STUDY OF GROUND DWELLING ANT POPULATIONS AND THEIR RELATIONSHIP TO SOME ECOLOGICAL FACTORS IN SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA

Mr. Yotin Suriyapong

A Thesis Submitted in Partial Fulfillment of the Requirements

for the Degree of Doctor of Philosophy in Environmental Biology

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การศึกษาประชากรมดที่อาศัยอยู่บนพื้นดินและความสัมพันธ์กับปัจจัยทางนิเวศบางประการในพื้นที่ป่าของสถานีวิจัยสิ่งแวดล้อมสะแกราช จังหวัดนครราชสีมา

นายโยธิน สุริยพงศ์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรดุษฎีบัณฑิต
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Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirement for the Degree of Doctor of Philosophy

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ผลการศึกษาตัวอย่างมดจำนวนทั้งสิ้น 50,673 ตัว ในพื้นที่ป่าของสถานีวิจัยสิ่งแวดล้อมสะแกราช จำแนกได้ 113 ชนิด 42 อันดับ 7 วงศ์ย่อย ชนิดมดที่พบมากที่สุดคือ *Pheidole plagiaria*, รองลงมา คือ *Dolichoderus thoracicus* และ *Anoplolepis gracilipes* การศึกษาดัชนีความหลากหลาย, ความสม่ำเสมอ และความหลากหลายของชนิด พบว่า ทุ่งหญ้ามีค่าสูงสุดในขณะที่ป่าเต็งรังบริเวณแนวกันไฟมีค่าต่ำสุด การศึกษาการเปลี่ยนแปลงตามฤดูกาลของสังคมมดพบว่า ฤดูมีผลต่อการเปลี่ยนแปลงจำนวนมด และการศึกษาเพื่อใช้มดเป็นตัวบ่งชี้ พบว่า มีมด 20 ชนิดที่มีศักยภาพสำหรับใช้เป็นตัวบ่งชี้ทางชีวภาพได้ เช่น *Tetraponera allaborans* จัดเป็นตัวบ่งชี้ที่ดีสำหรับป่าดิบแล้ง *Crematogaster (Physocrema) inflata, Phidologeton diversus* และ *Monomorium chinense* จัดเป็นตัวบ่งชี้ที่ดีสำหรับป่าเต็งรัง, ป่าเต็งรังบริเวณแนวกันไฟป่าและป่ารอยต่อ ในขณะที่ *Philidris* sp.1 of AMK และ *Leptogenys borneensis* จัดเป็นตัวบ่งชี้ที่ดีสำหรับป่าฟื้นสภาพรุ่นที่ 2 และ ทุ่งหญ้า ส่วน *Aphenogaster* sp.1 of AMK จัดเป็นตัวบ่งชี้ที่ดีสำหรับป่าปลูกทดแทน

ส่วนการวิเคราะห์ความสัมพันธ์ระหว่างปัจจัยทางนิเวศกับสังคมมดพบว่า มีความสัมพันธ์กันสูงมาก โดยปัจจัยที่มีความสัมพันธ์ในเชิงลบได้แก่ ความชื้นสัมพัทธ์ ความชื้นของลิตเตอร์ ความพรุนของดิน และความชื้นของดิน ในขณะที่ความเข้มแสง อุณหภูมิ มีความสัมพันธ์ในเชิงบวกกับสังคมมด ส่วนความหนาแน่นรวมของดิน อนุภาคดินร่วน อนุภาคดินทราย และฟอสฟอรัส ไม่มีความสัมพันธ์กับสังคมมด

สาขาวิชาชีววิทยา	ลายมือชื่อนักศึกษา....................................
ปีการศึกษา 2546	ลายมือชื่ออาจารย์ที่ปรึกษา...........................
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YOTIN SURIYAPONG : STUDY OF GROUND DWELLING ANT POPULATIONS AND THEIR RELATIONSHIP TO SOME ECOLOGICAL FACTORS IN SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA. THESIS ADVISOR : NATHAWUT THANEE, Ph.D. 187 PP. ISBN 974-533-318-2

ANT POPULATION/ SAKAERAT ENVIRONMENTAL RESEARCH STATION

A total sample of 50,673 ants were composed of 113 species of 52 genera within 7 subfamilies. The highest number of ants was *Pheidole plagiaria*. Site species richness, Shannon's index and Evenness were highest at grassland forest, and lowest at fire protected forest. Ants composition changes were dependent on season. There are twenty ants species that can use as indicator. *Tetraponera allaborans* was the best in dry evergreen forest. *Crematogaster (Physocrema) inflata, Phidologeton diversus* and *Monomorium chinense* were the best indicator in dry dipterocarp forest, fire protected forest and ecotone respectively. *Philidris* sp.1 of AMK and *Leptogenys borneensis* were the best indicator in secondary succession forest and grassland. *Aphenogaster* sp.1 of AMK was the best indicator in plantation forest.

For correlation of ecological factors, relative humidity, water content of litter, porosity and soil moisture were negatively correlated, while light intensity and temperature showed maximum positively correlation. Bulk density, silt particle, sand particle and phosphorus were not significantly correlated with ant composition.

School of Biology	Student's Signature………………………...
AcademicYear 2003	Advisor's Signature………………………..
	Co-advisor's Signature…………………….

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CHAPTER I

INTRODUCTION

1. General

Ants are eusocial insects which have successfully evolved since the Cretaceous Period. Ants are classified as a single family, the Formicidae, in order Hymenoptera. They can be found in any type of habitat from the Arctic Circle to the Equator, except in Iceland, Greenland and Antarctica (Holldobler and Wilson, 1990). The known-living ants are classified into 16 subfamilies, 296 genera and 15,000 species (Bolton, 1994).

Ants are very important and play a great impact on terrestrial ecosystem. In most terrestrial habitats, they are among the leading predators, feeding on other insects and small invertebrate, so that we can use ants as insect pest bio control (Suryanto, 1993). Ants help change the physical and chemical properties of soil by increasing its drainage and aeration properties (Culver and Beattie, 1983; Carlson and Whitford, 1991; Farji-Brener and Silva, 1995). Moreover, ants transport plant and animal remains into their nest chambers, mixing these materials with excavated earth, adds carbon, nitrogen and phosphorus to the soil (Brain, 1978).

Thailand is located in the tropical region which encompasses diverse kinds of natural ecosystems. These natural habitats are homes to some of the world's richest and unique plants and animals, resulting in a high diversity of ants. Baimai (1995) said that " the effective conservation and application of knowledge about learning things and their fundamental biology is very important". However, studies in biology and ecology dealing with ants in Thailand have been lagging behind due to the limited knowledge of both their morphology and taxonomy (Navanukroh, 1983; Osangthamnont, 1986 ; Lumsa-ed, 1995). Furthermore, Prakobvitayakit (quoted in Baimai, 1995)suggested that "the study of insects in different habitats is urgently needed".

Sakaerat Environmental Research Station (SERS) is situated at Wang Num Khew District, approximately 80 square kilometres in area. Formerly, SERS had a plentiful supply of dry evergreen forest and dry dipterocarp forest, but in the face of increasing exploitative pressures, people have extensively cleared large forest areas by their practices of shifting cultivation. After 1981 SERS moved people out of the forest and reforested these areas, resulting in two different types of forest, undisturbed and disturbed forest. As a result this has provided a good opportunity to study the impact of disturbed ecosystems and recovering forest on ant populations.

This investigation will provide information on species compositions, quantities, abundance, ants diversity, seasonal variation and some ecological factors effecting ant compositions. It may also help develop methodology of measuring soil fertility by using ants as an indicator. Information from this study will also increase knowledge and understanding of ecosystem changes, and be very useful for the management and conservation of the terrestrial ecosystem. Moreover, it will provide a database for reference and further research in Thailand.

2. Objectives

The objectives of this study are:

1) to study species compositions, species richness, species diversity and variation in the population of ground-dwelling ants in seven habitat types in SERS.

2) to identify some ecological factors that effect the change in the composition of ground-dwelling ants.

3) to develop means for the use of ant populations as a feasible index of soil fertility in forest ecosystems.

3. Scope and limitations of the study

1) The study of ground dwelling ant populations were investigated at seven stations representing seven different habitats; dry evergreen forest, dry dipterocarp forest, fire protected forest, ecotone, secondary succession forest, plantation forest and grassland forest.

2) The ecological factors affecting the ground dwelling ant populations were classified in three groups:

(1) The soil factors: soil texture, bulk density, soil porosity, soil water content, pH, organic matter, total nitrogen, phosphorus, potassium, magnesium and calcium

(2) The climatic factors: air temperature, relative humidity and light intensity

(3) Water content in litter

3) Quantitative sampling of ground dwelling ant populations were collected once a month for 12 months from January to December 2002.

CHAPTER II

LITERATURE REVIEW

Ants are classified order Hymenoptera and family Formicidae, which also include bees, wasps, sawflies, ichneumous, and similar forms. They are one of the most familiar kind of insects. There are several traits which are used to separate them from other insects. First, all ants have either a single small, distinct segment, the petiole, or two small segments, the petiole and postpetiole, between the mesosoma and gaster. These separated segments are absent in most insects, but a few group of wasps. Second, the character found only in ants is metapleural gland. This gland is in the side of the propodeum just above the hind legs and has a small opening area at the outside of the body. However not all ants have the metapleural gland. A few genera in the subfamily Formicinae, such as *Camponotus*, *Oecophylla* and *Polyrhychis*, have lost the metapleural gland. General information of ants and related literature are following.

1. Anatomy of ants

Diagrams of external anatomy which are basic to classification are provided in Figure 2-1

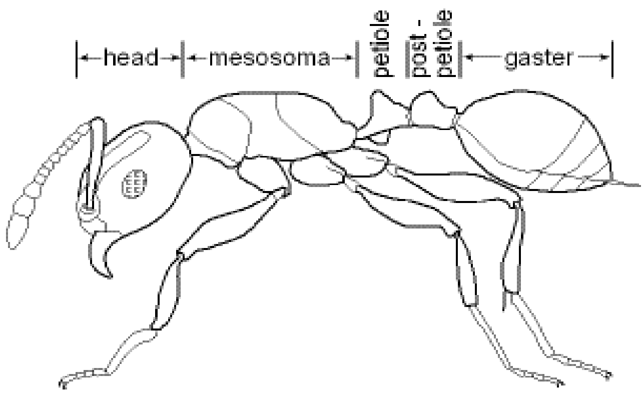


Figure 2-1 An external anatomy of ants

Source: Shattuck,1999

The ant's body is divided into four main sections: head, mesosoma, petiole and sometimes postpetiole, and gaster, which are discussed respectively as below.

1.1 Head

The head segment is composed of antennae, palps and clypeus (see Figure 2-2). The features of head are very important in identifying species and genera of ants.

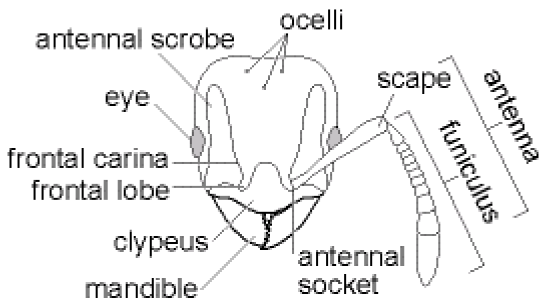


Figure 2-2. The features of head

Source: Shattuck,1999

1.1.1 The antennae are composed of two major parts. The first part called the scape is relatively long and forms a knee-like joint with the other parts. The second part is collectively called the funiculus. The number of antennae segments, the relative length of scape, the presence or absence of club, and the number of segments constituting the club are important to distinguish of genera.

1.1.2 The palps are small, segmented, sensory organs found in the mouthpart and visible from the underside of the head behind the mandibles. There are two pairs of, the outer pair situated on the maxillae (called the maxillary palps) and the inner pair situated on the labium (called the labial palps). The number of maxillary palp segments varies from 6 to 1 (with 6 being the most common) and the number of labial palp segments varies from 4 to none (with 4 being the most common)

1.1.3 The clypeus is a plate-like on the lower section of the front head between the mandibles and the antennae. Its lower edge is usually convex in the overall shape, but it can be highly modified with concave regions, teeth or variously shaped projections. The rear segment is usually narrow, convex or triangular and often extends between the forward sections of the frontal lobes. The central region of the clypeus is usually smooth and gently convex across its entire width, although in some groups, it may have a pair of weak to well-developed, diverging ridges.

In some groups the shape of frontal carinae is important. Frontal carinae is a pair of ridges on the front of the head; these ridges start just above the clypeus and between the antennal sockets and extend upwards. Their development varies from being very short, weakly developed or even absent resulting in the various length of the head. The lower section of the frontal carinae is often expanded towards the two sides of the head and partially or completely covers the antennal sockets. In this case the segment of the frontal carinae is called the frontal lobes.

Other important features in the head include the compound eyes, the position of the antennae sockets, the development of a psammophore, the presence of antennae scrobes, and the shape of the mandibles including the number and placement of teeth.

1.2 Mesosoma

Mesosoma, also called the alitrunk, is the middle segment of the body to which the legs are attached. It is behind the head and in front of the petiole. In workers the mesosoma is relatively simple, with a limited number of sutures and plates. However, queens have a much larger mesosoma with many sutures and plates. This additional complexity is required because queens typically have wings during the early part of their lives.

The mesosoma is composed of pronotum, mesonotum and metanotal groove(see Figure 2-3).

1.2.1 Pronotum is the upper surface of the first segment, immediately above the front legs. In most ants the pronotum forms a separate, distinct plate, but in some it is fused with the sclerite behind it to form a single plate.

1.2.2 Mesonotum is the upper surface of the mesosoma, between the pronotum and the metanotal groove. It is the central one-third of the mesosoma and has the middle pair of legs attached to its underside.

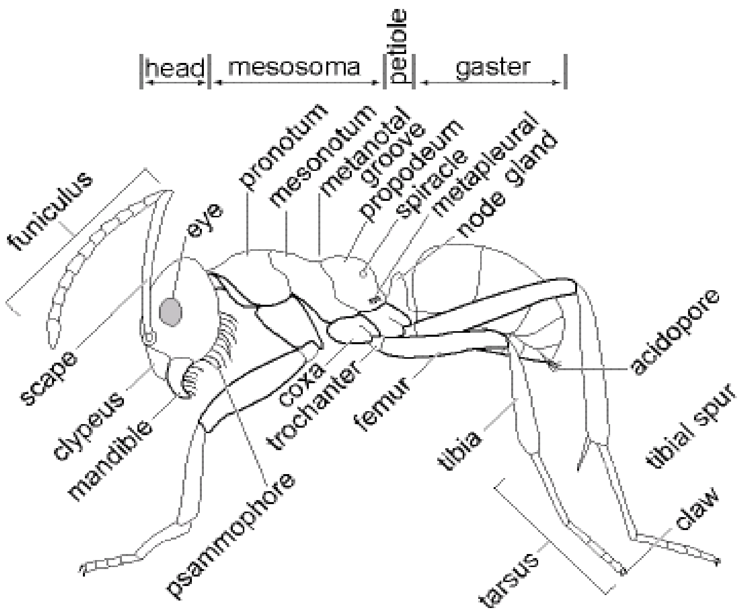


Figure 2-3 A typical Formicinae and in side view with the major structures labled

Source: Shattuck,1999

1.2.3 Metanotal groove is an angle or depression on the upper surface of the mesosoma which separates the mesonotum and the propodeum. In some groups of ants the metanotal groove is absent and the upper surface of the mesosoma is uniformly arched when viewed from the side. The propodeum is the rear segment of the mesosoma which is above the hind legs and immediately before the petiole. The metapleural gland, its opening area is located on the side of the propodeum immediately above the hind leg and below the propodeal spiracle, near the attachment point of the petiole. Its small opening is often surrounded by tiny ridges and located in a shallow, elongate depression. The opening is often protected by a fringe of elongate hairs or setae. In a few groups the metapleural gland is absent, and the area above the hind leg is smooth.

The legs are composed of five main segments. The segment nearest to the body is the coxa, followed by the very short trochanter, the long femur and tibia, and finally the tarsus respectively. The tarsus is composed of five small segments with a pair of small, curved claws at its tip. The claws are most commonly a single, curved shaft terminating in a sharp point. However, in some groups the claws have one or more small teeth along their inner margins. The junction of tibia and tarsus is usually armed with a large, stout, articulated, spike-like structure called tibial spur. The number of spurs varies from none to two, and they can be simple or comb-like (pectinate). These structures are best viewed from the front with the leg extending outwards from the body at the right angle to its long axis.

1.3 Petiole and post petiole

Petiole is the first segment behind the mesosoma and is present in all ants. Behind the petiole is either the post petiole or the gaster. The post petiole is found in only some subfamilies of ants. When present, it forms a distinct segment separate from the gaster. The upper surface of the petiole and postpetiole is often high and rounded or angular. This upright structure is called the node. In some cases the node is absent and the petiole is low and tube-like. The narrow forward section of the petiole in front of the node is called the peduncle. This section can be long, short or absent.

1.4 Gaster

The last segment of the body is the gaster. In most ants it is smooth, but in some the first segment is separated from the remainder by a shallow construction, and in a very few each segment is separated by shallow constrictions. A sting is often visible at the tip of the gaster although it is retractable. In some ants the sting is absent and the tip of the gaster terminates in a small, slit-like or circular, glanaular opening. The upper plate of the last segment of the gaster is called pygidium.

2. Colony of ants

Ants are eusocial insects which form various sizes of colonies. A social unit of ants contains several hundred to several thousand related members depending on the age of the colony. A typical colony contains three castes: worker, female (queen) and Gyne or male. These three castes can easily be distinguished from each other on the basis of external appearances. (see Figure 2-4)

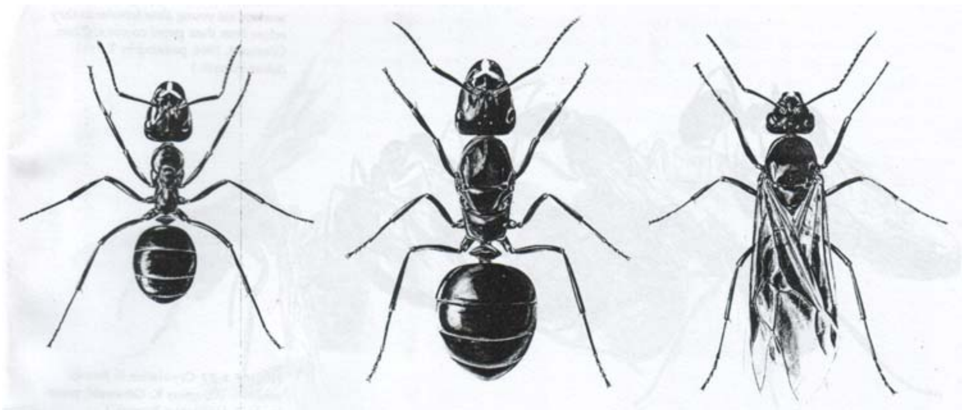


Figure 2-4 Caste of ant

Source: Holldobler and Wilson, 1990

Workers are by far the most numerous individuals in the nest. They are responsible for nest construction and maintenance, foraging, tending the brood and queen, and nest defence. All workers are female, they are sterile and do not lay eggs. The sizes of workers vary among different species or genera. Workers with large heads, which are visibly different from the smaller workers, are called soldiers.

Workers in a single nest can be in the same size or they can a greatly in size. If they are in the same or similar size they are said to be monomorphic. In some cases the variation in size can be so extreme that large workers are twice the size of small workers. If the variation continues the workers are said to be polymorphic. If there are only two distinct-sized classes of workers, they are called dimorphic.

Female ants or queens are generally similar to the workers. The primary difference is that they have larger bodies. A queen has ocelli on her head and her thorax which morphologically differs from that of the worker. The female has wings on her thorax, but the workers do not.

Gyne or male ants are generally about the same size as the workers or smaller. As compared to the females and the workers, the males can be characterized by: (1) well-developed compound eyes and ocelli, (2) the antenna composed of many segments, and (3) short scapes and a degenerated mandible. In many cases males look more like wasps than their own species.

3. Life Cycle

Ants are holometabolous insects. The life cycle of ants consists of four stages: egg, larva, pupa, and adult. All ants begins their lives as eggs which hatch into legless, grub-like larvae. Eggs are small, elongate and usually kept in clusters. The larva is very soft and whitish in color. It is also helpless and depends totally on worker ants for food and care. The ant larva is specialized for feeding and growing. Ants grow most rapidly this period. The larva molts many times as they increase in size. Having reached its final size, the larva becomes a pupa in which various adult structures, such as legs and in some cases wings, become apparent for the first time. The ant pupal stage is a transitional stage between the larva and the adult that emerges during the final molt. The entire life usually lasts from 6 to 10 weeks. However, some queens can live over 15 years, and some workers up to 7 years.

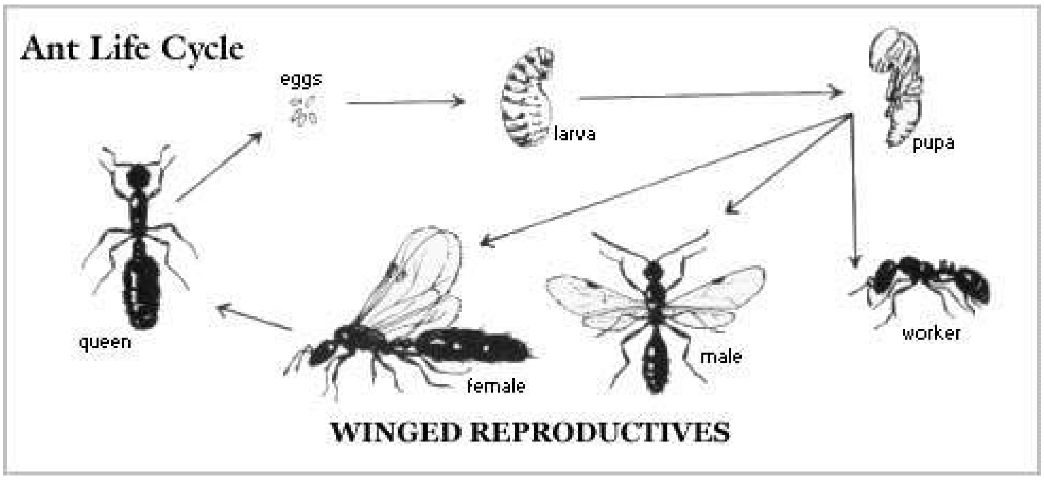


Figure 2-5 Life cycle of ant

Source: http:/flyfishalberta.com/hatches/ants.htm

The typical ant life cycle begins with the queen. This queen flies from her home nest to join other queens and males from her nest and other nests nearby. The queen searching for a male is often attracted to large distinctive objects such as tall trees, large shrubs or hill tops. These sites act as meeting places for queens and males from many nests, ensuring that they can find each other. The queen then mates with one or a few males while still in the air. Males die shortly after mating, but the queen loses her wings and goes to excavate a chamber and lay eggs. The queen remains in the nest with her brood while it developed to the first workers. Once these initial workers mature, they take care of the queen as she is producing more offsprings. Also they assume the tasks of foraging for food, maintaining and expanding the nest, and caring for the young. The colony grows as more workers mature. These new workers will take over the care of brood as well as bringing in additional food. The colony remains small during the first year, but in later years it grows rapidly, up to the maximum of 2,000-3,000 ants. It usually takes 3 to 6 years for a colony to reach this size, at which time winged reproductives are produced. In general the sexuals produced by the colony of a given region will fly on the same day and at the same time, enhancing their chance to meet in the nuptial flight and to close the cycle.

4. Feeding

The majority of ants are general predators or scavengers, feeding on a wide range of prey including other arthropods and seeds. Adult ants feed exclusively on liquid foods. They collect these liquids from their prey and other insects. Solid prey which is most often seen and carried by workers is generally intended as food for larvae. Adults which remain in the nest, including the queen, receive much or all of their food directly from returning foragers in a process called “trophallaxis”. During foraging, workers collect fluids which are stored in the upper part of their digestive system (the crop). While returning to the nest, these workers regurgitate a portion of the stored fluid and pass it on to other workers. In some extreme species, this fluid is transferred to special workers, called “repletes or honey ants”, which remain permanently in the nest and act as living storage vessels. They store food when available and distribute it to the colony in the shortage time.

While most ants feed on a wide variety of foods, others specialize on a much narrower rang. A number of species, especially those in the genera *Pyramica* and *Strumigenys*, show a strong preference for Collembola. *Discothyrea* prefer the eggs of assorted arthropods.

Many plant seeds have special food bodies (called elaiosomes) which are attractive to ants. Ants collect these seeds, eat the food bodies and sometimes the seeds as well. However, many seeds remain intact after a food body is removed and often placed within the ants'nest or on their midden piles where they later germinate.

In general, ants know a preference for foraging either during the day or at night. In some groups foraging occurs both during the day and at night, although there may be peaks of activity with fewer active foragers during other periods. In the arid zone, the foraging activities of many species are highly dependant on temperature. Some species such as *Tetramorium* and *Rhytidoponera* are active during the cold morning and evening hours while others such as *Melophorus* are active during the hottest time of the day.

5. Nest

Ants are one of the few groups which modify their surrounding environment to suit their nature. They often build eraborate nests in a range of situations, sometimes expending to the huge amount of energy in their construction. These nests are commonly occupied for years and some for decades. In addition, some ants use plant fibers or soil to construct protective coverings over their nests and feeding areas.

Nests in soil vary from small, simple chambers under rocks, logs or other objects on the ground to extensive excavations extending a meter or more into the soil. The exact structure of their nests varies depending on the species, soil type and situation. The entrances to these subterranean nests show a wide range of styles. Many are no more than a cryptic holes which are just large enough for a single worker to squeeze through. Others are single entrances surrounded by soil, which varies from a low and broad mound to a tall, narrow turret. A number of species assemble soil and leaves around their nest entrances to form large piles with well-defined, vertical sides and concave tops. Others collect plant materials to construct thatched mounds above their subterranean nests.

Iridomyrmex purpureus nests can grow to large size with ten thousand workers. They clear all vegetation from nest surfaces and cover them with small stones. A single colony can be composed of numerous individual nests separated up to several hundred meters. Individual nests may have 10 or more separate, small entrances which are large enough for individual workers to move through.

In a few arboreal species nests are constructed with leaves. For example, *Oecophylla smarigdina* glues individual leaves together with silk produced by their larvae.

6. Taxonomy of ants

In general, ants constitute the family Formicidae, the known living ants comprise 11 subfamilies, 297 genera, and approximately 8,800 species (Holldobler and Wilson, 1990). While in Thailand there are 9 subfamilies of ants (Wiwatwitaya, 1999). The overview of each subfamilies are following.

6.1 Dolichoderinae

Most of the species are generally predators or scavengers. Some also tend hemipterans to collect honeydew or are associated with caterpillars. Their nests are found in a wide variety of locations, including in the ground: they are found in rotten and living wood, in termite mounds, and in cracks between rocks. Dolichoderinae are found in worldwide in major habitats (Shattuck, 1999).

6.2 Formicinae

Formicinae is found worldwide, most of them are generally, scavengers, foraging on the ground or on vegetation, and expose at all times of the day and night. Their nests are usually fairly large ranging from hundreds to thousands of workers and from small and cryptic to large and obvious. They are generally active and move fast. Many of them defend their nests vigorously, attacking intruders with their large mandibles and formic acid sprays.

6.3 Myrmicinae

Myrmicinae range greatly in size, with the smallest about 1 mm long and the largest up to 10 mm. While many species are generally predators, some specialize on selected soft-bodied invertebrates such as Collembola. Others are important seed harvesters. Workers can be found foraging at all times of the day and night. Their nests are found in almost any suitable location from deep in the ground to the upper branches of trees. Their colonies are generally small with a few hundred to a few thousand workers. Only a few species have huge nests with many thousands of workers. Myrmicinae occurs throughout the world in major habitats. They are the largest subfamily of ants (Shattuck, 1999).

6.4 Pseudomyrmecinae

Pseudomyrmecinae is a pantropical group of arboreal, twig dwelling ants. A few species occur in farm in temperate regions, but most are confined to tropical forests, woodlands, and savannas. Pseudomyrmecinae ants typically nest in preformed cavities in dead plant tissue, such as hollow dead twigs or grass clumps that have been excavated by other insects.

6.5 Dorylinae

These are tropical group raiders known as driver ants in Africa and army ants in the New World (Sudd and Franks, 1987). However, their ecology is not well known. Dorylinae are the only predatory ants which breach the rule: other ants which maintain large colonies do so by a mixed alimentary strategy, in which other non-predatory sources of food, such as honeydew, seeds or fungi, supplement of the predatory diet, or in some other cases replace it.

6.6 Aenictinae

They occur throughout Africa, eastern China and Australia. Aenictinae includes a single genus (*Aenictus*) with 140 described species and subspecies. All known species are “army ants”, that forage using large raiding columns and have a nomadic life style (Shattuck, 1999).

6.7 Ponerinae

This is one of the smaller subfamilies in the nearctic region, with most species found in the tropical regions of the world. Most nearctic species are infrequently encountered and are small cryptic foragers in the soil, leaf litter, and rotten logs. However, in tropical regions, ponerinae can be large, conspicuously abundant, and inflict a painful sting. These are primitive ants that nest in small colonies of a few hundred individuals or less, mostly in soil or rotting wood. They are predacious and carnivorous, generally forage on the ground.

6.8 Cerapachyinae

This small tropical subfamily consists of about two hundred species placed in five genera. It is best represented in the old world, especially the Australasian region. A few species are found in northern Mexico and southwestern

USA. Nests occur in a wide range of sites, most commonly directly in the soil, in cracks or between slabs of rocks, in rotten wood on or in the ground, so they are rarely encountered.

They are noteworthy in that workers are specialist predator of other ants. They hunt during the day in long files over the ground surface with many workers moving rapidly together in a loose column.

6.9 Leptanillae

They are found in Africa, southern Europe, eastern Japan and Australia. No species are currently found in North or South America. Ecology knowledge about it is not well-known. Ants in this subfamily have minute body size, with less than 2.5 mm long. Their color is pale yellow.

7. Ant diversity

Ant can be found in any type of habitat. The number of species declines with increasing latitude, altitude and aridity (Fowler and Claver, 1991; Farji Brener and Ruggiero, 1994; Samson et al.,1997). Despite the fact that tropical areas and continental forests are amongst the poorest known, these areas have the greatest recorded species diversity (Holldobler and Wilson, 1990). Using comparable sampling methods, the non-canopy ant community found in 4 km^2 of forest lead to 98 species in Brazilian Amazonas, 66 in southern Brazil, 41 in Australia, and 12 in Tasmania, which represents a gradient from tropical and sub-tropical to temperate forests (Majer and Delabie, 1994)

The local diversity of ants is also very high. A survey of 250 km^2 of a Malaysian rain forest yielded 460 species (Majer and Delabie, 1994). In 2.6 km^2 of lowland rainforest in New Guinea 172 species (59 genera) were found, while 219 species (63 genera) and 272 species (71 genera) were recorded in 1.6 km^2 of forest and cocoa plantation at Ghana (Room, 1971) and Brazil, respectively (Kempf, 1964). The temperate ant fauna is also impressive, in 5.6 km^2 in Michigan, 87 species (23 genera) were found (Talbot, 1975), and in 8 km^2 in Florida 76 species (30 genera) were recorded (van Pelt, 1956). Even relatively arid zones can have high levels of ant species richness; for example in 18 km^2 of semi-arid zones south Australia, 248 species (32 genera) were collected (Andersen and Clay, 1996). Flooding reduces soil ant biodiversity as shown for an Amazonian rain forest where species richness decreased from 98 in the uplands, 88 in the lowlands to 55 in the flooded areas (Majer and Delabie, 1994).

8. Ants as bioindicators

Ants are widely regarded as powerful monitoring tools in environmental management because of their great abundance, diversity and functional importance, their sensitivity to perturbation, and the ease with which they can be sampled (Majer, 1983; Andersen, 1997). Ants bioindicators is now widely adopted in the Australian mining as part of best-practice environmental management. Ants bioindicators has also been applied to a wide range of other land-use situations (Andersen, 1990), including off-site mining impacts (Read, 1996; Madden and Fox, 1997; Hoffmann *et al*., 2000), forest management (Neumann, 1992; York, 1994), conservation assessment (Yeatman and Greenslade, 1980, Clay and Schneider, 2000), and grazing impacts in rangelands (Landsberg *et al*., 1999).

The use of ants as bioindicators is supported by a macro scale functional group scheme, which has been used extensively to analyse biogeographic patterns of community composition and the responses of ant communities to disturbance (greenslade, 1978; Andersen, 1997). There are seven such ant functional groups, and their major representatives in Australia are listed in Table 2-1.

Table 2-1 Summary of functional groups of Australian ants based on their relationships to environmental stress and disturbance.

Functional group	Ants species in Australia
1. Dominant Dolichoderinae	*Anonychomyrma, Froggattella, Iridomyrmex, Papyrius, Philidris*
2. Subordinate Camponotini	*Calomyrmex, Camponotus, Opisthopsis, Polyrhachis*
3. Climate specialists	
a. Hot	*Melophorus, Meranoplus, Monomorium* (part)
b. Cold	*Monomorium (part), Notoncus, Prolasius, Stigmacros*
c. Tropical	Many taxa
4. Cryptic	Very many small myrmicines and ponerines, including *Hypoponera*; most Dacetonini, and *Solenopsis*
5. Opportunists	*Paratrechina, Rhytidoponera, Tetramorium*
6. Generalized Myrmicinae	*Crematogaster, Monomorium, Pheidole*
7. Specialist Predators	*Bothroponera, Cerapachys, Leptogenys, Myrmecia*

The seven functional groups are as the following:

1) Dominant Dolichoderinae. Abundant, highly active and aggressive species, exerting a strong competitive influence on other ants. These favour hot and open habitats. *Iridomyrmex, Anonychomyrma*.

2) Subordinate Componotini. Co-occuring with, and behaviourally submissive to Dominant dolichoderines. With large body size and, often, noctural foragers. *Camponotus*, *Polyrhachis, Opisthopsis*.

3) Climate specialists. Hot climate specialists, Taxa adapted to arid environments with morphological, physiological or behavioural specializations which reduce their interaction with Dominant dolichoderines, *Melophorus*, *Meranoplus, Monomorium* (part). Cold climate specialists, Distribution centred on the cool-temperate zone. Occur in habitats where Dominant dolichoderines are generally not abundant, *Prolasius, Notoncus, Monomorium* (part). Tropical climate specialists: Distribution centred on the humid tropics. Occur in habitats where Dominant dolichoderines are generally not abundant. *Oecophylla, Tetraponera*, many other tropical taxa.

4) Crypticc species. These are small to minute species, predominantly myrmicines and ponerines, that nest and forage primarily within soil, litter, and rotting logs. They are most diverse and abundant in forested habitat and are a major component of leaf litter ants in rainforest. *Solenopsis, Hypoponera*, many other small myrmicines and ponerines.

5) Opportunists. These are unspecialized, poorly competitive, ruderal species, whose distributions appear to be strongly influenced by competition from other ants. They often have very wide habitat distribution, but predominate only at sites where stress or disturbance severely limit ant productivity and diversity, and therefore where behavioral dominance is low. *Rhytidoponera, Paratrechina, Aphenogaster, Tetramorium..*

6) Generalized Myrmicinae. Species of *Crematogaster*, *Monomorium*, and *Pheidole* are ubiquitous members of ant communities throughout the warmer regions of the world, and they are often among the most abundant ants.

7) Special predators. This group comprises medium-sized to large species that are specialist predators of other arthropods. They include solitary foragers, such as species of *Pachycondyla*, as well as group raiders, such as species of *Leptogenys*. Except for direct predation, they tend to have little interaction with other ants owing to their specialized diets and typically low population densities.

9. Some ecological factors influence on ants

One of the aims of this research is to study the factors that come into play in determining the abundance and distribution of ant populations. These ecological factors may be grouped under three heading. The first involves the elements of climate. The second involves various physical and chemical soil properties. And the last is the water content of litter.

9.1 Forest climate and its influence on ant population

Climate is defined as the environmental conditions in the immediate vicinity of an organism. These conditions include temperature, rainfall, relative humidity and light intensity.

(1) Temperature

Temperature is a factor that multiple effects on the physiology and behavior of insects and other animals. It is important ecological factor effecting foraging ants. The few studies of temperature have been concerned with foraging behavior of ants (Carcia, Rebeles, and Pena, 1994; Wehner and Wehner, 1992) and ant brood care (Roces and Nunez, 1995). Desert ants are adapted to higher temperatures and lower humidity. Some ants forage before sunrise and after sunset when the temperatures are not too hot. Others forage only after sunrise and before sunset to take advantage of the warmer temperatures. Most of the observed ants showed low above ground activity temperature reached above 40^{o}C, and generally ant activity was higher at cooler times of day (Beeman, Neveel, Nielsen, and Robertson, 2001; Romey, 2002). It also has an effect on brood rearing in colonies of *Myrmica rubra*, *M. ruginodis* and *M. scabrinodis*. Because of *Myrmica* colonies need the average higher temperatures in their nests for successful production of new adults (Kipyatkov and Lopatina, 2001).

