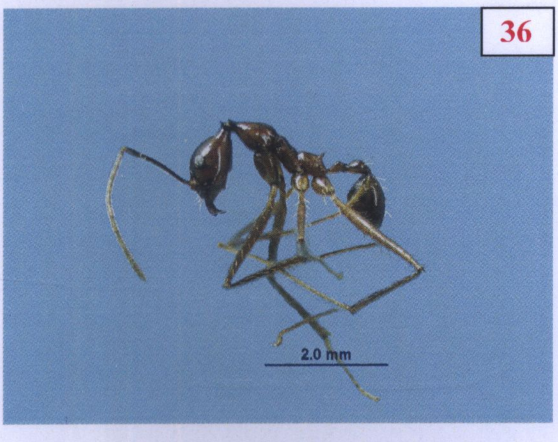

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Figure 32. *Oligomyrmex* sp.2

Figure 33. *Pachycondylla* sp.1

Figure 34. *Paratechina* sp.1

Figure 35. *Paratopula* sp.1

Figure 36. *Pheidole longipes* group

Figure 37. *Pheidole* sp.10

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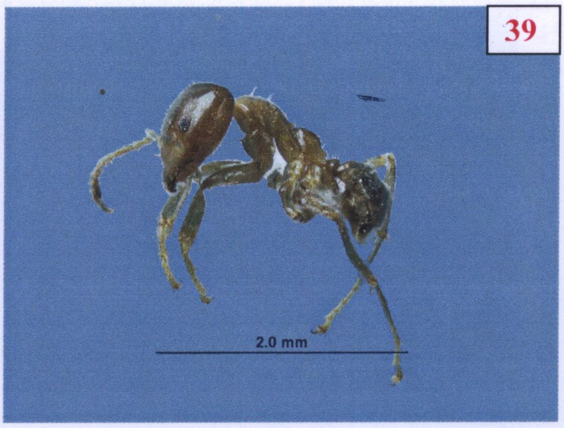

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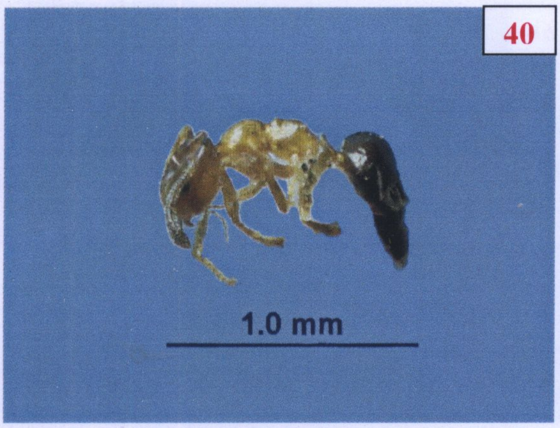

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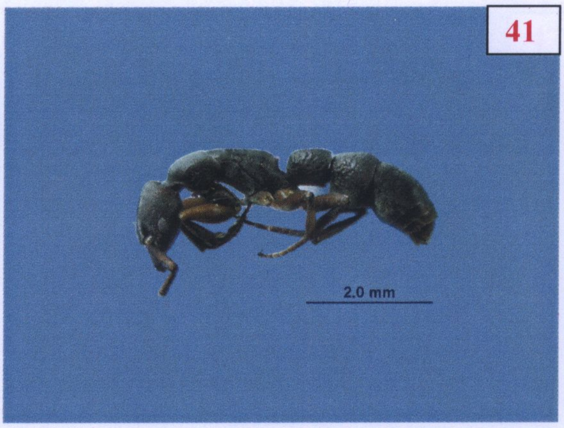

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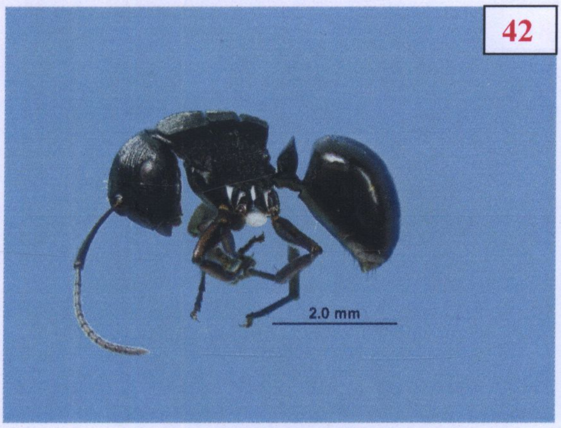

