DIVERSITY OF TERMITES (ORDER: BLATTODEA) IN HUTAN LIPUR BUKIT BAKAR, MACHANG, KELANTAN

by

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A thesis submitted in fulfilment of the requirements for the degree of Bachelor of Applied Science (Natural Resources Science) with Honours

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DECLARATION

I declare that this thesis entitled "Diversity of Termites (Order: Blattodea) in Hutan Lipur Bukit Bakar, Machang, Kelantan" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

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APPROVAL

"I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Applied Science (Natural Resources Science) with Honours"

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Date :

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LIST OF ABBREVIATION

cm	Centimeter
m	Metre
m a.s.l	Metres above sea level
lux	Illuminance

LIST OF SYMBOLS

°C	Degree Celcius
°F	Fahrenheit
x	Multiply
%	Percentage

Diversity of Termites (Order: Blattodea) in Hutan Lipur Bukit Bakar, Machang, Kelantan

ABSTRACT

Hutan Lipur Bukit Bakar is rich in biodiversity that consists of flora and fauna. However, the research on insects is still lacking in the area. Therefore, this study was conducted to determine the diversity of termite in Hutan Lipur Bukit Bakar, Machang, Kelantan. The objective of this study is to determine the diversity of termites based on their morphology and taxonomy. Standardized line transect method with 100m x 2m and divided into 20 sections used in order to collect termite samples. The size of each section is 5m × 2m. Termites sample were collected by two peoples within 30 minutes in each section. Termites were collected manually using forceps and preserved in 80% of ethanol. The study was conducted from July until August 2018. A total of 156 hits comprising of 25 species of termites from two families (Rhinotermitidae and Termitidae) and five sub-families (Coptotermitinae, Termitinae, Rhinotermitinae, Macrotermitinae and Nasutitermitinae) were collected in this study. There are ecological factors affected the diversity of termite in the area such as soil pH, soil temperature, canopy cover, light intensity, and elevation. Hutan Lipur Bukit Bakar has high diversity of termite which is H'=2.707. This value was obtained by using Shannon-Wiener Index, and had complete evenness which is 0.841. Termite species that dominant are *Odontotermes* sp. Litter-foragers and epigeal mound builder are have the higher termite diversity. Meanwhile, soil-feeding group and hypogeal or subterranean nester have the lowest termite diversity. In a nutshell, Hutan Lipur Bukit Bakar has high diversity of termite and there is still more termite species await to be collect because of the accelerating graph on species accumulative curve. Therefore, further studies and research on termite diversity are required in order to determine the species richness on this particular areas.

Kepelbagaian Anai-Anai (Order: Blattodea) di Hutan Lipur Bukit Bakar, Machang, Kelantan

ABSTRAK

Hutan Lipur Bukit Bakar kaya dengan kepelbagaian biodiversiti yang terdiri daripada flora dan fauna. Walau bagaimanapun, kajian mengenai serangga masih kurang di kawasan itu. Oleh itu, kajian ini dijalankan untuk menentukan kepelbagaian anai-anai di Hutan Lipur Bukit Bakar, Machang, Kelantan. Objektif kajian ini adalah untuk menentukan kepelbagaian anai-anai berdasarkan morfologi dan taksonomi mereka. Kaedah tali transek dengan panjang 100m x 2m dan dibahagikan kepada 20 bahagian digunakan untuk mengumpul sampel anai-anai. Saiz setiap bahagian adalah 5m × 2m. Sampel anai-anai dikumpulkan oleh dua orang dalam masa 30 minit dalam setiap bahagian. Anai-anai dikumpulkan secara manual menggunakan forsep dan diawetkan dalam 80% etanol. Kajian ini dijalankan dari Julai hingga Ogos 2018. Sejumlah 156 hits terdiri daripada 25 spesies anai-anai daripada dua keluarga (Rhinotermitidae and Termitidae) dan lima sub-keluarga (Coptotermitinae, Termitinae, Rhinotermitinae, Macrotermitinae dan Nasutitermitinae) yang dikumpulkan dalam kajian ini. Terdapat faktor ekologi yang memberi kesan terhadap kepelbagaian anai-anai di kawasan seperti pH tanah, suhu tanah, litupan kanopi, keamatan cahaya, dan ketinggian. Hutan Lipur Bukit Bakar mempunyai kepelbagaian anai-anai yang tinggi iaitu H’=2.707. Nilai ini diperolehi dengan menggunakan indeks Shannon-Wiener dan mempunyai kesempurnaan lengkap iaitu 0.841. Spesies anai-anai yang dominan adalah *Odontotermes* sp. Pemakan sarap dan pembuat sarang *epigeal* mempunyai kepelbagaian anai-anai yang lebih tinggi. Sementara itu, kumpulan pemakan tanah dan pembuat sarang *hypogeal* atau *subterranean* mempunyai kepelbagaian anai-anai terendah. Kesimpulannya, Hutan Lipur Bukit Bakar mempunyai kepelbagaian anai-anai yang tinggi dan terdapat lebih banyak spesies anai-anai yang menunggu untuk dikumpulkan kerana graf akumulasi spesies masih menunjukkan peningkatan spesies anai-anai. Oleh itu, kajian lanjut dan penyelidikan mengenai kepelbagaian anai-anai adalah diperlukan untuk menentukan kekayaan spesies di kawasan ini.

CHAPTER 1

INTRODUCTION

1.1 Background of Study

Insects are a group of living organisms that represent largest of animal phyla which is Phylum Arthropoda (Wigglesworth, 2017). Insects also have the largest biomass of the terrestrial animals. Previously, termites are a group of insect which classified under the Order Isoptera. Name Isoptera which in Latin means equal wing and it refers to the fact that the front sets of the wing on the reproductive termite (Rahman & Tawatao, 2003). However, Inward, Beccaloni, & Eggleton (2007) have discovered that termites are classified in the same order as cockroach (Blattodea) due to the phylogenetic analysis of these insects' species. Blattodea comprises termite under epifamily Termitoidae while cockroaches under different family of Cryptocercidae.

Termites are further classified into seven families which are Termitidae, Rhinotermitidae, Kalotermitidae, Termopsidae, Hodotermitidae, Serritermitidae, and Mastotermitidae (Rahman & Tawatao, 2003). Termites can be classified based on their morphology, feeding group and nesting group (Lo et al., 2007). Termite's morphological characteristics indicate characteristics such as the shape of the head and mandible, number of antennal segments and measurements of body parts (Thapa, 1981; Tho, 1992).