(2) Rainfall

Rainfall can influence tropical insects in various ways. It can damage them physically if it rains heavily. It can enhance the likelihood of their contracting diseases by increasing microclimatic humidity. It can reduce the temperature around them by evaporative cooling (Speight and Wylie, 2001). It also effects on the mound-building and foraging characteristics of the red imported fire ant. Most ants will not forage during or shortly after a rainfall (Science Education Connection, 1997). Both ant abundance and species richness were correlated with soil moisture. More mesaic plots had fewer ants and lower species richness. Furthermore, Watanasit, Phophuntin, and Permkam (2000) found that species richness and Shannon-Weiner diversity index were higher in the wet season than in the dry season, and rainfall was positively correlated with *Pheidole* sp2, *Paratopula* sp2, and *Paratopula* sp3.

(3) Relative humidity

Relative humidity (RH) is a microclimatic variable that derives from the combination of temperature and moisture. Relative humidity is generally higher in forest areas than in open environments, especially in summer when transpiration from trees is at its height. Extremes of relative humidity directly influence many of the activities of insects. Low humidity can affect the physiology and thus the development, longevity and oviposition of many insects. In high humidity, insects or their eggs may be drown or be infected more readily by pathogens.

The activities of many forest insects are controlled by relative humidity. It may influence nest building of *Camponotus* spp.. Sudd and Franks (1987) reported that *Camponotus* spp. occupy the soft tissues of trees and live underground. If the humidity is high, it will make the ground soft and enable them to build their nests more easily. Rodman (1991) showed that *Monomorium pharaonis* worker choose nesting areas with moisture (approximate 65%RH). Furthermore, Watanasit, Phophuntin, and Permkam (2000) found that the humidity was positively correlated with species richness and Shannon diversity index of *Camponotus* sp.6.

(4) Light intensity

Sunlight which penetrates the forest is modified by the selective absorption of leaves. Under the cover of trees light is richer in infrared and poorer in ultraviolet rays. Light intensity under the canopy varies widely according to the nature of trees. In the case of deciduous broadleaf trees, relative light is greater in winter when leaves have fallen. More than 60% of insects regarded as a threat in Sweden prefer to settle on trees expose to light rather than on tree situated in dense forest and 25% prefer dense forest to more open environments (Gardenfor and Baranowski, 1992)

Variation in the intensity of light generally have less direct consequence to animals than to plants, but light intensity nevertheless plays an important role in animal lives. Most animals depend to a considerable extent on their eyesight for finding food, for detection of enemies and for navigation (Kimmins, 1997). The intensity of light plays an important role in the level of activity of many insects. It was an important variable in predicting the occurrence of several *Myrmecochorous* species (Larma, 1985). The availability of sunlight greatly affects the distribution of *Formica rufu* (Cook, 2000)

9.2 Properties of forest soil and its influence on insects.

Insects that spend part or all of their lives in the ground exhibit special structural and behavioral adaptation to the physical and chemical conditions found in its. The major properties of soils are as the following.

(1) Soil temperature

Soil temperature is a factor of paramount importance in terms of the distribution and activity of soil animals. In general, soil animals are very sensitive to overheating and tend to migrate down the ground to avoid high temperatures (Killham, 1994). It was an important factor in influencing harvester ant activities (Whitford and Ettershank, 1975; Rissing, 1982; Crist and MacMahon, 1991).

(2) Soil texture

Soil texture refers to the content of sand, silt, and clay particles in the soil. Soils are placed into different textural classes based on their percentages of sand, silt, and clay particles. Particles greater than 2 mm in diameter are removed from the soil and are excluded from textural determination. Substrate preferences vary affect nest distribution. Sand was the most highly populated by ants. Different substrates may accommodate different species because of the types of plants they contain ants build. (Beeman, Neveel, Nielsen, and Robertson, 2001).

Nests of *Formica rufa* were found on soils containing varying amoumts of sand, silt and clay. Nests have not been recorded on the plateau gravel (Peck, Maquaid, and Campbell, 1998).

(3) Bulk density

The bulk density of soil is defined as the ratio of the mass (M) of oven-dried soil to its bulk volume (V), which includes the volume of the particles and the voids (pore space) between the particles. Bulk density is a dynamic soil property, altered by cultivation, compression of animals or machinery, weather, and loss of organic matters. It generally increases deeply in the soil profile. Normally forest soils varies from 0.2 g cm^{-3} in some organic layers to almost 1.9 g cm^{-3} in coarse sands. Soil which is high in organic matters has lower bulk densities than soil low in this component. Increasing in soil bulk density is generally harmful to the growth of trees in the same reasons that structure affects soil properties. Compacted soil have higher strength and can restrict penetration by roots. Reduced aeration in compacted soil can depress the activities of roots, aerobic microbes and animals. The network of galleries and chambers of ants reduces bulk density (Baxter and hole, 1967; Rogers, 1972).

(4) Soil porosity

The texture and structure of soil determine the size of the pores and the total porosity of soil. This pore space in soil is important for root growth, water retention, atmospheric gas exchange and water drainage. Sand contains less pore space than any of the other textures, and clay usually has the most. Soil porosity can be measured directly using water or calculated from the soil's bulk density and particle density. The network of galleries and chambers increases the porosity of the soil, increasing drainage and soil aeration (Denning et al., 1977; Gotwald, 1986; Majer et al., 1987; Cherrett, 1989).

(5) Soil reaction or Soil pH

Soil reaction is a soil parameter which is also closely controlled by the electrochemical properties of soil colloids. The term is used to indicate the acidity or alkalinity of soil. The degree of acidity or alkalinity is determined by the hydrogen ion (H^+) concentration in the soil solution. In acidic soil the H^+ concentration is greater than the OH^- concentration, whereas in alkaline soils the H^+ concentration is smaller than the OH^- concentration. In a soil with a neutral reaction, $H^+ = OH^-$. These conditions are usually expressed in pH values, ranging from 0 to 14. Few studies have found ant activity to influence soil pH (Wiken et al., 1976). Although there is some evidence that ant activity lowers the pH in alkaline soils and increase it in acid soils (Petal, 1980). Ant mounds have pH values between 5 and 7, and overall ant abundance seems not to be affected by soil pH (Lavelle et al., 1995).

(6**) Organic matter**

The solid portion of soil is composed of minerals and organic matters. Organic matters include plants and animals residues at various stages of decomposition, cells and tissues of soil organisms, and substances synthesized by the soil biota. Organic matters play many important roles in the soil ecosystems, all of which are of importance to sustainable agriculture. In general most studies effect of different ant species on anthill soil and anthill soil related parameters in comparison to adjacent areas outside of the nest influence have shown an increase in organic matter (Lockaby and Adams, 1985; Farji-Brener and Silva, 1995; Folgarait et al., 1997). But some studies have shown a decrease in organic matter (Czerwinski et al., 1971; Culver and Beattie, 1983).

(7**) Nitrogen**

Nitrogen occurs in either organic or inorganic forms in soil. The sources of soil nitrogen are exclusively from the atmosphere. The most frequent inorganic forms of nitrogen are nitrate (NO_3^-) and ammonium (NH_4^+) ions. But, in poor areated soils, nitrite (NO_2^-) may be formed and accumulate to toxic concentrations. Nitrate occurs almost entirely in solution and is therefore readily available to plants. Most ammonium ions are held in a readily exchangeable form on cation exchange sites. Others are fixed between the lattices of clay mineral from which they are released slowly. The effect of different ant species on anthill soil and anthill soil-related parameters in comparison to adjacent areas outside of the nest influence have shown an increase nitrogen such as *Atta laevigata* (Farji-Brener and Silva, 1995), *Pogonomyrmex occidentalis* (Whitford and DiMarco, 1995), and *Pogonomyrmex rugosus* (Carlson and Whitford, 1991).

(**8) Phosphorus**

Phosphorus in soil exists as either organic or inorganic compounds. Humus, manure, and other types of non humified organic matter are the major sources of organic phosphorus in soil. Some of the compounds in the soil organic fraction which is considered potential sources of phosphorus are phospholipids, nucleic acids and inositol phosphates. Inorganic phosphorus is derived mostly from the apatile mineral which are accessory minerals in all types of rocks. There are very little phosphorus in the atmosphere. *Solenopsis invicta, Pogonomyrmex rugosus* and *Camponotus punctulatus* have influence an increase phosphorus in ant mounds in comparison to adjacent soil samples. (Lockaby and Adams, 1985; Carlson and Whitford, 1991; Folgarait et al., 1997)

(9) Potassium

Potassium is a key nutrient for plants and is very motive in soil. Most kinds of soil have substantial quantities of potassium in solution, but potassium never dominate the total cation suite. Potassium occurs in a wide range of soil minerals and is readily available where there is active weathering of such materials. Potassium compounds are widely distributed in nature. The potassium content of normal soil is on the average 0.83% (Tan, 1994). *Formica canadensis, Pogonomyrmex rugosus* and *Camponotus punctulatus* have influence an increase potassium in ant mounds in comparison to adjacent soil samples. (Culver and Beattie, 1983; Carlson and Whitford, 1991; Folgarait et al., 1997)

(10) Magnesium

Magnesium in soil originates largely from the weathering of primary minerals. The minerals containing magnesium are dolomite, magnesium silicate, magnesium phosphates, magnesium sulfide and magnesium molybdates. As indicated previously, dolomite ($CaMg(CO_3)_2$,) the major constituent of dolomitic, limestone, is the most common source of magnesium in soil. It is a mineral found usually in sedimentary rocks. The average magnesium content in soil is approximately 0.5% whereas its concentration in soil water is estimated to be 10 mg/l. Farji-Brener and Silva (1995) found that *Atta laevigata* has influenced an increase magnesium in drained savanna with groves. Folgarait et al. (1997) found that *Camponotus punctulatus* has not effect to changing of magnesium in abandoned rice fields.

(11) Calcium

Calcium is the element that belongs to the alkaline earth metal group. The primary sources of calcium are calcite, aragonite, dolomite and gypsum. Calcite ($CaCO_3$) is the major constituent of limestone, calcareous marls, and calcareous sandstone. Calcium is a very important cation in soil. The average calcium content in soil is estimated to be 1.4%. Depending on climatic conditions and parent materials, the calcium content may vary considerably from one soil type to another. Soil in desert climates may be high in calcium, often containing calcite in the B horizon. Farji-Brener and Silva (1995) found that *Atta laevigata* has influenced an increase calcium in ant mounds in comparison to adjacent soil samples. *Pogonomyrmex occidentalis* has also influenced an increase calcium in ant mounds in comparison to adjacent soil samples (Whitford and DiMarco, 1995). But *Camponotus punctulatus* in abandoned rice fields has not influence to calcium in ant mounds in comparison to adjacent soil samples (Folgarait et al., 1997).

9.3 Water content of litter

Litter, from an ecological perspective means branches, leaves, flowers and fruits or small pieces of plants which accumulate on the ground (Tsai, 1974). According to Klinge (1974), litter means all of organic matter include dead parts of plant such as leaves, flowers, fruits, branches, barks and stems or living parts such as seeds and fresh leaves and cover animal body or insects which accumulate on the ground. However, litter covers only small amount of the plant parts and leaves which accumulate as organic matter. The amount of litter production varies from biome to biome. Several factors affecting litter-fall are plant species, environment, silvicultural practices, and time factor.

Litter on the forest floor is important as the source of the majority of the food and nesting habitat of ants and other insects. Many authors reported that litter are correlate with soil fauna. Gajaseni (1976) found that water content of litter was very important of soil fauna. As Ratanaphumma (1976) found that population, biomass and species composition of soil fauna were fluctuated causing by water content in litter. Moreover, Wallwork (1976) found that number of macro-soil fauna were correlated with environmental factors such as water content of soil and litter and relative humidity.

2.10 Species diversity measures

10.1 Defining biodiversity

Wilson (1992) defined biodiversity as "The variety of organisms considered at all levels, from genetic variants belonging to the same species through arrays of species to arrays of genera, families, and still higher taxonomic levels; including the variety of ecosystems, which comprise both communities of organisms within particular habitats and the physical conditions under which they live."

Biodiversity is an all-inclusive term to describe the total variability that occurs among living organisms of our planet, and it includes three main components:

1) the diversity of species that occurs in the world, from the familiar plants and animals to the less conspicuous fungi, bacteria, protozoans, and viruses.

2) the genetic variation that occurs within individual species that causes then to vary in their appearance (phenotype) or their ecological responses and allows then to react to the process of evolutionary section.

3) the diversity of habitat or ecological complexes in which species occur together, whether they be such well-known ones as rain forest, tundra, and coral reef or the complex of bacteria that inhabitat the human body or a gram of soil.

10.2 Species diversity

The study of biodiversity often begins with species diversity because it is the most familiar aspect of biodiversity as a whole. In ecological studies, samples will frequently consist of information on the number and relative abundance of the species present. The diversity of the sample will depend on two distinct components, species richness and species evenness or equability. Species richness simply refer to the total number of species present. Evenness is concerned with the relative abundance of species. In a community with high evenness, many species will have similar levels of abundance, no single species being significantly more abundant. Thus ecological communities may differ in term of their species richness and evenness.

10.3 Methods for measuring species diversity

An alternative for assessing community diversity is to calculate diversity indices based on the proportional abundance of species. A diversity index is a mathematical measure of species diversity in a community. Diversity indices provide more information about community than simply species richness (i.e., the number of species present); they also take the relative abundance of different species into account. Diversity indices provide important information about rarity and commonness of species in a community. The ability to quantify diversity in this way is an important tool for biologists trying to understand community structure

There are many diversity indices to calculated biodiversity. Of the many available, Shannon-Wiener index and Simpson's index have been widely used (Waite, 2000).

1) Shannon diversity index

This index is symbolized by ***H***, and is also known as the Shannon-Wiener Index. It is the most commonly used to characterize species diversity in a community. Shannon's index accounts for both abundance and evenness of the species present. The proportion of species ***i*** relative to the total number of species (p_i) is calculated, and then multiplied by the natural logarithm of this proportion ($\ln p_i$). The resulting product is summed across species, and multiplied by **–1** :

$$H = -\sum p_i \ln p_i$$

H = Shannon's diversity index

S = total number of species in the community (richness)

p_i = proportion of S made up of the *i* species

For natural community, the Shannon index usually falls between 1.5 and 3.5, and rarely exceed 4.5.

2) Evenness (Equitability)

As diversity is at a maximum when all species within a community are equally abundant, a measure of evenness is the ratio of the observed diversity to the maximum possible for the observed species number. The calculation of evenness or equitability index was determined of the form:

$$J = \frac{H'}{H'\ max}$$

J = Evenness or Equitability index

H′ = Shannon diversity index

H′ max = ln s

11. Multivariate analyses

11.1 Similarity

When we compare the flora or fauna sampled at different localities, we can approach the task by considering either the similarity or dissimilarity of their species assemblages. The conventional approach has been to measure, we can measure the similarity between two such community samples.

Similarity indices measure how alike objects are, e.g. how similar sampling unit are in terms of species composition or how alike specimens are in morphology. Dissimilarity indices measure how different objects are and should represent multivariate distance. These dissimilarity indices are also called distances and are calculated for every possible pair of objects.

There are two broad classes of similarity measures.

1) Binary similarity coefficients are the simplest similarity measures deal only with presence/absence data. There are more than 20 binary similarity measures, The simplest coefficients for binary coefficients are:

1.1) Coefficient of Jaccard

$$\mathbf{S_j} = \frac{\mathbf{a}}{\mathbf{a + b + c}}$$

$\mathbf{S_j}$ = Jaccard's similarity coefficient

a, **b**, **c** = As defined above in presence/absence matrix

1.2) Coefficient of Sorensen :

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

S_s = Sorensen's similarity coefficient

a, **b**, **c** = As defined above in presence/absence matrix

2) Distance coefficients are measures of dissimilarity rather than similarity. When a distance coefficient is zero, communities are identical. We can visualize distance measure of similarity by considering the simplest case of two species in two community samples. Distance coefficients typical require some measure of abundance for each species in the community. The examples coefficients for distance are:

2.1) Euclidean distance :

$$\Delta_{jk} = \sqrt{\sum (Xjk - Xik)^2}$$

Δ_{jk} = Euclidean distance between samples j and k

X_{ij} = Number of individuals (or biomass) of species i in sample j

X_{ik} = Number of individuals (or biomass) of species i in sample k

n = Total number of species

2.2) Bray-Curtis measure :

$$B = \frac{\Sigma\ X_{ij} - X_{ik}}{\Sigma\ X_{ij} + X_{ik}}$$

B = Bray-Curtis measure of dissimilarity

X_{ij}, X_{ik} = Number of individuals in species i in each sample(j,k)

n = Number of species in samples

2.3) Canberra metric :

$$C = \frac{1}{n} \left| \Sigma \frac{X_{ij} - X_{ik}}{X_{ij} + X_{ik}} \right|$$

C = Canberra metric coefficient of dissimilarity between samples ***j*** and ***k***

X_{ij} , X_{ik} = Number of individuals in species **i** in each sample(***j***,***k***)

n = Number of species in samples

11.2 Cluster analysis

Cluster analysis is a method for combining similar objects into groups or cluster, which can usually be displayed in a tree-like diagram, called a dendrogram (Quinn and Keough, 2002). In cluster analysis, the true number of clusters is not known and part of the analysis is to identify the number of cluster. Cluster analysis can be applied to sample data where any number of variables are measured on each sampling unit, but is usually applied to multivariate data.

The aim of classification is to group together a number of objects based on their attributes or variables to produce groups of objects where each object within a group is more similar to other objects in that group than to objects in other groups. The technique which classifies sampling units into a small number of homogeneous is known as cluster analysis.

Classification method comprise two principal types: herarchial, where objects are assigned to groups, which are themselves arranged into groups, add in a dendrodram, and non-hierarchial, where the objects are simply assigned to groups. The methods are further classified as either agglomerative, where the analysis proceeds from the objects by sequentially uniting them, or divisive, where all the objects start as members of a single group, which is repeatedly divided. For computational and presentational reason, hierarchaical-agglomerative methods are the most popular.

Agglomerative hierarchaical clustering

Agglomerative methods start with individual objects and join objects and then objects and groups together until all the objects are in one big group. Most algorithms for agglomerative cluster analysis start with a matrix of pair wise similarities or dissimilarities between the objects and the steps are as follows.

1) Calculate a matrix of dissimilarities ($\mathbf{d_{hi}}$) between all pairs of objects.

2) The first cluster is formed between the two objects with the smallest dissimilarity.

3) The dissimilarities between this cluster and the remaining objects are then recalculated.

4) A second cluster is formed between cluster 1 and the objects most similar to cluster.

5) The procedure continues until all objects are linked in clusters.

The results from a cluster analysis are usually presented in the form of a dendrogram.

11.3 Ordination

Ordination is a method for arranging species and samples along 1-3 dimensions such that similar species or samples are close together, and dissimilar species or samples are far apart. Ordination summarizes community data of many species and many samples by collapsing it on to a single graph that summarizes the patterns in the data. Ordination is useful for recognizing the pattern present in the community data. It must then be combined with environmental information and classification techniques to gain a more complete description and understanding of the community.

Many ordination methods are available, and considerable controversy exits over which technique is the best (Gauch, 1982; Digby and Kampton, 1987). All ordination techniques are computer-intensive and many ordination programs are available (Gauch, 1982).

Ordination is useful for recognizing the pattern present in community data. It must then be combined with environmental information and classification techniques to gain a more complete description and understanding of the community.

Principal cluster analysis (PCA) is the oldest and still one of the most frequently ordination techniques in community ecology. General descriptions of the procedure for biologists are given by Digby and Kempton (1987), and Kent and Coker (1992). The basic concept is to consider the community at each site as a point in n-dimensional space, where each of the axes represents a single species. PCA aims to express the relationship between the sites in a reduced number of dimensions, which can be presented graphically. The objectives of PCA is to identify which combinations of variables explain the largest amount of variation in the multivariate data set.

12. Related literatures

Gajaseni (1976) studied an ecological on population, biomass and species composition of soil fauna in dry evergreen forest at Sakaerat Environmental Research Station, Nakhon Ratchasima. The results concluded that 1) water content of soil and litter was very important to soil fauna, 2) soil fauna had some correlation to amount of nitrogen, phosphorus, potassium and organic matter in soil, and 3) distribution pattern of soil faunas are randomly.

Gunik (1999) studied a preliminary survey and assessment of ant (Formicidae:Hymenoptera) fauna of Bario, Kelabit highland Sarawak. The 71 morphospecies of ants collected were representatives of 6 sumfamilies. They were Dolichoderinae (5), Aenictinae (1), Formicinae (29), Myrmicinae (19), Ponerinae (16) and Pseudomyrmicinae (1). The genus *Polyrhachis* has the highest number of species (19), followed by *Tetramorium* with 6 species. From the specimen collected, Bario highlands appears to have a mixture of ant from the lowland and highland species.

Fellowes and Dudgeon (2000) studied common ants of lowland forests in Honh Kong, Tropical Chaina. The results concluded that 128 species were found mainly from the subfamilies Myrmicinae (41%), Formicinae (26%) and Ponerinae (22%). Most widespread in the forest sites surveyed were *Diacamma* sp.1 (at 80% of site), *Odontoponera* sp.1 (78%), *Pheidole* sp.9 (63%), *Polyrhachis tyraunica* (63%), *Pachycondyla* sp.1 (59%), *Paratrechina* sp.9 (53%), *Pheidole* sp.1 (51%) and *Camponotus nicobarensis* (51%). The commonest ground-dwelling ants of Hong Kong lowland secondary forest are generalist in the subfamilies Ponerinae, Myrmicinae, Formicinae and Dolichoderinae, with some obligate predators.

Maryati (1998) studied terrestrial ants (Fornicidae:Hymenoptera) of Sayap-Kinabalu Park, Sabah. The 58 species of ants collected were representatives of 5 subfamilies. The subfamilies were Ponerinae, Dorylinae, Myrmicinae, Dolichoderinae and Formicinae. Interestingly collection from this area showed a higher percentage of Ponerinae, followed by Myrmicinae and Formicinae.

Ratanaphumma (1976) studied an ecological on population, biomass and species composition of soil fauna in dry dipterocarp forest at Sakaerat Environmental Research Station, Nakhon Ratchasima. The results concluded that 1) population, biomass and species composition of soil fauna were fluctuated causing by water content in soil and litter, 2) there was no correlation of soil fauna and amount of nitrogen, phosphorus and potassium in soil, and 3) there was a random horizontal distribution pattern of soil faunas.

Rodman (1991) studied environmental factors affecting to the distribution of established and the formation of satellite colonies of the pharaoh ant (*monomorium pharaonis*). The laboratory studies indicated that *M.pharanis* workers choose nesting areas with moisture level approximately 65%RH. Further investigation concluded that *M.pharanis* colonies were able to regulate the microclimate within nesting areas. It was found that the workers could raise the moisture levels to approximately 10% above that of ambient levels, but they could lower the humidity within nesting areas.

Yimrattanabovorn (1993) studied seasonal fluctuations of soil fauna and concerning factors. The results of study concluded that 1) the number and biomass of macro-soil fauna were maximum in rainy season but minimum in summer with termites and ants were dominant species, and 2) there was no significant correlation between soil fauna population and plant nutrients.

Lum sa-ed (1995) studied allergic ants (Hymenoptera: Formicidae) and their venom in Southern Thailand. The result concluded that there were ten species of allergic ants such as *Odontoponera transversa* Smith, *Odontomachus rixosus* Smith, *Pachycondyla* sp., *Leptogenys* sp., *Tetraponera* sp., *Sima rufonigra* Jerdon, *Crematogaster* sp., *Myrmicaria* sp., *Monomorium* sp., and *Oecophylla smaragdina* F.

King, Andersen, and Cutter (1998) studied patterns of ant community structure and the responses of ant communities as bioindicators of ecological change in Australia. They found 50 ant species from 29 genera. Site species richness was highest of the undisturbed reference sites, and lowest at the unvegetated disturbed site, and overall was negatively related to mean ground temperature.

Peck, Mcquaid, and Campbell (1998) studied the use of ant species (Hymenoptera:Formicidae) as a biological indicator in agroecosystem conditions. They found that a total of 41 species of ants, and ant species assemblages were found to differ significantly between the fields and the field margin. Ant species assemblages were correlated with soil variables (cation exchange capacity, base saturation, electrical conductivity, organic carbon, nitrogen, pH, sand and soil moisture), tillage practices, and insecticide use. These results suggest that ants have potential as an environmental indicator in agroecosystem.

Whitford, Walter, and Rudolfo (1998) studied soil nutrient and vegetation associated with harvester ant nests on a desert watershed. They found that soil nutrient content and the species and abundance of annual plants were higher around ant nests than surrounding soil at the lower slope and mid-slope locations on the watershed. However at the upper slope locations, there were no difference in soil nutrients and/or annual plant species and abundance.

Bestelmeyer and Schooley (1999) studied community structure of ants and the role of trees in the Southern Sonoran, Mexico. They found 39 species and 21 genera of ants in a 97 ha area. Opportunistic species, *Camponotus* species, *Pheidole sclophila* and *P.titania* were more common near trees, whereas *Pheidole* sp. and granivorous species were more active in open areas.

Cook (2000) studied the distribution of the wood ant nests in an ancient woodland. The data indicated the availability of sunlight was shown to be crucial to nest site selection. Distribution of nests of *Formica rufu* were constructed within coppied areas, along paths or on the edge of woodland. All nests were found on well drained soil, and within areas with access to oak trees which were foraged for invertebrates. The majority of nests were located in the areas of light intensity approaching 100 lumen per sq.ft. However, nests were found under dense canopy, suggesting that *Formica rufa* can tolerate a certain degree of shade. There was a minimum light requirement of 30 lumen per sq.ft.

Watanasit, Phophuntin, and Permkam (2000) studied diversity of ants from Ton Nga Chang Wildlife Sanctury during May 1997 to March 1999. The result of study found seven subfamilies of ants, including 59 genera, species richness and Shannon-Wiener diversity index were higher in the wet season than in the dry season. Seasonal change influenced the number of individuals in subfamily Myrmicinae and in species of *Tapinoma* 1, *Pheidogeton* 1, *Pheidolegeton* 4 and *Paratopula* 1. Temperature was negatively correlated with *Pheidole* 3. Rainfall was positive correlated with *Pheidole* 2, *Paratopula* 2 and *Paratopula* 3. Humidity was also positively correlated with *Camponotus* 6.

Kalif, Claudia, Moutinho, and Malcher, (2001) studied the effect of both high and low impact logging on ant communities in northeastern Par State, in the Brazilian Amazon. They found that both methods of timber harvesting showed impacts on ant community composition when compared with unlogged forest. These impacts induced alteration took place at the level of species and genera. A2-fold reduction in the dominance of ants of the highly diverse genus *Pheidole* was associated with forest alterations in high-impact logging sites. Thus, logging in Amazonia can be to promote species shifts in ant communities. Ants of the genus *Pheidole* are potentially useful indicators for forest disturbances resulting from timber extraction.

CHAPTER III

MATERIALS AND METHOD

1. Study site description

1.1 Location

The study area is situated at the Sakaerat Environmental Research Station (SERS), located in Pakthong Chai district, Nakhon Ratchasima province. It is situated approximately at 14^{o} $30^{\prime}$ N, 101^{o} 55′ E, about 60 kilometers east of Nakhon Ratchasima and 300 kilometers northeast of Bangkok. The approximate area of the SERS is 81 km^2. It is the area which The Thailand Institute of Scientific and Technological Research (TISTR) had dedicated as a forest reserve for scientific purpose. (Figure 3-1)

1.2 Topography

The SERS occupies a portion of the Central Highlands near transition to the North-east (Khorat) Plateau. The topography is varied, ranging from the cuesta–like highlands to a broad, flat, slightly to moderately dissected surface slopes gently northeastward into an alluviated valley. The elevation of the area ranges from 200 to 800 meters above mean sea level. The major hills consist of Khao Phiat (elevation 762 meters), Khao Khieo (elevation 729 meters), Khao Sung (elevation 682 meters), Khao Noi (elevation 569 meters) and Khao Phoeng (elevation 438 meters).

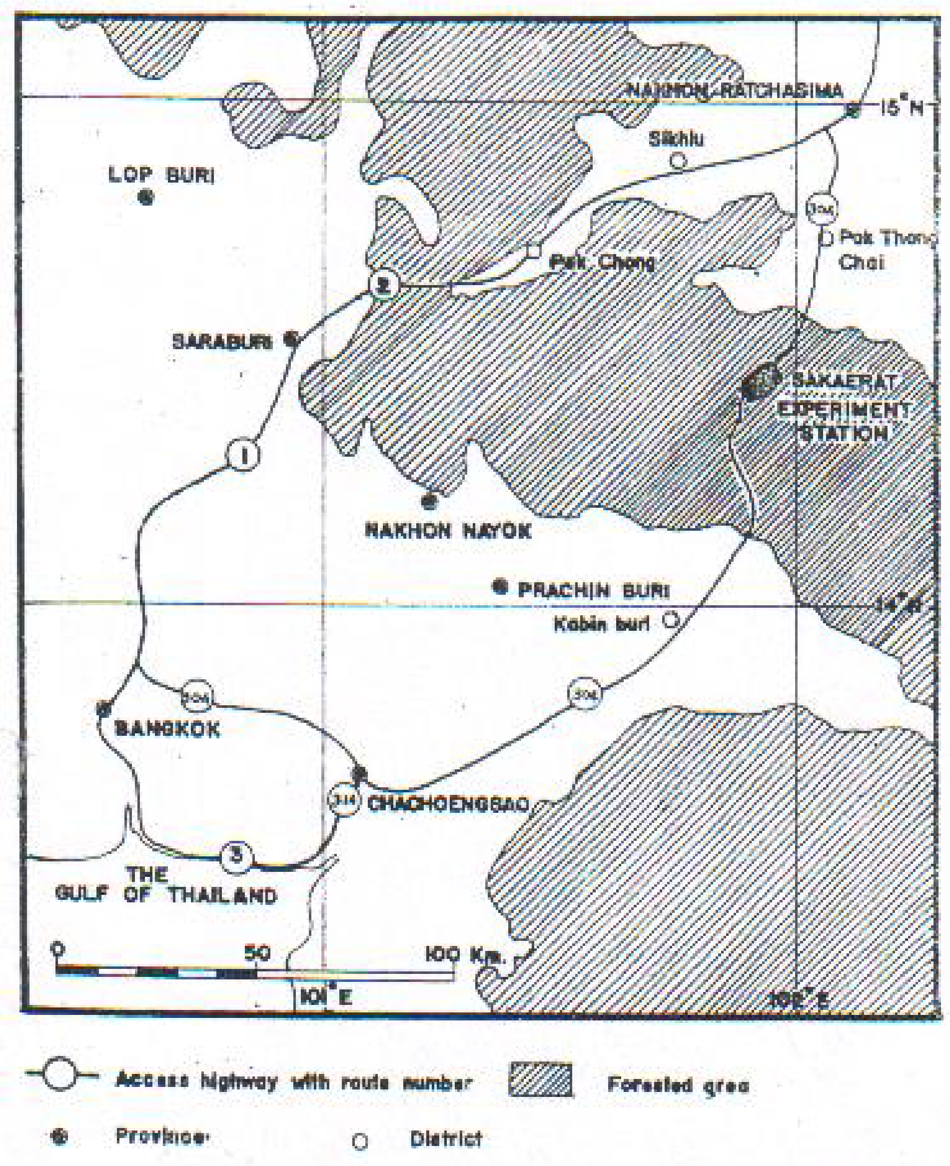


Figure 3-1 Location of Sakaerat Environmental Research Station (SERS).

Source: Wongseenin, 1971

Major streams draining the area of the SERS (Huai Lam Nang Kaeo, Huai Bong, Huai Hin Fon Meed, and Huai Nam Khem), flow gently northeastwards, from the lip of the cuesta to the southwest of the tower. Only the Huai Nam Khem can be considered a perennially flowing trunk stream. It is shortly dry during the dry season. (Figure 3-2)

1.3 Geography

The entire area of the SERS appears to be underlain by sandstone of the Phra Wihan formation of the Khorat group to a maximum thickness of 1,025 meters. It lies comformably on the purplish siltstone, micaceous sandstone, and conglomerate on the Phu Kradung formation on the same group. The Phar Wihan is overlain conformably by the Phu Phan formation of the Khorat group (Methikul and Silpalit,1968; Moormann and Rojanasoonthon, 1972).

Sandstones of the Phar Wihan formation appear whitish-gray when fresh, weathering to gray-brown, yellow-brown, or red, with flecks of altered mica and iron stains showing on the exposed surfaces. More than 90 per cent of the constituent minerals is angular to sub-rounded quartz, The remaining materials include hematite, magnetite, leucoxene, muscovite, sericite, zircon, chlorite, and a little feldspar. The textuer is clastic and the granular minerals are well sorted. Cementing materials are cherty, siliceous, or ferruginous.

1.4 Soil

The dominant great soil group of the SERS, occuring in all topographic positions is Red-Yellow Podzolic soils, on materials derived from both sandstone and shale. Series are Khao Yai for the deep members, Tha Yang for the shallow stony members, and Muak Lek for the deeper soils on shale-derived material. The depths of soil is 40-120 centimeters. Soil texture is mainly coarse sandy clay loam to sandy loam and clay loam. The scarps mostly consist of rock outcrop and some stony scree materials.

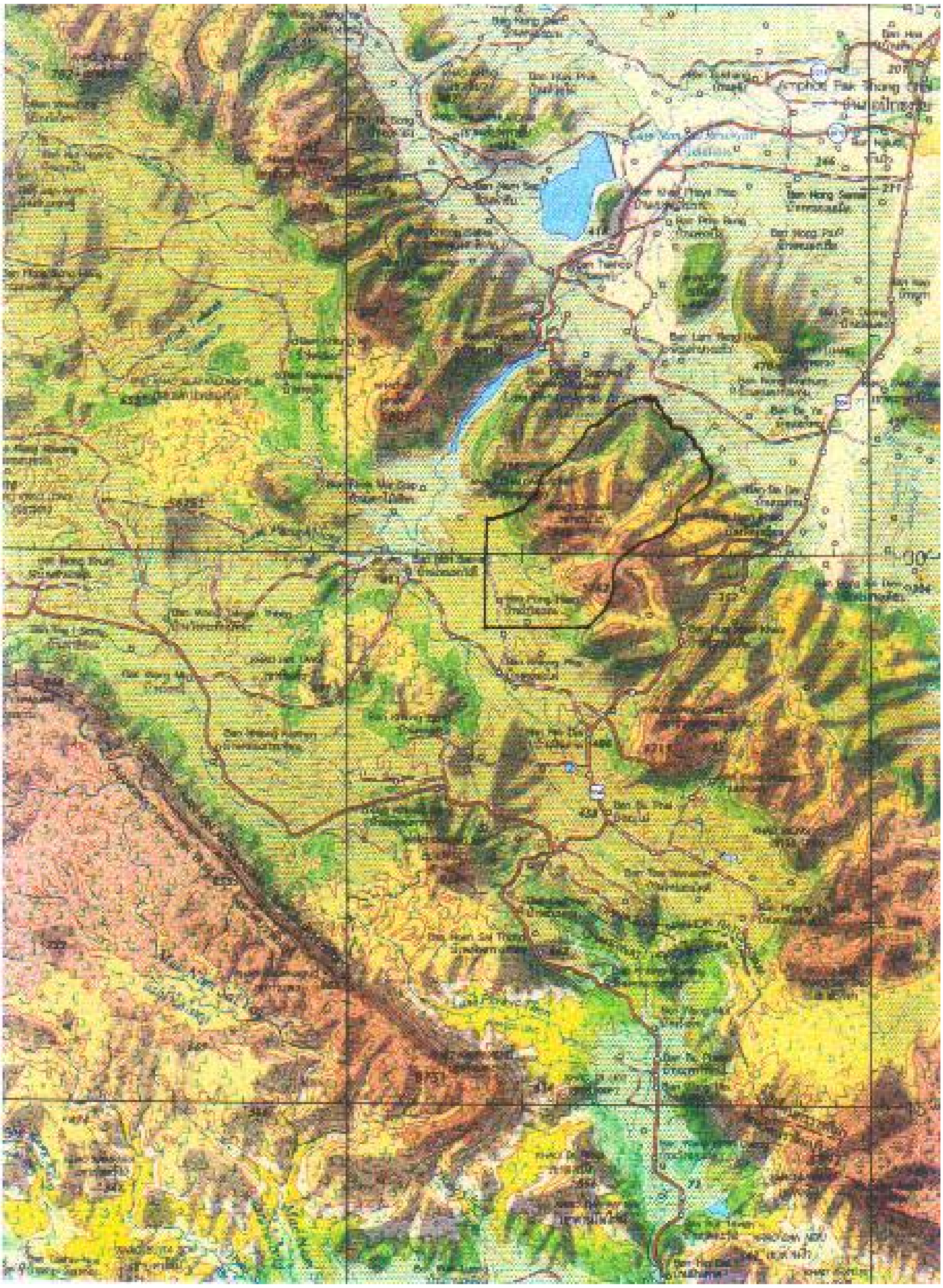


Figure 3-2 Topograhpy of Sakaerat Environmental Research Station

1.5 Climate

The SERS has been affected by some types of monsoon. The wet South-West Monsoon sweeps in from the Bay of Bengal and the Andaman Sea and the dry North-East Monsoon originates over the Great Plain of China. According to Koppen's climatic Classification, the climate of the Northeast is classified as a Tropical Savanna, (Griffiths, 1978). There are three seasons; the rainy (May to October), winter (November to February) and summer (March to mid-May) (Meteorology Department, 1977). There is few rain because the SERS is located in rain shadow of Khoa Yai National Park. The two main sources of precipitation in the study area are the South-West Moonsoon rainstorms and the occasional typhoons from the China Sea (Figure 3-3).

