SPECIES DIVERSITY AND TAXONOMY OF INFRAORDER ACULEATA (HYMENOPTERA: APOCRITA) IN THE NORTH OF THAILAND

TOUCHKANIN JONGJITVIMOL

A Thesis Submitted to the Graduate School of Naresuan University
in Partial Fulfillment of the Requirements
for the Doctor of Philosophy in Biological Sciencea
October 2008

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This thesis entitled "Species Diversity and Taxonomy of Infraorder Aculeata (Hymenoptera: Apocrita) in the North of Thailand" submitted by Touchkanin Jongjitvimol in partial fulfillment of the requirements for the Doctor of Philosophy Degree in Biological Sciences is hereby approved.

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ชื่อเรื่อง ความหลากหลายของชนิดและอนุกรมวิธานของแมลง Infraorder Aculeata (Hymenoptera: Apocrita) ในภาคเหนือของประเทศไทย

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บทคัดย่อ

การสำรวจและเก็บรวมรวบตัวอย่างของแมลงใน infraorder Aculeata ในภาคเหนือของประเทศไทยได้ทำการศึกษาระหว่างเดือนมกราคม 2549 ถึงเดือนมิถุนายน 2550 ด้วยเทคนิคการเก็บตัวอย่างศึกษาแบบสุ่มอย่างเป็นระบบ (systematic random sampling) ตามแหล่งอาหารและแหล่งอาศัย พบว่าในเขตพื้นที่การศึกษามีแมลงกลุ่มนี้จำนวนทั้งสิ้น 3 วงศ์ใหญ่ (superfamilies) คือ Apoidea, Chrysidoidea และ Vespoidea ซึ่งสามารถเก็บตัวอย่างได้ 120 ตัวอย่าง โดยสามารถจัดจำแนกชนิดได้ 88 ตัวอย่าง และไม่สามารถจัดจำแนกชนิดได้ 32 ตัวอย่าง ซึ่งตัวอย่างทั้งหมดสามารถจำแนกได้ 64 สกุล (genus) 24 วงศ์ย่อย (subfamily) และ 9 วงศ์ (family) คือวงศ์ Anthophoridae, Apidae, Chrysididae, Formicidae, Halictidae, Megachilidae, Scoliidae, Sphecidae และ Vespidae และพบว่ามดซึ่งจัดอยู่ในวงศ์ Formicidae มีจำนวนชนิดที่ถูกพบมากที่สุด (50.83% หรือ 61 ชนิด) จากดัชนีความหลากหลายของชนิด (Pielou's index) พบว่าแมลงใน infraorder Aculeata มีความหลากหลายของชนิดมากในพื้นที่ที่ทำการศึกษายกเว้นในพื้นที่ของป่าทุ่งหญ้า ในขณะที่พื้นที่ที่ทำการศึกษาทั้งหมดมีค่าดัชนีความเด่น (Simpson's index) ของชนิดแมลงที่พบน้อย และจากการวิเคราะห์ดัชนีความเหมือนของชนิดแมลงระหว่างพื้นที่ (Sorensen's similarity coefficient) พบว่าดัชนีความเหมือนระหว่างป่าเบญจพรรณและป่าดิบเขา (0.639) และป่าธรรมชาติและพื้นที่การเกษตร (0.621) มีความหลากหลายของชนิดแมลงที่พบเหมือนกัน

Title	SPECIES DIVERSITY AND TAXONOMY OF INFRAORDER ACULEATA (HYMENOPTERA: APOCRITA) IN THE NORTH OF THAILAND
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ABSTRACT

Species surveys and sample collections of insects in the infraorder Aculeata in the north of Thailand were carried out during January 2006 to June 2007. The technique of systematic random sampling was used for sample collections. All the specimens were recorded visiting flowers, from host plants and/or from colonies. We found that the aculeates collected were classified into 3 superfamilies, namely Apoidea, Chrysidoidea and Vespoidea. From totally 120 specimens, 88 specimens can be identified at the species level and 32 specimens were identified at the generic level. These species belonged to 64 genera, 23 subfamilies and 9 families, namely Anthophoridae, Apidae, Chrysididae, Formicidae, Halictidae, Megachilidae, Scoliidae, Sphecidae and Vespidae. Family Formicidae (ants) exhibited the highest species composition (50.83% or 61 species). The species diversity index using Pielou's indices among habitats were high, except in grassland while the dominant indexes using Simpson's index showed simple structure. Sorensen's similarity coefficient showed that deciduous with bamboo forest and hill evergreen forest (0.639), and natural forests combined and cultivated areas (0.621) had similar aculeate species structure.

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CHAPTER I

INTRODUCTION

Rationale and significance of the study

Insects are the largest group of living organisms in the world and they are also the most diverse group. The order Hymenoptera, with over 130,000 species, is the third largest group of insect orders. This order contains 2 suborders: Symphyta (sawflies) and Apocrita. The Apocrita is divided into 2 infraorders or series: Parasitica (parasitic wasps) and Aculeata. The infraorder Aculeata contains 3 superfamilies: Apoidea, Chrysidoidea and Vespoidea. These include bees, wasps and ants. They are found in all continents except Antarctica. Large numbers of this group have been reported in tropical areas (Goulet and Huber, 1993; Gauld and Bolton, 1996).

Each of aculeate species plays various important roles in ecosystem. The bees which are one of the members in this infraorder are primary consumers (herbivore) in the food chain. For herbivores, apart of some phytophagous insects, they feed on pollen and/or nectar of economic crops and wild plants. These, fortunately, lead to the fertilization of those plants via insect pollination (Speight, Hunter and Watt, 1999). In ecosystems, aculeate bees maintain plant diversity. Insect pollinators, which usually mean the bees in superfamily Apoidea, are important for the survival of many flowering plants in tropical forests. The bees move pollen from plant to plant, ensuring seed set and gene flow between plants and plant populations (O'Toole and Raw, 1999; Sato, 2002). In return, the plants provide the bees with floral resources (nectar and pollen) that are vital to their own survival. Furthermore, in term of benefits to humans, the bees are providers of natural products. For instance, honey is not the only product of bee exploitation, propolis, bee pollen, and royal jelly are used in many dietary supplements. In addition, they are used as a component in medicine and the cosmetic industry. Further more, some ants and wasps (Vespoidea) have been used in biological pest control programs. They are, therefore, important for balancing and functioning the food webs of most ecosystems.

Species diversity among insects differs according to different geographic structures such as climate, latitude, habitat and forest types. High diversity in geographic structure (habitat or spatial heterogeneity) gives rise to a higher species diversity in aculeate bees. This is because heterogeneous habitats can support more species complex than homogeneity habitats (Finnamore, 1997; Painka, 2000; Araújo, Antonini and Araújo, 2006). The northern region of Thailand is characterized by a heterogeneous structure, dominated by tropical forests i.e. mixed deciduous forests and deciduous dipterocarp forests. The species number of nectar feeding insects in those forests is directly correlated with the number species of plants. At present, national parks and wildlife sanctuaries in northern Thailand have been deforested all the time. This is one of the most serious threats, including human settlements and commercial agriculture etc, to biodiversity as well as changing climate and geography. LaSalle and Gauld (1997) proposed that the aculeate bees are sensitive to the change in habitat, thus, the deforestation may reduce both populations and species diversity. Although some parts of this region have been deforested and converted for agricultural purposes, this region is one of the most biologically diverse areas in Thailand. Moreover, forests in the north of Thailand are important natural resources for local people because they provide many valuable products including medicinal herbs, floral greenery, water and other resources. Biological diversity is a basic characteristic of forests. Understanding biodiversity within this region is essential to the future management of ecosystems within them.

The northern region of Thailand was investigated as the study area for species survey and taxonomic study of the insects in infraorder Aculeata. The obtained results provided useful knowledge on taxonomy and spices diversity of the infraorder Aculeata in the north of Thailand. This knowledge, therefore, will be used for further study in biology, taxonomy and sustainable conservation of aculeate bees in Thailand and elsewhere.

Purpose of the study

This study aims to survey species diversity and taxonomic study of insects in the infraorder Aculeata found in the north of Thailand.

Scope of the study

Areas in the Northern region of Thailand: Chiang Mai, Chiang Rai, Kamphaeng Phet, Lampang, Lamphun, Mae Hong Son, Nakhon Sawan, Nan, Phayao, Phetchabun, Phichit, Phitsanulok, Phrae, Sukhothai, Tak and Uttaradit was chosen as the study site at latitude 15.5 degrees north and longitude 100.5 degrees east. The surveys and sample collections were carried out during January 2006 to June 2007. The technique of systematic random sampling was used for sample collections. The specimens were identified using taxonomic literatures and references, and confirmed by experienced taxonomists from Natural History Museum (National Science Museum, Thailand), the Center of Excellence: Bee biology, biodiversity of insects and mites (Chulalongkorn University, Thailand), Department of Biology (Chiang Mai University, Thailand), Insect Museum (Kasetsart University, Kamphaeng Saen Campus, Thailand) and Institute of Zoology (Bulgarian Academy of Sciences, Bulgaria).

CHAPTER II

LITERATURE REVIEW

Taxonomy

The order Hymenoptera Linnaeus, 1758, with over 130,000 species, is the third largest order of insects (Romoser and Stoffolano, 1998). The order Hymenoptera is subdivided into 2 suborders; the primitive Symphyta (leaf rolling sawflies, common sawflies), and the highly specialized Apocrita. The Apocrita consists of 2 infraorders (series): Parasitica (parasitic wasps) and Aculeata. The ants, bees and wasps are examples of main families in the infraorder Aculeata. The taxonomic hierarchy of the infraorder Aculeata can be illustrated as follows (Borror, Triplehorn, and Johnson, 1989; Goulet and Huber, 1993; Gauld and Bolton, 1996; O'Toole and Raw, 1999; Elzinga, 2000):

Kingdom Animalia
Phylum Arthropoda
Class Insecta
Order Hymenoptera
Suborder Apocrita
Infraorder Aculeata
Superfamily Chrysidoidea
Vespoidea
Apoidea

Taxonomic note of Chrysidoidea

The members in the superfamily Chrysidoidea (i.e. cuckoo wasps) divides into 7 families which together comprise a holophyletic group within the Aculeata (Bethylidae, Chrysididae, Dryinidae, Embolemidae, Plumariidae, Scleroggibbidae and Scolebythidae) (Goulet and Huber, 1993; Gauld and Bolton, 1996). An estimate of 16,000 species has been reported (Finnamore, 1997).

The both sexes have the same number of flagellomeres of antenna, 8 or 10 segments. The posterolateral apex reaches the tegula and the lobe of their margin is

covered with the spiracle. The posterodorsal margin is shallow and concave. The metapostnotum is short and transversely fuse with the propodeum while the middle of the metapostnotum does not posteriorly expand. Fore wing venation reduces into 3 or fewer cells. Their body is not covered with bristle and the ovipositors are modified as sting (Goulet and Huber, 1993).

Taxonomic note of Vespoidea

The Vespoidea (ants and wasps) have an estimated 48,000 species worldwide (Finnamore, 1997). This superfamily is the largest superfamily in this infraorder which is grouped into 10 families: Bradynobaenidae, Formicidae, Mutillidae, Pompilidae, Rhopalosomatidae, Sapygidae, Scoliidea, Sierolomorphidae, Tiphiidae and Vespidea (Goulet and Huber, 1993; Gauld and Bolton, 1996).

Their body does not have plumose bristle. The flagella of antennae have 10 segments in females, and 11 in males. The posterolateral apex of the pronotum reaches the tegula while the posterodorsal margin is shallow, usually a U-shaped structure. The metapostnotum transversely fuse and expose with the propodeum but the middle of them does not posteriorly expand. Fore wing venations well develop into 9 or 10 cells while hind wing venations have 2 cells and a jugal lobe. The metasomal sterna 1 and 2 are often separated by a constriction. Females have no an articulation within gonocoxite 2 near the base. Ovipositors of some species are modified as sting (Goulet and Huber, 1993).

Taxonomic note of Apoidea

The Apoidea (bees) is the second largest superfamily in this infraorder with an estimate of 28,000 species (Finnamore, 1997). This superfamily consists of 20 families: Ampulicidae, Andrenidae, Anthophoridae, Apidae, Apiformes, Astatidae, Colletidae, Crabronidae, Ctenoplectidae, Halictidae, Heterogynaidae, Megachilidae, Melittidae, Mellinidae, Nyssonidae, Oxaeidae, Pemphredonidae, Philanthidae, Sphecidae and Spheciformes (Goulet and Huber, 1993; Gauld and Bolton, 1996). Bees are divided into 2 groups by their lifestyles: solitary or social. Most bees, including familiar species of bees, carpenter bees and leafcutter bees, are solitary because all females are fertile and there are no worker bees for these species. Their nests were constructed in the ground or other natural cavities. The principal social bees are the honey bees, stingless bees and bumbles. They share a nest, and divide the work of building the nest, caring for the off spring and

foraging for pollen and nectar. They play an important role in the pollination of flowering plants, including ornamental crops, fruit crops, and vegetables (O'Toole and Raw, 1999).

The body of these insects is covered with plumose bristles. The number of flagellomeres is similar to Vespoidea. The posterolateral apex of the pronotum is separated from the tegula by a distinct cuticular gap. The posterodorsal margin is U-shaped while lobe of the posterolateral margin covers the spiracle. Metapostnotum is long and fused with the propodeum but middle of it can posteriorly expand. Wing venation develops into 9 or 10 cells in fore wings while hind wings have 2 cells of venation, and have jugal lobe. The first and second metasomal sterna are often separated by a constriction. Females do not have articulation within the second gonocoxite. Most of their ovipositors are modified as sting (Goulet and Huber, 1993).

Diversity and distribution

The aculeates is comprised of ants, bees and both potter and paper wasps. They are a thermophilous insect that is very sensitive to local microclimates. As a result their nest sites are often situated in specific substrates. They need large areas and a diversity of flowering plants because of their dependence on particular types of flowering plants for feeding; pollen, nectar or prey is another factor in their distribution. Pawlikowski and Hirsch (2002) purposed that the principal factor affecting species diversity in the environments of the lower Vistula Valley was the process of habitat differentiation and the number of flowering plant species. Tropical and subtropical zones have the highest diversity of living creatures in the world, including flowering plants, thus, aculeate bees are distributed throughout most of this area. These insects have significant roles in terrestrial ecosystems, especially in the tropics, acting as pollinators and predators.

In the Neotropical region, aculeate bees are comprised of 25 families, 807 genera and about 13,000 described species. They were represented in the upper Jurassic and most families were common by the Cretaceous. Some of the extant genera appeared between the Paleocene and Miocene (Fernández, 2001). Finnamore (1997) reported that the aculeate bees fauna of five ecozones in the Yukon from north to south: Southern Arctic, Taiga Cordillera, Taiga Plains, Boreal Cordillera, and Pacific

Maritime, contained 153 species. Their study reported species of the following superfamilies; Chrysidoidea (Bethylidae, Chrysididae, Dryinidae and Embolemidae), Vespoidea (Sierolomorphidae, Sapygidae, Vespidae and Pompilidae) and Apoidea (Sphecidae). In the Oriental region, Yamane, Ikudome and Terayama, (1999) reported that species diversity of aculeates were found from the Nansei islands (Japan), consisted of 26 families, 188 genera and 598 species. These indicated the difference in the number of species in each area of the zoogeographical regions. The elevation and latitude are a cause of species diversity of aculeate bees. Finnamore (1997) reported that species numbers of aculeate species was an inverse relationship between 1,500 to 6,050 meters above sea level, where the latitudinal gradient increases the species diversity decreases, with latitude and elevation changes. Araújo, Antonini and Araújo (2006) suggested that the distribution of bee families in southern Brazil also seem to be related to latitudinal gradients. In the Neotropical region, the 3 families; Apidae, Halictidae and Megachilidae have a great proportion of species in tropical areas, and the abundance of them increases with higher latitudes at 1,500 meters above sea level.

Biology

Aculeate wasps are the most advanced group within the Hymenoptera, and are well recognized by the apotypic feature of a modified ovipositor to transmit venom rather than functioning as an egg-positioning device. They also exhibit an array of behavior and life history (Goulet and Huber, 1993; Gauld and Bolton, 1996).

Hymenopteran insects have primary parasitoid strategies termed idiobiont and koinobiont. Aculeate wasps (i.e. cuckoo wasps) are examples of idiobiont ectoparasitoids. Aculeate wasps use the ovipositor to inject eggs into a host like those of the infraorder Parasitica (koinobiont). Their larvae develop and feed on the host from outside the body. The aculeates can sting their preys and inject venom into them. After the preys are paralyzed, they will be carried back to the nests and will be consumed as food by developing offspring (Goulet and Huber, 1993; Gauld and Bolton, 1996; LaSalle and Gauld, 1997).

The aculeates also demonstrate a diverse array of social organization, from solitary wasps to communal nesting bees to highly organized societies of honey bees and ants. Even though, aculeate eggs are laid in a protected and enclosed space similar

to those parasitica eggs, they differ in development patterns in which offspring of the infraorder Parasitica usually live within or upon developing hosts (Goulet and Huber, 1993; Gauld and Bolton, 1996).

Honey bees, stingless bees and ants, including some wasps are social insects. They exhibit complete development or complete metamorphosis which is egg, larva, pupa and adult (Velthuis, 1997; Yamane, Ikudome and Terayama, 1999; O'Toole and Raw, 1999; Nakamura and Sonthichai, 2004). Their colony typically consists of several thousand members that cooperate in nest building, brood rearing and food collection, including nectar and pollen (Michener, 2007). A colony normally has a single queen, thousand workers, and several hundred drones. The social structure of the colony is maintained by the queen and workers and depends on an effective system of communication (Velthuis, 1997). In honey bees, Division of labor within the worker caste primarily depends on the age of the bee but varies with the needs of the colony. Reproduction and colony strength depend on the queen, the quantity of food stores, and the size of the worker force (O'Toole and Raw, 1999; Oldroyd and Wongsiri, 2006).

Morphology

The body of Aculeata (Figure 1) is similar to general insects: head, thorax (mesosoma) and abdomen (metasoma), and is covered by a hard exoskeleton. The first and/or second abdominal segment in some species (ants and wasps) have modified segments as a stalk, called a petiole in the first segment and postpetiole in the second segment (Bolton, 1997; Yamane, Ikudome and Terayama, 1999).

Head

The form of the antennae is particularly variable within the Aculeata i.e. filiform and geniculate. In the most generalized state there are ten flagella. The last flagellum is bent backward, called the antennal hook. The number of antennal segments in the aculeate wasps and bees is generally 12 in the female and 13 in the male, with a few exceptions where antenna is 12 segmented in both sexes of some ant species. On the other hand, it is highly variable in ants, ranging from 4 to 12 segments. The variations in antennal segments are useful in generic classification (Gauld and Bolton, 1996; Yamane, Ikudome and Terayama, 1999; Michener, 2007)

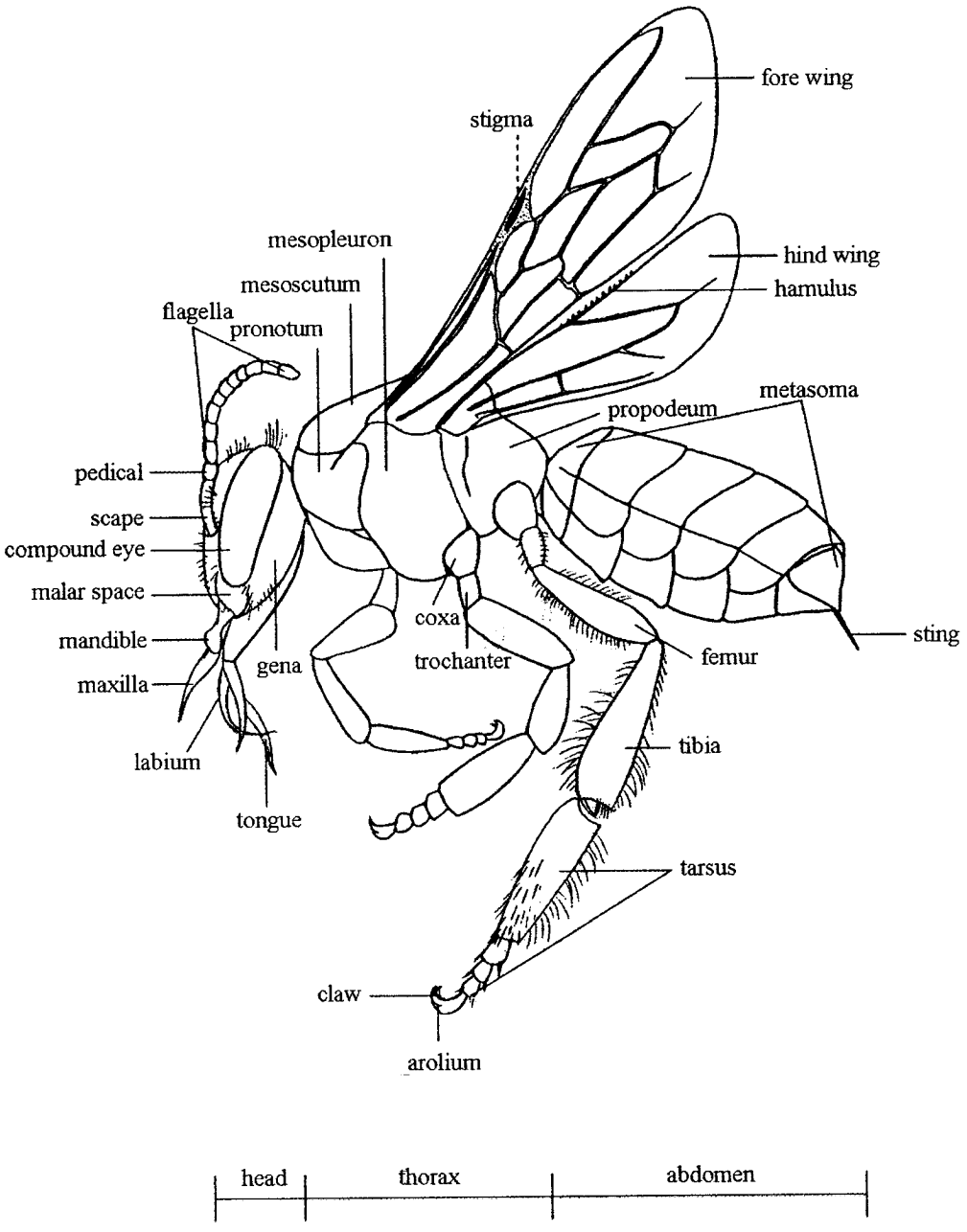


Figure 1 Terminology of the aculeate bee.

Compound eyes and simple eyes (ocelli) occupy lateral portions of the cranium, are generally composed of numerous ommatidia (facets). However, they vary in size and are completely lost in some species of ants. The position and development of eyes are very important in ant classification. The inner margins of the eyes (inner orbital margins) are convex, straight or emarginate. The ocelli are arranged in a triangle shape (anterior ocellus and 2 posterior ocelli). Ocelli may be completely lost in Mutillidae and workers of some ant species (Bolton, 1997; Yamane, Ikudome and Terayama, 1999).

Most mouthparts of the aculeate are complex. They have one to many teeth and/or denticles at the apex and on the inner or masticatory margin, and rarely on the basal or upper margin. They may have an excavation on outer margin or a small fovea basally on the outer face. Maxilla and labium are often modified; their shape is taxonomically very important in the bees. The numbers of segments of maxillary and labial palpi are useful at generic level classification throughout aculeate bees. (Yamane, Ikudome and Terayama, 1999; Michener, 2007).

Thorax (Mesosoma or Alitrunk)

The first segment at the abdomen is united to the thorax to form the mesosoma or alitrunk, with a constriction between the mesosoma and the remaining part of the abdomen in the aculeates (the constriction is not clear in the Symphyta). The last segment of mesosoma is called the first abdominal segment or the propodeum. The 3 segments of the thorax are generally separated from each other by distinct sutures but in some families i.e. Bethylidae, Mutillidae and Formicidae, the sutures are often completely lost (Gauld and Bolton, 1996; Yamane, Ikudome and Terayama, 1999; Michener, 2007).

Some bees have a flat structure (basitibial plate) at the base of the tibiae but some species of non-parasitic bees have long hairs (scopae) mainly on the femur and/or tibiae of legs, or have specially arranged hairs on their legs, pollen baskets (corbicula), for carrying pollen. Cleptoparasitic bees do not have such hairs. Tarsal claws may be simple, bifid, or unidentate to tridentate (Michener, 2007).

The fore and hind wings on each side are held together by numerous small hooks, called hamuli, rising on the anterior margin of hind wing. In many bethylids, most female mutillids and all the worker ants, wings are considerably reduced or

completely lost. The wings are membranous and subhyaline, but often clouded with yellow or black, occasionally with a purple or metallic luster. The reduction in wing venation occurs in nearly all species in this infraorder and much reduce in the Bethylidae, Formicidae and others. The wing cells are the enclosed areas which are very important in Hymenoptera classification. Pterostigma (stigma) is a thickened and darkened area medially on the anterior margin of the fore wings. Reduced veins and no stigma are obvious in hind wings. They may have a basal lobe (anal or jugal lobe) on the posterior margin (Gauld and Bolton, 1996; Yamane, Ikudome and Terayama, 1999; Michener, 2007).

Abdomen (Metasoma)

The abdomen (metasoma) normally consists of 10 segments but this number may not be visible without careful dissection. The first abdominal segment is closely associated with the thorax. The eighth to tenth abdominal segments are reduced and developed into an ovipositor or sting. Thus, only 6 visible segments in the female and 7 in the male are detectable. The metasoma is also called the gaster in wasps and bees, but the term gaster is restricted to the swollen part of the metasoma in ants. In ants, there are 1 or 2 small segments between the mesosoma and gaster which called the petiole and postpetiole. These structures correspond to the second and third segments of true abdomen. Ant gaster consists of third to seventh (eighth in the male), or fourth to seventh (eighth in the male) abdominal segments according to groups. The petiole may have a ventral plate-like process (subpetiolar process), or may be dorsally armed with one or several teeth or denticles called petiolar spines. The last sternum of the male is called the hypopygium or subgenital plate, and any modification of it is useful in classification (Gauld and Bolton, 1996; Yamane, Ikudome and Terayama, 1999).

Body hairs

Insects bear several types of body hair i.e. setae, bristles and pubescence, which in the hymenopteran often adheres to the body surface and may form bands or patches. However, they are often difficult to differentiate setae from pubescence under a dissecting microscope, and any slender flexible filament may be called the hairs. Their color, length, thickness, angle to the body surface, density, condition of apex and arrangement are of taxonomic importance throughout the Aculeata (Yamane, Ikudome, and Terayama, 1999).

Beneficial Aculeates

The Aculeats provide benefits to humans because they are predators of insect pests, pollinators of crops and/or provide natural products.

Aculeates as predators of insect pests

Ants and wasps are known as general predators of insect pests. The ants and wasps (Vespoidea) can paralyze, kill, and collect a large number of insects which they use as food sources for their young (Grabenweger et al., 2005). Ants are extremely abundant in many habitats and are generally predatory insects. For example in the USA, the red imported fire ant, *Solenopsis invicta* is common predators of the cotton aphid, bollworm (*Helicoverpa zea*) and beet armyworm (*Spodoptera exigua*) (Kaplan and Eubanks, 2002).

Aculeates as pollinators

A large proportion of plants that are important to human as food crops (e.g. fruits and vegetables) are pollinated by bees (Ambrose, 1997; Khan and Khan, 2004). Many species of aculeates have a long and pointed tongue which adapted for probing into flowers. Their bodies are covered with branched or feathery hairs. Pollination is a process by the aculeates travel from flower to flower, collecting nectar (converted to honey), and in the process, pick up pollen grains from anthers. In apinie, the pollen is collected on their hind legs which have dense of hairs, referred to as a pollen basket. As the aculeates fly from flower to flower, the pollen grains are transferred onto the stigma of the female flower. This transfer precedes fertilization, in which the pollen tubes grow down the stigma from the implanted pollen grains to the ovary. Cell nuclei from the pollen grain and the ovary then fuse to begin the process of ovulation (Buchmann and Nabhan, 1996; O'Toole and Raw, 1999).

In horticulture, the presence of bees in sufficient numbers is vital for economic crops, particularly as several commercially valuable crops are self-sterile. This is because bees can increase the rate of cross pollination of those economic corps (Gauld and Bolton, 1996).

Aculeates as providers of natural products

The Egyptians practiced apiculture for some 4,500 years ago, and today the honey industry is one of the major world commercial concerns. There is an annual world market of over one million tons of honey. Honey bees provide products such as

honey, beeswax, propolis, bee pollen, royal jelly and venom. Their products are used as food, in traditional medicines, supplementary foods and cosmetics (Goodman, 1991; Gauld and Bolton, 1996; Finnamore, 1997).

CHAPTER III

MATERIALS AND METHODS

Sample collection

1. Samples of the aculeates were collected from several areas in the north of Thailand. There were Chiang Mai, Chiang Rai, Kamphaeng Phet, Lampang, Lamphun, Mae Hong Son, Nakhon Sawan, Nan, Phayao, Phetchabun, Phichit, Phitsanulok, Phrae, Sukhothai, Tak and Uttaradit (Figure 2). Those areas included botanic gardens and parks, and different types of forests i.e. evergreen forest and deciduous forest between January 2006 and June 2007.

2. The method of systematic random sampling was used for sample collections (Krebs, 1999). The techniques for efficiently collecting flying and non-flying Aculeata were different. Flying species were collected by insect sweeping nets. Other apterous species were most frequently collected by hands, forceps and/or grates.

3. All specimens were preserved in 95% ethyl alcohol. Details of the samples (e.g. the localities, habitats and microhabitats) were recorded. The position and altitude of all insect samples were determined by means of a Global Positioning System (GPS) receiver (Garmin).

Sample classification

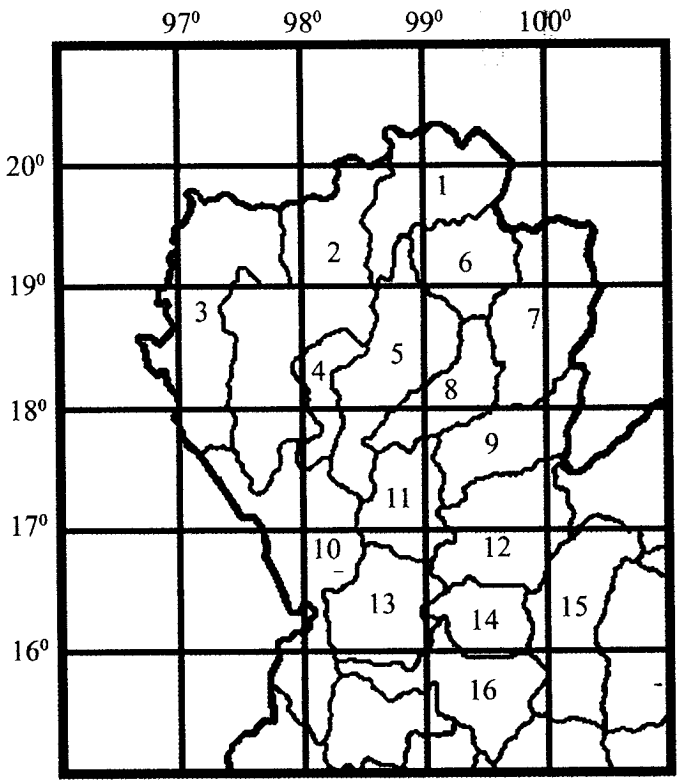
1. The insect samples of each species were divided into 2 groups. The first group was preserved as dried specimens and was used for further identification (Elzinga, 2000) and the second group was preserved at the Department of Biology, Naresuan University, Phitsanulok, Thailand.

2. The specimens were identified using taxonomic literatures and references following Schwarz (1939), Vecht (1966), Hirashima (1969), Mitchell (1980), Archer (1989), Sakagami, Inoue and Salmah (1990), Yamane (1990), Brothers and Finnamore (1993), Finnamore and Michener (1993), Goulet and Huber (1993), Bolton (1997), Shattuck (1999), Yamane, Ikudome and Terayama (1999), Carpenter and Garcete-Barrett (2002), Carpenter and Nguyen (2003), Gupta and Jonathan (2003), Michener

and Boongird (2004), Tüzün (2004), Nguyen et al. (2006), Oldroyd and Wongsiri (2006) and Michener (2007).

3. Specimens were confirmed by experienced taxonomists from the Natural History Museum (National Science Museum, Thailand), the Center of Excellence: Bee biology, biodiversity of insects and mites (Chulalongkorn University, Thailand), Department of Biology (Chiang Mai University, Thailand), Insect Museum (Kasetsart University, Kamphaeng Saen Campus, Thailand) and Institute of Zoology (Bulgarian Academy of Sciences, Bulgaria).

4. The dichotomous keys of families, subfamilies, genera and species were constructed for identification of all the collected insects in infraorder Aculeata in the studied areas, according to Goulet and Huber (1993).



1. Chiang Rai
2. Chiang Mai
3. Mae Hong Son
4. Lamphun
5. Lampang
6. Phayao
7. Nan
8. Phrae
9. Uttaradit
10. Tak
11. Sukhothai
12. Phitsanulok
13. Kamphaeng Phet
14. Phichit
15. Phetchabun
16. Nakhon Sawan

Figure 2 Provinces surveyed for the presence of aculeate bees.

Data analyses

The list of aculeate bee species was presented in each habitat which was done for species composition and species structure indices. The results were used to indicate the aculeate bee species structure in each type of habitat i.e. deciduous dipterocarp forest, evergreen forest and cultivated area.

Similarity index

The values, ranging from 0-1 scale of Sorensen coefficient; S_s (Krebs, 1999), were used to match species in 2 community areas, using the following equation:

$$S_s = \frac{2a}{2a+b+c}$$

where: S_s = Sorensen's similarity coefficient

a = number of species in sample A and sample B

b = number of species in sample B but not in sample A

c = number of species in sample A but not in sample B

Species diversity index

The species diversity of the aculeate bees living in each type of habitat was estimated using the Shannon-Wiener function; H' and Pielou's index of equitability; J' (Krebs, 1999). The J' values of this measure (0-1) were used to determine that the species diversity is more or less diverse than others, using the following equation:

$$H' = -\sum_{i=1}^{s}(p_i)(\log p_i)$$

To standardize this measure, calculate evenness from equation:

$$J' = \frac{H'}{\log N}$$

where: H' = species diversity of Shannon-Wiener index

J' = evenness measure of the Shannon-Wiener index

log = $\log_{10}$

N = number of species

p_i = proportion of the total sample belonging to i^{th} species

S = number of species

Dominant species index

The measurement of dominant species in each habitat was calculated using Simpson's index; C (Krebs, 1999). The value ranges from 0-1 and was used to determine the dominant species in each area. The calculation was done following equation:

$$C = \sum p_i^2$$

where: C = dominant species of Simpson's index

p_i = proportion of the total sample belonging to i^{th} species

CHAPTER IV

RESULTS

Species surveys and sample collections of the aculeate species in the north of Thailand (Table 4) were carried out during January 2006 to June 2007. Systematic random sampling was used for sample collections. We found 3 superfamilies of the infraorder Aculeata in northern Thailand. Those 3 superfamilies were Apoidea, Chrysidoidea and Vespoidea. From totally 120 specimens, the 88 specimens can be identified at the species level and 32 specimens were identified at the generic level. These species belonged to 64 genera, 23 subfamilies and 9 families. In Apoidea, there were 35 species in 5 families: Anthophoridae, Apidae, Halictidae, Megachilidae and Sphecidae. Five species were found in Chrysididae of the Chrysidoidea. In Vespoidea, There were 80 species in 3 families: Formicidae, Scoliidae and Vespidae. The summary of the aculeate bee species occurring in this thesis was provided in Table 1. The taxonomic list of insects in the infraorder Aculeata found in the north of Thailand and each species was numbered for references and kept at the Entomology Lab, the Department of Biology, Faculty of Science, Naresuan University, Phitsanulok (Table 5).

The species diversity index, Pielou's index (J') among the 8 habitats was slightly different, except grassland was mostly different. The index was the highest in hill evergreen forest (0.846) and was the lowest in grassland (0.369). The dominant index, Simpson's index differed from the species diversity index because grassland had the highest value (0.175) and hill evergreen forest had the lowest value (0.020). Moreover, the value of Pielou's index in natural forest (6 forest types combined) (0.880) was higher than that of cultivated area (0.663). The detail of species structure index from the 8 habitat types was shown in Table 2.

Table 1 The summary of insects in the infraorder Aculeata found in the north of Thailand.

Superfamilies/Families		Subfamilies	Tribes	Genera	Species
3	9	23	38	64	120
Apoidea					
	Anthophoridae	Anthophorinae	Anthophorini	*Amegilla*	*A. florea*
		Xylocopinae	Ceratinini	*Ceratina*	*Ceratina lieftincki*
				Pithilis	*P. smaragdula*
			Melectini	*Thyreus*	*Thyreus* sp.
			Xylocopini	*Xylocopa*	*X. confusa*
					X. latipes
		2	4	5	6
	Apidae	Apinae	Apini	*Apis*	*A. andreniformis*
					A. cerana
					A. dorsata
					A. florea
					A. mellifera
		Bombinae	Bombini	*Bombus*	*Bombus* sp.
		Meliponinae	Meliponini	*Hypotrigona*	*Hypotrigona* sp.
				Trigona	*T. apicalis*
					T. collina
					T. fimbriata
					T. fuscobalteata
					T. itama
					T. laeviceps
					T. melanoleuca
					T. minor
					T. nitidiventris
					T. peninsularis
					T. terminata
					T. thoracica
					T. ventalis
		3	3	4	20
	Halictidae	Halictinae	Halictini	*Halictus*	*Halictus* sp.
		1	1	1	1
	Megachilidae	Megachilinae	Megachihi	*Coelioxys*	*Coelioxys* sp.
				Megachile	*Megachile* sp.1
					Megachile sp.2
		1	1	2	3

Table 1 (Cont.).

Superfamilies/Families	Subfamilies	Tribes	Genera	Species
Sphecidae	Nyssoninae	Bembecini	*Bembix*	*Bembix* sp.
	Sceliphroninae	Sceliphronini	*Chalybion*	*Chalybion* sp.
			Sceliphron	*Sceliphron* sp.1
				Sceliphron sp.2
	Sphecinae	Sphecini	*Sphex*	*Sphex* sp.
	3	3	4	5
Total: 5	**10**	**12**	**16**	**35**
Chrysidoidea				
Chrysididae	Chrysidinae	Chrysidini	*Chrysis*	*Chrysis* sp.1
				Chrysis sp.2
				Chrysis sp.3
			Trichrysis	*Trichrysis* sp.
			Praestochrysis	*Praestochrysis* sp.
	1	1	3	5
Total: 1	**1**	**1**	**3**	**5**
Vespoidea				
Formicidae	Aenictinae	Aenictini	*Aenictus*	*A. binghami*
	Cerapachyinae	Cerapachyini	*Cerapachys*	*C. sulcinodis*
	Dolichoderina	Dolichoderin	*Dolichoderus*	*D. thoracicus*
				D. tuberifer
			Iridomyrmex	*I. anceps*
			Philidris	*Philidris* sp.
			Technomyrmex	*T. kraepelini*
				T. modiglianii
	Formicinae	Camponotini	*Camponotus*	*C. camelinus*
				C. leonadi
				C. rufoglaucus
				C. singularis
				Camponotus sp.1
				Camponotus sp.2
			Polyrhachis	*P. abdominalis*
				P. armata
				P. bihamata
				P. dives
				P. flavicornis
				P. furcata

Table 1 (Cont.).

Superfamilies/Families	Subfamilies	Tribes	Genera	Species
				P. hippomanes
				P. muelleri
				P. proxima
				P. tibialis
				Polyrhachis sp.1
				Polyrhachis sp.2
		Oecophyllini	*Oecophylla*	*O. smaragdina*
		Plagiolepidini	*Anoplolepis*	*A. gracilipes*
				Lepisiota sp.
			Paratrechina	*P. longicornis*
			Plagiolepis	*Plagiolepis* sp.
	Myrmicinae	Cataulacini	*Cataulacus*	*C. granulatus*
		Crematogastrini	*Crematogaster*	*C. coriaria*
				C. difformis
				C. rogenhoferi
		Formicoxenini	*Cardiocondyla*	*C. wroughtonii*
		Melissotarsini	*Rhopalomastix*	*R. janeti*
		Meranoplini	*Meranoplus*	*M. bicolor*
		Myrmecinini	*Pristomyrmex*	*P. punctatus*
		Pheidolini	*Pheidole*	*P. plagiaria*
		Pheidologetonini	*Pheidologeton*	*P. diversus*
		Solenopsidini	*Monomorium*	*M. destructor*
			Solenopsis	*S. geminata*
		Tetramoriini	*Rhoptromyrmex*	*R. wroughtoni*
			Tetramorium	*T. flavipes*
	Ponerinae	Ectatommini	*Gnamptogenys*	*bicolor*
		Leptogenyini	*Leptogenys*	*L. diminuta*
				L. kitteli
		Odontomachini	*Odontomachus*	*O. rixosus*
				O. simillimus
		Ponerini	*Diacamma*	*D. sculpturata*
				D. vargens
			Harpegnathos	*H. venator*
			Odontoponera	*O. denticulata*
			Pachycondyla	*P. astuta*
				P. chinensis
				P. luteipes
				P. rufipes

Table 1 (Cont.).

