ความหลากหลายทางชีวภาพของปลวกและความสัมพันธ์กับระบบนิเวศป่าเต็งรังและป่าดิบแล้งในสถานีวิจัยสิ่งแวดล้อมสะแกราช จังหวัดนครราชสีมา

นางพรศิริ ทิพย์สันเทียะ

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิทยาศาสตรมหาบัณฑิต
สาขาวิชาชีววิทยาสิ่งแวดล้อม
มหาวิทยาลัยเทคโนโลยีสุรนารี
ปีการศึกษา 2554

BIODIVERSITY OF TERMITES AND THEIR RELATIONSHIP TO DRY DIPTEROCARP AND DRY EVERGREEN ECOSYSTEMS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA PROVINCE

Pornsiri Thipsantia

A Thesis Submitted in Partial Fulfillment of the Requirements for the

Degree of Master of Science in Environmental Biology

Suranaree University of Technology

Academic Year 2011

BIODIVERSITY OF TERMITES AND THEIR RELATIONSHIP TO DRY DIPTEROCARP AND DRY EVERGREEN ECOSYSTEMS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA PROVINCE

Suranaree University of Technology has approved this thesis submitted in partial fulfillment of the requirements for a Master's Degree.

Thesis examining committee

(Assoc. Prof. Dr. Yupaporn Chaiseha)

Chairperson

(Asst. Prof. Dr. Nathawut Thanee)

Member (Thesis Advisor)

(Asst. Prof. Dr. Ratchadaporn Benchawattananon)

Member

(Mr. Taksin Artchawakom)

Member

(Prof. Dr. Sukit Limpijumnong)

Vice Rector for Academic Affairs

(Assoc. Prof. Dr. Prapun Manyum)

Dean of Institute of Science

พรศิริ ทิพย์สันเทียะ: ความหลากหลายทางชีวภาพของปลวกและความสัมพันธ์กับระบบนิเวศป่าเต็งรังและป่าดิบแล้ง ในสถานีวิจัยสิ่งแวดล้อมสะแกราช จังหวัดนครราชสีมา (BIODIVERSITY OF TERMITES AND THEIR RELATIONSHIP TO DRY DIPTEROCARP AND DRY EVERGREEN ECOSYSTEMS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA PROVINCE) อาจารย์ที่ปรึกษา: ผู้ช่วยศาสตราจารย์ ดร.ณัฐวุฒิ ธานี, 100 หน้า.

การศึกษาความหลากหลายทางชีวภาพของปลวกในป่าเต็งรังและป่าดิบแล้ง ของสถานีวิจัยสิ่งแวดล้อมสะแกราช จังหวัดนครราชสีมา ภาคตะวันออกเฉียงเหนือของประเทศไทย และศึกษาความสัมพันธ์ของปลวกกับปัจจัยสิ่งแวดล้อมบางประการ ระหว่างเดือนตุลาคม พ.ศ. 2552 ถึงเดือนกันยายน พ.ศ. 2553 โดยใช้วิธีการเก็บตัวอย่างปลวก 3 วิธี ได้แก่ การเก็บตัวอย่างโดยตรง การใช้หลุมดิน และการวางกับดักกล่อ จากการศึกษาพบปลวกทั้งสิ้น 3 วงศ์ จำแนกเป็น 6 วงศ์ย่อย 18 สกุล และ 25 ชนิด ป่าดิบแล้งมีความหลากหลายทางชนิดของปลวก 25 ชนิด ซึ่งสูงกว่าป่าเต็งรังที่พบความหลากหลายทางชนิด 18 ชนิด ปลวกในวงศ์ย่อย Kalotermitinae และ Rhinotermitinae พบเฉพาะในป่าดิบแล้งเท่านั้น ปลวก *Microcerotermes crassus* เป็นปลวกชนิดเด่นในทั้งสองป่า รองลงมาได้แก่ *Hypotermes makhamensis Globitermes sulphureus Macrotermes gilvus* และ *Macrotermes carbonarius* ตามลำดับ การศึกษาดัชนีความหลากหลายของปลวกแบบแชนนอน พบว่าป่าดิบแล้งมีค่าดัชนีความหลากหลายของปลวกสูงกว่าป่าเต็งรังคือ 3.079 และ 2.744 ตามลำดับ ในขณะที่ค่าความสม่ำเสมอในป่าดิบแล้งมีค่าเท่ากับ 0.0957 ซึ่งสูงกว่าในป่าเต็งรังที่มีค่าเท่ากับ 0.0949 ความหนาแน่นของประชากรปลวกมีค่าสูงที่สุดในเดือนกันยายน พ.ศ. 2553 (230.53 ตัวต่อตารางเมตร) และต่ำสุดในเดือนมกราคม พ.ศ. 2553 (113.43 ตัวต่อตารางเมตร) การศึกษาดัชนีความคล้ายคลึงในทั้งสองป่าพบว่ามีค่าเท่ากับ 0.8372 หรือร้อยละ 83.72 ความสัมพันธ์ระหว่างความหนาแน่นของประชากรปลวกกับปัจจัยทางด้านสิ่งแวดล้อมพบว่าความหนาแน่นของประชากรปลวกมีความสัมพันธ์เชิงบวกอย่างมีนัยสำคัญกับความชื้นของดิน (P<0.05, r=0.728) และมีความสัมพันธ์เชิงลบอย่างมีนัยสำคัญกับอุณหภูมิของดินในป่าเต็งรัง (P<0.05, r=-0.646) โดยไม่มีความสัมพันธ์กับปริมาณน้ำฝน อุณหภูมิของอากาศ ความชื้นสัมพัทธ์ และความเป็นกรด-ด่างของดิน สำหรับป่าดิบแล้งพบว่า ความหนาแน่นของประชากรปลวกไม่มีความสัมพันธ์กับทุกปัจจัยทางด้านสิ่งแวดล้อมที่ศึกษา (P<0.05) ผลการศึกษาโปรโตซัวในลำไส้ของปลวก พบโปรโตซัวเฉพาะในลำไส้ของปลวก *Schedorhinotermes* sp. เท่านั้น ซึ่งจัดเป็นปลวกกลุ่มกินไม้และถูกจัดเป็นปลวกชั้นต่ำ โดยโปรโตซัว *Trichonympha* sp. เป็นโปรโตซัวกลุ่มเด่นที่พบในการศึกษาครั้งนี้ รองลงมาได้แก่ *Psuedotrichonympha* sp. *Spironympha* sp. และ *Dinenympha* sp. ตามลำดับ สรุปได้ว่า การศึกษาครั้งนี้ทำให้ได้ข้อมูลที่มีประโยชน์เกี่ยวกับความ

หลากหลายทางชีวภาพของปลวก และความเปลี่ยนแปลงของประชากรปลวกในระบบนิเวศป่าเต็งรังและป่าดิบแล้งในสถานีวิจัยสิ่งแวดล้อมสะแกราช และความสัมพันธ์กับชนิดของโปรโตซัวในลำไส้ปลวก สามารถใช้เป็นข้อมูลพื้นฐานทั้งในด้านการจัดการปลวก และการอนุรักษ์ระบบนิเวศพร้อมกับการพัฒนาที่ยั่งยืนในอนาคต

สาขาวิชาชีววิทยา
ปีการศึกษา 2554

ลายมือชื่อนักศึกษา Pd
ลายมือชื่ออาจารย์ที่ปรึกษา

PORNSIRI THIPSANTIA: BIODIVERSITY OF TERMITES AND THEIR RELATIONSHIP TO DRY DIPTEROCARP AND DRY EVERGREEN ECOSYSTEMS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA PROVINCE. THESIS ADVISOR: ASST. PROF. NATHAWUT THANEE, Ph.D. 100 PP.

TERMITE BIODIVERSITY / FOREST ECOSYSTEMS / GUT PROTOZOA / SAKAERAT ENVIRONMENTAL RESEARCH STATION, NAKHON RATCHASIMA

The biodiversity of termites in two different forest types, dry dipterocarp forest (DDF) and dry evergreen forest (DEF) was studied at Sakaerat Environmental Research Station (SERS), Nakhon Ratchasima province, northeastern Thailand during October 2009 – September 2010. The relationship of termites and some environmental factors was also investigated. The three different sampling methods in use were direct search, soil pit and bait trap station. A total of 3 families, 6 subfamilies, 18 genera and 25 species were found in the studied areas. Species diversity of termites in DEF was found to be higher than that of DDF with 25 species of 18 genera recorded from DEF and 18 species of 14 genera from DDF, respectively. The subfamily Kalotermitinae and subfamily Rhinotermitinae were found only in DEF. While *Microcerotermes crassus* was found to be the dominant species in both DDF and DEF followed by *Hypotermes makhamensis, Globitermes sulphureus, Macrotermes gilvus,* and *Macrotermes carbonarius,* respectively. Termite diversity was determined by using Shannon's diversity index (H'), evenness and species richness. It was found that DEF and DDF had H'-index value of 3.079 and 2.744, respectively. The DEF had indicated as the higher evenness with 0.957

and 0.949 in DDF. The maximum density was in September 2010 (230.53 individuals/m^2) while the minimum density was in January 2010 (113.43 individuals /m^2). Sorensen's index was used for similarity of species components in each forest type which showed the value of 0.8372 or 83.72%. The termite density was positively significant correlated with soil moisture (P<0.05, r=0.728), whereas negatively significant correlated with soil temperature (P<0.05, r=-0.646) in the DDF. There was no correlations with rainfall, air temperature, relative humidity and soil pH. In the DEF showed no correlations between termite density and environmental factors in this study (P<0.05). The flagellated protozoa were presented only in species of termites *Schedorhinotermes* sp. which was a group of wood feeding termites and were classified into lower termites, but the higher termites were not found these protozoa. *Trichonympha* sp. was found to be the dominant protozoa species followed by *Psuedotrichonympha* sp., *Spironympha* sp. and *Dinenympha* sp., respectively. In summary, the information of this study provides the beneficial data of biodiversity and variation in the population of termites in DDF and DEF of SERS and the relationship between protozoa species in termite gut. In addition to knowledge based both for the termite management and ecosystem conservation together with the sustainable development in the future.

School of Biology | Student's Signature ____________

Academic Year 2011 | Advisor's Signature ____________

ACKNOWLEDGEMENTS

I would like to express my sincere appreciation and gratitude to Assistant Professor Dr. Nathawut Thanee, my thesis advisor, for his kind guidance and valuable discussions throughout this period of the study and thesis. I am grateful to the other members of my examining committee, Associate Professor Dr. Yupaporn Chaiseha, Chair of School of Biology as the Chairperson, Assistant Professor Dr. Ratchadaporn Benchawattananon, Dean of Faculty of Science and Technology, Loei Rajabhat University and Mr. Taksin Artchawakom, Director of Sakaerat Environmental Research Station (SERS), for their warm encouragement and suggestions of the thesis.

Special thanks to SERS staffs for the selection of the study sites and kind suggestions. Many thanks to the Royal Forest Department staffs for their kind advice and the use of the quick guide to identification of termite in Thailand to aid with the comparison of my termite specimens.

I would like to thank the Center for Scientific and Technological Equipment, Suranaree University of Technology for providing laboratory analyses and valuable comments and discussions.

Finally, I wish to express my gratitude to my parent and my family for their encouragement and support.

This research was financially supported by the National Research Council of Thailand and the Institute for the Promotion of Teaching Science and Technology.

Pronsiri Thipsantia

CONTENTS

CONTENTS (Continued)

CONTENTS (Continued)

CONTENTS (Continued)

LIST OF TABLES

LIST OF FIGURES

LIST OF FIGURES (Continued)

Figure **Page**

CHAPTER I

INTRODUCTION

1.1 General

Termites are one of eusocial and soil insects that are successfully evolved since the Cretaceous Period. They occur throughout tropic and subtropic regions and also can be found in many temperate areas and semi-arid environments of the world (Eggleton, Davies, Connetable, Bignell and Rouland, 2002). The number of species of termites is abundant because of their high development in social organization by symbiosis with microorganisms in their guts (Vongkaluang, Sornnuwat, Charoenkrung and Chutibhapakorn, 2001). Termites are members of the order Isoptera as they are colony living animals that inhabit in multiple dwelling and they form colonies in wood or on the ground in damp. Termites are classified into 7 families, 14 subfamilies, 280 genera and 2,500 species (Pearce, 1999).

Termites play an important role in nutrient cycles by accelerating decomposition. They are also named as soil engineers that modify the soil structure by constructing mounds and subterranean nests providing many species of animals and plants with diverse habitats and supplying materials for many food chains. (Matsumoto, 1976).

Thailand is located in the topical region which consists of high diversities of forest ecosystem which is suitable for termites growth and development. The various types of forest ecosystems, both of plants with covered species diversity, biomass and soil that play a great impact on different of plants providing the different of litter fall and dead logs and decaying wood. The abundance and number of species of termites in the ecosystem are dependant on the quantity of leaf litter fall because termites chiefly feed on litter and decompose it which providing nutrient cycles (Vongkaluang et al., 2001).

Sakaerat Environmental Research Station (SERS) is situated at Wangnamkhieo and Pakthongchai districts, Nakhon Ratchasima province, northeastern Thailand, an area of approximately 80 square kilometers. The SERS is one of the world biosphere reserves in Thailand and used for the research on the environment and ecology of tropical forest ecosystems. The topographical characteristics are dry evergreen forest and dry dipterocarp forest which consist of a variety of different plant species in two forest types providing a suitable environment for studying termite population and their relationship to some ecological factors that affect species compositions and biodiversity of termites.

The purposes of this study were to investigate the diversity of termites, evenness, abundance, seasonal variation of termite community and some ecological factors affecting termite diversity, and to investigate the protozoan in termite digestive system. In addition, the relationships between termites and some ecological factors and protozoan were also studied.

1.2 Objectives

The objectives of this study are:

1.2.1 To study biodiversity and variation in the population of termites in dry dipterocarp and dry evergreen forests of the SERS.

1.2.2 To investigate the seasonal variation of termite community and some ecological factors affecting termite diversity.

1.2.3 To identify the protozoa in digestive system of termite diversity.

1.3 Scope and limitation of the study

1.3.1 Biodiversity of termites was investigated in two different habitats; dry evergreen forest and dry dipterocarp forest in SERS.

1.3.2 The ecological factors affecting the termite populations were classified in 4 groups:

1.3.2.1 The soil factors: soil pH, soil temperature, and soil moisture.

1.3.2.2 The climatic factors: air temperature, relative humidity and annual rainfall.

1.3.2.3 The termites habitat: the vegetation type.

1.3.2.4 The protozoan in digestive system of termites.

1.3.3 Quantitative samplings of biodiversity of termites were collected for 12 months from October 2009 to September 2010.

CHAPTER II

LITERATURE REVIEW

2.1 Evolution of termites

Termites are one of eusocial and soil insects that can be classified into order Isoptera, and characterized by their colonial behaviors. Termites have been living on this planet for over 100 million years, before flowering plants, and could be dated back to the Mesozoic or late Paleozoic period. They are closely related taxonomically to wood-eating cockroach ancestors (Ahmad, 1965). They appear white in colour and are often called "white ants", however, they are different from ants and other social insects in term of morphology and phylogenetics.

One of the major differences between termites and other social insects; such as ants, bees, and wasps; is that their larval and pupal stages are not active within the colony. Another difference is that the male termite (king) remains with the female throughout her lifetime and does not die after mating. Termites also have a broad waist and straight antennae. Above all, termite reproductive stage has four wings of equal size and shape, which the other insects are not equal (Pearce, 1999).

2.2 External morphology (Weesner, 1969)

The Isoptera have three distinct body regions: head, thorax and abdomen.

The head

Important structures located on the head which are used for identification are:

1. Dorsal and lateral structures

1.1 The head capsule

1.2 The labrum

1.3 The clypeus

1.4 The antennae

1.5 The compound eyes

1.6 The ocelli

1.7 The fontanelle, A small opening may be observed in the midline on the top of head, just behind or between the compound eyes.

2. Ventral structures

2.1 The mandibles

2.2 The maxillae

2.3 The labium

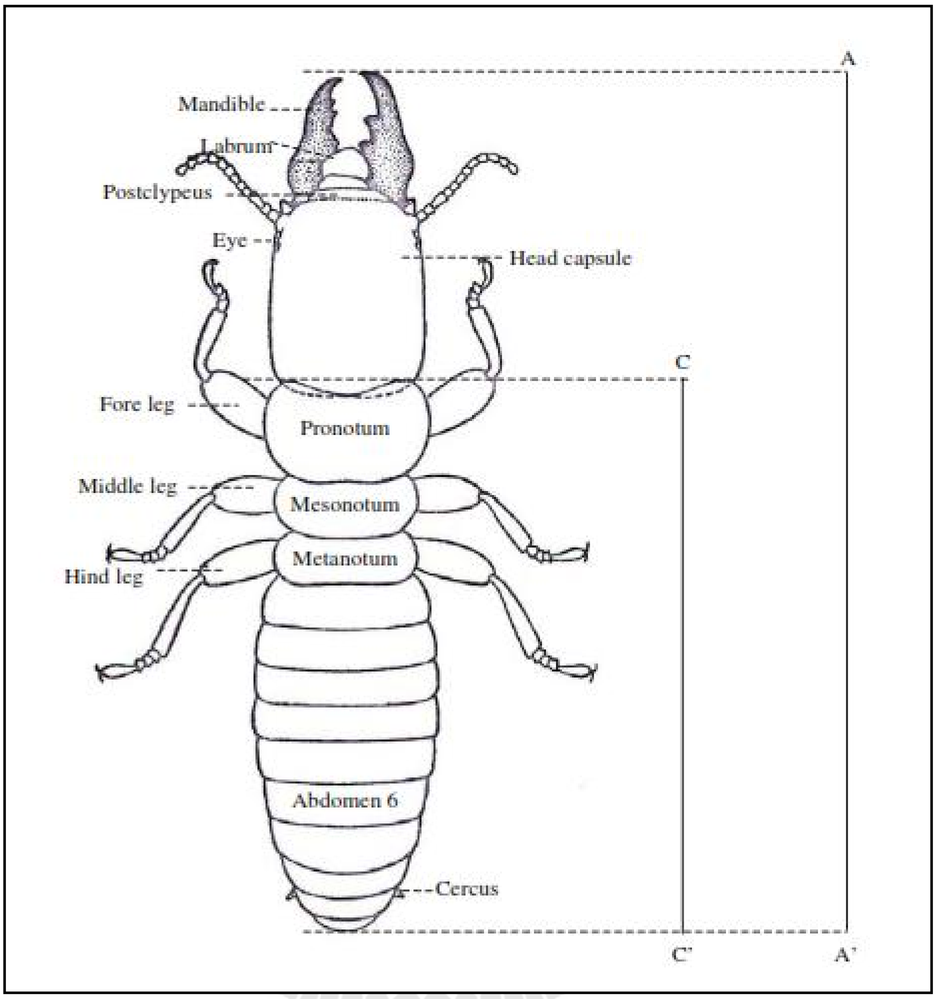
The thorax

The thorax is a complex structure with three distinct segments: the prothorax, the mesothorax and the metathorax, each bearing a pair of legs. The mesothorax and metathorax also bear a pair of wings in the alate.

The abdomen

The abdomen includes ten segments with a set of sclerotized plates: tergite, above, and stermites, below.

General features of soldier and taxonomic measurements which are basic to classification are provided in Figure 2.1.


A
Mandible
Labrum
Postclypeus
Eye
Head capsule
C
Fore leg
Pronotum
Middle leg
Mesonotum
Metanotum
Hind leg
Abdomen 6
Cercus
C'
A'

highest in equatorial rainforest and generally declining with increasing latitude (Colins, 1983). The dominance of termites in tropical ecosystems is mainly related to their ability of utilizing dead plant materials which are rich in cellulose. They play an important role in decomposition processes of organic matter in the ecosystem (Wongsiri, 1993).