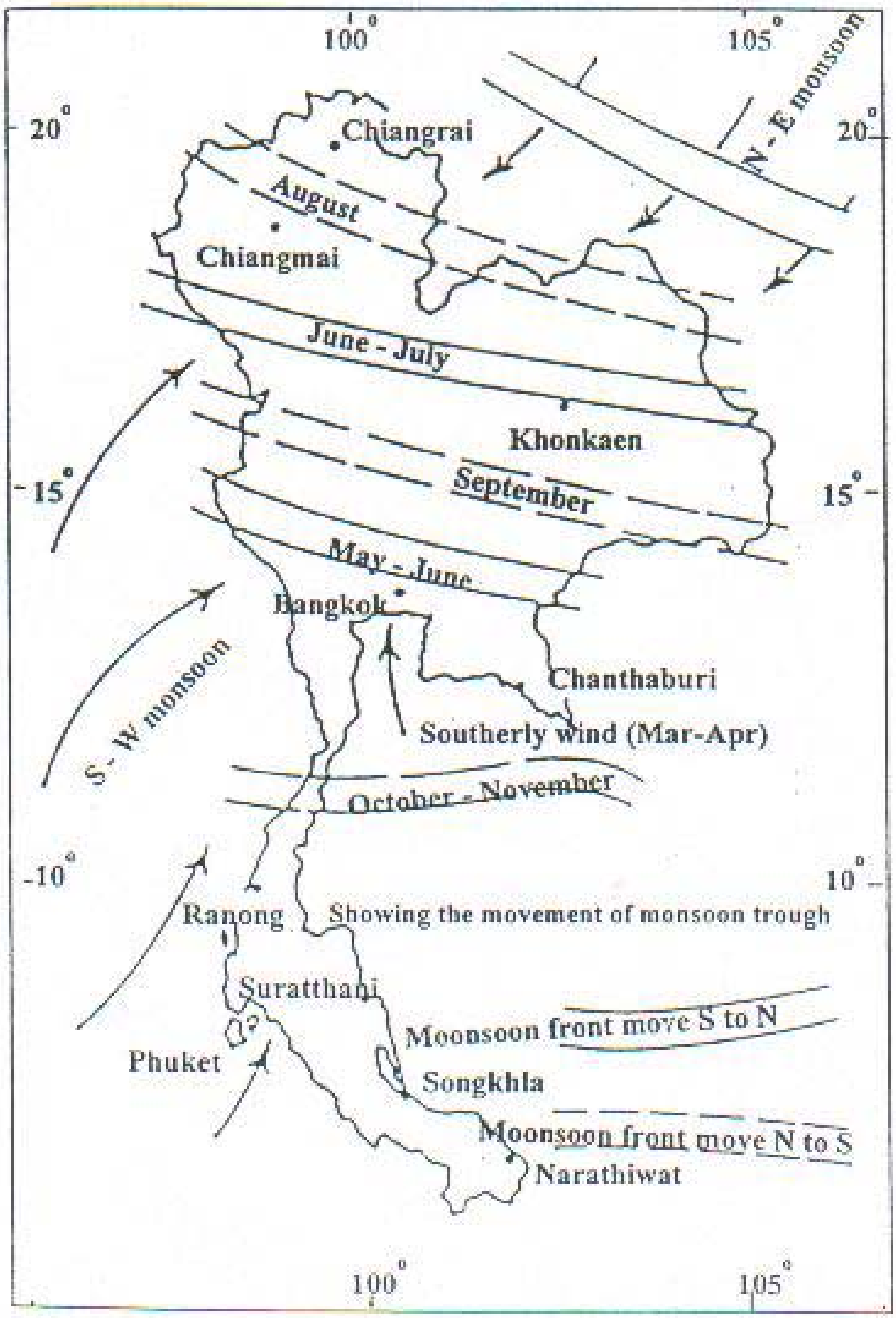


Figure 3-3 Wind direction and their periods of influence in the Kingdom of Thailand

Source : Meteorology Department, 1977.

According to the climatological data recorded by SERS, the average temperature from 1982 to 2001 indicated that the air temperature in this region was typical. The dry season, diurnal temperatures showed the largest variations during the day (nights were cool and day were warm). The smallest range between day and night temperatures occurred during the rainy season. In general, the lowest temperature was in December (21.7^{o}C), and the highest in April (29.5^{o}C). The temperature decreased from October to January and increased from February to September (Table 3-1). The monthly temperature fluctuation from 1982 to 2001 are shown in Figure 3-4.

Table 3-1 Average climatic data from 1982 to 2001 at the SERS

Month	Temperature			RH (%)	Railfall (mm)
	Max (^{o}C)	min (^{o}C)	Average (^{o}C)		
Jan	30.3	17.2	23.7	89.97	7.08
Feb	33.4	19.4	26.4	84.89	13.15
Mar	34.9	22.8	28.85	81.55	50.15
Apr	35.8	23.3	29.55	82.26	75.06
May	34.6	23.0	28.8	87.19	104.19
Jun	33.1	23.3	28.2	87.0	89.6
Jul	32.4	23.1	27.7	88.50	89.42
Aug	32.5	22.6	27.5	88.85	122.99
Sep	30.8	21.9	26.3	93.66	204.69
Oct	28.8	20.2	24.5	94.93	182.61
Nov	27.4	18.8	23.1	89.35	47.14
Dec	27.0	16.5	21.75	87.41	11.0

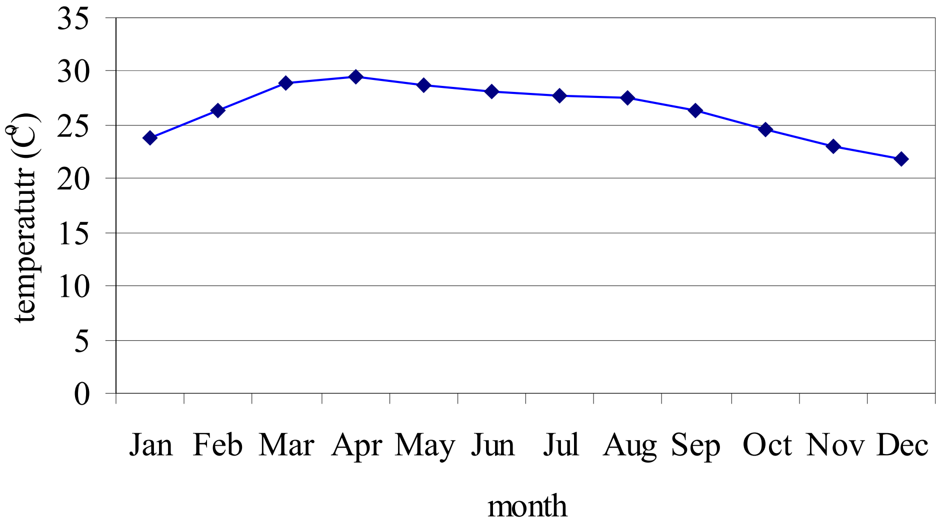


Figure 3-4 Changes of temperature from 1982 to 2001 at the SERS

In general, the lowest relative humidity is during 1982 to 2001 (about 81.55%) from March to April, and the highest (about 94.9%) is from September to November. The relative humidity increases after April until October, and decreases after February (Table 1). The monthly relative humidity fluctuation from 1982 to 2001 are shown in Figure 3-5.

In average, amount of rainfall per month was quite low, from December to February (about 7.08-13.5 mm), which is therefore called the dry season, and high from August to October, which is therefore called the rainy season (Table 1). The maximum amount of rainfall was 240.6 mm in September, and the minimum was 7.08 mm in January. The monthly rainfall fluctuation from 1982 to 2001 are shown in Figure 3-5.

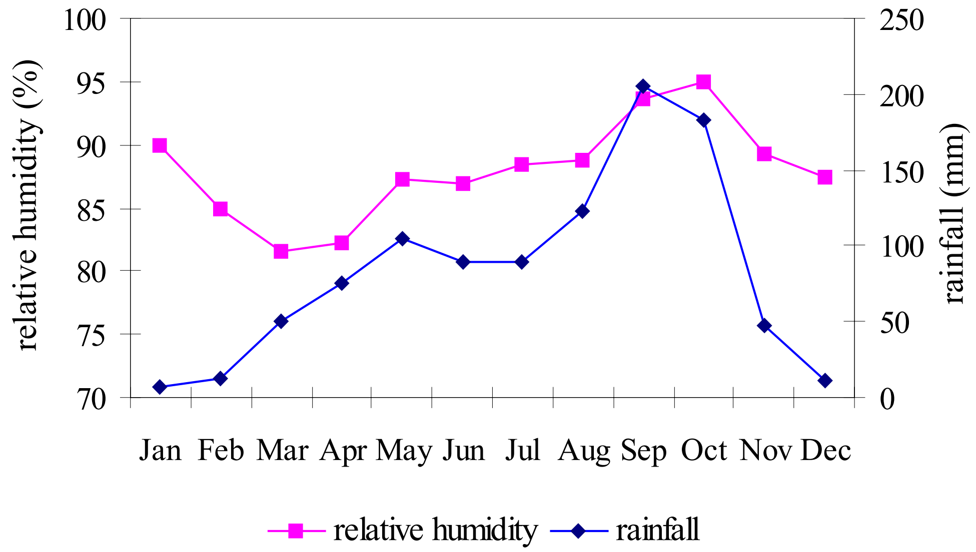


Figure 3-5 Changes of relative humidity and rainfall from 1982 to 2001 at the SERS

1.6 Vegetation and land use

There are two types of the main forests in the SERS: dry evergreen forest and dry dipterocarp forest. The dry evergreen forest covers an area about 36.67 km^2 (45.25%). The dry dipterocarp forest is an area about 15.21 km^2 (18.78%). There also are a grassland and abundant area which cover about 9.12 km^2 (11.26%). Furthermore there is a plantation area about 19.41 km^2 (23.95%). (Figure 3-6)

The dry evergreen forest occupies mostly in the south-west section including Khao Khiat, Khao Khieo, and Khao Ma Kha extending northeastward along the northern boundary to Khao Hin Kerng. It has a dense canopy of four-storey and consists of dominant species such as *Hopea ferrea* Pierre., *Hopea odorata* Roxb., *Shorea sericeiflora* Fisch.&Hutch., *Afzelia xylocrapa*, *Hydnocarpus ilicifolius* etc(Wacharakitti et al., 1980, Bunyavejchewin, 1986). The undergrowth consists of sapling and shrubs.

The dry dipterocarp forest appears in the northeast section of the SERS area. Generally, it has an open stand characteristic and composes of three-storey. The domimant species are *Shorea obtusa* Wall., *Shorea siamensis* Miq., *Dipterocarpus intricatus* Dyer, *Pentacme suavis*, *Shorea floribunda* and *Pterocarpus macrocarpus*(Wacharakitti et al., 1980, Bunyavejchewin, 1986). The ground is usually covered with tree seedlings and grasses. The dense mats of *Arundinaria pusilla* Cheval. & A. Camus which is known in Thai as “yaaphet” and *Imperata cylindrica* Beauv. are generally found. Ground fires occur annually during the dry season.

The forest plantation in the area was separately implemented by two institutes namely, Sakaerat Environmental Research Station and Research and Training Reafforestation Project supported by the Japanese government which has the field station inside the study area. Most of the forest plantation occupied on the flat plain of grass land in the central of the study area. There were five main species of forest trees planted in the plantation area; *Acacia auriculaeformis* Cunn., *Leucaena leucocephala* de Wit., *Melia azedarach* Linn., *Eucalyptus tereticornis* Sm. and *Eucalyptus camaldulensis* Dehn..

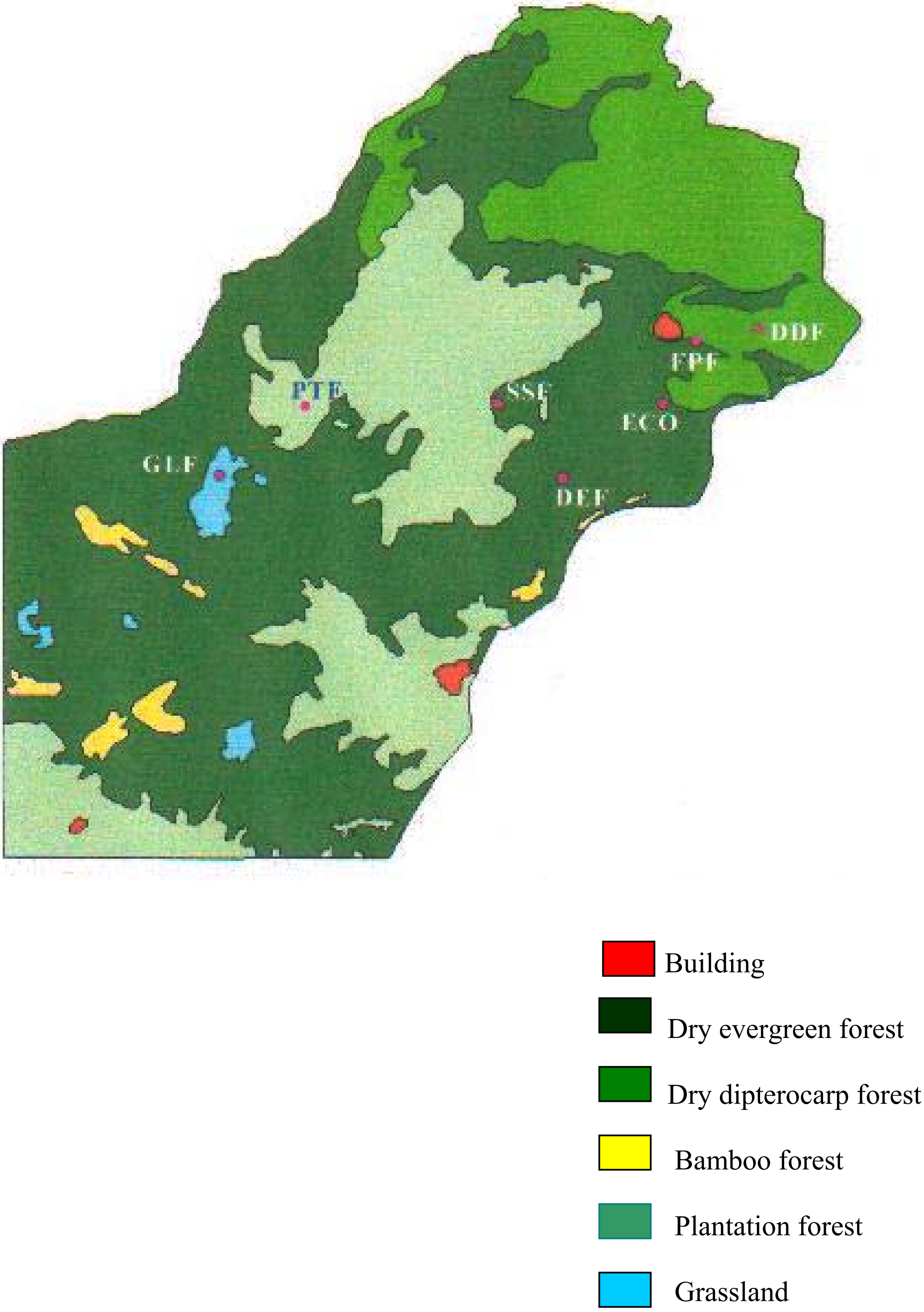


Figure 3-6 Land use and study plots of SERS

Source : Adapted from map of Sakaerat Environmental Research Station

1.7 Characteristics of the study area

There are seven plots in the SERS in this study. Their locations are shown in Figure 3-6. Each of the plots has characteristics as following

(1) The dry evergreen forest (DEF)

The study plot is situated at approximately 14° 30′ 08″ N, 101° 55′ 48.7″ E, and is about 3 kilometers from the head quarter. This plot was chosen as a representative of the major forest areas near the main micro-meteorogical tower and is in the least disturbed area. The area includes good stands of DEF and consists of dominant plant species such as *Hopea ferrea* Pierre., *Hopea odorata* Roxb. and canopy trees attain 30 to 40 meters. (Figure 3-7a)

(2) The dry dipterocarp forest (DDF)

The study plot is situated at approximately 14° 30′ 29.50″ N, 101° 56′ 17.6″ E, and lies on the main road to the head quarter. The condition of the second plot is very similar to that of the first plot. The area includes good stands of DDF and dominated by *Shorea obtusa* Wall., *Shorea siamensis* Mig., and *Arundinaria pusilla* Chevel A. camus. (Figure 3-7b)

(3) The fire protected forest (FPF)

The study plot is situated at approximately 14° 30′ 28.4″ N, 101° 55′ 56.1″ E, near the head quarter. This plot is a mixed deciduous evergreen species such as *Memecylon ovatum* Smith., *Shorea sericeiflora* Fisch.&Hutch. in the narrow strip between DEF and DDF, which is a result from complete fire protection. (Figure 3-7c)

(4) The ecotone (ECO)

The study plot is situated at approximately 14° 30′ 08.2″ N, 101° 55′ 48.5″ E. This plot is a joint between the dry evergreen forest and dry dipterocarp forest. It consists of large trees (Dipterocarpus) sparingly distributed amongst small shrubs and short grasses. (Figure 3-7d)

(5) The secondary succession forest (SSF)

The study plot is situated at approximately 14° 30′ 08.2″ N, 101° 55′ 48.5″ E. The original vegetation was a DEF which had been destroyed by humans during the last three decades, but retain a few large mature trees. Fire protection had been carried out for a long time. As such sapling and seeding in the area have drown up to become secondary succession forest. (Figure 3-7e)

(6) The plantation forest (PTF)

The study plot is situated at approximately 14° 30′ 13.7″ N, 101° 53′ 50.2″ E. In the previous time, these area used to be DEF and was deforestation about 30 years ago. In 1977 the SERS planted with lines of *Acacia mangium* at a spacing of 5mx5m in this area. Fire lines and road were also constructed surrounding the plantation area in order to protect them form the forest fire. (Figure 3-7f)

(7) The grassland forest (GLF)

The study plot is situated at approximately 14° 29′ 35.6″ N, 101° 52′ 30.4″ E. In the previous time, these areas used to be covered with the very dense forest, and because of the deforestation and shifting cultivation in the recent year caused them to become the grass land as seen in the present. This plot is in an area dominated by tall grass such as *Imperata cylindrica* Beauv., and *Saccharum spontaneum* Linn., some small shrubs and herbaceous species. (Figure 3-7g)

3-7a : DEF

3-7b : DDF

3-7c : FPF

3-7d : ECO

3-7e : SSF

3-7f : PTF

3-7g : GLF

Figure 3-7 Characteristics of the seven study areas in the SERS

2. Ants sampling method

The sampling method involves the selection of a good stand area and establishment of the permanent plot of 100m x 100m (1ha). The area has been divided into 25 small sample plots of 20m x 20m for each month study. All sample plots were assessed with a random position. Each sample plot was further divided into 100 sub-plots of 2m x 2m. Ten sub-plots, each of 2m x 2m, were chosen after the selection of a random process. The sub-plots have been divided into five quadrats each of 20cm x 20cm at the corner and the center (Figure 3-8). Hand collection with forceps was used to sample ground dwelling ants in the quadrats. All litter in each quadrat was transferred to the laboratory. In the corner and the center of the quadrat a 20cm x 20cm x 2cm depth pit was dug and again the sample was transferred to the laboratory. Litter sifting method was used for litter and soil samples. All removed ants were fixed in 95% ethyl alcohol for the later process at the Ant Museum of Forestry Faculty, Kasertsart University, Bangkok. Ants were collected from all types of habitat every month during January to December 2002.

Ground dwelling ants collected were identified to species level. The nomenclature of species follows Bolton (1994), Holldobler and Wison (1990) and Shattuck (1999).

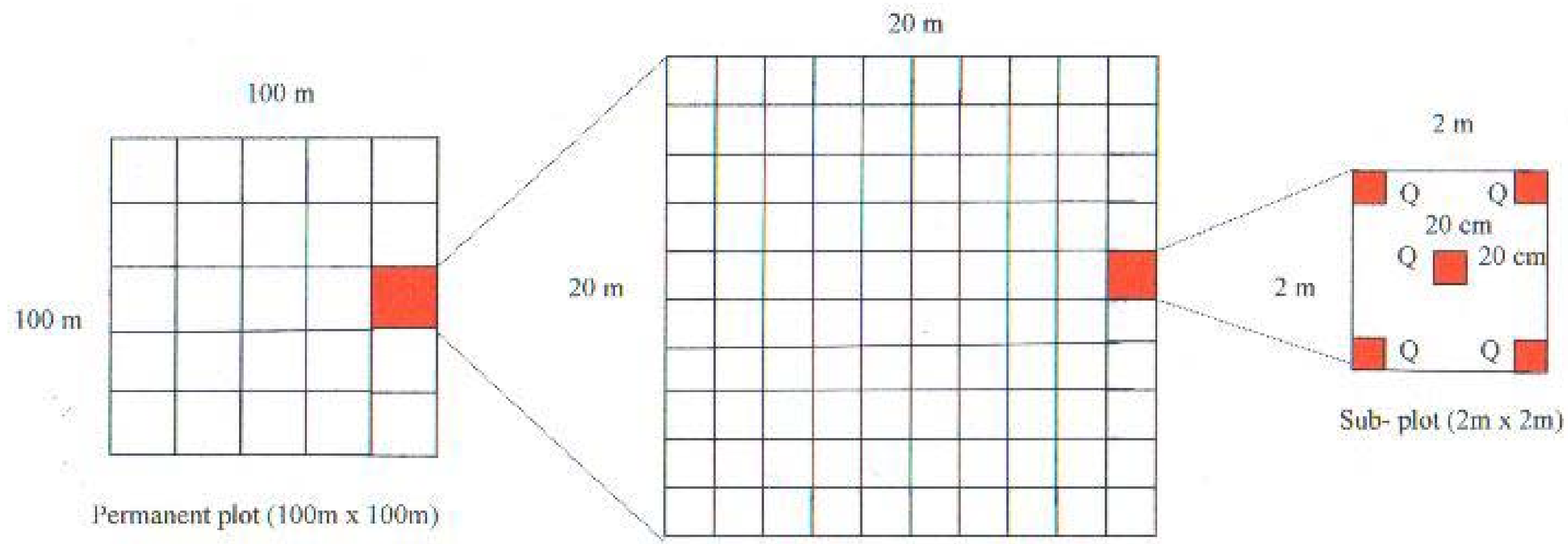


Figure 3-8 Sampling grid design used to sample the ant community within each plot. Q = quadrat.

3. Ecological factors collection

3.1 climate

The following climate characteristics were considered; air temperature relative humidity and light intensity. They were measured at their sites in the field.

3.2 soil properties

After extracting ants from all soil samples, the soil samples were carried out to the Suranaree University of Technology Laboratory (F3), where various analyses were conducted. After returning to the laboratory then the soil samples were dried indoor under laboratory conditions for 48 hours. The soil was crushed using a pestle and mortar and filter-tipped with a 2mm. sieve, rejecting roots and stones to give the fine earth fraction. Then an analysis was conducted in the following steps:

1) Soil pH was measured by suspending soil sample in water and KCl at soil-water ratio 1:1 and soil-KCl ratio 1:1.

2) Organic matter was measured by the Walkley-Black wet oxidation. The organic carbon in the sample was oxidized with a mixture of potassium dicromate and sulphuric acid without external heating. The excess potassium dicromate was tritrated with ferrous sulphate.

3) Total nitrogen was measured using a Kjeldahl oxidation. The analysis of total nitrogen requires the complete breakdown or oxidation of organic matter. Hydrogen peroxide was added as an additional oxidising agent. Selenium took place of the traditional mercury catalyst and lithium sulphate was used to raise the boiling point.

4) Phosphorus was measured using the perchloric acid digestion method. The absorbance of the solution was measured at 720 nm, using the spectrophotometer.

5) Potassium was measured by the AES. (atomic emission spectrometer) after diluting the extraction solution with the 0.63% cesium-solution. The wavelength for the K-measurement was 766.5 nm.

6) Calcium and magnesium were measured by the AAS. (atomic absorption spectrophotometer) after diluting the extraction solution with the 1.25% lanthanum solution. The wavelength for the Ca measurement was 422.7 nm, and for the Mg measurement 285.2 nm.

7) Soil texture was determined by the hydrometer method on air-dried soil that had been passed through a 2-mm soil sieve to remove small rocks, roots, pebbles, and debris followed by wet sieving to separate the sand fraction. Sand, silt, and clay were expressed as a percentage of oven dry weight.

8) The water content was measured from the weight loss of the known amount of the soil samples after drying for 24 hours at 105^{o}C in the oven.

9) Bulk density was determined by the core method. It was calculated from the ratio of the mass of oven-dried solids and the bulk volume of the solids plus pore space at some specified solid water content.

10) Soil porosity was calculated from the dry bulk density and the particle density (assumed to be 2.65 g/cm^3 for most mineral soils).

3.3. water content of litter

The litter have been dried at 105°C to a constant weight are said to be oven dry. The oven dry weight of litter is the fixed reference weight used to quantify the amount of water in litter. Water content of litter by weight was calculated as follows:

$$\%H_2O = \frac{\text{(wet weight litter – oven dry weight litter) x 100}}{\text{oven dry weight litter}}$$

4. Data analysis

4.1 Ant population

1) The total number of ant species collected from each habitat types were classified to subfamily, genus and species. The key used for the identification of ants was from Bolton (1994), Holldobler and Wison (1990) and Shattuck (1999). The key is used to identify and name specimens. There are three key sets: a single key to identify subfamilies, a series of key to identify genera within each subfamily and key to identify species within genera.

2) Species richness and diversity in each of habitat types was calculated as followed:

2.1) The specie list was determined three values for each species in a community, which included abundance, frequency and occurrence (Kreb, 1985).

$$\text{Abundance} = \frac{\text{number of individuals of species x X 100}}{\text{Number of plots of species x}}$$

$$\text{Frequency} = \frac{\text{number of plots of species x X 100}}{\text{Total plots of all species x}}$$

$$\text{Occurrence} = \frac{\text{number of finding of species x X 100}}{\text{Total times of sampling}}$$

2.2) Diversity index and evenness index were calculated by using the Shannon-Wiener index as the following :

$$H = -\Sigma (Pi)(\ln{*}Pi)$$

H = index of species diversity

S = number of species

Pi = proportion of total sample belonging to *i*th species

Evenness

$$E = \frac{H}{H\max}$$

E = Equitability or evenness index

H = Shannon diversity index

Hmax = ln S

3) The ant community structure was analyzed by using the Principal Components Analysis (PCA) technique. PCA is a type of cluster analysis, which classify the plots and constructs an ordered from a plots-by-species matrix that each group of plots can be characterized by a group of differential species by change the quantitative data (species abundance) of each species to the qualitative data. The results from a cluster analysis were presented in the form of a dendrogram. For this study, PC-ORD Program version 4.0 were used.

4.2 Ecological factors

The ecological characteristics were considered at each habitat type. The mean value of the sites was used in the statistical analyses. To test for the difference in the mean of the sites, Duncan's New Multiple Range Test was computed by using

SPSS program. And then the cluster of ecological characteristics was analyzed by PCA technique in PC-ORD Program version 4.0.

4.3 Ant community-ecological factor relationship analysis

The stepwise multiple regression were used to examine correlation between the number of ant species and various ecological factors by SPSS program. Ecological factors were treated as the independent variables, and ant species was used as the dependent variable.

CHAPTER IV

RESULTS AND DISCUSSION

The results of the study are divided into five parts for ease of the interpretation. The first is the climate factors. The second is on-site soil properties which was measured with seven habitat types. The third is comparison of ecological factors among habitat types. The forth is ants community and distribution. The last is the multiple regression analysis of ant community structure.

1. Climate factors

Climate factors composed of air temperature, relative humidity and light intensity. The results indicated that mean of temperature was the highest (29.5^{o}C) in GLF, and the lowest (24.25^{o}C) in DEF. Mean of relative humidity was the highest (89.7%) in DEF, followed closely by SSF, FPF, and PTF had the mean of 87.97%, 85.50% and 83.17% respectively, and the lowest (68.17%) was GLF. For the light intensity, GLF had the highest of 1,470.83 lux while DEF had the lowest of 207.50 lux. The mean and standard error of them in seven habitat types are shown in Table 4-1 and Figure 4-1.

The One-way ANOVA of climate factors of all habitat types were indicated significant differences at $P<0.05$ and the comparison among mean values of climate factors verified by Duncan's multiple range test were also shown in Table 4-1.

Table 4-1 Mean (±SE) of climate factors in seven habitat types.

Habitat type	Temperature* (°C)	RH * (%)	Light intensity * (lux)
DEF	24.25 (±0.79) ^{a}	90.09± (2.50) ^{c}	207.50 (±17.71) ^{a}
DDF	27.00 (±1.08) ^{a}	73.53± (1.79) ^{a}	955.00 (±54.09) ^{d}
FPF	25.33 (±0.95) ^{a}	83.14± (1.92) ^{b}	858.33 (±40.27) ^{d}
ECO	27.16 (±0.88) ^{a}	73.68± (2.20) ^{a}	858.33 (±56.01) ^{d}
SSF	25.41 (±0.84) ^{a}	87.96± (1.18) ^{b,c}	443.33 (±50.42) ^{b}
PTF	25.00 (±0.85) ^{a}	85.51± (1.84) ^{b,c}	651.66 (±32.65) ^{c}
GLF	29.91 (±1.25) ^{b}	68.17± (2.80) ^{a}	1,470.83 (±59.81) ^{e}

Remark: Significant difference are indicated by different small letter.

P< 0.05 for One-way ANOVA

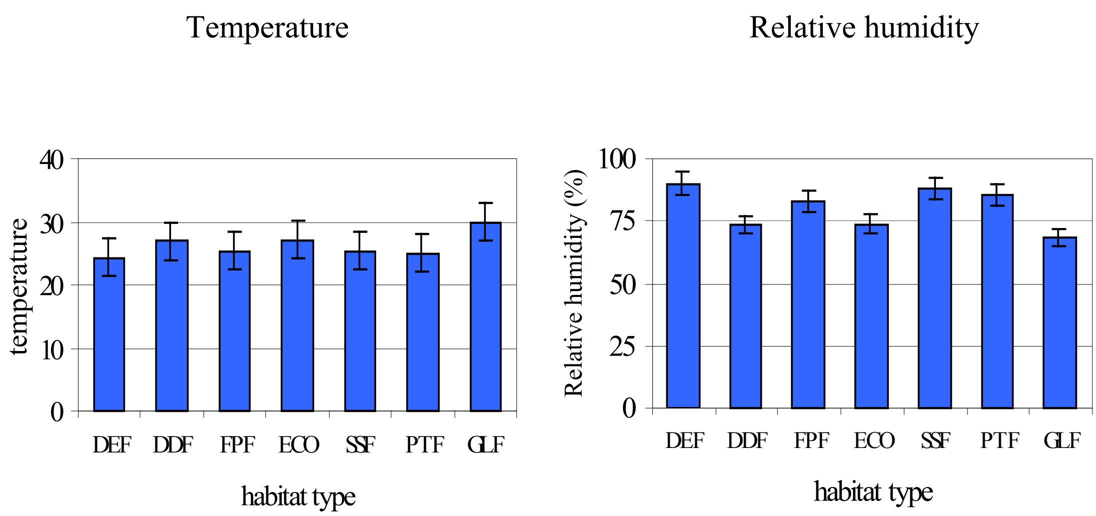


Figure 4-1 The mean (±SE) climate factors of seven habitat types

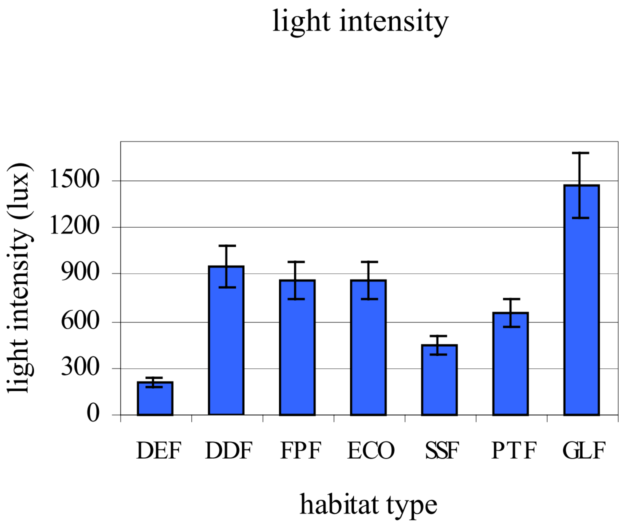


Figure 4-1 (continued)

Generally, the temperature of all habitat types varies by place and time, and the significant of variation for plants cover. As seen from this results, the mean temperature of all habitat types were significant different. The lowest recorded mean temperature was 24.25°C in DEF, while temperature as highest a 29.91°C has been recorded in GLF. This might be caused by plant cover. Because of DEF is high density of crown canopy and moisture content, it can reduce light and radiation from the sun. The modification of temperature by plant cover is both significant and complex. Shaded ground is cooler during the day than open area. Vegetation interrupts the laminar flow of air, impeding heat exchange by convection. This supported the results by Barbour et al. (1999), Kimmins (1997) and Dajoz (2000).

As the results, the mean relative humidity of all habitat types were significant difference. DEF of presented study had higher relative humidity than GLF due to it had higher tree density and more crown cover than GLF. Because of relative humidity is referring to water vapor content in the air. Water vapor gets into the air by evaporation from moist surfaces and from transpiration by plants. This supported the results studied by Dajoz (2000) who said that relative humidity is generally higher in forest than open area, especially in summer when transpiration from trees is at it height. Furthermore, temperature also influence relative humidity. Relative humidity generally is higher at night and early morning when the air temperature are lower; it is lower by day when temperatures increase. Thus, DEF had higher relative humidity than GLF due to it had lower temperature than GLF. This results supported by Smith (1996).

For light intensity, the mean of all habitat types were significant difference. GLF was the highest, while DEF was the lowest. This might be caused by crown density, stands density and canopy gap. In DEF consists of densed crown, densed stands and lowed canopy gap. This factors have influence reduction of light intensity on the forest floor. While the open area such as GLF is an area dominated by tall grass with some small shrubs and herbaceous species. Thus, this area will receive full sunlight. This results supported by Smith (1996) who said that the light intensity will vary according to average light conditions in the stand and the canopy. A crown dominant will receive full sunlight, while co-dominant, sub-dominant, suppressed and understory plants will general receive progressively less light.

2 Soil properties

The physical and chemical properties of soil in each habitat type were analyzed from January to December 2002, totally twelve months. The soil properties of all habitat types are summarized in Appendix A. The results of the mention properties can be described as follows:

2.1 Dry evergreen forest

The soil texture of the DEF were identified as sandy clay loam and sandy loam. The bulk density was about 1.22 g/cm^3, while the porosity was about 53.72%. The water content of soil was about 16.22%. The pH of soil was 4.30, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 6.5 ppm, 158.33 ppm, 270.16 ppm and 70.33 ppm respectively. The organic matter and the water content of litter were 6.08% and 30.35% respectively.

2.2 Dry dipterocarpus forest

The soil texture of the DDF were identified as sandy loam. The bulk density was about 1.38 g/cm^3, while the porosity was about 47.73%. The water content of soil was about 11.39%. The pH of soil was 5.54, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 5.33 ppm, 130.58 ppm, 712.91 ppm and 150.83 ppm respectively. The organic matter and the water content of litter were 3.63% and 13.78% respectively.