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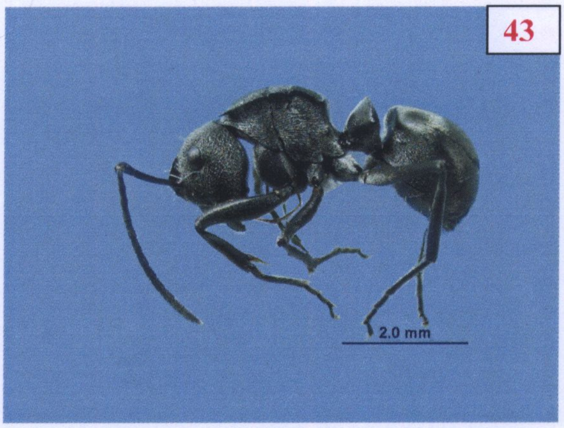


Figure 38. *Pheidologeton silenus*

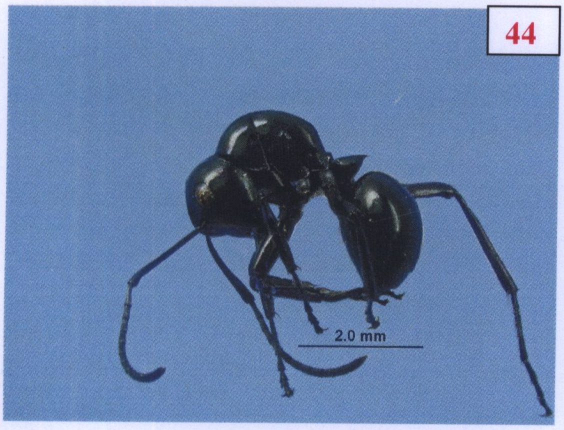
Figure 39. *Philidris* sp.1

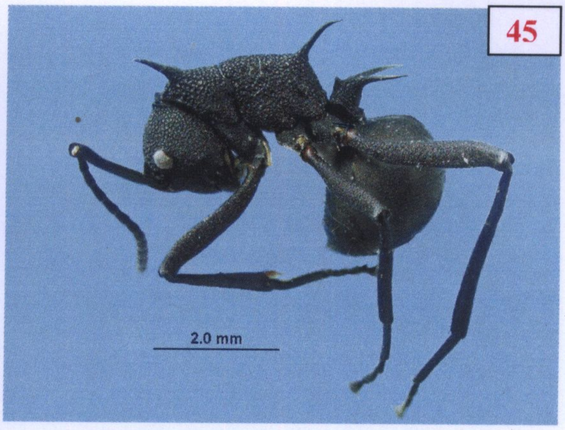
Figure 40. *Plagiolepis* sp.1

Figure 41. *Platythyrea paralella*

Figure 42. *Polyrhachis (Campomyrma)* sp.1

Figure 43. *Polyrhachis (Campomyrma)* sp.3





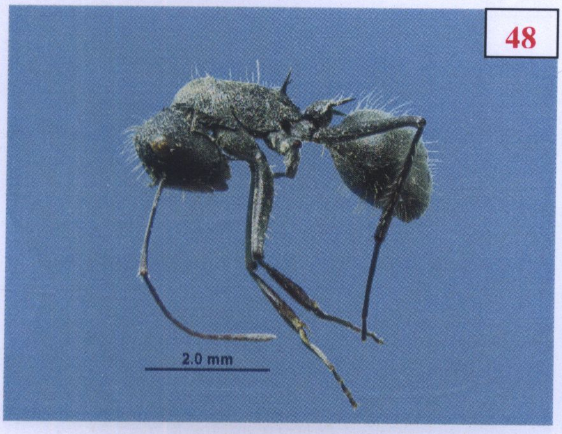


Figure 44. *Polyrhachis (Cyrtomyrma)* sp.1

Figure 45. *Polyrhachis (Myrmhopla)* sp.1