2.3 Colony of termites

Termites are polymorphic and eusocial insects which live and work together within nests or colonies of various sizes. A social unit of termites contains in large communities several hundreds to several millions members depending on the age and size of the colony (Pearce, 1999).

Termites take several different forms, each form or caste has different functions to perform within the colony. A typical colony contains three castes composing of reproductive (alate or swarmer or winged) forms, workers, and soldiers. These three castes can easily be distinguished from each other on the basis of external appearances (Figure 2.2).

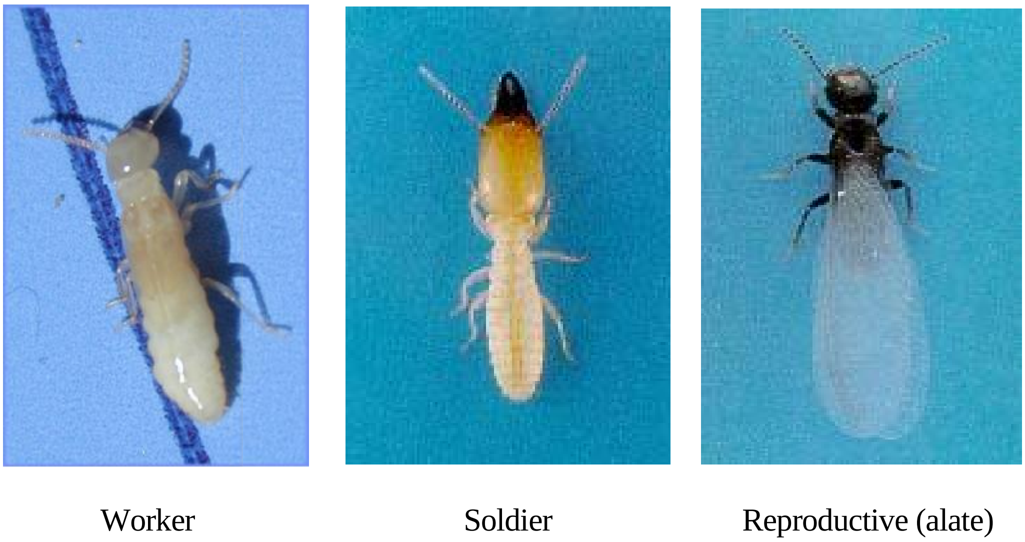


Figure 2.2 Castes of termite**.**

(Source: http://www.securitypest.com/gallery.htm).

The reproductive forms (alates or swarmers)

The reproductive forms are usually alates which mean winged termites. The winged reproductives refer to the parent of termites as the king and the queen whose function are the reproductive stage in a mature colony.

The major role of the queen or female termite is to lay eggs. The queen develops an enlarged abdomen coating ovariales and associated tissues by physogastric. In general, the queen also controls the production of each caste in a colony by pheromonal regulation.

The king or male termite can be distinguished from females by the presence of styles on the 9th sternal segment. The king is the fertile male of the community and is smaller than the queen but larger than the workers and the soldiers. The king is only responsible for fertilizing the queen and does not die after mating (Pearce, 1999).

The worker form

The worker caste account for the largest number of termites within the colony. These castes play the major role in the survival of the colony. They are responsible for the nest construction and maintenance, foraging, tending to the king, the queen and their young. The worker termites are generally unpigmented and also blind, wingless and have undeveloped reproductive organs (Sornnuwat et al., 2004).

The soldier form

The soldier castes are the only social insects with a true soldier caste which the major role is only to defend the colony. For the morphology, they are darker and bigger than worker caste and have defensive adaptations such as enlarged mandibles, with well developed jaws used to crush attackers. However, they are blind, wingless and have undeveloped reproductives organs like the worker caste (Sornnuwat et al., 2004).

2.4 Life cycle

Termites are ametabolous insects. The life cycle consists of three stages: egg, nymph, and adult (Pearce, 1999). All termites begin their lives as eggs which hatch into the young or nymphs, which are immature termites and resemble to the adult except that the youngs are smaller and usually possess wing pads and undeveloped reproductive system, whereas the adults posses fully developed wings. The nymphs are developed by moulting or shedding their outer cuticles several times until they develop to the mature forms as sterile workers or soldiers, depending to the need of the colony. These developments are determined by extrinsic factors such as pheromones and hormones of the queen. The entire life span of termites is 4 years. However, some queens can live over 10 years (Figure 2.3).

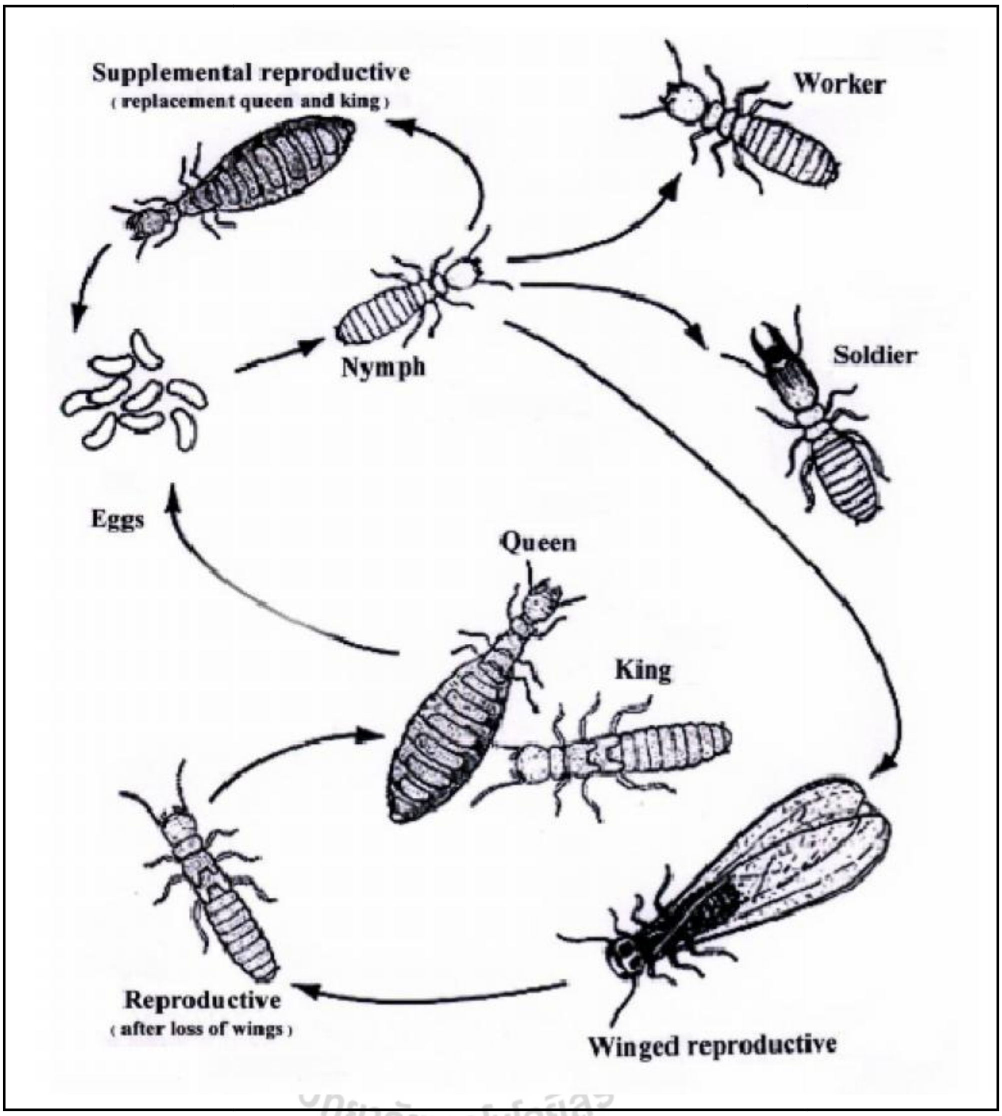


Figure 2.3 Life cycle of termite**.**

(Vongkaluang et al., 2001).

When the reproductive castes or alates are fully grown, they will leave together from their nests as a swarm under conditions of high humidity and low light in the day after rainfall.

Alates fly briefly until they find a mate. The female then mates with the male while still in the air. The male remains with the queen throughout their lifetime and survive after mating.

A pair of alates shed their wings and most of them get eaten by birds, bats, ants, spiders, frogs, toats, and lizards. The surviving alates select a new nesting site under suitable environmental conditions and food for feeding the new colony. The pair will become the king and the queen of the new colony. After that the queen lays eggs which hatch into nymphs. In the first time, the parent termites, the king and queen collect food for their the young until they develop into the first workers. Once these initial workers mature, they take care of the colony. Some of the young termites develop into the soldiers and reproductive stage (Vongkaluang et al., 2001).

The colony grows slowly for many years, accompanied by a continuous increase in the number of individuals, enlargement of the nest and much building activities.

2.5 Feeding

The majority of termites are detritivorous insects that are primarily wood feeders, but also feed on a variety of other organic substrates, such as living trees, leaf litter, soil, lichens, mosses, animal faeces, dung and humus. Termites can pass partially digested semi-liquid food from the crop or secretions by mouth or receive secretions from the anus of another termite. This is called “trophallaxis” which involves the exchange of secretions liquid food between individuals. This is especially important when there is a shortage of food and moisture and is important for the transmission of chemical messages and some of protozoan to other termites, throughout the colony and finally back to the queen (Pearce, 1999).

The Forest Economic and Forest Products Research Office, Royal Forest Department, Thailand surveyed the diversity of termites in Thailand and study in the different types of forest ecosystem, feeding habitats and the function of feeding group that can be classified to 2 types based on food types and nesting and based on microorganisms in digestive system (Vongkaluang et al., 2001).

1. Based on food types and nesting

1.1 Wood feeder

These primitive wood eating termites feed on wood that can be found in living trees and underground. Most of these termites are arboreal, subterranean or epigeal nesters. Some live in wood and are called “dry wood termites and damp wood termites”.

1.2 Soil and humus feeder

Termites feeding on the soil mixed with leaf litter in stilt root complexes. They are found in the soil profile, in the organic litter layer, such as mound-building termites and carton nest termites.

1.3 Wood and leaf feeder or fungus feeder

Termites that forage for leaf litter and small woody items litter in various stages of decay. This group includes some subterranean and other mound building termites (Harnboonsong, 1986).

1.4 Lichen feeder

Termite of this group forage for lichens, moss, algae, and fungi on tree bark. Most of these groups are mound-building termites.

2. Based on microorganisms in digestive system

In digestion, termites cannot produce cellulase to digest cellulose from their food, but they are an important host of microorganisms that symbiosis in their hindguts. These microorganisms including that bacteria, protozoan, and fungi which produce important enzymes such as cellulase, lignocellulase for digesting cellulose or lignin (Higashi and Abe, 1997). The types of organisms found in hindgut of termites can divide termites into two rough categories:

2.1 The lower termites

Most of these termites feed on wood and they have flagellate protozoa and bacteria in their hindguts. The protozoa can digest hemicelluloses to some extent cellulose. These are fermented anaerobically by protozoa in the gut to produce acetate and carbon dioxide, hydrogen and methane, which are released. In Thailand, there are 3 families; Kalotermitidae, Termopsidae and Rhinotermitidae (Sornnuwat et al., 2004).

2.2 The higher termites

This is the largest group of termite that feed on soil, humus, lichen, and fungus. They are a highly developed social organization for survival in dry ecosystems and the shot stage of food by adapting the mutualistic relationship with bacteria and fungi in their hindguts. Some bacteria can fix nitrogen for the formation of amino acids and proteins for growth and survival of termites. Some bacteria can produce enzymes for decomposing substrates in the environment. In Thailand, these termites belong to the family Termitidae (Sornnuwat et al., 2004).

2.6 Nesting

Termites live in colonies and create their own habitats. They live in nests or mounds known as “termitarium”, within wood, trees, buildings, subterranean, above ground as mounds, or arboreal (in trees) which depending on the termites species. Both the nests and mounds are constructed using soil from nearby area. The appearance and kind of nests vary with environmental conditions, such as moisture, availability and locality. Different colonies of the same species also have different nest forms. Termite nest system can be classified according to (Sornnuwat et al., 2004):

2.6.1 Wood nesting termites

Termites in these groups live inside a piece of wood for lifetime. They can live entirely within food sources and move to other sources of wood. In general, wood nesting termites can be found in dry wood called “dry wood termites”. Some termite colonies can be found in moist wood, damp wood, called “damp wood termite”. This includes the families Kolotemitidae, Rhinotermitidae and Termitidae.

2.6.2 Subterranean termites

Termites are nesting entirely below the ground. They use their feces or a mixture of feces and mineral soil in nest construction. This group also includes many species in genera *Coptotermes*, *Microtermes* and *Hypotermes*. They have a large impact on the economy of several countries.

2.6.3 Mound building termites

Termites with some part of their mounds or nests protruding above ground. They build the middle to large mounds on the ground beside trees. The materials used for construction are soil, salivary secretion and a mixture of faces with mineral soil. These groups are in genera *Odontotermes* and *Macrotermes*.

2.6.4 Carton nest termites

Termites that build a small nest on the ground or above the ground such as branches, trees, and the other inner structures. Nests are attached outwardly to trees at different heights. These nests are normally made of wood carton. These groups are genera of *Microcerotermes*, *Termes*, *Nasutitermes*, and *Hospitalitermes*.

2.7 Taxonomy of termites

There are seven families of termites that have been described worldwide: Mastotermitidae, Hodotermitidae, Termopsidae, Serritermitidae, Kalotermitidae, Rhinotermitidae and Termitidae. These families are devided into 14 subfamilies, 270 genera and approximately 2650 species (Pearce, 1999). While the current records of termite species from Thailand have been 4 families, 10 subfamilies, 39 genera and 199 species (Sornnuwat et al., 2004). The overviews of each family in Thailand are following.

2.7.1 Termopsidae

Termopsidae is a new record of termite family in Thailand. One new record of termite genus is *Archotermopsis* found in northern Thailand. The morphological characteristics of soldiers in these genera have the head without fontanelle and their antennae have more than 22 segments (Amornsak et al., 2003).

2.7.2 Kalotermitidae

Most of the species in this family are generally similar to the dry wood termites. This is the largest family of lower termites, one subfamily is Kalotermitinae with 4 genera and 24 species. These termites occur in small numbers in rain forests. Many species in this family are serious pests of forest products. Soldiers normally have robust, phramotic heads, which are of particular value in blocking and defending nest galleres (Collins, 1980).

2.7.3 Rhinotermitidae

This is the most important family of lower termites. They are damp wood termites which are found in standing or fallen trunks. They can cause damage to timber and living trees. Some of these species are an important pest infesting rubber trees. These groups are 4 subfamilies, 10 genera and 16 species. Soldier morphology has monomorphic and dimorphic types (Sornnuwat et al., 2004).

. 2.7.4 Termitidae

The family Termitidae is a highly specialized form of higher termite that contains three-quarters of all known species, especially subfamilies Termitinae and Nasutitermitinae. One of the important subfamily is the Macrotermitinae which can be cultivated species of the symbiotic basidiomycete fungus Termitomyces on faucal combs within their nests. Subfamilies Termitinae and Nasutitermitinae include both of wood and soil feeding and they dominate most tropical forest ecosystems.

Key to genera of termite of Thailand (Sornnuwat et al., 2004)

Soldier

1. Head without fontanelle...**2**
- Head with fontanelle..**6**
2. Antennae more than 22 segments .... ***Archotermopsis***
- Antennae less than 20 segments **3**
3. Head long or weakly phragmotic..**4**
- Head short and strongly phragmotic...***Cryptotermes***
4. Third segment of antennae elongated like club shape; antero-lateral margin of pronotum deeply concave...***Incisitermes***
- Third segment of antennae not elongate like club shape...**5**
5. Forehead steeply sloping, with antero-lateral lobes; antennae with less than 15 segments ....***Glyptotermes***
- Forehead gently sloping, without antero-lateral lobes; antennae with 15 or more segment...***Neotermes***
6. Pronotum flat...**7**
- Pronotum saddle shaped.. **11**
7. Mandibles saber-shaped, without any marginal teeth **8**
- Mandibles with prominent marginal teeth **10**

8. Fontanelle very wide and close to clypeus ....***Coptotermes***

\- Fontanelle small, circular, placed much behind clypeus **9**

9. Head elongate oval with a groove running forward from
the fontanelle .... ***Prorhinotermes***

\- Head rectangular, parallel sided ....***Reticulitermes***

10. Soldiers monomorphic; labrum prominent; mandibles with leaf shape
marginal teeth .... ***Parrhinotermes***

\- Soldiers dimorphic ....***Schedorhinotermes***

11. Mandibles well developed, functional; head not produce into a nasutus **12**

\- Madibles degenerate, non-functional; head produced into a nasutus
(nasutiforms) **31**

12. Mandibles symmetrical, curved at tips, used for biting... **13**

\- Mandibles slightly to strongly asymmetrical, used for snapping or for both
snapping and biting.. **25**

13. Left mandible without teeth but cutting edge crenulated basally **14**

\- Left mandible with one or two teeth or teeth or cutting edge serrated **19**

14. Labrum with hyaline tip; meso and metanotum greatly expanded laterally;
soldiers distinctly dimorphic ....***Macrotermes***

\- Labrum without hyaline tip; meso and metanotum not greatly expanded laterally;
soldiers monomorphic **15**

15. Head rectangular .... ***Microcerotermes***

\- Head round **16**

16. Mandible with crenulation... **17**

\- Mandible without crenulation **18**

17. Mandibles long, strongly curve..***Prohamitermes***

- Mandibles short, weakly curve ....***Hypotermes***

18. Mandibles weakly curved apically; head oval ....***Microtermes***

- Mandible strongly curved apically; head as nearly broad as long..........***Ancistrotermes***

19. Right mandible with distinct teeth **20**

- Right mandible with minute or without teeth .... ***Odontotermes***

20. Clypeus distinctly bilobed; head longer than wide; tooth of left mandible
laterally directed...***Amitermes***

- Clypeus not bilobed **21**

21. Head round or globular; mandibles long, strongly curve downward ....***Globitermes***

- Head shot parallel-sided **22**

22. Mandibles long, saber shaped, slightly curved apically ....***Synhamitermes***

- Mandibles short; stoutly built, not very strongly curved apically................................ **23**

23. Pronotum very strongly saddle shaped, anterior lobe longer than posterior lobe; head hypognathous, covered with dense coat of thin short hairs;
tarsi three-segmented ....***Indotermes***

- Pronotum not very strongly saddle shaped, anterior lobe not longer than
posterior lobe.. **24**

24. Mandibles with large broad tooth .... ***Speculitermes***

- Mandibles with small, pointed tooth ....***Euhamitermes***

25. Head with frontal projection.. **26**

- Head without frontal projection **28**

26. Mandibles slightly asymmetrical **27**

- Mandibles strongly asymmetrical, left mandible twisted;

right mandibles blade-like ....*Mirocapritermes*

27. Labrum shallowly cut; lateral sides almost straight; base of the antenna with a ridge; mandibles long and slender, rodlike, bent downward.............................*Termes*

- Labrum deeply cut; lateral sides convex; base of the antenna without ridge; mandibles anteriorly directed .... *Angulitermes*

28. Antennae with 13 segments; head distinctly narrowed anteriorly; mandibles with tip not bent in form of hook..*Homallotermes*

- Antennae with 14 segments; mandibles slightly to strongly Asymmetrical............... **29**

29. Antero-lateral corners of head rounded without projections....................................... **30**

- Antero-lateral corners of head with pointed projections below antennal sockets with its lateral corners produced into long needle-like projections; anterior margin of labrum deeply concave ....*Dicuspiditermes*

30. Labrum with anterior margin straight; anterolateral corners very short; tip of left mandible broad, not strongly bent .... *Pericapritermes*

- Labrum with anterior margin concave; its anterolateral corners long; tip of left mandible narrow, bent in form of hook..*Procapritermes*