Superfamilies/Families	Subfamilies	Tribes	Genera	Species
	Pseudomyrmecinae	Pseudomyrmecini	*Tetraponera*	*T. allaborans*
				T. attenuata
				T. rufonigra
	7	21	33	61
Scoliidae	Scoliinae	Campsomerini	*Campsomeris*	*Campsomeris* sp.
		Scoliini.	*Scolia*	*Scolia* sp.
	1	2	2	2
Vespidae	Eumeninae	-	*Delta*	*D. pyriforme*
				Delta sp.
		-	*Phimenes*	*P. flavopictus*
		-	*Rhynchium*	*Rhynchium* sp.
	Polistinae	Polistini	*Polites*	*P. olivaceus*
				Polites sp.
		Ropalidiini	*Parapolybia*	*P. varia*
			Polybioides	*Polybioides* sp.
			Ropalidia	*Ropalidia* sp.1
				Ropalidia sp.2
	Stenogastrinae	Stenogastrini	*Parischnogaster*	*Parischnogaster* sp.
	Vespinae	-	*Provespa*	*P. anomala*
		-	*Vespa*	*V. affinis*
				V. mandarinia
				V. soror
				V. tropica
				V. velutina
	4	3	10	17
Total: 3	**12**	**26**	**45**	**80**

Table 2 Ecological indices of aculeate bee species structure in the 8 different habitats: deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL), forest area (FA) and cultivated area (CA).

Habitats	Ecological indices	
	Pielou's index (J')	Simpson's index (C)
BB/DF	0.843	0.028
DDF	0.668	0.048
EGF	0.603	0.063
HEGF	0.846	0.020
MXF	0.691	0.047
GL	0.369	0.175
FA	0.880	0.238
CA	0.663	0.036

The calculated Sorensen's similarity coefficient, which matches in species between a pair area, was shown in Table 2. The study of species structure indices compared among the 8 types of habitats (Table 6): deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL) and cultivated area (CA), including forest area (FA) indicated that the difference in habitat type influences species differentiation in the aculeates which occupy these habitats. The similarity measurement, BB/DF and HEGF (0.639), and FA and CA (0.621) showed the most similar aculeate species structure. Moreover, the lower index indicates the differences in the aculeate species structure between the habitats: BB/DF and GL (0.081), DDF and GL (0.000), EGF and GL (0.000), HEGF and GL (0.079), and MXF and GL (0.045) (Table 3).

Table 3 The Sorensen's similarity coefficient of insect species in 8 habitats: deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL), forest area (FA) and cultivated area (CA).

Comparison of areas	Sorensen's similarity coefficient (S_s)
BB/DF and DDF	0.416
BB/DF and EGF	0.274
BB/DF and HEGF	0.639
BB/DF and GL	0.081
BB/DF and MXF	0.433
DDF and EGF	0.480
DDF and HEGF	0.364
DDF and GL	0.194
DDF and MXF	0.418
EGF and HEGF	0.352
EGF and GL	0.000
EGF and MXF	0.441
HEGF and GL	0.079
HEGF and MXF	0.471
MXF and GL	0.045
FA and CA	0.621

In addition, 3 ecological indices: the similarity index, species diversity index and domidant index in all habitats of natural forests and cultivalted areas in each location (Table 4) were shown in Table 8 and Table 9 (Appendix).

The species richness (Table 7) and species diversity index (J') (Table 8) of each habitat in each location (Table 4) showed that deciduous with bamboo forests in Phitsanulok 1 (75 species, 0.859), deciduous dipterocarp forests in Phetchabun (21 species, 0.892), evergreen forests in Tak 3 (21 species, 0.955), hill evergreen forests at Mae Hong Son (41 species, 0.852), mixed evergreen and deciduous forests at Chiang Mai (25 species, 0.842), grassland in Phitsanulok 1 (5 species, 0.428) and cultivated areas in Chiang Mai (48 species, 0.876) are the highest value of each habitat in each location.

From the calculated dominant index (C) (Table 8) of each habitat in each location (Table 4), we found that the deciduous with bamboo forests in Nan (0.059), deciduous dipterocarp forests in Sukhothai (0.080), evergreen forests in Chiang Mai 2 (0.120), hill evergreen forests in Nan (0.046), mixed evergreen and deciduous forests in Chiang Rai (0.092), grassland in Phitsanulok 2 (0.253) and cultivated areas in Phichit (0.069) showed the highest value of dominant species.

From the comparison of areas using Sorensen's similarity coefficient (S_s) in all habitats in each location (Table 4) found that the deciduous with bamboo forests between Nan and Uttaradit (0.865), deciduous dipterocarp forests between Tak 2 and Phitsanulok 2 (0.872), evergreen forests between Mae Hong Son and Tak 3 (0.800), hill evergreen forests between Mae Hong Son and Nan (0.676), mixed evergreen and deciduous forests between Tak 2 and Nakhon Sawan (0.781), grassland between Phitsanulok 1 and Phitsanulok 2 (0.670), and Phitsanulok 1 and Chiang Mai 2 (0.670), and cultivated areas between Lampang and Lamphun (0.861) showed the highest similarity index (Table 9).

Table 4 Study areas of aculeate species in 7 habitat types: deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL) and cultivated area (CA).

Type of Habitats	Locations				Altitude (msl.)
	Provinces	Districts	Tambols	Abbreviations	
BB/DF	Chiang Mai 1	Mueang	Suthep	CM1	396
	Chiang Rai	Phan	Mae Chedi Mai	CR	538
	Kamphaeng Phet	Khlong Lan	Kosampi	KP	322
	Mae Hong Son	Pai	Mae Hee	MHS	690
	Nakhon Sawan	Mae Wong	Mae Le	NSW	325
	Nan	Pua	*Pua*	N	264
	Phayao	Muang	Maeka	PY	568
	Phetchabun	Nam Nao	Nam Nao	PB	178
	Phitsanulok 1	Wang Thong	Chomphu	PL1	240
	Phitsanulok 2	Nakhon Thai	Nakhon Thai	PL2	227
	Phitsanulok 3	Wang Thong	Wang Nok Aen	PL3	56
	Sukhothai	Khirimat	Muang Kao	ST	540
	Tak 1	Mueang	Mae Tah	T1	488
	Tak 2	Samngao	Samngao	T2	322
	Uttaradit	Thapla	Nam Khrai	UD	231
DDF	Phayao	Muang	Maeka	PY	573
	Phetchabun	Nam Nao	Nam Nao	PB	479
	Phitsanulok 1	Wang Thong	Chomphu	PL1	540
	Phitsanulok 2	Nakhon Thai	Nakhon Thai	PL2	627
	Phitsanulok 3	Wang Thong	Wang Nok Aen	PL3	658
	Sukhothai	Khirimat	Muang Kao	ST	600
	Tak 1	Mueang	Mae Tah	T1	468
	Tak 2	Samngao	Samngao	T2	916
	Uttaradit	Thapla	Nam Khrai	UD	614
EGF	Chiang Mai 2	Chomthong	Ban Pong	CM2	2,572
	Mae Hong Son	Pai	Mae Hee	MHS	2,051
	Tak 3	Tha *Song Yang*	Tha *Song Yang*	T3	1,817

Table 4 (Cont.).

Type of Habitats	Locations				Altitude (msl.)
	Provinces	Districts	Tambols	Abbreviations	
HEGF	Chiang Mai 1	Mueang	Suthep	CM1	1,059
	Mae Hong Son	Pai	Mae Hee	MHS	1,719
	Nan	Pua	*Pua*	N	1,567
	Phitsanulok 1	Wang Thong	Chomphu	PL1	1,493
	Tak 3	Tha *Song Yang*	Tha *Song Yang*	T3	516
HEGF	Chiang Mai 1	Mueang	Suthep	CM1	586
	Chiang Rai	Phan	Mae Chedi Mai	CR	440
	Nakhon Sawan	Mae Wong	Mae Le	NSW	751
	Phetchabun	Nam Nao	Nam Nao	PB	838
	Tak 2	Muang	Mae Tah	T2	923
GL	Chiang Mai 2	Chomthong	Ban Pong	CM2	664
	Phitsanulok 1	Wang Thong	Chomphu	PL1	746
	Phitsanulok 2	Nakhon Thai	Nakhon Thai	PL2	440
CA	Chiang Mai 2	Chomthong	Ban Pong	CM2	2,444
	Lampang	Thoen	Lom Raet	LPA	429
	Lamphun	Mueang	Nai Mueang	LPU	220
	Phichit	Wachirabarami	Ban na	PC	37
	Phrae	Mueang	Nai Viang	PR	95

Key to the superfamilies of Aculeata found in northern Thailand

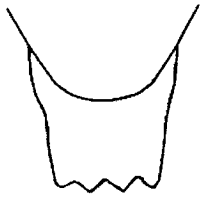
Modified from Goulet and Huber, 1993.

1. a) Wings absent; metasomal segment 1 and/or 2 node-like ..... Vespoidea (Formicidae)

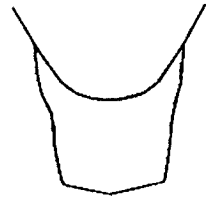
   b) Wings present ..... (2).

2(1b). a) Metasoma with 2-8 apical teeth ..... Chrysidoidea

   b) Metasoma not apical teeth ..... (3).



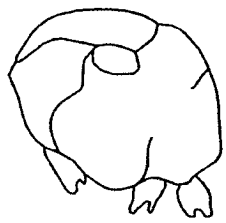
2a)



2b)

3(2b). a) Pronotum adnate tegulae ..... most Vespoidea

   b) Pronotum not adnate tegulae ..... (4).



3a)

3b)

4(3b). a) Hind leg without curbicula or pollen basket, or tarsomere 1 cylindrical as wide as other segments; body hairs with simples ..... Apoidea (Spheciformes)

   b) Hind leg with curbicula or tarsomere 1 wider than other segments; body hairs with branches ..... Apoidea (Apiformes)

4a)

4b)

Superfamily Apoidea

The Apoidea is dispersed worldwide. They are divided into 2 informal groups, the spheciformes (sphecid wasps) and the apiformes (bees) (Finnamore and Michener 1993). Both the spheciformes and apiformes were considered here. A total of 35 species in 16 genera were found in this study. These species belonged to 9 subfamilies in 5 families: Anthophoridae, Apidae, Halictidae, Megachilidae and Sphecidae.

Key to the families of Apoidea found in northern Thailand

Modified from Goulet and Huber, 1993; Yamane, Ikudome and Terayama, 1999.

1. a) Hind leg without curbicula or tarsomere 1 as wide as other tarsomeres; body hairs with short to long simples or unbranched; petiole composed of sternum only ..... Sphecidae

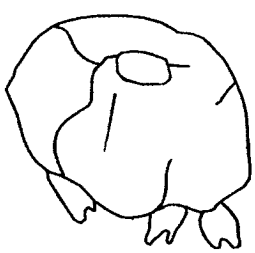
   b) Hind leg with curbicula or tarsomere 1 wider than other tarsomeres; body hairs with short to long branches ..... (2).

1a)

2b)

2(1b). a) Episternal groove on mesopleuron present ..... Halictidae

   b) Episternal groove on mesopleuron absent ..... (3).

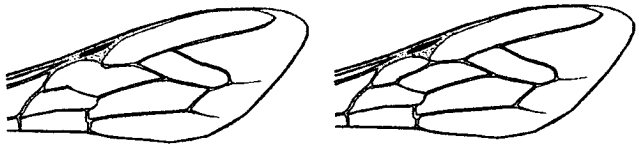


2a)

2b)

3(2b). a) Labrum longer than wide; fore wing 2 submarginal cells ..... Megachilidae

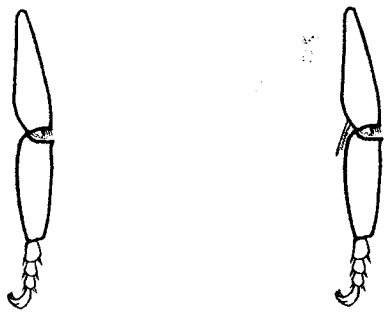
b) Labrum shorter than wide; fore wing 3 submarginal cells ..... (4).



3a) 3b)

4(3b). a) Hind leg with curbicula; hind tibia without apical spurs; hind wing without jugal lobe ..... Apidae

b) Hind leg without curbicula; hind tibia with apical spurs; hind wing with jugal lobe ..... Anthophoridae



4a) 4b)

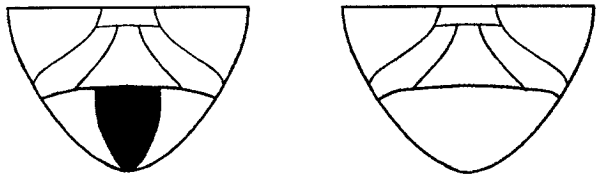
Family Anthophoridae

The family consists of 3 subfamilies, Nomadinae, Anthophorinae and Xylocopinae which are distributed around the world (Yamane, Ikudome and Terayama, 1999). Six species, in 4 tribes of 2 distinctive subfamilies: Anthophorinae (digger bees) and Xylocopinae (carpenter bees), were recognized in this study. We were able to identify the long-tongued bees. Pygidial plate and basitibial plate are present in almost all females. The pronotum is black, short and not extending back to the tegulae. The fore wing venation is well developed, and there are 3 submarginal cells and pterostigma in the fore wings. Hind femur lacks a well-defined trochantellus. Scopa is largely restricted to the hind tibia. The hind basitarsi is wider than the other segments.

Key to the species of Anthophoridae found in northern Thailand

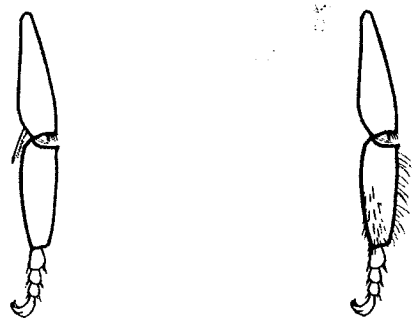
Modifed from Goulet and Huber, 1993; Yamane, Ikudome and Terayama, 1999.

1. a) Pygidial plate present ..... Anthophorinae (2).
   b) Pygidial plate absent ..... Xylocopinae (3).



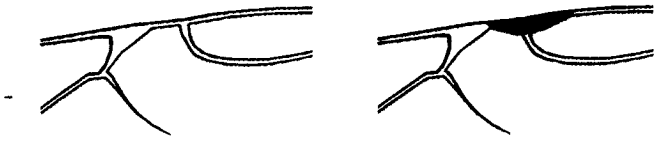
1a) 1b)

2(1a). a) Scopa absent ..... Melectictini
   - Body with patches of blue hairs ..... *Thyreus* sp.
   b) Scopa present ..... Anthophorini
   - Abdomen with blue bands on black ..... *Amegilla florea*



2a) 2b)

3(1b). a) Stigma absent ..... Xylocopini
   - Jugal lobe of hind wing shorter than vannal lobe
   ..... *Xylocopa* (4).
   b) Stigma present ..... Ceratinini (5).



3a) 3b)

4(3a). a) Yellow hair on thorax ..... *X. confusa*
   b) Body fully metallic black ..... *X. latipes*

5(3b). a) Body metallic green ..... *Pithitis smaragdula*
   b) Body not metallic green ..... *Ceratina lieftincki*

Subfamily Anthophorinae

The subfamily Anthophorinae is represented by a single species of genus *Amegilla* which are medium bees. They are distributed around the world (Michener, 2007). These insects have a strongly protuberant clypeus. Moreover, the marginal cell of the fore wing is shorter than the distance from its apex to wing tip. The apex of the marginal cell is rounded and separated from the wing margin. The fore wings have a small spot and stigma, whereas the hind wings have a jugal lobe.

Tribe Anthophorini

Genus *Amegilla* Friese, 1897

Amegilla is a genus of large bees in the tribe Anthophorini (Michener, 2007). They are widely distributed in Asia and Europe (Proshchalykin, 2004). Their body is medium-sized. The thorax is covered with brown hairs, but the metasomal terga lack have hair. The abdomen has a band with pale blue bands.

***Amegilla florea* (Smith, 1879)**

The length of body is 13-16 mm in the female. The head and mesosomal dorsum are densely covered by yellow-gray hairs. The compound eyes and ocelli are red-brown. The abdomens have 4 blue bands with black bases. The tibial scopa has yellowish hairs but the hairs in the anterior portion are black. Fore and hind wings are rather uniformly transparent. The fore wing has 3 submarginal cells without the stigma. The second submaginal cell is smaller than the first and second submaginal cells (Figure 3).

Subfamily Xylocopinae

The Xylocopinae occurs worldwide (Finnamore and Michener 1993). The total of 4 species in 4 genera form 3 tribes; Ceratinini, Melectini and Xylocopini were recorded in this study. All specimens were identified with characteristic of clypeus, which is not strongly protuberant and lateral parts as seen from underneath are bent backward, and not parallel to long-axis view with body.

Tribe Ceratinini

Genus *Ceratina* Latreille, 1802

Small carpenter bees are identified in the tribe Ceratinini (Daly, 1983; Warrit, 2007). *Ceratina* have black body. They have a weak scopa on the hind tibia. Most species have few yellow markings, most often restricted to the face, but often in other

parts of the body. The marginal cell is broad and longer than the distance from their apex to wing tip. In this study we found only one species, *Ceratina lieftincki*.

***Ceratina lieftincki* van der Vecht, 1952**

A body length of the female is about 4.5 mm. The head and thorax are mostly a black color but some parts of the gena, thorax, legs and abdomen (second to sixth metasomal terga) have whitish to yellow markings. The clypeus is like a thick inverted T. The abdomens have 5 yellow bands on a black background. The fore and hind wings are rather uniformly transparent (Figure 4).

Genus *Pithitis* Klug, 1807

Pithitis is a genus of the tribe Ceratinini. This genus is widely distributed from India through southeast Asia to Taiwan and Africa (Hirashima, 1969). Only one species, *Pithitis smaragdula* (Fabricius, 1787) was known from this study. Their body is brilliantly metallic green with a few pale markings on the head, thorax and legs, and is coarsely punctuated. Lower paraocular area is flat-bottomed punctures. The abdomen has a velvety black area on the terga and the sixth metasomal sternum has lateral teeth.

***Pithitis smaragdula* (Fabricius, 1787)**

This species is widely distributed in the Oriental region (Hirashima, 1969). The body of the female is about 8 mm in length with brilliantly metallic green in color. The middle of metasomal terga has a pair of longitudinal line while the fourth to sixth abdominal terga have a pair of velvety black section. The wings are rather uniformly transparent. This species is similar to the *Chrysis* species in the family Chrysididae but they lack apical teeth at the tip of their metasoma (Figure 5).

Tribe Melectini

Genus *Thyreus* Panzer, 1806

This genus is widely distributed worldwide except in the New World. *Thyreus* is a genus of the tribe Melectini (Michener, 2007). Their body has conspicuous patches of short blue to white hairs. The pattern of hair patches is easily recognized by having scutellum, posteriorly salient. The fore wing has 3 submarginal cells. The first submarginal cell is usually longer than the others. The jugal lobe of the hind wing is very small. The basitibial plates are absent. Only one species, *Thyreus* sp. was found from this study.

***Thyreus* sp.**

The total length of the female body is about 12 mm. The body is black with conspicuous patches of blue hairs. The first to sixth metasomal targa have 5 pair of blue hairs. The marginal cell of the fore wing is shorter than the distance from its apex to wing tip. The lateral of the mesothorax has obvious patches of blue hairs. The scutellum is posteriorly salient with black (Figure 6).

Tribe Xylocopini

Genus *Xylocopa* Latreille, 1802

This genus; carpenter bees are distributed worldwide. They are classified in the tribe Xylocopini which has a very large and robust body in genus *Xylocopa* (Finnamore and Michener 1993; Michener, 2007). Their colors are metallic black. Some species have yellowish areas on the face. They also lack a malar space, and the triangular second submarginal cell. The marginal cell is very slender and is longer than the distance from its apex to its wing tip. The jugal lobe of the hind wing is shorter than the vannal lobe. Two species were recorded in this study, *X. confusa* and *X. latipes*.

***Xylocopa confusa* Pérez, 1901**

This species is widely distributed across southeast Asia and Republic of Panama (Wcislo et al., 2004). They are large sizes bee, at about 2 cm. Their bodies are hairy. This species is characterized by yellow hair on the head and thorax. They have a black abdomen with black hairs. Their wings are uniformly dark brown (Figure 7).

***Xylocopa latipes* (Drury, 1773)**

This species is widely distributed across southeast Asia and India (Raju and Rao, 2006). They are very large bees. Their bodies are approximately 3-4 cm. Their body is fully metallic black and usually with black hairs. Their wings have metallic blue, green and purple colors under sunlight. The tibia of the fore legs is bright yellow (Figure 8).

Figure 3 A female of *Amegilla florea* (Smith, 1879).

Figure 4 A female of *Ceratina lieftincki* van der Vecht, 1952.

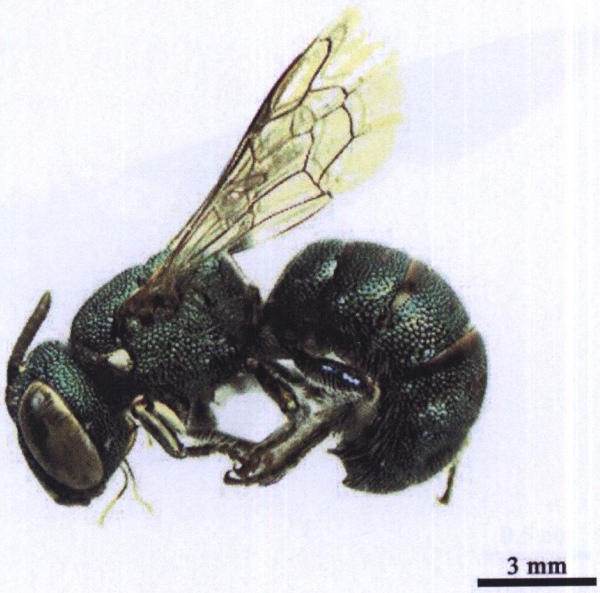


Figure 5 A female of *Pithitis smaragdula* (Fabricius, 1787).

Figure 6 A female of *Thyreus* sp.

Figure 7 A worker of *Xylocopa confusa* Pérez, 1901.

Figure 8 A worker of *Xylocopa latipes* (Drury, 1773).

Family Apidae

This family is represented around the world and consists of honey bees, stingless bees and bumble bees (Michener, 2007). An Apidae is identified by having corbicula on the hind tibia. Moreover, their pronotum has a collar-like plate without projections that reach the tegulae. The labrum is wider than long. Body hairs are branched or plumose. The first segment of the metatarsus is often enlarged and flattened. The front wing has three submarginal cells and a stigma is present. The jugal lobe of the hind wing is shorter than the submedian cell.

A total of 20 specimens in 3 subfamilies were found in this study. They were identified as 18 species and 2 specimens were identified at the genus level.

Key to the species of Apidae found in northern Thailand

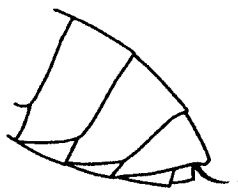
Modified from Sakagami, Inoue and Salmah, 1990; Michener, 2007.

1. a) Hind tibia with spurs ..... Bombinae
   - Hairy body with yellow color ..... *Bombus* sp.
   b) Hind tibia without spurs ..... (2).

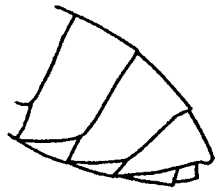
1a)

1b)

2(1b). a) Sting present ..... Apinae, *Apis* (3).
   b) Sting absent ..... Meliponinae (7).



2a)



2b)

3(2a). a) Body length more than 1.5 cm ..... *A. dorsata*
   b) Body length less than 1.5 cm ..... (4).

4(3b). a) M vein of hind wing not extending apically beyond r-m vein ..... *A. mellifera*

b) Rs and M veins of hind wing extending apically beyond r-m vein ..... (5).

4a) 4b)

5(4b). a) Abdominal tergites without white band ..... *A. cerana*

b) Abdominal tergites with white band ..... (6).

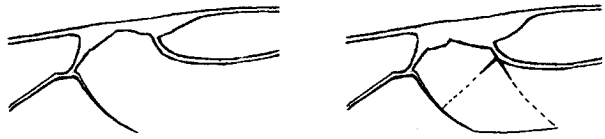
6(5b). a) Abdominal tergites 1 and 2 with black band ..... *A. andreniformis*

b) Abdominal tergites 1 and 2 with orange band ..... *A. florea*

7(2b). a) Fore wing venation more reduced; pterostigma wider ..... *Hypotrigona*

- Malar space shorter than flagella diameter; very small species, body length less than 3 mm ..... *Hypotrigona* sp.

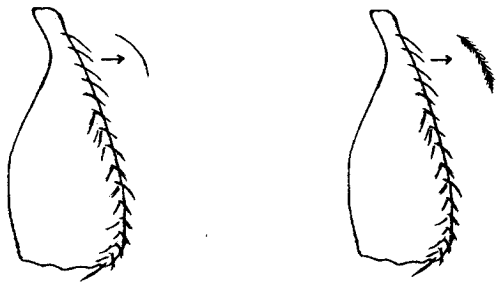
b) Fore wing venation less reduced; pterostigma narrower; small to large species, body length bigger than large *Hypotrigona* ..... *Trigona* (8).



7a) 7b)

8(7b). a) Simple hairs on hind tibia ..... (9).

b) Plumose hairs on hind tibia ..... (11).



8a) 8b)

9(8a). a) Hind tibia apically not expanded ..... *T. ventralis*

b) Hind tibia apically more expanded ..... (10).

9a)

9b)

10(9b). a) Hind tibia spoonlike ..... *T. terminate*

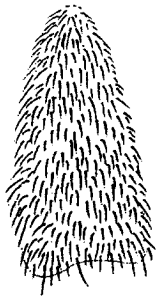
b) Hind tibia not spoonlike ..... *T. nitidiventris*

10a)

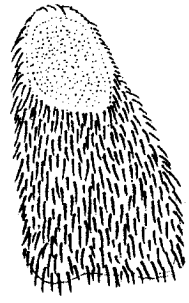
10b)

11(8b). a) Hind basitarsus without elliptical disc ..... *T. fimbriata*

b) Hind basitarsus with elliptical disc ..... (12).



11a)



11b)

12(11b). a) Mandible with only one tooth ..... (13).

b) Mandible with two teeth ..... (14).

12a)

12b)

13(12a). a) Thorax extensively reddish ..... *T. thoracica*

b) Thorax extensively blackish ..... *T. itama*

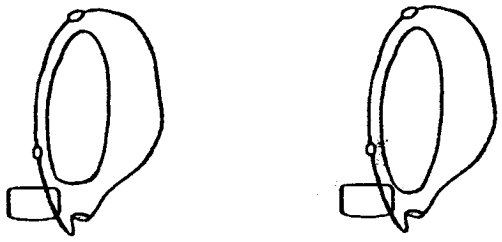
14(12b). a) Propodeum covered by mesoscutellum ..... (15).

b) Propodeum not covered by mesoscutellum ..... (17).

14a) 14b)

15(14a). a) Malar space longer than 2nd flagellum width ..... *T. peninsularis*

b) Malar space as short as 2nd flagellum width ..... (16).



15a) 15b)

16(15b). a) Metasoma and hind tibia with reddish ..... *T. apicalis*

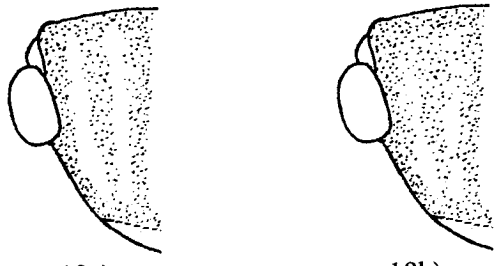
b) Body with blackish ..... *T. melanoleuca*

17(15b). a) Fore wing with bicolor; basally darker than apically ..... *T. collina*

b) Fore wing with unicolor and clean ..... (18).

18(17b). a) Line of mesoscutal hairs conspicuous ..... *T. fuscobalteata*

b) Line of mesoscutal hairs inconspicuous ..... (19).



18a) 18b)

19(18b). a) Body length 4 mm; mesoscutal hairs mixed with more dark hairs ..... *T. minor*

b) Body length 3 mm; mesoscutal hairs not mixed ..... *T. laeviceps*

Subfamily Apinae

The Apinae is in the subfamily that includes the majority of honey bees in the family Apidae (Michener, 2007). This subfamily consists of the corbiculate bees. The basitarsi lack scopal hairs and a pollen-carrying function. The tibial corbicula is a smooth, concave or sometimes flat area. They are surrounded by long hairs on the outer surface of the hind tibia. We found 5 species in the north of Thailand which were identified in the tribe Apini.

Tribe Apini

Genus *Apis* Linnaeus, 1758

These bees are the only living members of the tribe Apini (Oldroyd and Wongsiri, 2006). This genus consists of small to large size bees (1-2 cm). The eyes are covered with hair. The mandible of workers lack teeth and carinae. The claws of females are cleft. An arolia is present between claws but hind tibial spurs are absent. The wings are translucent and the prestigma is almost as long as or longer than the stigma. Both the jugal and vannal incisions of the hind wing are shallow. Pollen baskets are made of specialized hairs and are located on the outer surface of the tibiae of the hind legs. We found 5 species of honey bees in this study: *A. andreniformis* (small dwarf honey bee), *A. cerana* (indian honey bee), *A. dorsata* (giant honey bee), *A. florea* (dwarf honey bee) and *A. mellifera* (western honey bee).

***Apis andreniformis* Smith, 1858**

Apis andreniformis (small dwarf honey bee) is a very small honey bee from southern and southeastern Asia (Oldroyd and Wongsiri, 2006). Their bodies are about 1 cm long and about half the size of giant bees, *A. dorsata*. They are similar in size or slightly smaller than *Apis florea*. However, this species is identified with a uniformly black color of the first and second abdominal terga. The second abdominal tergum is deeply punctuated. The marginal setae on the hind tibiae are dark-brown to blackish (Figure 9).

***Apis cenara* Fabricius, 1793**

They are small honey bees (indian honey bee) of southern and southeastern Asia. *Apis cenara* is similar size or slightly smaller than *Apis mellifera*. The body length of a worker is around 12 mm. The head, thorax and first to fifth metasomal terga are covered by golden to orange hairs. The radius sector (Rs) and media (M)

veins of the hind wings are apically extended beyond the redius-media (R-M) vein (Figure 10).

***Apis dorsata* Fabricius, 1793**

The giant honey bee, *Apis dorsata*, is the world's largest honey bee (Oldroyd and Wongsiri, 2006). *Apis dorsata* workers are about 2 cm long. The giant honey bee is distributed over vast geographic areas in southeast Asia and is found throughout Thailand. The first and second abdominal terga are yellow to orange and other segments are black (Figure 11).

***Apis florea* Fabricius, 1787**

Apis florea is a very small honey bee from southern and southeastern Asia (Oldroyd and Wongsiri, 2006). The dwarf honey bees are 1 cm of body length. The first and second abdominal terga are reddish and other segments at least partially reddish. They are more reddish and the first abdomen is always red in an old worker. The second abdominal tergum is not deeply punctuated. The marginal setae on the hind tibiae are usually entirely white (Figure 12).

***Apis mellifera* Linnaeus, 1758**

The western honey bee, *Apis mellifera* is naturally distributed in central and western Asia, Africa and Europe (Pinto et al, 2007). The body length of workers is about 1.2 cm. Their body is golden brown and black with pale yellow to orange rings on the abdomen. The head, antennae, and legs are almost black. The redial sector (Rs) and media (M) veins of the hind wing are not apically extended beyond the redius-media (R-M) vein (Figure 13).

Subfamily Bombinae

Bombinae are distributed around the world (Cameron, Hines and Williams, 2007). Body length ranges from 1 to 2.5 cm (Michener, 2007). Their body is covered by yellow, black, orange or red hairs. Their females carry pollen and nectar on a corbicula on the hind leg which has long hairs on the upper part. The hind tibia has spurs. This subfamily is similar to Xylocopinae but Xylocopinae has a shiny body.

Tribe Bombini

Genus *Bombus* Latreille, 1802

These bees are members of the tribe Bombini. This genus is distributed around the world (Cameron, Hines and Williams, 2007; Michener 2007). They are

distinguished by the differentia of hair colors. The claws of the female are cleft. The arolia are present but small and the hind tibial spurs are present. The wings have complete strong venation. The hind wing lacks a jugal lobe.

***Bombus* sp.**

The body length in the female is 2 cm in average. Their head and thorax are covered by black hairs except the pronotum which is covered with yellow hairs. The first to second abdominal terga and the end of the abdomen are covered by yellow hairs with black hairs in the middle. The marginal cell is longer than the distance from its apex to the wing tip. The stigma is small but longer than the prestigma. This species is similar to carpenter bees, *Xylocopa* but can be distinguished by the difference of hair color on their body (Figure 14).

Subfamily Meliponinae

Meliponinae are abundant in subtropical and tropical regions of the world. Worldwide stingless bees are classified into 23 genera and 18 subgenera. Meliponinae is a subfamily of small bees in the family Apidae. They are similar to Apinae except they lack of sting. The stingless bee constitutes a diversified group, with many species building their nests in living or dead tree trunks (Sakagami, Inoue and Salmah, 1990; Camargo and Menezes-Pedro, 1992; Velthuis, 1997; Michener, 2007). They include certain characters: the wing venation is reduced, their body is covered with short to moderate hairs, the claws of the females are simple, hind legs have an arolia between the claws but without tibial spurs. The hind basitarsus, the base, is without an auricle. The space between the base of the eyes and the articulation of the jaws is the malar space, of taxonomic importance. A large numbers of species have been reported in tropical areas, of which 23 species have been reported in Thailand (Sakagami, Inoue and Salmah, 1990; Michener and Boongird, 2004). In this study, we found 14 species which are mostly distributed in deciduous with bamboo forests at an altitude of less than 400 meters above sea level. All species have been reported in Indo-Malayan areas (Sakagami, Inoue and Salmah, 1990; Klakasikorn et al., 2005).

Tribe Meliponini

Genus *Hypotrigona* Cockerell, 1934

Hypotrigona are the smallest Meliponinae known (about 2 mm). They are naturally distributed in Asia, Africa and Australia (Sakagami, Inoue and Salmah,

1990; Michener 2007). They have a long malar space. A nearly right-angled submarginal angle and bristles arranged in successive transversal rows on the inner surface of the hind basitarsus.

***Hypotrigona* sp.**

The body length of workers is about 2 mm. Their bodies are black and very shiny. Labrum, mandibles and tarsal joints are reddish-brown. The antennae are black with 12 segments; 2 segment of scape and pedicel, and 10 segments of flagella. The basal half of the clypeus is swollen and raised well above the sides of the face. The apical half of the clypeus has a downward slant. The wings are clear hyaline. The hind basitarsi have light golden bristles over their entire inner surface. The hairs on head, thorax, legs, and abdomen are less than on the basitarsi (Figure 15).

Genus *Trigona* Jurine, 1807

Trigona is the largest genus of the stingless bees and the most widely distributed genus of the Meliponinae. This genus is found in the Neotropics region from Mexico to Argentina and in the Indo-Australian region from India and Sri Lanka to Taiwan, including Thailand (Sakagami, Inoue and Salmah, 1990; Michener 2007). In this study, we found 13 species. Most of their characters differ from *Hypotrigona* because they have a short malar space and fore wing venation is less reduced, including a narrow pterostigma.

***Trigona apicalis* Smith, 1857**

The worker body length is about 6.5 mm. The head and thorax are black. Metasomal targa and hind tibia are brownish to reddish. The mandible, for the most part, is dark red. They have 2 usually large black teeth. The basal half of the fore wing is white but the apical half of the fore wing is deep brown to black. The malar space is as long as the width of the second flagella. The hind legs are covered with plumose hairs on posterior tibia and basitarsi has elliptical disc (Figure 16).

***Trigona collina* Smith, 1857**

The worker body length is about 6 mm. Their bodies and legs are black but tegula is black to blackish brown. The basal half of the fore wing is white but the apical half of the fore wing is dark brown to black. The hind leg has plumose hairs on rim of the tibia and has an elliptical disc on the basitarsi. This species is similar to *T.*

apicalis, however, the malar space width of *T. collina* is narrower than the width of the second flagella segment and less than the width of the scape (Figure 17).

***Trigona fimbriata* Smith, 1857**

They are the biggest bees in this genus. The worker body length is more than 8 mm. Their bodies are brownish to dark orange, including the wings. The malar space is moderately developed and the mandible has 2 usually large teeth. The distance between the rim of the compound eye and the base of the mandible is longer than the width of the second flagella. The clypeus is short but wide with dark hairs. The hind basitarsus do not have elliptical disc (Figure 18).

***Trigona fuscobalteata* Cameron, 1908**

The worker body is about 2.5 mm in length. The forewing, including tegula is about 3 mm in length. The wing has a rather uniform clarity throughout. The head and thorax are black, except the abdomen which varies from sepic brown to blackish. Anterior fringing of the hind tibiae is usually silvery-grey. The mesonotum is usually streaked with longitudinal hair bands. The hind leg has plumose hairs on the rim of the tibia and has an elliptical disc on the basitarsi. The width of the malar space is longer than the width of the second flagella (Figure 19).

***Trigona itama* Cockerell, 1918**

The worker body length is about 5.5 mm. The mandible, clypeus, scape (except at its extreme base) are black, including the erect hairs on the mesopleura. The distance between the base of the compound eye and the mandible is shorter than the width of the second flagella. The basal half of the fore wing is white but the apical half is brown. The hind legs are covered with plumose hairs on the posterior tibia and the basitarsi has elliptical disc. This species is similar to *T. collina* except only a single tooth of the mandible is present in *T. itama* (Figure 20).

***Trigona laeviceps* smith, 1857**

Trigona laeviceps is black body. The worker body length is about 3.5 mm. The mandible usually has 2 small teeth. The width of the malar space is shorter than width of the second flagella. The fore and hind wing are rather uniformly transparent. Posterior fringe of hind tibia consists of plumose hairs and hind basitarsus has elliptical disc. This species, *T. laeviceps*, is similar to *T. minor* because they lack G3

line on mesoscutal glabrous areas, but *T. laeviceps* is distinguished by its smaller size, and mesoscutum is covered by mixed dark hairs (Figure 21).

***Trigona melanoleuca* Cockerell, 1929**

The worker body is about 5.5 mm in length. The head, thorax and abdomen are black. They have 2 usually large and strong black teeth. The basal half of the fore wing is white but the apical half is dark brown to black. The hind legs are covered with plumose hairs on the rim of the tibia and the basitarsi has an elliptical disc. This species is similar to *T. apicalis* but the width of malar space of *T. melanoleuca* is shorter than that of their second flagella, and also their body is more metallic black (Figure 22).

***Trigona minor* Sakagami, 1978**

The length of the worker body is about 3.5 mm. The mandible has 2 small teeth. The width of the second flagella is longer than the distance between the rim of the compound eye and the base of the mandible. The wings are rather uniformly transparent. The posterior fringe of the hind tibia consists of plumose hairs and the hind basitarsus have an elliptical disc. The mesoscutal glabrous area is covered with hairs. G3 line is absent. *T. minor* is similar to *T. laeviceps* but is distinguished by its larger size, and mesoscutum is covered by dark hairs (Figure 23).

***Trigona nitidiventris* Smith, 1857**

The worker body is about 6 mm long with a black body. The mandibles are black except on the apical tips. The second to sixth metasoma segments are black but the first metasoma tergum is yellowish. The legs are partly brownish and the posterior fringed of tibia is covered with simple black hairs. The mesoscutal tomentum is well developed and extends to the mesoscutellum. The fore and hind wings are rather uniformly transparent (Figure 24).

***Trigona peninsularis* Cockerell, 1927**

The total length of the worker body is about 5 mm. Head, thorax and abdomen are black but most of the mandible is dark black. They have 2 large, black teeth with simple hairs. The fore wings are bicolors, basally brown with dark brown veins and apically white with orange veins, but the hind wings are rather uniformly transparent. This species is similar to *T. apicalis* and *T. melanoleuca* but the malar space is longer than the width of the second flagella (Figure 25).

***Trigona terminata* Smith, 1878**

The worker body is about 5 mm in length with black body. The mandibles are black except for the apical tips. The second to sixth metasoma segments are black but the first metasoma tergum is yellowish. A hind tibia is not spoon-shaped and the posterior fringe of the tibia is covered with simple black hairs. Fore and hind wing are rather uniformly transparent. This species is similar to *T. nitidiventris* but their bodies, *T. terminata* are larger and the hind tibia is not spoon-shaped (Figure 26).

***Trigona thoracica* Smith, 1857**

The worker body length is about 8 mm. The clypeus, supraclypeus, and scape are bright brown to reddish, and the head is black. The wings are rather uniformly transparent while the stigma of the fore wing is bright brown. The mesoscutum is dark brown to red. The abdomen is usually black and partly reddish. The width of the malar space is as long as that of the mandible which has 2 teeth. This species is recognized by reddish on mesonotum (Figure 27).

***Trigona ventralis* Smith, 1857**

The length of the worker body is about 4.5 mm with black body. The second to sixth metasoma terga are black but first metasoma tergum is cream in color. The mesoscutal tomentum is usually whitish and does not extend to the mesoscutellum. The posterior tibia fringed is covered with pale hairs. The fore and hind wings are rather uniformly transparent. This species is similar to *T. terminata* but their bodies are larger and the hind tibia is slightly spoon-shaped (Figure 28).

Figure 9 A worker of *Apis andreniformis* Smith, 1858.

Figure 10 A worker of *Apis cerana* Fabricius, 1793.

Figure 11 A worker of *Apis dorsata* Fabricius, 1793.

Figure 12 A worker of *Apis florea* Fabricius, 1787.

Figure 13 A worker of *Apis mellifera* Linnaeus, 1758.

Figure 14 A female of *Bombus* sp.

Figure 15 A worker of *Hypotrigona* sp.

Figure 16 A worker of *Trigona apicalis* Smith, 1857.