American Museum of Natural History had recorded 3106 living and fossil of termite species around the world (Krishna et al., 2013). These species were came from seven families and 280 genera that have been recorded worldwide (Kambhampati & Eggleton, 2000; Rahman & Tawatao, 2003). Termites dispersed widely throughout the tropics includes some temperate regions. In South America, Africa and Southeast Asia, termites also became one of the top diversities of fauna (Collins, 1988; Bignell & Eggleton, 1998). In the oriental region of Indo-Malayan, termites comprise 52 genera and 323 species meanwhile 89 species in Sumatra (Tho, 1992). Sabah were recorded 104 species from 33 genera (Thapa, 1981). There are about 75 species from 42 genera have been recorded in Peninsular Malaysia (Jasmi & Ahmad, 2011).

Termites gave both advantages and disadvantages towards the environment. Among all species that have been described worldwide, 10% of termite species which consist of 363 species considered as pest (Lewis, 1997). These pest species cause damage to the residential area, building, and furniture. Termites also act as decomposer in the forests. In addition, termites support the cycling matter, soil processes and energy flow in forest area (Holt & Lepage, 2000). Not only that, termites play important roles in the formation of soil, soil structures, the condition of soil and nitrogen-fixation (Eggleton et al., 1996).

1.2 Problem Statement

Hutan Lipur Bukit Bakar is rich in biodiversity that consists of flora and fauna. There are many research conducted in Hutan Lipur Bukit Bakar regarding the diversity of flora and ecotourism culture. However, the research on insects especially termites is still lacking in Kelantan. Therefore, this study was conducted in order to get data on diversity of termites in Hutan Lipur Bukit Bakar.

1.3 Objectives

The objective of this study is to determine the diversity of termites in Hutan Lipur Bukit Bakar, Machang, Kelantan.

1.4 Scope of Study

This study was focused on termites' species. The collection of termite samples had been done using standardized line transect in Hutan Lipur Bukit Bakar. Then, the samples had been identified and analysed based on their classification, morphology, characteristics and also structures of their body.

1.5 Significance of Study

Based on the study conducted, the species richness and abundance of termite species in Hutan Lipur Bukit Bakar were determined. This is because lacks of information on the diversity of termites in Hutan Lipur Bukit Bakar. This study is not only contributed to insects data of Kelantan which help in insects management in Hutan Lipur Bukit Bakar but also indirectly increased the specimen of insects in Natural Resources Museum at Universiti Malaysia Kelantan, Jeli Campus. Then, the information of termite species of the area was useful for future researcher and entomologist as references.

CHAPTER 2

LITERATURE REVIEW

2.1 Termites Classification

Termites are presently divided into seven families, 14 subfamilies, 280 genera and over 2000 species in this world (Kambhampati et al., 1996; Rahman & Tawatao, 2003). There are four termite families which are Termitidae, Kalotermitidae, Rhinotermitidae and Hodotermitidae that recorded in South Asia. Meanwhile, only three from seven families were found in Peninsular Malaysia which are Termitidae, Kalotermitidae, and Rhinotermitidae (Tho, 1992).

Termites also classified into two types which are lower termite and higher termite. This is because of evolution in termite level which in the anatomy of termites and their behavior (Rahman & Tawatao, 2003). The higher termite families are more advanced than lower termites. They have more complex and developed nest and social interaction. The higher termites is Termitidae (Watson et al., 1985) meanwhile the six from seven families which are Mastotermitidae, Termopsidae, Rhinotermitidae, Kalotermitidae, Serritermitidae and Hodotermitidae classified under lower termites.

Lower termites can be considered as primitive group of termites. They are known to digest cellulose, protozoans, and bacteria using cellulose decomposition in their hindgut (Breznak, 1982; Breznak & Brune, 1994). For example, Kalotermitidae is considered as primitive group of termite due to the nesting and feeding habit (Krishna, 1961). Because of their habits, Kalotermitidae is also known as dry wood termites and largest family of lower termites. They have about 25 genera and 350 species (Krishna, 1970; Wood & Johnson, 1986). There are three different genus under family Kalotermitidae which are *Cryptotermes*, *Glyptotermes*, and *Neotermes*. The termite species in this family are pest in the forest. For example, *C. cynocephalus* and *C. domesticus* are species that usually found in the Peninsular Malaysia forest (Collins, 1988).

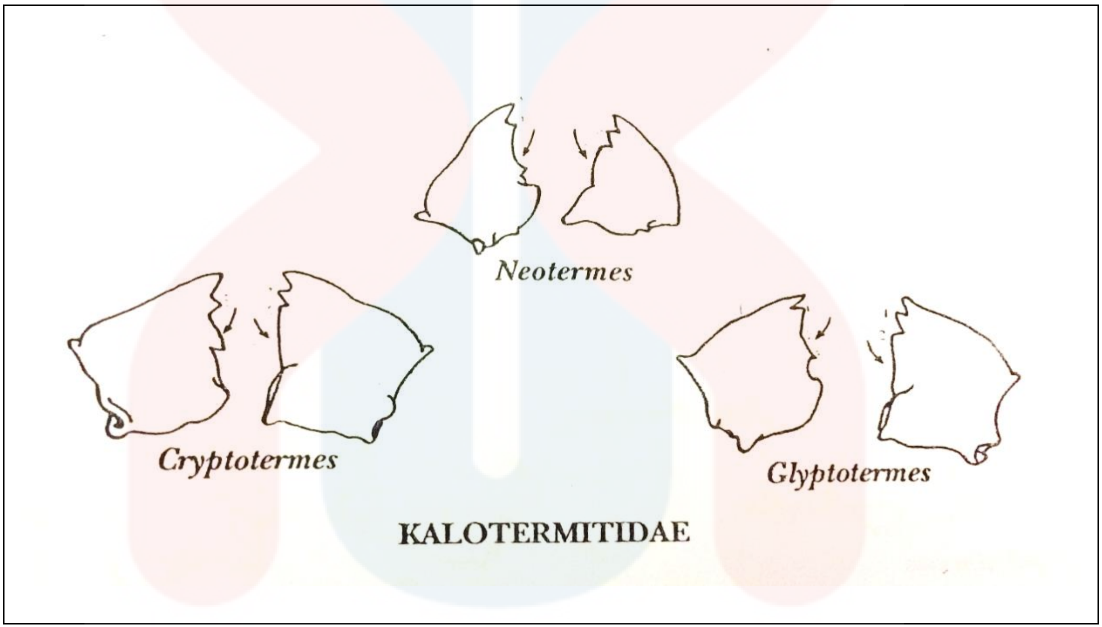

Figure 2.1: The mandible of a: *Neotermes*, b: *Cryptotermes*, c: *Glyptotermes*.