31. Head constricted behind antennae sockets **32**

- Head not constricted behind antennae sockets... **35**

32. Legs and antennae greatly elongated; hind femora as long as or longer than abdomen **33**

- Legs and antennae not unusually long; head not produced behind, not depressed at base of nasus...*Bulbitermes*

33. Third antennae segment moderately long and shorter than or subequal to fourth; soldiers generally with distinct color forms ....*Lacessititermes*

- Third antennae segment very long much longer than fourth **34**

34. Soldier monomorphic; head not greatly produced behind .... ***Hospitalitermes***

- Head triangular, greatly produced behind; soldiers distinct dimorphism; legs paler than the body ....***Longipeditermes***

35. Nasutus with minute projection at base on each side; head covered with minute hairs; mandibles without apical projection ....***Aciculitermes***

- Nasutus without projection at base **36**

36. Antennal articles long, apical projection of mandible with minute tooth; dorsal profile of head weakly concave; rostrum long...***Havilanditermes***

- Antennal articles short, apical projection of mandible without tooth; dorsal profile of head straight ....***Nasutitermes***

Classification of termite in Thailand

Classification of termite by Sornnuwat, Vongkaluang and Takematsu (2004), Pearce (1999) and Krishna (1970) is being classified as:

Kingdom Animalia

Phylum Arthropoda

Class Insecta

Order Isoptera

Family 1. Kalotermitidae

1.1 Subfamily Kalotermitinae

1.1.1 Genera *Cryptotermes*

1.1.2 Genera *Glyptotermes*

1.1.3 Genera *Neotermes*

1.1.4 Genera *Bifiditermes*

1.1.5 Genera *Incistitermes*

1.1.6 Genera *Postelectrotermes*

Family 2. Termopsidae

2.1 Subfamily Termopsinae

2.1.1 Genera *Archotermopsis*

Family 3. Rhinotermitidae

3.1 Subfamily Rhinotermitinae

3.1.1 Genera *Schedorhinotermes*

3.1.2 Genera *Parrhinotermes*

3.2 Subfamily Prorhinotermitinae

3.2.1 Genera *Prorhinotermes*

3.3 Subfamily Heterotermitinae

3.3.1 Genera *Reticulitermes*

3.4 Subfamily Coptotermitinae

3.4.1 Genera *Coptotermes*

Family 4. Termitidae

4.1 Subfamily Macrotermitinae

4.1.1 Genera *Macrotermes*

4.1.2 Genera *Microtermes*

4.1.3 Genera *Ancistrotermes*

4.1.4 Genera *Hypotermes*

4.1.5 Genera *Odontotermes*

4.2 Subfamily Termitinae

4.2.1 Genera *Amitermes*

4.2.2 Genera *Microcerotermes*

4.2.3 Genera *Globitermes*

4.2.4 Genera *Synhamitermes*

4.2.5 Genera *Prohamitermes*

4.2.6 Genera *Termes*

4.2.7 Genera *Dicuspiditermes*

4.2.8 Genera *Pericapritermes*

4.2.9 Genera *Procapritermes*

4.2.10 Genera *Mirocapritermes*

4.2.11 Genera *Homallotermes*

4.2.12 Genera *Angulitermes*

4.3 Subfamily Apicotermitinae

4.3.1 Genera *Indotermes*

4.3.2 Genera *Euhamitermes*

4.3.3 Genera *Speculitermes*

4.4 Subfamily Nasutitermitinae

4.4.1 Genera *Nasutitermes*

4.4.2 Genera *Bulbitermes*

4.4.3 Genera *Hospitalitermes*

4.4.4 Genera *Aciculitermes*

4.4.5 Genera *Havilanditermes*

4.4.6 Genera *Longipeditermes*

4.4.7 Genera *Lacessititermes*

2.8 Some ecological factors affecting on termites

The changes in environmental conditions can changes in termite distribution and populations growth. These ecological factors may be grouped under four heading as follows:

- The soil factors
- The climate factors
- The vegetation types
- The protozoan in digestive system of termite

2.8.1 The soil factors

Most termites are soil insects that live in the ground and exhibit special structural and behavioral adaptation to the physical and chemical conditions for survival. The major properties of soils are as follows.

- Soil temperature

The soil temperature is an important factor that affects termite presence in the area. Different species of termites can have differing temperature tolerance. The temperature within the nests varies between 10 ºC - 35 ºC depending on the species. Sometime the nest shape is specifically designed to regulate temperature. The kind of plant cover also affects soil temperature and termite foraging (Pearce, 1999).

- Soil texture

Soil texture refers to the content of sand, silt, and clay particles in the soil (Suriyapong, 2003). The activity of termites can disturb the soil profile, affects the soil texture and redistributes organic matter. The clay content is the most suitable for termite population. The brood chamber, runways and mounds may have the largest clay content. Sandy soils have very low organic matter content and fewer species of termites are present. Different soil type may accommodate different species because the soil temperature and moisture affect plant communities, which in turn affect termite presence.

2.8.2 The climates

The climatic features play important part in termite survival. These conditions include temperature, rainfall, and relative humidity.

- Temperature

The temperature is an important ecological factor affecting foraging termites. The temperature and moisture affects plant types which in turn affect termite species. In exposed areas, indirect sun termite are often found dwelling below the ground or inside nests at midday and early afternoon, when the temperature is at it's peak, they can come to the surface at thermal shadow.

In sandy regions, the surface temperature can be extremely high and any form of shade or vegetation is important. The small mounds are very hot in dry weather and lose heat more quickly over night. Inside nests, when the nest is in direct sunlight termites will move to the shaded side. They may also move below the ground or aggregate in the center of the nest (Pearce, 1999).

- Rainfall

Rainfall is an important factor that the trigger for the release of reproductive from the nest. Alates may not fly if the rainfall is low or absent. Rainfall is accompanied by a rapid change in the temperature, humidity and pressure that act as the trigger for flight. Heavy rainfall can reduce termite foraging activity. If there is a lack of rain, some termite dig down deeper to the water table.

- Relative humidity

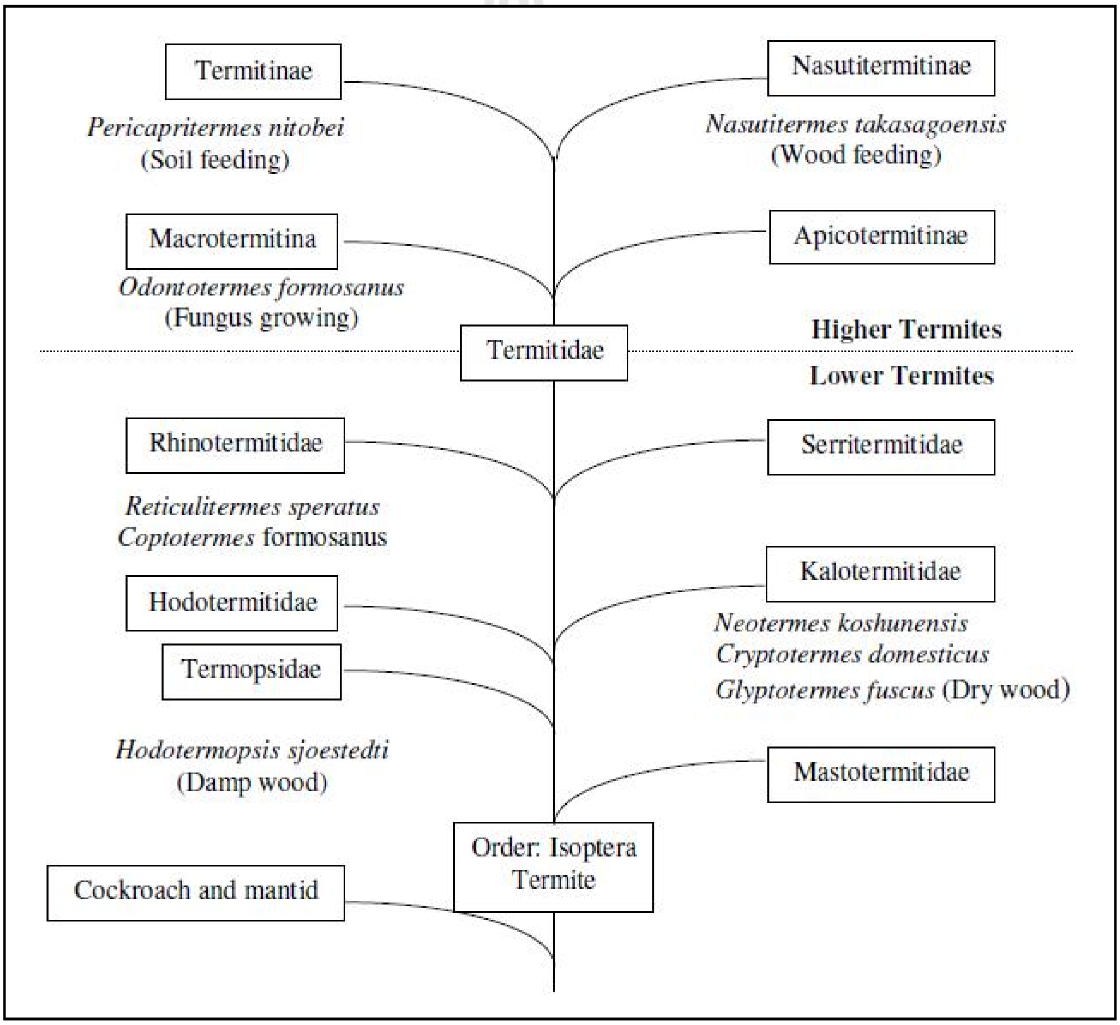
Relative humidity (RH) is a microclimatic variable that derives from the combination of temperature and moisture. It is generally higher in forest areas than in open environments, Termite are maintained at a high humidity to protect their soft body from drying out. The relative humidity is approximately 100%. The moisture required to maintain the temperature and humidity is obtained from the soil. When humidity low, termites can move to a region of lower temperature to survive (Pearce, 1999).

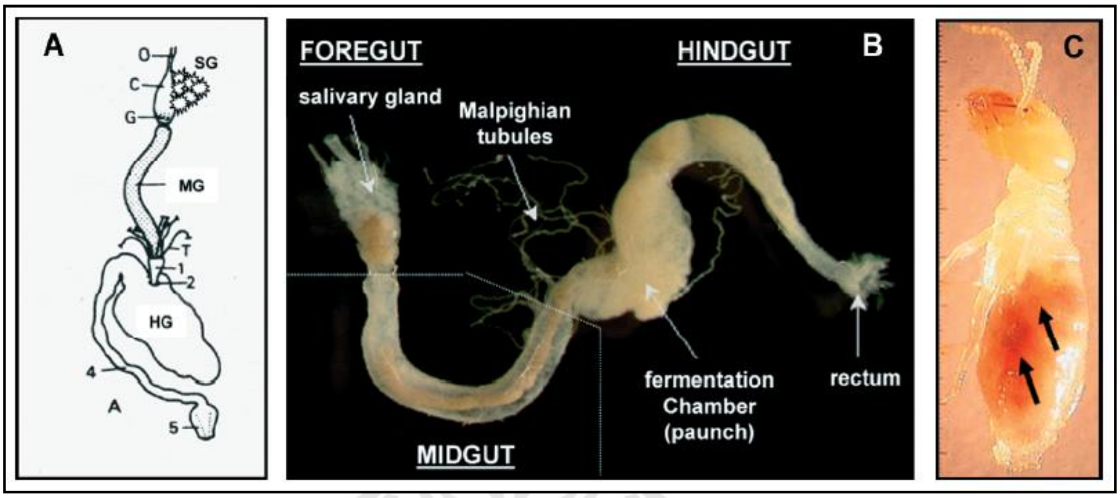
2.8.3 The vegetation types

In tropical evergreen forest which comprises of high diversities of plant species. The various types of forest ecosystems, both of plants with ecosystems, both of plants with covered species diversity, biomass and soil that have a great impact on the diversity of plants providing the different of litter fall and dead logs and decaying wood. The abundance and number of species of termite in the ecosystem depends on the quantity of leaf litter fall that is suitable for termites growth and development because termites chiefly feed on litter and decompose them which providing nutrient cycles (Vongkaluang et al., 2001).

2.8.4 The protozoa in digestive system of termite

Termites are abundant and play an important role in terrestrial ecosystems because of their ability to decompose lignocelluloses. This ability largely depends on the microbial community present in their guts. The relationship between termites and the cellulolytic microbial in their guts is a well known example of symbiosis association between the microbial community and termite intestine. The co-existence of termites and protozoas is a great example of a symbiotic relationship in two organisms which coexist. The term of symbiosis refers to a close ecological relationship between different species living in close association with one another species (Honiberg, 1970).


Termitinae
Pericapritermes nitobei
(Soil feeding)
Nasutitermitinae
Nasutitermes takasagoensis
(Wood feeding)
Macrotermitina
Odontotermes formosanus
(Fungus growing)
Apicotermitinae
Termitidae
Higher Termites
Lower Termites
Rhinotermitidae
Reticulitermes speratus
Coptotermes formosanus
Serritermitidae
Kalotermitidae
Neotermes koshunensis
Cryptotermes domesticus
Glyptotermes fuscus (Dry wood)
Hodotermitidae
Termopsidae
Hodotermopsis sjoestedti
(Damp wood)
Mastotermitidae
Order: Isoptera
Termite
Cockroach and mantid


A
O
SG
C
G
MG
T
1
2
HG
4
A
5
FOREGUT
HINDGUT
B
salivary gland
Malpighian tubules
fermentation Chamber (paunch)
rectum
MIDGUT
C

(1988) reported that twenty-five species of worker termites from Trat and Chanthaburi provinces were examined. Only five species of these termites contained seven species of flagellate protozoans living in their hind guts. In the termite, *Glyptotermes brevicaudatus* there was found only 1 species of protozoan: *Devescovina vestita*. In the termite, *Coptotermes gastroi* and *C. curvignathus* found 2 species of protozoans; *Spirotrichonympha flagellata* and *spirotrichonympha* sp. In the other two species of termites, *Schedorhinotermes medioobscrurus* and *S. rectangularis* there were found 4 species of protozoans: *Pseudotrichonympha grassi, Trichonympha agilis, T. campanula* and *T. spherical*.

2.9 Related literatures

The first publication of termites of Thailand reported only 5 species, *Bifiditermes indicus, Glyptotermes comesticus, Coptotermes havilandi, Macrotermes carbonarius* and *Odontotermes formosanus* (Holmgren, 1913). While Snyder (1949) reported that there were six species of termite in Thailand, *Macrotermes annandalei* was later on added to termite list of Thailand.

Ahmad (1950) reported that the relationship of the lower termite genera *Mastotermes* and cockroaches of family Cryptocercidae (*Cryptocercus punclulatus*). It was found that the protozoans living in their hind guts were closely related phylogenetically. It may be that the phylogenetic of termites evolution is related to cockroaches.

Ahmad (1965) studied the taxonomic of termite in Thailand. The specimens collected from 7 provinces were reported that totally 74 species of termites belonging to 29 genera and 3 families, Kalotermitidae, Rhinotermitidae and Termitidae whereas 32 species were reported new records of termites species. This report was the best studied taxonomic of termites in Thailand which had been used as reference key literature until now.

Krishna (1969) reported that the termite family Mastotermitidae and cockroaches family Cryptocercidae were differences in external morphology such as wings mandibles and tarsi but there were the paraprocts and styli were fully developed together and assumed as both of termite and cockroaches Cryptocercus may be the evolution from the winged cockroaches were found the protozoans living in hide guts which these cockroaches were lowest evolution and extinct.

Honiberg (1970) studied the relationship between the protozoans and the lower termites and it was found that the protozoans play an important role in the survival of termites. This is called "True mutualism symbiosis" which the flagellate protozoa are responsible for digest cellulose and hemicelluloses from their food.

Willson (1971) reported six families of termites can be classified in phylogentically into two large group as lower and higher termites. Lower termite comprise five families; Mastotermitidae, Kalotomitidae, Hodotermitedae, Rhinotermitidae and Seritermitidae. The higher termites are consisted of only one family (Termitidae) which the richest in species diversity occupying 75% of all species in the world. The Kalotermitidae are richest species diversity among the lower termite families.

Morimoto (1973) studied and survey of termite in Thailand. These specimens were collected under the Project of Japan U.S. Cooperative Science Program reported 48 species of termite belonging to 19 genera and 3 families. Whereas 13 species were new recordes in Thailand and 4 species, *Glyptotermes thailandis*, *Termes major*, *Nasutitermes grachynasutus* and *Hospitatlitermes asahinai* were new species.

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

Richards and Davies (1977) reported that the Serritermitidae includes only *Serritermes serifer* found in wooded savannas in Brazil.

Collins (1980) studied the distribution of soil macrofuana on the west ridge of Guanung Mulu, Sarawak. The results reported a significant negative correlation between increasing altitude and the abundance of termites in an altitudinal gradient on Mount Mulu, Sarawak, Malaysia. Termite density remained relatively high up to 800 m and then dramatically dropped from 800 m to 1,900 m. Above this altitude termites were absent.

Intanai (1987) studied taxonomic and ecology of termites in rubber plantation of Chanthaburi and Trat provinces. There were 25 species and 13 genera in the studied areas. These groups consisted of one species of family Kalotermitidae, 4 species of family Rhinotermitidae and 20 species of family Termitidae, while *Hypotermes obscuriceps* and *Nasutitermes profuscipennis* were later on added to the termite list of Thailand.

Yimarattanabovorn (1993) studied seasonal fluctuations of soil fauna and concerning factors. 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 there was no significant correlation between soil fauna population and plant nutrients.

Snyder (1994) explained that termites were widely distributed throughout the world and living species occur in all of the zoogeographical regions except the Arctic and

Antarctic regions.

Collin (1997) described that the lower termite distribution could be related to the latitudes line whereas the higher termite high distribution great majority in low latitudes line. The temperature and the moistures are major factor affecting foraging termites. The different of topography, geography and the climate changes in the world affecting the variety of different ecology providing the number of species and distribution in each area. The biodiversity of termites are increasing with the latitude were decrease.

Davies (1997) studied termite species richness in fire-prone and fire protected dry deciduous dipterocarp forest in Doi Suthep-Pui National Park, northern Thailand. There were recorded as 10 and 13 termite species in fire-protected and non fire-protected sites, respectively.

Higashi and Abe (1997) described that the lower termite in family Termopsidae were characterized by the presence of cellulytic protozoa in their hindgut and mainly consume wood, while the higher termites (Termitidae) were characterized by the absence of those protozoa and variously consume a range of dead and decaying material including sound wood, standing and fallen plant shoots and leaves, decaying wood, soil and humus.

Cook and Gold (1998) studied organization of the symbiotic flagellate community in 3 castes of the eastern subterranean termite, *Reticulitermes flavipes*. The results demonstrated that there were differences in flagellate community structure between sites, among castes and within individual termites.

Brune and Friedrich (2000) studied microecology of termite gut. The results were revealed that termite guts in fact axially and radially structured habitats with numerous microniches created by a combination of host and microbial activities which make termite guts as excellent model systems for studying functional interactions within highly organized microbial communities.

Jones (2000) studied termites assemblages in two distinct montane forest types lower montane and upper montane in Maliau Basin, Sabah. Similar species richness and relative abundance of wood feeding termites were found in both forest types. However, the lower montane forest had greater richness and relative abundance of species that feed on soil and highly decayed soil-like wood.

Inoue et al (2001) studied biodiversity of termite were distribution in different above mean sea level 100, 300, 500, 700 and 850 meters at Khoa Kichakut National Park in Chanthaburi, Thailand. There were 31 species of 18 genera of termites in the studied areas. *Microcerotermes carsus* was the dominant species at low altitude between 100 to 700 meters and absent at 850 meters but *Nasutitermes magtagensisformis* was the dominant species at high altitude but absent at 100-300 meters.

Eggleton et al. (2002) studied termites of the Mayombe forest reserve, Congo (Brazzaville). The results showed a very high species richness of termites, especially soil-feeding soldierless termites (Apicotermitinae). The assemblage, as estimated by the transects, resembled that previously characterized in comparable forest in southern Cameroon.