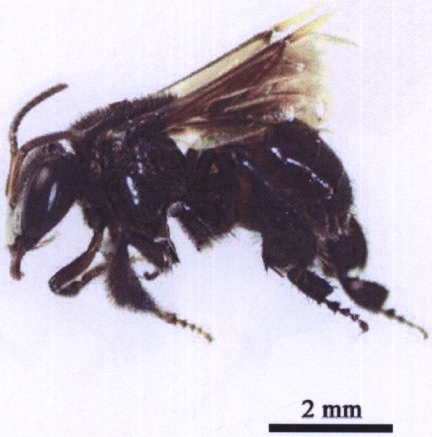


Figure 17 A worker of *Trigona collina* Smith, 1857.

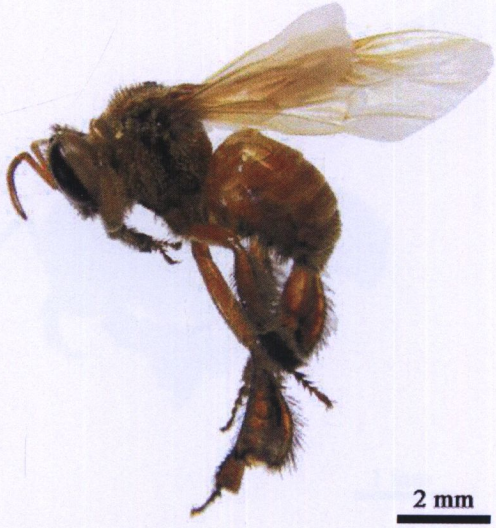


Figure 18 A worker of *Trigona fimbriata* Smith, 1857.

Figure 19 A worker of *Trigona fuscobalteata* Cameron, 1908.

Figure 20 A worker of *Trigona itama* Cockerell, 1918.

Figure 21 A worker of *Trigona laeviceps* smith, 1857.

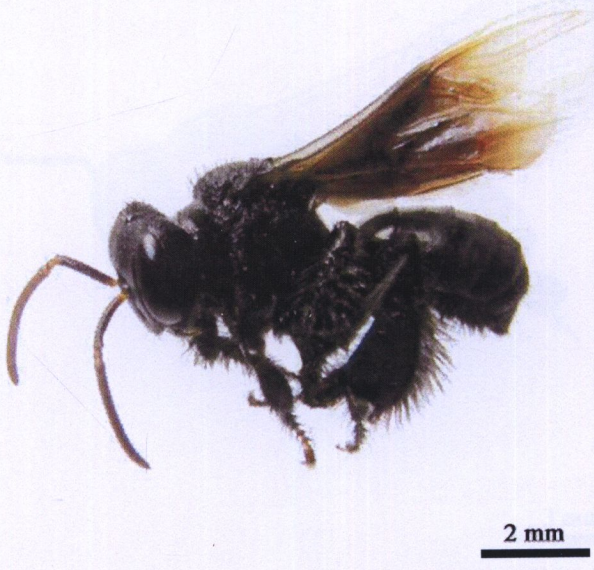


Figure 22 A worker of *Trigona melanoleuca* Cockerell, 1929.

Figure 23 A worker of *Trigona minor* Sakagami, 1978.

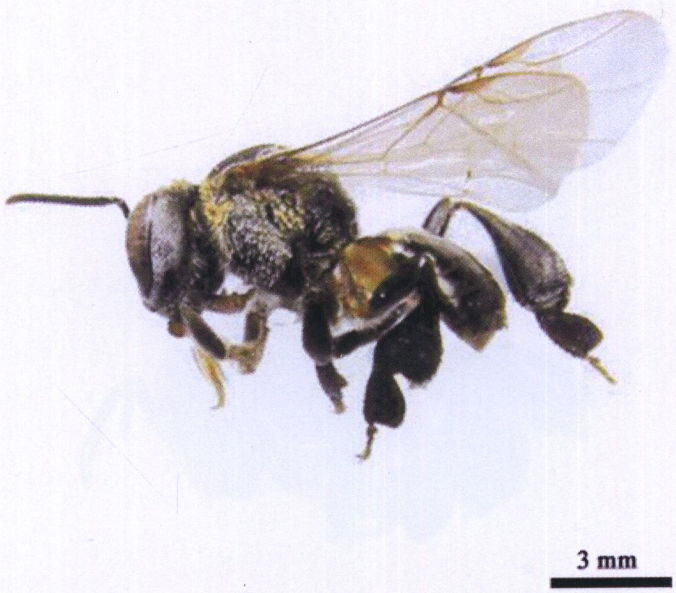


Figure 24 A worker of *Trigona nitidiventris* Smith, 1857.

Figure 25 A worker of *Trigona peninsularis* Cockerell, 1927.

Figure 26 A worker of *Trigona terminata* Smith, 1878.

Figure 27 A worker of *Trigona thoracica* Smith, 1857.

Figure 28 A worker of *Trigona ventralis* Smith, 1857.

Family Halictidae

This family consists of 3 subfamilies; Haclictinae, Nomiinae and Rophitinae. The largest and most common subfamily, the Haclictinae, contains genera *Halictus* and *Lasioglossum* (Finnamore and Michener, 1993). The *Halictus* in subfamily Haclictinae was the only one found in this study. Halictid bees are usually dark in color. The length of glossa is variable, short to long. A basitibial plate is present. The first flagellum of the antenna is shorter than the scape. The stigma of the fore wing is well developed. The sixth metasomal tergum of the female is located beneath the fifth tergum. The scopa of the ventral abdomen and/or hind legs is on trochanter to the tibia and is usually used for carrying pollen.

Tribe Halictini

Genus *Halictus* Latreille, 1804

Genus *Halictus*, Halictini is widespread throughout the Neotropical zone, North America, the Oriental region, the European region and Asia (Niu, Wu and Huang, 2004). Most species are black or dark brown in color. The second of radius-media (R-M) and media-cubitus (M-Cu) veins of the female fore wing are obvious. Females have a basitibial plate and a coarsely serrate spur on the hind tibia. Only one species, *Halictus* sp., was present in this work.

***Halictus* sp.**

The body of this species is black and partially covered by branched or plumose hairs. The first segment of the mid tarsus are often enlarged and flattened. The basal vein of the fore wing is strongly arched. The jugal lobe of the hind wing is longer than the submedian cell. The thorax is black. They have special hairs called scopa on their hind legs and ventral abdomen (Figure 29).

Family Megachilidae

The family Megachilidae is long-tongued bees and is mostly distributed in America, Africa, Asia and Australia. The labrum is rectangular which is longer than wide and broadly articulated to the clypeus (Mitchell, 1980; King, 1984; King and Exley, 1985; Yamane, Ikudome and Terayama, 1999; Fernández, 2001; Michener, 2007). Their fore wings have 2 submarginal cells because the first radial-medial (R-M) is fused to the second submarginal cell. Moreover, the first submarginal cell is longer than the second submarginal cell. Females have a ventral abdominal brush for carrying

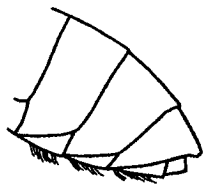
pollen and the metasomal sterna have scopa which is only found on the hind legs of this species. Two genera, *Coelioxys* and *Megachile* of subfamily Megachilinae were found in the north of Thailand.

Key to the species of Megachilidae found in northern Thailand

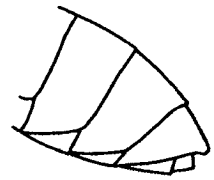
Modified from Yamane, Ikudome and Terayama, 1999.

1. a) Scopa present on metasomal sterna ..... *Coelioxys* sp.

   b) Scopa absent on metasomal sterna ..... *Megachile* (2)



1a)



1b)

2(1b). a) Black body; white hairs on mesoscutellum, propodeum and 1st metasomal segment ..... *Megachile* sp.1

   b) Black body; brownish to reddish hairs on body ..... *Megachile* sp.2

Subfamily Megachilinae

The family Megachilidae is commonly divided into 2 subfamilies; Megachilinae and Lithurginae (Genaro, 1998; Yamane, Ikudome and Terayama, 1999). In this study, we found only one subfamily, the Megachilinae in the tribe of Megachihi, which was identified into 2 genera: *Megachile* and *Coelioyxs*. The body is nonmetallic color. The length of the stigma is as long as broad but the length of prestigma is more than twice as broad. Moreover, the length of the inner margin to the radial (R) vein is longer than their width. The claws of female are usually simple. The outer surfaces of the hind tibiae are covered with plumose hairs, but not bristle. Arolia is absent, at least on hind legs.

Tribe Megachihi

Genus *Coelioxys* Latreille, 1809

Coelioyxs is similar to the large leaf-cutter bee; *Megachile*. This genus in tribe Megachihi is distributed in America, Asia and Australia (Mitchell, 1980). We found only one species in this study, *Coelioyxs* sp. This genus can be distinguished by the hairs on the eyes and their bodies are not hairy like *Megachile*. *Coelioyxs* are black in color and have a coarsely punctuated body. They have a more tapered abdomen and the axilla has several

spine-like protuberances posteriorly. Metasoma is conical and the first metasomal segment is the widest and the scopa is absent in females.

***Coelioxys* sp.**

The length of the female body is about 1.4 cm. Their body is black and mostly covered with whitish plumose hairs. The distance between the lateral ocellar is wider than the distance between lateral ocelli and compound eyes. Antenna is filiform with 12 segments; 1 segment of scape, 1 segment of pedicel and 10 segments of flagellum. Each apex of the metasomal tergum is covered by white hairs. The fore and hind wings are rather uniformly transparent (Figure 30).

Genus *Megachile* Latreille, 1802

This genus is mostly distributed in America, Asia and Australia, and often called leafcutter bees (Mitchell, 1980). In this study, we found 2 species of tribe Megachihi. Their black bodies are covered with plumose hairs. The arolia is absent at least on hind legs. A scopa is present on second to fifth metasomal sterna. The anterior mesepisternum is not separated from the lateral part by a carina.

***Megachile* sp.1**

The head, thorax and abdomen are black with hairs. The compound eyes and ocelli are brown. The body length of a female is about 1.5 cm. The antenna is filiform with 12 segments: 1 segment of scape, 1 segment of pedicel and 10 segments of flagellum. Their bodies are covered with short black hairs but the mesoscutellum and first to second metasomal terga are covered with white plumose hairs. The maxillae and labium are prominent on head. Scopa pale on the second to fourth metasomal sterna is black hairs. The basal half of the fore wing is white but the apical half of the fore wing is brown (Figure 31).

***Megachile* sp.2**

The total length of female body is about 1.5 cm and the body color is black. The antenna is filiform with 12 segments: 1 segment of scape, 1 segment of pedicel and 10 segments of flagellum. The head, rim of thorax, pronotum, mesoscutum, mesopleuron and first to third metasomal terga are covered with brown hairs. The maxillae and labium are prominent on the head. The scopa pale on the second to fourth metasomal sterna are covered by brownish hairs. More than half of the basal fore wing is white but the apex of the fore wing is brown to black (Figure 32).

Figure 29 A female of *Halictus* sp.

Figure 30 A female of *Coelioxys* sp.

Figure 31 A female of *Megachile* sp.1.

Figure 32 A female of *Megachile* sp.2.

Family Sphecidae

Most of this species are distributed around the world: the Oriental region and the Palearctic region (Budrys, 2000; Giovanettin, 2005). This family Sphecidae is spheciformes of superfamily Apoidea. In this study, we found 3 subfamilies: Nyssoninae, Sceliphroninae and Sphecinae. They are distinguished from vespids by having a short pronotum. The fore wings have 3 submarginal cells and the jugal lobe of the hind wings is wider than half the length of the anal area. The mid tibia has 2 apical spurs, 1 small and 1 large. Small rounded lobes extend towards but do not reach the tegulae. Their body hairs are simple rather than branched. The shape of the first metasomal sternum is cylindrical.

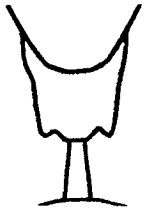
Key to the species of Sphecidae found in northern Thailand

Modified from Yamane, Ikudome and Terayama, 1999.

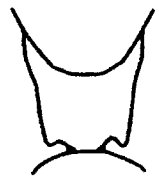
1. a) Petiole present ..... (2).

   b) Petiole absent ..... Nyssoninae

   - Medium ocelli parallel ..... *Bembix* sp.



1a)

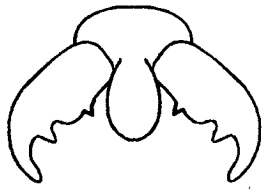


2a)

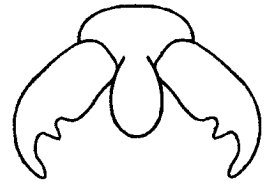
2(1a). a) Tarsal claws of fore leg and mid leg with 2 or more teeth ..... Sphecinae

   - Thorax with reddish hairs ..... *Sphex* sp.

   b) Tarsal claws of fore leg and mid leg with single teeth ..... Sceliphroninae (3).



1a)



2b)

3(2b). a) Petiole shorter than the width of abdomen ..... *Chalybion* sp.

   b) Petiole longer than the width of abdomen ..... (4).

4(3b). a) 1st metasomal segment yellow; leg yellow markings ..... *Sceliphron* sp.1

b) 1st metasomal segment black; femur of hind leg orange to red markings ..... *Sceliphron* sp.2

Subfamily Nyssoninae

This subfamily is found in most parts of the world (Calla, 1979), but in the north of Thailand was represented by a single species of the tribe Bembecini. These wasps have the mesonotum directed laterally and expand into the lamina that more or less overlies the base of the tegulae. The jugal lobe of the hind wing is shorter than the submedian cell. The petiole is absent.

Tribe Bembecini

Genus *Bembix* Fabricius, 1775

Bembix is identified in tribe Bembecini (Calla, 1979) which have 2 apical spurs on the middle tibiae. The fore wings have 3 submarginal cells. The shape of middle ocelli is nearly parallel.

***Bembix* sp.**

The length of body is about 2.2 cm in the female. Their body is black with yellow markings on the pronotum and metasoma, including the femur of the legs. This species differs from other species in family Sphecidae because the petiole is absent. Althought the shape of the *Bembix* species is similar to the *Vespa* species of family Vespidae, the middle ocelli of the *Bembix* species is nearly parallel. The propodeum is covered with white plumose hairs. The wings are uniformly transparent and do not have stigma (Figure 33).

Subfamily Sceliphroninae

Sceliphroninae are distributed around the world, but are abundant in the Old World (Yamane, Ikudome and Terayama, 1999). This subfamily is easily identified with the first metasomal segment (petiole) which is long. Two genera of subfamily Sceliphroninae; *Chalybion* and *Sceliphron* were found in the north of Thailand.

Tribe Sceliphronini

Genus *Chalybion* Dahibom, 1843

Chalybion is identified in tribe Sceliphronini and recorded in the Old World (Yamane, Ikudome and Terayama, 1999). Their body is metallic blue to bright blue-green and is covered with erect black hairs. The first metasomal segment is shorter than the width of the abdomen. The wings are nearly black. Only one species was collected from this area. Though this genus is similar to genus *Sceliphron* in shape and size, *Chalybion* is identified by their first metasomal segment which is shorter than the width of the gaster.

***Chalybion* sp.**

The length of the body is about 1.6 cm in female. Their body is metallic dark blue. The first metasomal segment is gently curved to straight, and is shorter than the width of the gaster. The pronotum and mesonotum are covered by coarse punctures with white hairs but the metanotum is longitudinally striated, except the propodeum which is covered with white hairs. Fore and hind wings are transparent with black color on the apex of the wings (Figure 34).

Genus *Sceliphron* Kiug, 1801

Many species of *Sceliphron* have yellowish markings on the body. The abdomen is long and the first metasomal segment is slender. The first metasomal segment is nearly linear line and is longer than the width of abdomen. The posterior of the first metasomal segment gradually widens toward the second metasomal segment. This genus is similar to genus *Chalybion* but the first metasomal segment of *Sceliphron* is longer than the width of abdomen.

***Sceliphron* sp.1**

The female body length is about 1.8 cm. The head, mesosoma and metasoma are black, except the first metasomal segment is marked with yellow color. Antennae have 12 segments; 1 segment of scape, 1 segment of pedicel and 10 segments of flagellum. The scape of the antenna is wider than other segments. The first metasomal segment is longer than the length of the abdomen. The legs are long with yellow markings on the femur. Fore and hind wing are uniformly transparent (Figure 35).

***Sceliphron* sp.2**

The body length of the female is about 2 cm. The head, mesosoma and metasoma are black, and the femur is red. The antennal number of *Sceliphron* sp.2 is similar to *Sceliphron* sp.1. The first metasomal segment is shorter than the length but they are longer than the width of the abdomen. The apically rim of mesoscutum and propodeum are yellow. The wings are bright brown and uniformly transparent (Figure 36).

Subfamily Sphecinae

They are distributed around the world (Yamane, Ikudome and Terayama, 1999). The subfamily Sphecinae is blue to black metallic or green with yellow stripes or markers. Most hairs on the body are plumose. The pronotum has a collar-like plate and does not reach the tegulae. The second medial-cubital (M-Cu) vein of the fore wing is contained the third submarginal cell (Sm). The tasal claws have 2 or more teeth. Planter lobes on the tarsus are absent. The first metasomal segment is very short and half as long as the width of the mesosoma. Genus *Sphex* was recorded in this study.

Tribe Sphecini

Genus *Sphex* Linnaeus, 1758

Genus *Sphex* is distributed around the world, but many species inhabit in Old World tropics (Yamane, Ikudome and Terayama, 1999). They are classified in tribe Sphecini. Only one species was recorded in this study. This genus is identified by their compound eyes which are straight for the most part, but curving in toward the ocelli. The lateral side of the propodeum has a deep furrow.

***Sphex* sp.**

The length of the female body is about 2.8 cm. Their body is black but the head and thorax are covered with red hairs. The metasoma is black in color. They have very short and slender petiole. All legs are red, except tarsus which are black. The fore and hind wings are transparent but the apex of the wings is black. This species is similar to the species *Vespa* (Vespidae) but *Sphex* sp. has a short petiole (Figure 37).

Figure 33 A female of *Bembix* sp.

Figure 34 A female of *Chalybion* sp.

Figure 35 A female of *Sceliphron* sp.1.

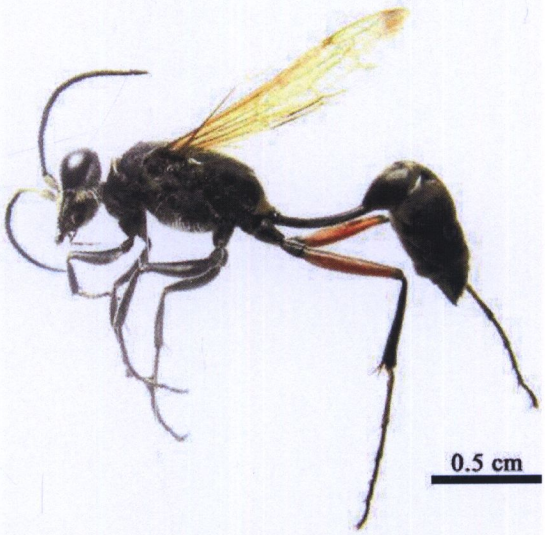


Figure 36 A female of *Sceliphron* sp.2.

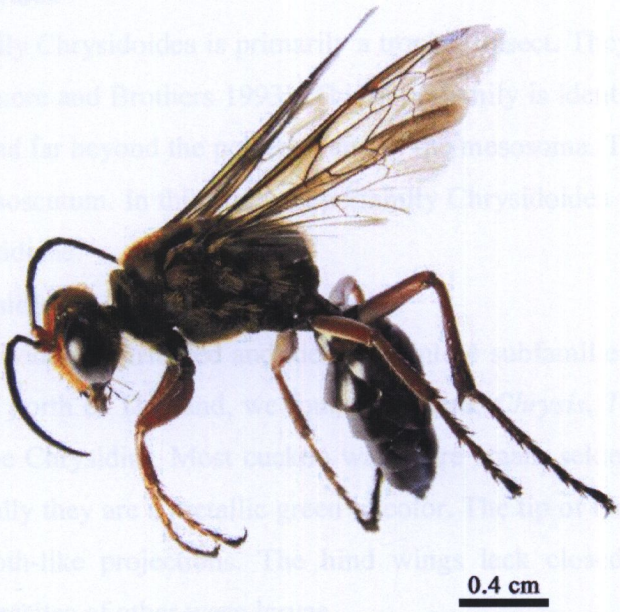


Figure 37 A female of *Sphex* sp.

Superfamily Chrysidoidea

The superfamily Chrysidoidea is primarily a tropical insect. They are divided into 7 families (Finnamore and Brothers 1993). This superfamily is identified by their fore wings which extend far beyond the posterior end of the mesosoma. The pronotum is twice as long as mesoscutum. In this study, superfamily Chrysidoidea was found in only one family, Chrysididae.

Family Chrysididae

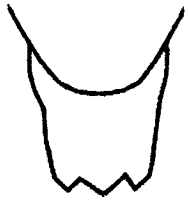
The family is widely distributed and identified into 4 subfamilies (Danks and Downes, 1998). In the north of Thailand, we found 3 genera; *Chrysis*, *Trichrysis* and *Praestohhrysis*, in tribe Chrysidini. Most cuckoo wasps are small, seldom exceeding 1.2 cm in length. Usually they are a metallic green in color. The tip of the abdomen in many species has tooth-like projections. The hind wings lack closed cells. Most species are external parasites of other wasp larvae.

Key to the species of Chrysididae found in northern Thailand

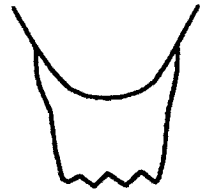
Modified from Yamane, Ikudome and Terayama, 1999.

1. a) Three teeth at apical metasoma ..... *Trichrysis*
   - 2nd abdominal segment longer than other segments ..... *Trichrysis* sp.

   b) More 3 teeth at apical metasoma ..... (2).



1a)



1b)

2(1b). a) Four, six or eight teeth at apical metasoma ..... *Chrysis*
   - four teeth ..... *Chrysis* sp.1
   - Six teeth ..... *Chrysis* sp.2
   - Eight teeth ..... *Chrysis* sp.3

   b) Five teeth at apical metasoma ..... *Praestochrysis*
   - Reddish marking on 2nd abdominal tergum ..... *Praestochrysis* sp.

Tribe Chrysidini

Genus *Chrysis* Linnaeus, 1761

Genus *Chrysis* in tribe Chrysidini is distributed around the world except the Arctic region (Danks and Downes, 1998). The color of the body is usually metallic green or blue. Their bodies are covered with coarse punctures. The compound eyes and ocelli are present on the vertex. Antennae have 12 or 13 segments. The tip of metasoma has 4, 6 or 8 apical teeth. We found 3 species in this genus.

***Chrysis* sp.1**

The total length is about 1.3 cm and blue-green in color. Their body is covered with coarse punctures and gray plumose hairs. The antennae have 12 segments; 1 scape, 1 pedicel and 10 flagella. Their compound eyes are large and brown. The mesoscutellum is shorter than the mesoscutum and the metanotum are fused to the propodeum which has 2 lateral teeth. Their abdomen has 5 segments and the apical rim of metasoma has 4 acute teeth (Figure 38).

***Chrysis* sp.2**

The length of the body is about 1 cm. Their body is greenish blue and covered with coarse punctures. The antennae have 12 segments; 1 scape, 1 pedicel and 10 flagella. The clypeus is short and wide. The metanotum are fused with the propodeum which has two lateral teeth. They have 4 abdominal segments. The second abdominal segment is the largest and the fourth abdominal segment is curved down. The apical metasoma has 6 acute teeth. Even though this species is similar to *Chrysis* sp.1 in body color, *Chrysis* sp.2 is distinguished by 6 acute teeth (Figure 39).

***Chrysis* sp.3**

The body length is about 7 mm. Their body is greenish blue and covered with coarse punctures. The antennae have 12 segments; 1 scape, 1 pedicel and 10 flagella. The metanotum are fused with the propodeum which has 2 lateral teeth. They have 4 abdominal segments. The length of the second abdominal segment is shorter than the first abdominal segment. The apical metasoma has 8 acute teeth. Although this species is similar to *Chrysis* sp.1 and *Chrysis* sp.2 in body color, *Chrysis* sp.3 can be identified by having 8 acute teeth (Figure 40).

Genus *Trichrysis* Lichtenstein, 1876

Trichrysis is distributed from the Ethiopian to the Asia region (Finnamore, 1997; Yamane, Ikudome and Terayama, 1999). The body is usually metallic green or blue in color with many pits on the surface. The antennae have 12 or 13 segments. This genus is separated from other genera by the metasoma with 3 apical teeth. One species, *Trichrysis* sp. in tribe was found in the north of Thailand.

***Trichrysis* sp.**

Their body length is about 7 mm and greenish blue with coarse punctures. The compound eyes and ocelli are present. The antennae have 13 segments; 1 scape, 1 pedicel and 11 flagella. The metanotum are fused with the propodeum which has 2 lateral teeth. The second abdominal tergum is longer than the other segments. They have 4 abdominal segments and the anal edge has a pit row. The middle tooth is the sharpest but the same length as the other teeth. This species is similar to *Chrysis* sp.3 but *Trichrysis* sp. has 3 teeth on apical metasoma (Figure 41).

Genus *Praestochrysis* Linsenmaier, 1959

Praestochrysis is distributed in the Ethiopian, Oriental, Australian and Palaearctic regions (Yamane, Ikudome and Terayama, 1999). Only one species in tribe was present in this study. This genus is easily separated from the other genera with 5 teeth at apical metasoma and their forth to twelfth antennal segments are wider than long. The compound eyes and ocelli are present.

***Praestochrysis* sp.**

Their body is about 7 mm in total length and green-blue with blue marking on the mesonotum. The antennae have 12 segments: 1 scape, 1 pedicel and 11 flagella. The metanotum are fused with the propodeum which has 2 lateral teeth. The second abdominal tergum has considerable coppery or red markings. They have 4 abdominal segments and a pit area on the anal edge. The middle tooth is sharper and longer than the other teeth. This species is similar to *Trichrysis* sp. in their body color but *Praestochrysis* sp. has 5 teeth at the apical metasoma (Figure 42).

Figure 38 A female of *Chrysis* sp.1.

Figure 39 A female of *Chrysis* sp.2.

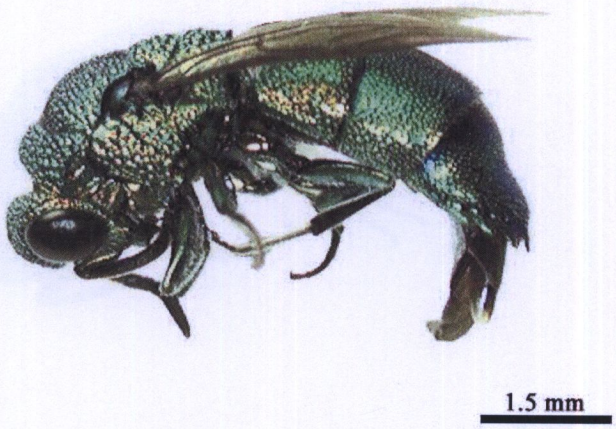


Figure 40 A female of *Chrysis* sp.3.

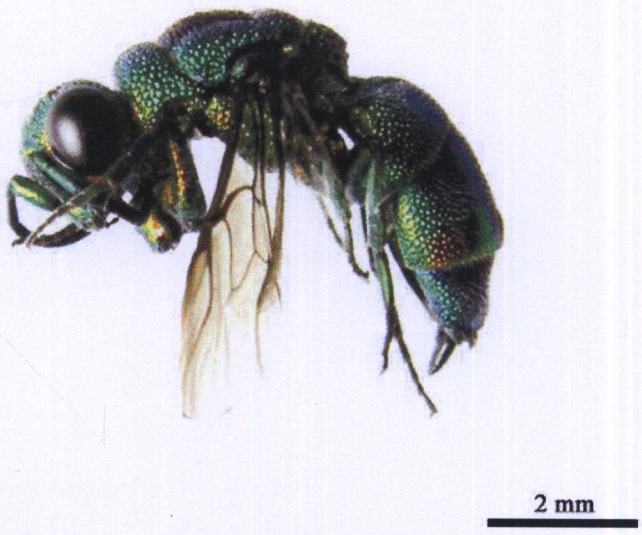


Figure 41 A female of *Trichrysis* sp.

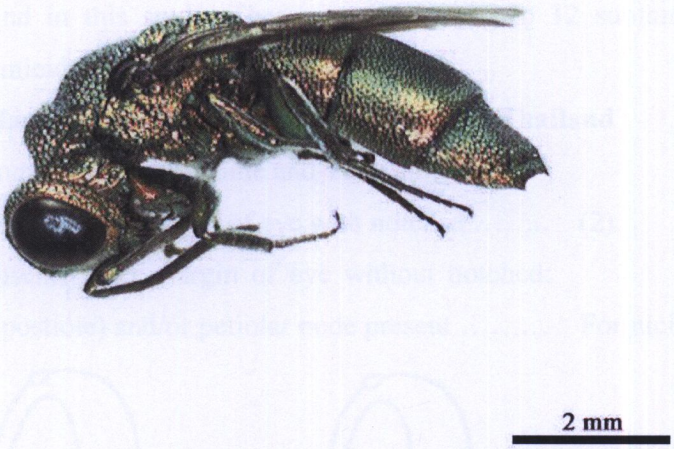


Figure 42 A female of *Praestochrysis* sp.

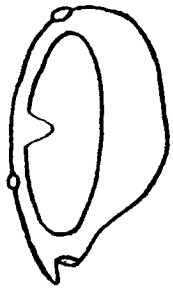
Superfamily Vespoidea

The Vespoidea is moderately large wasps. They are a mostly tropical group of 48,000 species in 10 families (Brothers and Finnamore, 1993). A total of 80 species in 45 genera were found in this study. These species belong to 12 subfamilies in 3 families, namely Formicidae, Scoliidae and Vespidae.

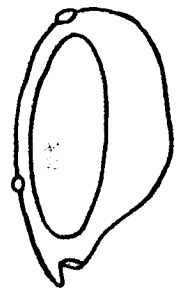
Key to the family of Vespoidea found in northern Thailand

Modified from Yamane, Ikudome and Terayama, 1999.

1. a) Wing presnt; inner margin of eye with notched ..... (2).
   b) Wing absent; inner margin of eye without notched; petiole (postiole) and/or petiolar node present ..... Formicidae

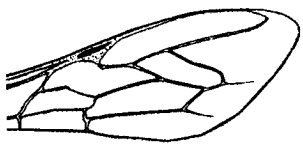


1a)

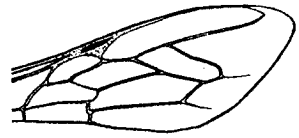


1b)

2(1a). a) Two submarginal cells ..... Scoliidae
   b) Three submarginal cells ..... Vespidae



2a)



2b)

Family Formicidae

Formicidae is the family of ants which is distinguished from the other aculeate families by the presence of a metapleural gland at posteroventral portion of propodeal side and of 1 or 2 metasomal segments (pedicel) between the alitrunk and gaster (Bolton, 1997). Recently 247 known ant species were recorded in Thailand and are distributed among 55 genera in 10 subfamilies (Jaitrong and Nabhitabhata, 2005). In this study, 33 genera of ants were recorded in 7 subfamilies: Aenictinae, Cerapachyinae, Dolichoderinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae.

Key to the subfamily of Formicidae found in northern Thailand
Modified from Bolton, 1997; Shattuck, 1999.

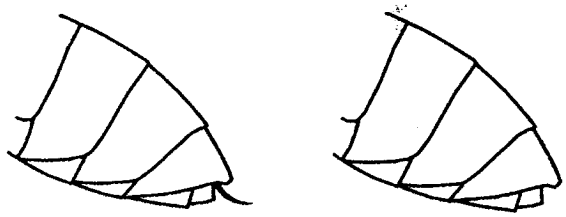
1. a) Mesosoma attached to the gaster by a single petiolar segment ..... (2).

   b) Mesosoma attached to the gaster by 2 petiolate segments ..... (5).

1a) 1b)

2(1a). a) Sting present at the tip of the gaster ..... (3).

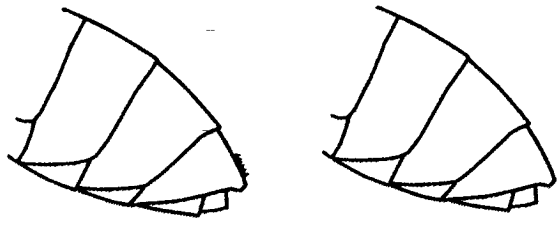
   b) Sting absent at the tip of the gaster; compound eyes present ..... (4).



2a) 2b)

3(2a). a) Upper surface of 7th abdominal segment with a row of small spines ..... Cerapachyinae

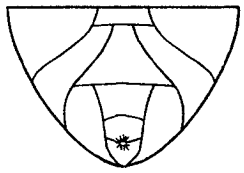
   b) Upper surface of 7th abdominal segment without a row of small spines ..... Ponerinae



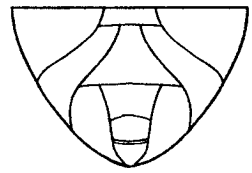
3a) 3b)

4(2b). a) Tip of the gaster with a circular opening ..... Formicinae

   b) Tip of the gaster with a slit-like opening ..... Dolichoderinae



4a)

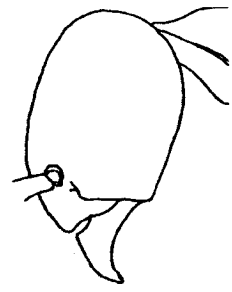


4b)

5(1b). a) Compound eyes present ..... (6).

b) Compound eyes and frontal lobes absent; antenna with 10 segments ..... Aenictinae

5a)



5b)

Subfamily Aenictinae

The subfamily Aenictinae contains a single genus, *Aenictus* which is distributed around the world: tropical and subtropical zones of the Ethiopian, Oriental and Australian regions (Bolton, 1997). All known species are army ants in tribe Aenictini which are about 2.5 to 4.0 mm in length. The compound eyes and the frontal lobes are absent. The antennae have 10 segments and the antennal sockets are completely visible when viewed from the front. The mesosoma is attached to the gaster by 2 distinct segments; the petiole and the postpetiole.

Tribe Aenictini

***Aenictus* Shuckard, 1840**

The workers of *Aenictus* in tribe Aenictini are small in size (less than about 4 mm). They are similar to some myrmicines. They lack the frontal lobes and compound eyes but the antennal sockets are completely visible. We found only one species, *Aenictus binghami* in this study.

***Aenictus binghami* Forel, 1900**

The length of a worker body is about 2.5 mm and black in color. Moreover, the compound eyes are completely absent. The antennae have 10 segments, including a scape and pedicel. The mandible has 7 teeth. The subpetiolar process, which is a

spine at the lower surface of the petiole, is small but strong with an obtusely angulate anteroventral corner (Figure 43).

Subfamily Cerapachyinae

These species are known throughout the world in tropical and subtropical areas (Bolton, 1997). A single genus, *Cerapachys* in tribe Cerapachyini was recorded in this area. A row of small spines (pygidial teeth) on the upper surface of the gaster are present and can be used to separate this subfamily from all other subfamilies of ants. The frontal lobes are reduced and the antennal sockets are completely present. The petiole has 1 segment and the gaster has a distinct constriction between first and second segments.

Tribe Cerapachyini

Genus *Cerapachys* Smith, 1875

These ants are mainly distributed in tropical and subtropical areas (Yamane, Ikudome and Terayama, 1999). One species, *Cerapachys sulcinodis* in tribe Cerapachyini was discovered in the study area. Genus *Cerapachys* is most often confused with ponerines but they have frontal lobes which are very narrow. The antennal sockets and compound eyes are completely visible. The lower surfaces of the gaster are smoother than the upper.

***Cerapachys sulcinodis* Emery, 1889**

They are slender ants. The worker's length is about 2.5 mm. Their body is red- brown to black with white hairs. The second gastric segment is longer than the length of the petiole and the first gastric segment combined. The shape of the mesosoma is the box-like and the tibia of the middle leg has 1 spur. The pygidial margin has the denticulate (Figure 44).

Figure 43 A worker of *Aenictus binghami* Forel, 1900.

Figure 44 A worker of *Cerapachys sulcinodis* Emery, 1889.

Subfamily Dolichoderinae

The species of Dolichoderinae can be found in most regions of the world (Yamane, Ikudome and Terayama, 1999). Four genera in tribe Dolichoderini were discovered in the study area, namely *Dolichoderus*, *Iridomyrmex*, *Philidris* and *Technomyrmex*. The compound eyes are usually present, but the ocelli are always absent. The antenna normally has 12 segments. The mesosoma is attached to the gaster by a single segmented petiole. The gaster is smooth without constrictions between the segments. The sting is absent and the tip of the gaster is slit-like opening without hairs. Members of subfamily Dolichoderinae is similar to those species of the subfamily Formicinae because both have a single segmented petiole and lack of sting. However, Dolichoderinae can be identified from Formicinae as the tip of the gaster has a slit-like opening while all formicines have a small circular opening.

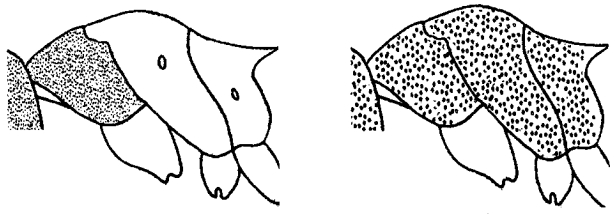
Key to the species of Dolichoderinae found in northern Thailand

Modified from Bolton, 1997; Shattuck, 1999.

1. a) Node of the petiole greatly reduced or absent; gaster with 5 plates on its upper surface ..... *Technomyrmex* (2).
   b) Node of the petiole present ..... 3.

1a) 1b)

2(1a). a) Head and thorax reddish brown, less finely punctuated ..... *T. kraepelini*
   b) Head and thorax black, more punctuated ..... *T. modiglianii*

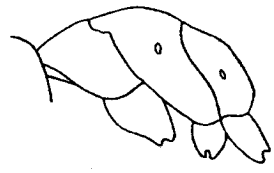


2a) 2b)

3(1b). a) Rear face of the propodeum generally concave ..... *Dolichoderus* (4).

b) Rear face of the propodeum usually rounded ..... 5.

3a)



3b)

4(3a). a) Head, alitrunk and petiole black ..... *D. thoracicus*

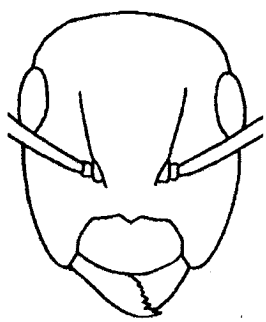
b) Head, alitrunk and petiole reddish brown ..... *D. tuberifer*

5(3b). a) Compound eyes placed relatively upward on the head, away from the clypeus and mandibles; rear margin of the head generally rounded as oval-shaped ..... *Iridomyrmex*

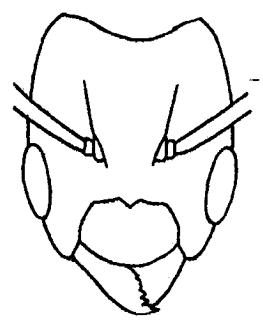
- Antenna without apical club; compound eyes small and less than half the size of the head; pronoturn and propodeum without spines ..... *I. anceps*

b) Compound eyes placed relatively downward on the head, closer to the clypeus and mandibles; rear margin of the head distinctly depressed or concave as heart-shape ..... *Philidris*

- Head, alitrunk, petiole and legs bright brown; mandibles with 10 brownish red teeth; gaster dark brown to black ..... *Philidris* sp.



5a)



5b)

Tribe Dolichoderini

Genus *Dolichoderus* Lund, 1831

The genus *Dolichoderus* contains the largest members of the subfamily Dolichoderinae. Two species in tribe Dolichoderini were found in this study site, namely *Dolichoderus thoracicus* and *Dolichoderus tuberifer*. The workers of them are less than about 5 mm. The body is often strongly sculptured and their antenna has 12 segments. Anterior hypostoma, which is underneath of the head near the base of the mandible, has slightly to well-developed rim. The pronoturn and/or propodeum have spines. If spines are absent, the rear face of the propodeum is often distinctly concave, but may be flat. The posterior margin of the propodeum varies from angulate to spine-shaped. The petiole is a distinct node which is not overhung by the gaster.

***Dolichoderus thoracicus* (F. Smith, 1860)**

This species is the common black ant. The total length of a worker's body is about 4 mm. Compound eyes are well developed and pronounced on the cranial surface. The head, alitrunk and petiole have coarse punctures. The mandible and legs are red-brown to black (Figure 45).

***Dolichoderus tuberifer* Emery, 1887**

The body length of a worker is about 2.5 mm. Compound eyes are present on the upper midline of the sides of the head. The head, alitrunk and petiole are red-brown with coarse punctures while the gaster is black, and oval-shaped. The legs are long and red (Figure 46).

Genus *Iridomyrmex* Mayr, 1862

Iridomyrmex in tribe Dolichoderini is distributed from India to China, Australia and New Caledonia (Shattuck, 1999). Their front margin of the clypeus is highly modified with convex areas while a central projection varies from strong to weak development. The compound eyes are located relatively high on the head and with a distance from the mandibles. Only one species, *Iridomyrmex anceps* was found in this study area.

***Iridomyrmex anceps* (Roger, 1863)**

The length of worker is about 3 mm with shiny black color. The head is large and rounded with large mandibles at the apex. The antenna has 12 segments and is longer than the head and prothorax combined. The geniculate does not have an apical

club. The compound eyes are small and less than half the size of the head. The pedicel has 1 segment and the node is an inverted-V-shaped crest. The pronoturn and propodeum do not have spines (Figure 47).