(Source: Tho, 1992)

Next is Rhinotermitidae which divided into six subfamilies which are Heterotermitinae, Coptotermitinae, Termitogetoninae, Psammotermitinae, Stylotermitinae, and Rhinotermitinae (Engel et al., 2011). Rhinotermitidae is known as damp wood termites because of their nesting habit. The worker caste in this family had three well developed and prominent marginal teeth on the left mandible and tooth at the base of the anterior cutting edge of the right mandible (Thapa, 1981). Other than Kalotermitidae and Rhinotermitidae, Hodotermitidae also under lower termite's classification. Hodotermitidae is known as rotten wood termites which generally found inhabiting moist wood.

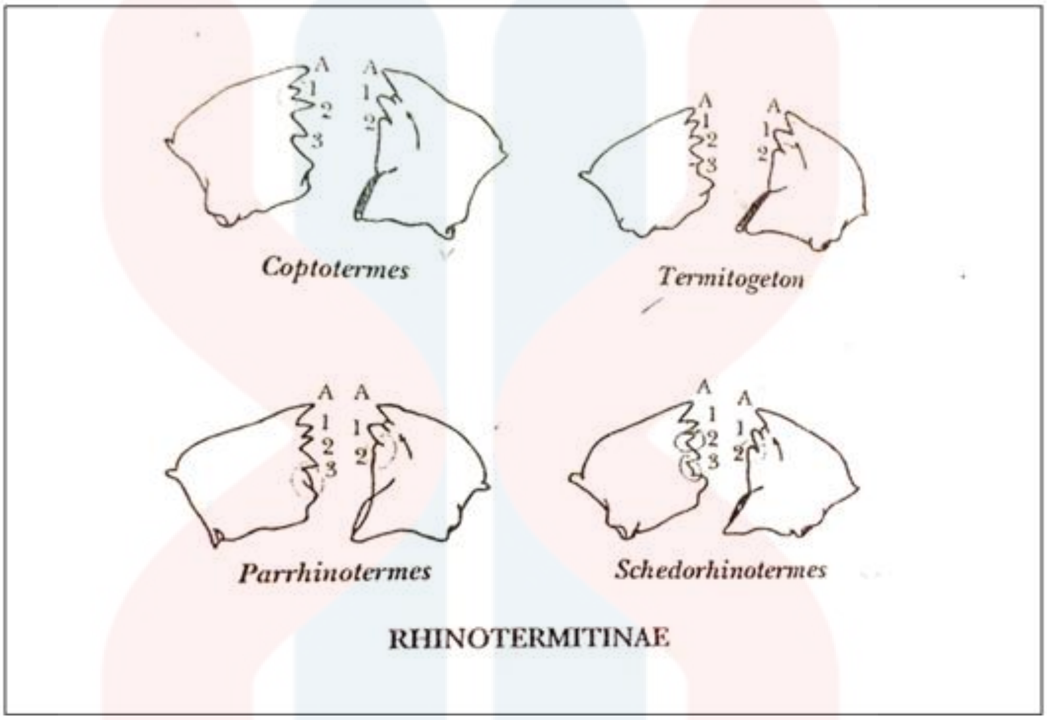

Figure 2.2: The left mandible has three marginal teeth. The right mandible has a subsidiary tooth.

(Source: Tho, 1992)

Termitidae is classified under higher termites which also comprise about three-quarters of termites species in the world (Krishna, 1970). Termitidae consists of four subfamilies which are Macrotermitinae, Termitinae, Apicotermitinae and Nasutitermitinae (Wood & Johnson, 1986; Collins, 1988). There are four genera from 13 genera of Macrotermitinae subfamilies found in Malaysia. Those genera are *Macrotermes*, *Microtermes*, *Odontotermes*, and *Hypotermes* (Rahman & Tawatao, 2003).

2.2 Termites Morphology

Termites live in colonies with very specific structure. There are different castes found in the colony which are reproductive (king and queen), soldiers and workers. Each caste has different morphological characteristics and function in the colony (Collins, 1984). The king and queen of termites act as functional reproductives. During early life, the reproductive are winged but after dispersing from original colony, those wings eventually lost (Lewis, 1997). The wings were shed and pair off in order to find a suitable harborage to build up the new colony.

There are six main morphological characteristics trait that chosen to identify the differences between species for soldier and worker. The morphology for worker and soldier which are head width, hind femur length, the distance between the apical tooth and first marginal teeth, the distance between first and second marginal teeth, distance between the second marginal tooth and molar extent of ridging on the molar plate (Collins, 1984).