Amornsak , Sarnthoy, and Kirtibutr. (2003) reported new records of Subfamily Nasutitermitinae at Khao Kichakut National Park in eastern Thailand, which two new unidentified species of termite genera of Subfamily Nasutitermitinae, *Hospitalitermes* sp. and *Bulbitermes* sp. were found. However, the taxonomic status of these unidentified termites species has not been completely resolved.

Chalermsan, Sarnthoy and Kirtibutr (2003) studied termites in Chanthaburi, Thailand by the belt-transect sampling method and applied this to monitor termite communities in moist-evergreen forest (MEF), hill-evergreen forest (HEF) and dry-evergreen forest (DEF) during December 1999 – January 2001. Data obtained by belt-transect sampling described the characteristics of termite's community in terms of its diversity and distribution. MEF showed the highest diversity of 2.10, DEF and HEF showed lower H-index of 1.72 and 1.49, respectively.

Sinma , Trakulnaeumsai, Noparatnaraporn and Kitpreechavanich (2003) studied actinomycetes from termites' guts. The result concluded that there were in a range of 6 x 10^4 to 94.2 x 10^4 colonies / 20 guts. Morphological characteristic of the isolates showed that they belonged to the genus *Streptomyces*.

Vongkhaluang, Sornnuwat, Charoenkrung, Chutibhapakorn and Yoko (2003) studied ecological and biodiversity of termite in Chanthaburi province were reported the highest species richness of termites were 37 species of 18 genera and 8 subfamilies in moist evergreen forest while the dry evergreen forest found 27 species belonging to 15 genera and 7 subfamilies and lowest specie richness of termites were 24 species of 13 genera and 5 subfamilies in hill evergreen forest. *Microcerotermes crassus* (the wood feeder termite) and *Ancistrotermes pakcetanicus* (the wood and leave feeder or fungus feeder termite) were dominant specie in moist evergreen forest and dry evergreen forest while *Bulbitermes parapusillus* and *Bullitermes laticephalus* (the wood feeder) were dominant species in hill evergreen forest but the wood feeder termite in subfamilies Coptotermitinae, Amitermitinae, Termitinae and Apicotermitinae were absence. The two genera of *Angulitermes* and *Liacessititermes* were new record of termite in Thailand in the moist evergreen and hill evergreen forest respectively.

Yamada et al. (2003) studied abundance and biomass of termites in dead wood in a dry evergreen forest in Thailand. There were 11 species of families Kalotermitidae, Rhinotermitidae and Termitidae. The abundance and biomass of termites in the dry evergreen forest were estimated to be 7,794 termites m^{-2} and 16.7 g m^{-2}, of which 16 and 21%, respectively.

Sornnuwat, Vongkaluang and Yoko (2004) studied and classification of termites from 53 provinces both on the mainland and on the island of Andaman Sea and Gulf of Thailand. The numbers of termites specimen collected from 1992-2004 are accounted over 4,300 specimens and studied the external morphological characteristics of soldier caste of speciemen were observed and classified into genera and specie based on the systematic keys of Ahmad (1958, 1965), Krishna (1965), Morimoto (1973), Thapa (1981) and Tho (1992). The morphological identification of soldier caste resulted in 178 species 37 genera 10 subfamilies and 4 families, while the current records of termite species from Thailand have been 199 species 39 genera 10 subfamilies and 4 families.

Dawes-Gromadzki (2005) studied termites fauna of a monsoonal rainforest near Darwin, northern Australia. A sampling protocol that employed direct search, soil pits and baiting techniques was used to sample litter, wood, mound, soil and arboreal nest microhabitats for termites. There were 3 families (Mastotermitidae, Rhinotermitidae and Termitidae) 5 genera and 5 species in the study area.

Yamada et al. (2005) studied carbon mieralization by termites in tropical forests, with emphasis on fungus-combs. The termite population was 16.7 g m^{-2} of biomass in dry evergreen forest, Thailand. Termites mineralized 11.2% of annual litter aboveground litterfall from their populations and fungus comb.

Boonriam et al. (2010) observed litter removal by termites in a dry evergreen forest at Sakaerat Environment Research Station, Thailand, by using coarse and fine wire mesh cages and reported that termites intensively removed litter samples by comparing the litter weight remaining between coarse and fine cages. Frequency of occurrence of intensive litter removal by termites was estimated from a curve of the percentage of the total collected cages along the sampling times.

Boonriam (2010) studied microbial contribution to the carbon mineralization and decomposition rate of litter on the forest floor in dry evergreen forest at Sakaerat Environmental Research Station and reported that the rate of litter weight loss was twice higher in coarse cages than in fine cages due to the intensity of litter removed by termites. The litter respiration rates by microbial decomposition on natural litter and litter samples were affected by litter quality in the rainy season.

CHAPTER III

MATERIALS AND METHODS

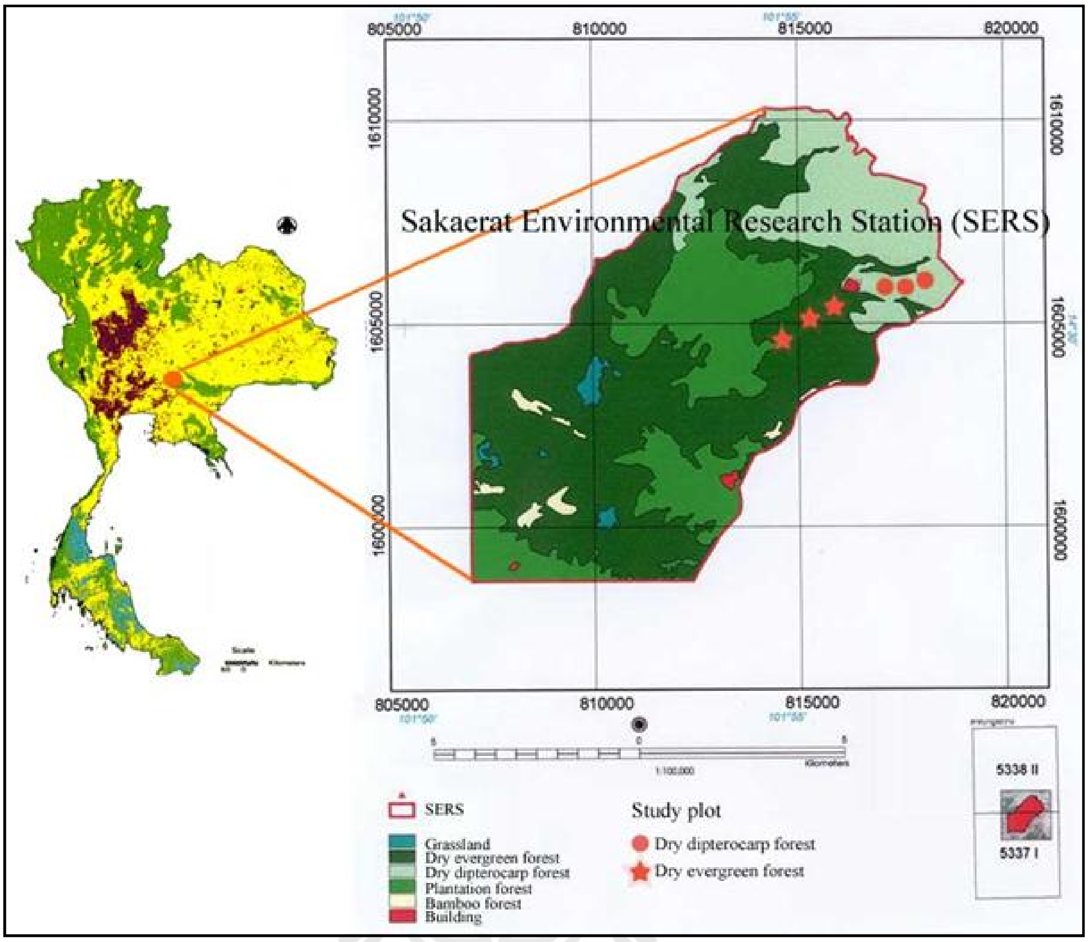
3.1 Study site description

3.1.1 Location

The study on biodiversity of termites and their relationship to some ecological factors in two different forests was investigated at the Sakaerat Environmental Research Station (SERS) in Wangnamkhieo and Pakthongchai districts, Nakhon Ratchasima province, northeastern Thailand (14º 30' N, 101º 55' E). It locates at approximately 60 kilometers east of Nakhon Ratchasima and 300 kilometers northeast of Bangkok. The station grounds cover an area of 78.08 km^2 or approximately 48,800 rais. It possesses the forest area for environmental and ecological purposes of tropical forest research of the Thailand Institute of Scientific and Technological Research (TISTR) as shown in Figure 3.1.

3.1.2 Topography and geography

The Sakaerat Environmental Research Station occupies a portion of the Central Highlands near the transition to the north-east (Khorat) Plateau. The topography is varied from flat, slightly to moderately dissected surface slopes gently northeastward into an alleviated valley. The sedimentary rock is sandstone; upper soil texture is characterized as clay loam, sandy loam, and sandy clay loam (Bunyavejchewin, 1987). The elevation of the area ranges from 200 to 800 meters above mean sea level. The important mountains on the station grounds are Khao Phiat (762 meters), Khao Khiew (790 meters), and Khao Sung (682 meters).


Sakaerat Environmental Research Station (SERS)
805000
810000
815000
820000
1610000
1605000
1600000
1:100,000
Kilometers
5338 II
5337 I
SERS
Grassland
Dry evergreen forest
Dry dipterocarp forest
Plantation forest
Bamboo forest
Building
Study plot
Dry dipterocarp forest
Dry evergreen forest

3.1.4 Vegetation and land use

The Sakaerat Environmental Research Station has different land use and vegetation types cover an area. The station is divided into five types of land use according to the data of SERS in 2000 as follows (http://www.tistr.or.th/sakaerat/Land_used /land_used.htm):

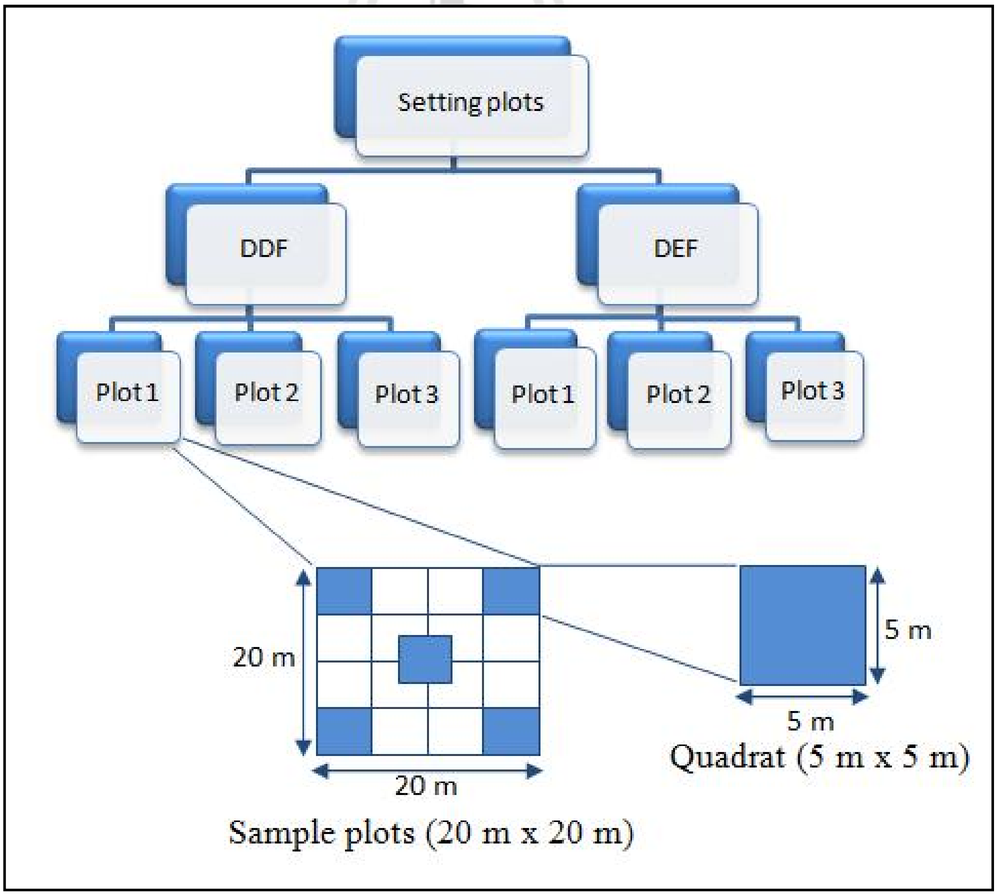
1. dry evergreen forest	46.82 km^2 or	29,260 rais
2. dry dipterocarp forest	14.51 km^2 or	9,066 rais
3. plantation forest	14.46 km^2 or	9,038 rais
4. grass land	0.93 km^2 or	582 rais
5. bamboo forest	1.12 km^2 or	697 rais
6. buildings	0.25 km^2 or	157 rais
Total	78.08 km^2 or	48,800 rais

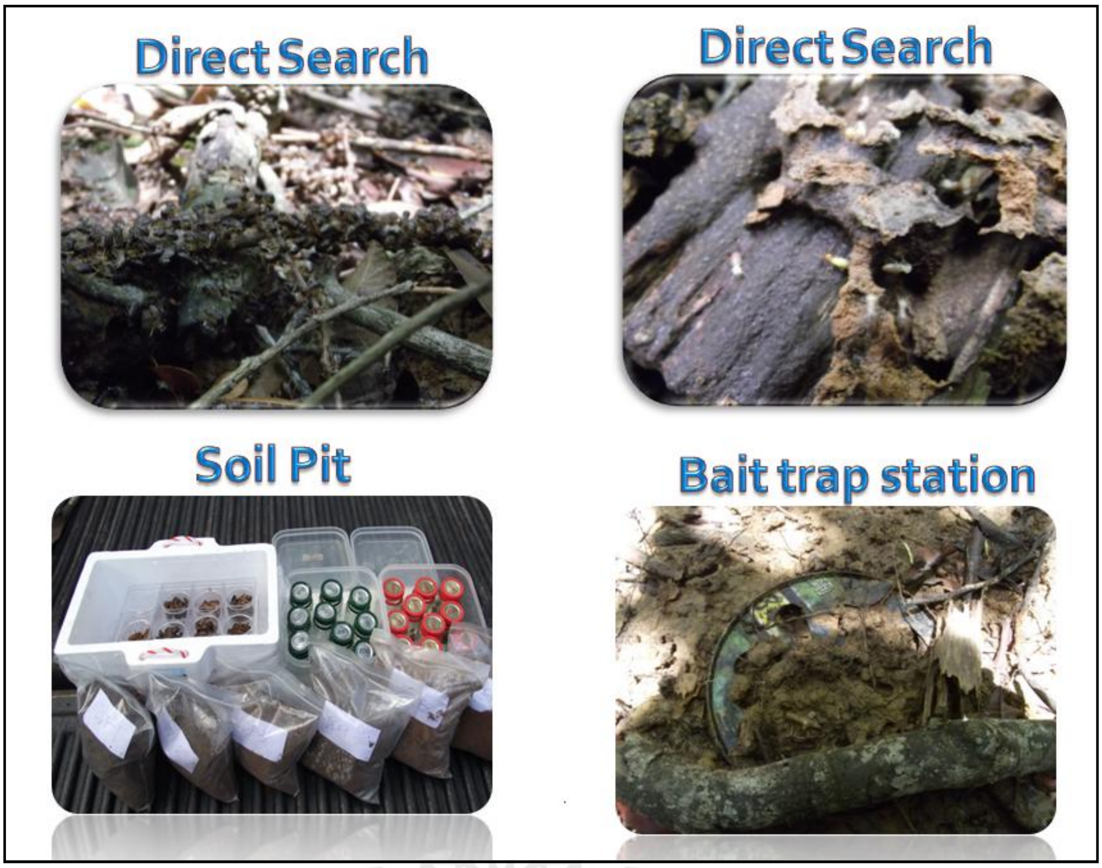
3.1.5 Study areas

In this study, the selected forest types were the dry dipterocarp forest and dry evergreen forest which covered the area about 14.51 km^2 (9,066 rais) and 46.82 km^2 (29,260 rais), respectively.

The dry dipterocarp forest (DDF)

The dry dipterocarp forest appears in the northeast section of SERS area. It is an open stand characteristic and composes of three stories and consists of dominant plant species such as *Shorea obtuse* (in Thai called teng), *Shorea siamensis* (in Thai called rang), *Dipterocarpus intricatus* (in Thai called yang-krad), *Dipterocarpus tuberculatus* (in Thai called pluang), and *Dipterocarpus obtusifolius* (in Thai called hiang). The under story is covered with tree seedling and grasses. In dry season ground fire in the forest usually occurs annually (Figure 3.2).


Setting plots
DDF
DEF
Plot 1
Plot 2
Plot 3
Plot 1
Plot 2
Plot 3
20 m
20 m
Sample plots (20 m x 20 m)
5 m
5 m
Quadrat (5 m x 5 m)


Direct Search
Direct Search
Soil Pit
Bait trap station

3.5 The protozoa in digestive system of termites

Five workers of each 5 species of dominant termite species (*Microcerotermes crassus*, *Hypotermes makhamensis*, *Globitermes sulphureus*, *Termes* sp., and *Schedorhinotermes* sp.) in this research were studied for the presence of protozoa in their hindguts using a stereomicroscope and light microscope. The whole gut of the worker was removed by clamping the anterior of the termite with one pair of forceps and pulling the tip of the abdomen with another pair of forceps. The guts were macerated together in 0.85% NaCl solution and broken with a dissecting needle on a slide under a binocular stereomicroscope.

3.6 Data analysis

Species diversity of termites in the study area was calculated by using numbers of termite species in sampling plots of dry dipterocarp and dry evergreen forests. Species diversity index (H') and species richness (H_{max}) were calculated by method of Shannon - Weiner index of diversity which was used with the following model (Shannon and Weaver, 1949).

Abundance

$$\boxed{H' = -\sum_{i=1}^{s} (\mathrm{Pi})(\ln * \mathrm{Pi})}$$

Where;

H' = the value of the Shannon-Wiener diversity index

s = the number of species in the community

Pi = the proportion of total sample belonging to the species i

The evenness is the ratio of the observed diversity to the maximum possible for observed species number. The equitability index is determined as follows:

Evenness

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

Where;

E = Equitability or evenness index

H' = Shannon diversity index

$H\max$ = ln S

Species richness

Species richness is the number of species in a sample or study site.