Figure 46. *Polyrhachis (Myrmhopla)* sp.3

Figure 47. *Polyrhachis (Myrmhopla)* sp.4

Figure 48. *Polyrhachis (Myrmhopla)* sp.6

Figure 49. *Polyrhachis (Myrmhopla)* sp.9

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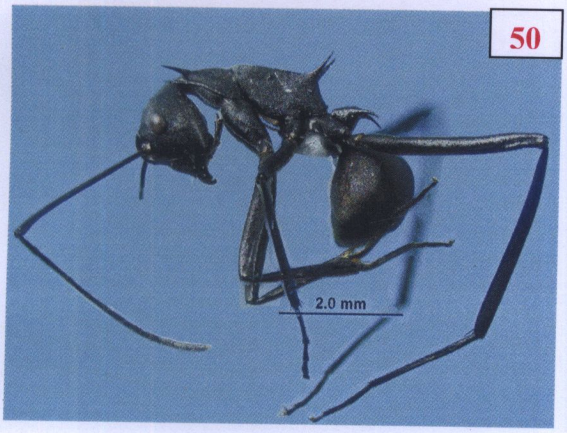

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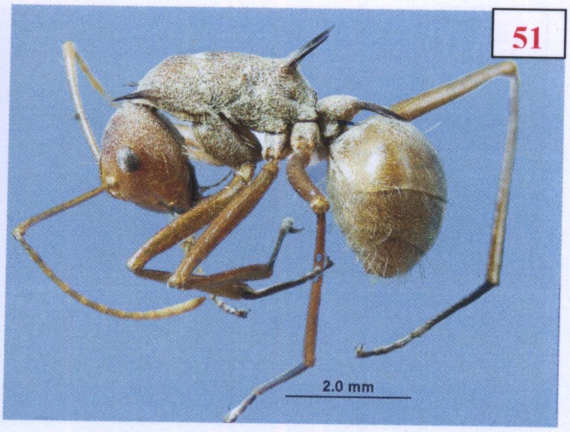

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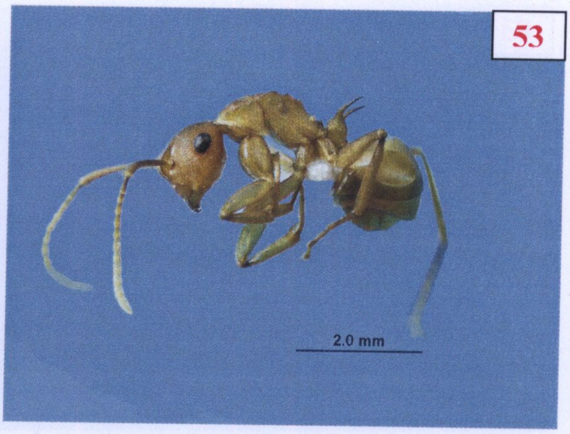

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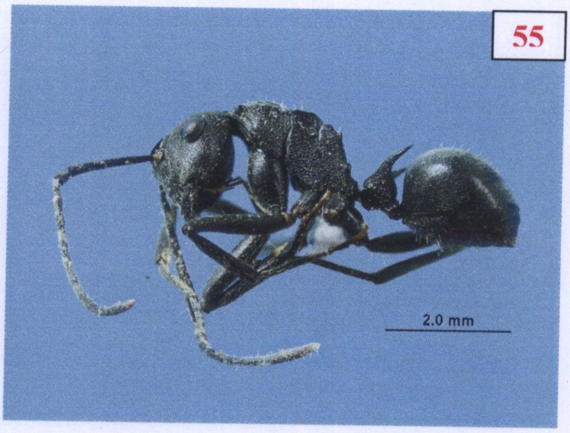