Genus *Philidris*, Shattuck 1992

This genus is separated from *Iridomyrmex* and is one of the smallest genus in this subfamily. *Philidris* in tribe Dolichoderini is distributed over the Oriental and Indo-Australian regions (Bolton, 1997). The front margin of the clypeus is highly modified with convex areas while a central projection has well developed. Occipital border of head is concave. The compound eyes are located relatively downward of the head, near the mandibles. Mandible has 10-12 teeth. Alitrunk is elongate in dorsal view and gaster is oval-shaped.

***Philidris* sp.**

The length of worker is about 1.5 mm. The shape of the head, including the mandible is heart-shaped. The head to petiole and legs are bright brown while the gaster is dark brown to black. Mandibles are brownish red with 10 teeth and the antennal scape is short. The compound eyes are black in color and less than half-length of the head. The pronoturn and propodeum do not have spines. A metanotal groove is present between the mesonotum and metanotum (Figure 48).

Genus *Technomyrmex*, Mayr 1872

Tribe Dolichoderini of *Technomyrmex* occur from Africa, to southern Asia and Australia (Bolton, 1997). The antenna has 12 segments. Anterior margin of clypeus is convex. The metanotum has a groove which is incised. The upper surface of the propodeum is shorter than the lower surface. The petiolar node is absent. The first segment of the gaster projects forward and partially or completely conceals the petiole. The petiole is flat and the gaster has 5 segments on its upper surface.

***Technomyrmex kraepelini* Forel, 1905**

The length of worker body is about 3 mm. Head and thorax are reddish brown and covered with fine punctuate. The head is longer than wide. The mesosoma and petiole are black and lack a dorsal spine. The gaster is brown to black. Compound eyes are small and positioned at midline of head (Figure 49).

***Technomyrmex modiglianii* Emery**

The worker body is about 2.5 mm in length. Their bodies are black with more punctuated on the head and thorax, and the head with mandibles is heart-shaped. The hair on the pronotum, mesonotum and gaster is short and white in color. The pronoturn and propodeum do not have spines and a metanotal groove is present. Compound eyes are larger than those in *Technomyrmex kraepelini* and positioned at the middle of the head (Figure 50).

Figure 45 A worker of *Dolichoderus thoracicus* (F. Smith, 1860).

Figure 46 A worker of *Dolichoderus tuberifer* Emery, 1887.

Figure 47 A worker of *Iridomyrmex anceps* (Roger, 1863).

Figure 48 A worker of *Philidris* sp.

Figure 49 A worker of *Technomyrmex kraepelini* Forel, 1905.

Figure 50 A worker of *Technomyrmex modiglianii* Emery, 1900.

Subfamily Formicinae

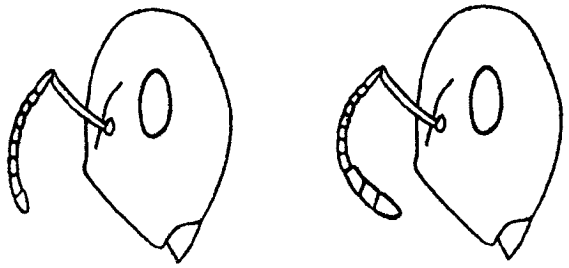
This subfamily is very varied in size and shape. Species of formicines are found worldwide with about 3,700 species in 49 genera (Shattuck, 1999). Seven genera in 3 tribes: Camponotini, Oecophyllini and Plagiolepidini were recorded in this thesis. They are similar to those species of the subfamily Dolichoderinae as both subfamilies have a petiole and do not have a sting. However, formicines are distinguished from dolichoderines as the tip of the gaster has a circular opening whereas all dolichoderines have a slit-like opening. Ocelli and compound eyes of the worker are present. The mesosoma is attached to the gaster by a petiole. The gaster is smooth, without constrictions between the segments.

Key to the species of Formicinae found in northern Thailand

Modified from Bolton, 1997; Shattuck, 1999.

1. a) Antennae with 10 segments (including the scape) ... (2).

   b) Antennae with 12 segments ..... (3).



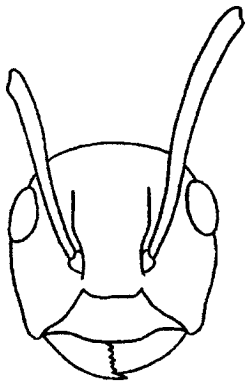
1a) 1b)

2(1a). a) Scapes longer than the rear margin of the head by more than two-thirds of their length or equal; pronotum longer than wide from dorsal view ..... *Anoplolepis*

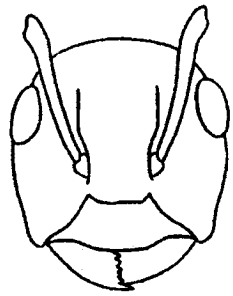
   - Gaster usually darker than head and thorax; erect hairs present on head and gaster but lacking on dorsum of mesosoma; propodeum and petiole without spines ..... *A. gracilipes*

   b) Scapes longer than the rear margin of the head less than one-quarter of their length from dorsal view .... *Plagiolepis*

   - Body with light brownish to black; petiole with an inverted-V-shaped crest ..... *Plagiolepis* sp.



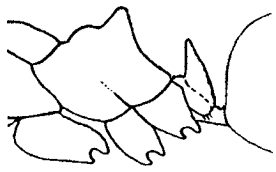
1a)



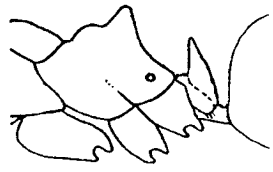
2b)

3(1b). a) Metapleural gland opening absent; pronotum and mesonotum with randomly placed of soft hairs ..... (4).

b) Metapleural gland opening present; 3-5 pairs of large, stout, dark hairs present on pronotum and mesonotum ..... *Paratrechina*



3a)



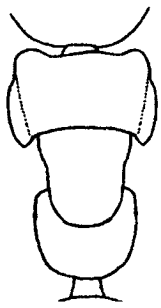
3b)

- Scapes and legs very long; whitish erect setae apparent; head, thorax, petiole, and gaster dark brown to blackish ..... *P. longicornis*

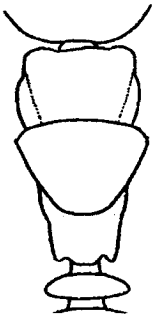
4(3a). a) Petiole long; node rounded or absent; mesonotum constricted and narrower than the pronotum and propodeum from top view ..... *Oecophylla*

- Body with light to dark brown to orange; petiole very slender; the mesosoma more domed ..... *O. smaragdina*in

b) Node of the petiole present; mesonotum wider than the pronotum and propodeum from top view ..... (5).



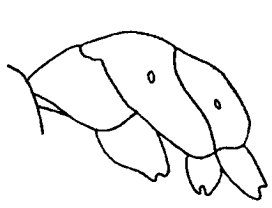
4a)



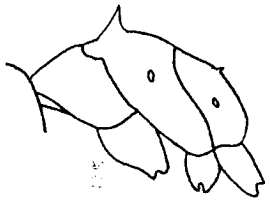
4b)

5(4b). a) Spines absent from the mesosoma and petiole ..... *Camponotus* (6).

b) Spines usually present on the mesosoma and/or petiole ..... *Polyrhachis* (11).



5a)



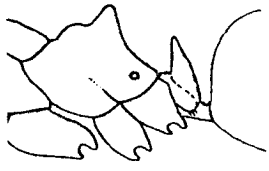
5b)

6(5a). a) Head brown to black ..... (7).

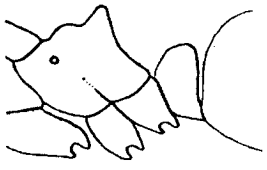
b) Head reddish ..... *C. singularis*

7(6a). a) Apically node of the petiole usually acute in lateral view ..... (8).

b) Apically node of the petiole usually round ..... *C. camelinus*



7a)



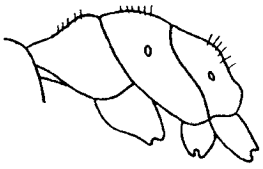
7b)

8(7a). a) Body is a single color ..... (9).

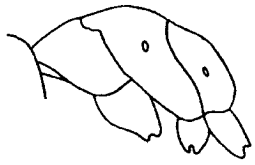
b) Body is bicolor ..... (10).

9(8a). a) More erect hairs on mesosoma and metasoma ..... *C. leonadi*

b) Less or absent erect hairs on mesosoma and metasoma ..... *C. rufoglaucus*



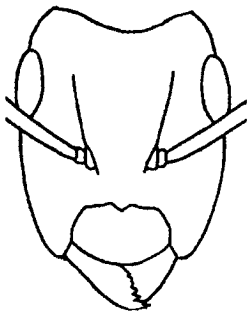
9a)



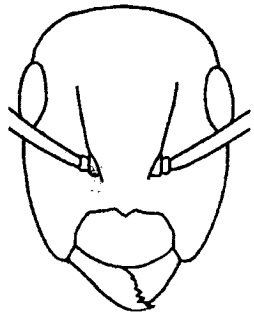
9b)

10(8b). a) Body is fat; compound eye is black; head of major with mandibles as heart-shaped ..... *Camponotus* sp.1

b) Body is long and slender; compound eye with red to reddish brown; head of major with mandibles as oval-shape ..... *Camponotus* sp.2



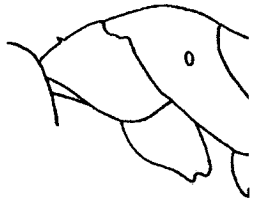
10a)



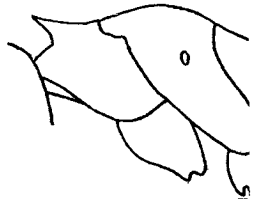
10b)

11(5b). a) Pronotal spines absent or node ..... (12).

b) Pronotal spines present ..... (13).



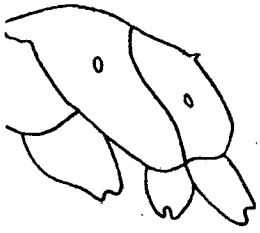
11a)



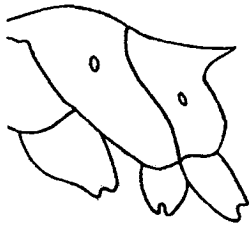
11b)

12(11a). a) Propodeal spines absent or node ..... *P. flavicornis*

b) Propodeal spines long ..... *P. hippomanes*



12a)



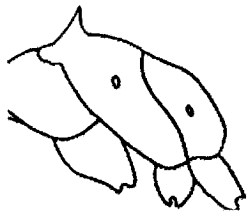
12b)

13(11b). a) Propodeal spines with laterally curved as hook ..... (14).

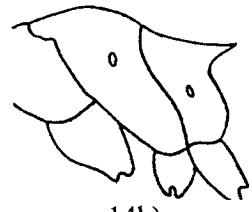
b) Propodeal spines without hook ..... (15).

14(13a). a) Mesonotum spines present; propodeal spines absent ..... *P. bihamata*

b) Mesonotum spines absent; propodeal spines present ..... *P. furcata*



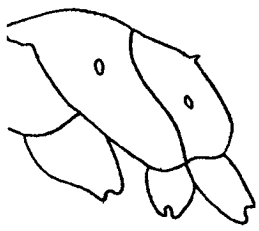
14a)



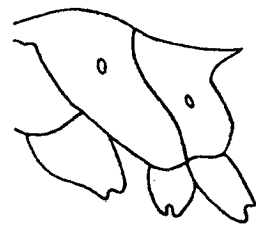
14b)

15(13b). a) Propodeal spine absent, but if present, limited to near the propodeal angle ..... (16).

b) Propodeal spine long ..... (18).



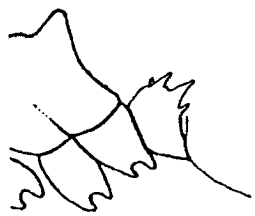
15a)



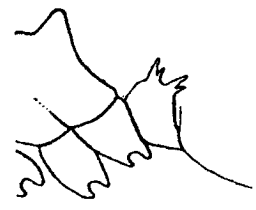
15b)

16(15a.) a) Distance between each pair of petiolar spines wider ..... (17).

b) Distance between each pair of petiolar spines narrow or near ..... *Polyrhachis* sp.2



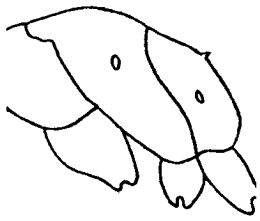
16a)



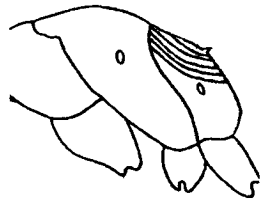
16b)

17(16a). a) Metasoma without longitudinal line ..... *P. proxima*

b) Metasoma with longitudinal line ..... *Polyrhachis* sp.1



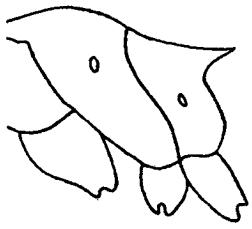
17a)



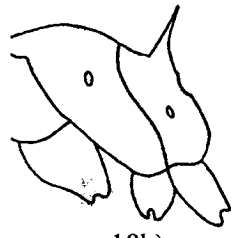
17b)

18(15b). a) Propodeal spines directed backward ..... (19).

b) Propodeal spines directed straight ..... (21).



18a)



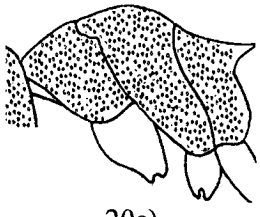
18b)

19(18b). a) Gaster black ..... (20).

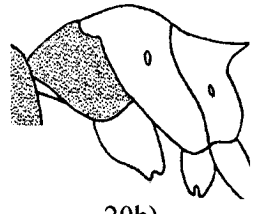
b) Gaster red ..... *P. muelleri*

20(19a). a) Head to metasoma covered with coarse punctures ..... *P. armata*

b) Head to metasoma covered with fine punctures or smooth ..... *P. abdominalis*



20a)



20b)

21(18b). a) Gaster covered with golden hair ..... *P. dives*

b) Gaster not covered with hair ..... *P. tibialis*

Tribe Camponotini

Genus *Camponotus* Mayr, 1861

They are found world-wide (except polar region) (Shattuck, 1999). *Camponotus* is one of the largest ants in tribe Camponotini. Species vary greatly in size and shape, ranging from 5-14 mm in overall length. This genus is identified from other genera as the distinct gap between the rear margin of the clypeus and the antennal sockets is very long. Furthermore, hairs on the top of the mesosoma and gaster are golden-colored. The upper plate of the first gastral segment is less than one-half the total length of the gaster. Our study found 6 species within this genus, namely *Camponotus camelinus*, *C. leonadi*, *C. rufoglaucus*, *C. singularis*, *Camponotus* sp.1 and *Camponotus* sp.2.

***Camponotus camelinus* (F. Smith, 1857)**

Camponotus camelinus has black body. They are medium-sized ants which are about 8 mm in length and covered with punctuate. Workers have long legs and a slender body. Spines on thorax and petiole are absent while erect hairs are the present on petiole and gaster. Petiolar node is an inverted-U-shaped crest (Figure 51).

***Camponotus leonadi* Emery, 1889**

Camponotus leonadi has a medium-sized body about 8 mm. Their body is blackish. In major worker, the head is bigger than a minor worker, and the head of a major worker has heart-shaped mandibles. They have long slender body. Spines on the propodeum are absent while erect hairs are present on the mesosoma and metasoma. The petiole is an inverted-V-shaped crest. The fore legs are stronger than the other legs (Figure 52).

***Camponotus rufoglaucus* (Jerdon, 1851)**

They are medium-sized ants with about 8 mm in length. In a major worker, the head has heart-shaped mandibles and is bigger than a minor worker. A worker has long slender body. Spines on the propodeum are absent. The petiolar node is an inverted-V-shaped crest. Although *C. rufoglaucus* are similar to *C. leonadi* in body color, *C. rufoglaucus* can be distinguished by the mesosoma and metasoma which have less erect hairs or are absent (Figure 53).

***Camponotus singularis* (F. Smith, 1858)**

They are medium-sized ants and about 8 mm long. Workers have long legs and slender body. Spines on the thorax are absent while erect hairs are present on the petiole and gaster. The petiole is an inverted-U-shaped crest. Although *C. singularis* are similar to *C. camelinus* with black body, *C. singularis* is distinguished by the head color which is dark brown to red-brown (Figure 54).

***Camponotus* sp.1**

They are medium-sized ants and about 6 mm long. The head, mesosoma, legs and petiole are bright brown while the mandible and gaster are black. The head of major worker including mandible is heart-shaped. The mesosomal surface is smooth. The compound eyes are elongated on the upper midline of head. Spines on the propodeum are absent while erect hairs are present on the gaster. The petiole is an inverted-V-shaped crest (Figure 55).

***Camponotus* sp.2**

They are medium-sized ant and about 6 mm in length. Workers have long legs and more slender than *Camponotus* sp.1. The head, mesosoma, legs and petiole are reddish brown while the gaster is black in color. Mesosomal surface is smooth. The compound eyes are elongated on the upper midline of the head. Spines on the propodeum are absent while erect hairs are present on gaster. The petiole is an inverted-V-shaped crest (Figure 56).

Genus *Polyrhachis* F. Smith, 1857

Polyrhachis in tribe Camponotini are found throughout the Old World tropics (Shattuck, 1999). They were found 12 species which is one of the larger groups of ants in the north of Thailand. The major workers are black and about 5-10 mm in total length. Most species of genus *Polyrhachis* are easily recognized with spines on the mesosoma and the top of the petiole but sometimes the mesosoma is smooth. Their mandible have 7 teeth. The length of the first gasteral segment is one-half of the total length of the gaster. The area above the hind leg is smooth and lacks an opening.

***Polyrhachis abdominalis* F. Smith, 1858**

The length of worker body is about 8 mm. The body is red-black with fine pits. The anterior margin of the clypeus is black and rounded. The compound eyes are reddish black and located on the upper midline of the head. The prothorax has a pair of

spines, directed obliquely forwards. The prothorax, metathorax and petiole are slightly convex and both have a divergent spine at the apex (Figure 57).

***Polyrhachis armata* (Le Guillou, 1842)**

The length of a worker body is about 9 mm. Althougth *Polyrhachis armata* is similar to *P. abdominalis* in color and shape, *P. armata* can be distinguished by thier surface which is more punctured than *P. abdominalis*, and gaster are brown (Figure 58).

***Polyrhachis bihamata* (Drury, 1773)**

Total length of a worker is about 7 mm. The color of the head and second gaster to the last gaster are black while the thorax, the node of petiolar and the first gaster are red brown to black, including the coxa to the femur of the legs. The antennae are long slender with 12 segments. The compound eyes are moderately large. The petiole has 2 strong spines directed laterally as hooks while the pronotum and mesonotum have a pair of curved spines, shorter than the spines on the petiole (Figure 59).

***Polyrhachis dives* F. Smith, 1857**

Total length of a workers is about 5 mm. They are black in color. The mesosoma is covered with coarse punctures and the dorsal surface of the mesosoma is arched. The dorsolateral margins do not have a carina. The pronotum and propodeum have a pair of well-developed short spine directed laterally. The spine on the mesonotum is absent while the petiole has a pair of long lateral spines and a pair of small median cornicles (little horn). The petiolar spines are longer than those of a mesosoma. The gaster is covered with golden hairs (Figure 60).

***Polyrhachis flavicornis* F. Smith, 1857**

Workers are about 5 mm in body length and metallic dark brown to black in body color. The body of this species is not covered with hairs but the head and mesosoma are covered with coarse punctures. The mesosoma do not have a pair of spines while the petiole has a pair of short lateral spines (Figure 61).

***Polyrhachis furcata* F. Smith, 1858**

Total length of a worker is about 5 mm. Body color is red-black with white hairs. Mesosoma and petiole are covered with coarse punctures. Pronotum, propodeum and petiole has a pair of well-developed spine, directed laterally but petiolar spines are lateral hook, which are longer than those of mesosoma (Figure 62).

***Polyrhachis hippomanes* F. Smith, 1861**

The worker body is about 5 mm in lenght. Their body is metallic dark brown to black while the legs are reddish brown. This species lacks hairs on the body. The head and mesosoma are covered with coarse punctures. The pronotum do not have a pair of spines while the propodeum has a pair of well-developed spines, directed laterally. Furthermore, the petiole has a pair of short lateral spines, which are as long as those of mesosoma (Figure 63).

***Polyrhachis muelleri* Forel, 1893**

The length of body is about 7 mm in worker. The head to the petiole is red-black while the gaster is red-brown, including compound eyes. The head, thorax, and petiole have fine punctures. The anterior margin of the clypeus is rounded. The pronotum has 2 long straight spines, directed obliquely forwards. The mesosoma and petiole have a pair of well-developed spines, directed laterally. This species is similar to *Polyrhachis abdominalis* but they can be distinguished by color of their gaster which is red-brown (Figure 64).

***Polyrhachis proxima* Roger, 1863**

The worker body is about 8 mm long. Their body is ferruginous black while the compound eyes are red-black. Their body is not covered with coarse punctures but they are covered by golden hairs. Pronotum has 2 long straight spines, directed obliquely forwards. The pronotum does not have a pair of spines but they have a pair of small horns. The petiole has a pair of well-developed straight spines directed laterally (Figure 65).

***Polyrhachis tibialis* F. Smith, 1858**

The worker body is about 6 mm in length. Their bodies are red-brown while compound eyes are red-black. They are covered with coarse punctures and with a fine short golden pubescent pile. Mesosoma has a short stout spine at each of the anterior angles, and a much longer one at the posterior angles. The petiole has a long acute spine curving backwards and outward over the abdomen on each side (Figure 66).

***Polyrhachis* sp.1**

The length of worker body is about 6 mm. Their body is red-black while the compound eyes are red-brown. Mesosoma has two long straight spines on pronotum, directed obliquely forwards and 2 curve denticles on the propodeum. Petiolar spines

are present and straight spines. Their body is covered with white hairs. Even though this species is similar to *Polyrhachis proxima* in body color, *Polyrhachis* sp.1 differed from *P. proxima* by longitudinal lines on the propodeum (Figure 67).

***Polyrhachis* sp.2**

Worker body is about 5 mm in lenght. Their body is black while the compound eyes are reddish-black. The thorax has 2 long straight spines on the pronotum, directed obliquely forwards and 2 curved denticles on the propodeum. The petiole has a pair of well-developed straight spines. Their gaster is covered with white hairs. Though this species is similar to *Polyrhachis* sp.1 in body color, *Polyrhachis* sp.2 can be distinguished from *Polyrhachis* sp.1 by longitudinal lines on the protonotum and metanotum (Figure 68).

Tribe Oecophyllini

Genus *Oecophylla* F. Smith, 1860

Oecophylla are large arboreal ants from the Africa, Asian, and Australian tropics (Bolton, 1997). Only one species, *Oecophylla smaragdina* in tribe Oecophyllini was found in this study. The mandibles have 10 or more teeth. The fourth tooth (counting from the tip) is longer than the third and fifth teeth. The node of the petiole is rounded. The mesonotum is constricted and narrower than the pronotum and propodeum from a top view. The area above the hind leg is smooth and without a small opening. The scale of the petiole is low and rounded, without distinct front, top or rear faces.

***Oecophylla smaragdina* (Fabricius, 1775)**

Their body length is about 8 mm. The head to petiole is light to dark brown to orange while the gaster is darker than the other segments. The antenna is very long with 12 segments. The mandible and clypeus are very large, long and convex, but not distinctly carinated. Their alitrunk is more domed but the petiole is very slender and round. The compound eyes are large and positioned at middle line of the head (Figure 69).

Tribe Plagiolepidini

Genus *Anoplolepis* Santschi, 1914

Genus *Anoplolepis* is widespread in southeast Asia and the Pacific (Shattuck, 1999). *Anoplolepis* is recognizable by its very long body, pale yellow legs, and 11-segmented antennae. The scapes are very long, surpassing the rear margin of the head

by two-thirds of their length or more. The position of the compound eyes is at the midline of the head, and ocelli are absent. The mandibles have 6-9 teeth. They are most similar to some species of *Camponotus* (subfamily Dolichoderinae) but they are easily distinguished from *Camponotus* by the number of antennal segments (*Camponotus* has 12 segments) and the circular opening at the tip of the gaster. One species, *Anoplolepis gracilipes* in tribe Plagiolepidini was found in this study.

***Anoplolepis gracilipes* (F. Smith, 1857)**

Anoplolepis gracilipes has a brownish body color, and is weakly sclerotized. They are small to medium-sized ants and about 3.5 mm in length. They are notable for its remarkably long legs and antennae. Workers have slender body with the gaster usually darker than the head and thorax. Spines on the propodeum are absent while the metanotal groove is present. One node (petiole), which is an inverted-U-shaped crest, is present. Erect hairs are present on the head and gaster, but lacking on the dorsum of the mesosoma. The tip of the gaster is often surrounded by a ring of short hairs (Figure 70).

Genus *Lepisiota* Santschi, 1926

The genus *Lepisiota* is found from Africa to Asia (Bolton, 1997). In this study, only one species in tribe Plagiolepidini was discovered. They are recognized by 11 segments of antennae. The compound eyes are well developed while ocelli are present but may be reduced. The apical margin of mandibles is oblique, dentate, and projected by clypeus. The alitrunk is constricted in the mesonotal region. The propodeum is swollen and has 2 toothlike processes. The petiole has 1 segment. The dorsal margin of the propodeum and petiole is bispinose or bidentate. The circular opening of the tip of the gaster is often surrounded by a fringe of hairs.

***Lepisiota* sp.**

The worker body is about 2 mm in length. Their head is dark brown to black. The thorax, legs and petiole are bright brown while the gaster is metallic black. The compound eyes are large and located at the middle line of the head. The antenna is longer than the alitrunk and petiole combined. The mesosoma is attached to the gaster by a single segment, the petiole. A sting is absent, and the tip of the gaster has a small circular opening that is usually surrounded by a ring of short hairs (Figure 71).

Genus *Paratrechina* Motschulsky, 1863

This genus in tribe Plagiolepidini occurs in North and South America, Europe, Africa, and the east through India, China and the south to Indonesia and Australia (Shattuck, 1999). Only one species, *Paratrechina longicornis* was found in this study area. They are identified by large and distinctive pairs of erect hairs on the upper surfaces of the pronotum and mesonotum.

***Paratrechina longicornis* (Latreille, 1802)**

This species is easily identified by a long antennal scape, long legs, and white erect setae. Their body size is small to medium between 2 - 3 mm. Their body is dark brown to black in color. The antenna has 12 segments without a club. They have only one petiole between the propodeum and the gaster, and a sting is absent. The compound eyes are elliptical, and located close to the posterior border of the head. The petiole is wedge-shaped with a broad base and inclined forward (Figure 72).

Genus *Plagiolepis* Mayr, 1861

Genus *Plagiolepis* occurs in southern Europe, Russia, Africa and in the east to India, Korea, and in the south to Asia and Australia (Shattuck, 1999). Only one species, *Plagiolepis* sp. in tribe Plagiolepidini is recorded from this study area. Members of the genus *Plagiolepis* are small ants with a stout body. The antennae have 11 segments and the scapes are shorter than one-quarter of head length. The propodeum is round and lacks teeth or protuberances.

***Plagiolepis* sp.**

Total length of workers is about 2.5 mm. The body color is light brown to black and the gaster is covered with erect hairs. This species has short antennal scapes which exceed the posterior margin of the head by less than the length of the second antennal segment. The compound eyes are elliptical shape on the upper midline of the head. The mesonotal groove is present while spines on body are absent. The petiole is an inverted-V-shaped crest (Figure 73).

Figure 51 A worker of *Camponotus camelinus* (F. Smith, 1857).

Figure 52 A worker of *Camponotus leonadi* Emery, 1889.

Figure 53 A worker of *Camponotus rufoglaucus* (Jerdon, 1851).

Figure 54 A worker of *Camponotus singularis* (F. Smith, 1858).

Figure 55 A worker of *Camponotus* sp.1.

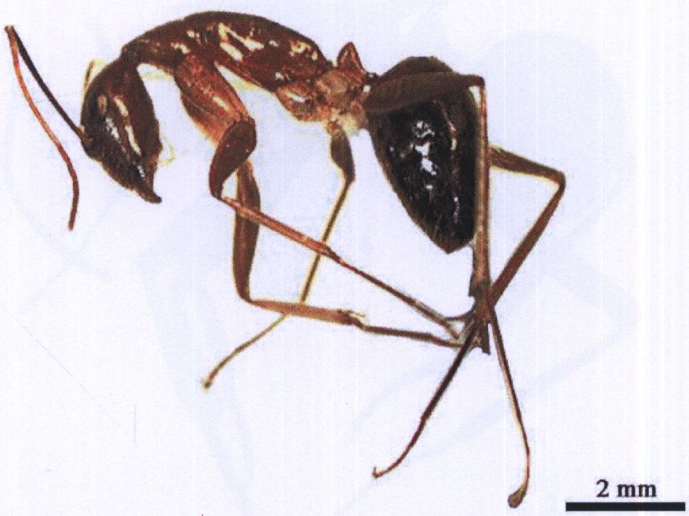


Figure 56 A worker of *Camponotus* sp.2.

Figure 57 A worker of *Polyrhachis abdominalis* F. Smith, 1858.

Figure 58 A worker of *Polyrhachis armata* (Le Guillou, 1842).

Figure 61 A worker of *Polyrhachis flavicornis* F. Smith, 1857.

Figure 62 A worker of *Polyrhachis furcata* F. Smith, 1858.

Figure 63 A worker of *Polyrhachis hippomanes* F. Smith, 1861.

Figure 64 A worker of *Polyrhachis muelleri* Forel, 1893.

Figure 65 A worker of *Polyrhachis proxima* Roger, 1863.

Figure 66 A worker of *Polyrhachis tibialis* F. Smith, 1858.

Figure 67 A worker of *Polyrhachis* sp.1.

Figure 68 A worker of *Polyrhachis* sp.2.

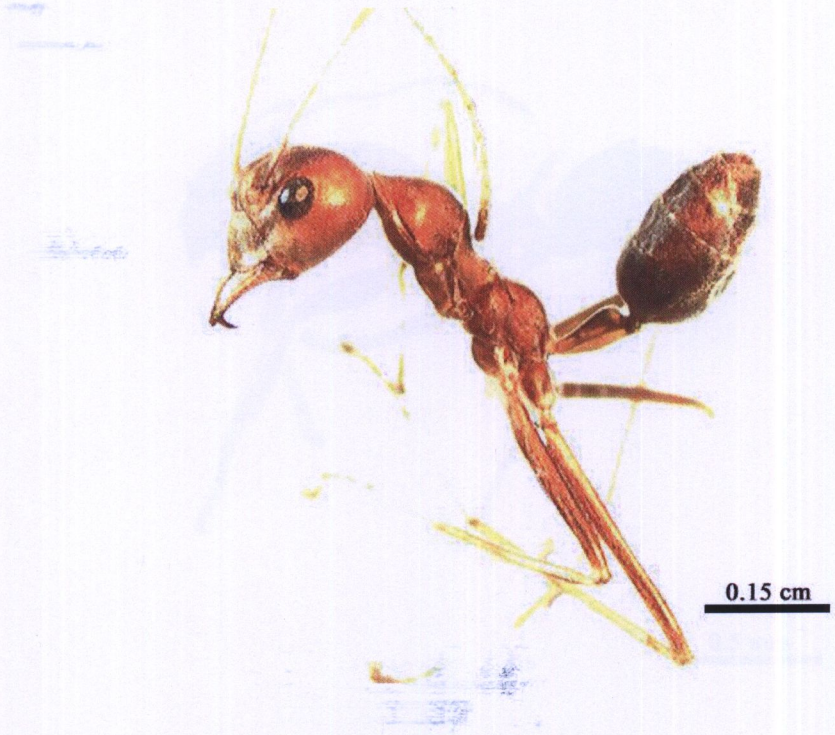


Figure 69 A worker of *Oecophylla smaragdina* (Fabricius, 1775).

Figure 70 A worker of *Anoplolepis gracilipes* (F. Smith, 1857).

Figure 71 A worker of *Lepisiota* sp.

Figure 72 A worker of *Paratrechina longicornis* (Latreille, 1802).

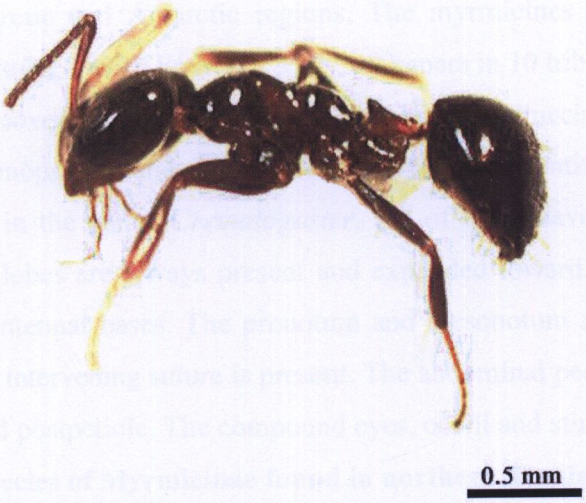


Figure 73 A worker of *Plagiolepis* sp.

Subfamily Myrmicinae

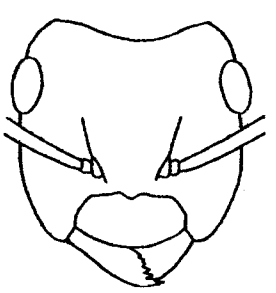
Subfamily Myrmicinae is distributed throughout the world in all major habitats, except the Arctic and Antarctic regions. The myrmicines are the largest subfamily of ants (Shattuck, 1999). From our study, 12 genera in 10 tribes: Cataulacini, Crematogastrini, Formicoxenini, Melissotarsini, Meranoplini, Myrmecinini, Pheidolini, Pheidologetonini, Solenopsidini and Tetramoriini have been identified. The most abundant species was in the genus *Crematogaster*. All of them have 12-segmented antenna. Their frontal lobes are always present and expanded towards and alongside the inner part of the antennal bases. The pronotum and mesonotum are fused into a single plate, even if an intervening suture is present. The abdominal pedicel consists of 2 segments; petiole and postpetiole. The compound eyes, ocelli and sting are present.

Key to the species of Myrmicinae found in northern Thailand

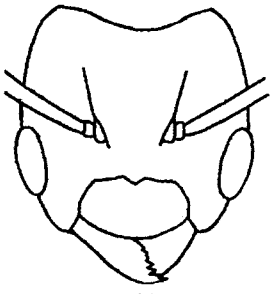
Modified from Bolton, 1997; Shattuck, 1999.

1. a) Antennal scrobe present under compound eyes ..... *Cataulacus*
   - Body covered with coarse punctures ..... *C. granulatus*

   b) Antennal scrobe absent, but if present upper compound eyes ..... (2).



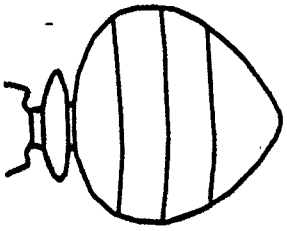
1a)



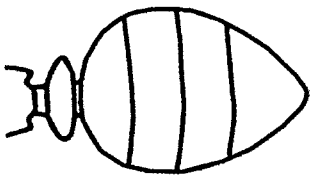
1b)

2(1a). a) Gaster with heart-shaped ..... *Crematogaster* (3)

b) Gaster with oval-shaped ..... (5).



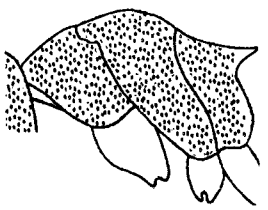
2a)



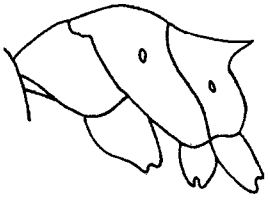
2b)

3(2a). a) Mesosoma covered with coarse punctures ..... (4).

b) Mesosoma covered without coarse punctures ..... *C. coriaria*



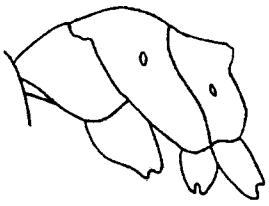
3a)



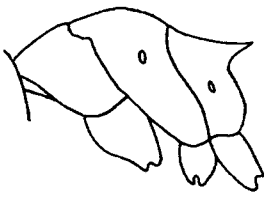
3b)

4(3a). a) Propodeal spines round ..... *C. difformis*

b) Propodeal spines acute ..... *C. rogenhoferi*



4a)

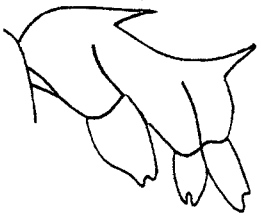


4b)

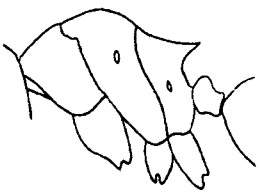
5(2b). a) Mesosomal spines with 2 pairs ..... (6).

b) Mesosomal spines with less than 2 pairs or absent; propodeal spines absent ..... *Pristomyrmex*

- Subpetiolar process absent ..... *P. punctatus*



5a)

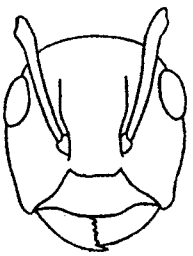


5b)

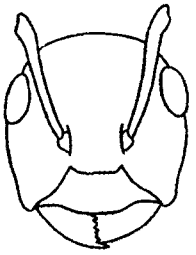
6(5a). a) Antennal scrobe obvious present or deep ..... (7).

b) Antennal scrobe unclear or shallow; antenna with 9 segments ..... *Meranoplus*

- Propodeal spines sharp and long ..... *M. bicolor*



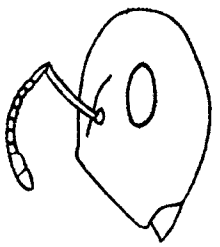
6a)



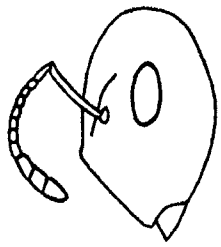
6b)

7(6a). a) 2 apical antennal segments form a club ..... (8).

b) 3 apical antennal segments form a club ..... (9).



7a)



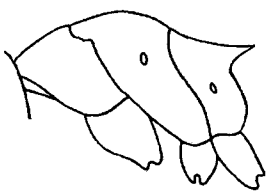
7b)

8(7a). a) Propodeal spines present ..... *Pheidologeton*

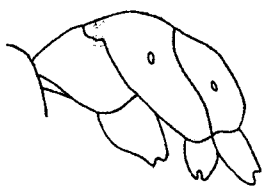
- Metanotal groove deeply incised ..... *P. diversus*

b) Propodeal spines absent ..... *Solenopsis*

- Antennal club longer than 3rd to 9th antennal segments combined ..... *S. geminata*



8a)

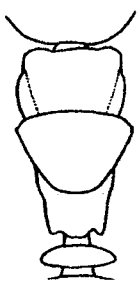


8b)

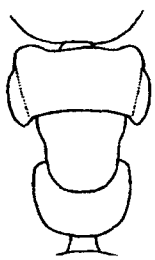
9(7b). a) Thorax with box-shaped ..... *Rhopalomastix*

- Spines on mesosoma and petioles absent ..... *R. janeti*

b) Thorax without box-shaped ..... (10).



9a)

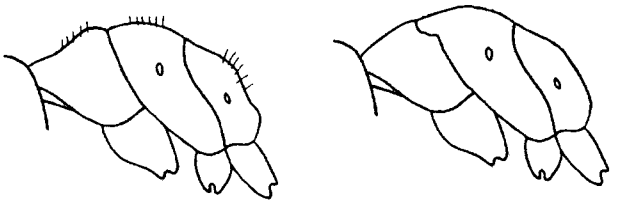


9b)

10(9b). a) Hairs on mesosoma present ..... (11).

b) Hairs on mesosoma absent ..... *Cardiocondyla*

- Anterior margin of postpetiole concave ..... *C. wroughtonii*

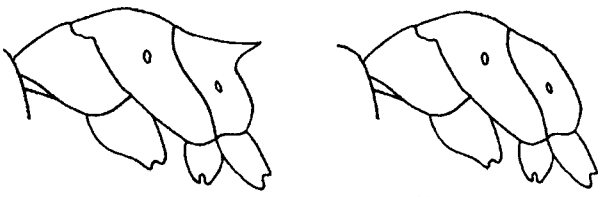


10a) 10b)

11(10a). a) Propodeal spines present ..... (12).

b) Propodeal spines absent ..... *Monomorium*

- Compound eyes large on the middle of head; metanotal groove present ..... *M. destructor*

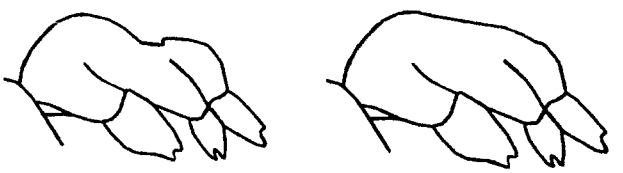


11a) 11b)

12(11a). a) Pronotum higher than other mesosomal segments; pronotal spine absent ..... *Pheidole*

- Pronotum and mesonotum usually separately raised ..... *P. plagiaria*

b) Mesosoma slightly curved or nearly straight ..... (13).