Similarity index

Similarity of termite species composition between sampling plots were examined by using the Sorensen' coefficiency as follows:

Sorensen' coefficiency

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

Where;

S = Sorensen' coefficient

a = Total number of species common to both regions

b = Total number of species in one region

c = Total number of species in the other regions

Termite diversity was determined by using Shannon's diversity index (H') evenness and species richness. The similarity of termite species composition between sampling plots were examined by using the Sorensen' coefficient. The correlation of termites and environmental factors were analyzed by using statistic program SPSS version 17.0, Pearson correlation coefficient at $P < 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

Study of biodiversity of termites in two different forest types, dry dipterocarp forest (DDF) and dry evergreen forest (DEF) was conducted in Sakaerat Environmental Research Station (SERS), Nakhon Ratchasima province, northeastern Thailand in October 2009 – September 2010. Their morphological characteristics were investigated based on the systematic keys of Ahmad (1965), Morimoto (1973) and Vongkalaung, Sornnuwat, Charoenkrung and Chutibhapakorn (2001). The results showed that totally 25 species belong to 18 genera, 6 subfamilies were collected from studied areas (Figure 4.1). The details were used in the identification and the characteristics of each subfamily were described as follows:

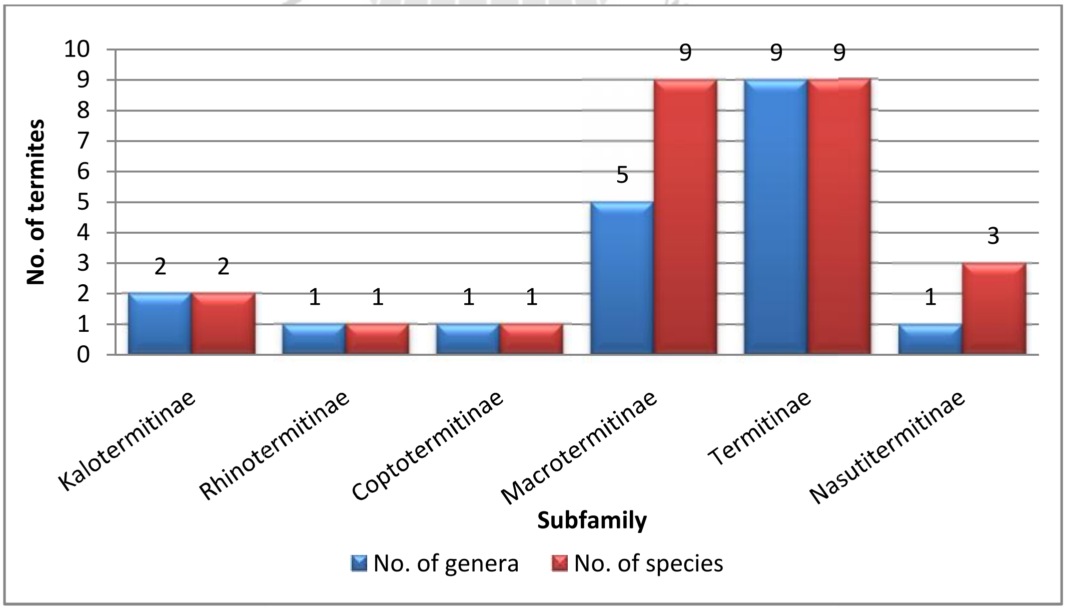


Figure 4.1 Species diversity of termite groups in the study sites. (dry dipterocarp forest and dry evergreen forest).

Subfamily Kalotermitinae

This subfamily is referred to dry-wood termites and includes the damp-wood termites because they nest primarily in wood which is usually above ground, without soil connection. Two species of this subfamily and one undetermined species of genus *Glyptotermes* were observed.

Subfamily Rhinotermitinae

This subfamily is all wood feeders and also inhabits a very wide range in rotten wood, dead branches and many trees. The nests are constructed inside stumps of old trees. One genus and one species of *Schedorhinotermes* sp. of this subfamily were observed.

Subfamily Coptotermitinae

This subfamily is attack wood and some of them are serious pests of agricultural and forest plantation. Nesting is generally underground or inside the trunks of trees, in logs and stumps, between wooden boards and in houses. One genus and one species of this subfamily were observed.

Subfamily Macrotermitinae

This subfamily is the most important termite group which plays an important role in the nutrient cycle by accelerating decomposition in the forest. They feed on dead wood and leaves and nest only soil and saliva to build their mound. Nine species of this subfamily were observed.

Subfamily Termitinae

This subfamily is the largest group of termites which are humivores feeding on substrates such as dung and plant litter in various stages of decomposition. They are subterranean termites and their nests are underground. Nine species of this subfamily were observed.

Subfamily Nasutitermitinae

This subfamily is free foraging in their foraging behavior. Their nests are found in various sites such as in dead wood, on tree trunks, on the ground, and in soil. One genus and three undetermined species of genus *Nasutitermes* were observed.

4.1 Termite identification

The identification of termite specimens were sparated into 3 main groups as follows:

- Morphological characteristic
- Food habitat
- Nest habitat

4.1.1 Termite group classified by their morphological characteristics

Dry dipterocarp forest (DDF)

Eighteen species of 14 genera and 4 subfamilies were recorded from dry dipterocarp forest (Table 4.1 and Figure 4.2):

1. Coptotermitinae: One species of *Coptotermes* (*Coptotermes curvignathus*).

2. Macrotermitinae: Three species of *Odontertermes*, three species of *Macrotermes* and one species each of genus *Hypotermes*, *Microtermes* and *Ancistrotermes*.

3. Termitinae: One species each of genus *Globitermes, Microcerotermes, Dicuspiditermes, Pericapritermes* and *Termes*.

4. Nasutitermitinae: One species of genus *Nasutitermes* and two undetermined species of *Nasutitermes*.

Dry evergreen forest (DEF)

Twenty – five species of 18 genera and 6 subfamilies were recorded from dry evergreen forest (Table 4.1 and Figure 4.2):

1. Kalotermitinae: One species of genus *Glyptotermes* and one undetermined spieces of *Glyptotermes*.

2. Rhinotermitinae: One undetermined species of genus *Schedorhinotermes*.

3. Coptertermitinae: One species of *Coptotermes* (*Coptotermes curvignathus*).

4. Macrotermitinae: Three species of *Odontertermes*, three species of *Macrotermes* and one species each of genus *Hypotermes*, *Microtermes* and *Ancistrotermes*.

5. Termitinae: One species each of genus *Amitermes*, *Globitermes*, *Microcerotermes*, *Dicuspiditermes*, *Mirocapritermes*, *Homallotermes*, *Procapritermes*, *Pericapritermes* and *Termes*.

6. Nasutitermitinae: One species of genus *Nasutitermes* and two undetermined species of *Nasutitermes*.

Table 4.1 Termite diversity in dry dipterocarp and dry evergreen forest of SERS**.**

Termites Family/Species	Forest types DDF	DEF	Average	Food habitat
Kalotermitinae				
1. *Glyptotermes brevicaudatus*	0	579	289.50	W
2. sp.1	0	545	272.50	W
Rhinotermitinae				
3. *Schedorhinotermes* sp.	0	2,282	1,141.00	W
Coptotermitinae				
4. *Coptotermes curvignathus*	1,258	1,841	1,549.50	W
Macrotermitinae				
5. *Macrotermes carbonarius*	1,993	3,093	2,543.00	W & L
6. *Macrotermes gilvus*	2,491	3,157	2,824.00	W & L
7. *Macrotermes annandalie*	1,500	1,493	1,496.50	W & L
8. *Odontotermes longignathus*	1,760	2,631	2,195.50	W & L
9. *Odontotermes feae*	1,768	2,535	2,151.50	W & L
10. *Odontotermes proformosanus*	1,047	1,762	1,404.50	W & L
11. *Hypotermes makhamensis*	4,119	4,790	4,454.50	W & L
12. *Microtermes* sp.	1,998	2,634	2,316.00	W & L
13. *Ancistrotermes pakistanicus*	1,268	1,427	1,347.50	W & L
Termitinae				
14. *Amitermes* sp.	0	1,588	794.00	S
15. *Globitermes sulphureus*	4,796	3,931	4,363.50	W
16. *Microcerotermes crassus*	5,041	4,434	4,737.50	W
17. *Dicuspiditermes makhamensis*	1,114	1,700	1,407.00	S
18. *Mirocapritermes* sp.	0	1,205	602.50	S
19. *Homallotermes* sp.	0	1,296	648.00	S
20. *Procapritermes* sp.	0	1,286	643.00	S
21. *Pericapritermes* sp.	1,694	1,339	1,516.50	S
22. *Termes* sp.	1,705	1,930	1,817.50	S
Nasutitermitinae				
23. *Nasutitermes* sp.	1,717	1,482	1,599.50	W
24. sp.2	1,123	1,089	1,106.00	W
25. sp.3	931	788	859.50	W
Total	37,323	50,837	44,080.00	

W = wood, W & L = wood and leave, S = soil

sp1, sp2 and sp3 = unidentified species 1, 2 and 3 (Unit in number of species)

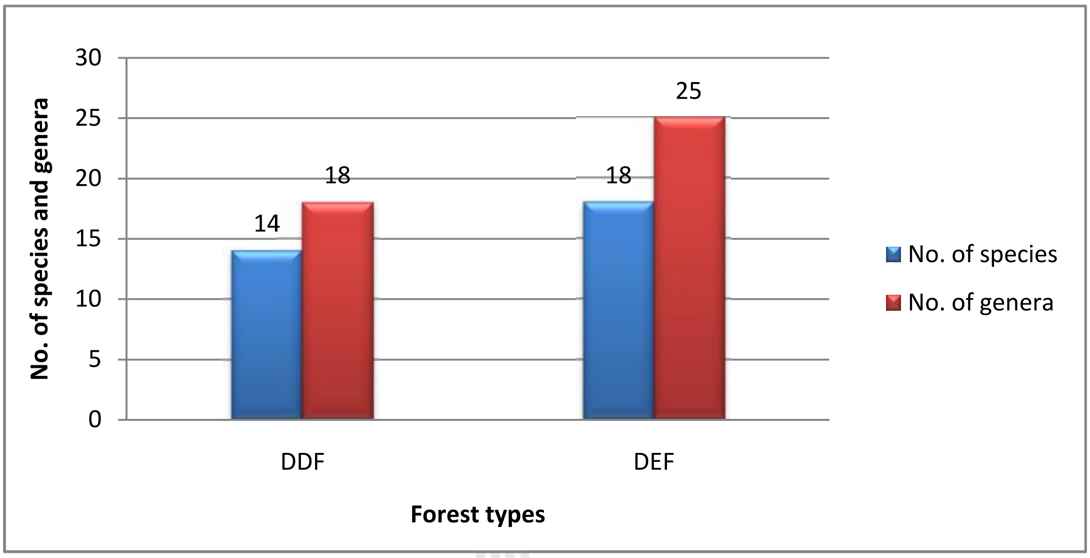


Figure 4.2 Species diversity of termite groups in dry dipterocarp forest (DDF) and dry evergreen forest (DEF).

Results of the survey as shown in Table 4.1 and Figure 4.2 revealed that the dry evergreen forest showed a higher number of species than dry dipterocarp forest (totally 25 species of 18 genera, 3 families to 18 species 14 genera 2 families).

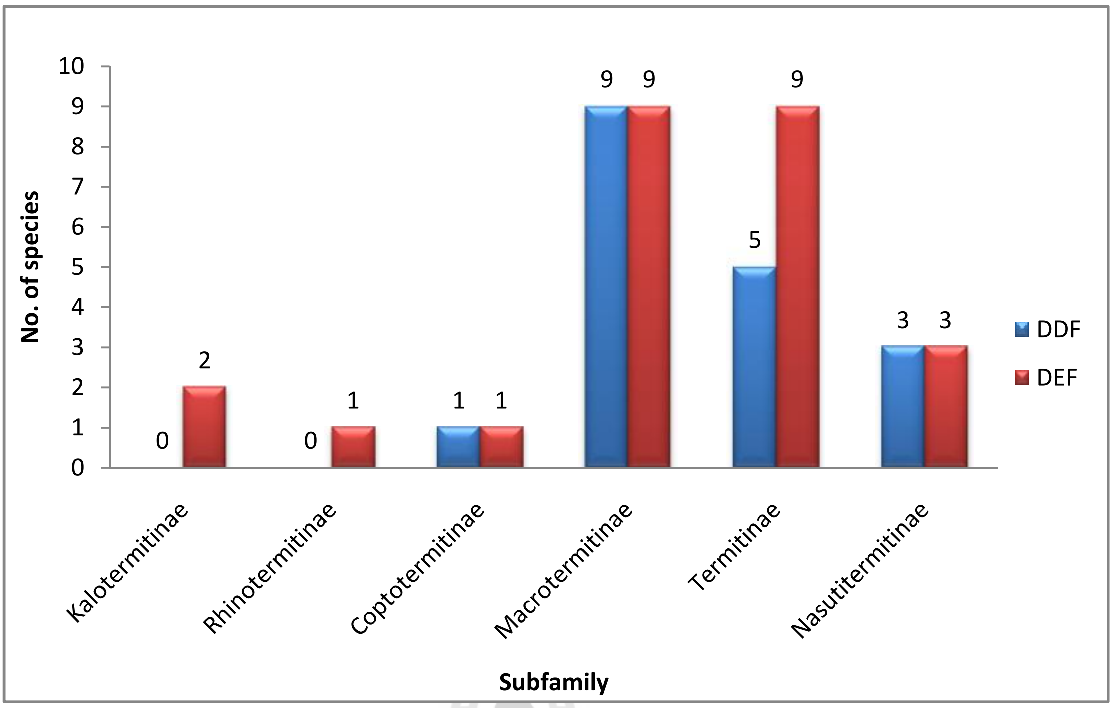


Figure 4.3 Species of termite in dry dipterocarp forest (DDF) and dry evergreen forest (DEF)**.**

From the results, it is revealed that subfamily Kalotermitinae and Rhinotermitinae were only found in dry evergreen forest (Table 4.1 and Figure 4.3) this might be dued to the fact that dry evergreen forest having higher litterfall including branches or stems and relative humidity than dry dipterocarp forest and may be more suitable for *Glyptotermes* and *Schedorhinotermes* to establish their colonies.

4.1.2 Termite group classified by food habitat

The classification of these termite groups is generally on the observation of the location of foraging such as on the ground, under leaves, logs, branches, and trees. Termites collected in dry dipterocarp and dry evergreen forests were classified into 3 different groups based on food habitat as follows:

- Wood feeders

- Wood and leaf feeders or fungus feeders
- Soil and humus feeders

Termite genera and species in dry dipterocarp and dry evergreen forests of Sakaerat Environmental Research Station, northeastern Thailand are classified by their food habitat as following (Table 4.1 and Figure 4.4).

Wood feeders

Termites in this group feed on wood and woody litter, including dead branches still attached to trees (Bignell and Eggleton, 2000).

In dry dipterocarp forest found 6 species of termites which were wood feeding termites. There were 1 species of subfamily Coptotermitinae, 3 species of subfamiliy Nasutitermitinae and 2 species of subfamily Termitinae.

Nine species of termites in dry evergreen forest were wood feeding termites. There were 2 species belonged to subfamily Kalotermitinae, 1 species of subfamily Rhinotermitinae, 1 species of subfamily Coptotermitinae, 2 species of subfamily Termitinae and 3 species belonged to subfamily Nasutitermitinae.

Wood and leaf feeders or fungus feeders

This feeding group forages on leaves and small woody items and often took back and stored their food temporarily in the nest (Bignell and Eggleton, 2000).

Nine species of termites found in both of dry dipterocarp forest and dry evergreen forest were wood and leaf feeders or fungus feeders. They belonged to subfamily Macrotermitinae.

Soil and humus feeders

These termites are humivores and live in soil or subterranean nest except *Termes cosmis* that build their nests on the ground, which is usually called epigeal nest.

Seven species of termites found in both of dry dipterocarp forest and dry evergreen forest were soil or humus feeders. They belonged to subfamily Termitinae.

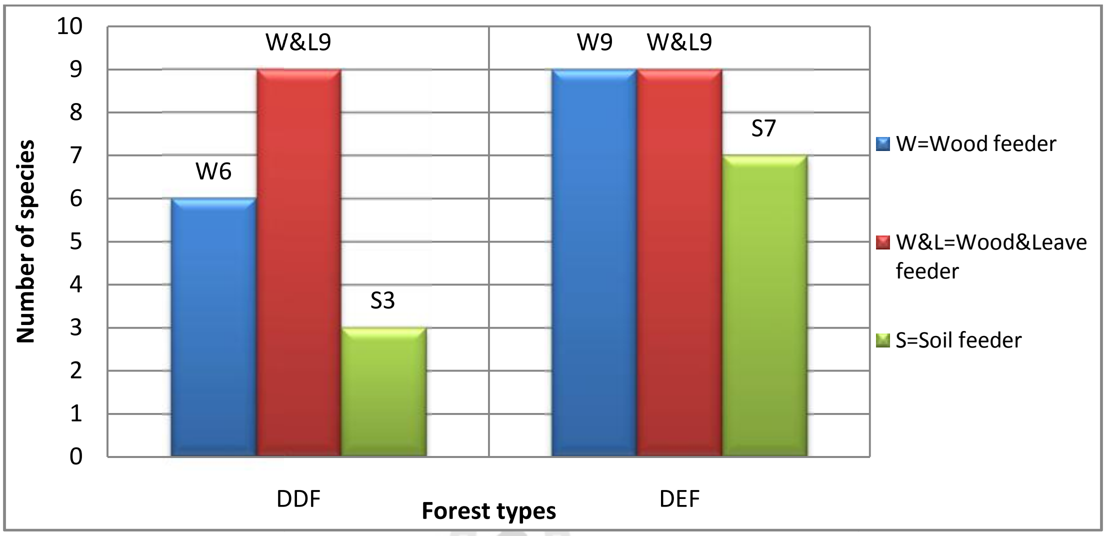


Figure 4.4 Functional group composition (food habitat) recorded from DDF and DEF in SERS.

Classification of feeding groups as shown in Figure 4.4 revealed that dry evergreen forest showed the higher number of wood feeding groups than dry dipterocarp forest. Wacharinrat, Dhanmanonda, Eiadtong and Srigongpan (2001) reported that total aboveground biomass in dry evergreen forest was higher than in dry dipterocarp forest. Therefore, this might be the reason that dry evergreen forest has the highest number of species of wood feeding termites. The number of wood and leaf feeding termites found in dry evergreen forest were similar to the dry dipterocarp forest. This might be due to this termites group having a high development equal for foraging food in both forest types. The soil and humus feeding termites were found in higher number of species in dry evergreen forest than in dry dipterocarp forest, this might be due to the fact that dry evergreen forest have higher organic matter and soil moisture than dry dipterocarp forest and may be suitable for soil or humus feeders to live (Figures 4.5 - 4.7).

- Epigeal nesting termites
- Subterranean termites

Arboreal nesting termites

This termite group usually nest on trees connected to the ground by covered galleries which decline from the trunk of the tree. Four species of arboreal nesting termites exists in both forest types. This group found of 1 species of *Microcerotermes* belonging to subfamiliy Termitinae and 3 species belonged to subfamily Nasutitermitinae (Figure 4.10).

Epigeal nesting termites

This group of termites usually has colonies centered on the ground of standing trees or against the side of trees. In dry dipterocarp forest, 7 species of termites build epigeal nests. This group consisted of 3 species of *Macrotermes* (Subfamiliy Macrotermitinae), 1 species each of *Globitermes*, *Microcerotermes*, *Dicuspiditermes* and *Termes*.

Ten species of termite in dry evergreen forest built epigeal nests. This group consisted of 3 species of *Macrotermes* (Subfamiliy Macrotermitinae), one species each of *Amitermes*, *Globitermes*, *Microcerotermes*, *Dicuspiditermes*, *Homallotermes*, *Procapritermes* and *Termes* (Figure 4.11).

Subterranean termites

This termite group lives underground, but build coverd runways to reach the wood above ground. Nests are built either in the soil underground or in wood above ground.

In dry dipterocarp forest, 9 species of termites were subterranean termites. One species each of subfamily Rhinotermitinae, Coptotermitinae, 6 species belonged to subfamily Macrotermitinae and 2 species belonging to subfamily Termitinae.

Eleven species of termites in dry evergreen forest were subterranean termites. This group consists of 1 species each of subfamily Rhinotermitinae, Coptotermitinae, 6 species belong to subfamily Macrotermitinae and 3 species belonging to subfamily Termitinae (Figure 4.12).

Table 4.2 Termite diversity in dry dipterocarp forest and dry evergreen forest of SERS classified by nest habitat.