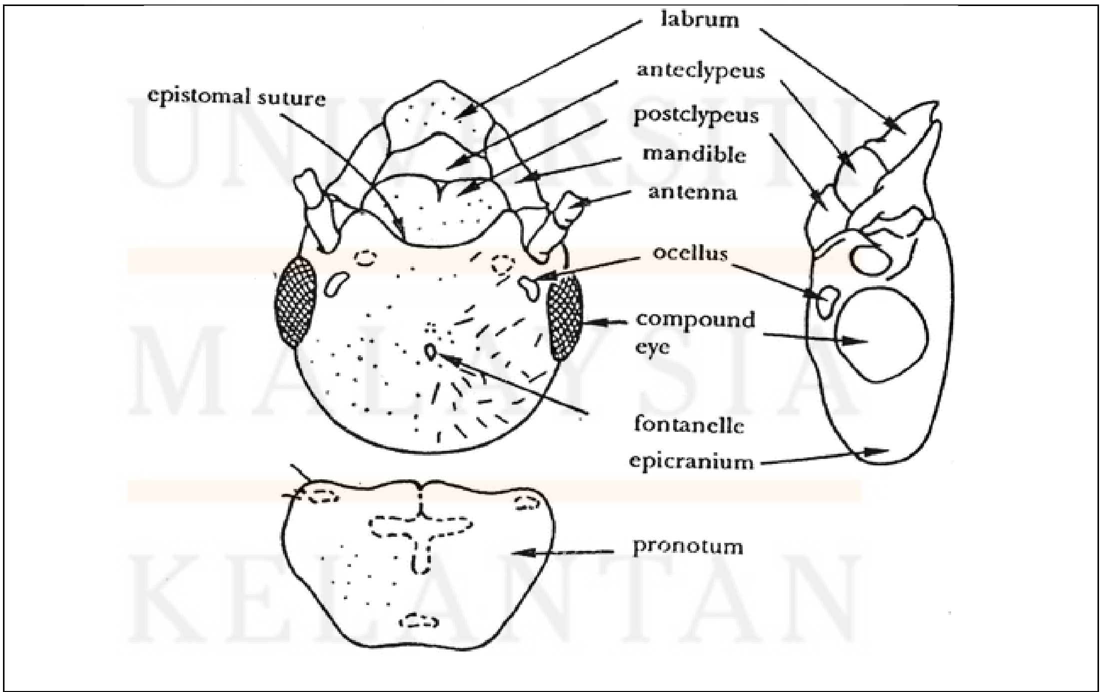

Figure 2.3: The morphology of termite based on imago head.

(Source: Tho, 1992)

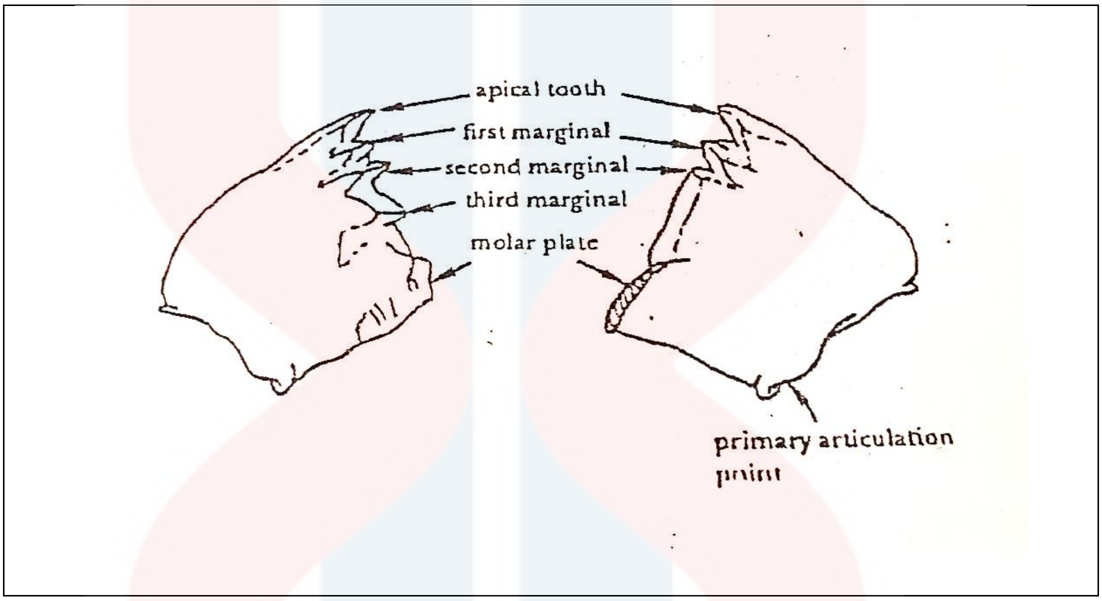

Figure 2.4: The structure of imago-worker mandibles.

(Source: Tho, 1992)

Soldier termite characteristic are based on the color appearance, shape of their head (Lo et al., 2007) and the structure of fontanelle (Tho, 1992). Soldier termite play role for protecting the colony from invaders like ants. The morphology of worker termites are wingless, sterile and blind. The function of worker termites are responsible for expanding the nest, ingesting food and building tunnels usually they causing structural damages (Rao et al., 2012).