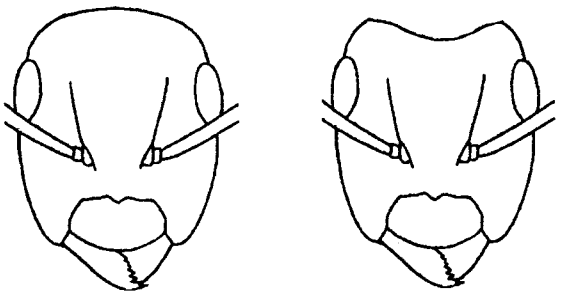
12a) 12b)

13(12b). a) Lower surface of the petiole rounded from side to side ..... *Tetramorium*

- Head without curve ..... *T. flavipes*

b) Lower surface of the petiole narrowed into a keel-like ridge ..... *Rhoptromyrmex*

- Head with curve ..... *R. wroughtoni*



13a) 13b)

Tribe Cataulacini

Genus *Cataulacus* F. Smith, 1853

Cataulacus in tribe Cataulacini is widespread in Africa and Asia (Bolton, 1997). Only one species, *Cataulacus granulatus* was reported in our study. This genus is similar to genus *Polyrhachis* but *Cataulacus* has 2 segments of the petiole. The antennae have 11 segments. The scape and the basal joint of the flagellum of antennae, tibiae and tarsi of the legs are reddish. Spines on the metanotum are sharp, long and diverged.

***Cataulacus granulatus* (Latreille, 1802)**

The length of a worker is about 4 mm. Their body is black while the scape, basal joint of antennae, tibiae and tarsi are red and covered with coarse punctures. Metanotal spines are sharp, long and diverge. The gaster is covered with white hairs (Figure 74).

Tribe Crematogastrini

Genus *Crematogaster* Lund, 1831

The head is subrectangular or oval with a convex curve. The antennae have 11 segments. The mandibles are small and the compound eyes are medium size and located behind the midline of the head. The anterior clypeal margin is straight or widely curved and convex while the frontal carinae and mesosoma are short. The petiole is low and rounded and lacks a node on its upper surface. The postpetiole is attached to the upper surface of the gaster. The propodeal spines vary from absent to long, and the petiole is flat ventrodorsally without a node. The attachment of the postpetiole to the gaster and heart-shaped gaster is highly distinctive and can be used as distinguishing criterion. *Crematogaster* in tribe Crematogastrini is an ecologically

diverse genus of ants found worldwide (Bolton, 1997). Three species of genus *Crematogaster* were found in the north of Thailand in our study.

***Crematogaster coriaria* Mayr, 1872**

The length of a worker is 3 mm in average. Their body is red-black to black while the scape, basal joint of antennae, tibiae and tarsi are red. There are no coarse punctures on body. The metanotal spines are sharp, long and diverged. The petiole and postpetiole are very long. The gaster is heart-shape, and covered with white hair (Figure 75).

***Crematogaster difformis* F. Smith, 1857**

The length of a *Crematogaster difformis* worker is about 6 mm. Their body is red-black to black while the tarsi are red. The head and pronotum are covered with coarse punctures. Spines on the metanotum are blunt and short. The petiole and postpetiole are as long as the second gaster tergum. The gaster is heart-shape with white hairs (Figure 76).

***Crematogaster rogenhoferi* Mayr, 1879**

The length of a *Crematogaster rogenhoferi* worker is approximately 5 mm. The head to postpetiole and legs are red-orange while the gaster is black. The head and mesosoma are covered with coarse punctures. Metanotal spines are sharp, long and diverged. The petiole and postpetiole are half of the gaster in length (Figure 77).

Tribe Formicoxenini

Genus *Cardiocondyla*, Emery 1869

Cardiocondyla in tribe Formicoxenini is widespread in Australia and Asia (Bolton, 1997). Only one species, *Cardiocondyla wroughtonii* was reported in this study. The total length of workers is approximately 3 mm. The rectangular head has a rounded occipital border. The triangular mandible usually has 5 teeth. The pronotum, mesonotum and propodeum are continuously flat to a weakly arched surface. The metanotal groove is shallow, but absent in some species. The propodeal spine varies in length. The peduncle and subpetiolar processes are slender. The postpetiole is wider than, and much broader than the petiole. Mid and hind legs are without tibial spurs. The combination of these characters can distinguish these ants from one another.

***Cardiocondyla wroughtonii* (Forel, 1890)**

The worker length is approximately 2 mm. The head, mesosoma, petiole and postpetiole are bright brown but the gaster is dark brown. The compound eyes are blackish, and relatively large and convex. The head is rectangular and the occipital border is almost straight, but slightly concave in the middle. Five teeth are arranged on the mandible. The promesonotal area is depressed and almost straight. The metanotal groove is distinct. The dorsal propodeum is roundly convex and higher than other segments. The propodeal spines are longer than their basal width. The petiole has a long peduncle and high node while the anterior margin of postpetiole is concave (Figure 78).

Tribe Melissotarsini

Genus *Rhopalomastix* Forel, 1900

Rhopalomastix is found in India, Sri Lanka and Australia (Shattuck, 1999). Only one species, *Rhopalomastix janeti* in tribe Melissotarsini was recorded from this study. The antennae have 10 segments, and the apical 2 segments of the antenna form a club. The clypeus margin has pairs of elongate hairs. The compound eyes are medium and situated on the midline of the sides of the head. The propodeum is rounded without spines or teeth.

***Rhopalomastix janeti* Donisthorpe, 1936**

The worker length is about 2 mm. The head to postpetiole is red-black in color while the gaster is darker than other segments. Their bodies are covered with black hairs. Their head is wider than long. The mesosoma is longer than the total length of gaster. The compound eyes are small and located on the midline of the sides of the head. Mesosomal and petiolar spines are absent. The petiole has arched nodes on their upper surfaces (Figure 79).

Tribe Meranoplini

***Meranoplus* F. Smith,1853**

Genus *Meranoplus* in tribe Meranoplini is distributed from Africa, India, Indonesia, New Guinea and Australia (Shattuck, 1999). Only one species, *Meranoplus bicolor* was found in this study. This genus is similar to *Crematogaster* but their antennae have only 9 segments. The upper surface of the mesosoma forms a broad shield with thin and sharp lateral edges which project outwards over the sides of the

mesosoma. The shield-like upper surface of the mesosoma can distinguished these ants from all others.

***Meranoplus bicolor* (Guerin-Meneville, 1844)**

The length of a worker is 6 mm in average. The head, thorax, legs and postpetiole are dark red while the gaster is black with white hairs. Their head to their postpetiole is covered by coarse punctures. The antennal scrobe is well-developed but narrow. Spines of pronotum are sharp and very long but the metanotal spines are short pairs. The petiole and postpetiole are very long. The petiolar node is an inverted-V-shaped crest but the postpetiolar node is an inverted-U-shaped crest. The petiole and the postpetiole are long, about one-half of the total length of the gaster (Figure 80).

Tribe Myrmecinini

Genus *Pristomyrmex* Mayr, 1866

Pristomyrmex in tribe Myrmecinini is distributed through Africa, Japan, Indonesia, New Guinea and Australia (Shattuck, 1999). Only one species, *Pristomyrmex punctatus* was found in this study. The length of the workers is about 4 mm. The frontal lobes are slightly developed. They have 11-segmented antennae, and the club has 3 segments. Clypeus has a longitudinal carina. The pronotal and propodeal spines are unique. The compound eyes are small to medium in size. Gastral hairs are absent.

***Pristomyrmex punctatus* Smith, 1860**

The length of workers is about 5 mm. Their body color is brown to red-brown while the gaster is black-brown. The compound eyes are small size and located on the midline of the sides of the head. The antennal scapes are longer than their head. Propodeal spines and the subpetiolar process are absent. The petiolar and postpetiolar nodes are subtriangular. The mesosoma to postpetiole are covered by coarse punctures. The gaster is very smooth (Figure 81).

Tribe Pheidolini

Genus *Pheidole* Westwood, 1839

Pheidole is the second most diverse genus of ants in the world. They are found worldwide (Bolton, 1997). Only one species, *Pheidole plagiaria* in tribe Pheidolini was recorded from this study. They are similar to *Pheidologeton*. 12-segmented antennae are their main characteristics which differ from *Pheidologeton*.

The 3 apical antennal segments form a club. The propodeum is lower than the pronotum and on the forward section of the mesonotum. The propodeum and mesonotum are connected by the sloping section of the mesonotum. In soldiers, the anteroventral margin of the cranium carries 1 or 2 pairs of small spines and a median projection.

***Pheidole plagiaria* F. Smith, 1860**

The major worker of this species is necessary for identification. The length of the body is about 4 mm in soldiers. The body color is brown to red-brown while the gaster is darker than the other segments. Their heads are large. Along the head to the postpetiole are covered by coarse punctures. The pronotum and mesonotum are separated with a groove. The petiole has arched nodes on their upper surfaces. The metanotum has 1 pair of small spines. The gaster is slender with white hairs (Figure 82).

Tribe Pheidologetonini

Genus *Pheidologeton* Mayr, 1862

Genus *Pheidologeton* is found in Africa, India, Indonesia and Australia (Shattuck, 1999). Only one species, *Pheidologeton diversus* in tribe Pheidologetonini was discovered in this study. The length of workers is about 5 mm. Mandibles have 5 or 6 teeth. The propodeum is lower than the pronotum and the forward section of the mesonotum. The pronotum and mesonotum are separated by a groove. The subpetiolar process is absent while the subpostpetiolar process is often present but small. This genus is similar to *Pheidole* with 11-segmented antennae and 2-segmented club are their main characteristics.

***Pheidologeton diversus* (Jerdon, 1851)**

The body length is approximately 2.5 mm with brown to red-brown body color. The mandibles have 5 teeth. The antennal scapes are shorter than posterior margin of head which is slightly convex. The compound eyes are small on the midline of the sides of the head. The promesonotum is strongly convex while the dorsum of propodeum is slightly convex. The metanotum has a groove. The propodeum have a pair of spines with acute apices (Figure 83).

Tribe Solenopsidini

Genus *Monomorium* Mayr, 1855

Monomorium is an ecologically diverse genus of ants found worldwide (Bolton, 1997). Only one species, *Monomorium destructor* in tribe Solenopsidini was found in this study. Their mandibles have 3-5 teeth (mostly 4). The compound eyes vary in size. The antennal segment varies from 10-12 segments, and the club has 3 segments. The front margin of the clypeus is more or less pronounced, with a single median hair. The upper surface of the head is smooth and lacks of grooves or depressions for the antennal scapes. Pronotum and mesonotum are fused to a single segment. The propodeal spines are absent. The petiole and the postpetiole are distinct, arched nodes on their upper surfaces.

***Monomorium destructor* (Jerdon, 1851)**

The length of a worker is about 3.5 mm. Their body is brown to red-brown from head to postpetiole while the gaster is black-brown. The mandibles have 4 teeth. The compound eyes are large and located on the midline of the sides of the head. The metanotal groove is present. The ventral outline of the petiole is less convex than in other species. The postpetiole is equal to its width (Figure 84).

Genus *Solenopsis* Wesrwood, 1840

Solenopsis geminata in tribe Solenopsidini are found worldwide (Bolton, 1997). They were recorded from our study. The compound eyes are small to medium in size. The antennae have 10 segments and the apical antenna has a 2 segmented club. Mandibles have 4 or 5 teeth. The clypeus margin above the mandibles has a single elongated hair. The clypeus has a pair of longitudinal carinae. The propodeal dorsum is convex and without spines. The petiolar node is higher than the postpetiolar node. A subpetiolar process is present.

***Solenopsis geminata* (Fabricius,1804)**

Major workers are used for species identification. Their body length is about 5 mm, and red-brown in color. The head is square shaped and the mandibles are very strong. The posterior margin of the head is convex. Compound eyes and ocelli are present. The length of the antennal club is longer than that of the third to ninth antennal segments combined. The legs, mesosoma and gaster have erect hairs. The

petiolar node is an inverted-V-shaped crest but the postpetiolar node is an inverted-U-shaped crest. (Figure 85).

Tribe Tetramoriini

Genus *Rhoptromyrmex*

Rhoptromyrmex are found in tropical areas of Africa, India, Indonesia, New Guinea and Australia (Shattuck, 1999). Only one species, *Rhoptromyrmex wroughtoni* in tribe Tetramoriini was discovered in this study. Although Genus *Rhoptromyrmex* is similar to *Rhopalomastix*, the ridge-like structure of the clypeus and the projection on the tip of the sting of *Rhoptromyrmex* are the main characteristics that differentiate them from *Rhopalomastix*. The clypeus margin is strongly arched and projected forward over the mandibles. The lower surface of the petiole is narrowed into a keel-like ridge. The propodeum near the insertion of the petiole is rounded flanges. The tip of the sting is triangular.

***Rhoptromyrmex wroughtoni* Forel, 1902**

The worker's length is about 2.5 mm. From the head to postpetiole is red-black while the gaster is darker than other segments. Moreover, the legs are red-brown. Their bodies are covered with hairs. The length of the mesosoma is longer than that of the gaster. The compound eyes are small and are above the midline of the sides of the head. The mesosoma are covered by coarse punctures. The mesosomal and petiolar spines are absent but the petiole has arched nodes on their upper surfaces (Figure 86).

Genus *Tetramorium* (Mayr, 1855)

Tetramorium in tribe Tetramoriini is found worldwide (Bolton, 1997). Only one species, *Tetramorium flavipes* was recorded from this study. The length of workers is less than 4 mm. The compound eyes are more or less developed, and situated on the midline of the head. The antennae have 11 or 12 segments and 3 apical segments form a club. The area of the clypeus beneath the antennal sockets is raised into a sharp-edged ridge. The front margin of the clypeus is weakly convex or flat. The lower surface of the petiole is rounded. The propodeal spines are variously developed, ranging from small to elongate spiniform. The petiolar node is generally distinct.

***Tetramorium flavipes* Emery, 1893**

The length of the workers is about 3.5 mm. Head to postpetiole are brown to red-brown and covered with coarse punctures. The gaster is dark brown to black. The antennae have 12 segments and the apical 3 segments form a club. The anterior margin of clypeus is concave. The propodeal spines have 1 pair while the petiolar node lacks spines. The petiole and postpetiole are arched nodes on their upper surfaces. The gaster is very smooth and covered with hairs (Figure 87).

Figure 74 A worker of *Cataulacus granulatus* (Latreille, 1802).

Figure 75 A worker of *Crematogaster coriaria* Mayr, 1872.

Figure 76 A worker of *Crematogaster difformis* F. Smith, 1857.

Figure 77 A worker of *Crematogaster rogenhoferi* Mayr, 1879.

Figure 78 A worker of *Cardiocondyla wroughtonii* (Forel, 1890).

Figure 79 A worker of *Rhopalomastix janeti* Donisthorpe, 1936.

Figure 80 A worker of *Meranoplus bicolor* (Guerin-Meneville, 1844).

Figure 81 A worker of *Pristomyrmex punctatus* Smith, 1860.

Figure 82 A major of *Pheidole plagiaria* F. Smith, 1860.

Figure 83 A worker of *Pheidologeton diversus* (Jerdon, 1851).

Figure 84 A worker of *Monomorium destructor* (Jerdon, 1851).

Figure 85 A worker of *Solenopsis geminata* (Fabricius, 1804).

Figure 86 A worker of *Rhoptromyrmex wroughtoni* Forel, 1902.

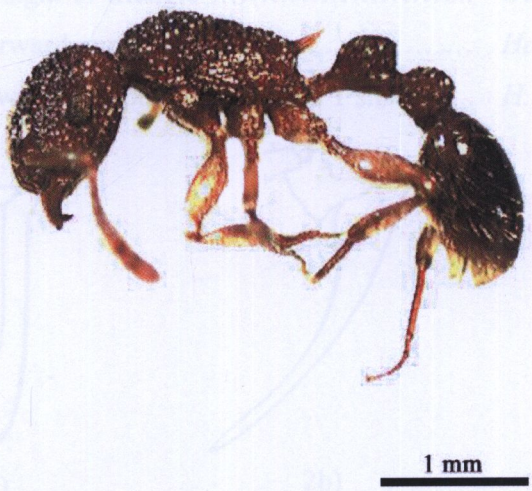


Figure 87 A worker of *Tetramorium flavipes* Emery, 1893.

Subfamily Ponerinae

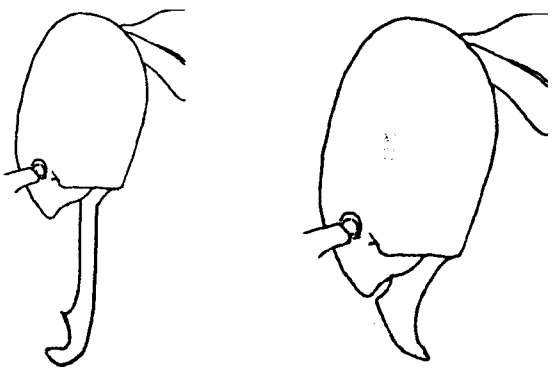
These ants are abundant in the Pantropical region (Hölldobler and Wilson, 1990). From our study, 7 genera in 4 tribes: Ectatommini, Leptogenyini, Odontomachini and Ponerini were identified. The ponerine workers are generally elongated. The petiole has 1 segment which is usually large and lacks an anterior peduncle. The pygidium is rounded shape and lacks a row of spines or teeth on this segment. Tibial apices have pectinate spurs. The sting is present at gastral apex.

Key to the Species of Ponerinae found in northern Thailand

Modified from Bolton, 1997; Shattuck, 1999.

1. a) Mandibles longer than half of head ..... (2).

   b) Mandibles shorter than half of head ..... (4).

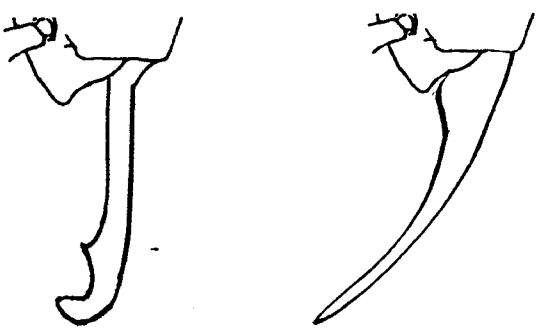


1a) 1b)

2(1a). a) Mandibles straight or triangle ..... *Odontomachus* (3).

   b) Mandibles forward curve ..... *Harpegnathos*

   - Hind tibia with two spurs, 1 large and 1 small ..... *H. venator*



2a) 2b)

3(2a). a) A single of petiolar spine ..... *O. rixosus*

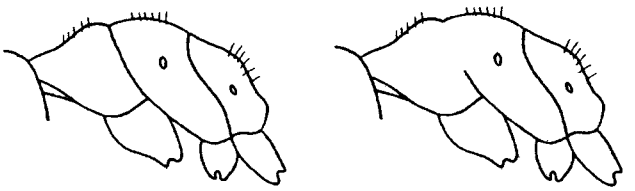
   b) A pair of petiolar spine ..... *O. simillimus*

3a) 3b)

4(1b). a) Pronotum and mesonotum separate ..... (5).

b) Pronotum and mesonotum fuse ..... *Gnamptogenys*

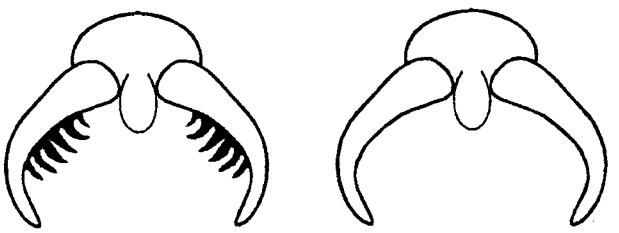
- Mesosomal and petiolar spines absent ..... *G. bicolor*



4a) 4b)

5(4a). a) Claws of hind legs with comb ..... *Leptogenys* (6).

b) Claws of hind legs with simple ..... (7).



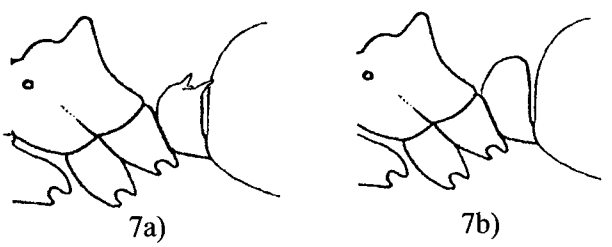
5a) 5b)

6(5a). a) Black body ..... *L. diminuta*

b) Red-black body ..... *L. kitteli*

7(5b). a) Petiolar spines present ..... *Diacamma* (8).

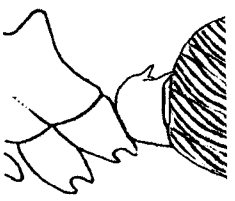
b) Petiolar spines absent ..... (9).



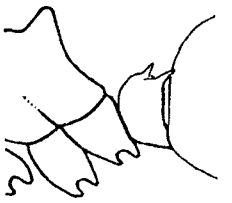
7a) 7b)

8(7a). a) Longitudinal line on anterior portion of 1st gastral segment present ..... *D. vargens*

b) Longitudinal line on anterior portion of 1st gastral segment absent ..... *D. sculpturata*



8a)

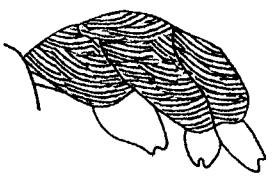


8b)

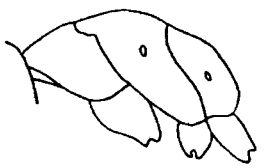
9(7b). a) Lateral surface of mesosoma with longitudinal line ..... *Odontoponera*

- Petiole acute ..... *O. denticulata*

b) Lateral surface of mesosoma without longitudinal line ..... *Pachycondyla* (10).



9a)



9b)

10(9b). a) Petiolar node connected to 1st gastral segment ..... *P. rufipes*

b) Petiolar node not connected to 1st gastral segment ..... (11).

10a)

10b)

11(10b). a) Metanotal groove present ..... (12).

b) Metanotal groove absent or slightly ..... *P. astuta*

11a)

11b)

11(10b). a) Red legs ..... *P. luttipes*

b) Black legs ..... *P. chinensis*

Tribe Ectatommini

Genus *Gnamptogenys* Roger, 1863

Gnamptogenys are found in America, Burma, Indonesia and Australia (Shattuck, 1999). Only one species, *Gnamptogenys bicolor* in tribe Ectatommini was reported in this study. Their head is elongate with the presence of compound eyes and ocelli. The antenna is filiform, and lacks a club. The propleura are separated from other segments while the pronotum is fused to the mesonotum. The promesonotal suture varies from present to absent. The anterior frontal lobe and the antennal socket are separated by rounded plate of the clypeus. Their coxa of the hind leg has a spine on its upper surface. The petiolar node is mostly a convex plate. The subpetiolar process varies in shape.

***Gnamptogenys bicolor* (Emery, 1889)**

The length of workers is about 4.5 mm. The head and the first gaster segment are red-brown to black while the mesosoma and petiole are bright red-brown. Their antennae have 12 segments. The occipital lobes are prominent. The compound eyes are situated on the posterior half of the head. The head to first gaster segment were covered with coarse punctures. The mesosomal and petiolar spines are present. The petiole has arched nodes on their upper surfaces. The metacoxal tooth is slender and straight. The gaster is covered with hairs, except the first gaster segment (Figure 88).

Tribe Leptogenyini

Genus *Leptogenys* Roger, 1861

Leptogenys are found in tropical regions of the world (Shattuck, 1999). Their body is long and slender. The body length is less than 15 mm. The clypeal margin is strongly angular. The antennal scapes are long. The compound eyes are well developed. Mandibles are variable in shape. Mid and hind tibiae have a pectinate spur. The claws on the hind legs have a series of small teeth (comb-like). Two species, *Leptogenys diminuta* and *Leptogenys kitteli* in tribe Leptogenyini were found from this study.

***Leptogenys diminuta* (F. Smith, 1857)**

The total body length of workers is approximately 8 mm. Their body is red-black to black. Head to mesosoma is slender. The anterior margin of the clypeus is a triangular shape. The compound eyes are large and situated on the midline of the head.

The pronotum is convex. The mesonotum has a groove. The petiole has a convex dorsal outline. The legs have small teeth on tarsal claws (Figure 89).

***Leptogenys kitteli* (Mayr, 1870)**

The anterior margin of clypeus is triangular. The compound eyes are large and situated above the midline of the head.. The mandible and mesosoma are elongated while the pronotum is convex. The mesonotal groove is distinct. This species is similar to *L. diminuta* in shape but *L. kitteli* are bright red in body color (Figure 90).

Tribe Odontomachini

Genus *Odontomachus* Latreille, 1804

Odontomachus is widespread in tropical and subtropical regions (Shattuck, 1999). Two species, *Odontomachus rixosus* and *Odontomachus simillimus* in tribe Odontomachini were found in this study. Their legs are long, and have pectinate spurs at the tibial apices. The head margin has a groove. The mandibles have 1-3 teeth near the tip. The antennae have 12 segments. The compound eyes are present, situated above on the midline of head. The petiole has a single spine and lacks an anterior peduncle. Their sting is present.

***Odontomachus rixosus* F. Smith, 1857**

The total length of workers is 1 cm on average. Their body is dark brown to black-brown while the legs are bright brown. The length of mandible is equal to head. Their scape is longer than the mandible and head. The truncate tooth of the apical mandibular dentition is short. A mesosomal groove is present on the mesonotum. The petiole is an inverted-V-shaped crest with a single spine. The gaster is smooth (Figure 91).

***Odontomachus simillimus* F. Smith, 1858**

The length of workers is about 6 mm. Their body is red-black. Their petiolar spines are short. The head to mesosoma were covered with longitudinal lines. The petiole has a pair of spines. The gaster is smooth and covered with erect hairs. The petiole is an inverted-V-shaped crest (Figure 92).

Tribe Ponerini

Genus *Diacamma* Mayr, 1862

This genus is found worldwide (Shattuck, 1999). From our study, 2 species in tribe Ponerini have been identified. Their bodies are large and are black to dark gray in

color. The head is an oval shape. The anterior clypeal margin is triangularly produced. The compound eyes are large and distinct, situated on the midline of the head. All of them have 12-segmented antennae which are filiform without a club. The mesosoma have pocket-like pits on each plate. The promesonotal suture is present. The petiole is large and usually has spines. The head, mesosoma and petiole have longitudinal lines.

***Diacamma sculpturata* (F. Smith, 1859)**

This species is a large ponerine ant. The length of the workers is about 1 cm. Their body is black. The gaster is light brown and is covered with erect hairs. The mandible and femur are red-brown. There is a pair of petiolar spines in a posterodorsal direction. The head to petiole are covered with longitudinal lines (Figure 93).

***Diacamma vargens* (F. Smith, 1860)**

The total length of workers is 8 mm in average. This species is similar to *D. sculpturata* in body color and shape. To differentiate *D. sculpturata* from *D. vargens*, longitudinal lines on the first gastral segment are remarked in *D. vargen* (Figure 94).

Genus *Harpegnathos* Jerdon, 1851

Harpegnathos in tribe Ponerini is found in south and southeast Asia (Bolton, 1997). Only one species, *Harpegnathos venator* was reported in this study. The compound eye and ocelli are present. The frontal lobes are blunt triangles. The mandible is a forcep-like shape. The mandibular base lacks small pit. The hind tibia has 2 spurs: 1 large and 1 small. The pretarsal claws have 1 or more teeth.

***Harpegnathos venator* (F. Smith, 1858)**

The length of the worker is 1 cm in average. Their body and abdomen is red-black to black while the mandibles, legs and antennae are red-brown to dark brown. The mandibles are long and forcep-like shape. Their antennae have 12 segments, and the club has 3 segments. The compound eyes are very large, and situated on the midline of the head. The head to petiole is covered with coarse punctures and erect hairs (Figure 95).

***Odontoponera* Mayr, 1862**

Odontoponera in tribe Ponerini is found in Asia and New Guinea (Bolton, 1997). Only one species, *Odontoponera denticulata* was reported in this study. The mandibles have 5 large teeth. The antennal sockets are behind the clypeal margin. The

mesosoma tagma lacks a pocket-like excavation above the mesopleuron. The petiolar spines are absent, but in some species, a node has tridentate to multidentate.

***Odontoponera denticulata* (F. Smith, 1858)**

The worker length is about 7 mm. Their bodies are brown-black while antennae, mandibles and legs are red-brown. The gaster is smooth. The compound eyes are small and situated on the midline of the head. The petiole is an inverted-V-shaped crest. The lateral surface of head to mesosoma has a longitudinal line while gaster is smooth (Figure 96).

Genus *Pachycondyla* F. Smith, 1858

Pachycondyla is found worldwide in the tropics and subtropics (Shattuck, 1999). Four species, *P. astuta*, *P. chinensis*, *P. luteipes* and *P. rufipes* in tribe Ponerini were recorded in this study. Their compound eyes are present. The mandibles are a triangular shape. Antennal insertions are covered with the frontal lobe. The clypeus extends across the entire width of the head. The frontal lobes and antennal sockets are well developed behind the front margin. The outer margin of the mid tarsus is simple without a distinct setae. The claws of tarsus are simple.

***Pachycondyla astuta* F. Smith, 1858**

The worker length is approximately 1.2 cm. Their bodies are black while legs and the first to second gasteral segments are red-brown. The body is covered with erect hairs. The compound eyes are small and situated on the midline of the head. The head to petiole have coarser punctures. The petiolar node is without a spine. The tibiae of the hind legs have 2 spurs: 1 large (comb-like) and 1 small (simple) (Figure 97).

***Pachycondyla chinensis* (Emery, 1895)**

The length of *Pachycondyla chinensis* workers is 4 mm in average. Their body is black while the mandibles and legs are light brown. The compound eyes are large, situated on the midline of the head. The propodeal surface is smoother than petiole and gaster. Although this species is similar to *P. luteipes*, the antennal scape of *P. chinensis* is longer than those in *P. luteipes* (Figure 98).

***Pachycondyla luteipes* (Mayr, 1862)**

The worker's length is about 5 mm. Their body is reddish black while the legs are reddish brown. Although this species is similar to *Pachycondyla chinensis*, *Pachycondyla luteipes* have relatively short antennal scapes which exceed the

posterior margin of the head by less than the length of the second antennal segment. Their propodeum is unsculptured, smooth and shining (Figure 99).

***Pachycondyla rufipes* (Jerdon, 1851)**

Their major worker length is about 1.2 cm. The body is reddish black to black but the legs are red-brown. This species is stronger and bigger than other species in the genus *Pachycondyla*. Their bodies are covered with coarse punctures. The petiolar node is wide and connects to gaster. Petiole is an inverted-V-shaped crest. The gaster is very smooth with erect hairs (Figure 100).

Figure 88 A worker of *Gnamptogenys bicolor* (Emery, 1889).

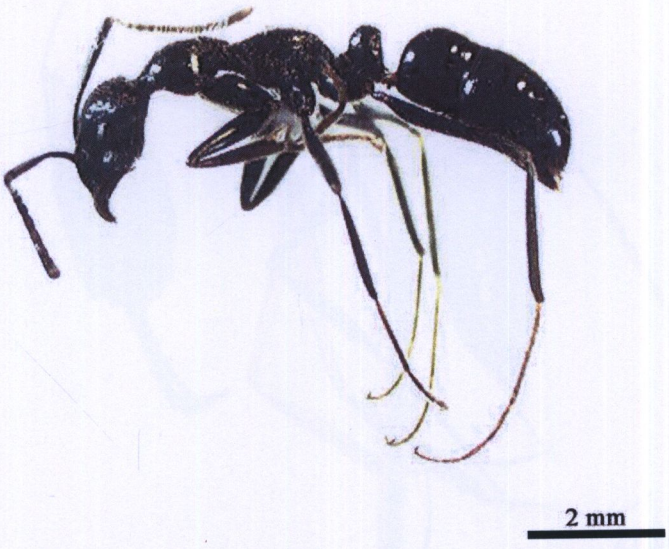


Figure 89 A worker of *Leptogenys diminuta* (F. Smith, 1857).

Figure 90 A worker of *Leptogenys kitteli* (Mayr, 1870).

Figure 91 A worker of *Odontomachus rixosus* F. Smith, 1857.

Figure 92 A worker of *Odontomachus simillimus* F. Smith, 1858.

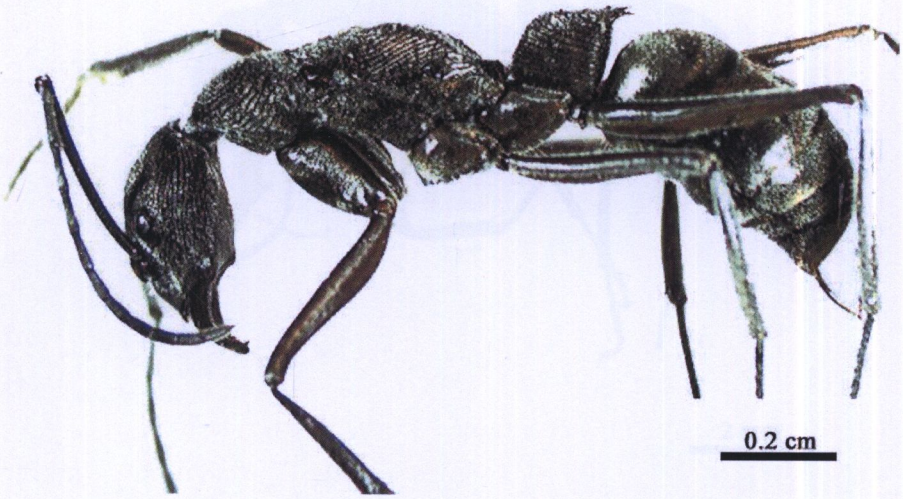


Figure 93 A worker of *Diacamma sculpturata* (F. Smith, 1859).

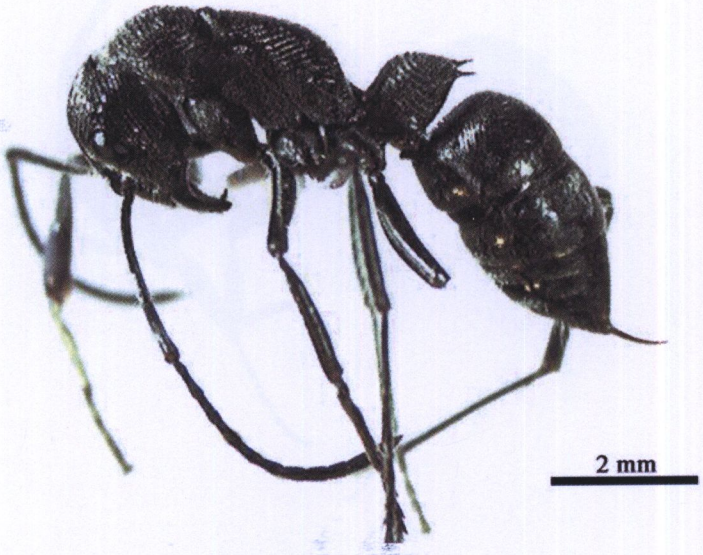


Figure 94 A worker of *Diacamma vargens* (F. Smith, 1860).

Figure 95 A worker of *Harpegnathos venator* (F. Smith, 1858).

Figure 96 A worker of *Odontoponera denticulata* (F. Smith, 1858).

Figure 97 A worker of *Pachycondyla astuta* F. Smith, 1858.

Figure 98 A worker of *Pachycondyla chinensis* (Emery, 1895).

Figure 99 A worker of *Pachycondyla luteipes* (Mayr, 1862).

Figure 100 A worker of *Pachycondyla rufipes* (Jerdon, 1851).

Subfamily Pseudomyrmecinae

This subfamily contains 3 genera which are found in tropical and subtropical regions (Shattuck, 1999). From our study, a single genus, *Tetraponera*, was recorded. This subfamily is slender in body shape. The compound eyes and ocelli are present. The antennae have 12 segments. The mesosoma is attached to the gaster by the petiole and postpetiole. The mandibles are triangular in shape and short. The pronotum is fused to the mesonotum. This subfamily is frequently confused with species in the subfamily Myrmicinae. To differentiate between Myrmicinae and Pseudomyrmecinae, the pronotum and mesonotum combined is remarkable in Pseudomyrmecinae.

Key to the species of Pseudomyrmecinae found in northern Thailand

Modified from Bolton, 1997; Shattuck, 1999.

1.	a)	Thorax red	*T. rufonigra*
	b)	Thorax black	2.
2(1b).	a)	Mesonotum with slope	*T. allaborans*
	b)	Mesonotum without slope	*T. attenuata*

2a)

2b)

Tribe Pseudomyrmecini

Genus *Tetraponera* F. Smith, 1852

This genus is found in Africa, southeast Asia, New Guinea and Australia (Shattuck, 1999). Three species in tribe Pseudomyrmecini were found in our study. Their elongate and slender body are distinguishing characteristics of these ants. The anterior clypeus is raised. The petiole and postpetiole are rounded in shape.

***Tetraponera allaborans* (Walker, 1859)**

Their bodies are about 4 mm. The body is slender, and red-black color. The mandibles have 5 teeth. The anterior margin of clypeus has a pair of teeth. The propodeum is higher than the rest of the mesosoma. Mesosomal spines are absent. (Figure 101).

***Tetraponera attenuata* F. Smith, 1877**

A total length of female is approximately 8 mm. Their bodies are slender, and black. The mandibles have 5 teeth. Anterior margin of clypeus has a pair of teeth. Propodeum is higher than the rest of mesosoma. Mesosomal spines are absent. Although this species is similar to *T. allaborans*, mesosomal spine of *T. attenuata* is longer than that of them (Figure 102).

***Tetraponera rufonigra* (Jerdon, 1851)**

Their body is slender and long with the total length of the female about 12 mm. Their head and gaster are black while mesosoma to postpetiole is orange-brown to red. The antennae and tibia to tarsus are marked with red color. The compound eyes are large and situated on the midline of the head. The mesosoma is covered with coarse punctures. (Figure 103).

Figure 101 A worker of *Tetraponera allaborans* (Walker, 1859).

Figure 102 A worker of *Tetraponera attenuata* F. Smith, 1877.

Figure 103 A worker of *Tetraponera rufonigra* (Jerdon, 1851).

Family Scoliidae

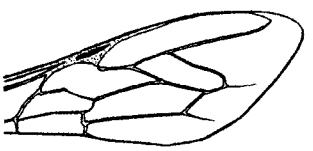
The Scoliidae is distributed in Palearctic, Neotropical, Mediterranean, and Australasian (Brothers and Finnamore, 1993; Gauld and Bolton, 1996; Tüzün, 2004). Their body is covered with hairs or a punctuate band on the metasoma. The fore and hind wings are uniformly transparent or metallic brown. The distal section of the wings has longitudinal wrinkles. The first marginal cell (M) is usually shorter than the first marginal and cubital (Cu) combined cell. The mesosternum and metasternum are separated by a straight transversed suture. In this study, we found 2 genera within 2 tribes; Campsomerini and Scoliini.

Key to the species of Scoliidae found in northern Thailand

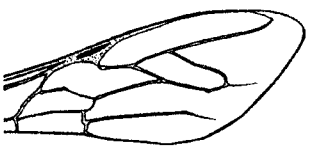
Modified from Yamane, Ikudome and Terayama, 1999.

1. a) 2M-Cu vein of fore wing present ..... Campsomerini
   - 2nd tergite of abdomen with a pair of small yellow band ..... *Campsomeris* sp.

   b) 2M-Cu vein of fore wing absent ..... Scoliini
   - 2nd tergite of abdomen with a pair of large black band ..... *Scolia* sp.



1a)



1b)

Subfamily Scoliinae

Scoliidae is divided into 2 tribes: Campsomerini and Scoliini (Gupta, and Jonathan, 2003). Scoliids are variable in color patterns, body size and shape. Their body is usually black and marked with spots of yellow, white or red. Their wings are a metallic iridescence or uniformly transparent. Fore wings have 2 cubital cells (Cu). The abdomen has black bands with pairs of yellow or red markings that differ in pattern and shape.

Tribe Campsomerini

***Campsomeris* Guérin, 1838**

This genus is identified in tribe Campsomerini. They are represented in America, Mexico and the Old World (Tüzün, 2004). Their dorsum of mesosoma and metanotum are extensively exposed and covered with a few hairs. The antenna of the males is longer than the females: 13 segments in male, and 12 segments in female. A 3-pronged plate is found at the tip of the abdomen. The fore wings have 2 submarginal cells. The second recurrent vein of the fore wing is absent, but they have origin from cubital cell.

***Campsomeris* sp.**

The total length of a female is 1.8 cm in average. Their bodies are black with yellow-brown markings. All appendages on the head are black. The pronotum is yellow-brown. The width of mesonotum is equal to metanotum with black plate, and both are covered with yellow hairs. The posterior corner of the metanotum is yellow-brown. The posterior margin of the metasomal tergum is covered with hairs. The apical bands on the metasomal tergum are yellow and narrow, and curved in a "V" shape in the middle. The fore wing is brown. The tip of the abdomen has 3 spines (Figure 104).

Tribe Scoliini.

***Scolia* Fabricius, 1775**

The members of *Scolia* have a black body with yellow or red markings. The flagellate length of the female is shorter than that of the male and curved in a "C" shape. This genus is identified in tribe Scoliini. They are found around the world (Tüzün, 2004). They differ from Campsomerini as the upper portion of the mesopleuron is laterally produced, and the second recurrent vein of the fore wing is absent, but they do not have origin from cubital cell.

***Scolia* sp.**

The body length is about 2.5 cm. The head and third abdominal segment are red while other appendages are black. Their wings are metallic brown. The mesosoma to second abdominal segment are covered with black hairs. The third to the last abdominal segments are covered with red hairs. The second tergite of the abdomen has a pair of large black bands. The third tergite of the abdomen has a pair of large red band (Figure 105).

Figure 104 A female of *Campsomeris* sp.

Figure 105 A female of *Scolia* sp.

Family Vespidae

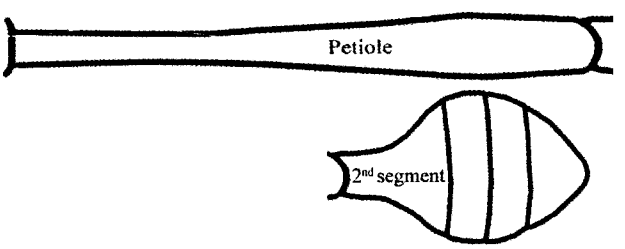
The distribution of Vespidae is in the Holarctic and Oriental Region (Archer, 1989). From our study, we reported 4 subfamilies: Eumeninae, Polistinae, Stenogastrinae and Vespinae. The inner margin of the compound eye has a notched area. The folded wings are parallel with their body at rest. The submarginal cells have 3 cells. The first discoidal cell of the fore wing is greater than half of the wing length. The length of jugal lobe in hind wing is shorter than that of the first marginal and cubital combined cell (1M + Cu). Pronotum reaches the tegulae. The posterior margin of pronotum is horseshoe-shaped or U-shape.