2.3 Fire protected forest

The Soil texture of the FPF were identified as sandy loam, loam, clay loam and sandy clay loam. The bulk density was about 1.29 g/cm^3, while the porosity was about 51.00%. The water content of soil was about 12.29%. The pH of soil was 5.51, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 6.08 ppm, 137.91 ppm, 616.58 ppm and 119.16 ppm respectively. The organic matter and the water content of litter were 4.71% and 16.74% respectively.

2.4 Ecotone

The soil texture of the ECO were identified as sandy loam, clay loam and sandy clay loam. The bulk density was about 1.27 g/cm^3, while the porosity was about 52.07%. The water content of soil was about 10.61%. The pH of soil was 5.58, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 6.00 ppm, 157.08 ppm, 752.50 ppm and 179.33 ppm respectively. The organic matter and the water content of litter were 3.38% and 13.04% respectively.

2.5 Secondary succession forest

The soil texture of the SSF were identified as sandy loam, loam and sandy clay loam. The bulk density was about 1.29 g/cm^3, while the porosity was about 51.16%. The water content of soil was about 14.07%. The pH of soil was 4.88, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 4.08 ppm, 213.33 ppm, 470.75 ppm and 135.16 ppm respectively. The organic matter and the water content of litter were 5.32% and 22.76% respectively.

2.6 Plantation forest

The soil texture of the PTF were identified as sandy loam, loam, and sandy clay loam. The bulk density was about 1.27 g/cm^3, while the porosity was about 51.88%. The water content of soil was about 11.89%. The pH of soil was 5.34, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 5.83 ppm, 161.66 ppm, 770.00 ppm and 70.25 ppm respectively. The organic matter and the water content of litter were 3.52% and 20.81% respectively.

2.7 Grassland forest

The soil texture of the GLF were identified as sandy loam, and sandy clay loam. The bulk density was about 1.43 g/cm^3, while the porosity was about 45.68%. The water content of soil was about 7.07%. The pH of soil was 5.09, which tended to become acidity soil. The total nitrogen, phosphorus, potassium, calcium and magnesium were about 2,100 ppm, 7.33 ppm, 172.91 ppm, 372.16 ppm and 77.91 ppm respectively. The organic matter and the water content of litter were 2.83% and 8.47% respectively.

3 Comparison of soil properties among habitat types

3.1 Physical properties

Mean and standard deviation of soil physical properties of all seven habitat types were shown in Table 4-2. It can be presented separately for each habitat types as following;

3.1.1 Soil texture

Soil texture of the DEF are identified as sandy loam to sandy loam clay, while the DDF are identified as sandy loam. For the FPF, soil texture are vary from loam, clay loam to sandy loam and sandy clay loam. For the ECO, the major soil texture were clay loam. For the SSF, the soil texture was similar to GLF soil, its texture was sandy loam and sandy clay loam. For the PTF, soil texture was sandy loam.

The results of mean values of particle size distribution were shown in Table 4-2 and Figure 4-2. DEF represented the highest mean value in sand particle (65.79%), followed by PTF, DDF, GLF, FPF and SSF were 61.78%, 57.04%, 56.94%, 53.91% and 52.30% respectively. The lowest sand particle was ECO with 43.93%.

Table 4-2 Mean and standard error of physical soil properties of seven habitat types

Habitat type	Sand * (%)	Silt * (%)	Clay * (%)	Bulk density * (g/cm^3)	Porosity * (%)	Water content of soil * (%)
DEF	65.79 ± 1.85^{c}	22.11 ± 1.80^{a}	13.48 ± 2.08^{a}	1.22 ± 0.02^{a}	53.72 ± 1.09^{c}	16.22 ± 1.48^{c}
DDF	$57.04\pm1.51^{b,c}$	22.61 ± 1.44^{a}	$20.53\pm1.49^{b,c}$	$1.38\pm0.03^{b,c}$	$47.73\pm1.26^{a,b}$	11.39 ± 1.21^{b}
FPF	53.91 ± 4.02^{b}	$25.06\pm2.87^{a,b}$	$21.87\pm2.28^{b,c,d}$	$1.29\pm0.02^{a,b}$	$51.00\pm0.95^{b,c}$	$12.29\pm1.20^{b,c}$
ECO	43.93 ± 4.09^{a}	29.62 ± 2.50^{b}	27.41 ± 2.14^{d}	1.27 ± 0.02^{a}	52.07 ± 0.98^{c}	$10.61\pm1.55^{a,b}$
SSF	$52.30\pm2.31^{a,b}$	$26.70\pm1.83^{a,b}$	$22.68\pm1.53^{c,d}$	$1.29\pm0.03^{a,b}$	$51.16\pm1.48^{b,c}$	$14.07\pm1.39^{b,c}$
PTF	$61.78\pm3.97^{b,c}$	$23.24\pm2.37^{a,b}$	$16.03\pm2.05^{a,b}$	1.27 ± 0.02^{a}	51.88 ± 0.93^{c}	11.89 ± 1.51^{b}
GLF	$56.94\pm2.46^{b,c}$	$23.36\pm1.32^{a,b}$	$20.18\pm1.88^{b,c}$	1.43 ± 0.04^{c}	45.68 ± 1.60^{a}	7.07 ± 1.06^{a}

Remark : Significant difference are indicated by different small letter.

* $P<0.05$ for One-way ANOVA

In case of silt, ECO was the highest (29.62%), followed by SSF and FPF with 26.70% and 25.06% respectively. Whereas GLF, PTF, DDF and DEF showed in the inferior results with 23.36%, 23.24%, 22.61% and 22.11% respectively. The clay particle, ECO was the highest (27.41%). While SSF, FPF, DDF, GLF and PTF showed the inferior results with 22.68%, 21.87%, 20.53, 20.18% and 16.03% respectively, and DEF represented the lowest clay particle (13.48%).

When statistically tested, sand and clay particle indicated significant difference, whereas silt particle indicated non-significant difference among habitat types.

Soil texture of the DEF and DDF that was found is similar to the results of Bunyavejchewin (1979) who found the texture of DEF in Nam Pong Basin was sandy clay loam and texture of the DDF was sandy loam. As the results of Sahunalu et.al. (1980) who found texture of the DEF at Sakaerat was sandy clay loam, and the DDF was sandy loam. For soil texture of the FPF and ECO are similar to the native forest which vary between sandy clay loam to sandy loam (Sahunalu et al., 1980). For the PTF, SSF and GF which represent of the disturbed area, the soil texture are similar to the native forest (DEF) were sandy clay loam to sandy loam (Sahunalu et al., 1980). It can be explained that texture of the DEF have trended to change from sandy clay loam to sandy loam due to soil erosion and leaching.

3.1.2 Bulk density

As resulted in Table 4-2 and Figure 4-2, the mean bulk density of all seven habitat types were slightly different. GLF was indicated the highest (1.43 g/cm^3), followed closely by DDF (1.38 g/cm^3), FPF (1.29 g/cm^3), SSF (1.29 g/cm^3), PTF (1.27) and ECO (1.27 g/cm^3) respectively, whereas DEF represented the lowest with 1.22 g/cm^3. The results was statistically tested (One-way ANOVA) the significant differences at $P < 0.05$ and the comparison among mean values of bulk density verified by Duncan's multiple range test were shown in Table 4-2.

As seen from this results, the mean bulk density of GLF higher than the others. This might be caused by organic matter. Soils high in organic matter have lower bulk density than soils low in this component. Soils that are loose and porous have low mass per unit volume (bulk density), while those that are compacted have high values (Fisher and Blinkley, 2000). These result as similar as the result of the experimental of Aksornkoae (1970) found bulk density range from 1.06 to 1.19 g/cm^3 in DEF and range from 1.16 to 1.24 g/cm^3 in DDF.

To compare DEF and DDF, the result as similar as the result of the experimental of Sabhasri et.al (1968) found that the bulk density of the A horizon and B horizon were 1.42 and 1.45 g/cm^3. The greater amount of bulk density in DDF would be depend upon the greater rock content of sandstone. Moreover, Sahunalu, Puriyakorn, suwannapinant and Khemnark (1980) found that bulk density of all habitat types in SERS range from 1.01 to 1.13 g/cm^3, However, show no signiflcant different between these 6 habitat types.

In undisturbed areas such as the DEF, DDF, FPF and ECO were low bulk density than disturbed areas such as the GF. The high bulk density in the GF was perhaps caused by deforestation which disturbed the surface soil. The result was is similar to that result found by Parchum (1973), Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980), and Verasak (1981) that found increase bulk density in disturbed areas due to texture had compacted and soil particle had cracked to fine texture soils.

3.1.3 Porosity

As resulted in Table 4-2 and Figure 4-2, the mean porosity of all seven habitat types were slightly different range from 45.68% to 53.72%. DEF indicated the highest result (53.72%) and the lowest (45.68%) was found in GLF. The One-way ANOVA of porosity of all habitat types was indicated significant differences at $P<0.05$. The comparison among mean values of porosity verified by Duncan's multiple range test were shown in Table 4-2.

Soil porosity were slightly difference in all habitat types. As seen from the results, the mean porosity were significant different. DEF was the highest, ECO, PTF, SSF, FPF and DEF have lower porosity than DEF. Whereas, GLF was the lowest porosity. The result is similar to the result revealed by Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980). They found that native forest such as DEF and DDF had higher porosity than the disturbed area such as GLF. Decreasing trend of the porosity are also clearly observed in the disturbed area. The increasing of porosity in DEF was caused by plants cover, soil texture and disturbation of soil. Porosity of most forest soil varies from 30 to 65%. The porosity of forested soil is normally greater than that of similar soil used for agricultural purposes because continuous cropping results in a reduction in organic matter and macropore spaces (Fisher and Binkley, 2000).

Soil texture were relate with porosity. Sandy surface soil have a range in pore volume of approximately 35 to 50%, compared to 40 to 60% or higher for medium- to fine texture soils. So the porosity of DEF (sandy clay loam) which fine texture has higher porosity more than GLF (sandy loam). Furthermore, the surface vegetation also has a considerable influence on the porosity soil. Changes in the composition of the surface vegetation, the amount and nature of soil organic matter and the activity of soil flora and fauna influence pore volume and soil structure. Porosity is reduce by compaction. This result supported by Niglaord (1971) that found tree species can also change the distribution of pore size in soil.

3.1.4 Water content of soil

Water content of all habitat types ranged from 7.07 to 16.22%. The average was 11.93%. The highest was the DEF and the lowest was the GLF. The SSF, FPF, PTF and DDF were high about 14.07, 12.29, 11.89 and 11.39% respectively. The dense forest soils such as DEF, SSF, FPF, PTF and DDF were higher water content than the deforested such as GLF. These results were supported by the Tropical environmental data (1967) which found the water content of soil from dense forest area higher than open forest area and grassland.

The higher water content of the DEF could be attributed to the lower rate of evaporation of moisture from soil due to thick canopy of the DEF in comparison with that of the DDF.

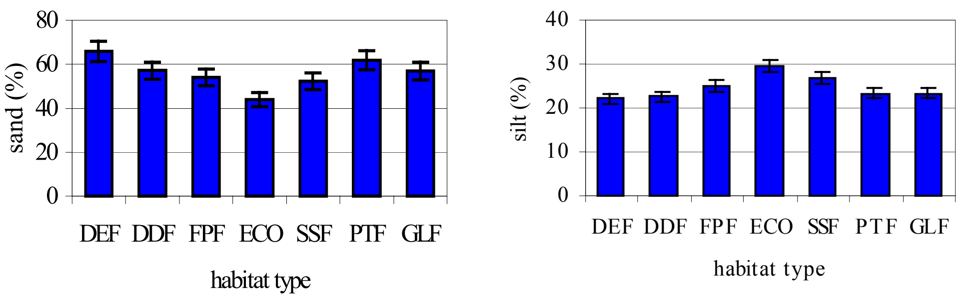


Figure 4-2 The mean physical properties soil of seven habitat types

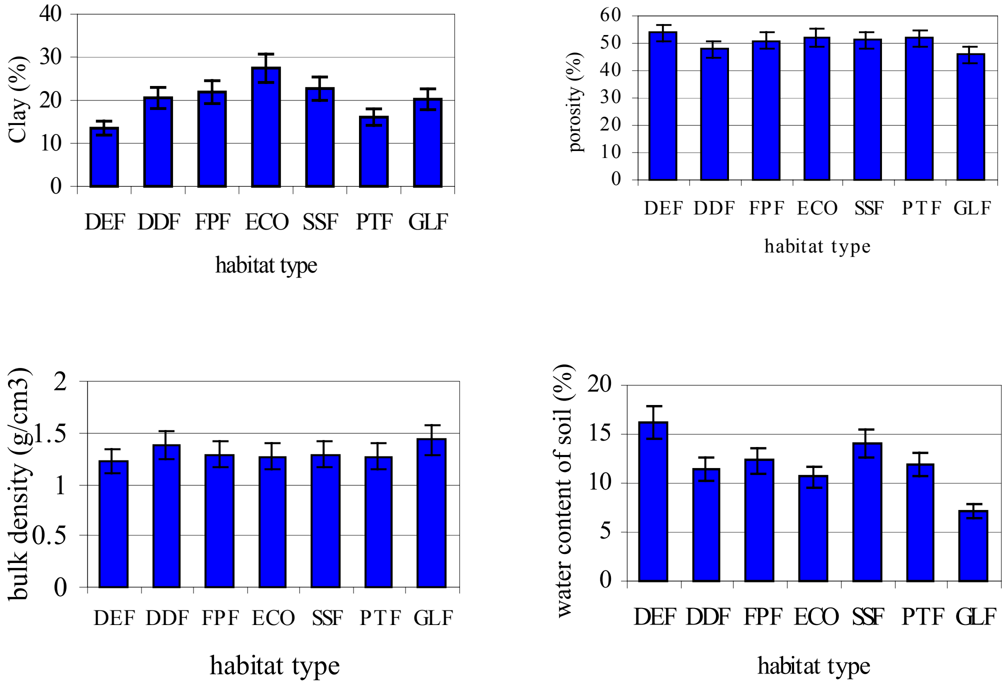


Figure 4-2 (continued)

3.2 Chemical properties

Mean and standard error of soil chemical properties of seven habitat types were shown in Table 4-3. It can be presented separately for each habitat types as following;

3.2.1 pH

Soil of all habitat types show an acid reaction pH ranged from 3.86 in DEF to 5.14 in FPF, with very difference between the habitat. This result was tested One-way ANOVA the significant different at $P<0.05$, and analyzed by Duncan's multiple range test as shown in Table 4-3.

Table 4-3 Mean and standard error of chemistry soil properties of seven habitat types

Habitat type	pH *	Organic matter * (%)	Nitrogen * (%)	Phosphorus (ppm)	Potassium * (ppm)	Calcium * (ppm)	Magnesium * (ppm)
DEF	4.30 ± 0.10^{a}	6.08 ± 0.30^{d}	0.2586 ± 0.01^{c}	6.50 ± 1.49^{a}	158.33 ± 9.91^{a}	270.16 ± 59.04^{a}	70.33 ± 22.68^{a}
DDF	5.54 ± 0.12^{d}	$3.63 \pm 0.10^{a,b}$	$0.2134 \pm 0.01^{a,b,c}$	5.33 ± 0.72^{a}	130.58 ± 7.33^{a}	712.91 ± 68.65^{c}	150.83 ± 13.43^{b}
FPF	$5.51 \pm 0.10^{c,d}$	4.17 ± 0.29^{b}	$0.1978 \pm 0.02^{a,b}$	6.08 ± 1.04^{a}	137.91 ± 15.24^{a}	$616.58 \pm 110.43^{b,c}$	$119.16 \pm 23.41^{a,b}$
ECO	5.58 ± 0.14^{d}	$3.38 \pm 0.13^{a,b}$	$0.2253 \pm 0.02^{a,b,c}$	6.00 ± 0.71^{a}	157.08 ± 15.39^{a}	752.50 ± 95.17^{c}	179.33 ± 32.51^{b}
SSF	4.88 ± 0.16^{b}	5.32 ± 0.48^{c}	$0.2326 \pm 0.01^{b,c}$	4.08 ± 0.88^{a}	213.33 ± 24.89^{b}	$470.75 \pm 95.59^{a,b,c}$	$135.16 \pm 16.06^{a,b}$
PTF	$5.34 \pm 0.21^{c,d}$	$3.52 \pm 0.04^{a,b}$	$0.2075 \pm 0.01^{a,b,c}$	5.83 ± 1.40^{a}	161.66 ± 11.18^{a}	770.00 ± 171.44^{c}	70.25 ± 19.05^{a}
GLF	$5.09 \pm 0.12^{b,c}$	2.83 ± 0.18^{a}	0.1730 ± 0.01^{a}	7.33 ± 1.16^{a}	$172.91 \pm 13.98^{a,b}$	$372.16 \pm 60.44^{a,b}$	77.91 ± 14.14^{a}

Remark : Significant difference are indicated by different small letter.

* $P<0.05$ for One-way ANOVA

As seen from this result, soils under all habitat types shoe very slightly more acidic pH condition. These result as similar as the result of the experimental of Wongseenin (1971) found that soils from DEF and DDF in SERS to be acidic in nature. The pH soil of DEF was lower than that of DDF, being approximately 4.5 and 5.5 respectively. And the result of Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980) found the soil of all area in the SERS forest normally show an acid reaction (pH range between 4.8 to 5.7).

The mean pH of DEF, PTF and SSF were lower than DDF, ECO and FPF. This might because by organic matter. In DEF, PTF and SSF, surface soils were always covered by vegetation and leaf litter all the year, therefore, pH of soil would be affected by the organic matter supplied from the vegetation. This leaded to the acidification of soil (Wachrinrat, 2000).

3.2.2 Organic matter

Organic matter of all habitat types as shown in Table 4-3 and Figure 4-3. The highest was the DEF (6.08%) followed by SSF and FPF were high 5.32% and 4.17% respectively. Whereas the lowest was the GF (2.83%). The analysis of variance on organic matter of all habitat types were tested significant difference at $P<0.05$, and the comparisons among mean value of organic matter verified by Duncan's multiple range test were shown in Table 4-3.

The results showed that the soil of DEF was found to be richer in organic matter in comparison with the other. This was due to the higher amount of litter produced in DEF. In natural vegetation community there was always an accumulation of plant materials at the soil surface which undergo decomposition. The results obtained in this study confirmed the above statement. Because plant residues are the principal material undergoing decomposition in soils and, hence, are the primary source of soil organic matter, we will begin by considering the makeup of these materials. Therefor, it can be stated that, in general the soils of the DEF are richer in nutrients than the DDF. This result is similar as the result revealed by Wongseenin (1971) and Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980).

3.2.3 Nitrogen

Nitrogen content of all habitat types were slightly different ranged from 0.1730% to 0.2586%. The highest was the DEF and the lowest was the GLF. The SSF and the ECO were high about 0.2326% and 0.2253% respectively. The analysis of variance on nitrogen of all habitat types were tested significant difference at $P<0.05$ and the comparisons among mean value of nitrogen verified by Duncan's multiple range test were shown in Table 4-3.

As seen from this result, the mean nitrogen of DEF were higher than the others. These result as similar as the result of the experimental of Aksornkoae (1970), Gojsene (1976), Ratanaphumma (1976), Bunyavejchewin (1979), and Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980). This was probably due to the higher contents of the mineral as the result of litter decomposition (Wongseenin, 1971).

3.2.4 Phosphorus

As the results showed in Table 4-3 and Figure 4-3, it was indicated that the mean of phosphorus of all habitat types were slightly different ranged from 4.08 ppm to 7.33 ppm. The highest was the GLF, followed by DEF, FPF, ECO, PTF and DDE were high about 6.50 ppm, 6.08 ppm, 6.00 ppm, 5.83 ppm and 5.33 ppm respectively. Whereas SSF was the lowest.

As seen from this results, the mean phosphorus content of DEF and DDF was different from the result of Wongseenin (1971) found the mean of DEF and DDF were 0.4 ppm and 2.2 ppm respectively. Gajaseni (1976) and Ratanaphumma (1976) found the mean phosphorus of DEF and DDF were 6.16 ppm and 33.45 ppm respectively. Whereas Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980) found the nean of DEF and DDF were 10.00 ppm and 20.33 ppm respectively. The high phosphorus content in DEF may be caused by the decomposition of litter, which released the phosphorus to the surface soil.

However, when analysis of variance tested by One-way ANOVA on phosphorus of all habitat types was shown non-significant differences ant P>0.05 among them

3.2.5 Potassium

Potassium content of all habitat types ranged from 130.58 ppm to 213.33 ppm. The highest was the SSF, followed by GLF, PTF, DEF, and ECO were high about 172.91 ppm, 161.66 ppm, 158.33 ppm and 157.08 ppm respectively. While the lowest was DDF. When statistically tested, they indicated significant differences among them.

As seen from this result, the mean potassium content was higher than the result of Wongseenin (1971) found potassium of DEF was 96.00 ppm to 102.00 ppm, and DDF was 60.00 ppm to 91.00 ppm. Whereas Gajaseni (1976) and Ratanaphumma (1976) found potassium of DEF was 138.08 ppm, and DDF was 100.00 ppm. Moreover, Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980) found potassium of DEF was 131.67 ppm, and DDF was 93.00 ppm.

To compare DEF and DDF, the potassium content were higher in DEF tha DDF. It may be caused by decomposition of leaf litter. Higher litter production in DEF contributed to the higher contents of the mineral as the result of litter decomposition (Chostexs, 1960).

3.2.6 Calcium

The result of mean of calcium of all habitat types were shown in Table 4-3 and Figure 4-3. PTF represented the highest mean value in calcium (770.00 ppm), followed by ECO (752.50 ppm), DDF (712.91 ppm), FPF (616.58 ppm), SSF (470.75 ppm), and GLF (372.16 ppm) respectively. Whereas DEF was the lowest with 270.16 ppm. The analysis of variance on calcium of all habitat types was shown significant differences at P<0.05 and the comparison among mean of calcium verified by Duncan's multiple range test were shown in Table 4-3.

As seen from this results were different from the results of Bunyavejchewin (1979) which found the DDF and DEF ranged from 129 ppm to 1,790 ppm and 48 ppm to 1,013 ppm respectively. Furthermore, Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980) found the DEF and DDF was 186.67 ppm and 417.33 ppm respectively.

3.2.7 Magnesium

As resulted in Table 4-3 and Figure 4-3, the mean magnesium of all habitat types in ECO was indicated the highest value (179.33 ppm), DDF, SSF, FPF and GLF showed the lower value were 150.83 ppm, 135.16 ppm, 119.16 ppm and 77.91 ppm respectively. The lowest in the PTF was 70.25 ppm. And DEF also had the low with 70.33 ppm. When analysis of variance tested by One-way ANOVA on magnesium of all habitat types was shown significant differences at P<0.05, and the comparison among mean of calcium verified by Duncan’s multiple range test were shown in Table 4-3.

As seen from this results the mean magnesium of DEF and DDF were different from the results of Bunyavejchewin (1979) found the mean magnesium of DEF ranged from 43.00 ppm to 275.00 ppm, and DDF ranged from 80.00 to 580.50 ppm. Whereas, Sahunalu, Puriyakorn, Suwannapinant and Khemnark (1980) found the mean magnesium of DEF was 262.67 ppm, and DDF was 125.33 ppm.

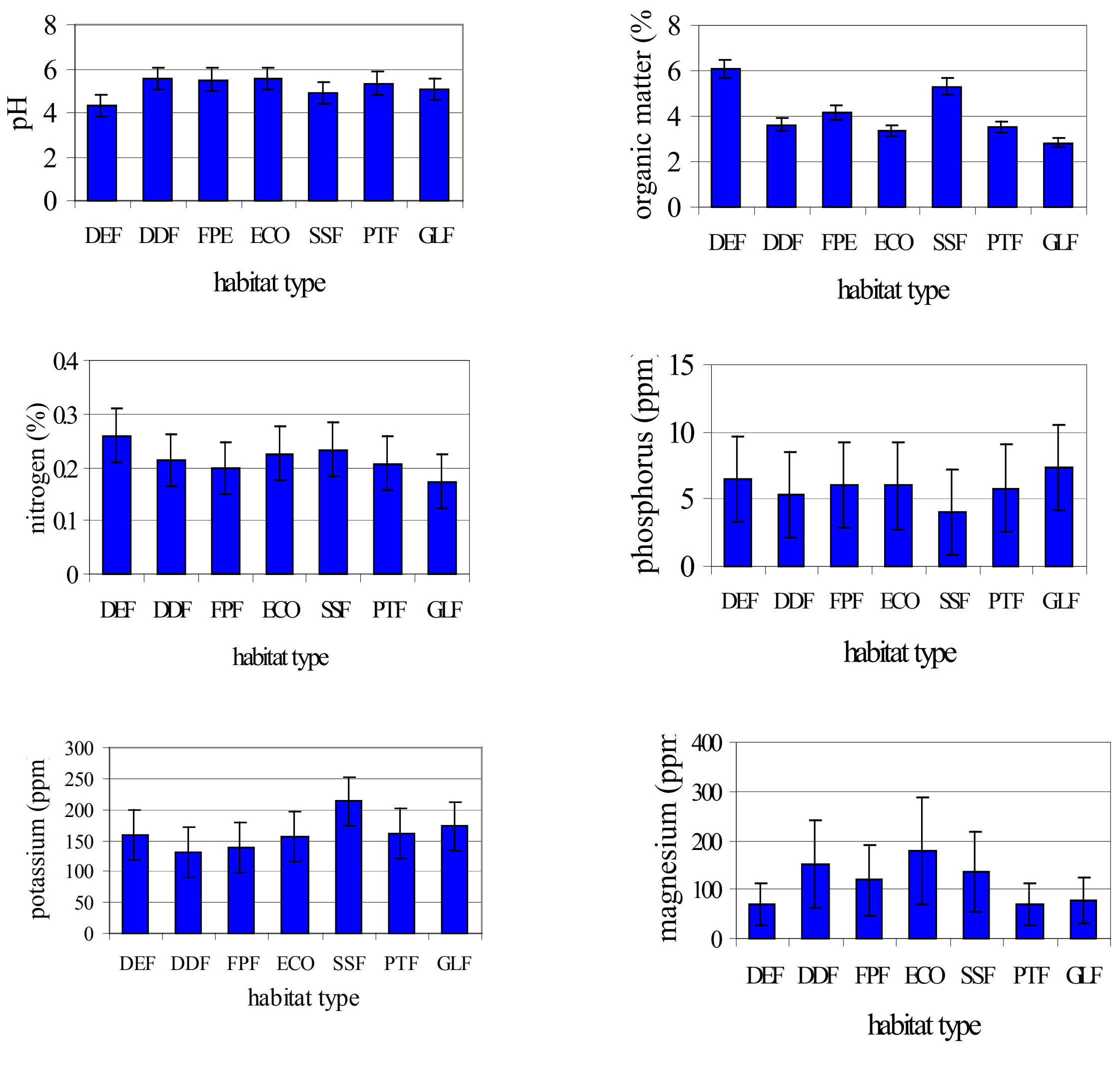


Figure 4-3 Chemical soil properties of seven habitat types

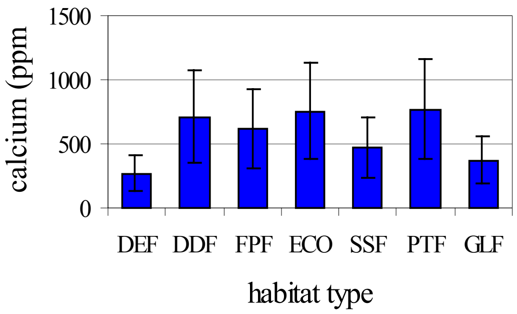


Figure 4-3 (continued)

3.3 Water content of litter

As results in Table 4-4 and Figure 4-4, DEF resulted the highest water content of litter (30.35%), while SSF, PTF, FPF, DDF and ECO showed respectively inferior results, whereas GLF indicated with the lowest (8.47%). This result was One-way ANOVA tested the significance at P<0.05 and the analyzed by Duncan's multiple range test in Table 4-4.

Table 4-4 Mean and standard error of water content of litter of all habitat types.

Habitat type	Water content of litter (%)*
DEF	30.35 ±16.32 [c]
DDF	13.78 ±11.17 [a,b]
FPF	16.74 ± 12.27 [a,b]
ECO	13.04 ± 8.72 [a,b]
SSF	22.76 ± 15.31 [b,c]
PTF	20.81 ± 13.31 [b,c]
GLF	8.47 ± 5.74 [a]

Remark : Significant difference are indicated by different small letter.

* P< 0.05 for One-way ANOVA

The results indicated that DEF, SSF, PTF, ECO FPF and DDE were higher water content of litter than GLF. This might due to thickness of litter on the forest floor and cover vegetation. A layer of litter in DEF has accumulated on the forest floor at an average thickness of 1 to 3 centimeter and includes leaves, twigs, fruit, bark and decompose animals. All litter absorbed amount of water. While GLF has lowest water content of litter due to a litter was lower.

Furthermore, dense vegetation, dense crown and thick canopy of DEF has influence to water content of litter. To compare DEF and the other such as SSF, PTF found that water content of litter has closely value. Because of SSF and PTF has amount of litter, dense vegetation and dense crown similar to DEF. For DDF, ECO and FPF have lower dense vegetation and dense crown than DEF. Thus the water content of litter were lower than DEF.

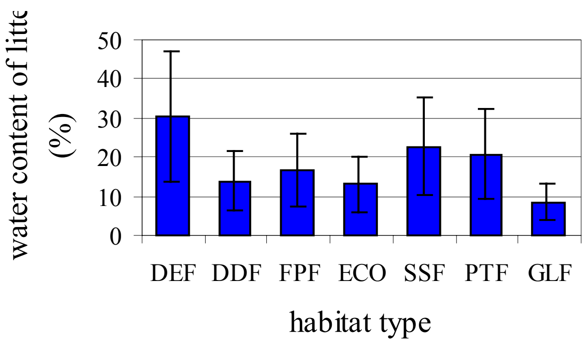


Figure 4-4 The mean and standard error water content of litter of seven habitat types

4. Ant Community and Distribution

4.1 Ant Composition

A total of 50,673 ants were caught and kept in a litter for shifting extraction and hand collection. As shown in Table 4-5, 113 species belonging to 42 genera were collected from the studied area. *Myrmicinae* was in the highest amount (44) among the subfamilies, followed by *Ponerinae* (26) and *Formicinae* (24). The genus *Pheidole* contained the most species (11), followed by the genus *Tetramorium*, *Leptogenys*, *Crematogaster*, and *Camponotus* which has 9, 9, 8, and 7 species respectively.

Table 4-5 Subfamily, genera and species of ants at the SERS

Subfamily	Genera	Number of species
Ponerinae	*Amblyopone*	1
	Anochetus	1
	Diacamma	5
	Gnamptogenys	1
	Hypoponera	2
	Leptogenys	9
	Odontomachus	1
	Odontoponera	1
	Pachycondyla	4
	Platythyrea	1
Dolichoderinae	*Dolichoderus*	2
	Iridomyrmex	1
	Ochetellus	1
	Philidris	1
	Technomyrmex	3
	Bothriomyrmex	1
Formicinae	*Anoplolepis*	1
	Camponotus	7

Table 4-5 (continued)

Subfamily	Genera	Number of species
	Myrmoteras	1
	Oecophylla	1
	Paratrechina	4
	Plagiolepis	1
	Polyrhachis	6
	Prenolepis	1
	Pseudolasius	1
Myrmicinae	*Aphaenogaster*	1
	Cataulacus	1
	Cardiodondyla	2
	Crematogaster	8
	Meranoplus	1
	Monomorium	4
	Myrmicaria	1
	Pheidole	11
	Pheidologeton	2
	Rhoptromyrme	1
	Proatta	1
	Solenopsis	1
Aenictinae	*Aenictus*	4
Pseudomyrmecinae	*Tetraponera*	5
Cerapachyinae	*Cerapachys*	1
Total	42	113

As a result, the subfamily proportion of ants is in accordance with the studies of Wiwatwitaya and Rojanawongse (2001) and Poonjumpa (2002), which found that the subfamily Myrmicinae was the highest, followed by Ponerinae and Formicinae respectively. The result of the study is also similar to the study of Noon-anant (2003), which found that Myrmicinae was the highest subfamily, followed by Ponerinae and Formicinae. This may be due to the fact that Myrmicinae is the largest subfamily in the world, based on both the number of genera and species and that this subfamily occurs throughout the world in all major habitats more than the others (Holldobler and Wilson, 1990; Bolton, 1994; Anderson, 2000).

Cerapachyinae and Pseudomyrmicinae were found less than the others. This may be due to the fact that the groups are small and specifically found in hollow stems, or in specially developed parts of plant (Sudd and Franks, 1987). However, Leptanillinae and Dorylinae can not be found in this study. This may be due to the fact that these subfamilies are small and rare, and also their food source and habitats are limited. Furthermore, the difference in results may be also to different collection effort (time, sampling, area size), sampling method and various biases such as the skill and experienced of the investigator (Wiwatwitaya, 2000; Bestelmeyer et.al, 2000).

Among all species, *Pheidole plagiaria*, *Pheidologeton diversus*, *Dolichoderus thoracicus*, *Anoplolepis gracilipes* and *Dolichoderus tuberifera* were dominant in the area. *P.plagiaria* is the most abundant genus found in this collection. They were found in all habitat types such as lowland evergreen forest, pine or hill evergreen forest (Wiwatvitaya, 2000; Sonthichai, 2000 and Prasityousil, 2003). Because *Pheidole* is the second largest genus of ants in the world, they can be encountered almost everywhere and at any time. Most species form their nests in the soil. Foraging is most common on the ground (Shattuck, 1999). Furthermore, these species inhabit in open land and forest edges (Zanini and Cherix, 2000).

Tetramorium is found throughout tropical regions all over the world. In Thailand, it has been found throughout the country such as in lowland evergreen forest, hill evergreen forest, and deciduous forest (Wiwatvitaya, 2000; Sonthichai, 2000 and Noon-anant, 2003). Their nests are in the soil in all location and major habitats. They forage individually on the ground, often in large numbers, and are most active during the morning and evening hours (Shattuck, 1999).

Letogenys is a large genus and found throughout tropical regions of the world. In Thailand, it has been found throughout the country (Wiwatvitaya, 2000; Sonthichai, 2000 and Noon-anant, 2003). They are found in a wide range of habitats from rain forests to the arid zone. They build nests either in loose debris on the surface of the ground or in the soil. Foraging occurs throughout the day and night (Shattuck, 1999).

Camponotus can be found in tropical Asian forests such as the lowland secondary forest of Hong Kong, Khao Yai National Park, lowland tropical rain forest of Bala forest (Wiwatvitaya, 2000; Fellowes and Dudgeon, 2000 and Noon-anant, 2003). Because *Camponotus* is one of the most common and widespread group of ants in the world, they can be expected in all habitat throughout the continent. Their nests are found in a wide range of sites including in the soil with or without covering, between rocks, in wood, among the roots of plants and in twigs on standing shrubs or trees (Shattuck, 1999).

Crematogaster is one of the most common genus of ants. They are found everywhere in Thailand including lowland tropical rain forest, hill evergreen forest, mixed decidous (bamboo) forest (Sonthichai, 2000; Phoonjumpa, 2001; and Noon-anant, 2003). Some of the *Crematogaster* species also are more common in non-forest habitat (Fellowes, 1996). Because *Crematogaster* is regularly encountered, often in large numbers, their nests are found in a wide range of sites including in soil with or without coverings, cracks of rocks, and arboreal trunks and twigs. Foraging takes place on the ground as well as on low vegetation and trees, and often involves distinct trails (Shattuck, 1999).

Some ant genera such as *Oecophylla*, *Philidris* and *Tetraponera* were found in the lowest number of species. This may be due to the fact that the species are arboreal ants. *Philidris* forms nests in cavities of living plants or in rotten wood above the ground. The nests of *Oecophylla* were always in trees or shrubs. *Tetraponera* are highly arboreal, nesting in hollow twigs or branches of trees or shrubs. These species are always found on vegetation although they occasionally forage on the ground around tree branches or shrubs.

4.2 Seasonal changes in abundance of ants

The Walter's climatic diagram of the SERS is divided into two seasons: wet and dry seasons. The wet season occurs during mid-May to October while the dry season from November to April (Wachrinrat, 2000). Total abundance of ants were 3,617.01 individuals per m^2, ranging from a minimum of 33.33 individuals per m^2 in February to a maximum of 306.54 individuals per m^2 in November.

The abundance of ant composition tended to be low during the dry season, from December to February or April. The abundance was higher from July to November. Especially in March and November, it was very high because there was irregular heavy rain that effected the increase of the abundance.