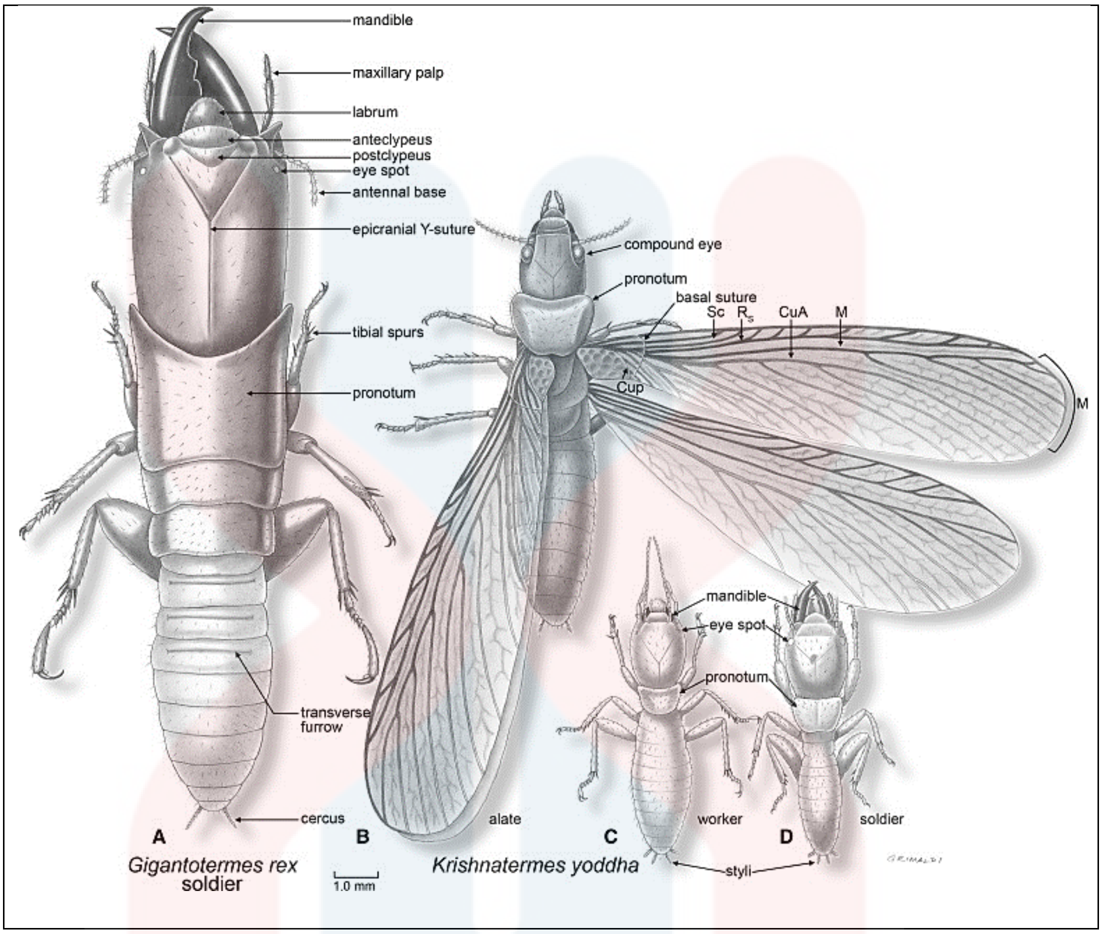

Figure 2.5: Morphology of alate, worker, and soldier termites.

(Source: Engel et al., 2016)

2.3 Life cycles of termites

Termites consist of three castes which are the reproductive (king and queen), soldiers and workers (Collins, 1984). Termites undergo incomplete metamorphosis. Termites' life begins when the queen lays eggs. The queen can hatch between hundreds to thousands of egg per day which depends on the colony size. At first, those eggs are translucent white and feeble then become very active when they about to hatch (Edwards & Mill, 1986).

Then, the reproductive produced nutrient-rich salivary secretions to feed the larvae. These larvae usually undergo a number of moults till them becoming mature form. They will either become soldiers or workers depends on the colony needs (Harris, 1957). Not only has that, extrinsic factors such as hormones and pheromones also affected in determining the development of termites species (Krishna, 1970).

Before the colony foundation was built, the larvae become the workers and then a few larvae are found with large head and jaws which is slightly different in shape after sometimes. These larvae grow into a soldier (Harris, 1957). After many years, the colony continues grows and the number of individuals became increase, the structure of nest became more complex and building activity was increased (Bignell & Eggleton, 1998). A full cycle of development is completed when the larvae appear with wing buds which then became winged termites (Harris, 1957).

2.4 Factors that influence diversity of termites

Termites usually found in tropical and temperate areas of the world (Santos et al., 2010). Termites also considered as dominant invertebrates in tropical soil and act as "ecosystem engineers" which provide ecosystem services such as decomposition, carbon and nitrogen cycling, soil structuring and the stimulation of microbial activity in the terrestrial ecosystem (Wood & Sand, 1978; Sugimoto et al., 2000; Donovan et al., 2002). Termite and soil had mutual relationship which both were depend on each other to balance ecosystem. This indicated soil became environmental factors that affected termite diversity.

Another environmental factors such as soil moisture, soil temperature, relative humidity, light intensity and also canopy cover influenced the distribution of termite species in various world region (Gutierrez & Whitford, 1989). In addition to environmental factors, geological history also effect the structure of termite community (Bignell & Eggleton, 2000). The diversity of termite usually decrease with increased elevation. This is due to formation of clouds happen at lower altitudes lead sunlight to reflect and temperature decline at lower altitude (Gathorne-Hardy et al., 2001).

Moreover, temperature play important role to termite species because they are ectothermic. However, different trophic groups reacted differently to the temperature because of their feeding habits. For example, soil feeders were not affected because they feed on lower energy food substrates compared to wood feeders (Jones, 2000; Davies et al., 2003). Furthermore, rainfall also can attributed to the reduction of species richness and abundance of termite species in rain forest ecosystem. This is because rainfall can lead to the high levels of inundated microhabitats and colony death (Dibog et al., 1998; Bignell & Eggleton, 2000).

2.5 Importance of termites

Termites are invertebrates that dominated in the tropical forest (Rao et al., 2012). Termites play important roles in the ecological processes of soil. Termites are considered as main decomposers because of their ability to lengthen aridity and evade dehydration in dry climates (Abe et al., 2000). Termites are known as ecosystem engineer whereas consuming the living, dead and decay plant in tropical forest (Holt & Lepage, 2000).

Furthermore, termites are also known as detritivores which help in balance the ecosystem. Termites play strong roles in detritus consumption. Detritus litter is consist of wood, grasses, humus and other material. Soil formation started from the detritivorous recycling of lignocellulosic materials that have been done by termites (Park et al., 1996). Termites not only assist in nutrient regulation of the soil for agriculture purpose but also responsible for improving the condition, composition, and fertility of the soil (Davies & William, 1978).

CHAPTER 3

MATERIALS AND METHOD

3.1 Study Area

This study was conducted in Hutan Lipur Bukit Bakar which is located at N 5˚ 43’, E 102˚ 16’ (Norashikin et al., 2015). Bukit Bakar located in the reserve compartment 6 of Ulu Sat Permanent Reserved Forests was gazetted as the recreational forest in 1975. Hutan Lipur Bukit Bakar is hill dipterocarp forest that covering 314 hectares which is home to many unique species of flora and fauna (Norashikin et al., 2015). Hutan Lipur Bukit Bakar was managed by Kelantan State Forestry Department. The study was conducted from July 8, 2018 for a month in Hutan Lipur Bukit Bakar. There were three sampling points that had been chosen around the study area.