Key to the species of Vespidae found in northern Thailand

Modified from Vecht, 1966; Archer, 1989; Carpenter and Nguyen, 2003; Yamane, Ikudome and Terayama, 1999; Nguyen, 2006.

1. a) Fore wings not longitudinally folded at rest ..... Stenogastrinae
   - Anterior of 2nd abdominal segment in dorsal view nearly parallel sided ..... *Parischnogaster*
   - length twice longer than that of gaster ..... *Parischnogaster* sp.

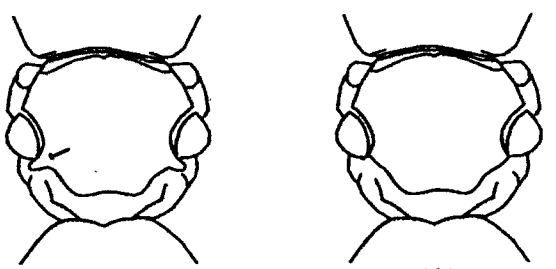
   b) Fore wings longitudinally folded at rest ..... (2).



1a)

2(1b). a) Parategula present; bifid claws ..... Eumeninae (3).

b) Parategula absent; simple claws ..... (5).

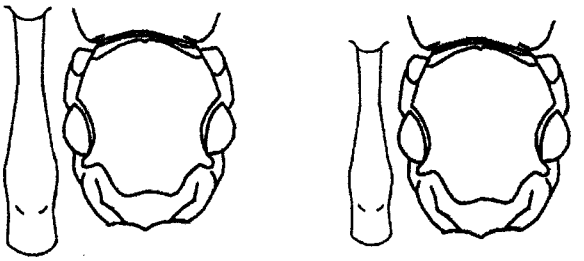


2a) 2b)

3(2a). a) Petiole much longer than mesosoma ..... *Phimenes*

- 1st abdomen with 3 pairs yellow markings ..... *P. flavopictus*

b) Petiole slightly longer than or equal that of mesosoma ..... *Delta* (4).



3a) 3b)

4(3b). a) 3rd to last metasomal tergum yellow ..... *D. pyriforme*

b) 3rd to last metasomal tergum reddish brown ..... *Delta* sp.

5(2b). a) Dorsal carina of hind coxa absent; jugal lobe of hind wing present ..... Polistinae (6).

b) Dorsal carina of hind coxa present; jugal lobe of hind wing absent ..... Vespinae (10).

5a) 5b)

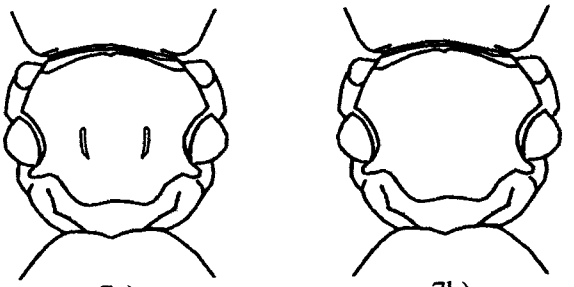
6(5a). a) Petiole funnel-shaped as petiole absent; dorsal propodeum narrow ..... Polistini, *Polistes* (7).

b) Petiole varies in shape; petiole long; propodeum with orifice often broadly rounded dorsally ..... Ropalidiini (8).

6a) 6b)

7(6a). a) Mesosoma with yellow markings and 2 vertical yellow lines ..... *P. olivaceus*

b) Mesosoma without yellow markings and without 2 vertical yellow lines ..... *Polites* sp.

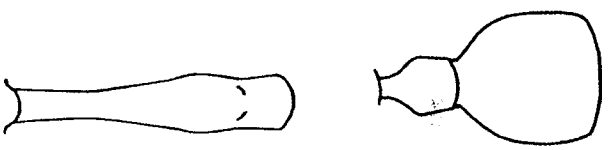


7a) 7b)

8(6b). a) Petiolar near linear ..... *Polybioides*

- Posterior abdominal margins with yellow bands ..... *Polybioides* sp.

b) Petiole not parallel; mesepisternum without scrobal sulcus ..... *Ropalidia* (9).



8a) 8b)

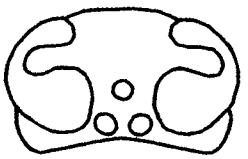
9(8b). a) Posterior abdominal margins with yellow bands ..... *Ropalidia* sp.1

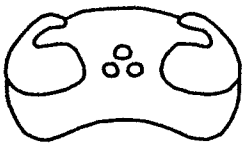
b) 2nd to last abdominal segments black, except the posterior margin of 2nd abdominal segment with yellow band ..... *Ropalidia* sp.2

10(5b). a) Ocelli very large; posterior ocelli closer to inner eye than to each other; vertex short; distance from the posterior ocellus to posterior margin of vertex nearly shorter than or equal that between posterior ocelli ..... *Provespa*

- Body slender and brownish; clypeus brownish .... *P. anomala*

b) Ocelli not large; posterior ocelli closer to each other than to eye; vertex long; distance from the posterior ocellus to posterior margin of vertex greater than distance between posterior ocelli and eye; normally brightly colored; stout body ..... *Vespa* (11).





10a) 10b)

11(10b). a) 1st and/or 2nd abdominal segments yellow bands ... 12.

b) 1st and 2nd abdominal segments orange-brown bands at the posterior margins ..... 14.

12(11a). a) 1st and 2nd abdominal segments yellow orange ..... *V. affinis*

b) 2nd abdominal segments yellow orange ..... 13.

13(12b). a) Mesoscutellum black ..... *V. tropica*

b) Mesoscutellum dark yellow to bright brown ..... *V. soror*

14(11b). a) 3rd abdominal segments dark orange with an irregular black marking in the middle ..... *V. velutina*

b) 3rd abdominal segments orange-brown bands at the posterior margins ..... *V. mandaria*

Subfamily Eumeninae

The subfamily Eumeninae is distributed in various zoogeographical regions; the Palearctic, Nearctic, Ethiopian, Oriental and Australian and Neotropical regions (Yamane, 1990; Carpenter and Garcete-Barrett, 2002; Carpenter and Nguyen, 2003). We reported 4 species in 3 genera in this study; *Delta*, *Rhynchium* and *Phimenes.* Their wings are longitudinally folded at rest. Most species are black or brown, and commonly marked with strikingly contrasting patterns of color: yellow, white, orange, or red. The clypeus is variable in shape: pointed, truncate or rounded in the males of some species. The acroglossal buttons are present on the apices of glossa and paraglossae. Their mandibles are often developed into a lobe or tooth. The pronotal lobe is separated from the tegula. The horizontal lobe projects from the posterolateral corner of the mesoscutum known, as the parategula is usually present. Fore wings have 3 submarginal cells. The hind coxae have a longitudinally dorsal carina. The claws are usually bifid.

Tribe -

Genus *Delta* Saussure, 1855

The genus is distributed in Southern Palearctic, Oriental, Australian, Ethiopia and Neotropical regions (Yamane, Ikudome and Terayama, 1999; Carpenter and Garcete-Barrett, 2002). We found 2 species of *Delta* in this study. The clypeal length is longer than the width. The mandible is very long but lack of mandibular teeth. The compound eyes have a notch. The mesosoma is short. The first metasomal segment (petiole) is very slender. The petiole is slightly longer than the mesosoma, but the posterior of the petiole is wide. The second metasomal segment is bell-shaped and posteriorly narrowed.

***Delta pyriforme* Fabricius, 1781**

The body length is approximately 2 cm in females. Their body is black with yellow and red-brown markings. Clypeus, pronotum and mesonotal apex are yellow. The metanotum and the first metasomal tergum are red-brown while the anterior, inferior and posterior petioles are black. The anterior half of the second metasomal tergum is red-brown but the posterior half is yellow. The third to the last metasomal tergum are yellow. The middle of the metasomal tergum has a small black spot (Figure 106).

***Delta* sp.**

The female body is about 2 cm in the total length. Their body is red-brown with yellow and black markings. The clypeus is yellow. The metanotum has a black line. The anterior petiole is black with red-brown markings. The second abdominal segments have black bands at the inferior and anterior part. The third to the last metasomal tergum are red-brown (Figure 107).

Tribe -

Genus *Phimenes* Giordani Soika, 1992

This species of genus *Phimenes* is distributed from tropical Asia to Oceania (Yamane, Ikudome and Terayama, 1999). Only one species, *Phimenes flavopictus* was recorded from this study area. Their second metasomal segment is bell-shaped. The anterior of the second metasomal segment is narrower than the posterior petiole. Even though this genus is very similar to the genus *Delta*, their petiole is linear and much longer than the mesosoma.

***Phimenes flavopictus* (Blanchard, 1841)**

This species is widely distributed in south and southeast Asia (Yamane, Ikudome and Terayama, 1999). Their body length is about 2.5 cm in females and the body color is bright yellow with black markings. The antennal scape is black and rather curved. The pronotum is yellow. The mesonotum have 2 vertical and 2 longitudinal yellow lines on the mesosoma. The tegula is yellow with black marking. The first abdominal targa has 3 pairs of yellow markings while the second to sixth abdominal targa have a pair of yellow markings (Figure 108).

Tribe -

Genus *Rhynchium* Spinola, 1806

This genus is widespread in Middle East and Africa (Yamane, Ikudome and Terayama, 1999). Only one species, *Rhynchium* sp. was recorded from this study area. The parastigma is longer than half of the stigma length. The tegula margin does not reach the parategula. The scutellum and posterior part of the mesoscutum are smooth and sparsely punctate.

***Rhynchium* sp.**

This species is similar to species of *Vaspa* but *Rhynchium* sp. has parategula and bifid claws. The female is about 1.6 cm in the total length. The body color is red-brown with black marking. The fore wings have 3 submarginal cells. The wings are bright brown and uniformly transparent. The clypeus is pyriforrn, moderately punctate, with the apex narrowly truncate. The ocellar region is a narrow longitudinal depression near to the outer side of each posterior. Posterior margin of the pronotum is U-shaped. The abdominal band is black and brown. Half of the anterior first and second metasomal segments is black (Figure 109).

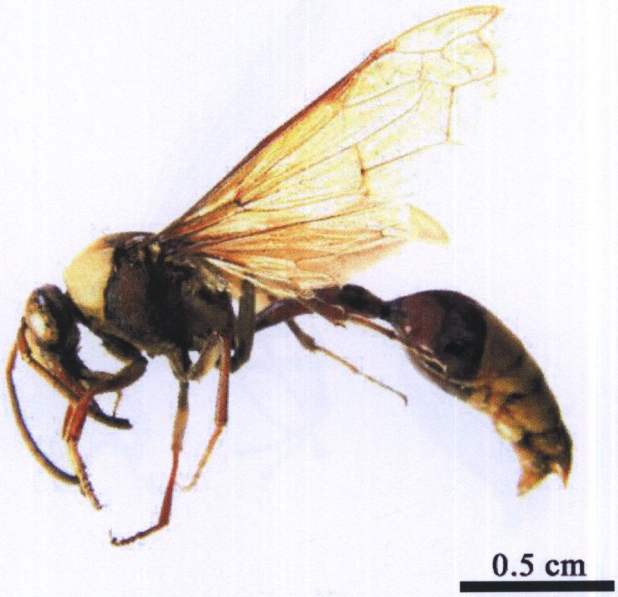


Figure 106 A female of *Delta pyriforme* Fabricius, 1781.

Figure 107 A female of *Delta* sp.

Figure 108 A female of *Phimenes flavopictus* (Blanchard, 1841).

Figure 109 A female of *Rhynchium* sp.

Subfamily Polistinae

Polistinae (paper wasps) is the second largest subfamilies in the Vespidae. They are social wasps. Polistinae are distributed all over the world. The Brazilian Polistinae fauna is also recorded as having the largest number of this subfamily. The 2 tribes; Polistini (comprising only the cosmopolitan genus *Polistes*) and Ropalidiini (comprising all the Old World genera; *Ropalidia*, *Parapolybia* and *Polybioides*) were found in southeast Asia (Carpenter, 1993; Mancini et al., 2006). From our study, 4 genera, *Parapolybia*, *Polybioides*, *Polistes* and *Ropalidia* were recorded. This subfamily is similar to subfamily Vespinae in parategula and vertical lamella on the mesoscutum. Vespinae differs from Polistinae as the hind coxa of Polistinae lacks a dorsal carina. The hind wing has a jugal lobe. The metasoma is variable in shapes.

Tribe Polistini

Genus *Polistes* Latreille, 1802

The paper wasps, *Polistes* are classified in tribe Polistini of the Polistinae. Most of them are found in tropical or subtropical areas (Carpenter 1993; Mancini et al., 2006). From our study, we found 2 species, *Polistes olivaceus* and *Polistes* sp. in this genus. Their petiole is funnel-shaped in a dorsal view. The first metasomal segment is shorter than second metasomal segment. The dorsal propodeum is narrow. The posterior pronotum has a carina.

***Polistes olivaceus* (DeGeer, 1773)**

Polistes olivaceus is a native species from the Oriental region and Australia (Harris, 1979). Their bodies are approximately 2 cm in total length. Their bodies are almost brown with yellow markings. The mesosoma has 2 vertical yellow lines. This species is similar to *Parapolybia varia* in body color. To differentiate between *P. varia* from *P. olivaceus*, the 11-segmented antennae in the female and the linear petiole of *P. olivaceus* are distinctive (Figure 110).

***Polistes* sp.**

The female is about 1.5 cm in total length. Their head and mesosoma are red-brown while the abdomen is black with yellow marking on the first metasomal segment. The third to fourth metasomal margins have a yellow band. Their wings are bright brown and uniformly transparent. The apex of the fore wings has black spot.

The coxa of the hind legs has yellow marking. The lateral surface of the metanotum has longitudinal lines (Figure 111).

Tribe Ropalidiini

Genus *Parapolybia* de Saussure, 1854

The distribution area of *Parapolybia* extends from southeast Asia, Iran, Japan, the Philippine Islands and New Guinea (Vecht, 1966). We found only one species, *Parapolybia varia* from this area. The pronotum has a pretegular carina and mesepisternum. A scrobal sulcus is present. Both *Parapolybia* and *Ropalidia* have 12-segmented antennae in the female and carina on the pronotum. *Parapolybia* is identified by the petiole which is not linear.

***Parapolybia varia* (Fabricius, 1787)**

The lesser paper wasp, *Parapolybia varia* is approximately 1.7 cm in total length. Their bodies are mostly brown with yellow markings. The mesosoma has 2 vertical yellow lines. This species is similar to *Polistes olivaceus* in body color but *Parapolybia varia* is a slender bodied wasp with a long petiole (Figure 112).

Genus *Polybioides* du Buysson, 1913

Polybioides is classified in tribes Ropalidiini of Polistinae. They are found in the Oriental area, southeast Asia and Africa (Vecht, 1966). We found only one species, *Polybioides* sp. in our study. This genus differs from to *Ropalidia* and *Parapolybia* as *Polybioides* have 11-segmented antennae in the female, linear petiole and a pronotal carina.

***Polybioides* sp.**

The female is about 1.6 cm in total length. The body is brown-black with yellow markings. The width and length of their head are equal. The compound eyes and ocelli are black. Their occipital carina is complete and slightly curved. The clypeus is yellow and convex. The second metasomal segment is longer than other segments. The posterior margins of the abdominal segments have yellow bands. The legs are yellow with brown-black markings. Even though this species is similar to *Parapolybia varia* in body color, *Polybioides* sp. is easily identified as they have a petiole (Figure 113).

Genus *Ropalidia* Guérin-Méneville, 1831

Paper-wasps, *Ropalidia* are mainly distributed in tropical and subtropical areas and the Old World. A few species are distributed in Australia and South Africa. They are classified in tribes Ropalidiini of Polistinae (Kojima and Carpenter 1997; Carpenter and Nguyen, 2003; Saito and Kojima, 2005). From our result, 2 species in this genus were recorded. Their antennae have 12 segments in the female. A pronotal carina is present. Although *Ropalidia* is similar to *Parapolybia* in antennal segments and pronotal carina, we can clearify the genus *Ropalidia* with the pronotum that lacks a pretegular carina and the scrobal sulcus of mesepisternum.

***Ropalidia* sp.1**

Their female is approximately 1.7 cm in total length. The head, pronotum and mesonotum are red-brown. The width of the head is as wide as the length. The compound eyes and ocelli are black. Their occipital carina is complete, and slightly curved. The clypeus is convex and slightly wider than the length. The antennal scape is slightly curve. The mandible is stout. The propodeum has a furrow or depression. Their metasoma is black. The anterior part of the first metasomal segment is narrower than the posterior part. The second metasomal segment is wider than the other segments. The posterior margins of the first and second abdominal segments have yellow bands (Figure 114).

***Ropalidia* sp.2**

The total length of a female is 1 cm in average. The head is black while the gena is red-brown. The mesonotum are black, except the pronotum which is red-brown. The compound eyes and ocelli are brown-black. An occipital carina is present. The clypeus is convex and slightly wider than its length. The antennal scape has a curved shape. The mandible is stout. The propodeum has a furrow but is smaller than *Ropalidia* sp.1. The metasoma is black. The anterior part of the first metasomal segment longer than the posterior part which their anterior part has black band. The posterior part has a red band. The second metasomal segment is wider than the other segments. The second to last abdominal segments are black, except the second abdominal segment which has a yellow band at the posterior margin (Figure 115).

Subfamily Stenogastrinae

The subfamily Stenogastrinae is distributed in India, Indo-Malayan and New Guinean (Turillazzi, 1989). They are a group of social wasps and an endemic species in the Oriental Region (Carpenter and Starr, 2000). They are distinguished from other subfamilies by the pronotal lobe that is separated from the tegula. The wings do not fold longitudinally at rest. The clypeus projects ventrally. There are no acroglossal buttons. In our study, a single species, *Parischnogaster* sp. in the genus *Parischnogaster* was record.

Tribe Stenogastrini

Genus *Parischnogaster* von Schulthess, 1914

The genus in tribe Stenogastrini is distributed throughout southeast Asia (Carpenter, and Nguyen, 2003). The posterior margin of their hind wings is covered with short hairs. The vertex lacks the longitudinal groove. The anterior part of the second abdominal segments in dorsal view is nearly parallel in shape.

***Parischnogaster* sp.**

The female body is approximately 1.3 cm in the total length. Their body is dark brown with yellow markings. The compound eyes are large. The mandibles are yellow and have 3 teeth. The clypeus is bright brown to yellow and the apex of the clypeal margin has a small spot. The gena is narrower than the length of the second flagella segment. The antenna is club-shaped. The posterior pronotum and mesonotum are denser and deeper than in other areas. The propodeum are smoother than the pronotum and mesonotum. The petiole is twice as long as the length of the gaster. The legs are red-brown (Figure 116).

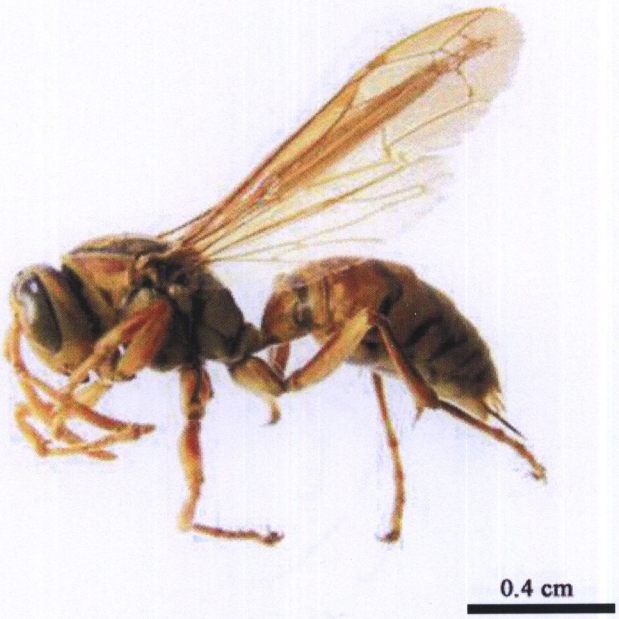


Figure 110 A female of *Polistes olivaceus* (DeGeer, 1773).

Figure 111 A female of *Polistes* sp.

Figure 112 A female of *Parapolybia varia* (Fabricius, 1787).

Figure 113 A female of *Polybioides* sp.

Figure 114 A female of *Ropalidia* sp.1.

Figure 115 A female of *Ropalidia* sp.2.

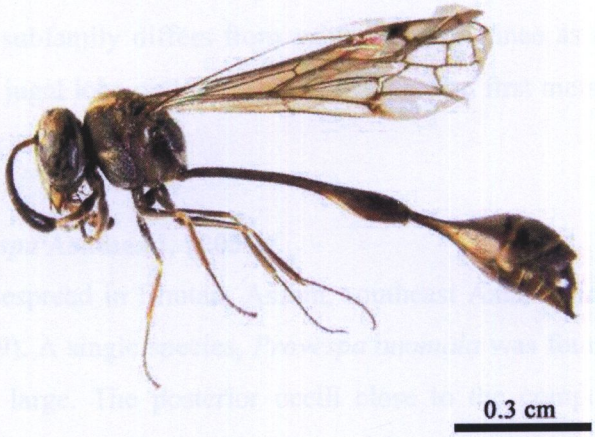


Figure 116 A female of *Parischnogaster* sp.

Subfamily Vespinae

Vespinae are found in southeast Asia (Archer, 1989). In this study, 2 genera; *Provespa* and *Vespa* were recorded. They lack the parategula. Mesoscutum have vertical lamella. This subfamily differs from subfamily Polistinae as their hind coxa has dorsal carina. The jugal lobe on hind wing is absent. The first metasomal segment does not form a petiole.

Tribe -

Genus *Provespa* Ashmead, 1903

They are widespread in Bhutan, Assam, southeast Asia, China, Borneo, and Sumatra (Archer, 1989). A single species, *Provespa anomala* was found in this study. Their ocelli are very large. The posterior ocelli close to the compound eyes. The distance between the lateral ocelli, and the distance between the lateral ocelli to the head margin are equal in length. Their vertex is short.

***Provespa anomala* (de Saussure, 1854)**

The female body is approximately 2 cm in total length. Their body is uniformly brown, except the clypeus is dark brown. The clypeal margin has truncated edges while the lateral angles are blunt. The mesoscutal length is longer than width. The width of the first gastral tergum is longer than its length (Figure 117).

Tribe -

Genus *Vespa* Linnaeus, 1758

The genus *Vespa* is commonly known as hornet. They are distributed in tropical Asia, European regions, North America, the Middle East and the Mediterranean region. There are 23 species recognized in this genus. (Archer, 1989; Carpenter and Nguyen, 2003). From our study, 5 species were found. They are identified with long vertex. The distance between the lateral ocelli to the occiput is longer than that of the lateral ocelli to compound eyes. Their pronotal carina is nearly complete. The head and mesosoma are marked with red spots.

***Vespa affinis* (Linnaeus, 1764)**

They are median *Vespa*. The total length of worker is 2 cm in average. Their head, clypeus and mesosoma are black. The antennae, compound eyes and ocelli are dark brown to black. The thorax is covered with coarse punctures. The pronotum and mesonotum are covered with erect hairs. The wings and tegulae are dark brown. They

are easily identified by a yellow-orange band on the first and second metasomal segment. The third to the last metasomal segment are black (Figure 118).

***Vespa mandarinia* Smith, 1852**

This species is the largest *Vespa* in this study. The total length is about 3.5 cm in workers. The head and antennae are brown to dark brown. The compound eyes are dark brown. The mesosoma is black while the mesoscutum is bright brownish with gold-colored. The scutellum has a deeply impressed line. The gaster is black. The posterior margins of each abdominal tergite have orange-brown bands. The sixth abdominal segment is orange-brown (Figure 119).

***Vespa soror* du Buysson, 1905**

The total length of worker's body is 3 cm in average. All head appendages are dark yellow to brown. The compound eyes are dark brown to black. The pronotum and mesonotum are covered with erect hairs. The wings and tegulae are dark brown. They are identified from other species in *Vespa* by dark yellow to brown on the mesoscutellum (Figure 120).

***Vespa tropica* (Linnaeus, 1758)**

The workers are medium size hornets with a total length of approximately 2.5 cm. The head, antennae and clypeus are dark brown-red. The third to last abdominal segment is black. Although this species is very similar to *Vespa affinis*, they are easily clearified from *Vespa affinis* by yellow orange band on the second abdominal segment (Figure 121).

***Vespa velutina* Lepeletier, 1836**

The total length of worker is about 2 cm. All head appendages are bright brown. Their compound eyes are dark brown. The abdomen is black while the first and second abdominal segments are dark brown. The posterior margin of the first and second abdominal segments is orange-brown band. The middles of the third to sixth gasteral segments are dark orange with black marking. The last gasteral segment is orange brown (Figure 122).

Figure 117 A worker of *Provespa anomala* (de Saussure, 1905).

Figure 118 A worker of *Vespa affinis* (Linnaeus, 1764).

Figure 119 A worker of *Vespa mandarinia* Smith, 1852.

Figure 120 A worker of *Vespa soror* du Buysson, 1905.

Figure 121 A worker of *Vespa tropica* (Linnaeus, 1758).

Figure 122 A worker of *Vespa velutina* Lepeletier, 1836.

CHAPTER V

CONCLUSIONS AND DISCUSSIONS

The aculeate insects in northern Thailand were surveyed and collected both in natural forests and cultivated areas during January 2006 to June 2007. The aculeate species found in this area were composed of 3 superfamilies; Apoidea, Chrysidoidea, and Vespoidea. So far a total of 120 specimens within 9 families were identified. There were 35 species in 16 genera of 10 subfamiles belonging to 5 families of Apoidea, 5 species in 3 genera of a single subfamily and family of Chrysidoidea, and 80 species in 45 genera of 12 subfamilies belonging to 3 families of Vespoidea. This is similar to the report of Finnamore (1997) that the 3 superfamilies: Apoidea, Chrysidoidea, and Vespoidea were found the Yokun in Canada. Also, Yamane, Ikudome and Terayama (1999) reported that those 3 superfamiles in the Nansei islands, Japan comprised of 26 families and 188 genera. A total number of species in our study is lower than that in Japan as these islands are complete natural forests (Suzuki, 1980). Moreover, the Nansei islands were created as a result of the Okinawa Trough formation and tectonic shifting some 15 million years ago (Rryu et al., 2006). In result of that, there are many endemic animals still living in Nansei Islands (Suzuki, 1980), including endemic species of aculeates species (Yamane, Ikudome and Terayama, 1999). This may be because geographic zone of these islands is divided into 2 regions; the northern islands limit of the Oriental region and the southern limit of the Palearctic region (Suzuki, 1980) while northern Thailand is classified in Oriental region (Maxwell, 2004). In addition, Suzuki (1980) concluded that this area has high species diversity because of ecotone which is a transition area between 2 adjacent ecological communities. In accordance with the study of Fernández (2001) reported that in the Neotropical region of South American, there were 3 superfamiles: Apoidea, Chrysidoidea, and Vespoidea which comprised of 25 families and 807 genera. This area is the most species diversity of these insects due to the most species diversity of plants in the world (Gurevitch, Scheiner and Fox, 2002) which leads to high diversity of the aculeate species (LaSalle and Gauld, 1993).

The family formicidae in the superfamily Vespoidea showed the highest species composition (50.83%). Compare to 247 known species in Thailand in 9 subfamilies (Jaitrong and Nabhitabhata, 2005), 61 species in 7 subfamilies were found in our study. It is, therefore, 24.67% of ants known in Thailand were recorded in the north of Thailand. The reasons that explain the highest number of this family may be due to the Formicidae are one of the large families of aculeates with a large number of members. They also have wide distribution and are found in all zoogeographic regions, including Thailand (Bolton, 1997). Ant species have successfully occupied several habitats including forests and urban environments. In accordance with the study of Watanasit, Noon-anant and Binnima (2005) which found 44 ant species belonging to 6 subfamilies (Dolichoderinae, Dorylinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae) in an open area at Prince of Songkla University in the south of Thailand. From the study of Sitthicharoenchai and Chantarasawat (2006) which worked in 3 habitat types; deciduous dipterocarp forest, mango plantation, and grassland in Nan province, they found 46 species of ants which belonging to 5 subfamilies; Dolichoderinae, Formicinae, Myrmicinae, Ponerinae and Pseudomyrmecinae. Apart from previous works, Bickel and Watanasit (2005) studied diversity of leaf litter ant in Ton Nga Chang Wildlife Sanctuary and in rubber plantations, 28 genera comprising 59 ant species from 5 subfamilies were found. All recorded species were from subfamily Cerapachyinae, Dolichoderinae, Formicinae, Myrmicinae and Ponerinae. This successful in adaptation is probably related to their feeding habits because they feed on variety of foods; i.e. natural food sources of honeydew, plant secretions, insects (Laakso and Setala, 1998; Kamura et al., 2007). Our result concluded that the ants distribute in all types of habitat, and seems well correlated with previous works.

A total of 20 species, 4 genera within 3 subfamilies were identified in the family Apidae, known as honey bees, stingless bees and bumble bees. From our study, this number showed that Apidae was the second large group in number species in the infraorder Aculeata. This is also reported by Finnamore (1997) that the superfamily Apoidea is the second large group of the infraorder Aculeata. Michener (2007) explained that this group of insects distribute worldwide in all continents except Antarctica. The results of high species number of Apoidea in the north of Thailand

may be due to natural forests and cultivated areas have plenty of species diversity of plants which supported the food sources and habitats for the bees. In this study, we found that nesting sites of *Trigona* species can be divided into 4 groups; 1) cavities in tree trunks, 2) cavities in termite mounds, 3) underground cavities, and 4) cavities in buildings. Jongjitvimol and Wattanachaiyingcharoen (2007) found that the trunks of 14 tree species: *Caesalpinia sappan*, *Eugenia cumini*, *Ficus annulata*, *F. locor*, *F. religiosa*, *Herea brasiliensis*, *Hopea odorata*, *Irvingia malayana*, *Knema globulalia*, *Parkia speciosa*, *Shorea curtisii*, *Strychnos nuxvomica*, *Syzygium cumini* and *Tamarindus indica* were used as the host plants of *T. collina*. In addition, Jongjitvimol and Wattanachaiyingcharoen (2006) reported that 29 plant species found in deciduous with bamboo forests were exploited by 3 *Trigona* species of stingless bees: *T. apicalis*, *T. collina* and *T. fimbriata* in Phitsanolok province. In accordance with the report of Kaewkaw et al. (2008) which found 91 flowering-plant species were visited by stingless bees in Queen Sirikit Botanic Garderden in Chiang Mai province. The stingless bees with 14 species found showed the highest species number of this family. Most samples were found in deciduous with bamboo forest at an altitude of less than 400 meters above sea level. All species have been reported in Thailand (Sakagami, Inoue and Salmah, 1990; Klakasikorn et al., 2005; Jongjitvimol and Wattanachaiyingcharoen, 2006). In this study, the stingless bee, *T. collina* showed the highest species composition (384 nests). They are among the most common flower-visiting insects in the canopy and the under-storey of forests in Thailand, and are most likely play role as crucial pollinators (Thapyai, 1996; Tasen, 2001; Jongjitvimol and Wattanachaiyingcharoen, 2006). Also, we found most *T. collina* nests (149 nests) in cavities within the mounds of *Macrotermes* spp. The benefits of colony aggregation are postulated to be increased opportunities for outbreeding by virgin queens (Cameron et al., 2004; Jongjitvimol et al., 2005).

From our study, the vespid wasps (Vespidae) are the third group in species number. Seventeen species in 10 genera were identified in 4 subfamilies; Eumeninae, Polistinae, Stenogastrinae and Vespinae. Most of them were found in subfamily Vespinae. There were 6 species in 2 genera; *Provespa* and *Vespa*. Of the 23 species of *Vespa* known in the world, 18 species have been recorded in Thailand (Archer, 1989). LaSalle and Gauld (1997) reported that social wasps were indicators of ecological

importance in forests. In our study, 65 nests of *Vespa* were found in underground cavities, on trees and buildings. Most of them (45 nests) were found on buildings and tree in the city and cultivated area. This result showed that the number of their nests in forest areas were less than those in the city and cultivated areas. This may be because the increasing of the disturbance of forests in Thailand induced the vespid wasps into towns as previous report of Nakamura and Sonthichai (2004).

In general, altitude is an important factor influencing community structure, abundance, and diversity. The diversity of animals decreases with an increasing of altitude (Finnamore, 1997). Lower productivity of plants at higher elevations has been argued to cause such declines in abundance and diversity of insects (Romero-Alcaraz and Ávila, 2000). We surveyed the areas in northern Thailand at an average altitude of 622 meters above sea level. The highest area in the region reaches 2,572 meters above sea level (Chiangmai), while the lowest area is at 37 meters above sea level (Phichit). Hoffmann (2005) proposed that insect species richness was significantly affected by flowering plant species richness and flowering plant abundance. The difference in the number of aculeate species in each forest may be due to the difference in plant species, including the difference in food sources and host plants. Sanders, Moss, and Wagner (2003) and Zhu (2006) reported that values of species richness were shown in the higher level in the elevation range from 500 to 1,700 meters above sea level and species richness were decreased with an increasing elevation at 1,700 to 2,500 meters above sea level. At the level between 1,500 and 6,050 meters above sea level, Finnamore (1997) reported the negative relationship between the altitude and the species numbers of aculeate species. This negative relationship is that the latitudinal gradient increases, the species diversity decreases. In this study, the highest species number of aculeates was found in deciduous with bamboo forests (96 species), following by hill evergreen forest (70 species), mixed evergreen and deciduous forest (38 species), deciduous dipterocarp forest (29 species) and evergreen forest (21 species). In addition, the highest value of diversity index (J') of aculeates was found in hill evergreen forest (J' = 0.846), following by deciduous with bamboo forests (J' = 0.843), mixed evergreen and deciduous forest (J' = 0.691), deciduous dipterocarp forest (J' = 0.668) and evergreen forest (J' = 0.603). The grassland was

the less in their species richness ($J' = 0.369$). This may be because this area is less abundant in plant species, hence, less food source and shelter providing to those insects. Moreover, we found that the value of species diversity index in deciduous with bamboo forest ($J' = 0.843$) had slightly lower than hill evergreen forest ($J' = 0.846$) while the highest species number (96 species) of aculeates was found in deciduous with bamboo forests. This might be because the number of individuals of each species or frequency found of each species in hill evergreen forest (286 specimens) is lower than that in deciduous with bamboo forest (1,264 specimens).

From the result of the diversity index showed that the diversity of aculeate species in each forest; bamboo forests, hill evergreen forest, mixed evergreen and deciduous forest, deciduous dipterocarp forest and evergreen forest was higher than 0.5 which indicated the high species diversity. This result differed from of the dominant index (Simpson's index: C). The highest dominant index (0.202) of aculeates was found in grassland, following by evergreen forest (0.061), deciduous dipterocarp forest (0.051), mixed evergreen and deciduous forest (0.047), cultivated areas (0.044), hill evergreen forest (0.035), forest area (0.027) and mixed evergreen and deciduous forest (0.020). Although grassland has the highest dominant index of aculeates, they have less plant and aculeate diversity. Therefore, some dominant species can occur, even at lower than 0.5. The Simpson's index of other areas is lower than 0.5 which means that all areas do not have dominant species. This is may be due to the abundance of forest resources, and also the complex community. Floral abundance might support species diversity of aculeates leading to less competition among creatures. Gathmann, Greiler and Tscharntke (1994) proposed that diverse vegetation obviously supplied a greater amount of nutritious pollen, thereby supporting more bee species and therefore, plant diversity through bee pollinations. This is a plausible explanation for the species richness and the diversity index of all forests (120 species, $J' = 0.880$) which were higher than that of cultivated areas (54 species, $J' = 0.663$).

In addition to altitude changes, food sources and host plants influenced the aculeate species richness. From the Sorensen's similarity coefficient: S_s showed that natural forests and cultivated areas ($S_s = 0.621$) were similar in relation of species

presence-absence. This may be because 54 species found in cultivated areas were presented in natural forests. In addition, food sources and host plants in continuously agricultural process enhance the survival and reproduction of these aculeate species. Similar result was found in natural forests. This may be because deforestation, slash and burn for agriculture, and forest fire in natural forests affected on tree growth, and survival of insects by destroying flora and fauna (Hoamuangkaew, 2007). Therefore, they lead to migration of aculeates from natural forests to cultivated areas and human dwellings.

From the calculated 3 ecological indices: species diversity index (J'), dominant index (C) and similarity index (S_s) in each type of habitats, we found that the species diversity indices in each habitat were higher than 0.5 (Table 8) which mean that those areas are high species diversity, except grassland. Also dominant species in each habitat were lower than 0.5 (Table 8) which means that all areas do not have dominant species. From the diversity index and dominant index showed that those areas are more abundant in plant diversity leading to resource partitioning in foods and shelters of aculeate species (LaSalle and Gauld, 1993). Finally, the comparison of each type of habitats showed that the similarity index in each habitat were higher than 0.5 (Table 9) which means that those areas were more similar in species structure of aculeates. This may be because each type of habitats is similar in plant community structures, including food plants and host plants (Maxwell et al., 1995; Maxell, 1996; Maxwell et al., 1997; Maxwell, 1998; Maxwell, 2004) which are niche of aculeate species (O'Toole and Raw, 1999).

According to the identification handbooks (Chapter III), we were unable to identify 32 specimens to species level. They were classified in 24 genera: *Bembix*, *Bombus*, *Camponotus*, *Campsomeris*, *Chalybion*, *Chrysis*, *Coelioxys*, *Delta*, *Halictus*, *Hyoptrigona*, *Lepisiota*, *Megachile*, *Philidris*, *Polites*, *Polybioides*, *Polyrhachis*, *Praestochrysis*, *Rhynchium*, *Ropalidia*, *Sceliphron*, *Scolia*, *Sphex*, *Thyreus* and *Trichrysis* (Table 5).

Our report is the first study of species diversity and taxonomy of the insects in the infraorder Aculeata in Thailand. Even though some parts of forests in the north of Thailand have been deforested and converted for agricultural purposes, they are high in biological diversity. The forests are important natural resources for people and

insects because they are rich in floral, fauna and water resources. Thus, the more aculeate insects mean the more complete forest due to these insects play role as pollinators of plants. We proposed that the areas are important for the maintenance of the aculeate species.

REFERENCES

REFERENCES

Ambrose, J. T. (1997). **Insect note: Beekeeping**. USA: North Carolina State University.

Araújo, V. A., Antonini, Y. and Araújo, A. P. A. (2006). Diversity of bees and their floral resources at altitudinal areas in the southern Espinhaço range, Minas Gerais, Brazil. **Neotropical Entomology**. 35(1), 30-40.

Archer, M. E. (1989). **A key to the world species of the Vespinae (Hymenoptera) part 1: Keys, checklist and distribution**. York: The Academic Board Research Committee of the College of Ripon and York St John.

Bickel, T. O. and Watanasit, S. (2005). Diversity of leaf litter ant communities in Ton Nga Chang Wildlife Sanctuary and nearby rubber plantations, Songkhla, Southern Thailand. **Songklanakarin Journal of Science and Technology**, 27(5), 943-955.

Bolton, B. (1997). **Identification guide of the ant genera of the world** (2nd ed.). Massachusetts: Cambridge.

Borror, D. J., Triplehorn, C. A. and Johnson, N. F. (1989). **Study of insects** (6th ed.). USA: Saunders College Publishing.

Brothers, D. J. and Finnamore, A. T. (1993). Superfamily Vespoidea. In H. Goulet and J. T. Huber (Eds.), **Hymenoptera of the world: An identification guide to families** (pp. 161-278). Ottawa: Agriculture Canada Publication.

Buchmann, S.T. and Nabhan, G.P. (1996). **The forgotten pollinators**. Washington, D.C.: Inland Press.

Budrys, E. (2000). Notes on the synonymy and distribution of Asiatic *Psen* Latr. and *Psenulus* Kohl (Hymenoptera, Sphecidae, Psenini). **Acta Zoologica Lituanica**, 10(1), 63-69.

Callan, E. McC. (1979). The Sphecidae (Hymenoptera) of New Zealand. **New Zealand Entomologist**, 7(1), 30-41.

Camargo J. M. F. and Menezes-Pedro S. R. (1992). Systematics, phylogeny and biogeography of the Meliponinae (Hymenoptera, Apidae): A mini-review. **Apidologie**, 23(6), 509-522.

Cameron, E. C., Franck, P. and Oldroyd, B. P. (2004). Genetic structure of nest aggregations and drone congregations of the Southeast Asian stingless bee *Trigona collina*. **Molecular Ecology**, 13(8), 2357-2364.

Cameron, S. A., Hines, H. M. and Williams, P. H. (2007). A comprehensive phylogeny of the bumble bees (*Bombus*). **Biological Journal of the Linnean Society**, 91(1), 161-188.

Carpenter, J. M. (1993). Biogeographic patterns in the Vespidae (Hymenoptera): Two views of Africa and South America. In P. Goldblatt (Ed.), **Biological relationships between Africa and South America** (pp. 139-155). New Halen: Yale University.

Carpenter, J. M., and Garcete-Barrett, B. R. (2002). A key to the Neotropical genera of Eumeninae (Hymenoptera: Vespidae). **Boletin del Museo Nacional de Historia Natural del Paraguay**, 14(1-2), 52-73.