Termites Family/Species	Nest habitat			
	W	A	E	S
Kalotermitinae				
1. *Glyptotermes brevicaudatus*	✓			
2. sp.1	✓			
Rhinotermitinae				
3. *Schedorhinotermes* sp.				✓
Coptotermitinae				
4. *Coptotermes curvignathus*				✓
Macrotermitinae				
5. *Macrotermes carbonarius*			✓	
6. *Macrotermes gilvus*			✓	
7. *Macrotermes annandalie*			✓	
8. *Odontotermes longignathus*				✓
9. *Odontotermes feae*				✓
10. *Odontotermes proformosanus*				✓
11. *Hypotermes makhamensis*				✓
12. *Microtermes* sp.				✓
13. *Ancistrotermes pakistanicus*				✓
Termitinae				
14. *Amitermes* sp.			✓	
15. *Globitermes sulphureus*			✓	
16. *Microcerotermes crassus*		✓	✓	
17. *Dicuspiditermes makhamensis*			✓	
18. *Mirocapritermes* sp.				✓
19. *Homallotermes* sp.			✓	
20. *Procapritermes* sp.			✓	
21. *Pericapritermes* sp.				✓
22. *Termes* sp.			✓	✓
Nasutitermitinae				
23. *Nasutitermes* sp.		✓		
24. sp.2		✓		
25. sp.3		✓		

W = Nest in wood, A = Arboreal nest, E = Epigeal nest, S = Subterranean nest

sp1, sp2 and sp3 = unidentified species 1, 2 and 3 (Unit in number of species)

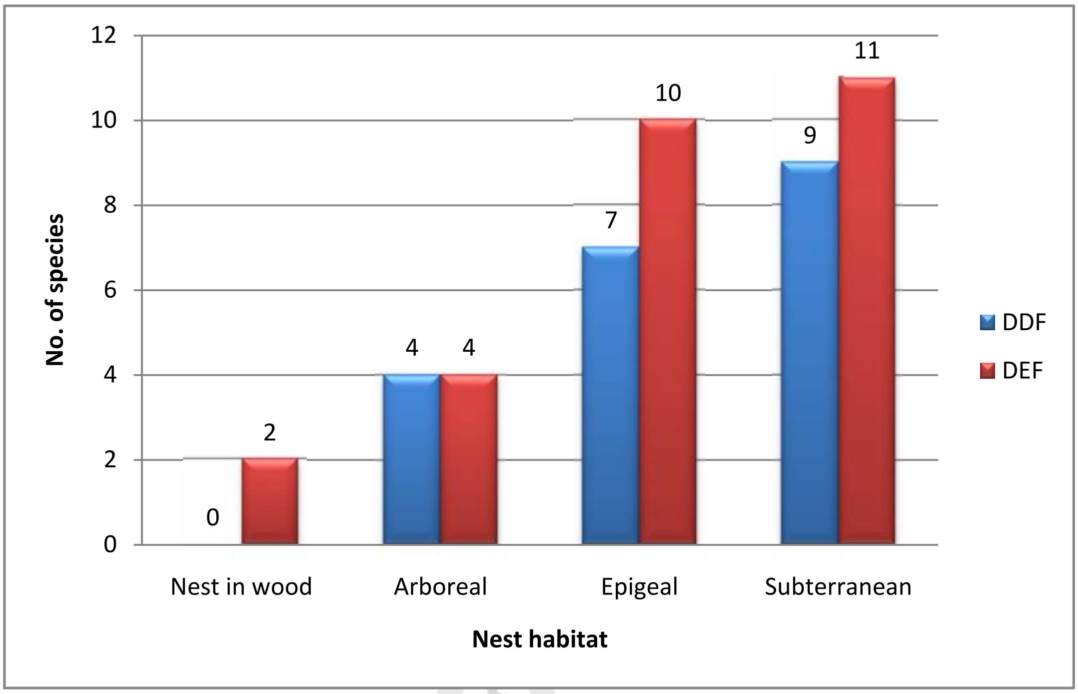


Figure 4.8 Termite species in different nest types in dry diptercarp forest (DDF) and dry evergreen forest (DEF).

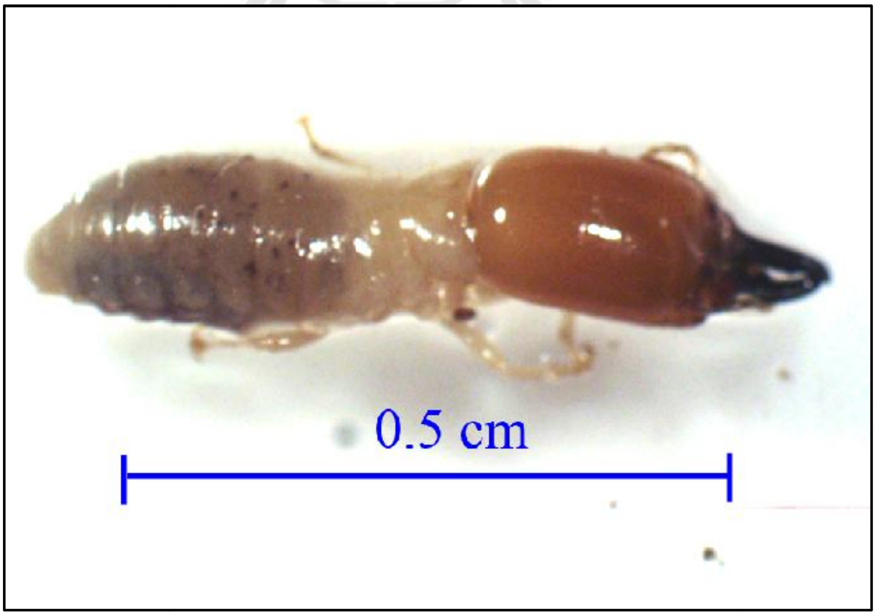


Figure 4.9 Wood nesting termites (*Glyptotermes*).

Table 4.3 Species diversity index and evenness index of termite in SERS**.**

Forest types	Families	Sub families	Genera	Species	Species richness	Shannon's Index	Evenness
DDF	2	4	14	18	18.0	2.744	0.949
DEF	3	6	18	25	25.0	3.079	0.957

DDF = dry dipterocarp forest, DEF = dry evergreen forest

The result of the diversity index as shown in Table 4.3 revealed that the dry evergreen forest showed the highest index of diversity of 3.079 which was consistent with highest number of termite species found in dry evergreen forest. The lowest species diversity index was in the dry dipterocarp forest with 2.744. The highest evenness was also found in dry evergreen forest with 0.957 and the lowest evenness index was in dry dipterocarp forest with 0.949.

4.3 Population density of termites

Population density of termites based on the number of individuals from different months of two forest ecosystems in SERS. The average population density varied from 113.43 ind/m^2 (individual per square meter) in January 2010 to 230.53 ind/m^2 in September. The maximum density was in September 2010 (230.53 ind/m^2) followed by June 2010 (229.20 ind/m^2) in August 2010 (223.73 ind/m^2) and in July 2010 (222.55 ind/m^2), respectively. The minimum density was in January 2010 (113.43 ind/m^2) and in February 2010 (126.63 ind/m^2).

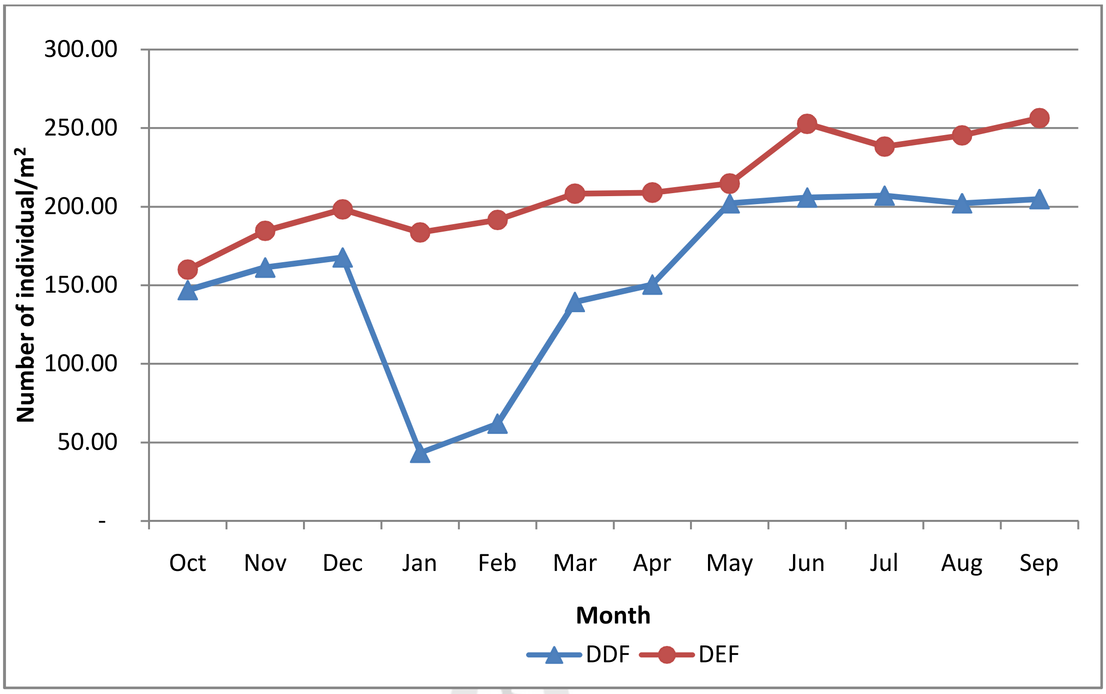
Table 4.4 Monthly variation of termite density in SERS.

Month	Forest types		Average
	DDF	DEF	
October 2009	146.80	159.85	153.33
November 2009	161.20	184.55	172.88
December 2009	167.55	198.20	182.88
January 2010	43.30	183.55	113.43
February 2010	61.85	191.40	126.63
March 2010	139.30	208.15	173.73
April 2010	150.35	208.90	179.63
May 2010	202.00	214.65	208.33
June 2010	205.75	252.65	229.20
July 2010	206.90	238.20	222.55
August 2010	202.05	245.40	223.73
September 2010	204.70	256.35	230.53
Average	157.65±15.99	211.82±8.85	184.73±11.45

DDF = dry dipterocarp forest, DEF = dry evergreen forest

Unit in individual per square meter

The monthly density of termites showed that there were considerable differences between months in dry dipterocarp forest and termite density found tended to be lower in the summer season (March 2010 - Apirl 2010) in both dry diptorocarp forest and dry evergreen forest.



300.00
250.00
200.00
150.00
100.00
50.00
-
Number of individual/m²
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
DDF
DEF

Table 4.5 Frequency of dominant species in dry dipterocarp forest and dry evergreen forest at SERS.

Dominant Species	Forest types			
	DDF		DEF	
	Frequency	No. Ind.	Frequency	No. Ind.
1. *Microcerotermes crassus*	12	5,041	12	4,434
2. *Globitermes sulphureus*	12	4,796	12	3,931
3. *Hypotermes makhamensis*	12	4,119	12	4,790
4. *Macrotermes gilvus*	11	2,491	12	3,157
5. *Macrotermes carbonarius*	11	1,993	12	3,093

DDF = dry dipterocarp forest, DEF = dry evergreen forest

No. Ind. = number of individual

The results revealed that *Microcerotermes crassus* was found to be the dominant species in both dry dipterocarp forest and dry evergreen forest followed by *Hypotermes makhamensis, Globitermes sulphureus, Macrotermes gilvus* and *Macrotermes cabonarius*, respectively.

Table 4.6 Frequency of termites recorded in dry dipterocarp forest and dry evergreen forest at SERS.

Termites Family/Species	Forest types			
	DDF		DEF	
	Frequency	No. Ind.	Frequency	No. Ind.
Kalotermitinae				
1. *Glyptotermes brevicaudatus*	0	0	7	579
2. sp.1	0	0	9	545
Rhinotermitinae				
3. *Schedorhinotermes* sp.	0	0	12	2,282
Coptotermitinae				
4. *Coptotermes curvignathus*	9	1,258	12	1,841
Macrotermitinae				
5. *Macrotermes carbonarius*	11	1,993	12	3,093
6. *Macrotermes gilvus*	11	2,491	12	3,157
7. *Macrotermes annandalie*	10	1,500	10	1,493
8. *Odontotermes longignathus*	10	1,760	12	2,631
9. *Odontotermes feae*	10	1,768	12	2,535
10. *Odontotermes proformosanus*	10	1,047	11	1,762
11. *Hypotermes makhamensis*	12	4,119	12	4,790
12. *Microtermes* sp.	10	1,998	11	2,634
13. *Ancistrotermes pakistanicus*	8	1,268	10	1,427
Termitinae				
14. *Amitermes* sp.	7	0	11	1,588
15. *Globitermes sulphureus*	12	4,796	12	3,931
16. *Microcerotermes crassus*	12	5,041	12	4,434
17. *Dicuspiditermes makhamensis*	8	1,114	12	1,700
18. *Mirocapritermes* sp.	0	0	10	1,205
19. *Homallotermes* sp.	0	0	9	1,296
20. *Procapritermes* sp.	0	0	9	1,286
21. *Pericapritermes* sp.	8	1,694	10	1,339
22. *Termes* sp.	10	1,705	11	1,930
Nasutitermitinae				
23. *Nasutitermes* sp.	10	1,717	11	1,482
24. sp.2	8	1,123	12	1,089
25. sp.3	7	931	8	788

DDF = dry dipterocarp forest, DEF = dry evergreen forest

sp1, sp2 and sp3 = unidentified species 1,2 and 3 (Unit in number of species)

No. Ind. = number of individual

4.5 Similarity index of termite community

The similarity of termite species composition among sampling plots was examined by using the Sorensen' coefficiency, which is a statistic used for comparing the similarity of two forest types.

Table 4.7 showed the similarity index of dry diptorocarp forest and dry evergreen forest. Results from the study show the value of 0.8372 or 83.72% of similarity index of two forest types.

Table 4.7 Similarity coefficiency**.**

		DDF	
		Found	Not found
DEF	Found	18 (a)	7 (b)
	Not found	0 (c)	0 (d)

DDF = dry dipterocarp forest, DEF = dry evergreen forest

$$\text{Index of Similarity (S)} = \frac{2a}{2a+b+c}$$

$$= \frac{2(18)}{2(18)+7+0}$$

$$= 0.8372 \text{ or } 83.72\%$$

Where;

a = The number of species shared by two sites

b = The number of species found only in DEF

c = The number of species found only in DDF

According to the results shown in Table 4.7 revealed that the similarity of termites in both two forest types were quite high. This may be because of the difference of ecological factors and habitat structures affected the similarity of termite community. The dry evergreen forest probably had more appropriate soil moisture and relative humidity than dry dipterocarp forest and might be suitable for termites in subfamily Kalotermitinae and Rhinotermitinae to establish their colonies.

4.6 Relationship between termite density and environmental factors

The ecological characteristics were determined at each forest type. The differences in the mean of the environmental factors were tested by Pearson correlation coefficient (2 tails) to find the relationship between the termite density and meteorological factors. All data were calculated by using SPSS version 17.0 program for windows. The Table 4.8 shows the correlations between termite density and environmental factors in both forest types.

Table 4.8 The correlations between termite density and environment factors in dry dipterocarp forest (DDF) and dry evergreen forest (DEF).

Factors	Pearson correlation coefficient	
	DDF	DEF
Rainfall	0.573	0.395
Air temperature	0.263	0.452
Relative humidity	0.303	0.181
Soil moisture	0.728**	0.378
Soil pH	0.375	-0.393
Soil temperature	-0.646*	-0.548

Pearson correlation coefficient *, **, significant at $P < 0.05$ and $P < 0.01$, respectively

In dry dipterocarp forest, the results showed positively significant correlation between soil moisture and termite density (0.728; $P < 0.05$) but negatively significant correlation between soil temperature and termite density (-0.646; $P < 0.05$) as shown in Figure 4.14.

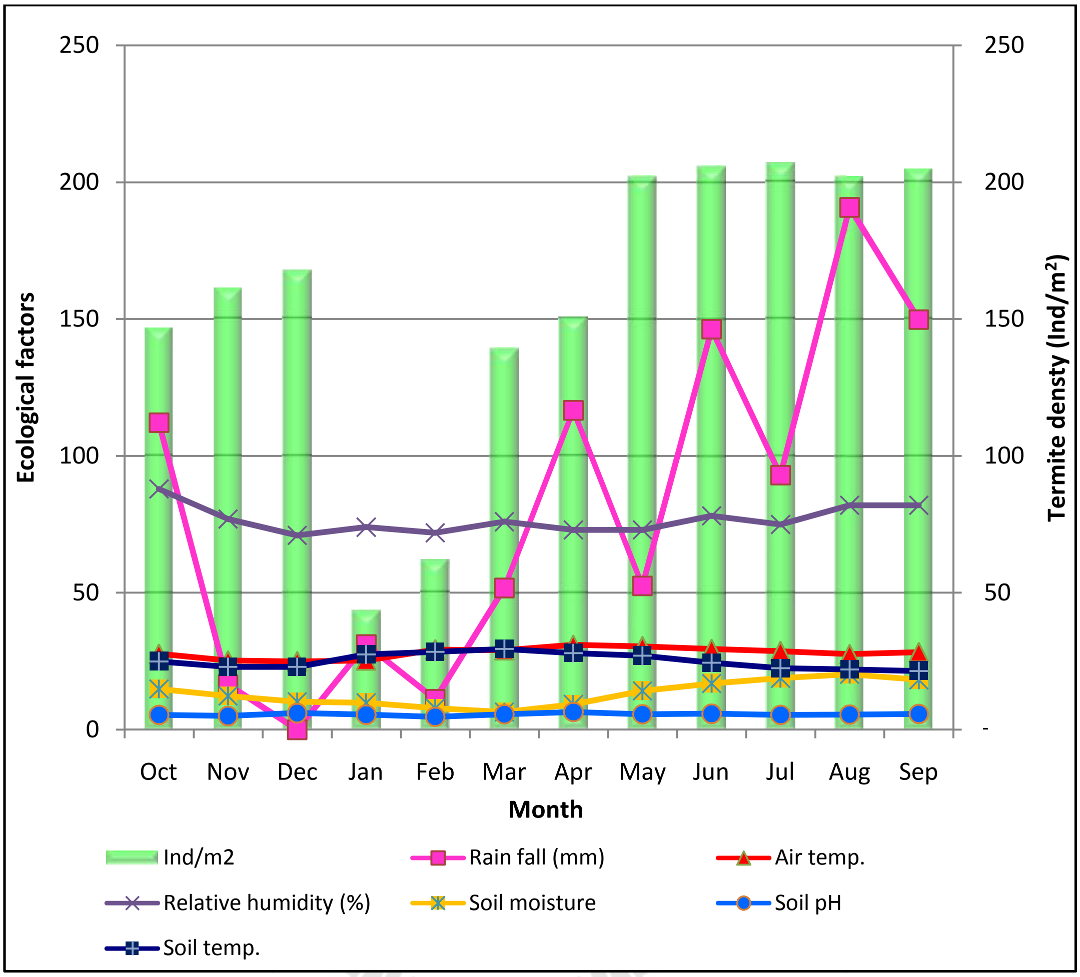


Figure 4.14 Monthly ecological factors and density of termites in DDF.

However, the dry evergreen forest showed no significant correlation with environmental factors. There was positive but non-significant correlation among rainfall (0.395; $P < 0.05$), air temperature (0.452; $P < 0.05$), relative humidity (0.181; $P < 0.05$) and soil moisture (0.378; $P < 0.05$) with termite density and negative but non-significant correlation between soil pH (-0.393; $P < 0.05$), soil temperature (-0.548; $P < 0.05$) and termite density as shown in Figure 4.15.