Figure 50. *Polyrhachis (Myrmhopla)* sp.11

Figure 51. *Polyrhachis (Myrmhopla)* sp.13

Figure 52. *Polyrhachis (Myrmatopa)* sp.1

Figure 53. *Polyrhachis (Myrmatopa)* sp.3

Figure 54. *Polyrhachis (Myrmatopa)* sp.5

Figure 55. *Polyrhachis (Myrmatopa)* sp.6


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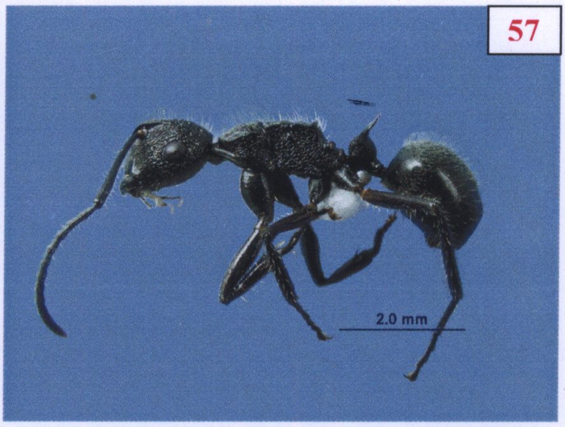
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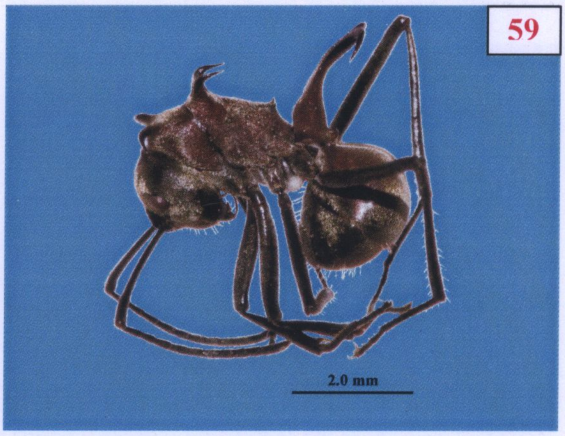
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Figure 56. *Polyrhachis (Myrmatopa)* sp.7

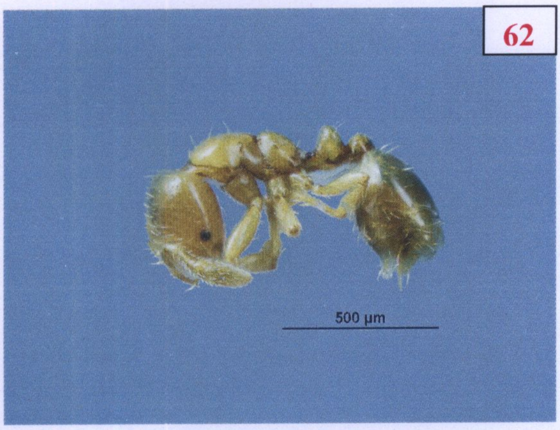
Figure 57. *Polyrhachis (Myrmatopa)* sp.8

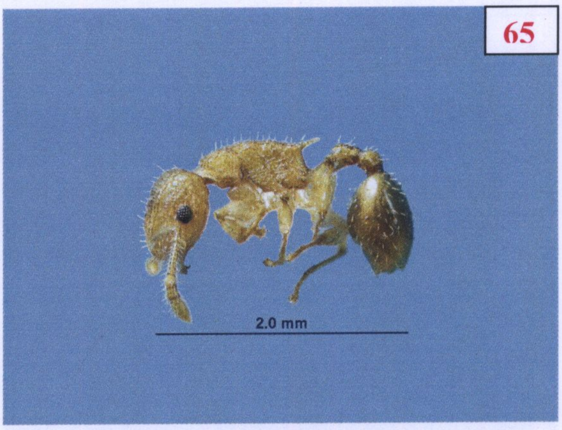
Figure 58. *Polyrhachis (Myrmothrinax)* sp.1

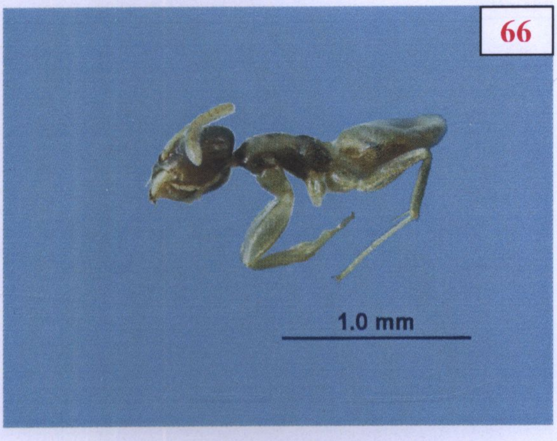
Figure 59. *Polyrhachis (Polyrhachis)* sp.1