The difference of the abundance of ant composition between the dry and wet seasons is shown in Figure 4-5.

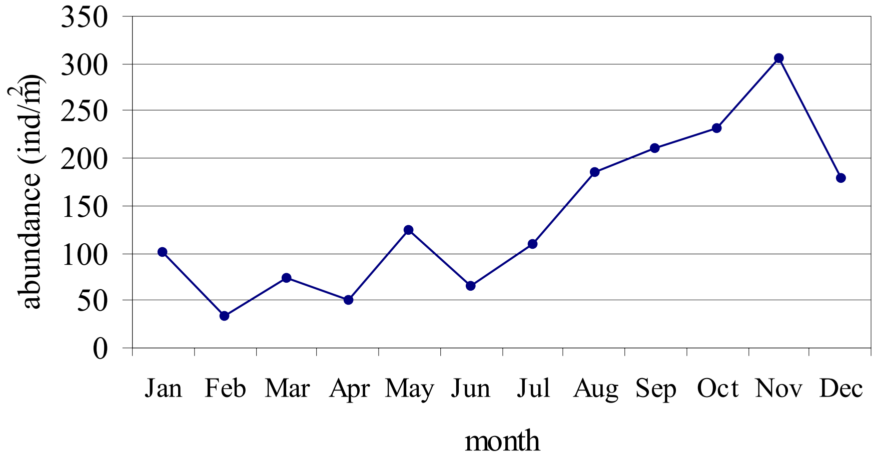


Figure 4-5 Seasonal change in abundance of ant composition in 2002 at the SERS

4.3 Community structure of ants

As shown in Appendix III, the widespread species which occurred in all habitat types were *Diacamma rugosum, Leptogenys diminuta, Odontoponera denticulata, Dolichoderus thoracicus, Anoplolepis gracilipes, Camponotus (Myrmosericus) rufoglaucus, Paratrechina longicornis, Monomorium destructor, Pheidologeton diversus and Pheiole plagiaria*.

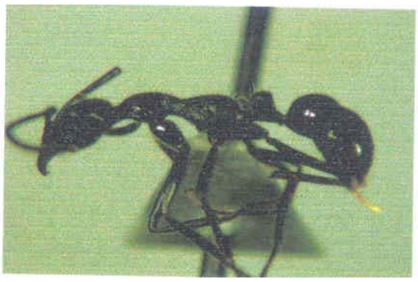
Camponotus (Myrmosericus) rufoglaucus

Diacamma rugosum

Figure 4-6 The widespread species which occurred at all habitat types

Paratrechina longicornis

Pheidologeton diversus



Leptogenys diminuta

Odontoponera denticulate

Figure 4-6 (continued)

In the present study, the abundance of ant may be classified into two groups, common species (over 25% of the total abundance) and rare species (less than 25% of the total abundance) (Adapted from Gaston, 1994). The abundance, frequency and occurrance of ant species in each habitat type are shown in Appendix III. The results can be shown as the followings:

1) In DEF, the number of ant species (36) had frequency lower than 50%. *Dolichoderus thoracicus* was the highest frequency of 62 % followed by *Odontoponera denticulata* of 58 % whereas *Aenictus laeviceps* had the lowest frequency of 20.83 %.

Pheidole plagiaria was the most common species and accounted for 16.7 % of the total abundance. *Dolichoderus thoracicus* and *Aenictus laeviceps* were also common species which had the lower relative abundance of 9.40% and 7.75% respectively. The other ant species (49 species) were rare species (Figure 4-7)

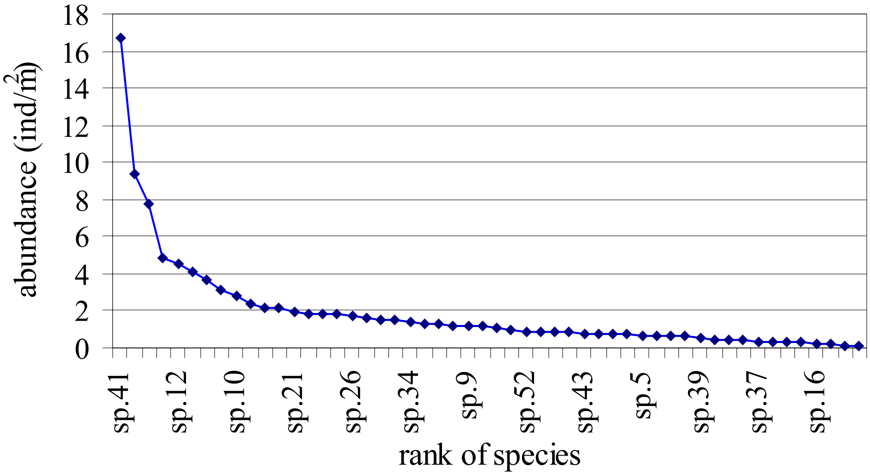


Figure 4-7 The abundance of ants species in DEF

For the occurrence, more than half (36 species) occur higher than 50 percent. The ants which contained the largest proportion in occurrence as *Dolichoderus thoracicus*, which was 100%. The other ant species such as *Odontoponera denticulata* , *Diacamma vagans, Camponotus (Myrmosericus) rufoglaucus and Pheidole plagiria* were lower, that is, 91.67%, 83.33%, 83.33% and 83.33% respectively. *Aenictus laeviceps* was the least proportion of occurrence at 16.67%.

The ant species that occurred in DEF were *Leptogenys* sp.10 of AMK, *Camponotus (Colobobsis) preaeruta*, *Camponotus (Myrmosaulus) auriventris, Cardiocondyla emeryi, Monomorium floricola, Tetramorium walshi, Crematogaster (Crematogaster)* sp.2 of AMK and *Tetraponera allaborans.*

2) In DDF, the number of ant species (28 species) was the higher frequency, that is, it is more than 50%. Thirteen species, including *Diacamma vagans*, *Odontoponera denticulata*, *Anoplolepes gracilipis* showed the highest frequency of 54.17%. Two other species showed frequency lower than 50%. *Crematogaster (Crematogaster)* sp.2 of AMK and *Aenictus* sp.13 of AMK showed the lowest frequency of 25%.

Crematogaster (Physocrema) inflata and *Pheidole plagiria* were common species with 13.18% and 12.44% respectively whereas the other ant species (45 species) were rare species (Figure 4-8)

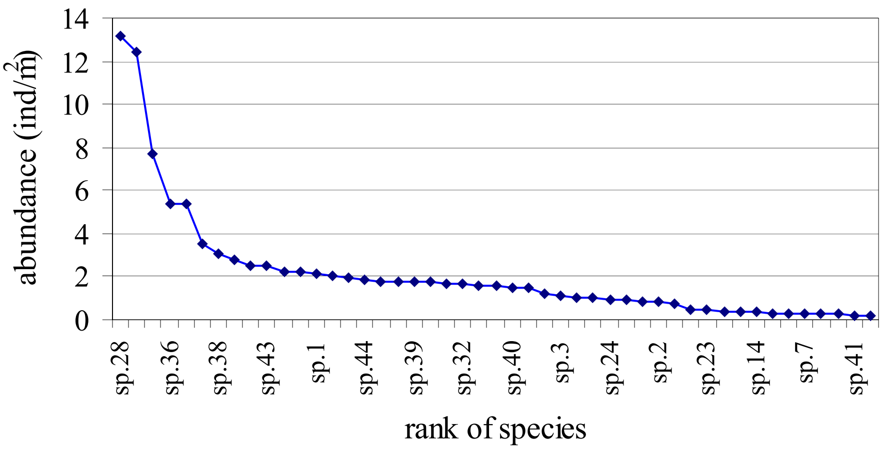


Figure 4-8 The abundance of ants species in DDF

The occurrence of 41 species were higher than 50%, and 14 species including *Odontoponera denticulata* , *Diacamma vagans, Camponotus (Myrmosericus) rufoglaucus,Crematogaster (Physocrema) inflata* were the highest with 83.33%. There were only 3 species occurring lower than 50%.

The ant species which occurred in only DDF were *Diacamma* sp.5 of AMK, *Cataulacus granulatus*, *Crematogaster (Crematogaster) rogenhoferii*, *Crematogaster (Crematogaster)* sp1 of AMK, *Strumigenys* sp.1 of AMK, *Tetramorium ciliatum, Aenictus platifrons, Tetraponera difficilis* and *Tetraponera ruflonigra*.

3) In FPF, there were 14 species occurring in 50 percent or more of the community. *Odontomachus rixosus* and *Anoplolepis gracilipes* showed the highest frequency of 58% while *Oecophylla smaragdina* showed the lowest one, 25%.

Pheidologeton diversus was common and accounted for 35.61% of relative abundance. 25 species including *Anoplolepis gracilipes, Leptogenys diminuta Leptogenys kitteli* etc. were rare species while 16 species were very rare (Figure 4-9).

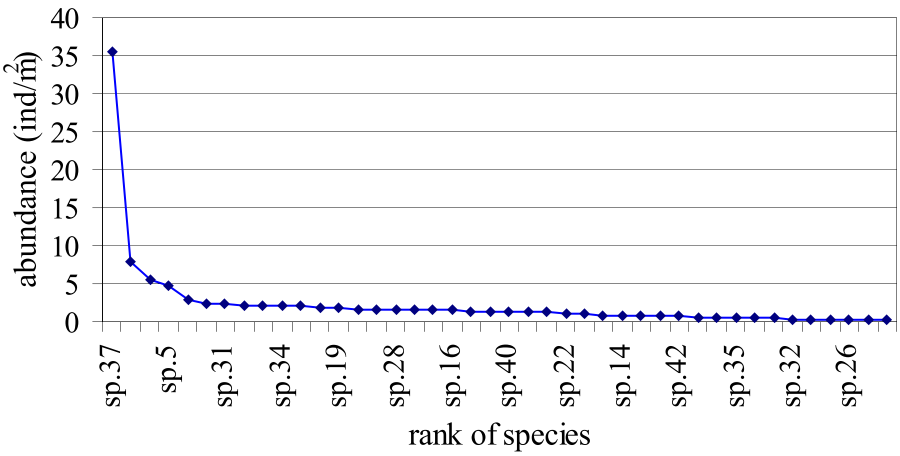


Figure 4-9 The abundance of ants species in FPF

Anoplolepes gracilipes showed the highest occurrence, 100%, followed by *Odontomachus rixosus, Diacamma rugosum, Diacamma vagans, Leptogenys diminuta, Pachycondyla astuta* and *Pheidologeton diversus,* 91.67%, 83.33%, 83.33%, 83.33%, 83.33%, and 83.33% respectively. There were only 3 species occurring lower than 50 percent.

The ant species which occurred in only FPF were *Polyrhachis (Myrma)* sp.1 of AMK, *Cardiocondyla nuda* and *Pheidole* sp. of AMK.

4) In ECO, the results indicated that 35 ants species showed lower frequency than 50%. *Anoplolepis gracilipes* showed the highest one, 58%. Two species, *Pheidole platifrons* and *Pheidile* sp.15 of AMK, showed the lowest, 29.17%.

Pheidole planifrons was the most common species with 16.04% of relative abundance while *Monomorium chinensis* was common species accounted for 9.46%. Many ant species (44 species) were rare species (Figure 4-10).

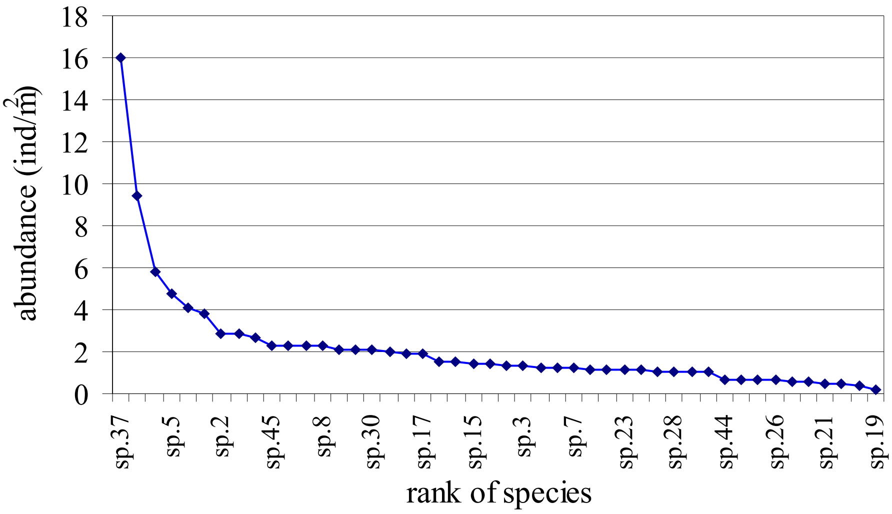


Figure 4-10 The abundance of ants species in ECO

For the occurrence, more than half (28 species) occur higher than 50%. *Anoplolepis gracilipes* was the highest, 91.67%. The others including *Leptogenys birmana*, *Odontoponera denticulata*, *Odontomachus rixosus*, *Camponotus (Myrmosericus) rufoglaucus,etc. were* 75%. Eight species were lower than 50%.

The ant species which occurred in only ECO were *Cardiocondyla emeryi, Paratrechina* sp.8 of AMK*, Monomorium chinense, Pheidole* sp.15. of AMK and *Tetramorium* sp.12 of AMK.

5) In SSF, the results indicated that only five species showed higher frequency than 50%. *Leptogenys diminuta* showed the highest, 54.17%, followed by *Leptogenys birmana, Odontomachus rixosus, Odontoponera denticulata and Camponotus (Myrmosericus) rufoglaucus* which showed 50%. *Pheidologeton affinis* showed the lowest one, 16.67%.

Dolichoderus tuberiferi was the most common species and accounted at 16.60% of the total abundance. Whereas the less common species were *Pheidole plagiaria* and *Dolichoderus thoracicus*, which showed 9.46% and 9.20% respectively. The other ant species (41 species) were rare species (Figure 4-11).

Leptogenys diminuta showed the highest occurrence, 83.33%, followed by *Leptogenys birmana*, *Odontoponera denticulata*, *Odontomachus rixosus* and *Camponotus (Myrmosericus) rufoglaucus* which were 75.00%. Nineteen species were lower than 50%. Whereas *Pheidologeton affinis* was the least proportion of occurrence, 16.67%.

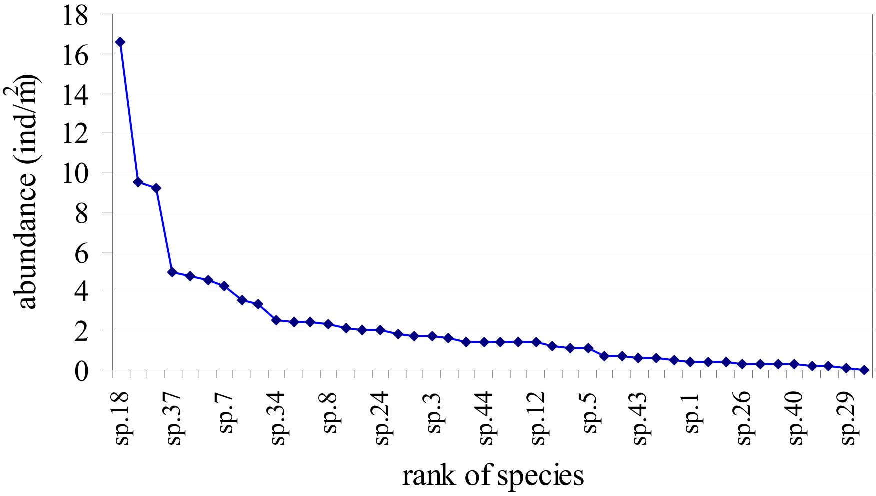


Figure 4-11 The abundance of ants species in SSF

The ant species which occurred in only SSF were *Technomyrmex* sp.2 of AMK, *Amblyopone rectinata, Pachycondyla birmana, Pheidole inornata, and Polyrhachis (Campomyrma) halidayi.*

6) In PTF, the frequency of 39 ant species was lower than 50%. *Leptogenys diminuta, Dolichoderus thoracicus and Pheidologeton affinis* showed the highest frequency, 58.83% while *Pheidole* sp.11 of AMK showed the lowest, 25%.

Dolichoderus thoracicus was the most common species with 10.05% of the total abundance while *Pheidologeton affinis* was less common (8.28%). Twenty-six species including *Pheidologeton diversus, Plagiolepis* sp.1 of AMK*, Myrmicaria* sp.3 of AMK etc. were rare species, and twenty-two species were very rare species (Figure 4-12).

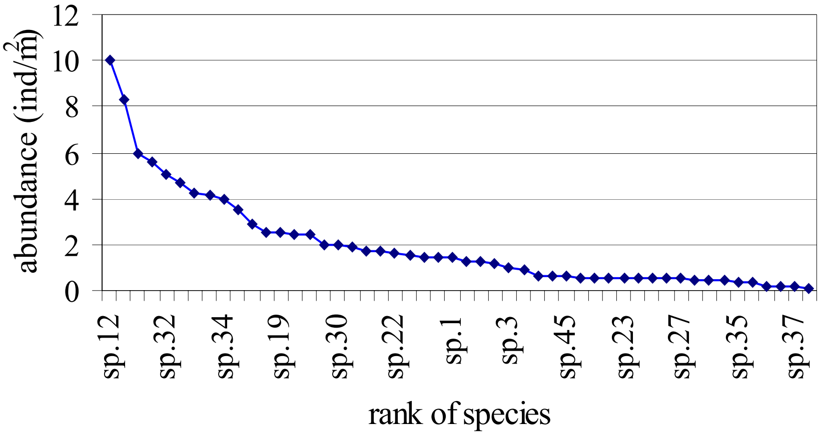


Figure 4-12 The abundance of ants species in PTF

Leptogenys diminuta, Dolichoderus thoracicus and *Pheidologaton affinis* showed the largest proportion of occurrence, 100%, followed by *Pachycondyla astuta*, *Pachycondyla leeuwenhoveki* and *Iridomyrmex ancep* which were 83.33%. Thirteen ant species were lower than 50%. *Pheidole* sp.11 of AMK showed the lowest occurrence with 25.00%.

The ant species which occurred in only PTF were *Leptogenys* sp.23 of AMK, *Technomyrmex kheperra, Myrmoteres* sp.3 of AMK, *Pheidole* sp.4 of AMK, *Proatta butteli*, *Tetramorium bicarinatum, Tetramorium* sp.13 of AMK and *Aenictus nishimurai*.

7) In GLF, only eight species showed the frequency higher than 50%. *Anoplolepis gracilipes* showed the highest, 58.33%, while *Parathechina* sp.2 of AMK showed the lowest, 16.67%.

Monomorium destructor was the most common species. It showed the highest relative abundance of 9.92%. *Pheidologeton diversus* and *Anoplolepis gracilipes* were common species, 8.44% and 8.08% respectively. The other ant species (52 species) were rare species (Figure 4-13).

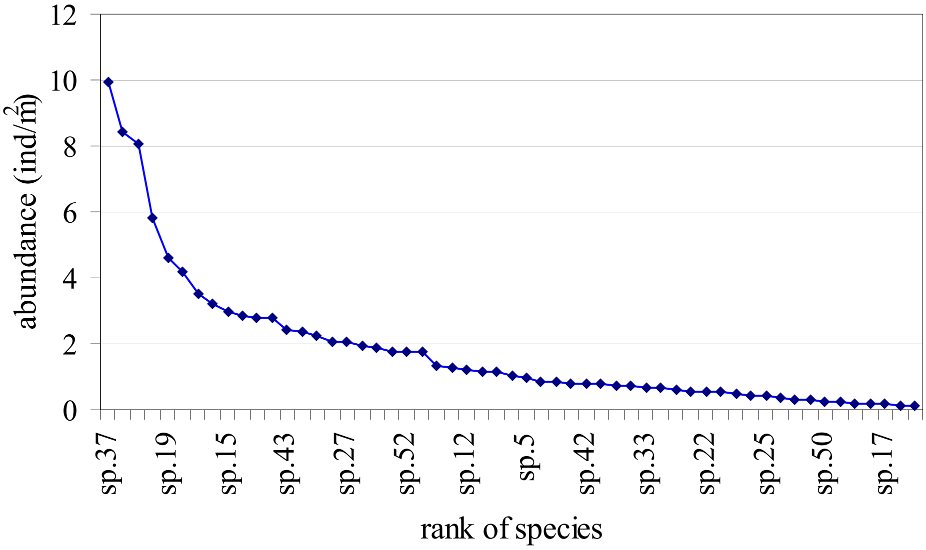


Figure 4-13 The abundance of ants species in GLF

The ant species which showed the highest proportion in occurrence was *Anoplolepis gracilipes,* 91.66%, followed by *Odontoponera denticulata, Diacamma rugosum, Odontomachus rixosus,Leptogenys borneensis, Dolichoderus thoracicus, Pheidologaton affinis* and *Pheidologaton diversus* which were 75%. The other ant species (22 species) were lower than 50%. *Paratrechina* sp.2 of AMK showed the lowest 16.67 percent.

The ant species occurring in only GLF were *Hypoponera* sp.7 of AMK, *Platythyrae parallela, Pheidole* sp. 8 of AMK, *Tetramorium smithii* and *Bothiomymex* sp.1 of AMK.

4.4 Seasonal Change in Common Species

Seasonal changes in the abundance of common species in the study areas are summarized as followed (Figure 4-14).

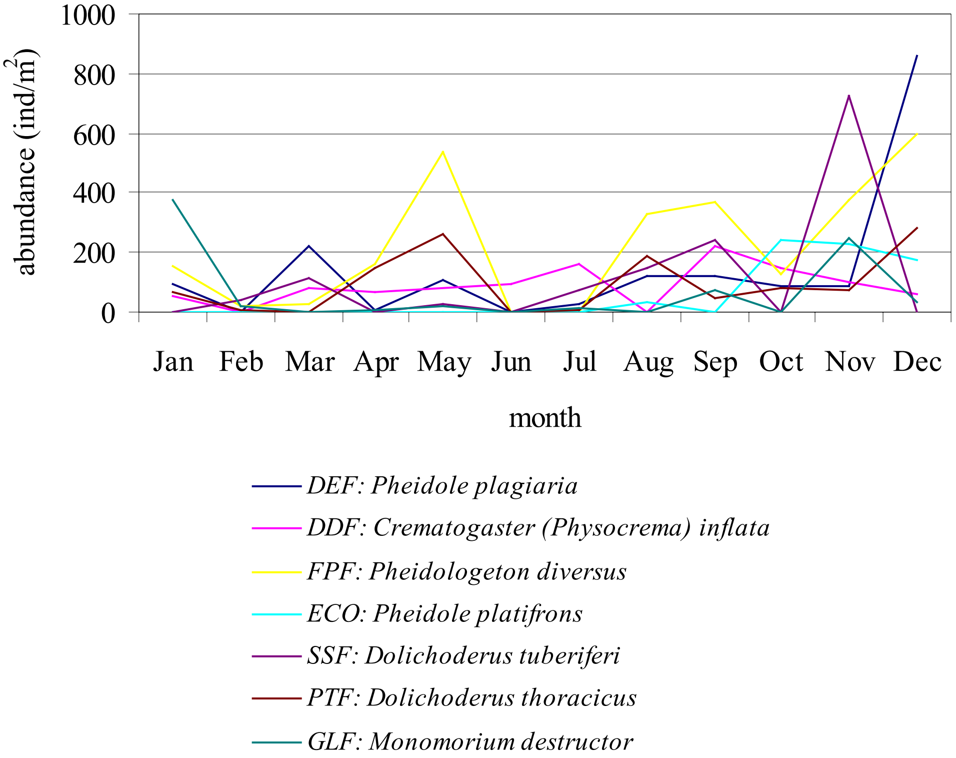


Figure 4-14 Seasonal change of common species in the study areas

The most common ant species showed a decrease in number through the dry period (February) and then rapidly increased in number in April, the time when the soil condition became wet by the rainy season (June to November). We have observed one exception of high abundance of ant in February and November 2002. In these months humidity of soil condition increased by a irregular rainfall. This trend was similar to the study results of Ratanaphumma (1976), Yimrattanabovorn (1993) and (Wiwatiwitaya, 2003) concluding that the population, biomass and species composition of soil fauna were fluctuated by water content in soil and litter. As these results it suggested that seasonal changes of abundance of ants were dependent upon humidity condition

4.5 Total species richness

The species richness of each plots are shown in table 4-6. As the results showed that species richness was highest (55) in GLF. DEF and PTF were represented by 52 and 50 species respectively. FPF had the lowest species richness (42). This results can be explained that GLF was the disturbed area, and the overall abundance of ants increased due to the dominance of exotic species such as *Pheidologeton diversus*, *P.affinis*, *Oecophylla smaragnina*. These ants species were found in disturbance areas (Shattuck, 1999). Species richness of DEF was higher than DDF, FPF, ECO, SSF and PTF. It may be due to humidity, tree species and density of trees (Fowler and Claver, 1991; Folgarait, 1996).

4.6 Shannon diversity index and Evenness

Species diversity was investigated by Shannon's index (H′). There was different in each habitat types (Table 4-6). The results showed that GLF was the highest index of diversity of 2.84. ECO and PTF had the lower diversity index than GLF with 2.69 and 2.68 respectively. The lowest species diversity index was in the FPF having 1.24.

Table 4-6 Species diversity index and evenness index of ants in the SERS.

Habitat type	DEF	DDF	FPF	ECO	SSF	PTF	GLF
Shannon's index	2.357	2.369	1.240	2.697	2.370	2.684	2.840
Evenness	0.5965	0.6189	0.3319	0.7043	0.6262	0.6860	0.7086
Species richness	52.0	47.0	42.0	46.0	44.0	50.0	55.0

From the species diversity index, were calculated to evenness, and found that GLF had the highest of evenness of 0.7086, followed by ECO, PTF, SSF, DDF, and DEF was 0.7043, 0.6860, 0.6262, 0.6189, and 0.5965 respectively. The lowest evenness was 0.3319.

It can be clarified that the community within GLF, ECO and PTF were much more diverse than SSF, DDF, DEF and FPF. However value of the index usually lie between 2.3-2.7, thus the Shannon's index of the whole habitat types at the SERS was a high diversity of ant community. In addition, the correlation of diversity and evenness had the same tendency.

As the results, GLF and PTF were higher diversity index than DEF, it can be explained that the overall of ants increased due to the dominance of exotic ants species. Furthermore, Many factors such as soil moisture, depth of litter, density of tree and soil type determine the availability and suitability of nest sites and foraging behavior. These factors consequently affect the diversity of ant in an area. (Greenslade, 1979)

DEF and SSF were closely index of diversity. It can be explained that ecological factors of them were similarity. Because of the original trees of SSF were a DEF which had been destroyed by human, but retain a few large mature trees. Fire protection had been carried out for along time. As such sapling and seeding in the area have drown up to become SSF.

4.7 Similarity index of ant community

From the species number of ants composition in the SERS, they were conducted to calculate for similarity index and compared in each communities by using Bray-Curtis equation and the results showed in Table 4-7.

Table 4-7 Similarity index of ant community of the SERS.

	DEF	DDF	FPF	ECO	SSF	PTF	GLF
DEF	-	-	-	-	-	-	-
DDF	50.60	-	-	-	-	-	-
FPF	51.14	50.96	-	-	-	-	-
ECO	50.82	50.69	58.59	-	-	-	-
SSF	57.30	50.13	48.03	58.07	-	-	-
PTF	52.15	48.60	55.48	44.46	48.37	-	-
GLF	48.66	48.18	64.51	55.00	47.56	54.68	-

As the results, it was found that FPF and GLF shown the highest of similarity index (64.51%) followed by FPF and ECO (58.59%) and ECO and SSF (58.07%) respectively. While ECO-PTF shown the lowest of similarity index (44.46%) including SSF and GLF, SSF and FPF were 47.56% and 48.03% respectively. The results were indicated that the similarity index of ants was moderate similarity. This may caused to the different of ecological factors and habitat structure. (Sonthichai, 2000; Wiwatwitaya, 2001; Parsityousil, 2001)

Similarity index of FPF and GLF was the highest it may be explained that ecological factors of them most similar than the other. In contrast ECO and PTF was the lowest, it can be explained that ecological factors of them were less similar and caused to low similarity index.

The results above, it can be conclude that ecological factors were the main affecting to similarity of ant community. Furthermore, another reason that is relative to similarity of ant community were species and density of trees. Similarity index of DEF and DDF, DEF and FPF, DEF and ECO, DEF and SSF, DEF and PTF were higher than DEF and GLF, it may be caused by cover tree and density of tree. DEF and DDF have dense tree while GLF was dominate by tall grass.

4.8 Cluster analysis of ant community

The results of cluster analysis is shown in Figure 4-15. It can be seen that the dendrogram separated seven habitat types into three groups at 54% of similarity. The first group consisted of DEF,ECO and SSF at 54.07% of similarity. The second group compost of GLF, FPF, and PTF at 55.09% of similarity, while the third group was solely DDF.

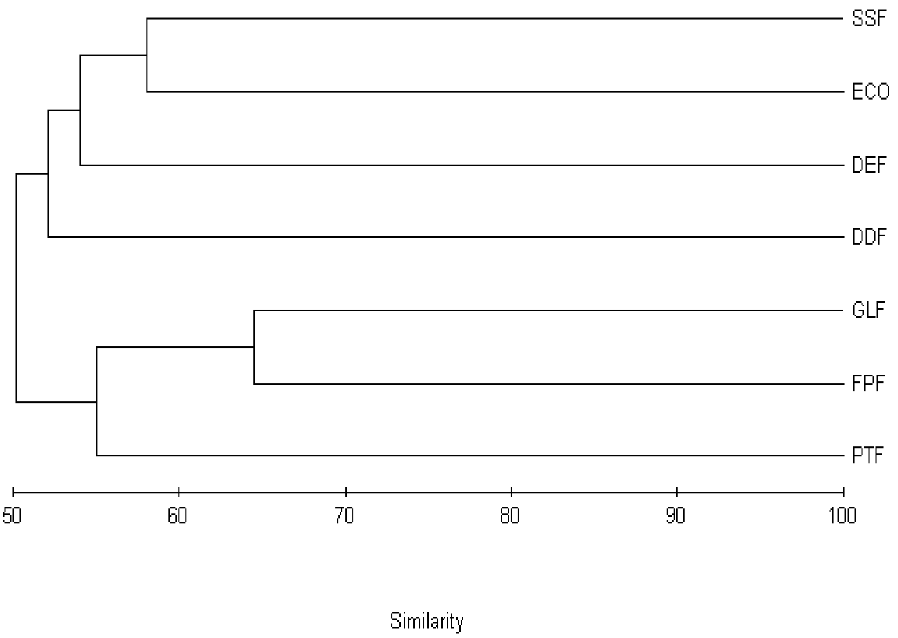


Figure 4-15 Dendrogram for hierarchical clustering of ants in seven habitat types.

Then, the ordination of PCA were analyzed, and the result is shown in dimension ordered. The result indicated that the habitat types were three separate groups (Figure 4-16).

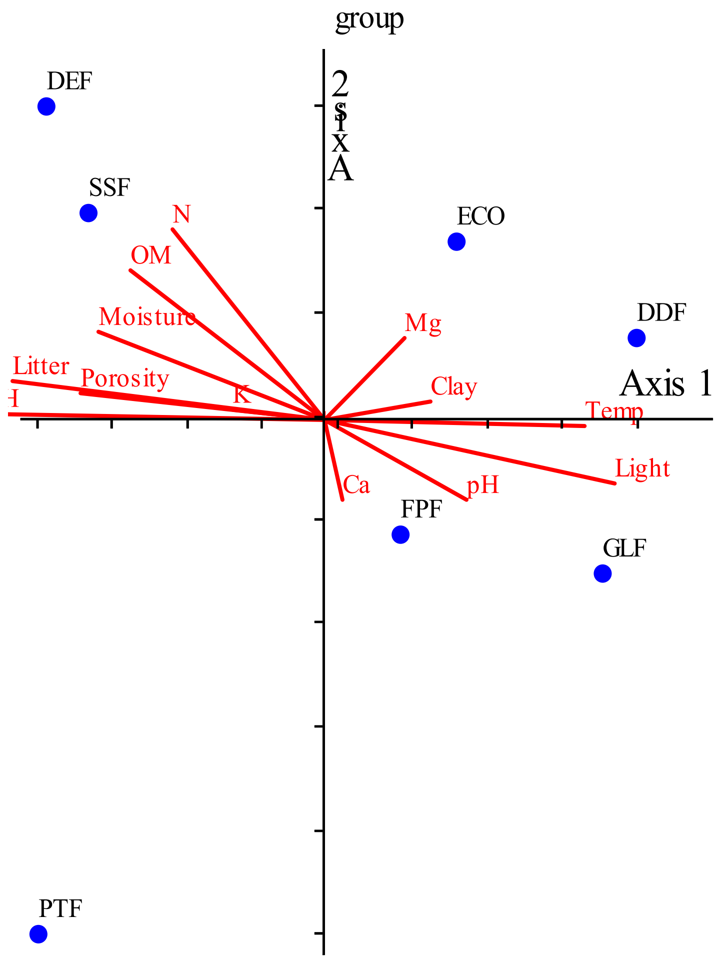


Figure 4-16 PCA ordination of ecological factors

The PCA plot is consistent with the cluster analysis results in showing how the DEF and group of DEF, ECO, GLF, FPF and PTF are separated widely in space, while group of DEF and SSF and group of FPF and GLF from comparatively tight and closely space group.

The output from PCA analysis were also utilized to identify the relationship of ant community and ecological factors. The Pearson and Kendall correlation with ordination axes shown in Table 4-8.

Table 4-8 The Pearson and Kendall correlation with ordination axes.

Axis	1		2		3	
Factors	r	r-sq	r	r-sq	r	r-sq
Temperature	.786	.619	-.187	.035	.332	.110
RH	-.900	.809	.200	.040	-.145	.021
Light intensity	.806	.649	-.464	.216	.263	.069
Porosity	-.751	.564	.313	.098	.007	.000
Bulk density	.247	.061	.259	.067	.307	.094
Sand	-.441	.194	-.185	.034	-.314	.099
Silt	.100	.010	.261	.068	.419	.176
Clay	.528	.279	.173	.030	.269	.072
Soil moisture	-.700	.491	.523	.273	-.319	.102
Organic matter	-.632	.400	.659	.435	-.109	.012
pH	.550	.303	-.487	.237	-.162	.026
Nitrogen	-.546	.299	.729	.532	-.266	.071
Phosphorus	.309	.096	-.275	.076	.482	.232
Potassium	-.460	.212	.199	.040	.377	.142
Calcium	.173	.030	-.458	.210	-.394	.156
Magnesium	.482	.232	.408	.167	-.165	.027
Water content of litter	-.846	.716	.380	.144	-.198	.039

The ordination diagram is shown in Figure 4-17. In can be explained as following.

1) The plots related to temperature are included GLF, ECO and DDF (r = .786 in axis 1 and r = -.187 in axis 2)

2) The plots related to relative humidity are included DEF, SSF and PTF (r = -.900 in axis 1 and r = .200 in axis 2)

3) GLF is dominantly related to light intensity, while DDF, ECO and FPF are secondary dominant. The correlation coefficient (r) is .806 in axis 1 and -.464 in axis 2.

4) DEF, ECO, PTF, FPF and SSF are highly related to porosity (r = -.751 in axis 1 and r = .313 in axis 2).

5) The plot dominantly related to clay is ECO, while SSF, DDF, FPF and GLF are secondary dominant. The correlation coefficient (r) is .528 in axis 1 and .342 in axis 2.

6) DEF is dominantly related to soil moisture, while SSF, DDF and FPF are secondary dominant. The correlation coefficient (r) is included -.700 in axis 1 and .523 in axis 2.

7) The plots highly related to organic matter are DEF and SSF (r= -.632 in axis 1 and r = 659 in axis 2)

8) The plots related to pH are included ECO, DDF, FPF, PTF and GLF. The correlation coefficient (r) is .550 in axis 1 and -.487 in axis 2.

9) DEF is dominantly related to nitrogen, while SSF, ECO and DDF are secondary dominant. The correlation coefficient (r) is included -.546 in axis 1 and .729 in axis 2.