Figure 3.1: Map of Machang, Kelantan

(Sources: Kamaruzzaman et al., 2016)

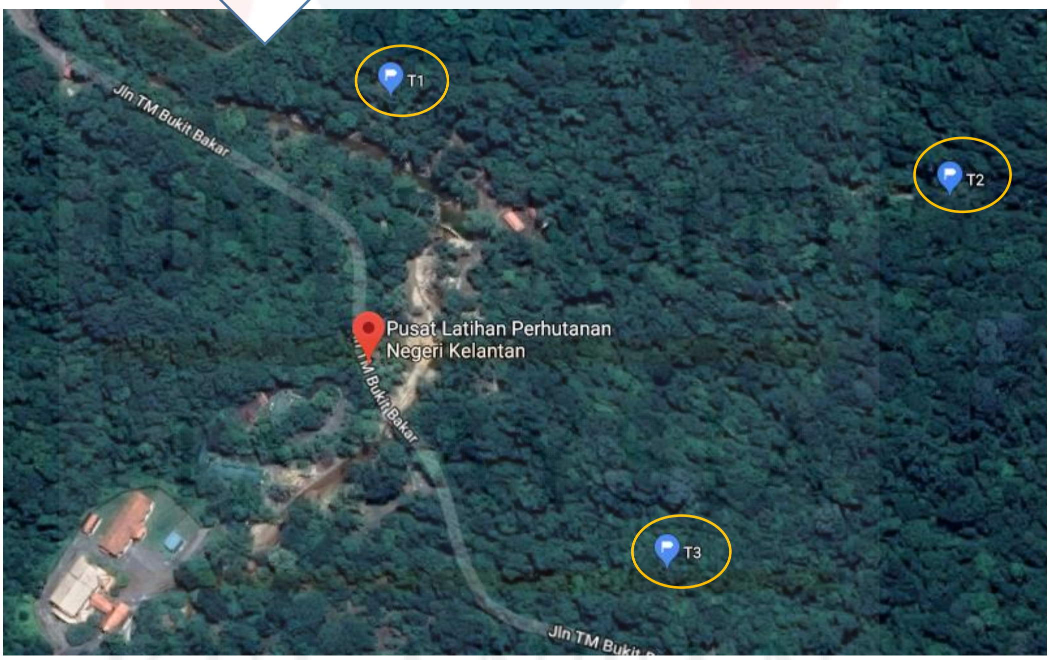

Figure 3.2: Map of Bukit Bakar Recreational Forest, Machang, Kelantan with data collection area

(Sources: Google Maps, 2018)

3.2 Apparatus and Materials

These were the lists of apparatus and materials that had been used in this study. The apparatus and materials as shown in Table 3.1.

Table 3.1: The apparatus and materials that had been used to collect the samples

Process	Apparatus and Materials	Description
Transect sampling	• Measuring tape • Ropes	• The measuring tape, ropes and markers used to mark and make the transect line
Collecting process	• Forceps	• The forceps used in collecting the samples
Preservation	• 80% of Ethanol	• Ethanol of the given concentration used to preserve the sample
Identification	• Stereo microscope	• Stereo microscope used to identify the genus and species of termites based on their morphology characteristics.

3.3 Methods

3.3.1 Collection of Termites

Standardized line transect sampling method (Anantharaju et al., 2014; Kori & Arumugam, 2017) had been used in this study for termite collection in Hutan Lipur Bukit Bakar area. There were three line transects were conducted around the study area. The line sampling had been divided into 20 contiguous section which is 100 meters long and 2 meters wide. The size of each section is 5m × 2m. Then, termites sample were collected by two peoples within 30 minutes in each section (Anantharaju et al., 2014). Termites were collected manually using forceps. For further identification process, there were at least ten workers and soldier castes had been collected in the study area.

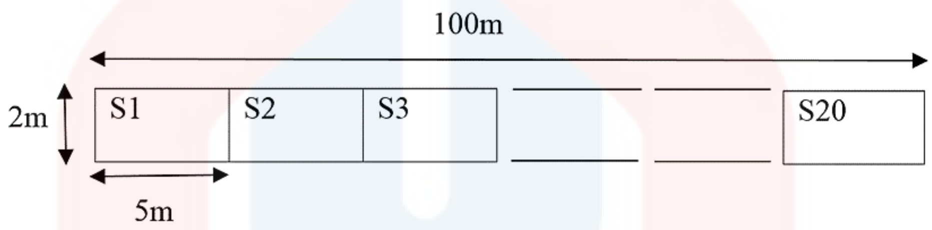

Figure 3.3: Standardized line transect method

(Sources: Kori & Arumugam, 2017)

3.3.2 Ecological Parameters

The variables or parameters that had been measured were soil pH, soil temperature, depth of leaf litter, percentage of canopy cover, and light intensity in the sample area. These parameters were taken in order to investigate the factor that influence termite diversity using specific apparatus. Portable Global Positioning System (GPS) were used to measure elevation in the study areas. Digital soil pH meter was used to measure pH and temperature of the soil, while a ruler is used to take the measurement of the depth of leaf litter of each section in transect lines. Canopy cover was measured by canopy cover application (Canopy Cover Free) and light intensity measured by light meter.

3.3.3 Preservation of Termites

The preservation of samples was conducted right after the termites were collected. The samples of termite were preserved in 80% of ethanol (Anantharaju et al., 2014; Kori & Arumugam, 2017). The suitable percentages to preserve termite species is 80% of ethanol due to termites' soft bodies. Termite's bodies will be distorted and stiff if the concentration of ethanol exceeds 80%. Not only termites used ethanol for preservation but also other soft-bodied insects and the related arthropod (Chintkuntla, 2015). Then, the labelling regarding the collection areas and termites classification had been done (Rahman & Tawatao, 2003).

3.3.4 Identification of Termites

According to Emerson (1938; 1943), identification is a process to classify termite samples to genus or species level. Identification process had been done using stereo microscope and image software (Motic Images Plus 2.0) at the laboratory. Termite genera and species were classified by morphological characteristic (Sornnuwat et al., 2001) using the previous research by Thapa (1981) and Tho (1992). Characteristic of body structure used to identify termite such as the presence of tooth on mandible, presence of hyaline tip and pronotum structure in genus level. Meanwhile, measurement of different parts of termite body such as length of head, width of head, length of pronotum, and width of pronotum used to determine termite in species level (Anantharaju et al., 2014).

3.3.5 Data Analysis

Species accumulation curve shows the rates of new species that are found in order to measure the species diversity in the sampled area. Species accumulative curve also represents the species richness that found in the area. This curve had been done by species sampling that obtained randomly in the few subareas. Then, the two subareas were combined and calculated to plot the curve which repeated to all subareas (Ugland, Gray, & Ellingsen, 2003).