Carpenter, J. M. and Nguyen, P. L. T. (2003). Keys to the genera of social wasps of South-East Asia. **Entomological Science**, 6(3), 183-192.

Carpenter, J. M. and Starr, C. K. (2000). A new genus of hover wasps from Southeast Asia (Hymenoptera: Vespidae; Stenogastrinae). **American Museum Novitates**, 3291(1), 1-12.

Daly, H. V. (1983). Taxonomy and ecology of Ceratinini of North Africa and the Iberian Peninsula (Hymenoptera: Apoidea). **Systematic Entomology**, 8(1), 29-62.

Danks, H. V. and Downes J. A. (1998). Insects of the Yukon. **Journal of the North American Benthological Society**, 17(3), 377-378.

Elzinga, R.J. (2000). **Fundamentals of entomology** (5th ed.). USA: Kansas State University, Prentice-Hall.

Fernández, F. C. (2001). Checklist of genera and subgenera of aculeate Hymenoptera of the Neotropical region (Hymenoptera: Vespomorpha). **Biota Colombiana**, 2(2), 87-130.

Finnamore, A. T. (1997). Aculeate wasps (Hymenoptera: Aculeata) of the Yukon, Other than Formicidae. In H.V., Danks and J.A., Downes (Eds.), **Insects of the Yukon** (pp. 867-900). Ottawa: Biological Survey of Canada (Terrestrial Arthropods) Publication.

Finnamore, A. T. and Michener, C. D. (1993). Superfamily Apoidea. In H. Goulet and J. Huber (Eds.), **Hymenoptera of the world: An identification guide to families** (pp. 279-357). Ottawa: Agriculture Canada Publication.

Gathmann, A., Greiler, H. J. and Tscharntke, T. (1994). Trap nesting bees and wasps colonizing set-aside fields: Succession and body size, management by cutting and sowing. **Oecologia**, 98(1), 8-14.

Gauld, I. and Bolton, B. (Eds.). (1996). **The Hymenoptera** (2nd ed.). New York: London and Oxford University Press.

Genaro, J. A. (1998). Distribution and synonymy of some caribbean bees of the genera *Megachile* and *Coelioxys* (Hymenoptera: Megachilidae). **Caribbean Journal of Science**, 34(1-2), 151-152.

Giovanettin, M. (2005). Ecology, behavior and bionomics: Nesting ecology of a neotropical solitary wasp (Hymenoptera: Sphecidae) in Panamá. **Neotropical Entomology**, 34(5), 713-719.

Goodman, R. (Ed.). (1991). **Beekeeping** (7th ed.). USA: North Melboume Creative Solutions.

Goulet, H. and Huber, J. (Eds.). (1993). **Hymenoptera of the world: An identification guide to families**. Ottawa: Agriculture Canada Publication.

Grabenweger, G., Kehrli, P., Schlick-Steiner, B., Steiner, F., Stolz, M. and Bacher, S. (2005). Predator complex of the horse chestnut leafminer *Cameraria ohridella*: identification and impact assessment. **Journal of Applied Entomology**, 129 (7), 353–362.

Gupta, S. K. and Jonathan, J. K. (2003). **Fauna of India and the adjacent countries: Hymenoptera: Scoliidae.** India: Zoological Survey of India Publications.

Gurevitch, J., Scheiner, S. M. and Fox, G. A.. (2002). **The ecology of plants**. USA: Sinauer Associates.

Harris, A. C. (1979). Occurrence and nesting of the yellow oriental paper wasp, *Polistes olivaceus* (Hymenoptera: Vespidae), in New Zealand. **New Zealand Entomologist**, 7(1), 41-44.

Hirashima, Y. (1969). Synopsis of the genus *Pithitis* Klug of the world (Hymenoptera: Anthophoridae). **Pacific Insects**, 11(3-4), 649-669.

Hoamuangkaew, W. (2007). Forest management. **Journal of Forest Management**, 1(1), 62-81.

Hoffmann, F. (2005). **Biodiversity and pollination : Flowering plants and flower-visiting insects in argicultural and semi-natural landscapes**. The Netherlands: Febodruk B.V. Enschede.

Hölldobler, B. and Wilson, E. O. (1990). **The ants**. Cambridge: Belknap Press of Harvard University Press.

Jaitrong, W. and Nabhitabhata, J. (2005). A list of known ant species of Thailand (Formicidae: Hymenoptera). **The Thailand Natural History Museum Journal**, 1(1), 9-54.

Jongjitvimol, T., Boonthavon, K., Wattanachaiyingcharoen,W. and Deowanish, S. (2005). Nest dispersion of a stingless bee species; *Trigona collina* Smith, 1857 (Apidae: Meliponinae) in mixed deciduous forests in Thailand. **The Natural History Journal of Chulalongkorn University**, 5(2), 69-71.

Jongjitvimol, T. and Wattanachaiyingcharoen, W. (2006). Pollen food sources of the stingless bees *Trigona apicalis* Smith, 1857, *T. collina* Smith, 1857 and *T. fimbriata* Smith, 1857 (Apidae, Meliponinae) in Thailand. **The Natural History Journal of Chulalongkorn University**, 6(2), 75-82.

Jongjitvimol, T., and Wattanachaiyingcharoen, W. (2007). Distribution, nesting sites and nest structures of the stingless bee species, *Trigona collina* Smith, 1857 (Apidae, Meliponinae) in Thailand. **The Natural History Journal of Chulalongkorn University**, 7(1), 25-34.

Kaewkaw, R., Eaidthong, W., Sawatthum, A., Wongrisi, S. and Juntawong, N. (2008). Database of plant species for stingless bee (*Trigona* sp.) in Queen Sirikit Botanic Garden, Chiang Mai province. In **Bees and Bee Porducts** (pp. 9). Chiangmai: Chiangmai University.

Kamura, C. M., Morini, M. S. C., Figueiredo, C. J., Bueno, O. C. and Campos-Farinha, A. E. C. (2007). Ant communities (Hymenoptera: Formicidae) in an urban ecosystem near the Atlantic Rainforest. **Brazilian Journal of Biology**, 67(4), 635-641.

Kaplan, I. and Eubanks, M.D. (2002). Disruption of cotton aphid (Homoptera: Aphididae) natural enemy dynamics by red imported fire ants (Hymenoptera: Formicidae). **Community and Ecosystem Ecology**, 31(6), 1175-1183.

Khan, M. R. and Khan, M. R. (2004). The role of honey bees *Apis mellifera* L. (Hymenoptera: Apidae) in pollination of apple. **Pakistan Journal of Biological Sciences**, 7 (3), 359-362.

King, J. (1984). Immature stages of some Megachilidae (Hymenoptera: Apoidea). **Journal of the Australian Entomological Society**, 23(1), 51-57.

King, J. and Exley, E. M. (1985). A revision of *Chalicodoma* (Chalicodomoides) Michener (Hymenoptera: Megachilidae). **Journal of the Australian Entomological Society**, 24(3), 187-191.

Klakasikorn, A., Wongsiri, S., Deowanish, S. and Duangphakdee, O. (2005). New record of stingless bees (Meliponini: *Trigona*) in Thailand. **The Natural History Journal of Chulalongkorn University**, 5(1), 1-7.

Kojima, J. and Carpenter, J. M. (1997). Catalog of species in the polistine tribe Ropalidiini (Hymenoptera: Vespidae). **American Museum Novitates**, 3199(1), 1-96.

Krebs, C. J. (1999). **Ecology methodology** (2nd ed.). Canada: An Imprint of Addison Wesley Longman.

Laakso, J. and Setala, H. (1998). Composition and trophic structure of detrital food web in ant nest mounds of *Formica aquilonia* and in the surrounding forest soil. **Oikos**, 81(1), 266-278.

LaSalle, J. and Gauld, I.D. (Eds.). (1997). **Hymenoptera and biodiversity**. UK: CABI Publishing.

Mancini, K., Lino-Neto, J., Campos, L. A. O. and Dolder, H. (2006). Sperm ultrastructure of the wasp *Agelaia vicina* (Hymenoptera, Vespidae). **Insectes Sociaux**, 53(3), 333-338.

Maxell, J. F. (1996). Vegetation of the Mae Soi Conservation Area, Chom Tong District, Chiang Mai Province, Thailand, **Tigerpaper (FAO)**, 23(1), 22-27.

Maxwell, J.F. (1998). Botanical Notes on the Flora of Northern Thailand, 6. **The Natural History Bulletin of the Siam Society**, 46(2), 151-159.

Maxwell, J. F. (2004). A synopsis of the vegetation of Thailand. **The Natural History Journal of Chulalongkorn University**, 4(2), 19-29.

Maxwell, J. F., Elliott, S., Palee, P. and Anusarnsunthorn, V. (1995). The vegetation of Doi Khuntan National Park, Lamphun-Lampang Provinces, Thailand. **The Natural History Bulletin of the Siam Society**, 43(2), 185-206.

Maxwell, J. F., Elliott, S., Palee, P. and Anusarnsunthorn, V. (1997). The vegetation of Jae Sawn National Park, Lamphun Province, Thailand. **The Natural History Bulletin of the Siam Society**,45(1), 71-97.

Michener, C. D. (2007). **The bees of the world** (2nd ed.). USA: John Hopkins University Press.

Michener, C. D. and Boongird, S. (2004). A new species of *Trigona* from Peninsular Thailand (Hymenoptera: Apidae: Meliponini). **Journal of the Kansas Entomological Society**, 77(2), 143-146.

Mitchell, T. B. (1980). **A generic revision of the megachiline bees of the Western Hemisphere**. North Carolina: North Carolina State University.

Nakamura, M. and Sonthichai, S. (2004). Nesting habits of some hornet species (Hymenoptera, Vespidae) in Northern Thailand. **Kasetsart Journal of Natural Science**, 38(2), 196–206.

Nguyen, L. T. P., Saito, F., Kojima, J. and Carpenter, J. M. (2006). Vespidae of Viet Nam (Insecta: Hymenoptera) 2: Taxonomic notes on Vespinae. **Zoological Science**, 23(1), 95-104.

Niu, Z. Q., Wu, Y. R. and Huang, D. W. (2004). A taxonomic study on the subgenus *Seladonia* (Hymenoptera: Halictidae: *Halictus*) in China with a description of a new species. **Zoological Studies**, 43(4), 647-670.

Oldroyd, B. P. and Wongsiri, S. (2006). **Asian honey bees: Biology, conservation and human interactions**. London: Harvard University Press.

O'Toole, C. and Raw, A. (1999). **Bees of the world**. UK: Blandford.

Pianka, E. R. (2000). **Evolutionary ecology** (6th ed.). USA: The University of Texas at Austin, An Imprint of Addison Wesley Longman.

Pawlikowski, T. and Hirsch, J. (2002). Bees (Hymenoptera: Apoidea) as indicators of xerisation processes in the lower Vistula Valley. **Acta Zoologica Cracoviensia**, 45(4), 321-336.

Pinto, M. A., Sheppard, W. S., Johnston, J. S., Rubink, W. L., Coulson, R. N., Schiff, N. M., et al. (2007). Honey bees (Hymenoptera: Apidae) of African origin exist in non-Africanized areas of the Southern United States: evidence from mitochondrial DNA. **Annals of the Entomological Society of America**, 100(2), 289-295.

Proshchalykin, M. Y. (2004). A check list of the bees (Hymenoptera, Apoidea) of the southern part of the Russian Far East. **Far Eastern Entomologist**, 143(1), 1-17.

Raju, A. J. S. and Rao, S. P. (2006). Nesting habits, floral resources and foraging ecology of large carpenter bees (*Xylocopa latipes* and *Xylocopa pubescens*) in India. **Current Science**, 9(9), 1210-1217.

Romero-Alcaraz, E. and Ávila, J. M. (2000). Effect of elevation and type of habitat on the abundance and diversity of scarabaeoid dung beetle (Scarabaeoidea) assemblages in a Mediterranean area from southern Iberian Peninsula. **Zoological Studies**, 39(4), 351-359.

Romoser, W.S. and Stoffolano, J.G. (1998). **The science of entomology** (4th ed.). USA: McGraw-Hill.

Rryu, Y., Matsuda, H., Machiyama, H., Piller, W. E., Quinn, T. M. and Mutti, M. (2006). Introductory perspective on the COREF project. **Island Arc**, 15(4), 393-406.

Saito, F., and Kojima, J. (2005). Colony cycle in the south-eastern coastal populations of *Ropalidia plebeiana*, the only *Ropalidia* wasp occurring in temperate Australia. **Entomological Science**, 8(3), 263-275.

Sakagami, S. F., Inoue, T. and Salmah, S. (1990). Stingless bees of central Sumatra. In S. F. Sakagami, R. Ohgushi, and D.W. Roubik (Eds), **Natural history of social wasps and bees in Equatorial Sumatra** (pp. 125-138). Sapporo: Hokkaido University Press.

Sanders, N. J., Moss, J. and Wagner, D. (2003). Patterns of ant species richness along elevational gradients in an arid ecosystem. **Global Ecology and Biogeography**, 12(2), 93-102.

Sato, H. (2002). The role of autonomous self-pollination in floral longevity in varieties of *Impatiens hypophylla* (Balsaminaceae). **American Journal of Botany**, 89(2), 263-269.

Schwarz, H. F. (1939). The Indo-Malayan species of *Trigona*. **Bulletin of the American Museum of Natural History**, 76(1), 83-141.

Shattuck, S. O. (1999). **Australian ants: Their biology and identification**. Collingwood: CSIRO Publishing.

Sitthicharoenchai, D. and Chantarasawat, N. (2006). Ant species diversity in the establishing area for Advanced Technology Institute at Lai-Nan sub-district, Wiang Sa district, Nan province, Thailand. **The Natural History Journal of Chulalongkorn University**, 6(2), 67-74.

Speight, M. R., Hunter, M. D. and Watt, A. D. (1999). **Ecology of insects: Concepts and applications**. Great Britain: Blackwell Science.

Suzuki, H. (1980). Trombiculid fauna in Nansei Islands and their characteristics (Prostigmata, Trombiculidae). **Tropical Medicine**, 22(3): 137-159.

Tasen, W. (2001). **The role of some major insect pollinators on pollination of teak (*Tectona grandis* Linn.f.)**. Master thesis, M.Sc., Kasetsert University, Bangkok.

Thapyai, C. (1996). **The reproductive ecology of forest plants on some successional stages**. Master thesis, M.Sc., Kasetsert University, Bangkok.

Turillazzi, S. (1989). The origin and evolution of social life in the Stenogastrinae (Hymenoptera, Vespidae). **Journal of Insect Behavior**, 2(5), 649-661.

Tüzün, A. (2004). Studies on Scoliidae (Insecta: Hymenoptera) fauna of Ankara province. **F. Ü. Fen ve Mühendislik Bilimleri Dergisi**, 16(1), 25-29.

Vecht, J. van der. (1966). The East Asiatic and Indo-Australian species of *Polybioides* du Buysson and *Parapolybia* de Saussure (Hym., Vespidae). **Zoologische Verhandelingen**, 82(1), 1–42.

Velthuis, H. H. W. (1997). **The biology of stingless bees**. Brazil: University of São Paulo Press.

Watanasit, S., Noon-anant, N. and Binnima, N. (2005). Preliminary survey of ants at a reserve area of Prince of Songkla University, Songkhla Province, Southern Thailand. **Songklanakarin Journal of Science and Technology**, 27(1), 39-46.

Warrit, N. (2007). *Ceratina* (*Ceratinidia*) *compacta*, a small carpenter bee in Thailand: An apparent recent addition to the fauna (Hymenoptera, Apidae). **Journal of the Kansas Entomological Society**, 80(1), 72-77.

Wcislo, W. T., Gonzalez, V. H. and Arneson, L. (2004). A review of deviant phenotypes in bees in relation to brood parasitism, and a gynandromorph of *Megalopta genalis* (Hymenoptera: Halictidae). **Journal of Natural History**, 38(11), 1443-1457.

Yamane, S. (1990). A revision of the Japanese Eumenidae (Hymenoptera, Vespoidea). **Insecta Matsumurana**, 43, 1-189.

Yamane, S., Ikudome, S. and Terayama, M. (1999). **Identification guide to the Aculeata of the Nansei Islands, Japan**. Sapporo: Hokkaido University Press.

Zhu, H. (2006). Forest vegetation of Xishuangbanna, south China. **Forest Stud China**, 8(2), 1-58.

APPENDIX

Table 5 Taxonomic list of insect in the infraorder Aculeata found in the north of Thailand.

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08001	Apoidea	Anthophoridae	Anthophorinae	Anthophorini	*Amegilla florea* (Smith ,1879)	blue-banded bee	แมลงภู่
NUTJ08002	Apoidea	Anthophoridae	Xylocopinae	Ceratinini	*Ceratina lieftincki* van der Vecht, 1952	small carpenter bee	แมลงภู่
NUTJ08003	Apoidea	Anthophoridae	Xylocopinae	Ceratinini	*Pithilis smaragdula* (Fabricius, 1787)	carpenter bee	แมลงภู่
NUTJ08004	Apoidea	Anthophoridae	Xylocopinae	Melectini	*Thyreus* sp.	blue carpenter bee	แมลงภู่
NUTJ08005	Apoidea	Anthophoridae	Xylocopinae	Xylocopini	*Xylocopa confusa* Pérez, 1901	large carpenter bee	แมลงภู่
NUTJ08006	Apoidea	Anthophoridae	Xylocopinae	Xylocopini	*Xylocopa latipes* (Drury, 1773)	large carpenter bee	แมลงภู่
NUTJ08007	Apoidea	Apidae	Apinae	Apini	*Apis andreniformis* Smith, 1858	small dwarf honey bee	ผึ้งม้าม/มิ้มเล็ก
NUTJ08008	Apoidea	Apidae	Apinae	Apini	*Apis cerana* Fabricius, 1793	indian honey bee	ผึ้งโพรง
NUTJ08009	Apoidea	Apidae	Apinae	Apini	*Apis dorsata* Fabricius, 1793	giant honey bee	ผึ้งหลวง
NUTJ08010	Apoidea	Apidae	Apinae	Apini	*Apis florea* Fabricius, 1787	dwarf honey bee	ผึ้งมิ้ม
NUTJ08011	Apoidea	Apidae	Apinae	Apini	*Apis mellifera* Linnaeus, 1758	western bee	ผึ้งยุโรป/ผึ้งพันธุ์
NUTJ08012	Apoidea	Apidae	Bombinae	Bombini	*Bombus* sp.	bumble bee	ผึ้งหึ่ง
NUTJ08013	Apoidea	Apidae	Meliponinae	Meliponini	*Hyoptrigona* sp.	stingless bee	ชันโรง
NUTJ08014	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona apicalis* Smith, 1857	stingless bee	ชันโรง
NUTJ08015	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona collina* Smith, 1857	stingless bee	ชันโรง
NUTJ08016	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona fimbriata* Smith, 1857	stingless bee	ชันโรง
NUTJ08017	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona fuscobalteata* Cameron, 1908	stingless bee	ชันโรง
NUTJ08018	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona itama* Cockerell, 1918	stingless bee	ชันโรง

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08019	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona laeviceps* Smith, 1857	stingless bee	ชันโรง
NUTJ08020	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona melanoleuca* Cockerell, 1929	stingless bee	ชันโรง
NUTJ08021	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona minor* Sakagami, 1978	stingless bee	ชันโรง
NUTJ08022	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona nitidiventris* Smith, 1857	stingless bee	ชันโรง
NUTJ08023	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona peninsularis* Cockerell, 1927	stingless bee	ชันโรง
NUTJ08024	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona terminata* Smith, 1878	stingless bee	ชันโรง
NUTJ08025	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona thoracica* Smith, 1857	stingless bee	ชันโรง
NUTJ08026	Apoidea	Apidae	Meliponinae	Meliponini	*Trigona ventalis* Smith, 1857	stingless bee	ชันโรง
NUTJ08027	Apoidea	Halictidae	Halictinae	Halictini	*Halictus* sp.	leafcutter bee	ผึ้งกัดใบ
NUTJ08028	Apoidea	Megachilidae	Megachilinae	Megachihi	*Coelioxys* sp.	leafcutter bee	ผึ้งกัดใบ
NUTJ08029	Apoidea	Megachilidae	Megachilinae	Megachihi	*Megachile* sp.1	leafcutter bee	ผึ้งกัดใบ
NUTJ08030	Apoidea	Megachilidae	Megachilinae	Megachihi	*Megachile* sp.2	leafcutter bee	ผึ้งกัดใบ
NUTJ08031	Apoidea	Sphecidae	Nyssoninae	Bembecini	*Bembix* sp.	sand wasp	ต่อทราย
NUTJ08032	Apoidea	Sphecidae	Sceliphroninae	Sceliphronini	*Chalybion* sp.	digger wasp	ต่อหมาร่า
NUTJ08033	Apoidea	Sphecidae	Sceliphroninae	Sceliphronini	*Sceliphron* sp.1	digger wasp	ต่อหมาร่า
NUTJ08034	Apoidea	Sphecidae	Sceliphroninae	Sceliphronini	*Sceliphron* sp.2	digger wasp	ต่อหมาร่า
NUTJ08035	Apoidea	Sphecidae	Sphecinae	Sphecini	*Sphex* sp.	digger wasp	ต่อหมาร่า
NUTJ08036	Chrysidoidea	Chrysididae	Chrysidinae	Chrysidini	*Chrysis* sp.1	kuckoo wasp	ต่อกาเหว่า

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08037	Chrysidoidea	Chrysididae	Chrysidinae	Chrysidini	*Chrysis* sp.2	kuckoo wasp	ต่อกาเหว่า
NUTJ08038	Chrysidoidea	Chrysididae	Chrysidinae	Chrysidini	*Chrysis* sp.3	kuckoo wasp	ต่อกาเหว่า
NUTJ08039	Chrysidoidea	Chrysididae	Chrysidinae	Chrysidini	*Trichrysis* sp.	kuckoo wasp	ต่อกาเหว่า
NUTJ08040	Chrysidoidea	Chrysididae	Chrysidinae	Chrysidini	*Praestochrysis* sp.	kuckoo wasp	ต่อกาเหว่า
NUTJ08041	Vespoidea	Formicidae	Aenictinae	Aenictini	*Aenictus binghami* Forel, 1900	army ant	มดทหารบิงแฮม
NUTJ08042	Vespoidea	Formicidae	Cerapachyinae	Cerapachyini	*Cerapachys sulcinodis* Emery, 1889	cannibal ant	มดท้องคอดสีนิล
NUTJ08043	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Dolichoderus thoracicus* (F. Smith, 1860)	dolly ant	มดก้นห้อยธรรมดา
NUTJ08044	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Dolichoderus tuberifer* Emery, 1887	dolly ant	มดก้นห้อยเอวกลม
NUTJ08045	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Iridomyrmex anceps* (Roger, 1863)	meat ant	มดดำทุ่ง
NUTJ08046	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Philidris* sp.	golden ant	มด
NUTJ08047	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Technomyrmex kraepelini* Forel, 1950	house ant	มดเอวแบนโคนขา
NUTJ08048	Vespoidea	Formicidae	Dolichoderinae	Dolichoderini	*Technomyrmex modiglianii* Emery, 1900	house ant	มดเอวแบนหัวใจ
NUTJ08049	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus camelinus* (F. Smith, 1857)	sugar ant	มดตะลานป่าหัวดำ
NUTJ08050	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus leonadi* Emery, 1889	sugar ant	มดตะลานขนทอง
NUTJ08051	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus rufoglaucus* (Jerdon, 1851)	sugar ant	มดตะลานขาขน
NUTJ08052	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus singularis* (F. Smith, 1858)	sugar ant	มดตะลานป่าหัวแดง
NUTJ08053	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus* sp.1	sugar ant	มดตะลาน
NUTJ08054	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus* sp.2	sugar ant	มดตะลาน

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08055	Vespoidea	Formicidae	Formicinae	Camponotini	*Camponotus* sp.2	sugar ant	มดตะลาน
NUTJ08056	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis abdominalis* F. Smith, 1858	spiny ant	มดหนามกระทิงแดง
NUTJ08057	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis armata* (Le Guillou, 1842)	spiny ant	มดหนามหีบเรียบ
NUTJ08058	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis bihamata* (Drury, 1773)	spiny ant	มดหนามเดียวใหญ่
NUTJ08059	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis dives* F. Smith, 1857	spiny ant	มดหนามกระทิงขน
NUTJ08060	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis flavicornis* F. Smith, 1857	spiny ant	มดหนามยอดไม้ดำ
NUTJ08061	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis furcata* F. Smith, 1858	spiny ant	มดหนามกระทิง
NUTJ08062	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis hippomanes* F. Smith, 1861	spiny ant	มดหนามฮิบโปเล็ก
NUTJ08063	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis muelleri* Forel, 1893	spiny ant	มดหนามกระทิงเล็ก
NUTJ08064	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis proxima* Roger, 1863	spiny ant	มดหนามหีบทองง่าม
NUTJ08065	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis tibialis* F. Smith, 1858	spiny ant	มดหนามกระทิงเทา
NUTJ08066	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis* sp.1	spiny ant	มดหนามกระทิง
NUTJ08067	Vespoidea	Formicidae	Formicinae	Camponotini	*Polyrhachis* sp.2	spiny ant	มดหนามกระทิง
NUTJ08068	Vespoidea	Formicidae	Formicinae	Oecophyllini	*Oecophylla smaragdina* (Fabricius, 1775)	weaver ant	มดแดง
NUTJ08069	Vespoidea	Formicidae	Formicinae	Plagiolepidini	*Anoplolepis gracilipes* (F. Smith, 1857)	crazy ant	มดน้ำผึ้ง
NUTJ08070	Vespoidea	Formicidae	Formicinae	Plagiolepidini	*Lepisiota* sp.	ant	มด
NUTJ08071	Vespoidea	Formicidae	Formicinae	Plagiolepidini	*Paratrechina longicornis* (Latreille, 1802)	black crazy ant	มดรำคาญขายาว
NUTJ08072	Vespoidea	Formicidae	Myrmicinae	Cataulacini	*Cataulacus granulatus* (Latreille, 1802)	ant	มดปล้องไผ่ธรรมดา

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08073	Vespoidea	Formicidae	Myrmicinae	Crematogastrini	*Crematogaster coriaria* Mayr, 1872	acrobat ant	มดยี้ดำ
NUTJ08074	Vespoidea	Formicidae	Myrmicinae	Crematogastrini	*Crematogaster difformis* F. Smith, 1857	acrobat ant	มดยี้โป่งดำ
NUTJ08075	Vespoidea	Formicidae	Myrmicinae	Crematogastrini	*Crematogaster rogenhoferi* Mayr, 1879	acrobat ant	มดยี้ทุ่ง
NUTJ08076	Vespoidea	Formicidae	Myrmicinae	Formicoxenini	*Cardiocondyla wroughtonii* (Forel, 1890)	sneaking ant	มดเกล็ดเรียบเหลือง
NUTJ08077	Vespoidea	Formicidae	Myrmicinae	Melissotarsini	*Rhopalomastix janeti* Donisthorpe, 1936	ant	มด
NUTJ08078	Vespoidea	Formicidae	Myrmicinae	Meranoplini	*Meranoplus bicolor* (Guerin-Meneville,1844)	shield ant	มดโล่ห์บ้าน
NUTJ08079	Vespoidea	Formicidae	Myrmicinae	Myrmecinini	*Pristomyrmex punctatus* Smith,1860	spiny jungle ant	มดเต่าดำ
NUTJ08080	Vespoidea	Formicidae	Myrmicinae	Pheidolini	*Pheidole plagiaria* (F. Smith, 1860)	big-headed ant	มดคันใหญ่ร่องโค้ง
NUTJ08081	Vespoidea	Formicidae	Myrmicinae	Pheidologetonini	*Pheidologeton diversus* (Jerdon,1851)	army ant	มดง่ามทุ่ง
NUTJ08082	Vespoidea	Formicidae	Myrmicinae	Solenopsidini	*Monomorium destructor* (Jerdon, 1851)	singapore ant	มดละเอียดท้องดำ
NUTJ08083	Vespoidea	Formicidae	Myrmicinae	Solenopsidini	*Solenopsis geminata* (Fabricius, 1804)	fire ant	มดคันไฟ
NUTJ08084	Vespoidea	Formicidae	Myrmicinae	Tetramoriini	*Rhoptromyrmex wroughtoni* Forel, 1902	ant	มดปลวกทุ่ง
NUTJ08085	Vespoidea	Formicidae	Myrmicinae	Tetramoriini	*Tetramorium flavipes* Emery, 1893	pennant ant	มดริ้วขาเหลือง
NUTJ08086	Vespoidea	Formicidae	Ponerinae	Ectatommini	*Gnamptogenys bicolor* (Emery, 1889)	army ant	มดค่อมอกแดง
NUTJ08087	Vespoidea	Formicidae	Ponerinae	Leptogenyini	*Leptogenys diminuta* (F. Smith, 1857)	genial killer ant	มดเล็บหวีอกคอด
NUTJ08088	Vespoidea	Formicidae	Ponerinae	Leptogenyini	*Leptogenys kitteli* (Mayr, 1870)	genial killer ant	มดเล็บหวีอกร่อง
NUTJ08089	Vespoidea	Formicidae	Ponerinae	Odontomachini	*Odontomachus rixosus* F. Smith, 1857	trap-jaw ant	มดกระโดดเหลือง
NUTJ08090	Vespoidea	Formicidae	Ponerinae	Odontomachini	*Odontomachus simillimus* F. Smith, 1858	trap-jaw ant	มดกระโดดบ้าน

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08091	Vespoidea	Formicidae	Ponerinae	Ponerini	*Diacamma sculpturata* (F. Smith, 1859)	bladder ant	มดหนามคู่ท้องร่อง
NUTJ08092	Vespoidea	Formicidae	Ponerinae	Ponerini	*Diacamma vargens* (F. Smith, 1860)	bladder ant	มดหนามคู่ดำ
NUTJ08093	Vespoidea	Formicidae	Ponerinae	Ponerini	*Harpegnathos venator* (F. Smith, 1858)	jumping ant	มดเขี้ยวโง้ง
NUTJ08094	Vespoidea	Formicidae	Ponerinae	Ponerini	*Odontoponera denticulata* (F. Smith, 1858)	ant	มดไอ้ขี่นดำ
NUTJ08095	Vespoidea	Formicidae	Ponerinae	Ponerini	*Pachycondyla astuta* F. Smith, 1858	striped foaming ant	มดปุยฝ้ายป่า
NUTJ08096	Vespoidea	Formicidae	Ponerinae	Ponerini	*Pachycondyla chinensis* (Emery, 1895)	striped foaming ant	มดปุยฝ้ายจั่วจีน
NUTJ08097	Vespoidea	Formicidae	Ponerinae	Ponerini	*Pachycondyla luteipes* (Mayr, 1862)	striped foaming ant	มดปุยฝ้ายจั่วตาสิบ
NUTJ08098	Vespoidea	Formicidae	Ponerinae	Ponerini	*Pachycondyla rufipes* (Jerdon, 1851)	striped foaming ant	มดปุยฝ้ายขาตาลแดง
NUTJ08099	Vespoidea	Formicidae	Pseudomyrmecinae	Pseudomyrmecini	*Tetraponera allaborans* (Walker, 1859)	black tree-ant	มดตะนอยดำเล็ก
NUTJ08100	Vespoidea	Formicidae	Pseudomyrmecinae	Pseudomyrmecini	*Tetraponera attenuata* F. Smith, 1877	black tree-ant	มดตะนอยดำใหญ่
NUTJ08101	Vespoidea	Formicidae	Pseudomyrmecinae	Pseudomyrmecini	*Tetraponera rufonigra* (Jerdon, 1851)	black tree-ant	มดตะนอยอกส้ม
NUTJ08102	Vespoidea	Scoliidae	Scoliinae	Campsomerini	*Campsomeris* sp.	hairy flower wasps	ต่อรู
NUTJ08103	Vespoidea	Scoliidae	Scoliinae	Scoliini	*Scolia* sp.	scoliid wasps	ต่อรู
NUTJ08104	Vespoidea	Vespidae	Eumeninae	-	*Delta pyriforme* Fabricius, 1781	wasp	ต่อ
NUTJ08105	Vespoidea	Vespidae	Eumeninae	-	*Delta* sp.	yellow jacket	แตน
NUTJ08106	Vespoidea	Vespidae	Eumeninae	-	*Phimenes flavopictus* (Blanchard, 1841)	yellow jacket	แตน
NUTJ08107	Vespoidea	Vespidae	Eumeninae	-	*Rhynchium* sp.	wasp	ต่อ
NUTJ08108	Vespoidea	Vespidae	Polistinae	Polistini	*Polistes olivaceus* (DeGeer, 1773)	paper wasp	แตน

Table 5 (Cont.).

Numbers	Superfamilies	Families	Subfamilies	Tribes	Scientific names	Common names	Thai names
NUTJ08109	Vespoidea	Vespidae	Polistinae	Polistini	*Polites* sp.	paper wasp	แตน
NUTJ08110	Vespoidea	Vespidae	Polistinae	Ropalidiini	*Parapolybia varia* (Fabricius, 1787)	paper wasp	แตน
NUTJ08111	Vespoidea	Vespidae	Polistinae	Ropalidiini	*Polybioides* sp.	paper wasp	แตน
NUTJ08112	Vespoidea	Vespidae	Polistinae	Ropalidiini	*Ropalidia* sp.1	paper wasp	แตน
NUTJ08113	Vespoidea	Vespidae	Polistinae	Ropalidiini	*Ropalidia* sp.2	paper wasp	แตน
NUTJ08114	Vespoidea	Vespidae	Stenogastrinae	-	*Parischnogaster* sp.	hover wasp	แตน
NUTJ08115	Vespoidea	Vespidae	Vespinae	-	*Provespa anomala* (de Saussure, 1905)	wasp	แตน
NUTJ08116	Vespoidea	Vespidae	Vespinae	-	*Vespa affinis* (Linnaeus, 1764)	tiger wasp	ต่อหัวเสือ
NUTJ08117	Vespoidea	Vespidae	Vespinae	-	*Vespa mandarinia* Smith, 1852	wasp	ต่อหลวง
NUTJ08118	Vespoidea	Vespidae	Vespinae	-	*Vespa soror* du Buysson, 1905	giant yellow jacket	ต่อหัวเหลือง
NUTJ08119	Vespoidea	Vespidae	Vespinae	-	*Vespa tropica* (Linnaeus, 1758)	giant yellow jacket	ต่อหลุม
NUTJ08120	Vespoidea	Vespidae	Vespinae	-	*Vespa velutina* Lepeletier, 1836	oriental wasp	ต่อภาคพื้น

Table 6 Species composition and species richness of the aculeate bees collected from 8 different habitats: deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL), forest area (FA) and cultivated area (CA).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
1	*Amegilla florea*	/						/	/
2	*Ceratina lieftincki*	/						/	/
3	*Pithilis smaragdula*	/						/	
4	*Thyreus* sp.	/			/			/	
5	*Xylocopa confusa*	/	/	/	/	/		/	/
6	*Xylocopa latipes*	/	/	/	/	/		/	/
7	*Apis andreniformis*	/			/			/	/
8	*Apis cerana*	/	/	/	/	/		/	/
9	*Apis dorsata*	/	/	/	/	/		/	/
10	*Apis florea*	/	/	/	/	/		/	/
11	*Apis mellifera*	/			/			/	/
12	*Bombus* sp.			/	/			/	
13	*Hyoptrigona* sp.				/			/	
14	*Trigona apicalis*	/			/			/	/
15	*Trigona collina*	/			/			/	/
16	*Trigona fimbriata*	/			/			/	/

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
17	*Trigona fuscobalteata*	/			/	/		/	
18	*Trigona itama*				/			/	
19	*Trigona laeviceps*	/						/	/
20	*Trigona melanoleuca*	/		/	/			/	/
21	*Trigona minor*			/	/			/	
22	*Trigona nitidiventris*	/			/			/	/
23	*Trigona peninsularis*	/				/		/	/
24	*Trigona terminata*	/			/			/	/
25	*Trigona thoracica*	/						/	/
26	*Trigona ventalis*	/						/	/
27	*Halictus* sp.	/						/	/
28	*Coelioxys* sp.				/			/	/
29	*Megachile* sp.1	/	/					/	/
30	*Megachile* sp.2	/						/	/
31	*Bembix* sp.				/	/		/	/
32	*Chalybion* sp.	/	/	/	/	/		/	/
33	*Sceliphron* sp.1	/			/			/	
34	*Sceliphron* sp.2	/			/			/	

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
35	*Sphex* sp.	/		/				/	
36	*Chrysis* sp.1	/						/	/
37	*Chrysis* sp.2	/						/	/
38	*Chrysis* sp.3				/			/	
39	*Trichrysis* sp.			/	/			/	
40	*Praestochrysis* sp.	/		/	/			/	
41	*Aenictus binghami*				/	/		/	
42	*Cerapachys sulcinodis*				/			/	
43	*Dolichoderus thoracicus*	/	/		/			/	
44	*Dolichoderus tuberifer*	/	/	/	/	/		/	/
45	*Iridomyrmex anceps*		/		/		/	/	
46	*Philidris* sp.	/						/	
47	*Technomyrmex kraepelini*		/	/		/		/	/
48	*Technomyrmex modiglianii*		/	/		/		/	/
49	*Anoplolepis gracilipes*						/	/	
50	*Camponotus camelinus*				/			/	/
51	*Camponotus leonadi*	/			/			/	
52	*Camponotus rufoglaucus*	/	/					/	

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
53	*Camponotus singularis*	/	/	/				/	
54	*Camponotus* sp.1	/						/	
55	*Camponotus* sp.2	/						/	
56	*Lepisiota* sp.				/			/	/
57	*Oecophylla smaragdina*	/			/	/	/	/	/
58	*Paratrechina longicornis*	/			/			/	
59	*Plagiolepis* sp.	/			/			/	
60	*Polyrhachis abdominalis*	/	/					/	
61	*Polyrhachis armata*	/			/			/	
62	*Polyrhachis bihamata*	/				/		/	/
63	*Polyrhachis dives*	/			/	/		/	
64	*Polyrhachis flavicornis*	/			/	/		/	
65	*Polyrhachis furcata*	/				/		/	
66	*Polyrhachis hippomanes*	/		/		/		/	
67	*Polyrhachis muelleri*	/	/		/	/		/	
68	*Polyrhachis proxima*	/		/	/	/		/	
69	*Polyrhachis tibialis*	/			/			/	
70	*Polyrhachis* sp.1	/						/	

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
71	*Polyrhachis* sp.2					/		/	
72	*Cardiocondyla wroughtonii*				/	/		/	
73	*Cataulacus granulatus*	/			/			/	
74	*Crematogaster coriaria*	/						/	
75	*Crematogaster difformis*	/						/	
76	*Crematogaster rogenhoferi*	/				/		/	/
77	*Meranoplus bicolor*					/		/	/
78	*Monomorium destructor*	/	/				/	/	
79	*Pheidole plagiaria*	/			/	/		/	
80	*Pheidologeton diversus*	/			/			/	/
81	*Pristomyrmex punctatus*	/		/	/	/		/	
82	*Rhopalomastix janeti*	/						/	
83	*Rhoptromyrmex wroughtoni*	/			/			/	
84	*Solenopsis geminata*	/						/	/
85	*Tetramorium flavipes*	/	/		/	/		/	
86	*Diacamma sculpturata*	/						/	/
87	*Diacamma vargens*	/	/				/	/	
88	*Gnamptogenys bicolor*	/			/			/	

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
89	*Harpegnathos venator*				/			/	
90	*Leptogenys diminuta*	/						/	
91	*Leptogenys kitteli*	/						/	
92	*Odontomachus rixosus*	/						/	
93	*Odontomachus simillimus*	/			/			/	
94	*Odontoponera denticulata*	/			/		/	/	
95	*Pachycondyla astuta*	/						/	
96	*Pachycondyla chinensis*	/						/	
97	*Pachycondyla luteipes*				/			/	
98	*Pachycondyla rufipes*	/						/	
99	*Tetraponera allaborans*	/				/		/	/
100	*Tetraponera attenuata*				/			/	
101	*Tetraponera rufonigra*					/		/	
102	*Campsomeris* sp.	/						/	
103	*Scolia* sp.	/			/	/		/	
104	*Delta pyriforme*	/	/					/	/
105	*Delta* sp.	/	/					/	/
106	*Phimenes flavopictus*	/	/		/			/	/

Table 6 (Cont.).

No.	Scientific names	BB/DF	DDF	EGF	HEGF	MXF	GL	FA	CA
107	*Rhynchium* sp.	/	/					/	/
108	*Parapolybia varia*	/			/			/	
109	*Polistes olivaceus*	/			/	/		/	/
110	*Polites* sp.	/			/	/		/	/
111	*Polybioides* sp.	/			/			/	
112	*Ropalidia* sp.1	/	/		/	/		/	/
113	*Ropalidia* sp.2	/			/			/	/
114	*Parischnogaster* sp.					/		/	
115	*Provespa anomala*	/				/		/	/
116	*Vespa affinis*	/	/	/	/	/		/	/
117	*Vespa mandarinia*	/	/	/	/			/	/
118	*Vespa soror*	/	/		/			/	/
119	*Vespa tropica*	/	/		/	/		/	/
120	*Vespa velutina*	/	/		/			/	/
	Total	**96**	**29**	**21**	**70**	**38**	**6**	**120**	**54**

Table 7 Species composition and species richness of the aculeate bees collected from each type of habitats: deciduous with bamboo forest (BB/DF), deciduous dipterocarp forest (DDF), evergreen forest (EGF), hill evergreen forest (HEGF), mixed evergreen and deciduous forest (MXF), grassland (GL) and cultivated area (CA) in each study area.