10) SSF and GLF are highly related to potassium (r = -.460 in axis 1 and r = .199 in axis 2)

11) PTF, DDF, ECO and FPF are highly related to calcium (r = .173 in axis 1 and r = -.458 in axis 2)

12) ECO, DDF and SSF are highly related to magnesium (r = .482 in axis 1 and r = .408 in axis 2)

13) DEF is highly related to water content of litter (r = -.846 in axis 1 and r = .380 in axis 2)

In addition, the PCA analysis is also provided the diagram of radiating line of joint plot diagram to identify the relationship between ecological factors and species composition. The angle and length of the line indicate the direction and strength of the relationship. Thus, the result of joint plot diagram in Figure 4-17 can be identified plot composition as follows:

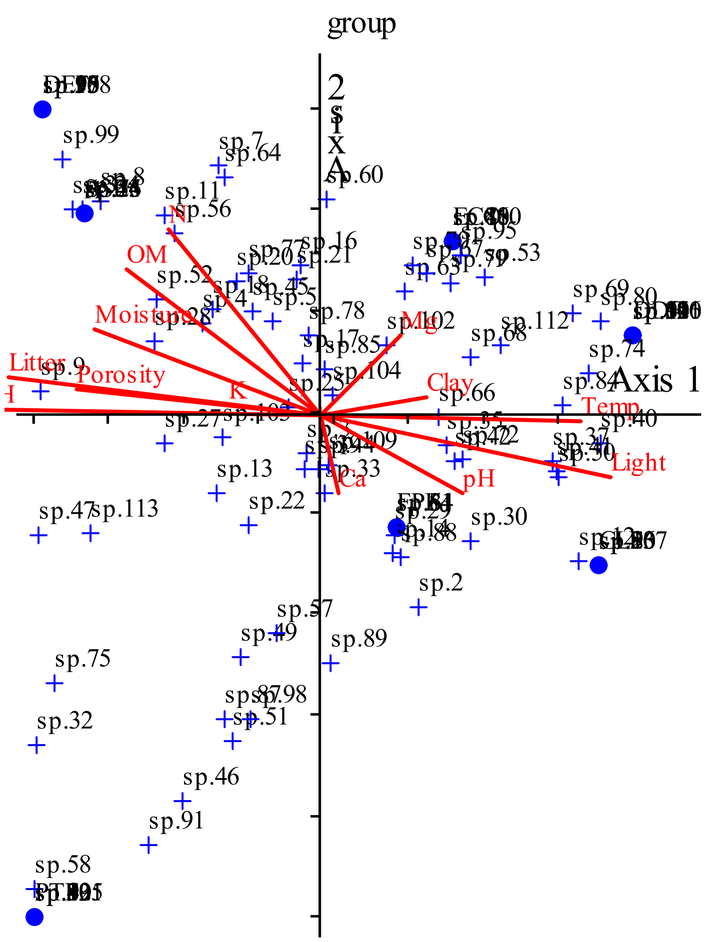


Figure 4-17 The joint plot diagram showing the relationship between a set of ecological factors and ant abundance.

On axis 1, temperature, relative humidity, light intensity, porosity, soil moisture and water content of litter are the most significant factors determining in ant composition, followed by clay, pH, potassium and magnesium. On axis 2, nitrogen is the most significant factors follow by organic matter and calcium.

4.9 Ant indicator for plant community

An indicator value (IV) combines the frequency, abundance and occurrence of a species in a particular habitat types. Am IV ranges from 0 (no fidelity) to 15 (perfect fidelity). The IV of ants were divided into 5 levels as follow;

Highest IV when $12 < IV \leq 15$

High IV when $9 < IV \leq 12$

Moderate IV when $6 < IV \leq 9$

Low IV when $3 < IV \leq 6$

Lowest IV when $0 < IV \leq 3$

In general, the most wide spread species showed little fidelity with respect to habitat types. This applies to *D.rugosum*, *L.diminuta*, *O.denticulata*, *D.thoracicus*, *A.gracilipes*, *Camponotus (Myrmosericus) rufoglaucus*, *P.longicornis* etc., which occurred at most habitat, within each habitat types (Appendix III). There are only 20 ant species that can be found only one habitat and use as indicators as following.

T.allaborans, *Leptogenys* sp.10 of AMK, *M.floricola*, *T.walshi* and *Camponotus (Colobobsis) praeruta* were moderate indicator with indicator value 9,7,7,7,7 respectively indicated DEE.

Crematogaster (Physocrema) inflata was the highest indicator value (15) followed by *P.yeensis* (12), *T.difficilis* (11), *Diacamma* sp.8 of AMK (11) and *Crematogaster (Crematogaster) rogenhoferi* consistently indicated DDF.

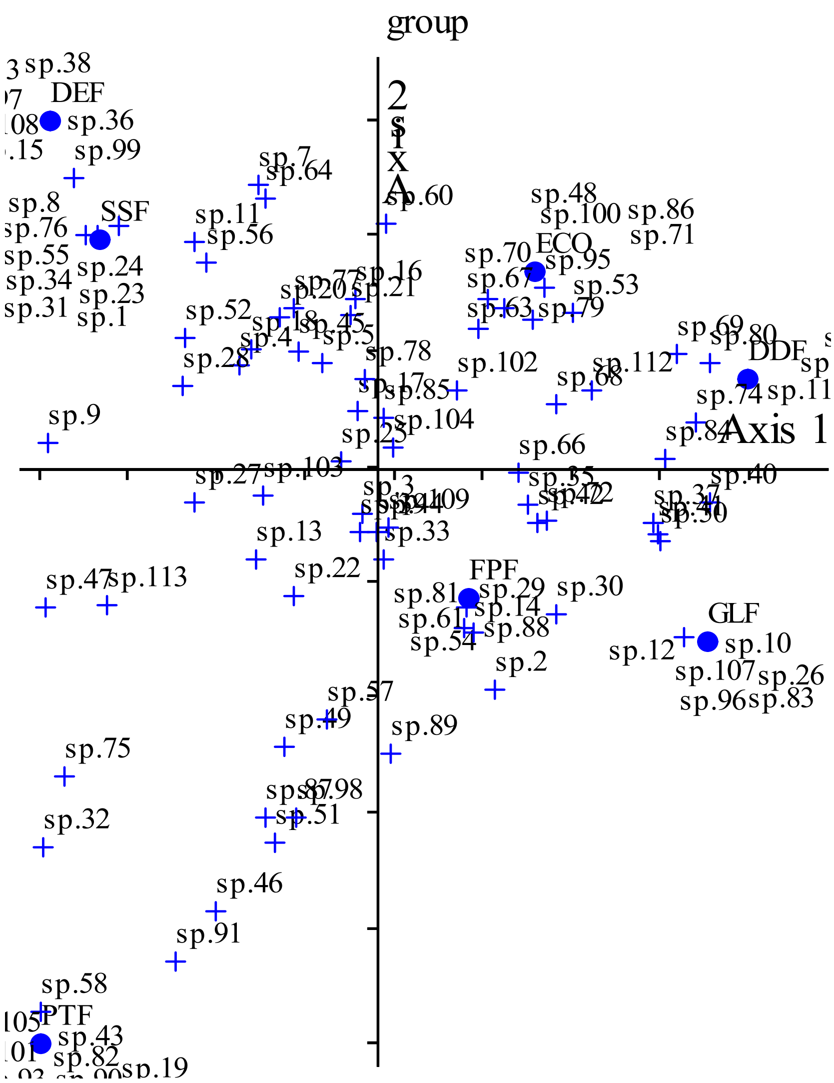


Figure 4-18 PCA ordination of study plots based on the ordination of ant species with corresponds to the habitat types.

M.chinense was the high indicator value (11) for ECO.

P.diversus was the highest indicator value (14) followed by *I.ancep* (9) and *L.kitteli* consistently indicated FPF.

Phillidris sp.1 of AMK was the high indicators value (10), followed by *Pachycondyla (Brachyponera) luteipes* was the moderate indicator value (9) for indicated SSF.

Two species of *Aphenogaster* sp.1 of AMK and *Tetramorium* sp.13 of AMK were moderate indicator value with 9 for PTF.

For GLF, *L.bornensis* was the high indicator (10) followed by *T.smithii* (7) and *Bothriomyrmex* sp.1 of AMK (7) were moderate indicator value.

These results for species indicators were consistent with species ordination patterns from PCA (Figure 4-18)

5. Multiple Regression Analysis

From the abundance of ant composition were employed to become dependent variable to identify the relationship of ecological factors which were the independent variables. The multiple regression analysis was then proceeded. The relation equation were form as follows;

$Y_{A.\ reclinata} = -35.461 + .237\ K$ $\qquad R^2 = .714$

$Y_{D.\ vagans} = -881.946 + 19.682\ Porosity$ $\qquad R^2 = .669$

$Y_{G.\ binghamii} = -100.682 + .474\ K + 8.432\ OM$ $\qquad R^2 = .932$

$Y_{Hypoponera\ sp.1\ of\ AMK} = -241.091 - 2.759\ Clay + 3.772\ Porosity +$

$3.975\ Temp + 0.070\ Mg$ $\qquad R^2 = .999$

$Y_{H.ypoponera\ sp.7\ of\ AMK} = -53.095 + 2.344\ Temp - .058\ Mg$ $\qquad R^2 = .953$

$Y_{L.birmana} = -165.007 + 2.070\ K + 75.661\ OM - 5.130\ RH$ $\qquad R^2 = .972$

$Y_{L.borneensis} = -1131 + 50.256\ Temp - 1.263\ Mg$ $\qquad R^2 = .927$

$Y_{Leptogenys\ sp.10\ of\ AMK} = 523.498 - 77.535\ pH - .676\ K$ $\qquad R^2 = .934$

$Y_{Leptogenys\ sp.16\ of\ AMK} = .883\ K - 4.219\ porosity$ $\qquad R^2 = .957$

$Y_{O.denticulata} = 1067.67 - 208.852\ pH + 1.084\ Mg$ $\qquad R^2 = .981$

$Y_{O.\ rixosus} = -123.934 + 71.227\ OM$ $\qquad R^2 = .589$

$Y_{P.\ birmana} = -30.142 + .201\ K$ $\qquad R^2 = .714$

$Y_{Pachycondyla\ (Brachyponera)\ luteipes}$ = -211.695 + 1.419 K R^2 = .718

$Y_{P.\ parallela}$ = -57.179 + 2.524 Temp - .063 Mg R^2 = .953

$Y_{D.\ thoracicus}$ = 2275.498 – 85.703 Clay R^2 = .815

$Y_{D.\ tuberifera}$ = -2144.541 + 15.439 K R^2 = .781

$Y_{I.\ Ancep}$ = -282.034 + 62.931 pH R^2 = .696

$Y_{Phillidris\ sp.1\ of\ AMK}$ = -893.106 + 4.253 K + 23.53 moisture R^2 = .904

$Y_{Technomyrmex\ sp.2\ of\ AMK}$ = -26.596 + .178 K R^2 = .714

$Y_{A.\ gracilipes}$ = -67.653 + .606 Light intensity R^2 = . 689

$Y_{Camponotus\ (Colobobsis)\ praeruta}$ = 553.242 –81.940 pH - .714 K R^2 = .934

$Y_{Camponotus\ (Colobobsis)\ sp.6\ of\ AMK}$ = -1593.513 + 64.222 Temp R^2 = .926

$Y_{Camponotus\ auriventris}$ = 83.284 –12.335 pH - .107 K R^2 = .934

$Y_{Camponotus\ (myrmosericus)\ rufoglaucus}$ = .166 Ca R^2 = .607

$Y_{Camponotus\ (Myrmembly)\ sp.3\ of\ AMK}$ = 265.153 – 5.059 Porosity R^2 = .868

$Y_{Camponotus\ (Tanaemyrmex)\ sp.1\ of\ AMK}$ = -123.218 + 4.892 Temp R^2 = .815

$Y_{Paratrechina\ sp.5\ of\ AMK}$ = 130.647 –5.552 Clay R^2 = .679

$Y_{Polyrhachis\ (Cyrtomyrma)\ laevissima}$ = -479.980 + 19.040 Temp R^2 = .815

$Y_{Polyrhachis\ (Myrma)\ proxima}$ = -58.543 + .726 Mg R^2 = .765

$Y_{Polyrhachis\ (Campomyrma)\ halidayi}$ = -65.602 + .438 K R^2 = .714

$Y_{Pronolepis\ sp.1\ of\ AMK}$ = 339.214 – 61.559 pH R^2 = .966

$Y_{Pseudolasius\ sp.1\ of\ AMK}$ = 275.075 – 1.134 Mg – 24.162 OM R^2 = .960

$Y_{Crematogaster\ (Paracrema)\ coriaria}$ = 477.883 + 12.504 Clay -.990 RH

+ 8.324 litter R^2 = .997

$Y_{M.\ bicolor}$ = -97.007 + 1.267 Mg R^2 = .811

$Y_{M.\ destructor}$ = -3015.729 + 123.222 Temp R^2 = .817

$Y_{M.\ floricola}$ = 232.005 – 34.362 pH - .229 K R^2 = .934

$Y_{P.\ inornata}$ = -17.730 + .118 K R^2 = .714

$Y_{P.plagiaria}$ = -3176.874 + 17635.512 N R^2 = .729

$Y_{Pheidole\ sp.8\ of\ AMK}$ = -388.000+ 17.126 Temp - .425 Mg R^2 = .953

$Y_{Pheidole\ sp.11\ of\ AMK}$ = 327.776 - .080 Ca – 12.973 OM R^2 = 1.000

– 37.022 pH – 1.649 Moisture

$Y_{T.\ smithii}$ = -159.284 + 7.031 Temp - .175 Mg R^2 = .953

$Y_{T.\ walshi}$ = 350.982 – 51.984 pH - .453 K R^2 = .934

$Y_{Tetramorium\ sp.10\ of\ AMK}$ = -70.303 + 11.543 OM + .198 K R^2 = .959

$Y_{A.\ laeviceps}$ = 283.518 – 10.538 Clay R^2 = .583

$Y_{Bothriomyrmex\ sp.1\ of\ AMK}$ = -1168.084 + 51.559 temp - 1.281 Mg R^2 = .953

$Y_{T.\ allaborans}$ = 588.935 – 87.227 pH - .760 K R^2 = .966

$Y_{T.\ attenuata}$ = 119.549 - .740 Mg R^2 = .624

As the results indicated that ants composition were correlated with 13 ecological factors significantly, and could be explained as follows:

Temperature was positively correlated with *Hypoponera* sp.1 of AMK, *Hypoponera* sp.7 of AMK, *L.borneensis*, *P.parallela*, *Camponotus (Colobobsis*) sp.6 of AMK*, Camponotus (Tanaemyrmex)* sp.1 of AMK*, P.laevissima ,M.destructor, Pheidole* sp.11 of AMK, *T.smithii* and *Bothriomyrmer* sp.1 of AMK whereas negatively correlated with the *Camponotus (Colobobsis) praeruta*.

Light intensity was positively correlated with *Anoplolepis gracilipes*.

Relative humidity was negatively correlated with *Crematogaster (Paracrema) coriaria* and *Leptogenys birmana.*

Porosity was positively correlated with *Hypoponera* sp.1 of AMK and *D.vagans* whereas negatively correlated with *Leptogenys* sp.16 of AMK and *Camponotus (Myrmembly)* sp.3 of AMK.

Clay was positively correlated with *Crematogaster (Paracrema) coriaria* whereas negatively correlated with *Hypoponera* sp.1 of AMK, *D.thoracicus*, *Paratrechina* sp.5 of AMK and *Aenictus laeviceps*.

Soil moisture was positively correlated with *Phillidris* sp.1 of AMK whereas negatively correlated with *Pheidole* sp.11 of AMK.

Organic matter was positively correlated with *Tetramorium* sp.10 of AMK, *O.rixosus*, *L.birmana* and *G.binghamii* whereas negatively correlated with *Psudolasius* sp. 1 of AMK and *Pheidole* sp.11 of AMK.

pH was negatively correlated with *Leptogenys* sp.10 of AMK, *O.Denticulata*, *I.ancep*, *Camponotus (Myrmosaulus) auriventris*, *Pronolepis* sp.1 of AMK, *M.floricola*, *Pheidole* sp.11 of AMK, *T.walshi* and *T.allaborans*.

Nitrogen was positively correlated with *Pheidole plagiaria*.

Potassium was positively correlated with *A.reclinata*, *G.binghamii*, *Hypoponera* sp.11 of AMK, *Leptogenys* sp.16 of AMK, *P.birmana*, *P.luteipes*, *D.tuberifera*, *Phillidris* sp.1 of AMK, *Technomyrmex* sp.2 of AMK, *P.halidayi*. *P.inornara* and *Tetramorium* sp.10 of AMK whereas negatively correlated with *Leptogenys* sp.10 of AMK, *C.praeruta*, *C.auriventris*, *M.floricola*, *T.walshi*, *T.allaborans*.

Calcium was positively correlated with *Camponotus (Myrmosericus) rufoglucus*, whereas negatively correlated with *Pheidole* sp.11 of AMK.

Magnesium was positively correlated with *Hypoponera* sp.1 of AMK, *O.denticulata*, *P.proxima* and *M.bicolor* whereas negatively correlated with *Hypoponera* sp.7 of AMK, *L.borneensis*, *P.parallela*, *Pseudolasius* sp.1 of AMK, *Pheidole* sp.8 of AMK, *T.smithii*, *Bothriomyrmex* sp.1 of AMK and *T.attenuta*.

Water content of litter was positively correlated with *Crematogaster (Paracrema) coriaria*.

As the results multiple regression analysis, the relation for the whole ant community which showed the high values of R^2 (0.589-1.000). This indicated that the ecological factors were clearly correlated to ant community. Potassium was the highest correlated with 18 ants species followed by magnesium (12), temperature (12) and organic matter (9). While light intensity, nitrogen and water content of litter were lowest correlated with 1 ants species.

No direct study of relationship between ecological factors and ant community had been carried out, therefore comparable data are limited. Nonthelesss, an attempt had been made to compare work on the ant community with that carried ant by other indirect study.

The result indicated that temperature and relative humidity was correlate with ant community. Because of the activity of many forest insects are controled by climatic factors such as relative humidity, temperature (Dajoz, 2000). Thus temperature and relative humidity had influenced to ant community. This result support by Holldobler and Wilson (1990) who found that foraging activity in ants and other arthropods is affected by temperature and humidity.

Furthermore, ant activity also depend upon water content of litter. Because of ant composition are higher in the wet period than dry period.

pH had effect on the ant community. It may be indicated that pH had not effect to ant community. This finding is support by Curry (1994) who found that soil animal in general are not very sensitive to pH and are actively in soil over a wide range of pH. Moreover, pH may act indirect effect by reducing the quality and range of food resource available to ant.

Nitrogen, Potassium and Magnesium are correlated to ant community. Because of ants act as ecosystem engineers in the soil system. They play a significant role in soil processes by altering the physical and chemical environment and affecting plant and soil organisms (Folgarait, 1998). Most study have shown affect of ant species on anthill soil in comparison to adjacent area influence. Some ant species *Formica fusca* have effect to increase calcium and phosphorus, and decrease in potassium (Levan and Stone, 1983). *Pogonomyrmex rugosus* have effect to increase nitrogen, phosphorus and potassium (Carlson and Whitford, 1991). *Atta laevigata* have effect to increase nitrogen, calcium and magnesium (Farji Brener and Silva, 1995). Thus, this results imply that nitrogen, potassium and magnesium might be correlated with ant community.

CHAPTER V

CONCLUSION

1. Conclusion

1.1 Climatic factors comprising temperature, relative humidity and light intensity tend to vary in parallel, related to the presence and properties of the plant cover. The major soil texture was sandy loam, the minor was sandy clay loam. GLF had the highest bulk density, whereas DEF had the highest porosity. Soils from both habitat types were found to be acidic. Organic matter nitrogen calcium and water content of litter at DEF were higher concentrations, whereas pH and magnesium were lower. Total phosphorus were least different. Calcium were highest in the PTF while magnesium was lowest. Eco had the highest in pH and magnesium content.

1.2 At least 7 subfamilies, 42 genera, 113 ant species were collected and identified. Myrmicinae was the greatest genera (14), followes by Ponerinae (10) and Formicinae (9). The genus *Pheidole* has the highest number of speciec (11), folloewd by the genus *Tetramorium*, *Leptogenys*, *Crematogaster*, and *Camponotus* which has 9, 9, 8 and 7 species respectively.

1.3 The presence number of ants was the highest in PTF, while FPF had the lowest. The most abundance species was *Pheidole plagiaria*, followed by *Pheidologeton diversus, Dolichoderus thoracicus*, *Anoplolepis gracilipes* and *Dolichoderus tuberiferi*. Whereas the lowest was *Aenictus platifrons*.

1.4 *T.allaborans, Leptogenys* sp.10 of AMK, *M.Floricola, T.walshi* and *Camponotus (Colobobsis) praeruta* were moderate indicators in dry evergreen forest. *Crematogaster (Physocrema) inflata, P.yeensis, T.difficilis, Diacamma* sp.8 of AMK and *Crematogaster (Crematogaster) rogenhoferi* consistently indicated dry dipterocap forest. *M.chinense* was the indicator in ecotone. *P.diversus, I.ancep* and *L.kitteli* were indicators in fire protected forest. *Phillidris* sp.1 of AMK, *Pachycondyla (Brachyponera) luteipes* were indicators in secondary succession forest. *Aphenogaster* sp.1 of AMK and *Tetramorium* sp.13 of AMK were indicator in plantation forest. For grassland forest, *L.bornensis, T.smithii* and *Bothiriomyrmex* sp.1 of AMK were indicator.

1.5 Species richness, species diversity and evenness were found the highest at GLF, while FPF were the lowest.

1.6 The community structure of ants in the SERS was influenced by relative humidity, light intensity, temperature, porosity, soil moisture, water content of litter, clay, organic matter, pH, nitrogen, potassium, calcium and magnesium.

2 Recommendation

2.1 For this study, the collection of ant data were carried out for only 1 year. For obtaining the clarify and reliable results, further studies should be observed and collected data more than 1 year.

2.2 Some ant species, such as *Dolichoderus thoracicus*, *Crematogaster (Physocrema) inflata*, *Anoploltpis gracilipes* and *Leptogenys diminuta* have high potential to be an indicator species of the forest. Further studies should be focused on the autecology of them in order to understand the role of ant in soil functioning.

2.3 A combination of pitfalls, litter sifting, baiting and hand sorting increase the efficiency of species captures in comparison to any single method by itself. Therefor further studies should to use several methods of collect so that the reliability significant results could be obtained.

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Appendix A

Table 1 Surface soil properties in dry evergreen forest of SERS

month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.17	55.84	52.10	26.50	21.35	Sandy loam	12.42	5.17	5.49	0.2915	4.00	235.00	901.00	311.00
Feb	1.06	60.00	58.20	32.27	9.63	Sandy loam	8.54	4.08	5.81	0.3215	10.00	175.00	173.00	58.00
Mar	1.19	55.09	49.30	25.82	26.43	Sandy clay loam	9.12	4.27	4.48	0.2395	4.00	120.00	173.00	81.00
Apr	1.20	54.71	51.00	24.27	27.83	Sandy clay loam	13.32	4.82	4.79	0.2810	22.00	180.00	192.00	81.00
May	1.28	51.69	61.37	17.73	22.45	Sandy clay loam	17.79	3.99	5.50	0.2710	5.00	130.00	173.00	58.00
Jun	1.20	54.71	54.00	20.23	16.59	Sandy loam	16.61	4.23	6.71	0.1900	5.00	200.00	249.00	35.00
Jul	1.25	52.83	61.42	25.18	13.42	Sandy loam	20.30	3.86	6.31	0.3660	6.00	170.00	211.00	23.00
Aug	1.16	56.22	65.27	15.60	20.43	Sandy clay loam	23.30	4.40	8.22	0.2745	6.00	140.00	288.00	35.00
Sep	1.24	53.20	59.44	17.67	21.35	Sandy clay loam	24.10	4.03	7.26	0.2020	4.00	145.00	153.00	12.00
Oct	1.18	55.47	61.32	17.93	22.86	Sandy clay loam	20.26	4.37	6.69	0.3350	4.00	140.00	268.00	58.00
Nov	1.29	51.32	59.85	21.12	20.33	Sandy clay loam	16.25	4.16	6.38	0.1780	4.00	130.00	173.00	46.00
Dec	1.48	44.15	51.31	26.97	23.72	Sandy clay loam	12.68	4.24	5.39	0.1540	4.00	135.00	288.00	46.00
Mean	1.22	53.72	65.79	22.11	13.48	-	16.22	4.30	6.08	0.2586	6.50	158.33	270.16	70.33
SD.	0.10	3.79	6.42	6.26	7.20	-	5.15	0.36	1.05	0.06	5.17	34.33	204.52	78.58

Table 2 Surface soil properties in dry dipterocarp forest of SERS

month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.28	51.69	57.20	21.35	22.78	Sandy loam	7.82	6.01	5.67	0.2835	6.00	180.00	1074.00	156.00
Feb	1.42	46.41	59.34	22.33	18.33	Sandy loam	5.79	4.95	4.11	0.2055	4.00	90.00	870.00	144.00
Mar	1.53	42.26	69.78	17.72	14.82	Sandy loam	6.52	5.80	3.14	0.1570	4.00	125.00	463.00	100.00
Apr	1.43	46.03	67.54	16.67	17.65	Sandy loam	7.61	6.09	3.47	0.1735	5.00	120.00	500.00	100.00
May	1.60	39.62	66.50	18.41	16.21	Sandy loam	10.25	5.32	4.91	0.2455	5.00	135.00	907.00	200.00
Jun	1.24	53.20	72.61	11.48	17.40	Sandy loam	12.93	5.67	4.66	0.2330	5.00	125.00	537.00	133.00
Jul	1.49	43.77	59.82	20.32	21.00	Sandy loam	15.82	5.40	3.38	0.1690	4.00	95.00	741.00	133.00
Aug	1.33	49.81	64.50	21.49	14.90	Sandy loam	17.79	5.03	3.32	0.1660	13.00	135.00	296.00	122.00
Sep	1.23	53.58	55.71	35.31	10.80	Sandy loam	17.24	5.51	4.29	0.2145	4.00	140.00	1000.00	211.00
Oct	1.34	49.43	73.90	25.70	2.72	Sandy loam	14.36	5.55	4.26	0.2130	5.00	165.00	667.00	211.00
Nov	1.41	46.79	69.35	29.62	2.45	Sandy loam	11.32	4.95	4.06	0.2030	4.00	115.00	870.00	89.00
Dec	1.32	50.18	73.27	25.00	2.71	Sandy loam	9.26	6.20	5.96	0.2980	5.00	145.00	630.00	211.00
Mean	1.38	47.73	57.04	22.61	20.53	-	11.39	5.54	3.63	0.2134	5.33	130.58	712.91	150.83
SD.	0.117	4.368	5.238	4.990	5.166	-	4.199	0.433	0.365	0.453	2.498	25.39	237.820	46.524

Table 3 Surface soil properties in fire protected forest of SERS

month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.27	52.07	70.35	21.00	9.75	Sandy loam	10.94	6.31	3.19	0.1800	11.00	230.00	786.00	115.00
Feb	1.32	50.18	61.57	21.40	18.83	Sandy loam	5.03	5.70	4.57	0.2035	2.00	90.00	403.00	46.00
Mar	1.17	55.84	74.73	14.36	12.19	Sandy loam	7.70	5.68	5.74	0.1870	9.00	105.00	613.00	35.00
Apr	1.26	52.45	68.24	14.72	18.60	Sandy loam	9.16	5.19	3.20	0.2278	3.00	255.00	843.00	219.00
May	1.19	55.09	65.49	15.50	20.00	Sandy clay loam	10.94	5.50	3.57	0.1330	10.00	150.00	173.00	184.00
Jun	1.24	53.20	55.00	17.70	28.65	Sandy clay loam	13.36	5.33	2.89	0.3820	12.00	120.00	1150.00	265.00
Jul	1.49	43.77	43.25	37.55	19.28	Loam	15.46	5.30	4.32	0.1635	6.00	115.00	403.00	46.00
Aug	1.37	48.30	41.61	44.63	13.84	Loam	18.28	5.14	4.83	0.0925	2.00	145.00	153.00	127.00
Sep	1.27	52.07	39.60	32.00	28.45	Clay loam	18.90	5.98	5.64	0.2070	6.00	100.00	594.00	104.00
Oct	1.34	49.43	32.27	34.91	34.50	Clay loam	15.61	5.39	5.31	0.1635	6.00	95.00	556.00	12.00
Nov	1.37	48.30	49.68	21.42	29.25	Sandy clay loam	11.25	5.49	3.62	0.1665	3.00	140.00	307.00	81.00
Dec	1.29	51.32	45.22	25.60	29.20	Sandy clay loam	10.90	5.15	3.24	0.2675	3.00	110.00	1418.00	196.00
Mean	1.29	51.00	53.91	25.06	21.87	-	12.29	5.51	4.17	0.1978	6.08	137.91	616.58	119.16
SD.	0.087	3.295	13.929	9.975	7.932	-	4.178	0.354	1.027	0.073	3.620	52.805	382.541	81.118

Table 4 Surface soil properties in ecotone forest of SERS

month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	Texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.35	49.05	68.00	26.29	15.85	Sandy loam	6.53	6.30	2.06	0.2250	6.00	155.00	863.00	173.00
Feb	1.23	53.58	59.62	21.43	19.00	Sandy loam	3.65	6.31	3.36	0.1860	7.00	180.00	1093.00	207.00
Mar	1.42	46.41	67.41	17.41	15.29	Sandy loam	3.57	5.94	3.24	0.2485	5.00	205.00	920.00	345.00
Apr	1.13	57.35	27.68	45.40	27.00	Clay loam	6.55	5.72	3.78	0.2810	6.00	245.00	958.00	207.00
May	1.20	54.71	38.05	25.40	36.65	Clay loam	11.93	6.01	3.48	0.3750	10.00	250.00	1418.00	414.00
Jun	1.29	51.32	27.67	45.48	27.05	Clay loam	12.16	5.43	3.61	0.2440	11.00	140.00	652.00	127.00
Jul	1.28	51.69	35.00	33.23	31.81	Clay loam	14.36	5.41	3.49	0.1365	4.00	135.00	326.00	69.00
Aug	1.24	53.20	40.25	30.45	29.47	Clay loam	18.70	4.80	3.51	0.2205	4.00	80.00	345.00	12.00
Sep	1.23	53.58	37.20	32.44	30.40	Clay loam	17.79	5.09	3.26	0.2780	5.00	115.00	748.00	207.00
Oct	1.15	56.60	33.00	28.22	38.81	Clay loam	16.45	5.14	3.44	0.2710	6.00	145.00	748.00	92.00
Nov	1.38	47.92	47.65	22.23	30.27	Sandy clay loam	9.08	5.74	3.50	0.0815	2.00	105.00	633.00	115.00
Dec	1.34	49.43	45.68	27.47	27.36	Sandy clay loam	6.60	5.11	3.89	0.1570	6.00	130.00	326.00	184.00
Mean	1.27	52.07	43.93	29.62	27.41	-	10.61	5.58	3.38	0.2253	6.00	157.08	752.50	179.33
SD.	0.090	3.401	14.189	8.678	7.432	-	5.384	0.497	0.457	0.077	2.486	53.319	329.684	112.634

Table 5 Surface soil properties in secondary succession forest of SERS

Month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.18	55.47	49.62	26.38	24.50	Sandy loam	10.38	4.56	3.65	0.1980	3.00	160.00	222.00	67.00
Feb	1.10	58.49	51.29	29,73	20.15	Sandy loam	6.23	4.64	4.29	0.3350	6.00	205.00	315.00	178.00
Mar	1.23	53.58	49.85	25.34	26.72	Sandy clay loam	8.98	4.58	5.55	0.2600	2.00	150.00	389.00	200.00
Apr	1.29	51.32	69.64	19.82	16.41	Sandy loam	11.24	4.33	6.40	0.1810	4.00	220.00	56.00	122.00
May	1.60	39.62	47.29	21.37	32.85	Sandy clay loam	15.62	4.49	4.57	0.3450	4.00	210.00	500.00	156.00
Jun	1.26	52.45	49.05	24.90	27.59	Sandy clay loam	13.81	6.41	5.05	0.2710	13.00	250.00	1111.00	111.00
Jul	1.29	51.32	56.72	24.35	20.27	Sandy clay loam	17.28	5.08	6.64	0.2000	2.00	455.00	963.00	200.00
Aug	1.17	55.84	51.00	24.80	27.21	Sandy clay loam	20.58	4.97	6.92	0.1845	3.00	190.00	611.00	144.00
Sep	1.37	48.30	37.34	42.48	20.50	Loam	20.24	4.72	8.95	0.1965	4.00	235.00	167.00	144.00
Oct	1.47	44.52	47.81	32.65	19.66	Loam	20.79	4.72	3.20	0.2120	4.00	225.00	278.00	22.00
Nov	1.25	52,83	58.25	29.15	13.91	Sandy loam	12.20	4.72	4.70	0.2035	2.00	125.00	259.00	89.00
Dec	1.32	50.18	59.74	19.43	22.50	Sandy loam	11.56	5.41	3.45	0.2055	2.00	135.00	778.00	189.00
Mean	1.29	51.16	52.30	26.70	22.68	-	14.07	4.88	5.32	0.2326	4.08	213.33	470.75	135.16
SD.	0.136	5.143	8.014	6.342	5.308	-	4.835	0.560	1.672	0.057	3.058	86.243	331.147	

Table 6 Surface soil properties in plantation forest of SERS

Month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.28	51.69	58.45	21.90	19.75	Sandy loam	8.81	5.14	3.47	0.0995	3.00	140.00	307.00	23.00
Feb	1.43	46.03	43.63	33.45	23.00	Loam	4.40	5.30	3.32	0.3350	6.00	135.00	1227.00	138.00
Mar	1.25	52.83	66.00	18.00	16.00	Sandy loam	5.18	6.55	3.46	0.1970	13.00	195.00	1418.00	35.00
Apr	1.32	50.18	83.00	9.38	7.65	Sandy loam	8.01	5.22	3.23	0.1870	13.00	110.00	479.00	12.00
May	1.17	55.84	37.17	37.69	25.62	Loam	10.69	4.30	3.51	0.1870	2.00	130.00	192.00	23.00
Jun	1.23	53.58	59.10	21.62	20.43	Sandy loam	14.15	4.81	3.45	0.2140	15.00	165.00	211.00	35.00
Jul	1.19	55.09	74.00	20.17	5.90	Sandy loam	18.90	4.44	3.48	0.1700	2.00	140.00	249.00	35.00
Aug	1.24	53.20	48.00	25.65	26.49	Sandy clay loam	18.53	4.78	3.64	0.1600	3.00	110.00	211.00	161.00
Sep	1.30	50.94	58.28	32.28	9.65	Sandy loam	20.03	5.14	3.81	0.2305	3.00	205.00	594.00	35.00
Oct	1.22	53.96	68.05	26.27	15.87	Sandy loam	14.01	6.45	3.56	0.2240	3.00	190.00	1898.00	58.00
Nov	1.23	53.58	69.45	17.47	13.21	Sandy loam	10.25	6.25	3.64	0.2340	4.00	205.00	1246.00	219.00
Dec	1.44	45.66	76.28	15.00	8.85	Sandy loam	9.81	5.76	3.76	0.2510	3.00	215.00	1208.00	69.00
Mean	1.27	51.88	61.78	23.24	16.03	-	11.89	5.34	3.52	0.2074	5.83	161.66	770.00	70.25
SD.	0.085	3.239	13.755	8.226	7.111	-	5.250	0.755	0.167	0.057	4.858	38.749	593.91	66.011

Table 7 Surface soil properties in grassland forest of SERS

Month	Bulk density (g/cm^3)	Porosity (%)	Sand (%)	Silt (%)	Clay (%)	texture	Soil moisture (%)	pH	OM (%)	N (%)	P (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)
Jan	1.27	52.07	45.90	25.90	28.25	Sandy clay loam	2.82	4.75	2.81	0.1255	5.00	125.00	249.00	46.00
Feb	1.32	50.18	49.00	24.00	27.00	Sandy clay loam	2.94	5.66	1.78	0.1265	6.00	130.00	537.00	138.00
Mar	1.39	47.54	59.15	21.65	20.43	Sandy loam	2.51	5.28	1.97	0.1455	6.00	145.00	383.00	23.00
Apr	1.51	43.01	54.67	25.78	19.69	Sandy clay loam	5.33	5.59	3.58	0.2305	9.00	265.00	690.00	92.00
May	1.48	44.15	51.38	24.61	24.78	Sandy clay loam	5.26	5.19	3.12	0.2315	19.00	215.00	556.00	161.00
Jun	1.37	48.30	48.31	22.66	29.52	Sandy clay loam	8.65	4.81	2.54	0.0850	10.00	150.00	115.00	92.00
Jul	1.54	41.88	58.91	25.37	18.37	Sandy loam	7.16	5.35	2.85	0.1770	5.00	160.00	345.00	58.00
Aug	1.76	33.58	58.25	32.25	9.62	Sandy loam	9.26	5.59	2.98	0.2070	4.00	255.00	728.00	138.00
Sep	1.62	38.86	54.47	25.25	20.49	Sandy loam	13.81	4.48	3.65	0.2205	6.00	190.00	249.00	23.00
Oct	1.37	48.30	76.26	14.00	9.81	Sandy loam	12.68	4.52	3.50	0.1600	5.00	130.00	134.00	12.00
Nov	1.28	51.69	67.45	17.48	15.25	Sandy loam	8.61	4.76	2.08	0.1800	7.00	170.00	192.00	69.00
Dec	1.36	48.67	59.63	21.47	19.00	Sandy loam	5.87	5.18	3.12	0.1870	6.00	140.00	288.00	83.00
Mean	1.43	45.68	56.94	23.36	20.18	-	7.07	5.09	2.83	0.1730	7.33	172.91	372.16	77.91
SD.	0.147	5.560	8.544	4.573	6.526	-	3.695	0.420	0.629	0.046	4.052	48.451	209.370	49.005