Species diversity estimated by choosing the amount of species appear in a given region or gathering and registering how consistently passed on the species classifications is inside that gathering. Arrangements of species assorted variety are used which may give basically weight species that are transcendently found in the scene. Biodiversity indices such as Shannon-Wiener Index and Simpson Index is quantitative measure that accounts both species richness and species evenness. The Shannon-Wiener Index (Equation 3.1) is a method used to characterize the diversity of species in this study by using this formula:

Shannon-Wiener Index, H' = $-\sum_{i=1}^{s} pi \ln pi$ (Equation 3.1)

Where,

Range is from 0 to H_{max} = 0 to ln S

H'= Shannon-Wiener Index

$\sum$ = summation of calculation

S = the number of species (species richness)

p_i = total number of individuals for each species in the community

ln = natural logarithm

Species evenness (H_E) used for population size comparison of the species in the community. The calculation can be done by dividing H' by H_{max}. H_{max} is referred to the maximum diversity of the community.

Rarefaction (Simberloff, 1978; Gotelli & Graves, 1996) is a method that used to estimate the number of species that would be found which then compare unequal sampling effort of the communities. Calculations of rarefaction had been done by EcoSim software (Calandra et al., 2016).

CHAPTER 4

RESULT AND DISCUSSION

4.1 Termite Assemblage

A total of 156 hits comprising of 25 species of termites from two families were sampled in Hutan Lipur Bukit Bakar, Machang in three different area using standardized line transect method. Termite's morphology are based on the characteristic of imagoes and soldiers of each species of Thapa (1981) and Tho (1992). The recorded two families are Rhinotermitidae and Termitidae. This comprises of 17 genera and five sub-families. From 156 hits of termite samples, there were 53 samples collected at transect 1. Meanwhile, around 46 and 57 termite samples collected at transect 2 and transect 3 respectively.

The sample collection was conducted by following the natural trail in Hutan Lipur Bukit Bakar. Termite were collected in three sampled areas with different topography which are lowland area (T1), near the river side (T2) and hilly area (T3). According to sample collection, transect 1 and transect 2, termite samples consists of five sub-families which were Coptotermitinae, Rhinotermitinae, Termitinae, Macrotermitinae, and Nasutitermitinae. Meanwhile, Coptotermitinae was not found in the transect 3 which left transect 3 in four sub-families only. In the previous study, at Agropark UMK, Jeli Campus, the number of termite species collected were 29 species from five sub-families which is quite similar to this study (Kori & Arumugam, 2017).

Tho (1992) listed on estimated number of 175 species of termite from 42 genera and nine sub-families all across Peninsular Malaysia. However, from the total number of termite species collected in Hutan Lipur Bukit Bakar, only 12% of termite are listed in Tho checklist. Major forest types in Peninsular Malaysia are lowland, hill, and upper hill dipterocarp forest. Hutan Lipur Bukit Bakar are part of lowland forest and hill dipterocarp forest.

Table 4.1: Termite assemblage at feeding groups: W=wood-feeders, S/W=soil/wood interface-feeders, S=soil-feeders, E=epiphyte-feeders, L=litter=foragers. Nesting groups: W=wood nesters, H=hypogeal or subterranean nesters, E=epigeal mound builders, A=arboreal nesters.

Species	T1	T2	T3	Total	Feeding group	Nesting group
Family Rhinotermitidae						
Sub-family Coptotermitinae						
Coptotermes curvignathus Holmgren	-	4	-		W	W
Coptotermes kalshoveni Kemner	1	-	-		W	W
Subtotal hits	1	4	0	5		
Sub-family Rhinotermitinae						
Schedorhinotermes medioobscurus Holmgren	-	2	2		W	W
Schedorhinotermes sarawakensis Holmgren	3	-	-		W	W
Schedorhinotermes malaccensis Holmgren	-	1	-		W	W
Subtotal hits	3	3	2	8		
Family Termitidae						
Sub-family Termitinae						
Prohamitermes mirabilis (Haviland)	-	4	1		S/W	W
Amitermes minor	1	-	-		S	H
Globitermes sulphureus (Haviland)	1	-	1		S/W	E
Microcerotermes serrula (Desneux)	1	-	-		W	W
Termes propinquus Holmgren	1	-	2		S/W	W
Discuspiditermes nemorosus (Haviland)	1	1	3		S/W	E
Subtotal hits	5	5	7	17		
Sub-family Macrotermitinae						
Macrotermes carbonarius Hagen	13	-	-		L	E
Macrotermes gilvus Hagen	9	9	10		L	E
Odontotermes grandiceps Holmgren	1	-	-		L	E

Odontotermes oblongatus Holmgren	-	2	1		L	E
Odontotermes sarawakensis	4	4	6		L	E
Odontotermes sp.	11	6	14			E
Hypotermes xenotermitis	4	-	2		L	E
Microtermes obesi Holmgren	1	3	1		L	E
Subtotal hits	43	24	34	101		
Sub-family Nasutitermitinae						
Nasutitermes longinasus Holmgren	-	1	5		S/W	A
Bulbitermes constrictiformis Holmgren	-	3	3		S/W	A
Bulbitermes germanus (Haviland)	-	2	-		S/W	A
Longipeditermes mandibulatus (Haviland)	1	2	4		L	A
Subulioiditermes sp.	-	1	-		S	H
Aciculitermes sp.	-	1	2		S	H
Subtotal hits	1	10	14	25		
Number of species				25		
Relative abundance (total hits)	53	46	57	156		

4.1.1 Forest Ecology of Termite Assemblage

The diversity of termites in Hutan Lipur Bukit Bakar was investigated based on qualitative data gathering from the forest sites. Differences of diversity is influenced by few factors which are variation in elevation, soil types, competition, and food resources. These factors may contribute to changes in termite assemblages.

The result below (Table 4.2) shows the average of data collection of soil pH, soil temperature, depth of leaves litter, percentage of canopy cover and light intensity that may influenced termite assemblages in three different transect lines.