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
BB/DF	1	*Amegilla florea*	/	/	/	/	/
	2	*Ceratina lieftincki*	/	/		/	
	3	*Pithilis smaragdula*	/	/			/
	4	*Thyreus* sp.	/	/		/	
	5	*Xylocopa confusa*	/	/	/	/	/
	6	*Xylocopa latipes*	/	/	/	/	/
	7	*Apis andreniformis*	/	/		/	
	8	*Apis cerana*	/	/	/	/	/
	9	*Apis dorsata*	/	/	/	/	/
	10	*Apis florea*	/	/	/	/	/
	11	*Apis mellifera*					
	12	*Trigona apicalis*	/	/	/	/	/
	13	*Trigona collina*	/	/	/	/	/
	14	*Trigona fimbriata*	/	/	/	/	/
	15	*Trigona fuscobalteata*	/	/		/	/
	16	*Trigona laeviceps*	/	/		/	/
	17	*Trigona melanoleuca*	/	/		/	
	18	*Trigona nitidiventris*	/	/		/	
	19	*Trigona peninsularis*	/	/			
	20	*Trigona terminata*	/	/		/	/
	21	*Trigona thoracica*					
	22	*Trigona ventalis*	/	/		/	
	23	*Halictus* sp.		/			
	24	*Megachile* sp.1	/	/	/	/	/
	25	*Megachile* sp.2				/	
	26	*Chalybion* sp.	/	/	/	/	/
	27	*Sceliphron* sp.1	/	/			
	28	*Sceliphron* sp.2	/	/			/
	29	*Sphex* sp.	/	/		/	/
	30	*Chrysis* sp.1	/	/	/	/	/
	31	*Chrysis* sp.2	/	/			
	32	*Praestochrysis* sp.					
	33	*Dolichoderus thoracicus*					
	34	*Dolichoderus tuberifer*	/	/			/
	35	*Philidris* sp.					
	36	*Camponotus leonadi*			/	/	
	37	*Camponotus rufoglaucus*					
	38	*Camponotus singularis*					

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
	39	*Camponotus* sp.1					
	40	*Camponotus* sp.2					
	41	*Oecophylla smaragdina*	/				/
	42	*Paratrechina longicornis*	/				
	43	*Plagiolepis* sp.					
	44	*Polyrhachis abdominalis*					
	45	*Polyrhachis armata*	/	/	/	/	/
	46	*Polyrhachis bihamata*					
	47	*Polyrhachis dives*					
	48	*Polyrhachis flavicornis*	/	/			
	49	*Polyrhachis furcata*		/			
	50	*Polyrhachis hippomanes*	/			/	
	51	*Polyrhachis muelleri*					
	52	*Polyrhachis proxima*		/		/	
	53	*Polyrhachis tibialis*		/	/	/	
	54	*Polyrhachis* sp.1					
	55	*Cataulacus granulatus*		/	/		
	56	*Crematogaster coriaria*	/	/		/	
	57	*Crematogaster difformis*		/		/	/
	58	*Crematogaster rogenhoferi*	/				
	59	*Monomorium destructor*	/	/	/	/	
	60	*Pheidole plagiaria*				/	/
	61	*Pheidologeton diversus*		/		/	/
	62	*Pristomyrmex punctatus*	/	/	/		
	63	*Rhopalomastix janeti*					
	64	*Rhoptromyrmex wroughtoni*					
	65	*Solenopsis geminata*					
	66	*Tetramorium flavipes*					
	67	*Diacamma sculpturata*	/	/	/	/	/
	68	*Diacamma vargens*		/		/	/
	69	*Gnamptogenys bicolor*	/		/		
	70	*Leptogenys diminuta*	/				/
	71	*Leptogenys kitteli*					
	72	*Odontomachus rixosus*		/		/	
	73	*Odontomachus simillimus*					
	74	*Odontoponera denticulata*				/	
	75	*Pachycondyla astuta*					
	76	*Pachycondyla chinensis*					
	77	*Pachycondyla rufipes*					
	78	*Tetraponera allaborans*	/	/	/	/	/
	79	*Campsomeris* sp.	/	/			
	80	*Scolia* sp.	/	/	/	/	/
	81	*Delta pyriforme*		/	/	/	
	82	*Delta* sp.	/	/	/	/	/
	83	*Phimenes flavopictus*	/	/	/		
	84	*Rhynchium* sp.	/	/	/	/	/

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
	85	*Parapolybia varia*			/		
	86	*Polistes olivaceus*		/		/	
	87	*Polites* sp.					
	88	*Polybioides* sp.	/		/	/	/
	89	*Ropalidia* sp.1	/	/	/	/	/
	90	*Ropalidia* sp.2	/	/	/	/	/
	91	*Provespa anomala*	/	/		/	
	92	*Vespa affinis*	/	/	/	/	/
	93	*Vespa mandarinia*	/	/	/	/	/
	94	*Vespa soror*	/	/			
	95	*Vespa tropica*	/	/	/	/	/
	96	*Vespa velutina*	/	/	/	/	/
		Total	**55**	**59**	**34**	**51**	**38**
			N	**PY**	**PB**	**PL1**	**PL2**
BB/DF (Cont.)	1	*Amegilla florea*	/	/	/	/	/
	2	*Ceratina lieftincki*				/	
	3	*Pithilis smaragdula*				/	
	4	*Thyreus* sp.			/	/	/
	5	*Xylocopa confusa*	/	/	/	/	/
	6	*Xylocopa latipes*	/	/	/	/	/
	7	*Apis andreniformis*	/		/	/	
	8	*Apis cerana*	/		/	/	/
	9	*Apis dorsata*	/		/	/	/
	10	*Apis florea*	/		/	/	/
	11	*Apis mellifera*	/				
	12	*Trigona apicalis*	/		/	/	/
	13	*Trigona collina*	/		/	/	/
	14	*Trigona fimbriata*	/		/	/	/
	15	*Trigona fuscobalteata*					
	16	*Trigona laeviceps*			/	/	/
	17	*Trigona melanoleuca*	/	/			
	18	*Trigona nitidiventris*		/		/	/
	19	*Trigona peninsularis*					
	20	*Trigona terminata*				/	/
	21	*Trigona thoracica*					
	22	*Trigona ventalis*					
	23	*Halictus* sp.					
	24	*Megachile* sp.1	/	/	/	/	/
	25	*Megachile* sp.2			/		/
	26	*Chalybion* sp.	/	/	/	/	/
	27	*Sceliphron* sp.1				/	/
	28	*Sceliphron* sp.2				/	
	29	*Sphex* sp.			/	/	
	30	*Chrysis* sp.1	/	/	/	/	/
	31	*Chrysis* sp.2			/	/	/

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			N	PY	PB	PL1	PL2
	32	*Praestochrysis* sp.					
	33	*Dolichoderus thoracicus*				/	/
	34	*Dolichoderus tuberifer*	/		/		/
	35	*Philidris* sp.				/	
	36	*Camponotus leonadi*			/	/	/
	37	*Camponotus rufoglaucus*		/			/
	38	*Camponotus singularis*					
	39	*Camponotus* sp.1					/
	40	*Camponotus* sp.2					/
	41	*Oecophylla smaragdina*	/	/	/	/	/
	42	*Paratrechina longicornis*		/	/		
	43	*Plagiolepis* sp.					/
	44	*Polyrhachis abdominalis*				/	
	45	*Polyrhachis armata*	/	/	/	/	/
	46	*Polyrhachis bihamata*				/	
	47	*Polyrhachis dives*				/	
	48	*Polyrhachis flavicornis*				/	/
	49	*Polyrhachis furcata*				/	/
	50	*Polyrhachis hippomanes*				/	
	51	*Polyrhachis muelleri*				/	/
	52	*Polyrhachis proxima*				/	
	53	*Polyrhachis tibialis*	/			/	
	54	*Polyrhachis* sp.1				/	
	55	*Cataulacus granulatus*		/		/	
	56	*Crematogaster coriaria*		/		/	
	57	*Crematogaster difformis*	/	/	/		/
	58	*Crematogaster rogenhoferi*			/		
	59	*Monomorium destructor*	/			/	
	60	*Pheidole plagiaria*				/	
	61	*Pheidologeton diversus*	/	/	/	/	/
	62	*Pristomyrmex punctatus*			/	/	
	63	*Rhopalomastix janeti*				/	
	64	*Rhoptromyrmex wroughtoni*				/	
	65	*Solenopsis geminata*				/	
	66	*Tetramorium flavipes*				/	
	67	*Diacamma sculpturata*	/	/		/	/
	68	*Diacamma vargens*		/		/	
	69	*Gnamptogenys bicolor*	/		/	/	
	70	*Leptogenys diminuta*	/			/	
	71	*Leptogenys kitteli*	/	/	/	/	
	72	*Odontomachus rixosus*		/		/	
	73	*Odontomachus simillimus*				/	
	74	*Odontoponera denticulata*	/	/			
	75	*Pachycondyla astuta*				/	
	76	*Pachycondyla chinensis*				/	
	77	*Pachycondyla rufipes*				/	

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			N	PY	PB	PL1	PL2
	78	*Tetraponera allaborans*	/		/	/	
	79	*Campsomeris* sp.	/			/	
	80	*Scolia* sp.	/	/	/	/	
	81	*Delta pyriforme*		/		/	/
	82	*Delta* sp.	/			/	/
	83	*Phimenes flavopictus*	/	/	/	/	/
	84	*Rhynchium* sp.			/	/	/
	85	*Parapolybia varia*			/	/	/
	86	*Polistes olivaceus*			/	/	
	87	*Polites* sp.				/	
	88	*Polybioides* sp.				/	/
	89	*Ropalidia* sp.1	/	/	/	/	/
	90	*Ropalidia* sp.2	/	/	/	/	/
	91	*Provespa anomala*	/			/	
	92	*Vespa affinis*	/	/	/	/	/
	93	*Vespa mandarinia*		/	/		
	94	*Vespa soror*		/		/	
	95	*Vespa tropica*	/		/	/	/
	96	*Vespa velutina*					
		Total	**37**	**29**	**40**	**75**	**44**
			PL3	**ST**	**T1**	**T2**	**UD**
BB/DF (Cont.)	1	*Amegilla florea*	/	/	/	/	/
	2	*Ceratina lieftincki*					
	3	*Pithilis smaragdula*			/	/	
	4	*Thyreus* sp.	/				
	5	*Xylocopa confusa*	/	/	/	/	/
	6	*Xylocopa latipes*	/	/	/	/	/
	7	*Apis andreniformis*		/		/	/
	8	*Apis cerana*	/	/	/	/	/
	9	*Apis dorsata*	/	/	/	/	/
	10	*Apis florea*	/	/	/	/	/
	11	*Apis mellifera*					
	12	*Trigona apicalis*	/	/	/	/	/
	13	*Trigona collina*	/	/	/	/	/
	14	*Trigona fimbriata*	/	/	/	/	/
	15	*Trigona fuscobalteata*			/	/	
	16	*Trigona laeviceps*					
	17	*Trigona melanoleuca*		/	/	/	
	18	*Trigona nitidiventris*		/	/	/	
	19	*Trigona peninsularis*			/	/	
	20	*Trigona terminata*		/	/	/	
	21	*Trigona thoracica*			/		
	22	*Trigona ventalis*					
	23	*Halictus* sp.					
	24	*Megachile* sp.1	/	/	/	/	/

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
	25	*Megachile* sp.2			/	/	
	26	*Chalybion* sp.	/	/	/	/	/
	27	*Sceliphron* sp.1	/	/	/		
	28	*Sceliphron* sp.2			/		
	29	*Sphex* sp.	/	/	/		
	30	*Chrysis* sp.1	/	/	/	/	/
	31	*Chrysis* sp.2		/			
	32	*Praestochrysis* sp.				/	
	33	*Dolichoderus thoracicus*			/	/	
	34	*Dolichoderus tuberifer*	/	/			/
	35	*Philidris* sp.					
	36	*Camponotus leonadi*					/
	37	*Camponotus rufoglaucus*		/	/		
	38	*Camponotus singularis*	/	/			/
	39	*Camponotus* sp.1					
	40	*Camponotus* sp.2					
	41	*Oecophylla smaragdina*		/		/	/
	42	*Paratrechina longicornis*	/			/	
	43	*Plagiolepis* sp.					
	44	*Polyrhachis abdominalis*					
	45	*Polyrhachis armata*	/	/	/	/	/
	46	*Polyrhachis bihamata*			/		
	47	*Polyrhachis dives*	/		/		
	48	*Polyrhachis flavicornis*	/		/	/	
	49	*Polyrhachis furcata*	/		/	/	/
	50	*Polyrhachis hippomanes*		/		/	
	51	*Polyrhachis muelleri*		/	/		/
	52	*Polyrhachis proxima*	/		/		/
	53	*Polyrhachis tibialis*	/		/	/	
	54	*Polyrhachis* sp.1					
	55	*Cataulacus granulatus*	/	/			
	56	*Crematogaster coriaria*			/		
	57	*Crematogaster difformis*		/		/	
	58	*Crematogaster rogenhoferi*	/	–		/	/
	59	*Monomorium destructor*	/	/	/		
	60	*Pheidole plagiaria*	/	/	/		
	61	*Pheidologeton diversus*	/	/	/		/
	62	*Pristomyrmex punctatus*	/	/	/		/
	63	*Rhopalomastix janeti*	/		/		
	64	*Rhoptromyrmex wroughtoni*				/	
	65	*Solenopsis geminata*					
	66	*Tetramorium flavipes*			/		
	67	*Diacamma sculpturata*		/	/	/	
	68	*Diacamma vargens*	/	/	/		/
	69	*Gnamptogenys bicolor*	/	/	/		/
	70	*Leptogenys diminuta*		/	/		

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
	71	*Leptogenys kitteli*			/		/
	72	*Odontomachus rixosus*		/	/		
	73	*Odontomachus simillimus*			/		
	74	*Odontoponera denticulata*	/		/		/
	75	*Pachycondyla astuta*			/		
	76	*Pachycondyla chinensis*	/		/		
	77	*Pachycondyla rufipes*			/		
	78	*Tetraponera allaborans*	/	/	/		/
	79	*Campsomeris* sp.		/			
	80	*Scolia* sp.		/	/		/
	81	*Delta pyriforme*	/		/		/
	82	*Delta* sp.				/	
	83	*Phimenes flavopictus*		/	/	/	/
	84	*Rhynchium* sp.	/		/	/	/
	85	*Parapolybia varia*			/		/
	86	*Polistes olivaceus*	/			/	
	87	*Polites* sp.				/	
	88	*Polybioides* sp.	/				
	89	*Ropalidia* sp.1	/	/	/	/	/
	90	*Ropalidia* sp.2	/	/	/	/	/
	91	*Provespa anomala*			/		
	92	*Vespa affinis*	/	/	/	/	/
	93	*Vespa mandarinia*					/
	94	*Vespa soror*	/	/	/		/
	95	*Vespa tropica*	/		/	/	
	96	*Vespa velutina*			/	/	
		Total	**45**	**45**	**64**	**43**	**39**
			PY	**PB**	**PL 1**	**PL2**	**PL3**
DDF	1	*Xylocopa confusa*	/	/	/	/	/
	2	*Xylocopa latipes*	/	/	/	/	/
	3	*Apis cerana*	/	/	/	/	/
	4	*Apis dorsata*	/	/	/	/	/
	5	*Apis florea*	/	/	/	/	/
	6	*Megachile* sp.1	/	/	/	/	/
	7	*Chalybion* sp.	/	/	/	/	/
	8	*Dolichoderus thoracicus*			/		
	9	*Dolichoderus tuberifer*	/	/	/		
	10	*Iridomyrmex anceps*			/	/	
	11	*Technomyrmex kraepelini*	/		/	/	
	12	*Technomyrmex modiglianii*		/			/
	13	*Camponotus rufoglaucus*	/	/			/
	14	*Camponotus singularis*			/	/	/
	15	*Polyrhachis abdominalis*		/	/	/	
	16	*Polyrhachis muelleri*			/		
	17	*Monomorium destructor*		/		/	

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	CR	KP	MHS	NSW
	18	*Tetramorium flavipes*		/		/	
	19	*Diacamma vargens*		/		/	
	20	*Delta pyriforme*		/		/	
	21	*Delta* sp.	/	/		/	
	22	*Phimenes flavopictus*		/			
	23	*Rhynchium* sp.	/			/	/
	24	*Ropalidia* sp.1		/	/		
	25	*Vespa affinis*	/	/	/	/	/
	26	*Vespa mandarinia*					
	27	*Vespa soror*		/	/	/	/
	28	*Vespa tropica*	/	/	/	/	/
	29	*Vespa velutina*					
		Total	**14**	**21**	**18**	**20**	**14**
			ST	**T1**	**T2**	**UD**	
DDF (Cont.)	1	*Xylocopa confusa*	/	/	/	/	
	2	*Xylocopa latipes*	/	/	/	/	
	3	*Apis cerana*	/	/	/	/	
	4	*Apis dorsata*	/	/	/	/	
	5	*Apis florea*	/	/	/	/	
	6	*Megachile* sp.1	/	/	/	/	
	7	*Chalybion* sp.	/	/	/	/	
	8	*Dolichoderus thoracicus*		/			
	9	*Dolichoderus tuberifer*		/		/	
	10	*Iridomyrmex anceps*			/		
	11	*Technomyrmex kraepelini*	/	/	/		
	12	*Technomyrmex modiglianii*	/				
	13	*Camponotus rufoglaucus*		/	/	/	
	14	*Camponotus singularis*					
	15	*Polyrhachis abdominalis*		/	/	/	
	16	*Polyrhachis muelleri*		/			
	17	*Monomorium destructor*			/		
	18	*Tetramorium flavipes*			/		
	19	*Diacamma vargens*	/	/	/	/	
	20	*Delta pyriforme*	/	/	/	/	
	21	*Delta* sp.	/	/	/		
	22	*Phimenes flavopictus*	/		/		
	23	*Rhynchium* sp.					
	24	*Ropalidia* sp.1				/	
	25	*Vespa affinis*	/	/	/	/	
	26	*Vespa mandarinia*		/		/	
	27	*Vespa soror*		/	/		
	28	*Vespa tropica*	/	/	/	/	
	29	*Vespa velutina*		/	/	/	
		Total	15	21	21	17	

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas		
			CM2	MHS	T3
EVG	1	*Xylocopa confusa*	/	/	/
	2	*Xylocopa latipes*	/	/	/
	3	*Apis cerana*	/	/	/
	4	*Apis dorsata*	/	/	/
	5	*Apis florea*	/	/	/
	6	*Bombus* sp.	/	/	/
	7	*Trigona melanoleuca*	/	/	/
	8	*Trigona minor*	/	/	/
	9	*Chalybion* sp.	/	/	/
	10	*Sphex* sp.	/		/
	11	*Trichrysis* sp.			/
	12	*Praestochrysis* sp.			/
	13	*Dolichoderus tuberifer*	/	/	/
	14	*Technomyrmex kraepelini*			/
	15	*Technomyrmex modiglianii*			/
	16	*Camponotus singularis*		/	/
	17	*Polyrhachis hippomanes*			/
	18	*Polyrhachis proxima*			/
	19	*Pristomyrmex punctatus*		/	/
	20	*Vespa affinis*		/	/
	21	*Vespa mandarinia*		/	/
		Total	**11**	**14**	**21**

			CM1	PB	MHS	T3	N
HEGF	1	*Thyreus* sp.		/	/		/
	2	*Xylocopa confusa*	/		/	/	
	3	*Xylocopa latipes*	/	/	/	/	/
	4	*Apis andreniformis*	/	/	/	/	/
	5	*Apis cerana*	/	/	/	/	/
	6	*Apis dorsata*	/	/	/	/	/
	7	*Apis florea*	/	/	/	/	/
	8	*Apis mellifera*	/				
	9	*Bombus* sp.	/				
–	10	*Hyoptrigona* sp.	/	/			
	11	*Trigona apicalis*	/	/	/	/	/
	12	*Trigona collina*	/	/	/	/	/
	13	*Trigona fimbriata*	/	/	/	/	/
	14	*Trigona fuscobalteata*	/	/	/	/	/
	15	*Trigona itama*			/		
	16	*Trigona melanoleuca*	/	/			
	17	*Trigona minor*	/				
	18	*Trigona nitidiventris*	/	/	/	/	/
	19	*Trigona terminata*	/	/	/	/	/
	20	*Coelioxys* sp.			/	/	
	21	*Bembix* sp.		/		/	

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	PB	MHS	T3	N
	22	*Chalybion* sp.		/			/
	23	*Sceliphron* sp.1			/		
	24	*Sceliphron* sp.2		/	/		/
	25	*Chrysis* sp.3		/			
	26	*Trichrysis* sp.		/			
	27	*Praestochrysis* sp.			/		
	28	*Aenictus binghami*				/	
	29	*Cerapachys sulcinodis*				/	
	30	*Dolichoderus thoracicus*		/	/	/	/
	31	*Dolichoderus tuberifer*	/	/	/	/	/
	32	*Iridomyrmex anceps*	/	/		/	/
	33	*Camponotus camelinus*	/	/		/	/
	34	*Camponotus leonadi*		/		/	/
	35	*Lepisiota* sp.				/	
	36	*Oecophylla smaragdina*	/	/			
	37	*Paratrechina longicornis*	/	/	/	/	
	38	*Plagiolepis* sp.		/			
	39	*Polyrhachis armata*	/	/	/	/	/
	40	*Polyrhachis dives*	/	/		/	/
	41	*Polyrhachis flavicornis*		/			
	42	*Polyrhachis muelleri*	/	/			
	43	*Polyrhachis proxima*	/	/	/	/	/
	44	*Polyrhachis tibialis*		/			
	45	*Cardiocondyla wroughtonii*	/	/			
	46	*Cataulacus granulatus*			/		/
	47	*Pheidole plagiaria*		/	/	/	
	48	*Pheidologeton diversus*	/	/	/		
	49	*Pristomyrmex punctatus*		/	/		/
	50	*Rhoptromyrmex wroughtoni*	/	/		/	
	51	*Tetramorium flavipes*	/		/		/
	52	*Gnamptogenys bicolor*	/		/	/	
	53	*Harpegnathos venator*		/			/
	54	*Odontomachus simillimus*			/		
	55	*Odontoponera denticulata*		/			
	56	*Pachycondyla luteipes*			/		/
	57	*Tetraponera attenuata*	/		/		/
	58	*Scolia* sp.			/	/	
	59	*Phimenes flavopictus*		/		/	
	60	*Parapolybia varia*	/		/		
	61	*Polistes olivaceus*			/		
	62	*Polites* sp.		/	/	/	
	63	*Polybioides* sp.			/		
	64	*Ropalidia* sp.1		/			
	65	*Ropalidia* sp.2		/			
	66	*Vespa affinis*	/	/	/		

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM1	PB	MHS	T3	N
	67	*Vespa mandarinia*	/				/
	68	*Vespa soror*	/	/	/	/	/
	69	*Vespa tropica*	/	/	/	/	/
	70	*Vespa velutina*	/		/		
		Total	**38**	**47**	**41**	**34**	**31**
			CM1	**CR**	**NSW**	**PB**	**T2**
MXF	1	*Xylocopa confusa*	/	/	/	/	/
	2	*Xylocopa latipes*	/	/	/	/	/
	3	*Apis cerana*	/	/	/	/	/
	4	*Apis dorsata*	/	/	/	/	/
	5	*Apis florea*	/	/	/	/	/
	6	*Trigona fuscobalteata*	/	/	/	/	/
	7	*Trigona peninsularis*	/		/		
	8	*Bembix* sp.		/	/		/
	9	*Chalybion* sp.	/	/		/	
	10	*Aenictus binghami*		/	/	/	/
	11	*Dolichoderus tuberifer*	/	/	/	/	/
	12	*Technomyrmex kraepelini*		/	/	/	/
	13	*Technomyrmex modiglianii*	/			/	/
	14	*Oecophylla smaragdina*	/				/
	15	*Polyrhachis bihamata*	/	/			
	16	*Polyrhachis dives*	/		/		/
	17	*Polyrhachis flavicornis*	/	/		/	
	18	*Polyrhachis furcata*	/		/		/
	19	*Polyrhachis hippomanes*	/		/		/
	20	*Polyrhachis muelleri*			/		/
	21	*Polyrhachis proxima*	/	/		/	
	22	*Polyrhachis* sp.2					/
	23	*Cardiocondyla wroughtonii*	/			/	
	24	*Crematogaster rogenhoferi*	/	/			
	25	*Meranoplus bicolor*			/	/	
	26	*Pheidole plagiaria*	/				
	27	*Pristomyrmex punctatus*	/				
	28	*Tetramorium flavipes*					/
	29	*Tetraponera allaborans*					/
	30	*Tetraponera rufonigra*		/			/
	31	*Scolia* sp.	/				
	32	*Polistes olivaceus*	/				
	33	*Polites* sp.				/	
	34	*Ropalidia* sp.1			/		
	35	*Parischnogaster* sp.				/	
	36	*Provespa anomala*			/	/	
	37	*Vespa affinis*	/	/	/	/	/
	38	*Vespa tropica*	/	/	/	/	/
		Total	**25**	**18**	**20**	**20**	**22**

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas		
			CM 2	PL1	PL2
GL	1	*Iridomyrmex anceps*	/	/	/
	2	*Anoplolepis gracilipes*	/	/	
	3	*Oecophylla smaragdina*	/		/
	4	*Monomorium destructor*		/	/
	5	*Diacamma vargens*	/	/	
	6	*Odontoponera denticulata*		/	/
		Total	**4**	**5**	**5**

			CM2	LPA	LPU	PC	PR
CA	1	*Amegilla florea*	/	/	/	/	/
	2	***Ceratina lieftincki***	/				
	3	*Xylocopa confusa*	/	/	/	/	/
	4	*Xylocopa latipes*	/	/	/	/	/
	5	*Apis andreniformis*	/				/
	6	*Apis cerana*	/	/	/	/	/
	7	*Apis dorsata*	/	/	/	/	/
	8	*Apis florea*	/	/	/	/	/
	9	*Apis mellifera*	/	/	/	/	/
	10	*Trigona apicalis*	/	/	/	/	/
	11	*Trigona collina*	/	/	/	/	/
	12	*Trigona fimbriata*	/	/	/	/	/
	13	*Trigona laeviceps*	/	/	/	/	/
	14	*Trigona melanoleuca*	/	/	/		/
	15	*Trigona nitidiventris*	/	/			/
	16	*Trigona peninsularis*	/	/	/		
	17	*Trigona terminata*	/	/	/		/
	18	*Trigona thoracica*	/				
	19	*Trigona ventalis*	/	/	/		
	20	*Halictus* sp.	/				
	21	*Coelioxys* sp.	/	/			
	22	*Megachile* sp.1	/	/	/	/	/
	23	*Megachile* sp.2	/	/	/	/	/
	24	*Bembix* sp.	/				
	25	*Chalybion* sp.	/	/	/	/	/
	26	*Chrysis* sp.1	/	/	/	/	/
	27	*Chrysis* sp.2	/	/	/	/	/
	28	*Dolichoderus tuberifer*	/	/	/	/	/
	29	*Technomyrmex kraepelini*		/			/
	30	*Technomyrmex modiglianii*			/		/
	31	*Camponotus camelinus*	/	/			
	32	*Lepisiota sp.*	/				
	33	*Oecophylla smaragdina*	/	/	/	/	/
	32	*Lepisiota sp.*	/				
	33	*Oecophylla smaragdina*	/	/	/	/	/
	34	*Polyrhachis bihamata*	/				

Table 7 (Cont.).

Type of Habitats	No.	Scientific names	Study areas				
			CM2	LPA	LPU	PC	PR
	32	*Lepisiota* sp.	/				
	33	*Oecophylla smaragdina*	/	/	/	/	/
	34	*Polyrhachis bihamata*	/				
	35	*Crematogaster rogenhoferi*	/	/			/
	36	*Meranoplus bicolor*	/	/	/	/	/
	37	*Pheidologeton diversus*		/	/	/	
	38	*Solenopsis geminata*	/	/	/	/	/
	39	*Diacamma sculpturata*	/	/			
	40	*Tetraponera allaborans*	/	/			
	41	*Delta pyriforme*		/	/		/
	42	*Delta* sp.				/	
	43	*Phimenes flavopictus*	/	/			
	44	*Rhynchium* sp.	/			/	
	45	*Polistes olivaceus*	/			/	/
	46	*Polites* sp.		/	/		
	47	*Ropalidia* sp.1	/	/		/	/
	48	*Ropalidia* sp.2	/	/	/	/	/
	49	*Provespa anomala*	/	/	/	/	/
	50	*Vespa affinis*	/	/	/	/	/
	51	*Vespa mandarinia*	/				/
	52	*Vespa soror*	/	/			
	53	*Vespa tropica*	/	/	/	/	/
	54	*Vespa velutina*	/				
		Total	**48**	**41**	**32**	**29**	**35**

Table 8 The Pielou's index (J') and Simpson's index (C) of aculeate bee species structure in 7 habitat types:, deciduous dipterocarp forest, evergreen forest, hill evergreen forest, mixed evergreen and deciduous forest, grassland and cultivated area.

Type of habitats	Habitats	Ecological indices	
		J'	C
Deciduous with bamboo forests	Chiang Mai 1	0.819	0.035
	Chiang Rai	0.840	0.030
	Kamphaeng Phet	0.719	0.052
	Mae Hong Son	0.808	0.034
	Nakhon Sawan	0.759	0.039
	Nan	0.707	0.059
	Phayao	0.708	0.046
	Phetchabun	0.738	0.050
	Phitsanulok I	0.859	0.032
	Phitsanulok 2	0.760	0.043
	Phitsanulok 3	0.753	0.049
	Sukhothai	0.791	0.034
	Tak 1	0.848	0.030
	Tak 2	0.782	0.036
	Uttaradit	0.749	0.043
Deciduous dipterocarp forests	Phayao	0.777	0.076
	Phetchabun	0.892	0.052
	Phitsanulok 1	0.843	0.062
	Phitsanulok 2	0.877	0.055
	Phitsanulok 3	0.772	0.078
	Sukhothai	0.780	0.080
	Tak 1	0.876	0.058
	Tak 2	0.890	0.053
	Uttaradit	0.807	0.076
Evergreen forests	Chiang Mai 2	0.739	0.120
	Mae Hong Son	0.843	0.082
	Tak 3	0.955	0.061
Hill evergreen forests	Chiang Mai 1	0.840	0.030
	Mae Hong Son	0.852	0.030
	Nan	0.769	0.046

Table 8 (Cont.).

Type of habitats	Habitats	Ecological indices	
		J'	C
	Phitsanulok1	0.888	0.025
	Tak 3	0.803	0.038
Mixed evergreen and deciduous forests	Chiang Mai 1	0.842	0.053
	Chiang Rai	0.728	0.092
	Nakhon Sawan	0.781	0.068
	Phetchabun	0.777	0.068
	Tak 2	0.807	0.060
Grasslands	Chiangmai 1	0.381	0.250
	Phitsanulok 1	0.428	0.220
	Phitsanulok 2	0.379	0.253
Cultivated areas	Chiang Mai 2	0.876	0.043
	Lampang	0.826	0.052
	Lamphun	0.764	0.063
	Phichit	0.737	0.069
	Phrae	0.814	0.050

Table 9 The Sorensen's similarity coefficient (S_s) of aculeate species in 7 habitat types: deciduous with bamboo forest, deciduous dipterocarp forest, evergreen forest, hill evergreen forest, mixed evergreen and deciduous forest, grassland and cultivated area.

Type of habitats	Comparison of areas	S_s
Deciduous with bamboo forests	Chiang Mai and Kamphaeng Phet	0.674
	Chiang Mai and Mae Hong Son	0.757
	Chiang Mai and Nakhon Sawan	0.733
	Chiang Mai and Nan	0.784
	Chiang Mai and Phayao	0.521
	Chiang Mai and Phetchabun	0.688
	Chiang Mai and Phitsanulok 1	0.698
	Chiang Mai and Phitsanulok 2	0.633
	Chiang Mai and Phitsanulok 3	0.646
	Chiang Mai and Sukhothai	0.708
	Chiang Mai and Tak 1	0.648
	Chiang Mai and Tak 2	0.714
	Chiang Mai and Uttaradit	0.600
	Chiang Rai and Chiang Mai	0.842
	Chiang Rai and Kamphaeng Phet	0.638
	Chiang Rai and Mae Hong Son	0.815
	Chiang Rai and Nakhon Sawan	0.731
	Chiang Rai and Nan	0.646
	Chiang Rai and Phayao	0.539
	Chiang Rai and Phetchabun	0.673
	Chiang Rai and Phitsanulok 1	0.758
	Chiang Rai and Phitsanulok 2	0.660
	Chiang Rai and Phitsanulok 3	0.667
	Chiang Rai and Sukhothai	0.706
	Chiang Rai and Tak 1	0.746
	Chiang Rai and Tak 2	0.660
	Chiang Rai and Uttaradit	0.594
	Kamphaeng Phet and Nakhon Sawan	0.718
	Kamphaeng Phet and Nan	0.706
	Kamphaeng Phet and Phayao	0.508
	Kamphaeng Phet and Phetchabun	0.694

Table 9 (Cont.).

Type of habitats	Comparison of areas	S_s
	Kamphaeng Phet and Phitsanulok 1	0.582
	Kamphaeng Phet and Phitsanulok 2	0.641
	Kamphaeng Phet and Phitsanulok 3	0.584
	Kamphaeng Phet and Sukhothai	0.608
	Kamphaeng Phet and Tak 1	0.563
	Kamphaeng Phet and Tak 2	0.613
	Kamphaeng Phet and Uttaradit	0.675
	Mae Hong Son and Kamphaeng Phet	0.690
	Mae Hong Son and Nakhon Sawan	0.742
	Mae Hong Son and Phayao	0.557
	Mae Hong Son and Phetchabun	0.659
	Mae Hong Son and Phitsanulok 1	0.683
	Mae Hong Son and Phitsanulok 2	0.638
	Mae Hong Son and Phitsanulok 3	0.653
	Mae Hong Son and Sukhothai	0.660
	Mae Hong Son and Tak 1	0.678
	Mae Hong Son and Tak 2	0.660
	Mae Hong Son and Uttaradit	0.598
	Mae Hong Soni and Nan	0.651
	Nakhon Sawan and Nan	0.685
	Nakhon Sawan and Phayao	0.508
	Nakhon Sawan and Phetchabun	0.701
	Nakhon Sawan and Phitsanulok 1	0.715
	Nakhon Sawan and Phitsanulok 2	0.584
	Nakhon Sawan and Phitsanulok 3	0.617
	Nakhon Sawan and Sukhothai	0.767
	Nakhon Sawan and Tak 1	0.608
	Nakhon Sawan and Tak 2	0.642
	Nakhon Sawan and Uttaradit	0.641
	Nan and Phayao	0.600
	Nan and Phetchabun	0.780
	Nan and Phitsanulok 1	0.566
	Nan and Phitsanulok 2	0.612
	Nan and Phitsanulok 3	0.718
	Nan and Sukhothai	0.773
	Nan and Uttaradit	0.865
	Phetchabun and Phayao	0.545
	Phetchabun and Sukhothai	0.718

Table 9 (Cont.).

Type of habitats	Comparison of areas	S_s
	Phetchabun and Uttaradit	0.785
	Phitsanulok 1 and Phayao	0.567
	Phitsanulok 1 and Phetchabun	0.678
	Phitsanulok 1 and Phitsanulok 2	0.758
	Phitsanulok 1 and Phitsanulok 3	0.667
	Phitsanulok 1 and Sukhothai	0.733
	Phitsanulok 1 and Uttaradit	0.679
	Phitsanulok 2 and Phayao	0.488
	Phitsanulok 2 and Phetchabun	0.741
	Phitsanulok 2 and Phitsanulok 3	0.704
	Phitsanulok 2 and Sukhothai	0.737
	Phitsanulok 2 and Uttaradit	0.706
	Phitsanulok 3 and Phayao	0.500
	Phitsanulok 3 and Phetchabun	0.756
	Phitsanulok 3 and Sukhothai	0.723
	Phitsanulok 3 and Uttaradit	0.762
	Sukhothai and Phayao	0.564
	Sukhothai and Uttaradit	0.783
	Tak 1 and Nan	0.594
	Tak 1 and Phayao	0.511
	Tak 1 and Phetchabun	0.667
	Tak 1 and Phitsanulok 1	0.803
	Tak 1 and Phitsanulok 2	0.602
	Tak 1 and Phitsanulok 3	0.626
	Tak 1 and Sukhothai	0.654
	Tak 1 and Tak 2	0.598
	Tak 1 and Uttaradit	0.611
	Tak 2 and Nan	0.625
	Tak 2 and Phayao	0.548
	Tak 2 and Phetchabun	0.625
	Tak 2 and Phitsanulok 1	0.566
	Tak 2 and Phitsanulok 2	0.682
	Tak 2 and Phitsanulok 3	0.545
	Tak 2 and Sukhothai	0.575
	Tak 2 and Uttaradit	0.543
	Uttaradit and Phayao	0.500

Table 9 (Cont.).

Type of habitats	Comparison of areas	S_s
Deciduous dipterocarp forests	Phetchabun and Phayao	0.686
	Phetchabun and Sukhothai	0.778
	Phetchabun and Uttaradit	0.789
	Phitsanulok 1 and Phayao	0.710
	Phitsanulok 1 and Phetchabun	0.649
	Phitsanulok 1 and Phitsanulok 2	0.737
	Phitsanulok 1 and Phitsanulok 3	0.688
	Phitsanulok 1 and Sukhothai	0.606
	Phitsanulok 1 and Uttaradit	0.686
	Phitsanulok 2 and Phayao	0.706
	Phitsanulok 2 and Phetchabun	0.780
	Phitsanulok 2 and Phitsanulok 3	0.706
	Phitsanulok 2 and Sukhothai	0.743
	Phitsanulok 2 and Uttaradit	0.649
	Phitsanulok 3 and Phayao	0.786
	Phitsanulok 3 and Phetchabun	0.686
	Phitsanulok 3 and Sukhothai	0.714
	Phitsanulok 3 and Uttaradit	0.645
	Sukhothai and Phayao	0.759
	Sukhothai and Uttaradit	0.710
	Tak 1 and Phayao	0.743
	Tak 1 and Phetchabun	0.750
	Tak 1 and Phitsanulok 1	0.769
	Tak 1 and Phitsanulok 2	0.750
	Tak 1 and Phitsanulok 3	0.629
	Tak 1 and Sukhothai	0.722
	Tak 1 and Tak 2	0.821
	Tak 1 and Uttaradit	0.824
	Tak 2 and Phayao	0.706
	Tak 2 and Phetchabun	0.872
	Tak 2 and Phitsanulok 1	0.649
	Tak 2 and Phitsanulok 2	0.878
	Tak 2 and Phitsanulok 3	0.647
	Tak 2 and Sukhothai	0.800
	Tak 2 and Uttaradit	0.757
	Uttaradit and Phayao	0.710

Table 9 (Cont.).

Type of habitats	Comparison of areas	S_s
Evergreen forests	Chiang Mai 2 and Mae Hong Son	0.783
	Chiang Mai 2 and Tak 3	0.688
	Mae Hong Son and Tak 3	0.800
Hill evergreen forests	Chiang Mai 1 and Mae Hong Son	0.605
	Chiang Mai 1 and Nan	0.638
	Chiang Mai 1 and Phitsanulok 1	0.667
	Chiang Mai and Tak 3	0.606
	Mae Hong Son and Nan	0.676
	Mae Hong Son and Tak 3	0.649
	Phitsanulok 1 and Mae Hong Son	0.575
	Phitsanulok 1 and Nan	0.667
	Phitsanulok 1 and Tak 3	0.667
	Tak 3 and Nan	0.646
Mixed evergreen and deciduous forests	Chiang Mai 1 and Chiang Rai	0.651
	Chiang Mai 1 and Nakhon Sawan	0.591
	Nakhon Sawan and Chiang Rai	0.632
	Phetchabun and Chiang Mai 1	0.636
	Phetchabun and Chiang Rai	0.750
	Phetchabun and Nakhon Sawan	0.650
	Tak 2 and Chiang Mai 1	0.609
	Tak 2 and Chiang Rai	0.650
	Tak 2 and Nakhon Sawan	0.781
	Tak 2 and Phetchabun	0.571
Grasslands	Phitsanulok 1 and Phitsanulok 2	0.670
	Phitsanulok 1 and Chiang Mai 2	0.670
	Phitsanulok 2 and Chiang Mai 2	0.500
Cultivated areas	Chiang Mai 2 and Lampang	0.831
	Chiang Mai 2 and Lamphun	0.700
	Chiang Mai 2 and Phichit	0.693
	Chiang Mai 2 and Phrae	0.771
	Lampang and Lamphun	0.861
	Lampang and Phichit	0.754
	Lampang and Phrae	0.827
	Lamphun and Phichit	0.820
	Lamphun and Phrae	0.875
	Phichit and Phrae	0.813

BIOGRAPHY

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Article

Jongjitvimol, T., and Wattanachaiyingcharoen, W. (2007). Distribution, nesting sites and nest structures of the stingless bee species, *Trigona collina* Smith, 1857 (Apidae, Meliponinae) in Thailand. **The Natural History Journal of Chulalongkorn University**, 7(1), 25-34.

Others

Jongjitvimol, T., and Wattanachaiyingcharoen, W. (2007). Food resource partitioning of stingless bees; *Trigona apicalis* Smith, 1857 *Trigona collina* Smith, 1857 and *Trigona fimbriata* Smith, 1857 (Apidae, Meliponinae) in a mixed deciduous forest. **Songklanakarin Journal of Science and Technology**, 29(4), 993-1002.

Wattanachaiyingcharoen, W., and Jongjitvimol, T. (2007). First record of the predator, *Pahabengkakia piliceps* Miller, 1941 (Reduviidae, Harpactorinae) in the stingless bee, *Trigona collina* Smith, 1857 (Apidae, Meliponinae) in Thailand. **The Natural History Journal of Chulalongkorn University**, 7(1), 71-74.