Appendix B

Table 1 Distribution of ants in DEF across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Diacamma sculpturatum	1	0	7	0	0	1	0	9	17	11	24	1
Diacamma rugosum	11	0	3	5	0	0	1	13	29	24	37	1
Diacamma vagans	3	1	0	0	1	7	26	10	35	59	37	10
Diacamma sp.11 of AMK	1	1	0	0	0	3	14	7	11	27	9	0
Gnamptogenys binghami	1	0	0	0	1	0	0	0	0	19	0	0
Hypoponera sp.1 of AMK	2	0	0	3	0	0	0	4	0	0	0	17
Leptogenys birmana	4	1	0	0	4	0	0	1	77	50	23	-
Leptogenys diminuta	0	0	12	0	0	0	0	75	31	52	12	10
Leptogenys sp.10 of AMK	3	0	0	0	9	0	0	20	7	33	10	6
Leptogenys sp.15 of AMK	51	0	0	0	32	0	0	0	4	0	0	0
Leptogenys sp.21 of AMK	0	0	0	0	20	0	0	0	0	0	13	0
Odontoponera denticulata	51	15	5	0	1	9	6	3	99	27	31	4
Odontomachus rixosus	63	0	54	0	0	0	29	0	82	25	16	59
Pachycondyla astuta	0	1	0	0	0	1	1	0	1	5	19	4
Pachycondyla (Brachyponera) luteipes	1	0	0	0	0	0	1	0	0	1	1	0
Pachycondyla leeuwenhoveki	0	2	0	0	1	2	0	0	4	1	2	0

Table 1 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dolichoderinae												
Dolichoderus thoracicus	3	59	216	1	2	215	321	101	2	58	41	153
Dolichoderus tuberifera	4	0	32	0	0	0	0	21	70	106	108	9
Philidris sp.1 of AMKUFF	5	9	43	0	0	0	0	1	28	16	4	23
Technomyrmex kraepelini	2	0	1	0	0	0	0	0	3	1	3	0
Formicinae												
Anoplolepis gracilipes	10	0	79	4	21	0	3	5	0	4	57	1
Camponotus (Colobopsis praeruta	0	0	0	0	2	0	0	13	7	27	34	10
Camponotus(Myrmosaulus) auriventris	2	0	0	0	0	0	0	0	3	1	3	5
Camponotus (Myrmosericus) rufoglaucus	1	1	9	5	1	0	0	1	7	3	5	1
Camponotus (Tanaemyrmex) sp.7 of AMK	1	0	0	0	0	0	7	0	12	1	1	3
Paratrechina longicornis	8	0	3	0	0	0	0	0	43	19	24	11
Paratrechina sp.5 of AMK	5	3	0	1	1	0	47	0	1	0	1	0
Plagiolepis sp.1of AMK	0	0	7	0	0	0	0	19	6	1	13	2
Polyrhachis (Myrma) illaudata	4	0	1	0	1	0	31	5	2	49	17	9

Table 1 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Psedolasius sp.1 of AMK	7	0	15	0	0	6	0	0	9	0	5	3
Pronolepis sp.1 of AMK	0	0	15	0	0	11	0	21	17	9	0	3
Myrmicinae												
Aphenogaster sp.1 of AMK	0	1	0	0	0	0	2	0	1	0	0	2
Cardiocondyla emeryi	0	0	4	0	0	0	2	1	5	0	3	6
Crematogaster (Crematogaster) sp.1 of AMK	10	0	4	0	0	8	15	3	0	29	38	10
Crematogaster (Crematogaster) sp.2 of AMK	60	0	0	0	0	0	10	42	0	39	21	83
Crematogaster (Crematogaster) sp.9 of AMK	0	4	0	0	0	0	0	0	7	3	1	0
Crematogaster (Physocrema) inflata	0	2	0	0	28	0	17	0	0	34	12	0
Monomorium destructor	1	0	0	0	0	5	0	0	3	8	14	9
Monomorium floricola	0	3	0	3	3	0	0	0	8	14	5	3
Myrmicaria sp.3 of AMK	0	0	0	0	0	3	1	0	5	0	25	6
Pheidole plagiaria	95	0	219	4	107	0	29	118	122	88	90	862
Pheidole tandjogensis	5	0	0	0	3	0	0	0	43	5	67	28

Table 1 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pheidole sp.11 of AMKUFF	0	0	8	0	0	0	0	5	0	9	17	3
Pheidologeton affinis	4	0	0	0	0	25	0	31	29	7	15	0
Pheidologeton diversus	0	0	0	0	0	0	3	0	5	9	3	0
Tetramorium walshi	0	0	1	0	0	0	8	16	0	23	7	4
Tetramorium sp.10 of AMKUFF	0	0	2	0	0	0	19	0	5	7	0	1
Aenictinae												
Aenictus binghami	5	0	0	0	13	8	0	0	19	27	34	11
Aenictus ceylonicus	0	0	0	0	21	0	0	0	1	49	83	0
Aenictus laeviceps	0	0	0	0	0	0	37	0	0	124	0	0
Pseudomyrmecinae												
Tetraponera allaborans	4	0	0	0	7	3	3	19	4	57	2	0
Tetraponera attenuata	3	0	0	0	5	5	1	0	28	7	19	6
Total	427	103	740	26	280	312	634	570	892	1168	1006	1379

Table 2 Distribution of ants in DDF across months. Data are number of ants records in litter shifting.

Species	months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Anochetus sp.8 of AMK	20	0	0	0	8	11	0	1	6	34	43	12
Diacamma rugosum	2	0	0	1	0	10	2	17	14	2	3	11
Diacamma vagans	14	1	0	0	1	9	17	10	8	11	7	9
Diacamma sp.8 of AMK	1	1	0	4	2	24	15	6	2	23	1	0
Diacamma sculpturatum	3	0	0	5	0	3	2	1	1	0	0	1
Leptogenys diminuta	13	0	7	0	73	0	17	34	16	29	2	10
Leptogenys sp.15 of AMK	1	1	1	3	0	0	1	0	0	6	4	2
Odontomachus rixosus	15	0	0	0	2	0	21	10	24	19	43	27
Odontoponera denticulata	0	2	1	0	12	20	2	5	1	17	9	4
Pachycondyla leeuwenhoeki	3	2	7	0	0	0	4	0	1	1	3	0
Dolichoderinae												
Dolichoderus thoracicus	0	1	0	22	0	211	0	27	0	78	0	35
Dolichoderus tuberifera	13	0	6	0	12	0	23	17	29	41	9	1
Iridomyrmex anceps	7	4	1	0	2	0	1	1	9	5	0	34
Technomyrmex kraepelini	0	1	0	0	0	0	3	0	1	7	3	1
Anoplolepis gracilipes	11	0	3	0	160	38	42	23	49	32	57	18

Table 2 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Formicinae												
Camponotus (Myrmosericus)rufoglaucus	20	0	12	31	16	1	10	0	1	8	10	8
Camponotus (Myrmembly) sp.3 of AMK	3	1	0	1	0	2	2	7	1	3	7	1
Camponotus (Colobobsis) sp.6 of AMK	1	13	0	17	0	2	26	0	16	29	14	10
Camponotus (Tanaemyrmex) sp.7 of AMK	1	2	0	4	0	21	7	23	20	41	38	4
Oecophylla smaragdina	0	4	8	0	0	12	0	23	34	16	17	1
Paratrechina longicornis	3	5	1	1	0	1	0	10	15	9	13	4
Paratrechina sp.2 of AMK	1	0	1	0	1	3	0	7	4	3	1	1
Plagiolepis sp.1 of AMK	10	0	0	0	1	5	0	1	1	2	7	3
Polyrhachis (Myrma) proxima	1	4	1	0	0	2	7	15	27	2	10	5
Myrmicinae												
Cataulacus granulatus	0	0	1	0	2	1	1	0	0	0	2	0
Crematogaster (Crematogaster rogenhoferii	10	0	14	5	21	0	7	4	12	29	10	17

Table 2 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crematogaster (Paracrema)coriaria	15	0	0	6	0	1	9	5	37	2	27	13
Crematogaster (Physocrema)inflata	52	0	82	68	83	93	158	0	224	145	98	60
Crematogaster (Crematogaster) sp.3 of AMKUFF	10	0	0	0	4	1	9	17	42	17	23	37
Crematogaster (Crematogaster) sp.1 of AMK	5	0	3	12	0	0	18	17	0	25	17	13
Crematogaster (Crematogaster) sp.2 of AMK	0	0	0	0	0	0	0	0	35	20	31	27
Meranoplus bicolor	5	0	0	10	1	0	13	20	12	31	6	21
Monomorium destructor	30	0	0	0	5	0	11	4	9	3	17	1
Monomorium pharaonis	3	1	5	0	0	1	0	9	11	19	21	5
Pheidole plagiaria	15	49	0	24	0	0	23	9	61	57	291	374
Pheidole tandjojensis	0	0	0	0	134	0	25	17	20	34	28	47
Pheidole sp.9 of AMK	0	0	0	5	5	22	0	37	21	29	18	10
Pheidole yeensis	10	5	120	0	0	5	9	3	14	20	38	24
Pheidologaton affinis	2	0	0	0	27	21	10	15	26	17	1	8
Pheidologaton diversus	4	7	1	0	1	0	7	15	24	38	11	10
Strumigenys sp.1 of AMK	1	0	1	2	1	0	0	0	4	0	1	0

Table 2 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tetramorium ciliatum	2	0	0	2	0	0	0	1	7	1	1	3
Aenictinae												
Aenictus ceylonicus	27	12	7	23	0	21	0	6	10	0	73	0
Aenictus laeviceps	10	3	2	0	0	33	0	27	13	29	12	5
Aenictus sp.13 of AMK	3	0	0	0	0	0	0	0	0	1	1	0
Pseudomyrmecinae												
Tetraponera difficilis	7	0	0	1	9	23	6	29	14	17	24	10
Tetraponera ruflonigra	2	3	2	0	0	1	1	5	0	3	3	1
Total	356	122	287	247	583	598	509	482	887	955	1055	888

Table 3 Distribution of ants in FPF across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Diacamma rugosum	8	0	0	2	20	11	8	19	16	25	34	8
Diacamma vagans	4	0	18	0	13	7	28	11	9	15	27	10
Leptogenys borneensis	1	0	3	0	2	0	5	1	9	4	1	6
Leptogenys diminuta	42	0	10	0	55	9	41	28	26	127	52	29
Leptogenys kitteli	0	0	5	110	53	23	16	10	0	5	9	96
Leptogenys sp.15 of AMK	5	0	0	0	0	9	0	21	10	34	19	0
Leptogenys sp.21 of AMK	0	1	0	8	0	3	0	0	10	17	3	0
Odontomachus rixosus	5	1	3	3	18	9	27	0	25	18	10	75
Odontoponera denticulata	0	0	1	5	5	1	14	2	2	1	0	0
Pachycondyla astuta	4	0	1	1	1	0	1	28	14	43	10	8
Dolichoderinae												
Dolichoderus thoracicus	7	1	0	32	36	1	0	1	0	0	0	0
Iridomyrmex anceps	10	1	0	0	22	5	21	4	17	10	2	0
Ochetellus sp.1 of AMKUFF	0	0	0	0	4	3	1	1	0	0	5	0
Cerapachinae												
Cerapachys sulcinodis	1	0	0	0	7	13	10	5	0	3	0	0

Table 3 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Formicinae												
Anoplolepis gracilipes	66	24	36	49	223	72	7	53	47	34	29	82
Camponotus (Myrmosericus)rufoglaucus	0	17	7	18	2	0	10	1	3	14	27	0
Camponotus (Colobopsis) sp.6 of AMK	6	1	16	-	-	-	-	-	2	-	-	-
Camponotus (Tanaemyrmex) sp.7 of AMK	0	0	14	0	19	0	0	0	4	0	0	28
Oecophylla smaragdina	0	0	13	0	11	0	0	0	16	0	0	0
Paratrechina longicornis	7	0	3	1	10	0	31	0	3	27	10	0
*Plagiolepis sp.*1 of AMK	0	3	0	8	1	0	98	9	0	0	14	0
Polyrhachis (Myrmhopla) dives	3	0	0	3	12	0	6	11	7	15	9	0
Polyrhachis (Myrma) illaudata	1	0	1	2	0	9	0	7	2	0	1	0
Polyrhachis (Myrma) sp.1	1	0	0	0	7	0	1	3	1	1	1	0
Psedolasius sp.1 of AMK	0	0	0	0	3	0	1	8	12	7	4	0
Myrmicinae												
Cardiocondyla nuda	1	0	0	0	2	0	0	3	7	1	3	0

Table 3 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crematogaster (Crematogaster) sp.1 of AMK	4	3	0	0	0	0	0	15	29	10	16	0
Crematogaster (Crematogaster) sp.9 of AMK	2	0	0	0	2	0	10	43	18	10	5	0
Crematogaster (Physocrema) inflata	1	3	0	2	5	0	2	1	1	1	0	0
Crematogaster (Paracrema) coriariaa	1	0	0	2	4	0	25	3	8	13	7	0
Monomorium destructer	10	0	13	0	32	0	27	10	24	13	7	0
Monomorium pharaonis	0	1	0	0	0	0	2	1	1	5	8	0
Pheidole sp.	10	0	4	0	13	0	0	18	7	12	4	0
Pheidole plagiaria	8	0	7	0	10	4	8	24	12	27	41	0
Aenictinae												
Aenictus binghami	4	0	7	5	1	1	0	16	21	8	23	0
Aenictus laeviceps	2	0	0	0	25	0	0	4	3	3	1	0
Pseudomyrmecinae												
Tetraponera attenuata	1	0	0	5	1	4	0	0	4	7	13	0
Total	375	89	202	421	1164	200	416	699	772	679	813	937

Table 4 Distribution of ants in ECO across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Diacamma rugosum	4	0	2	0	0	0	13	21	49	28	34	37
Diacamma sculpturatum	0	25	0	0	13	8	0	9	19	0	5	17
Diacamma vagans	0	0	10	0	0	0	0	53	27	31	46	10
Diacamma sp.11 of AMK	3	0	0	0	25	7	3	1	1	5	10	0
Leptogenys sp.15 of AMK	0	0	58	0	0	0	68	0	0	53	41	28
Leptogenys birmana	3	0	0	3	5	17	0	13	5	1	9	3
Leptogenys diminuta	15	0	0	0	0	0	0	3	6	11	23	19
Leptogenys kitteli	0	0	31	0	0	0	21	38	7	11	26	31
Odontomachus rixosus	13	0	5	11	0	8	13	0	10	69	34	50
Odontoponera denticulata	3	0	1	0	3	5	0	3	40	8	29	16
Pachycondyla astuta	0	0	0	0	7	0	0	6	16	4	17	34
Pachycondyla leewenhoveki	1	0	10	0	0	0	15	8	27	14	23	9
Dolichoderinae												
Dolichoderus thoracicus	2	0	0	1	1	0	0	5	5	16	24	76
Iridomyrmex ancep	3	0	0	0	4	2	3	0	16	13	2	5
Technomyrmex kraepelini	1	0	0	0	0	0	0	14	0	5	17	39

Table 4 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Formicinae												
Anoplolepis gracilipes	26	34	25	12	0	17	43	27	28	59	42	11
Camponotus (Colobopsis) Sp.6 of AMK	0	0	0	11	0	0	0	0	26	31	20	10
Camponotus (Myrmosericus) rufoglaucus	3	28	10	31	4	9	0	11	1	0	1	0
Camponotus (Tanaemyrmex) sp.1 of AMK	0	0	5	0	0	0	0	0	1	2	2	1
Camponotus (Tanaemyrmex) sp.7 of AMK	0	0	12	0	0	0	0	0	7	13	26	4
Cardiocondyla emeryi	3	0	3	1	1	1	15	9	0	4	10	0
Oecophylla smaragdina	0	0	6	0	17	0	8	0	5	0	14	29
Paratrechina longicornis	5	0	0	0	4	1	1	0	29	16	37	2
Paratrechina sp.8 of AMK	1	0	3	3	0	0	17	36	20	29	13	11
Plagiolepis sp.1 of AMK	0	16	0	0	1	0	0	0	2	5	9	5
Polyrhachis leevisima	1	0	0	0	0	0	0	5	5	7	13	8
Polyrhachis (Myrma) illaudata	0	0	3	3	2	0	5	0	5	0	4	3
Polyrhachis (Myrma) proxima	1	0	0	0	0	0	4	33	18	3	12	7

Table 4 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Myrmicinae												
Crematogaster (Crematogaster) sp.1 of AMK	37	0	0	0	0	0	28	51	7	74	43	0
Crematogaster (Crematogaster) sp.9 of AMK	0	0	0	32	0	0	0	23	4	0	41	9
Crematogaster (Orthocrema) sp.1 of AMK	5	0	0	0	11	28	30	38	0	15	29	5
Crematogaster (Paracrema) coriaria	0	0	0	2	0	0	29	17	21	74	43	11
Crematogaster (Physocrema) inflata	8	0	0	0	9	12	4	21	17	5	23	1
Meranoplus bicolor	0	0	0	8	0	0	11	41	0	27	35	1
Monomorium chinense	41	0	0	23	0	67	91	72	134	129	273	59
Monomorium destructer	27	0	0	0	39	0	0	42	37	79	54	21
Pheidole platifrons	0	0	0	0	0	0	0	32	0	241	225	172
Pheidole plagiaria	0	1	0	120	0	24	19	43	170	51	84	32
Pheidole yeensis	1	0	0	0	0	5	0	1	7	0	12	3
Pheidole sp.15 of AMK	0	0	0	0	38	0	0	17	0	29	4	0
Pheidologaton diversus	0	0	32	0	7	0	14	0	23	39	17	0

Table 4 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Tetramorium khererra	1	0	0	9	11	0	10	24	13	21	11	5
Tetramorium sp.12 of AMKUFF	1	0	3	0	1	1	0	0	34	21	19	0
Aenictinae												
Aenictus ceylonicus	1	0	0	5	1	1	1	0	21	16	11	0
Aenictus binghami	5	0	0	1	0	6	0	76	10	29	41	0
Pseudomyrmecinae												
Tetraponera sp.1 of AMKUFF	1	0	0	3	0	5	0	3	47	29	31	10
Total	216	104	219	279	204	224	466	796	920	1317	1539	794

Table 5 Distribution of ants in SSF across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Amblyopone rectinata	0	0	2	1	3	0	9	0	5	0	0	0
Diacamma rugosum	0	0	5	6	0	0	0	11	0	38	30	16
Diacamma sculpturatum	0	0	6	0	4	2	0	15	19	11	30	0
Diacamma vagans	0	8	0	0	0	0	2	29	32	18	23	10
Leptogenys birmana	2	0	0	3	0	0	0	28	4	13	0	0
Leptogenys diminuta	0	31	56	10	38	0	60	15	84	27	108	10
Leptogenys sp.15 of AMK	3	0	0	0	0	0	1	23	19	41	59	0
Leptogenys sp.16 of AMK	5	0	28	0	21	0	3	0	1	0	0	0
Odontomachus rixosus	0	0	0	11	19	23	14	57	31	22	18	27
Odontoponera denticulata	0	26	4	0	6	54	23	53	1	2	18	0
Pachycondyla astuta	0	1	0	0	17	23	9	0	26	7	19	11
Pachycondyla birmana	0	0	0	1	0	0	0	0	4	8	3	1
Pachycondyla (Brachyponera) leuteipes	0	0	1	8	0	0	9	12	37	11	15	27
Pachycondyla leeewenhoeki	0	0	2	0	0	0	3	0	7	18	0	4
Cerapachyinae												
Cerapachys sulcinodis	0	0	1	0	0	0	3	9	13	72	120	0

Table 5 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Dolichoderinae												
Dolichoderus tuberifera	0	38	114	2	26	0	73	146	239	0	728	0
Dolichoderus thoracicus	0	0	18	0	4	0	1	0	54	374	26	91
Pheilidris sp.1 of AMK	105	35	0	0	49	0	0	26	41	72	37	28
Technomyrmex sp.2 of AMK	0	2	0	0	0	0	0	4	5	3	1	0
Formicinae												
Anoplolepis gracilipes	1	0	0	41	19	0	0	47	9	17	29	11
Camponotus (Myrmoserícus) rufoglucus	0	0	1	6	0	9	2	10	25	43	23	9
Camponotus (Colobopsis) sp.6	0	0	0	0	0	0	4	0	5	3	3	0
Oecophylla smaragdina	0	12	2	0	0	0	0	54	31	18	27	1
Parathechina longicornis	0	0	0	0	0	0	17	43	38	21	39	47
Polyrhachis (Myrma) proxima	4	0	9	0	0	1	1	5	0	0	1	0
Polyrhachis (Campomyrma) halidayi	0	0	0	0	4	0	9	0	7	7	0	10
Pronolepis sp.1 of AMK	0	1	2	7	0	0	0	15	3	0	7	0
Myrmicinae												
Crematogaster (Crematogaster) sp. 1 of AMKUFF	1	0	0	0	0	1	1	1	0	0	0	0

Table 5 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Crematogaster (Crematogaster) sp. 9	0	21	0	9	6	0	0	0	0	21	0	0
Crematogaster (Orthocrema) sp.1	0	0	0	0	3	0	0	7	9	0	4	0
Crematogaster (Paracrema) coriaria	0	4	0	0	0	0	0	0	21	13	28	0
Meranoplus bicolor	0	0	0	7	0	0	0	41	23	8	17	0
Monomorium destructor	1	0	0	0	0	0	1	0	80	43	21	11
Myrmicaria sp.3 of AMK	0	0	0	0	0	0	0	37	22	46	81	0
Pheidole plagiaria	101	0	0	0	32	0	0	44	53	17	337	0
Pheidole platifrons	0	0	18	0	0	0	21	120	15	63	89	27
Pheidole yeensis	0	0	1	0	0	0	4	2	1	0	0	0
Pheidole inornata	0	0	0	0	0	2	0	2	0	3	3	0
Pheidole sp.11 of AMK	0	3	2	0	0	0	0	0	7	3	1	1
Pheidologaton affinis	0	0	0	0	0	0	0	0	0	1	0	0
Pheidologaton diversus	0	9	0	3	0	0	0	1	5	0	2	0
Tetramorium sp.10 of AMK	1	0	0	0	4	0	0	0	7	11	9	0
Aenictus												
Aenictus ceylonicus	6	11	0	0	8	0	0	7	13	24	32	19
Total	245	209	280	115	263	115	319	892	1031	1128	2025	379

Table 6 Distribution of ants in PTF across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Anochetus sp.8 of AMK	10	0	0	19	0	5	21	34	16	13	10	9
Diacamma rugosum	0	0	14	0	39	1	0	29	51	23	0	32
Diacamma sculpturatum	4	0	0	7	3	8	0	1	9	4	13	6
Diacamma vagans	0	0	16	0	0	0	0	7	3	11	9	16
Hypoponera sp.1 of AMK	1	0	0	3	0	0	1	5	3	1	0	0
Leptogenys diminuta	94	35	103	0	51	24	74	18	49	37	51	10
Leptogenys kitteli	0	0	63	0	14	0	0	23	17	31	10	0
Leptogenys sp.23 of AMK	3	0	11	0	7	0	0	5	0	1	1	0
Odontoponera denticulata	0	0	6	0	10	11	0	4	1	1	8	1
Pachycondyla astuta	0	10	4	0	22	13	18	29	35	21	17	8
Pachycondyla leeuwenhoeki	1	0	5	3	0	17	5	5	1	7	11	3
Dolichoderinae												
Dolichoderus thoracicus	69	10	0	151	260	1	8	185	49	82	731	284
Dolichoderus tuberifera	173	0	34	0	0	7	0	43	18	29	37	21
Iridomyrmex anceps	1	0	7	0	2	5	5	4	1	22	7	16
Philidris sp.1 of AMK	1	0	0	0	1	9	3	3	0	0	0	0
Technomyrmex kheperra	0	0	4	0	3	3	0	15	7	3	2	0

Table 6 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Technomyrmex kraepelini	1	0	3	3	0	0	0	11	8	13	7	5
Formicinae												
Anoplolepis gracilipes	0	22	0	0	3	0	21	7	10	45	2	0
Camponotus (Myrmosericus)rufoglaucus	0	0	0	0	8	0	0	34	49	23	31	15
Camponotus (Tanaemyrmex) sp.7 of AMK	3	5	0	0	0	0	3	0	10	23	17	4
Myrmoteres sp.3 of AMK	0	0	0	0	0	0	0	41	13	21	19	12
Oecophylla smaragdina	43	15	0	16	3	0	0	9	6	37	0	6
Paratrechina longicornis	0	0	6	0	0	0	13	5	8	1	2	0
Paratrechina sp.2 of AMK	4	0	0	3	0	0	12	0	14	39	48	21
Paratrechina sp.5 of AMK	1	0	0	0	15	0	7	29	0	14	0	0
Plagiolepis sp.1 of AMK	0	0	29	0	143	0	0	53	40	0	31	0
Polyrhachis (Myrma) illaudata	0	0	1	0	0	3	3	0	1	19	0	0
Polyrhachis (Myrmhopla) dives	2	0	4	0	1	0	0	12	27	40	23	0
Pseudolasius sp.1 of AMK	0	0	0	0	9	0	0	0	61	0	11	43
Myrmicinae												
Aphenogaster sp.1 of AMK	7	0	0	5	13	7	0	42	2	53	39	0

Table 6 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monomorium destructer	1	0	0	0	5	0	0	9	11	48	3	0
Myrmicaria sp.3 of AMK	3	0	0	51	250	0	45	26	7	13	29	55
Pheidole platifrons	13	9	5	3	0	0	12	61	10	17	15	0
Pheidole plagiaria	0	0	35	0	111	0	25	31	37	21	19	56
Pheidole sp.9 of AMK	0	0	0	3	3	0	2	0	5	7	0	0
Pheidole sp.11 of AMK	1	0	0	0	2	0	0	0	0	0	0	0
Pheidole sp.4 of AMK	1	0	3	5	0	1	1	0	0	0	0	1
Pheidologaton affinis	21	13	0	3	5	10	19	128	273	194	249	51
Pheidologaton diversus	2	0	10	0	0	13	0	238	95	37	50	0
Proatta butteli	0	0	0	0	0	4	11	2	9	3	0	0
Rhoptomyrmex wroughtonii	1	0	0	0	1	3	7	0	1	1	0	0
Solenopsis germinata	2	0	0	0	45	28	0	2	0	21	0	13
Tetramorium bicarinatum	0	0	0	0	1	0	0	4	0	9	11	3
Tetramorium sp.3 of AMK	4	0	0	7	0	3	1	0	17	0	9	2
Tetramorium sp.13 of AMK	9	3	3	5	1	0	14	0	5	7	11	0
Aenictinae												
Aenictus ceylonicus	24	0	0	0	0	11	71	0	94	0	13	11

Table 6 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Aenitus laeviceps	1	0	0	0	1	0	21	0	19	0	23	0
Aenitus nishimurai	4	0	0	0	0	29	11	43	0	0	135	0
Pseudomyrmecinae												
Tetraponera attenuata	1	0	0	1	0	0	0	7	0	13	0	9
Cerapachyinae												
Cerapachys sulcinodis	47	20	0	0	21	9	17	0	23	0	46	0
Total	553	142	366	288	1053	225	451	1204	1115	1005	1092	713

Table 7 Distribution of ants in GLF across months. Data are number of ants records in litter shifting.

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ponerinae												
Anochetus sp.8 of AMK	12	0	3	7	0	13	0	0	22	47	25	0
Diacamma rugosum	0	6	4	8	37	7	0	8	33	0	28	25
Gnamptogenys binghamii	1	0	0	0	0	0	0	0	0	1	1	1
Hypoponera sp.7 of AMK	0	0	0	0	2	0	0	1	7	3	0	0
Leptogenys birmana	0	0	0	0	0	11	0	11	0	1	16	8
Leptogenys borneensis	9	3	0	0	5	0	130	41	26	32	14	27
Leptogenys diminuta	3	7	0	0	4	0	1	9	5	3	1	0
Leptogenys kitteli	96	0	0	0	1	0	16	7	28	43	19	10
Leptogenys sp.16 of AMK	0	13	0	0	0	0	0	3	3	12	7	5
Odontoponera denticulata	0	1	0	0	1	4	10	26	4	20	7	5
Odontomachus rixosus	0	0	1	0	2	2	5	1	17	24	13	9
Pachycondyla astuta	8	0	0	0	0	0	9	25	11	7	13	10
Platythyrae parallela	0	0	0	0	1	0	0	1	1	7	4	0
Dolichoderinae												
Dolichoderus thoracicus	1	0	109	3	4	0	0	31	47	25	16	10
Dolichoderus tuberifera	0	0	50	3	1	58	0	43	0	71	6	2
Iridomyrmex ancep	0	0	0	0	12	0	0	11	5	3	2	1

Table 7 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Ochetellus sp.1 of AMK	0	0	0	0	1	0	0	0	1	4	1	1
Formicinae												
Anoplolepis gracilipes	3	35	5	17	56	165	155	0	44	41	21	336
Camponotus (Colobopsis) sp.6 of AMK	0	54	1	0	4	1	0	156	0	39	41	66
Camponotus (Myrmosericus)rufoglaucus	0	0	6	0	0	0	11	30	0	5	7	1
Camponotus (Myrmembly) sp.3 of AMK	0	0	5	6	0	1	0	0	1	0	15	7
Camponotus (Tanaemyrmex) Sp1 of AMK	0	0	0	0	0	5	0	0	7	1	4	10
Camponotus (Tanaemyrmex) Sp.7 of AMK	28	0	0	1	0	0	23	14	18	2	1	0
Oecophylla smaragdina	0	0	0	6	3	22	0	7	19	0	13	9
Paratrechina longicornis	3	0	0	0	1	0	0	6	9	1	4	0
Paratrechina sp.2 of AMK	0	0	0	0	0	3	0	23	0	0	0	0
Plagiolepis sp.1 of AMK	0	0	0	0	0	29	1	4	0	48	0	0

Table 7 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Polyrhachis (Crytomyrma) laevissima	0	0	26	4	0	0	0	15	37	19	5	0
Polyrhachis (Myrmhopla) dives	0	0	0	0	8	0	5	0	0	1	15	0
Polyrhachis (Myrma) illavdata	0	0	2	1	0	0	0	0	1	2	3	0
Pronolepis sp.1 of AMK	0	1	0	0	0	3	0	5	8	11	3	0
Psedolasius sp.1 of AMK	0	0	0	30	1	0	0	0	72	0	9	0
Crematogaster (Crematogaster) Sp.1 of AMK	0	0	2	0	0	2	4	0	9	15	7	0
Crematogaster (Crematogaster) Sp.9 of AMK	1	0	0	0	0	60	28	0	0	32	54	0
Crematogaster (Orthocrema) sp1	1	0	3	0	0	0	2	0	7	0	6	3
Myrmicinae												
Crematogaster (Paracrema)coriaria	0	5	0	24	0	0	0	6	56	0	22	3
Monomorium destructor	376	18	0	4	19	0	11	0	72	0	250	34
Myrmicaria sp.3 of AMK	0	0	1	0	0	1	1	4	0	0	0	0
Pheidole plagiaria	0	0	26	0	0	0	18	0	21	43	9	0
Pheidole platifrons	0	0	0	18	0	0	6	14	0	7	13	9
Pheidole tangjogensis	0	0	0	0	7	0	3	5	16	0	8	0

Table 7 (continued)

Species	Months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Pheidole sp.11 of AMK	0	32	3	1	0	9	4	3	0	4	0	5
Pheidole sp.8 of AMK	0	0	0	0	65	0	0	0	19	4	7	0
Pheidologaton affinis	10	0	15	35	0	6	47	71	26	3	158	0
Pheidologaton diversus	145	0	0	0	24	39	16	30	11	29	284	173
Phoptomyrmex wrougtonii	0	0	0	0	5	0	3	1	0	0	1	1
Solenopsis geminata	3	5	0	1	1	0	0	17	0	1	0	0
Tetramorium kheperra	0	1	0	1	0	0	1	1	0	0	1	0
Tetramorium smithii	5	0	1	0	0	11	0	13	0	1	0	8
Tetramorium sp.3 of AMK	1	0	0	0	0	5	0	0	4	0	1	1
Aenictinae												
Aenictus binghami	3	5	0	0	61	0	42	0	0	4	19	0
Aenictus laeviceps	0	0	0	0	15	0	0	11	0	35	10	17
Bothriomyrmex sp.1 of AMK	96	0	0	0	75	0	26	12	0	0	77	0
Pseudomyrmecinae												
Tetraponera attenuate	10	0	0	0	0	0	0	1	38	41	13	0
Tetraponera sp.1 of AMK	0	1	0	0	9	4	32	4	0	5	3	3
Total	815	187	263	170	425	461	610	671	705	697	1257	800

APPENDIX C

Appendix C

Table 1 Species composition of ant communities in the SERS. Data are number of ants records in litter shifting.