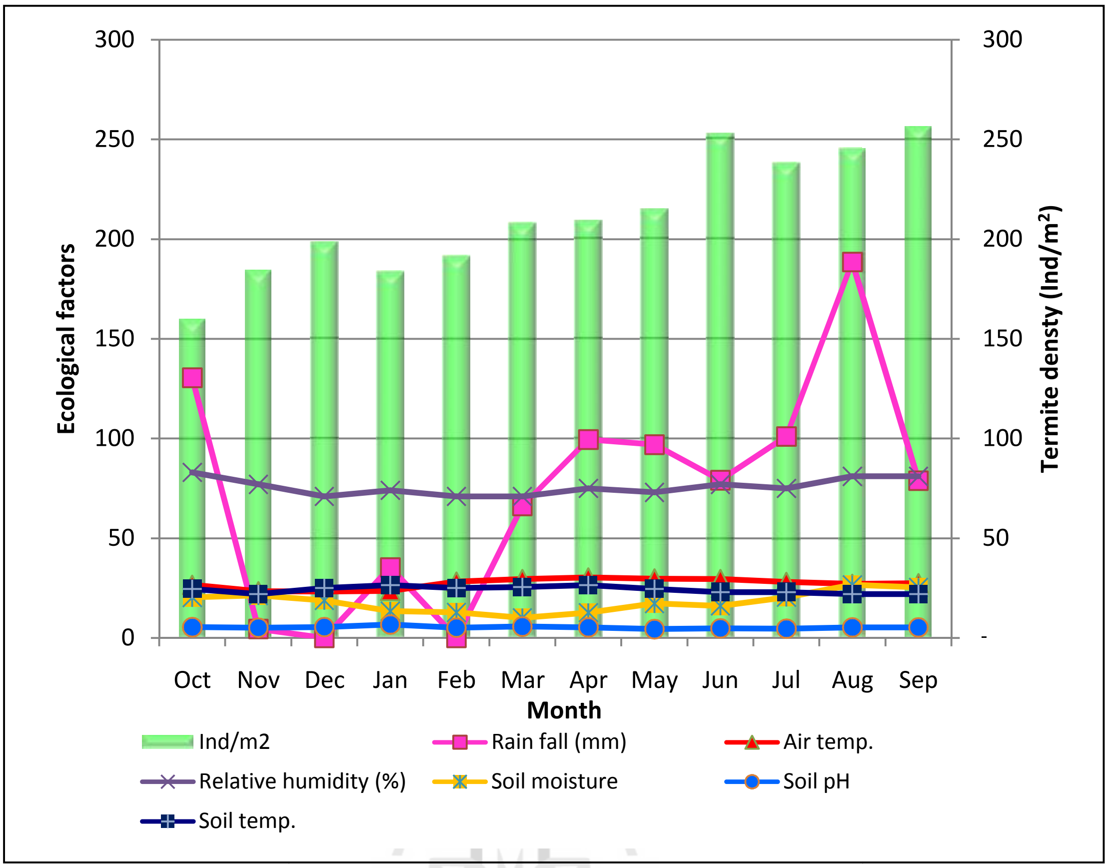


Figure 4.15 Monthly ecological factors and density of termites in DEF.

The information above lead to the speculation that dry evergreen forest probably have more suitable soil organic matter and soil moisture for better feeding sites and for survival of termites than dry dipterocarp forest. As shown in Figures 4.7 and 4.8 monthly termite population density revealed that seasonal changes did not have much effect to species richness and tended to decrease in the summer season. Soil moisture and relative humidity had more effect to species richness and termite activity than temperature and soil pH.

4.7 The relationship between termites and protozoa

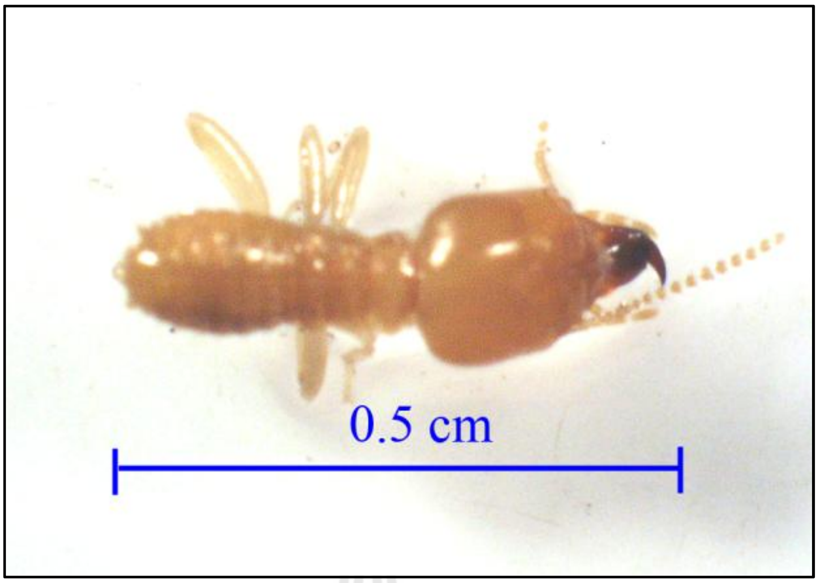
In this study, the protozoa were studied from whole guts of worker termite in 3 different feeding groups which were dominant species in each feeding inhabit as shown in Table 4.9.

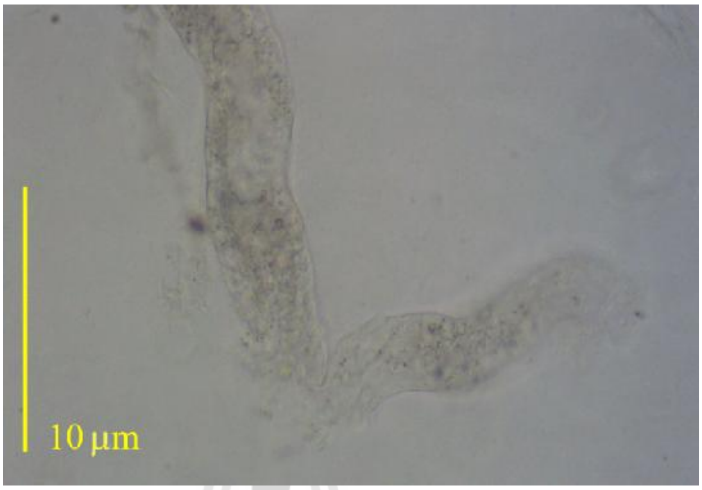
Table 4.9 The diversity of the protozoa in the gut of termite**.**

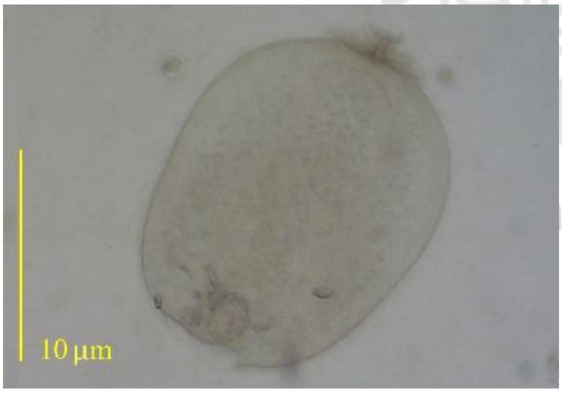
Termite species	Food habitat	Protozoa			
		Tricho-nympha	*Pseudo-trichonympha*	*Spiro-nympha*	*Dine-nympha*
1. *Termes* sp.	S	-	-	-	-
2. *Schedorhinotermes* sp.	W	✓	✓	✓	✓
3. *Microcerotermes crassus*	W	-	-	-	-
4. *Macrotermes gilvus*	F	-	-	-	-
5. *Hypotermes makhamensis*	F	-	-	-	-

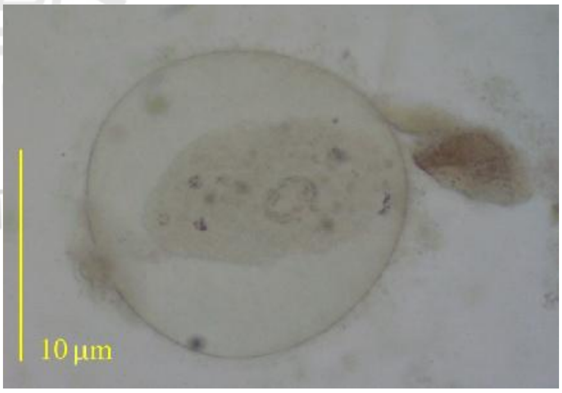
S = Soil feeding termites, W = Wood feeding termites, F = Fungus feeding termites

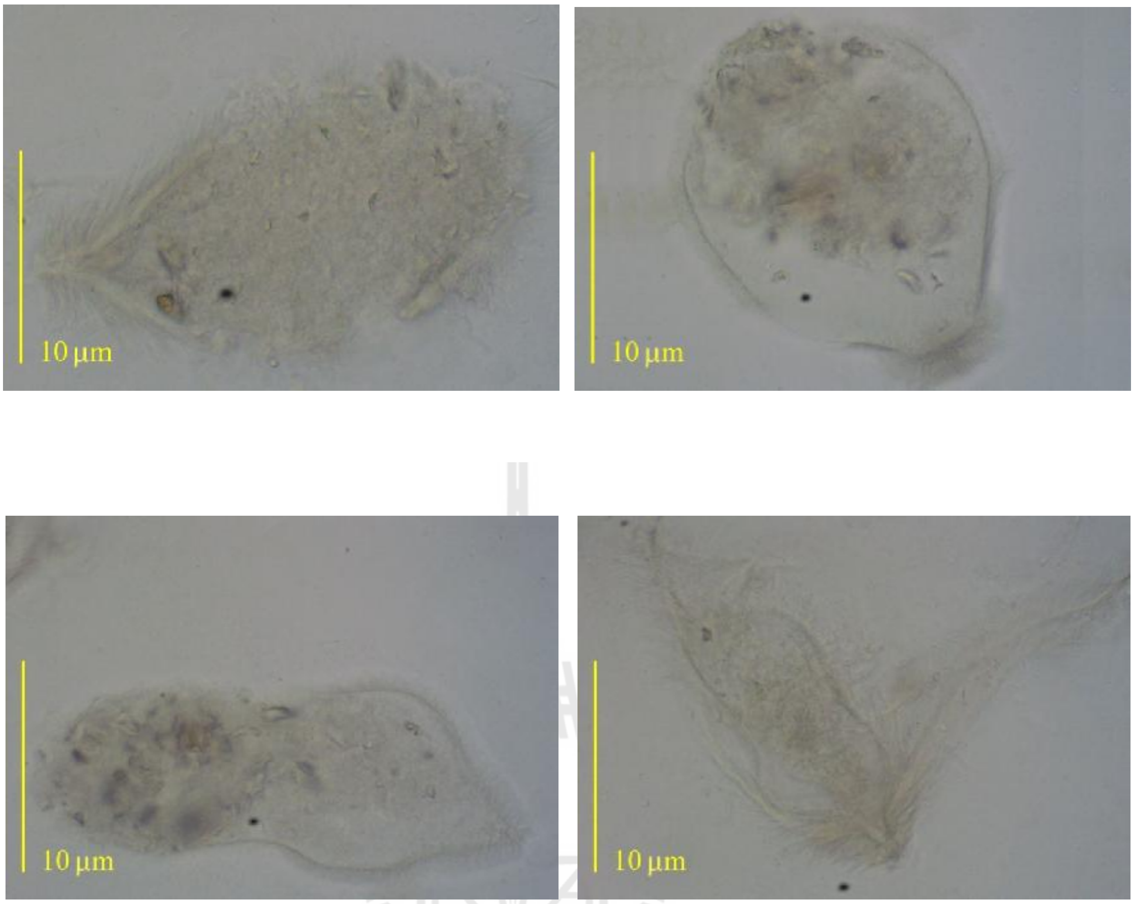
According to the results as shown in Table 4.9 it revealed that many genera of flagellates protozoa were presented in only one species of termites as *Schedorhinotermes* sp. which is a group of wood feeding termites and has been classified into lower termites, but the higher termites were not found these protozoa.


0.5 cm


10 μm


10 μm


10 μm


10 µm
10 µm
10 µm
10 µm

CHAPTER V

CONCLUSIONS

5.1 Conclusion

1. A total of 25 species, 18 genera and 6 subfamilies of termites were found from dry dipterocarp and dry evergreen forest at Sakarerat Environmental Research Station (SERS) by three different methods; direct search, soil pit and bait trap station in October 2009 – September 2010.

2. Macrotermitinae was found to be the dominant subfamily in both dry dipterocarp and dry evergreen forest, followed by subfamilies Termitinae and Nasutitermitinae, respectively. Because termites in these groups can adapt in instances of food shortage and habitat destruction. The subfamilies Kalotermitinae and Rhinotermitinae were found only in dry evergreen forest.

3. Dry evergreen forest had a higher number of termites species than dry difterocarp forest. The first dominant species in both dry evergreen forest and dry dipterocarp forest was *Microcerotermes crassus*, followed by *Hypotermes makhamensis, Globitermes sulphureus*, *Macrotermes gilvus*, and *Macrotermes carbonarius,* respectively.

4. The termites based on their food habitat were classified into three different termite groups as:

- Wood feeders: *Glyptotermes, Schedorhinotermes, Coptotermes, Globitermes, Microcerotermes* and *Nasutitermes.*
- Wood and leaf feeders: *Macrotermes, Odontotermes, Hypotermes,*

Microtermes and Ancistrotermes.

- Soil or humus feeder: *Amitermes, Dicuspiditermes, Mirocapritermes, Homallotermes, Procapritermes, Pericapritermes and Termes.*

5. The diversity index (H'), evenness and species richness of termite in dry evergreen forest was found to be higher than dry dipterocarp forest that had H' Index value of 3.079 and 2.744 and an evenness of 0.957 and 0.949 and species richness 25 and 18 species, respectively.

6. Similarity of species component in each forest type using Sorensen's index showed the value of 0.8372 or 83.72%.

7. The termite density was positively significantly correlated ($P < 0.05$) with soil moisture (r = 0.728), but negatively significantly correlated with soil temperature (r = -0.646) in the dry dipterocarp forest. However, the dry evergreen forest showed no significant correlation with environmental factors. Monthly termite population density revealed that seasonal change did not have much effect to species richness and tended to decrease in the summer season.

8. Many genera of flagellated protozoa were presented only in species of termites such as *Schedohinotermes* sp. They are a group of wood feeding termites and have been classified into lower termites, but the higher termites were not found to have these protozoa. *Trichonympha* sp. was found to be the dominant species followed by *Psuedotrichonympha* sp., *Spironympha* sp. and *Dinenympha* sp., respectively.

5.2 Recommendation

1. There should be a lot of different types of termites that live in urban and rural areas to be used as a comparison with existing data.

2. The study of relationship between termites and mushrooms to promote the cultivation of mushrooms to promote economic trade in the community should be taken into account.

3. The study of protozoa in the termite gut to use enzymes to degrade waste to industry should be considered.

REFERENCES

REFERENCES

Ahmad, M. (1950). The phylogeny of termites genera based on imago-worker mandibles. **Bulletin of the American Museum of Natural History.** 95(2): 37 - 86.

Ahmad, M. (1965). Termites of Thailand. **Bulletin of the American Museum of Natural History.** 131: 1 - 111. *In* Sornnuwat, Y., Vongkaluang, C. and Yoko, T. (2003). A Systematic key to termites of Thailand. [Online]. Available: http://www.thaiscience.info/ Article%20for%20 ThaiScience/Article/5/Ts-5%20a%20systematic%20key %20to%20for%20of%20 thailand.pdf. Accessed date: August 23, 2009.

Amornsak, W., Sarnthoy, O. and Kirtibutr, N. (2003). New records of two Nasutitermmitinae termites (Isoptera: Termitidae) from hill evergreen forest on Kitchakut National Park in Thailand. **Kasetsart.** 37: 421 - 428.

Bignell, D.E. and P. Eggleton. (2000). **Termites in ecosystems**, pp. 363 - 387. *In* T. Abe, D.E. Bignell and M. Higashi (eds.). Termites: Evolution, Sociality, Symbioses, Ecology. Netherlands: Academic.

Boonriam, W. (2010). **Microbial contribution to the carbon mineralization and decomposition rate of litter on the forest floor in dry evergreen forest at Sakaerat Environmental Research Station.** M.Sc.Thesis, School of Biology, Institute of Science, Suranaree University of Technology, Thailand.

Boonriam, W., Yamada, A., Saitoh, S., Hassin, S., Wiwatwitaya, D., Artchawakom, T. and Thanee, N. (2010). How much area is foraged by termites in tropical forests? *In* **Proceeding of The Seventh Conference of The Pacific Rim**

Termite Research Group. 2-3 March 2010, Singapore, pp.154-158.

Brune, A. and Friendrich, M. (2000). Microecology of the termite gut: structure and function on a microscale. **Microbiology.** 3: 263-269.

Bunyavejchewin, S. (1986). Ecological studies of tropical semi-evergreen rain forest at Sakaerat, Nakhon Ratchasima, northeast Thailand. **Siam Society.** 34: 35-57.

Buurman , P., Van, B. and Velthorst, E.J. (1996). **Manual for soil and water analysis.** Leiden: Backhuys.

Chalermsan, Y., Sarnthoy, O. and Kirtibutr, N. (2003). Belt-transect: a sampling device for termite communitite study. **Kasetsart.** 37: 150-156.

Collins, N.M. (1980). The distribution of soil macrofauna on the West Ridge of Gunung (Mount) Mulu, Sarawak. **Oecologia.** 44: 263-275.

Collins, N.M. (1983). Termite populations and their role in litter removal in Malaysian rain forests. *In* **Tropical rain forest ecology and management.** Oxford: Blackwell Scientific.

Collins, N.M. (1997). **Termite,** pp. 109-125. *In* Kirtibutr, N. and Abe, T. (eds). Biology and ecology of termites. Bangkok : Kasetsart University.

Cook, T.J. and Gold, R.E. (1998). Organization of the symbiotic flagellate community in three castes of the eastern subterranean termite, *Reticulitermes flavipes* (Isoptera: Rhinotermitidae). **Sociobiology.** 31: 25-30.

Davies, R.G. (1997). Termtie species richness in fire-prone and fire-protected dry deciduous dipterocarp forest in Doi Suthep-Pui National Park, northern Thailand. **Jounal of Tropical Ecology.** 13: 153-160.

Dawes - Gromadzki, T.Z. (2005). The termite (Isoptera) fauna of a monsoonal rainforest near Darwin, northern Australia. **Australian Journal of Entomology.** 44: 152 -

157.

Eggleton, P., Davies, D.E., Connetable, S., Bignell, D.E. and Rouland, C. (2002). The termites of Mayombe Forest Reserve, Congo (Brazzaville): transect sampling reveals an extremely high diversity of ground-nesting soil feeders. **Journal of Natural History.** 36: 1239-1246.

Gajaseni, J. (1976). **An ecological study on population, biomass and species composition of soil fauna in dry evergreen forest, Sakaerat, Nakhon ratchasima.** M.Sc. Thesis, Chulalongkorn University, Thailand.

Harnboonsong, Y. (1986). **Fungus growing termites.** M.Sc. Thesis, Kasetsart University, Bangkok. Thailand.

Higashi, M. and Abe, T. (1997). **Global diversification of termites driven by the evolution of symbiosis and sociality,** pp. 28-57. *In* Kirtibutr, N. and Abe, T. (eds). Biology and ecology of termites. Bangkok : Kasetsart University.

Holmgren, N. (1913). **Terrmitenstudien,** pp. 57. *In* Morimoto, K. (eds). Termites from Thailand. Bulletin of the Government Forest Experiment Station, Meguro. 257: 57-80.

Honiberg, B.M. (1970). Protozoa associated with termites and their role in digestion. **Biology of Termites.** 2: 1-35.

Inoue, T.,Takematsu, Y., Yamada, A., Hongoh, Y.,Johjima, T., Moriya, S., Sornnuwat, Y., Vongkaluang, C., Ohkuma, M. and Kudo, T. (2001). Biodiversity of termites in Khao Kichagoot National Park. **Termite Symbion Bio-recycle project.** 4: 7275-7280.

Intanai, I. (1987). **Taxonomic studies and some of their ecological factors of termites in Chanthaburi and Trat provinces.** M.S. Thesis, Chulalongkorn University, Thailand.

J.C.C.Pest Management Co., Ltd. (2003). **General knowledge of termites.** [Online.] Available: http://jcc2u.com/book_termite/book_termite.html. Accessed date: March 10, 2010.