Figure 60. *Prenolepis* sp.1

Figure 61. *Rhopalomastix* sp.1







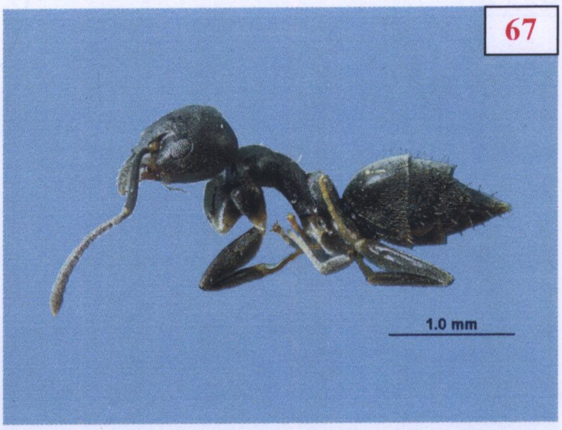


Figure 62. *Solenopsis* sp.1

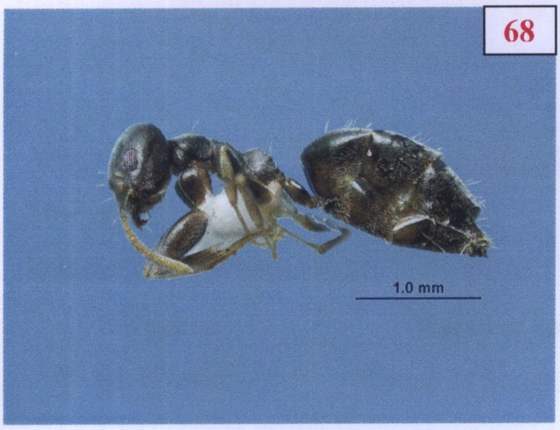
Figure 63. *Strumigeny* sp.2

Figure 64. *Volenhovia* sp.1

Figure 65. *Vombisidris* sp.1

Figure 66. *Tapinoma* sp.1

Figure 67. *Technomyrmex elatior*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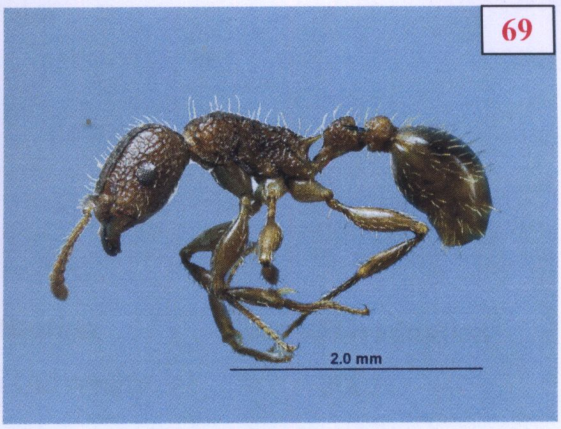
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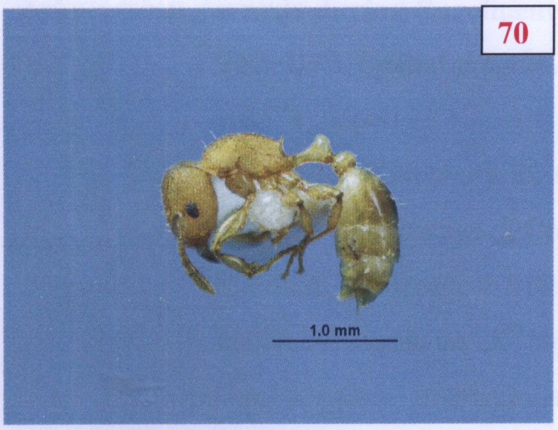
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Figure 68. *Technomyrmex vitieusis*

Figure 69. *Tetramorium* sp.1

Figure 70. *Tetramorium* sp.2

Figure 71. *Tetraponera attanuata*

Figure 72. *Tetraponera pilosa*

Figure 73. *Tetraponera* sp.1

VITAE

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Student ID	4822100

Education al Attainment

Degree	Name of Institution	Year of Graduation
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Scholarship Awards during Enrolment

- TRF/BRT Spatial program for Biodiversity Research and training grant BRT T_150011.
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List of Publication and Proceeding

- Watanasit, S. and Jantarit, S. 2006. The ant nest of *Crematogaster rogenhoferi* (Mayr, 1879) (Hymenoptera: Formicidae) at Tarutao National Park, Satun Province, Southern Thailand. Songklanakarin J. Sci. Technol. 28(4): 723-730.
- Jantarit, S., Watanasit, S. and Sotthibandhu, S. Canopy Ants on the Briefly Deciduous Tree (*Elateriospermum tapos*) in a Tropical

Rainforest, of Southern Thailand. Songklanakarin J. Sci. Technol. (In press)

- Jantarit, S., Watanasit, S. and Sotthibandhu, S. Evergreen VS Deciduous Tree in Tropical Rainforest, a Comparison the Species Richness Using Canopy Ants as an Agent. (In preparation)