Species	DEF	DDF	FPF	ECO	SSF	PTF	GLF	Total
1. *Amblyopone reclinata*	0	0	0	0	20	0	0	20
2. *Anochetus* sp.8 of AMK	0	135	0	0	0	137	129	401
3. *Diacamma rugosum*	124	62	151	188	106	189	156	976
4. *Diacamma sculpturatum*	71	16	0	96	87	55	0	325
5. *Diacamma vagans*	189	87	142	177	122	62	0	779
6. *Diacamma* sp.8 of AMK	0	79	0	0	0	0	0	79
7. *Diacamma* sp.11 of AMK	73	0	0	55	0	0	0	128
8. *Gnamptogenys binghamii*	21	0	0	0	50	0	4	75
9. *Hypoponera* sp.1 of AMK	26	0	0	0	0	14	0	40
10. *Hypoponera* sp.7 of AMK	0	0	0	0	0	0	13	13
11. *Leptogenys birmana*	160	0	0	59	226	0	47	492
12. *Leptogenys borneensis*	0	0	32	0	0	0	287	319
13. *Leptogenys diminuta*	192	201	419	77	439	546	33	1907
14. *Leptogenys kitteli*	0	0	327	165	0	158	220	870
15. *Leptogenys* sp.10 of AMK	88	0	0	0	0	0	0	88
16. *Leptogenys* sp.15 of AMK	87	19	98	248	146	0	0	598
17. *Leptogenys* sp.16 of AMK	0	0	0	0	58	0	43	101
18. *Leptogenys* sp.21 of AMK	46	0	42	0	0	0	0	88
19. *Leptogenys* sp.23 of AMK	0	0	0	0	0	28	0	28
20. *Odontoponera denticulata*	251	73	31	108	187	42	78	770
21. *Odontomachus rixosus*	328	161	194	213	222	0	74	1147
22. *Pachycondyla astuta*	32	0	111	84	113	177	83	600
23. *Pachycondyla birmana*	0	0	0	0	17	0	0	17
24. *Pachycondyla (Brachyponera) luteipes*	4	0	0	0	120	0	0	124
25. *Pachycondyla leeuwenhoveki*	12	21	0	107	34	58	0	232
26. *Plathyhyrae parallela*	0	0	0	0	0	0	14	14
27. *Dolichoderus thoracicus*	1172	374	78	130	568	1172	246	3740
28. *Dolichoderus tuberifera*	350	151	0	0	1366	362	234	2463
29. *Iridomyrmex ancep*	0	64	92	48	0	70	34	308
30. *Ochetellus* sp.1 of AMK	0	0	14	0	0	0	8	22
31. *Philidris* sp.1 of AMK	129	0	0	0	393	17	0	539
32. *Technomyrmex kheperra*	10	0	0	0	0	37	0	47
33. *Technomyrmex kraepelini*	0	16	0	76	0	51	0	143

Table 1 (continued)

Species	DEF	DDF	FPF	ECO	SSF	PTF	GLF	Total
34. *Technomyrmex* sp.2 of AMK	0	0	0	0	15	0	0	15
35. *Anoplolepis gracilipes*	184	433	722	324	174	110	878	2825
36. *Camponotus (Colobobsis) praeruta*	93	0	0	0	0	0	0	93
37. *Camponotus (Colobobsis)* sp.6 of AMK	0	128	66	98	15	0	362	669
38. *Camponotus (Myrmosaulus) Auriventris*	14	0	0	0	0	0	0	14
39. *Camponotus (Myrmosericus) rufoglaucus*	34	117	99	98	128	160	60	696
40. *Camponotus (Myrmembly)* sp.3 of AMK	0	28	0	0	0	0	35	63
41. *Camponotus (Tanaemyrmex)* sp.1 of AMK	0	0	0	11	0	0	27	38
42. *Camponotus (Tanaemyrmex)* sp.7 of AMK	25	161	65	62	0	65	87	465
43. *Myrmoteres* sp.3 of AMK	0	0	0	0	0	106	0	106
44. *Oecophylla smaragdina*	0	115	40	79	145	135	79	593
45. *Paratrechina longicornis*	108	62	92	95	205	35	24	621
46. *Paratrechina* sp.2 of AMK	0	22	0	0	0	141	26	189
47. *Paratrechina* sp.5 of AMK	59	0	0	0	0	66	0	125
48. *Paratrechina* sp.8 of AMK	0	0	0	133	0	0	0	133
49. *Plagiolepis* sp.1 of AMK	48	30	133	38	0	296	82	627
50. *Polyrhachis (Cyrtomyrma) laevissima*	0	0	0	39	0	0	106	145
51. *Polyrhachis (Myrmhopla) dives*	0	0	66	0	0	109	29	204
52. *Polyrhachis (Myrma) illavdata*	119	0	23	25	0	27	9	203
53. *Polyrhachis (Myrma) proxima*	0	74	0	78	21	0	0	173
54. *Polyrhachis (Myrma*) sp.1 of AMK	0	0	15	0	0	0	0	15
55. *Polyrhachis (Campomyrma*) *halidayi*	0	0	0	0	37	0	0	37
56. *Pronolepis* sp.1 of AMK	76	0	0	0	35	0	31	142
57. *Psedolasius* sp.1 of AMK	45	0	35	0	0	124	112	316
58. *Aphenogaster* sp.1 of AMK	6	0	0	0	0	168	0	174
59. *Cataulacus granulatus*	0	7	0	0	0	0	0	7

Table 1 (continued)

Species	DEF	DDF	FPF	ECO	SSF	PTF	GLF	Total
60. *Cardiocondyla emeryi*	21	0	0	47	0	0	0	68
61. *Cardiocondyla nuda*	0	0	17	0	0	0	0	17
62. *Crematogaster (Crematogaster) rogenhoferii*	0	129	0	0	0	0	0	129
63. *Crematogaster (Crematogaster)* sp.1 of AMK	117	110	77	240	4	0	39	587
64. *Crematogaster (Crematogaster)* sp.2 of AMK	255	113	0	0	0	0	0	368
65. *Crematogaster (Crematogaster)* sp.3 of AMK	0	160	0	0	0	0	0	160
66. *Crematogaster (Crematogaster)* sp.9 of AMK	15	0	90	109	57	0	175	446
67. *Crematogaster (Orthocrema)* sp.1of AMK	0	0	0	161	23	0	22	206
68. *Crematogaster (Paracrema) coriaria*	0	115	63	197	66	0	116	557
69. *Crematogaster (Physocrema) inflata*	93	1063	16	100	0	0	0	1272
70. *Meranoplus bicolor*	0	119	0	123	96	0	0	338
71. *Monomorium chinensis*	0	0	0	889	0	0	0	889
72. *Monomorium destructor*	40	80	136	299	157	77	784	1573
73. *Monomorium floricola*	39	0	0	0	0	0	0	39
74. *Monomorium pharaonis*	0	75	18	0	0	0	0	93
75. *Myrmicaria sp.3* of AMK	40	0	0	0	186	479	7	712
76. *Pheidole inornata*	0	0	0	0	10	0	0	10
77. *Pheidole plagiaria*	1734	903	141	544	584	335	117	4358
78. *Pheidole platifrons*	0	0	30	670	353	145	67	1265
79. *Pheidole tandjogensis*	151	305	0	0	0	0	39	495
80. *Pheidole yeensis*	0	248	0	29	8	0	0	285
81. *Pheidole* sp.3 of AMK	0	0	68	0	0	0	0	68
82. *Pheidole* sp.4 of AMK	0	0	0	0	0	12	0	12
83. *Pheidole* sp.8 of AMK	0	0	0	0	0	0	95	95
84. *Pheidole* sp.9 of AMK	0	147	0	0	0	20	0	167
85. *Pheidole* sp.11 of AMK	42	0	0	0	17	3	61	123
86. *Pheidole* sp.15 of AMK	0	0	0	88	0	0	0	88
87. *Pheidologaton affinis*	111	127	76	0	1	966	371	1652
88. *Pheidologaton diversus*	20	118	2697	132	20	445	751	4183

Table 1 (continued)

Species	DEF	DDF	FPF	ECO	SSF	PTF	GLF	Total
89. *Phoptomyrmex wrougtonii*	0	0	18	0	0	14	11	43
90. *Proatta butteli*	0	0	0	0	0	29	0	29
91. *Solenopsis geminata*	0	0	0	0	0	111	28	139
92. *Strumigenys* sp.1 of AMK	0	10	0	0	0	0	0	10
93. *Tetramorium bicarinatum*	0	0	0	0	0	28	0	28
94. *Tetramorium ciliatum*	0	17	0	0	0	0	0	17
95. *Tetramorium khererra*	0	0	0	105	0	0	5	110
96. *Tetramorium smithii*	0	0	0	0	0	0	39	39
97. *Tetramorium walshi*	59	0	0	0	0	0	0	59
98. *Tetramorium* sp.3 of AMK	0	0	35	0	0	43	12	90
99. *Tetramorium* sp.10 of AMK	34	0	0	0	32	0	0	66
100. *Tetramorium* sp.12 of AMK	0	0	0	80	0	0	0	80
101. *Tetramorium* sp.13 of AMK	0	0	0	0	0	58	0	58
102. *Aenictus binghami*	117	0	86	168	0	0	134	505
103. *Aenictus ceylonicus*	154	179	0	57	120	224	0	734
104. *Aenictus laeviceps*	161	134	38	0	0	65	88	486
105. *Aenictus nishimurai*	0	0	0	0	0	222	0	222
106. *Aenictus* sp.13 of AMK	0	5	0	0	0	0	0	5
107. *Bothriomyrmex* sp.1 of AMK	0	0	0	0	0	0	286	286
108. *Tetraponera allaborans*	99	0	0	0	0	0	0	99
109. *Tetraponera attenuata*	74	0	35	0	0	31	103	243
110. *Tetraponera difficilis*	0	140	0	0	0	0	0	140
111. *Tetraponera ruflonigra*	0	21	0	0	0	0	0	21
112. *Tetraponera* sp.1 of AMK	0	0	0	129	0	0	61	190
113. *Cerapachys sulcinodis*	0	0	39	0	218	183	0	440
Total number of ants	7552	6954	6767	7078	7054	8207	7061	50,673
Total number of species	52	47	42	46	44	50	55	113
Total number of genera	27	25	26	25	25	30	31	42

APPENDIX D

Table 1 Relative abundance, frequency and occurrence of ant communities in DEF of the SERS.

Species	RA	F	Occur	WRA	WF	WO	IV
Diacamma rugosum	1.32	50	75.00	1	4	4	9
Diacamma sculpturatum	0.85	45.83	66.67	1	4	4	9
Diacamma vagans	1.82	54.17	83.33	1	5	5	11
Diacamma sp.11 of AMK	0.87	45.83	66.67	1	4	4	9
Gnamptogenys binghamii	0.67	25.00	25.00	1	1	1	3
Hypoponera sp.1 of AMK	0.62	29.17	33.33	1	2	2	5
Leptogenys birmana	2.20	41.67	58.33	1	3	3	7
Leptogenys diminuta	3.08	37.55	50.00	1	3	3	7
Leptogenys sp.10 of AMK	1.21	41.67	58.33	1	3	3	7
Leptogenys sp.15 of AMK	2.79	25.00	25.00	1	1	1	3
Leptogenys sp.21 of AMK	1.10	29.17	33.33	1	2	2	5
Odontomachus rixosus	4.51	41.67	58.33	2	3	3	8
Odontoponera denticulata	2.19	58.33	91.67	1	5	5	11
Pachycondyla astuta	0.44	41.67	58.33	1	3	3	7
Pachycondyla (Brachyponera) luteipes	0.09	29.17	33.33	1	2	2	5
Pachycondyla leeuwenhoveki	0.19	33.33	50.00	1	2	3	6
Dolichoderus thoracicus	9.40	62.5	100	3	5	5	13
Dolichoderus tuberiferi	4.81	41.67	58.33	2	3	3	8
Philidris sp.1 of AMKUFF	1.55	45.83	66.67	1	4	4	9
Technomyrmex kraepelini	0.19	33.33	41.67	1	2	2	5
Anoplolepis gracilipes	1.96	50.00	75.00	1	4	4	9
Camponotus (Colobobsis) praeruta	1.49	37.5	50.00	1	3	3	7
Camponotus (Myrmosaulus) auriventris	0.27	33.33	41.67	1	2	2	5
Camponotus (Myrmosericus) rufoglaucus	0.32	54.17	83.33	1	5	5	11
Camponotus (Tanaemyrmex) sp.7 of AMK	0.40	37.50	50.00	1	3	3	7
Paratrechina longicornis	1.73	37.50	50.00	1	3	3	7
Paratrechina sp.5 of AMK	0.81	41.67	58.33	1	3	3	7
Plagiolepis sp.1 of AMK	0.77	37.5	50.00	1	3	3	7
Polyrhachis (Myrma) illavdata	1.27	50.00	75.00	1	4	4	9
Pronolepis sp.1 of AMK	1.22	37.5	50.00	1	3	3	7

Table 1 (continued)

Species	RA	F	Occur	WRA	WF	WO	IV
Psedolasius sp.1 of AMK	0.72	37.5	50.00	1	3	3	7
Aphenogaster sp.1 of AMK	0.14	25.00	33.33	1	1	2	4
Cardiocondyla emeryi	0.33	37.5	50.00	1	3	3	7
Crematogaster (Crematogaster) sp.1 of AMK	1.40	45.83	66.67	1	4	4	9
Crematogaster (Crematogaster) sp.2 of AMK	4.09	37.50	50.00	2	3	3	8
Crematogaster (Crematogaster) sp.9 of AMK	0.36	29.17	33.33	1	2	2	5
Crematogaster (Physocrema) inflata	1.79	33.33	41.67	1	2	2	5
Monomorium destructor	0.64	37.7	50.00	1	3	3	7
Monomorium floricola	0.53	41.67	58.33	1	3	3	7
Myrmicaria sp.3 of AMK	0.77	33.33	41.67	1	2	2	5
Pheidole plagiaria	16.70	54.17	83.33	5	5	5	15
Pheidole tandjogensis	2.42	37.50	50.00	1	3	3	7
Pheidole sp.11 of AMK	0.80	33.33	41.67	1	2	2	5
Pheidologaton affinis	1.78	37.50	50.00	1	3	3	7
Pheidologaton diversus	0.41	29.17	33.33	1	2	2	5
Tetramorium walshi	0.94	37.50	50.00	1	3	3	7
Tetramorium sp.10 of AMK	0.65	33.33	41.67	1	2	2	5
Aenictus binghami	1.61	41.67	58.33	1	3	3	7
Aenictus ceylonicus	3.70	29.17	33.33	2	2	2	6
Aenictus laeviceps	7.75	20.83	16.67	3	1	1	5
Tetraponera allaborans	1.19	45.83	66.67	1	4	4	9
Tetraponera attenuate	0.89	45.83	66.67	1	4	4	9

Table 2 Relative abundance, frequency and occurrence of ant communities in DDF of the SERS.

Species	R-A	Freq	Occur	W1	W2	W3	Total
Anochetus sp.8 of AMK	2.10	45.83	66.67	1	4	4	9
Diacamma rugosum	0.85	50.00	75.00	1	4	4	9
Diacamma sculpturatum	0.28	41.67	58.33	1	3	3	7
Diacamma vagans	1.08	54.17	83.33	1	5	5	11
Diacamma sp.8 of AMK	0.98	54.17	83.33	1	5	5	11
Leptogenys diminuta	2.77	50.00	75.00	1	4	4	9
Leptogenys sp.15 of AMK	0.29	45.83	66.67	1	4	4	9
Odontoponera denticulata	0.90	54.17	83.33	1	5	5	11
Odontomachus rixosus	2.50	45.83	66.67	1	4	4	9
Pachycondyla leeuwenhoveki	0.37	41.67	58.33	1	3	3	7
Dolichoderus thoracicus	7.75	37.50	50.00	3	3	3	9
Dolichoderus tuberiferi	2.08	50.00	75.00	1	4	4	9
Iridomyrmex ancep	0.88	50.00	75.00	1	4	4	9
Technomyrmex kraepelini	0.33	37.50	50.00	1	3	3	7
Anoplolepis gracilipes	5.38	54.17	83.33	2	5	5	12
Camponotus (Colobobsis) sp.6 of AMK	1.77	50.00	75.00	1	4	4	9
Camponotus (Myrmosericus) rufoglaucus	1.45	54.17	83.33	1	5	5	11
Camponotus (Myrmembly) sp.3 of AMK	0.34	54.17	83.33	1	5	5	11
Camponotus (Tanaemyrmex) sp.7 of AMK	2.00	54.17	83.33	1	5	5	11
Oecophylla smaragdina	1.78	45.83	66.67	1	4	4	9
Paratrechina longicornis	0.77	54.17	83.33	1	5	5	11
Paratrechina sp.2 of AMK	0.30	50.00	75.00	1	4	4	9
Plagiolepis sp.1 of AMK	0.46	45.83	66.67	1	4	4	9
Polyrhachis (Myrma) proxima	0.92	54.17	83.33	1	5	5	11
Cataulacus granulatus	0.17	33.33	41.67	1	2	2	5
Crematogaster (Crematogaster) rogenhoferii	1.60	54.17	83.33	1	5	5	11
Crematogaster (Crematogaster) sp.1 of AMK	1.71	45.83	66.67	1	4	4	9
Crematogaster (Crematogaster) sp.2 of AMK	3.51	25.00	33.33	2	1	2	5

Table 2 (continued)

Species	R-A	Freq	Occur	W1	W2	W3	Total
Crematogaster (Crematogaster) sp.3 of AMK	2.21	50.00	75.00	1	4	4	9
Crematogaster (Paracrema) coriaria	1.59	50.00	75.00	1	4	4	9
Crematogaster (Physocrema) inflata	13.23	54.17	83.33	5	5	5	15
Meranoplus bicolor	1.64	50.00	75.00	1	4	4	9
Monomorium destructor	1.24	45.83	66.67	1	4	4	9
Monomorium pharaonis	1.03	50.00	75.00	1	4	4	9
Pheidole plagiaria	12.49	50.00	75.00	5	4	4	13
Pheidole tandjogensis	5.42	41.67	58.33	3	3	3	9
Pheidole yeensis	3.08	54.17	83.33	2	5	5	12
Pheidole sp.9 of AMK	2.28	41.67	66.67	1	3	4	8
Pheidologaton affinis	1.75	50.00	75.00	1	4	4	9
Pheidologaton diversus	1.46	54.17	83.33	1	5	5	11
Strumigenys sp.1 of AMK	0.20	37.5	50.00	1	3	3	7
Tetramorium ciliatum	0.30	41.67	58.33	1	3	3	7
Aenictus ceylonicus	2.47	50.00	75.00	1	3	4	8
Aenictus laeviceps	1.85	50.00	75.00	1	3	4	8
Aenictus sp.13 of AMK	0.20	25.00	25.00	1	1	1	3
Tetraponera difficilis	1.74	54.17	83.33	1	5	5	11
Tetraponera ruflonigra	0.29	50.00	75.00	1	3	4	8

Table 3 Relative abundance, frequency and occurrence of ant communities in FPF of the SERS.

Species	R-A	Freq	Occur	W1	W2	W3	Total
Diacamma rugosum	1.99	54.16	83.33	1	5	4	10
Diacamma vagans	1.87	54.16	83.33	1	5	4	10
Leptogenys borneensis	0.46	50.00	75.00	1	4	4	9
Leptogenys diminuta	5.53	54.16	83.33	1	5	4	10
Leptogenys kitteli	4.79	50.00	75.00	1	4	4	9
Leptogenys sp.15 of AMK	2.15	37.50	50.00	1	3	2	6
Leptogenys sp.21 of AMK	0.92	37.5	50.00	1	3	2	6
Odontoponera denticulata	0.51	45.83	66.67	1	4	3	8
Odontomachus rixosus	2.39	58.33	91.67	1	5	5	11
Pachycondyla astuta	1.46	54.16	83.33	1	5	4	10
Dolichoderus thoracicus	1.71	37.50	50.00	1	3	2	6
Iridomyrmex ancep	1.35	50.00	75.00	1	4	4	9
Ochetellus sp.1 of AMK	0.37	33.33	41.67	1	2	2	5
Anoplolepis gracilipes	7.94	58.33	100	2	5	5	12
Camponotus (Colobobsis) sp.6 of AMK	1.24	41.66	58.33	1	3	3	7
Camponotus (Myrmosericus) rufoglaucus	1.45	50.00	75.00	1	4	4	9
Camponotus (Tanaemyrmex) sp.7 of AMK	2.14	29.16	33.33	1	2	1	4
Oecophylla smaragdina	1.76	25.00	25.00	1	1	1	3
Paratrechina longicornis	1.51	45.83	66.67	1	4	3	8
Plagiolepis sp.1 of AMK	2.92	37.50	50.00	1	3	2	6
Polyrhachis (Myrmhopla) dives	1.08	45.83	66.67	1	4	3	8
Polyrhachis (Myrma) illavdata	0.43	41.66	58.33	1	3	3	7
Polyrhachis (Myrma) sp.1 of AMK	0.28	41.66	58.33	1	3	3	7
Psedolasius sp.1 of AMK	0.77	37.50	50.00	1	3	2	6
Cardiocondyla nuda	0.37	37.50	50.00	1	3	2	6
Crematogaster (Crematogaster) sp.1 of AMK	1.69	37.5	50.00	1	3	2	6
Crematogaster (Crematogaster) sp.9 of AMK	1.69	41.66	58.33	1	3	3	7
Crematogaster (Paracrema) coriaria	1.04	45.83	66.67	1	4	3	8
Crematogaster (Physocrema) inflata	0.26	45.83	66.67	1	4	3	8

Table 3 (continued)

Species	R-A	Freq	Occur	W1	W2	W3	Total
Monomorium destructor	2.24	45.83	66.67	1	4	3	8
Monomorium pharaonis	0.39	37.50	50.00	1	3	2	6
Pheidole plagiaria	2.06	50.00	75.00	1	4	4	9
Pheidole platifrons	0.49	45.83	66.67	1	4	3	8
Pheidole sp.3 of AMK	1.28	41.66	58.33	1	3	3	7
Pheidologaton affinis	1.25	45.83	66.67	1	4	3	8
Pheidologaton diversus	35.61	54.16	83.33	5	5	4	14
Phoptomyrmex wrougtonii	0.39	37.50	50.00	1	3	2	6
Tetramorium sp.3 of AMK	0.51	50.00	75.00	1	4	4	9
Aenictus binghami	1.26	50.00	75.00	1	4	4	9
Aenictus laeviceps	0.83	37.50	50.00	1	3	2	6
Tetraponera attenuate	0.66	41.66	58.33	1	3	3	7
Cerapachys sulcinodis	0.85	37.50	50.00	1	3	2	6

Table 4 Relative abundance, frequency and occurrence of ant communities in ECO of the SERS.

Species	R-A	Freq	Occur	W1	W2	W3	Total
Diacamma rugosum	2.25	45.83	66.67	1	4	3	8
Diacamma sculpturatum	1.31	41.67	58.33	1	3	3	7
Diacamma vagans	2.82	37.50	50.00	1	3	2	6
Diacamma sp.11 of AMK	0.65	45.83	66.67	1	4	3	8
Leptogenys birmana	0.62	50.00	75.00	1	4	4	9
Leptogenys diminuta	1.22	37.50	50.00	1	3	2	6
Leptogenys kitteli	2.25	41.67	58.33	1	3	3	7
Leptogenys sp.15 of AMK	4.75	33.33	41.67	2	2	2	6
Odontoponera denticulata	1.14	50.00	75.00	1	4	4	9
Odontomachus rixosus	2.26	50.00	75.00	1	4	4	9
Pachycondyla astuta	1.34	37.50	50.00	1	3	2	6
Pachycondyla leeuwenhoveki	1.28	45.83	66.67	1	4	3	8
Dolichoderus thoracicus	1.55	45.83	66.67	1	4	3	8
Iridomyrmex ancep	0.57	45.83	66.67	1	4	3	8
Technomyrmex kraepelini	1.45	33.33	41.67	1	2	2	5
Anoplolepis gracilipes	2.82	58.33	91.67	1	5	5	11
Camponotus (Colobobsis) sp.6 of AMK	1.87	33.33	41.67	1	2	2	5
Camponotus (Myrmosericus) Rufoglaucus	1.04	50.00	75.00	1	4	4	9
Camponotus (Tanaemyrmex) sp.1 of AMK	0.21	33.33	41.67	1	2	2	5
Camponotus (Tanaemyrmex) sp.7 of AMK	0.24	33.33	41.67	1	2	2	5
Oecophylla smaragdina	1.26	37.50	50.00	1	3	2	6
Paratrechina longicornis	1.13	45.83	66.67	1	4	3	8
Paratrechina sp.8 of AMK	1.41	50.00	75.00	1	4	4	9
Plagiolepis sp.1 of AMK	0.60	37.50	50.00	1	3	2	6
Polyrhachis (Cyrtomyrma) laevissima	0.62	37.50	50.00	1	3	2	6
Polyrhachis (Myrma) illavdata	0.34	41.67	58.33	1	3	3	7
Polyrhachis (Myrma) proxima	1.06	41.67	58.33	1	3	3	7
Cardiocondyla emeryi	0.50	50.00	75.00	1	4	4	9
Crematogaster (Crematogaster) sp.1 of AMK	3.83	37.50	50.00	2	3	2	7
Crematogaster (Crematogaster) sp.9 of AMK	2.08	33.33	41.67	1	2	2	5

Table 4 (continued)

Species	R-A	Freq	Occur	W1	W2	W3	Total
Crematogaster (Orthocrema) sp.1 of AMK	1.92	45.83	66.67	1	4	4	9
Crematogaster (Paracrema) coriaria	2.69	41.67	58.33	1	3	3	7
Crematogaster (Physocrema) inflata	1.06	50.00	75.00	1	4	4	9
Meranoplus bicolor	1.96	37.50	50.00	1	3	3	7
Monomorium chinense	9.46	50.00	75.00	3	4	4	11
Monomorium destructor	4.09	41.67	58.33	2	3	3	8
Pheidole plagiaria	5.79	50.00	75.00	2	4	4	10
Pheidole platifrons	16.04	29.17	33.33	5	2	2	9
Pheidole yeensis	0.46	37.50	50.00	1	3	3	7
Pheidole sp.15 of AMK	2.10	29.17	33.33	1	2	2	5
Pheidologaton diversus	2.10	37.50	50.00	1	3	3	7
Tetramorium khererra	1.11	50.00	75.00	1	4	4	9
Tetramorium sp.12 of AMK	1.09	41.67	58.33	1	3	3	7
Aenictus binghami	2.29	41.67	58.33	1	3	3	7
Aenictus ceylonicus	0.68	45.83	66.67	1	2	4	7
Tetraponera sp.1of AMK	1.54	45.83	66.67	1	2	4	7

Table 5 Relative abundance, frequency and occurrence of ant communities in SSF of the SERS.

Species	R-A	Fre	Occur	W1	W2	W3	Total
Amblyopone reclinata	0.39	33.33	41.67	1	2	2	5
Diacamma rugosum	1.72	37.50	50.00	1	3	3	7
Diacamma sculpturatum	1.21	41.67	58.33	1	3	3	7
Diacamma vagans	1.70	41.67	58.33	1	3	3	7
Gnamptogenys binghamii	0.97	33.33	41.67	1	2	2	5
Leptogenys birmana	2.45	50.00	75.00	1	4	4	9
Leptogenys diminuta	4.27	54.17	83.33	2	5	5	12
Leptogenys sp.15 of AMK	2.37	37.50	50.00	1	3	3	7
Leptogenys sp.16 of AMK	1.13	33.33	41.67	1	2	2	5
Odontoponera denticulata	2.02	50.00	75.00	1	4	4	9
Odontomachus rixosus	2.4	50.00	75.00	1	4	4	9
Pachycondyla astuta	1.38	45.83	66.67	1	4	4	9
Pachycondyla birmana	0.33	33.33	41.67	1	2	2	5
Pachycondyla (Brachyponera) luteipes	1.46	45.83	66.67	1	4	4	9
Pachycondyla leeuwenhoveki	0.66	33.33	41.67	1	2	2	5
Dolichoderus thoracicus	9.22	37.5	50.00	3	3	3	9
Dolichoderus tuberifera	16.60	45.83	66.67	5	4	4	13
Philidris sp.1 of AMK	4.78	45.83	66.67	2	4	4	10
Technomyrmex sp.2 of AMK	0.29	33.33	41.67	1	2	2	5
Anoplolepis gracilipes	2.12	45.83	66.67	1	4	4	9
Camponotus (Colobobsis) sp.6 of AMK	0.37	29.17	33.33	1	2	2	5
Camponotus (Myrmoserícus) Rufoglaucus	1.38	50.00	75.00	1	4	4	9
Oecophylla smaragdina	2.02	41.67	58.33	1	3	3	7
Paratrechina longicornis	3.33	37.50	50.00	1	3	3	7
Polyrhachis (Myrma) proxima	0.34	37.5	50.00	1	3	3	7
Polyrhachis (Campomyrma) halidayi	0.72	33.33	41.67	1	2	2	5
Pronolepis sp.1 of AMK	0.57	37.50	50.00	1	3	3	7
Crematogaster (Crematogaster) sp.1 of AMK	0.10	29.17	33.33	1	2	2	5
Crematogaster (Crematogaster) sp.9 of AMK	1.39	29.17	33.33	1	2	2	5
Crematogaster (Orthocrema) sp.1 of AMK	0.56	29.17	33.33	1	2	2	5

Table 5 (continued)

Species	R-A	Fre	Occur	W1	W2	W3	Total
Crematogaster (Paracrema) coriaria	1.61	29.17	33.33	1	2	2	5
Meranoplus bicolor	1.87	33.33	41.67	1	2	2	5
Monomorium destructor	2.55	37.50	50.00	1	3	3	7
Myrmicaria sp.3 of AMK	4.53	29.17	33.33	2	2	2	6
Pheidole inornata	0.24	29.17	33.33	1	2	2	5
Pheidole plagiaria	9.48	37.50	50.00	3	3	3	9
Pheidole platifrons	4.91	41.67	58.33	2	3	3	8
Pheidole yeensis	0.19	29.17	33.33	1	2	2	5
Pheidole sp.11 of AMK	0.28	37.50	50.00	1	3	3	7
Pheidologaton affinis	0.05	16.67	16.67	1	1	1	3
Pheidologaton diversus	0.39	33.33	41.67	1	2	2	5
Tetramorium sp.10 of AMK	0.62	33.33	41.67	1	2	2	5
Aenictus ceylonicus	1.46	45.83	66.67	1	4	4	9
Cerapachys sulcinodis	3.54	37.50	50.00	2	3	3	8

Table 6 Relative abundance, frequency and occurrence of ant communities in PTF of the SERS.

Species	R-A	Freq	Occur	W1	W2	W3	Total
Anochetus sp.8 of AMK	1.43	50.00	75.00	1	4	4	9
Diacamma rugosum	2.54	41.67	58.33	2	3	3	8
Diacamma sculpturatum	0.57	50.00	75.00	1	4	4	9
Diacamma vagans	0.97	37.50	50.00	1	3	3	7
Hypoponera sp.1 of AMK	0.22	37.50	50.00	1	3	3	7
Leptogenys diminuta	4.68	58.33	91.67	3	5	5	13
Leptogenys kitteli	2.48	37.50	50.00	2	3	3	8
Leptogenys sp.23 of AMK	0.44	37.50	50.00	1	3	3	7
Odontoponera denticulata	0.49	41.67	66.67	1	3	4	8
Pachycondyla astuta	1.67	54.17	83.33	1	5	4	10
Pachycondyla leeuwenhoveki	0.54	54.17	83.33	1	5	4	10
Dolichoderus thoracicus	10.05	58.33	91.67	5	5	5	15
Dolichoderus tuberifera	4.27	45.83	66.67	3	4	4	11
Iridomyrmex ancep	0.66	54.17	83.33	1	5	4	10
Philidris sp.1 of AMK	0.32	33.33	41.67	1	2	2	5
Technomyrmex kheperra	0.49	41.67	58.33	1	3	3	7
Technomyrmex kraepelini	0.60	45.83	66.67	1	4	4	9
Anoplolepis gracilipes	1.48	41.67	58.33	1	3	3	7
Camponotus (Myrmosericus) Rufoglaucus	2.51	37.50	50.00	2	3	3	8
Camponotus (Tanaemyrmex) sp.7 of AMK	0.87	41.67	58.33	1	3	3	7
Myrmoteres sp.3 of AMK	2.00	33.33	41.67	1	2	2	5
Oecophylla smaragdina	1.59	45.83	66.67	1	4	4	9
Paratrechina longicornis	0.55	37.50	50.00	1	3	3	7
Paratrechina sp.2 of AMK	1.90	41.67	58.33	1	3	3	7
Paratrechina sp.5 of AMK	1.34	33.33	41.67	1	2	2	5
Plagiolepis sp.1 of AMK	5.58	33.33	41.67	3	2	2	7
Polyrhachis (Myrma) illavdata	0.51	33.33	41.67	1	2	2	5
Polyrhachis (Myrmhopla) dives	1.46	41.67	58.33	1	3	3	7
Psedolasius sp.1 of AMK	2.92	29.17	33.33	2	2	2	6
Aphenogaster sp.1 of AMK	1.98	45.83	66.67	1	4	4	9
Monomorium destructor	1.21	37.50	50.00	1	3	3	7
Myrmicaria sp.3 of AMK	5.02	50.00	75.00	3	4	4	11
Pheidole plagiaria	3.95	45.83	66.67	2	4	4	10

Table 6 (continued)

Species	R-A	Freq	Occur	W1	W2	W3	Total
Pheidole platifrons	1.52	50.00	75.00	1	4	4	9
Pheidole sp.4 of AMK	0.18	37.50	50.00	1	3	3	7
Pheidole sp.9 of AMK	0.37	33.33	41.67	1	2	2	5
Pheidole sp.11 of AMK	0.09	25.00	25.00	1	1	1	3
Pheidologaton affinis	8.28	58.33	91.67	5	5	5	15
Pheidologaton diversus	5.99	41.67	58.33	3	3	3	9
Phoptomyrmex wrougtonii	0.22	37.50	50.00	1	3	3	7
Proatta butteli	0.54	33.33	41.67	1	2	2	5
Solenopsis geminata	1.74	37.5	50.00	1	3	3	7
Tetramorium bicarinatum	0.52	33.33	41.67	1	2	2	5
Tetramorium sp.3 of AMK	0.58	41.67	58.33	1	3	3	7
Tetramorium sp.13 of AMK	0.60	50.00	75.00	1	4	4	9
Aenictus ceylonicus	3.52	37.50	50.00	2	3	3	8
Aenictus laeviceps	1.22	33.33	41.67	1	2	2	5
Aenictus nishimurai	4.19	33.33	41.67	3	2	2	7
Tetraponera attenuata	0.58	33.33	41.67	1	2	2	5
Cerapachys sulcinodis	2.46	41.67	58.33	2	3	3	8

Table 7 Relative abundance, frequency and occurrence of ant communities in GLF of the SERS.

Species	R-A	Freq	Occur	W1	W2	W3	Total
Anochetus sp.8 of AMK	1.86	41.67	58.33	1	3	3	7
Diacamma rugosum	1.75	50.00	75.00	1	4	4	9
Gnamptogenys binghamii	0.10	29.17	33.33	1	2	2	5
Hypoponera sp.7 of AMK	0.32	29.17	33.33	1	2	2	5
Leptogenys birmana	0.95	33.33	41.67	1	2	2	5
Leptogenys borneensis	3.22	50.00	75.00	2	4	4	10
Leptogenys diminuta	0.41	45.83	66.67	1	4	4	9
Leptogenys kitteli	2.78	45.83	66.67	2	4	4	10
Leptogenys sp.16 of AMK	0.72	37.50	50.00	1	3	3	7
Odontoponera denticulata	0.87	50.00	75.00	1	4	4	9
Odontomachus rixosus	0.83	50.00	75.00	1	4	4	9
Pachycondyla astuta	1.20	41.67	58.33	1	3	3	7
Plathyhyrae parallela	0.28	33.33	41.67	1	2	2	5
Dolichoderus thoracicus	2.76	50.00	75.00	2	4	4	10
Dolichoderus tuberifera	2.96	45.83	66.67	2	4	4	10
Iridomyrmex ancep	0.57	37.5	50.00	1	3	3	7
Ochetellus sp.1 of AMK	0.16	33.33	41.67	1	2	2	5
Anoplolepis gracilipes	8.08	58.33	91.67	5	5	5	15
Camponotus (Colobobsis) sp.6 of AMK	4.58	45.83	66.67	3	4	4	11
Camponotus (Myrmosericus) Rufoglaucus	1.01	37.50	50.00	1	3	3	7
Camponotus (Myrmembly) sp.3 of AMK	0.59	37.50	50.00	1	3	3	7
Camponotus (Tanaemyrmex) sp.1 of AMK	0.54	33.33	41.67	1	2	2	5
Camponotus (Tanaemyrmex) sp.7 of AMK	1.25	41.67	58.33	1	3	3	7
Oecophylla smaragdina	1.14	41.67	58.33	1	3	3	7
Paratrechina longicornis	0.40	37.50	50.00	1	3	3	7
Paratrechina sp.2 of AMK	1.31	16.67	16.67	1	1	1	3
Plagiolepis sp.1 of AMK	2.07	29.17	33.33	1	2	2	5
Polyrhachis (Cyrtomyrma) Laevissima	1.78	37.50	50.00	1	3	3	7
Polyrhachis (Myrmhopla) dives	0.73	29.17	33.33	1	2	2	5

Table 7 (continued)

Species	R-A	Freq	Occur	W1	W2	W3	Total
Polyrhachis (Myrma) illavdata	0.18	33.33	41.67	1	2	2	5
Pronolepis sp.1 of AMK	0.52	37.5	50.00	1	3	3	7
Psedolasius sp.1 of AMK	2.83	29.17	33.33	1	2	2	5
Crematogaster (Crematogaster) sp.1of AMK	0.65	37.50	50.00	1	3	3	7
Crematogaster (Crematogaster) sp.9 of AMK	3.54	33.33	41.67	1	2	2	5
Crematogaster (Orthocrema) sp.1of AMK	0.37	37.50	50.00	1	3	3	7
Crematogaster (Paracrema) Coriaria	1.95	37.5	50.00	1	3	3	7
Monomorium destructor	9.92	45.83	66.67	5	4	4	13
Myrmicaria sp.3 of AMK	0.17	29.17	33.33	1	2	2	5
Pheidole plagiaria	2.36	33.33	41.67	1	2	2	5
Pheidole platifrons	1.13	37.50	50.00	1	3	3	7
Pheidole tandjogensis	0.79	33.33	41.67	1	2	2	5
Pheidole sp.8 of AMK	2.40	29.17	33.33	1	2	2	5
Pheidole sp.11 of AMK	0.77	45.83	66.67	1	4	4	9
Pheidologaton affinis	4.17	50.00	75.00	3	4	4	11
Pheidologaton diversus	8.44	50.00	75.00	5	4	4	13
Phoptomyrmex wrougtonii	0.22	33.33	41.67	1	2	2	5
Solenopsis geminata	0.47	37.50	50.00	1	3	3	7
Tetramorium smithii	0.65	37.50	50.00	1	3	3	7
Tetramorium kheperra	0.10	33.33	41.67	1	2	2	5
Tetramorium sp.3 of AMK	0.24	33.33	41.67	1	2	2	5
Aenictus binghami	2.26	37.50	50.00	1	3	3	7
Aenictus laeviceps	1.78	33.33	41.67	1	2	2	5
Bothriomyrmex sp.1 of AMK	5.79	33.33	41.67	3	2	2	7
Tetraponera attenuata	2.08	33.33	41.67	2	2	2	6
Tetraponera sp.1of AMK	0.77	45.83	66.67	1	4	4	9

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