Jones, D.T. (2000). Termite assemblages in two distinct montane forest types at 1000 m elevation in Maliau Basin, Sabah. **Journal of Tropical Ecology.** 16: 271-286.

Krishna, K. (1969). **Biology of termites.** New York : Academic.

Lamotte, S., Gajaseni, J. and Malaisse, F. (1998). Structure diversity in three forest types of north-eastern Thailand (Sakaerat Reserve, Pak Tong Chai). **Biotechnology, Agronomy, Society and Environment.** 2: 192-202.

Lewis, J. and Forschler, B. (2004). Protist communities from four castes and three species of *Reticulitermes* (Isoptera: Rhinotermitidae). **Annuals of the Entomological Society of America.** 97: 1242-1251.

Matsumoto, T. (1976). The role of termites in an equatorial rain forest ecosystem of west Malaysia. **Oecologia.** 22: 153-178.

Morimoto, K. (1973). **Termites from Thailand.** In: Sornnuwat, Y., Vongkaluang, C. and Yoko, T. (2003). A systematic key to termites of Thailand. [Online]. Abailable: http://www.thaiscience.info/Article%20for%20ThaiScience/Article/5/Ts-5%20 a% 20systematic%20key%20to%20for%20of%20thailand .pdf. Accessed date: August 23, 2009.

Ohkuma, M., Ohtoko, K., Iida, T., Tokura, M., Moriya, S., Usami, R., Horikoshi, K. and Kudo, T. (2000). Phylogenetic identification of hypermastigoes, *Pseudotrichomympha, Spirotrichonympha, Holomastigotoides,* and parabaslian symbionts in the hindgut of termites. **Eukaryot Microbiology.** 47: 249 - 259.

Pearce, M.J. (1999). **Termites: Biology and pest management.** London: CAB International.

Ratmithat, A. (1988). Protozoa in termites. *In* **Proceedings of Animal Wildlife in Thailand 1988,** 22-24 December 1988, Thailand, pp.15: 1 - 6.

Richard, O.W. and Davies, R.G. (1977). **Imms' general textbook of entomology.** 10th ed., Vol. II, London: Chapman & Hall , pp. 606-642.

Roonwall, M.L. (1969). Measurement of termites (Isoptera) for taxonomic purposes. **Journal of the Zoological Society of India.** 21(1): 9-66.

Sajap, A. and Lardizabal, M. (1998). Major protozoan fauna in the tropical subterranean termite, *Coptotermes curvignathus* Holmgren (Isoptera: Rhinotermitidae). **Sociobiology.** 32(1): 119-124.

Sakaerat Environmental Research Station. (2008). **Map.** [Online.] Available: http://www.tistr.or.th/sakaerat/Nature%20Trail.jpg. Accessed date: February 11, 2010.

Security Pest Control. (2005). **Termite Gallery.** [Online.] Available: http://www.security pest.com/gallery.htm. Accessed date: March 10, 2010.

Shannon, C.E. and Weever, W. (1949). **The mathematical theory of communication.** Urbana: University Illinois Press.

Sinma, K., Trakulnaeumsai, S., Noparatnaraporn, N. and Kitpreechavanich, V. (2003). **Actinomycetes from termites guts and its degradation of lignocellulosic compounds and uric acid.** [Online]. Available: http://kucon.lib.ku.ac.th /Fulltext/KC4305017.pdf. Accessed date: August 20, 2009.

Snyder, T.E. (1948). **Our enemy the termite.** New York : Comstock.

Sornnuwat, Y., Vongkaluang, C., and Yoko, T. (2004). **A systematic key to termites of**

Thailand. [Online]. Available: http://www.thaiscience.info/Article%20 for%20 ThaiScience/Article/5/Ts-5%20a%20systematic%20key%20to%20termites% 20of%20thailand.pdf. Accessed date: August 23, 2009.

Stiling, P. (1999). **Ecology: Theory and applications.** Third Edition. USA: Prentice Hall International.

Suriyapong, Y. (2003). **Study of ground dwelling ant populations and their relationship to some ecological factors in Sakaerat Environmental Research Station, Nakhon Ratchasima.** Ph.D. Thesis, School of Biology, Institute of Science, Suranaree University of Technology. Nakhon Ratchasima.

Thailand Institute of Scientific and Technological Research. (2000). **Sakaerat Environmental Research Station.** [online] Available: http://www.tistr.or.th /sakaerat/Land_used/land_used.htm Accessed date: August 11, 2010.

Vongkaluang, C., Sornnuwat, Y., Charoenkrung, K. and Chutibhapakorn, S. (2001). **Survey and study on ecology and diversity of termites in three forest types of Chanthaburi Province, Eastern Thailand**, pp. 126-145. *In* Seminar on "Termite Symbion Bio-Recycle Project", 28-30 June 2001. Phuket Merlin Hotel, Phuket.

Vongkaluang, C., Sornnuwat, Y., Charoenkrung, K., Chutibhapakorn, S. and Takematsu, Y. (2003). Survey and study on ecology and diversity of termites in three forest types of Chanthaburi province, eastern Thailand, pp. 523-528. *In* **Proceeding of The 2nd International Conference on Medicinal Mushroom and the International Conference Biodiversity and Bioactive Compounds.** 17-19 July 2003, Pattaya, Thailand.

Vongkaluang, C., Sornnuwat, Y., Charoenkrung, K., Chutibhapakorn, S., and Yoko, T.

(2004). **Survey and study on ecology and diversity of termites in eastern and western Thailand; Chantaburi and Kanchanaburi Province.** [Online]. Available: http://www.forest.go.th/forprod/research/ abstract/1004.pdf.

Wacharinrat, C., Dhanmanonda, P., Eiadtong, W. and Srigongpan. R. (2001). **Structural characteristics of evergreen forest at eastern forest complex, Thailand**, pp. 89-125. *In* Seminar on "Termite Symbion Bio - Recycle Project", 28 - 30 June 2001. Phuket Merlin Hotel, Phuket.

Weesner, F.M. (1969). **External Anatomy,** pp. 19 - 47. *In* Krishna, K. (1969). Biology of termites. New York: Academic.

Wilson, E.O. (1971). **The insect societies.** Cambridge : Harvard University.

Wongsiri, S. (1993). **Economic pest of Thailand.** Thailand: Odean Wung Burapha.

Yamada, A. Inoue, T., Sugimoto, A., Takematsu, Y., Kumai, T., Hyodo, F, Fujita, A., Tayasu, I., Klangkaew, C., Kirtibutr, N., Kudo, T. and Abe, T. (2003). Abundance and biomass of termites (Insecta: Isoptera) in dead wood in a dry evergreen forest of Thailand. **Sociobiology.** 42: 569 - 585.

Yamada, A., Inoue, T., Wiwatwitaya, D., Ohkuma, M., Kudo, T., Abe, T. and Sugimoto, A. (2005). Carbon mineralization by termites in tropical forests, with emphasis on fungus-combs. **Ecological Research.** 20: 453 - 460.

Yimrattanabovorn, J. (1993). **Seasonal fluctuations of soil fauna and its influence on the decomposition of organic matters in teak plantation at Chagwat Phitsanulok.** M.S. Thesis, Chulalongkorn University, Thailand.

Zhou, X., Smith, J., Oi, F., Koehler, P., Bennett, G. and Scharf, M. (2007). Correlation of cellulose gen expression and cellulolytic activity throughout the gut of the termite *R. flavipes.* **Gene.** 395: 29 - 39.

APPENDICES

APPENDIX A

TERMITE DIVERSITY FOUND IN DRY DIPTEROCARP AND DRY EVERGREEN FORESTS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION

Table A1 Distribution of termites in DDF of SERS from October 2009 - September 2010

Species	Months												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Kalotermitinae													
1. *Glyptotermes brevicaudatus*	-	-	-	-	-	-	-	-	-	-	-	-	-
2. sp.1	-	-	-	-	-	-	-	-	-	-	-	-	-
Rhinotermitinae													
3. *Schedorhinotermes* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Coptotermitinae													
4. *Coptotermes curvignathus*	31	140	220	-	-	80	225	28	170	278	-	86	1,258
Macrotermitinae													
5. *Macrotermes carbonarius*	243	-	187	62	65	274	58	145	50	218	376	315	1,993
6. *Macrotermes gilvus*	58	271	179	78	-	245	205	335	248	205	315	352	2,491
7. *Macrotermes annandalie*	136	52	214	-	95	85	132	341	183	220	-	42	1,500
8. *Odontotermes longignathus*	195	149	192	55	-	82	110	-	335	242	223	177	1,760
9. *Odontotermes feae*	220	90	220	-	115	100	150	314	-	331	140	88	1,768
10. *Odontotermes proformosanus*	130	100	20	62	-	145	42	138	142	-	233	35	1,047
11. *Hypotermes makhamensis*	291	312	281	235	246	403	309	392	357	445	470	378	4,119
12. *Microtermes* sp.	93	150	215	-	184	-	249	217	125	165	233	367	1,998
13. *Ancistrotermes pakistanicus*	-	40	23	-	-	116	-	154	186	185	330	234	1,268

Table A1 (Continued).

Species	Months												
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Total**
Termitinae													
14. *Amitermes* sp.	90	54	-	-	-	-	80	111	72	63	-	42	512
15. *Globitermes sulphureus*	436	381	405	166	254	360	415	516	505	415	481	462	4,796
16. *Microcerotermes crassus*	436	438	391	208	216	388	453	430	459	586	560	476	5,041
17. *Dicuspiditermes makhamensis*	-	116	75	-	-	37	93	224	120	200	-	249	1,114
18. *Mirocapritermes* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-
19. *Homallotermes* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-
20. *Procapritermes* sp.	-	-	-	-	-	-	-	-	-	-	-	-	-
21. *Pericapritermes* sp.	181	22	229	-	-	-	132	283	235	-	321	291	1,694
22. *Termes* sp.	83	265	96	-	-	215	86	212	241	132	133	242	1,705
Nasutitermitinae													
23. *Nasutitermes* sp.	198	226	157	-	62	101	90	-	350	225	50	258	1,717
24. sp.2	115	207	96	-	-	80	120	150	127	228	-	-	1,123
25. sp.3	-	211	151	-	-	75	58	50	210	-	176	-	931
Total	2,936	3,224	3,351	866	1,237	2,786	3,007	4,040	4,115	4,138	4,041	4,094	37,835

Table A2 Distribution of termites in DEF of SERS from October 2009 - September 2010

Species	Months												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Kalotermitinae													
1. *Glyptotermes brevicaudatus*	0	28	54	65	0	0	36	0	0	91	0	0	274
2. sp.1	0	0	0	0	0	39	0	28	56	36	28	0	187
Rhinotermitinae													
3. *Schedorhinotermes* sp.	0	93	83	97	0	0	88	96	130	0	0	145	732
Coptotermitinae													
4. *Coptotermes curvignathus*	73	0	80	50	84	62	0	0	50	96	124	125	744
Macrotermitinae													
5. *Macrotermes carbonarius*	80	0	130	185	0	154	95	85	0	91	144	120	1084
6. *Macrotermes gilvus*	89	129	0	135	0	73	114	108	92	116	87	192	1135
7. *Macrotermes annandalie*	0	0	63	80	0	130	52	0	80	0	94	0	499
8. *Odontotermes longignathus*	120	78	0	133	116	0	80	110	119	0	123	101	980
9. *Odontotermes feae*	98	151	0	0	97	123	0	136	100	0	121	145	971
10. *Odontotermes proformosanus*	78	0	39	0	0	95	74	115	0	86	0	0	487

Table A2 (Continued).

Species	Months												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Macrotermitinae													
11. *Hypotermes makhamensis*	93	133	90	114	145	116	80	100	155	85	100	165	1376
12. *Microtermes* sp.	0	0	85	96	115	0	95	120	0	100	150	0	761
13. *Ancistrotermes pakistanicus*	0	0	50	35	0	0	80	95	0	48	85	0	393
Termitinae													
14. *Amitermes* sp.	0	52	65	95	78	115	0	54	0	85	0	62	606
15. *Globitermes sulphureus*	136	110	86	98	80	90	78	89	125	129	132	125	1278
16. *Microcerotermes crassus*	120	96	70	90	125	130	175	110	90	120	65	133	1324
17. *Dicuspiditermes makhamensis*	0	40	100	0	85	50	80	60	0	50	65	90	620
18. *Mirocapritermes* sp.	0	0	0	0	90	0	75	0	0	138	50	0	353
19. *Homallotermes* sp.	0	0	40	75	0	0	85	0	150	150	0	0	500

Table A2 (Continued).

Species	Months												
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Termitinae													
20. *Procapritermes* sp.	0	52	0	0	55	50	0	128	50	0	145	0	480
21. *Pericapritermes* sp.	0	50	80	50	0	0	0	60	125	50	0	57	472
22. *Termes* sp.	0	0	115	0	120	0	90	80	100	50	0	125	680
Nasutitermitinae													
23. *Nasutitermes* sp.	58	95	0	0	90	0	0	85	0	35	62	52	477
24. sp.2	25	0	0	45	50	38	54	0	90	0	0	0	302
25. sp.3	0	25	49	0	0	50	0	0	0	56	0	0	180
Total	**970**	**1,132**	**1,279**	**1,443**	**1,330**	**1,315**	**1,431**	**1,659**	**1,512**	**1,612**	**1,575**	**1,637**	**16,895**

APPENDIX B

DATA OF ECOLOGICAL FACTORS

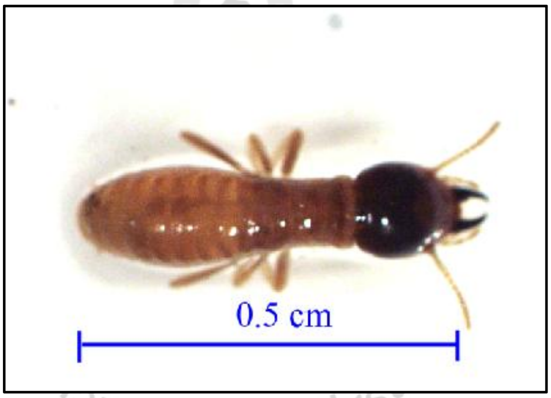
Table B1 Monthly ecological factors and density of termites in DDF and DEF from October 2009 - September 2010 (http://www.tistr.or.th/sakaerat/Meteorlogical.HTM)

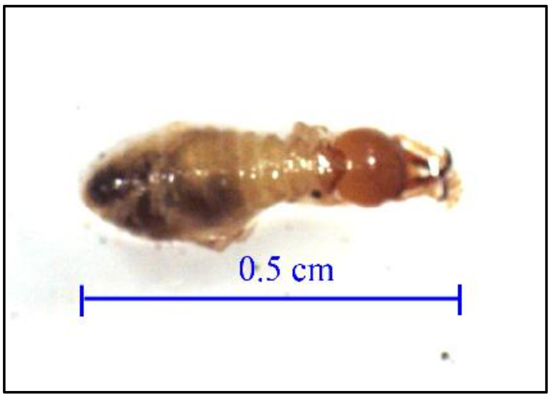
Forest types	Month	Ind/m^2	Climate factors			Soil factors		
			Rain fall (mm)	Air temp.	Relative humidity (%)	Soil moisture	Soil pH	Soil temp.
DDF	Oct, 09	146.80	112.2	27.75	88.0	14.93	5.48	25.00
	Nov, 09	161.20	16.5	25.30	77.0	12.32	5.03	23.00
	Dec, 09	167.55	0	24.90	71.0	10.26	6.10	23.00
	Jan, 10	43.30	31.2	25.30	74.0	9.82	5.52	27.50
	Feb, 10	61.85	11.2	29.25	72.0	7.89	4.75	28.50
	Mar, 10	139.30	51.8	29.05	76.0	6.48	5.67	29.50
	Apr, 10	150.35	116.7	31.05	73.0	9.26	6.49	28.00
	May, 10	202.00	52.6	30.40	73.0	14.25	5.72	27.00
	Jun, 10	205.75	146.3	29.50	78.2	16.93	5.86	24.50
	Jul, 10	206.90	93	28.65	75.0	18.82	5.44	22.50
	Aug, 10	202.05	190.8	27.70	82.0	20.30	5.53	22.00
	Sep, 10	204.70	149.8	28.40	82.0	18.24	5.81	21.50
DEF	Oct, 09	159.85	130.5	26.65	83.0	20.30	5.37	24.50
	Nov, 09	184.55	4.5	23.45	77.0	21.26	5.16	22.00
	Dec, 09	198.20	0.00	23.30	71.0	18.79	5.42	25.00
	Jan, 10	183.55	35.3	23.60	74.0	13.42	6.71	26.50
	Feb, 10	191.40	0.00	28.25	71.0	12.79	5.09	25.00
	Mar, 10	208.15	66.2	29.50	71.0	10.12	5.72	25.50
	Apr, 10	208.90	99.5	30.30	75.0	12.68	5.28	26.50
	May, 10	214.65	96.9	29.65	73.0	17.26	4.39	24.50
	Jun, 10	252.65	79.1	29.60	77.0	16.10	4.83	23.00
	Jul, 10	238.20	101	28.15	75.0	20.34	4.68	23.00
	Aug, 10	245.40	188.6	27.15	81.0	26.61	5.26	22.00
	Sep, 10	256.35	78.9	27.50	81.0	25.30	5.33	22.00

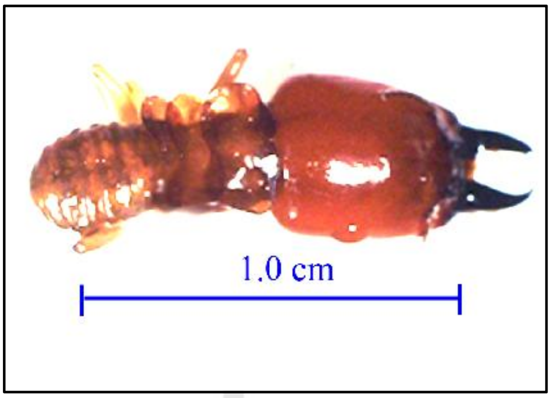
APPENDIX C

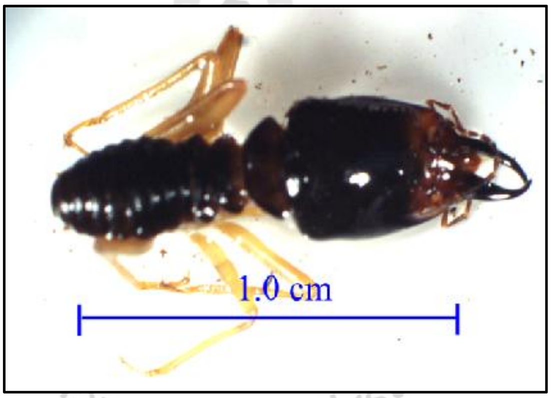
DOMINANT SPECIES OF TERMITES IN DRY DIPTEROCARP AND DRY EVERGREEN FORESTS AT SAKAERAT ENVIRONMENTAL RESEARCH STATION


0.5 cm


0.5 cm


0.5 cm


1.0 cm


1.0 cm

CURRICULUM VITAE

Name Mrs. Pornsiri Thipsantia

Date of Birth 21 November 1979

Place of Birth Roi Et, Thailand

Education

1998-2002 Bachelor of Science in Biology, Mahasarakham University, Mahasarakham

Position

2003-present Teacher at Phothongpittayakhom School, Phanomprai district, Roi Et

Publications

Pornsiri Thipsantia and Nathawut Thanee. (2011). Biodiversity of termites and their relationship to dry dipterocarp and dry evergreen ecosystem at Sakaerat Environmental Research Station, Nakhon Ratchasima province, Thailand. (Proceedings). **The 7th International Conference "Inter-University Cooperation Program" "Regional Stability through Economic, Social and Environmental development in the Greater Mekong Sub-region and Asia-Pacific".** 7-12 August 2011, Sri Lanka.

Grants and Fellowships

This research was financially supported by the National Research Council of Thailand (NRCT) and the Institute for the Promotion of Teaching Science and Technology (IPST).