Table 4.2: Ecological parameters in each transect lines

Transect line	Soil pH	Soil temperature (°C)	Depth of leaves litter (cm)	Canopy cover (%)	Light intensity (lux)
T1	6.95	24.8	4.3	50.3	1 946.7
T2	6.89	27.2	4.1	45.5	2 951.7
T3	6.83	26	3.6	50.8	947.7
Mean	6.89	26	4.0	48.87	1 948.7

Table 4.3: Elevation and coordinate at three different transect lines

Transect line	Elevation (m a.s.l)		Coordinate
	Section 1	Section 20	
T1	49.5	109.8	N 5˚43'11.6" E 102˚15'36.1"
T2	170.4	123.6	N 5˚43'09.3" E 102˚15'47.9"
T3	159.0	125.6	N 5˚43'01.6" E 102˚15'41.9"

Table 4.2 shows the average for soil pH was 6.89 which acidic. According to Li et al. (2017), most termites nested in acidic and weakly alkaline soils, with soil pH values between 3.5 and 8.7. The results supported a preference of most termites for an acidic soil environment in order to get nutrient from soil as their food. The optimum temperatures for termites within range from 75°F to 95°F (24°C to 35°C). However, termites may die in a matter of minutes if the temperature above 100°F or below 25°F (Potter, 2013). The mean of soil temperature for three different sampled locations was 26°C equals to 79°F indicated termite species live in the suitable habitat. Litter depth reflects the balance of litterfall and decomposition (Kaspari & Yanoviak, 2008). The mean for depth of leaf litter in three different transect lines is 4.0 cm.

According to Dibog et al. (1999), the denser forest plantations harbored higher abundances of termites than stands with thinner canopies and argued that canopy cover is important due to its influence on sun exposure, micro climate conditions and ground moisture. The average for percentage of canopy cover and light intensity were 48.87% and 1 948.7 lux. Canopy cover and light intensity were related to each other which was the higher percentage of canopy cover cause the lower value for light intensity. This shows T3 had the higher value in canopy cover and lower value in light intensity compared to other transects lead to the higher number of total hits in species collection.

Based on obtained data (Table 4.3), the elevation for T2 was the most highest among three sampled location which was in elevation 170.4 meter above sea level at the start transect line and end with 123.6 m a.s.l. T2 also had the lowest total number of hits compared to T1 and T3. This shows termite diversity decrease along with increase elevation (Gathorne-Hardy et al., 2001).

4.1.2 Species Accumulation Curve

Based on result obtained from each transect lines which had 20 sections at three different areas, a species accumulative curve was plotted. The graph below shows termite sampling already have enough sampling data. The sufficient data gathered can be proved when the curve line became constant from T2S20 and remain unchanged till T3S20. The graph shows the species accumulative curve increased and slightly fluctuated start from T1S10 until T1S15. Then, the curve became constant at T1S16 to T1S20. The figure shows the curve increasing steadily at point T2S2 to T2S8 and point T2S10 to T2S18. At point T2S20, the curve had reached a plateau.

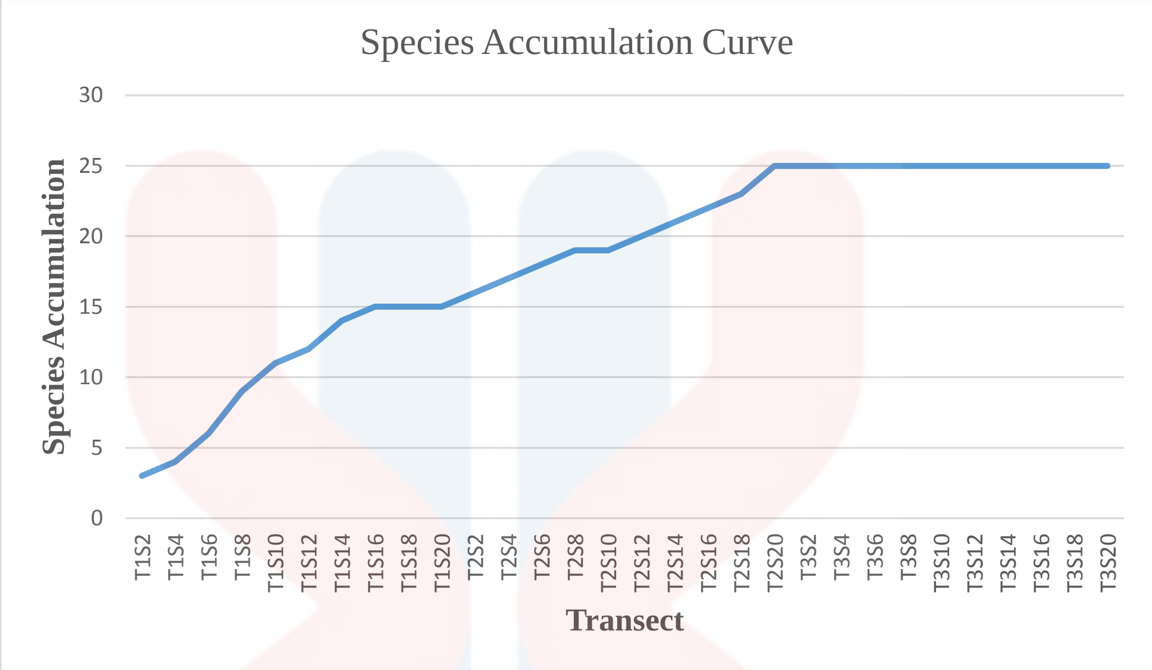

Figure 4.1: Species accumulation curve for termite species in the transect line

4.2 Species Richness of termite

The termite sample collected in three different area were dominated by sub-family Macrotermitinae which is *Odontotermes* sp. The total hits for this species are 30 hits which higher number of hits collected at T3 with 14 hits. *Odontotermes* sp was classified under higher termite and epigeal mound builder in nesting group.

Based on recorded data, sub-family Mcrotermitinae had 101 hits which from T1 (43 hits), T2 (24 hits) and T3 (34 hits). The total number of termite species collected from this sub-family are eight species which are *Macrotermes carbonarius* Hagen, *M. gilvus* (Hagen), *Odontotermes grandiceps* Holmgren, *O. oblongatus* Holmgren, *O. sarawakensis* Holmgren, *Odontotermes* sp, *Hypotermes xenotermitis* (Wasmann), and *Microtermes* obesi Holmgren. Then, sub-family Coptotermitinae has the lowest total number of hits with only two species collected (*Coptotermes kalshoveni* Kemner and *C. curvignathus* Holmgren).

In previous study at Agropark UMK, Jeli Campus, the termite species that dominated are also from sub-family Macrotermitinae but different species which is *Microtermes pakistanicus* Ahmad (Kori & Arumugam, 2017). This species classified as higher termite (Rahman & Tawatao, 2003). The higher number of hits for this species are 13 hits. This data obtained indicated that termite species that collected in Hutan Lipur Bukit Bakar are quite similar to the termite in Agropark UMK, Jeli Campus.

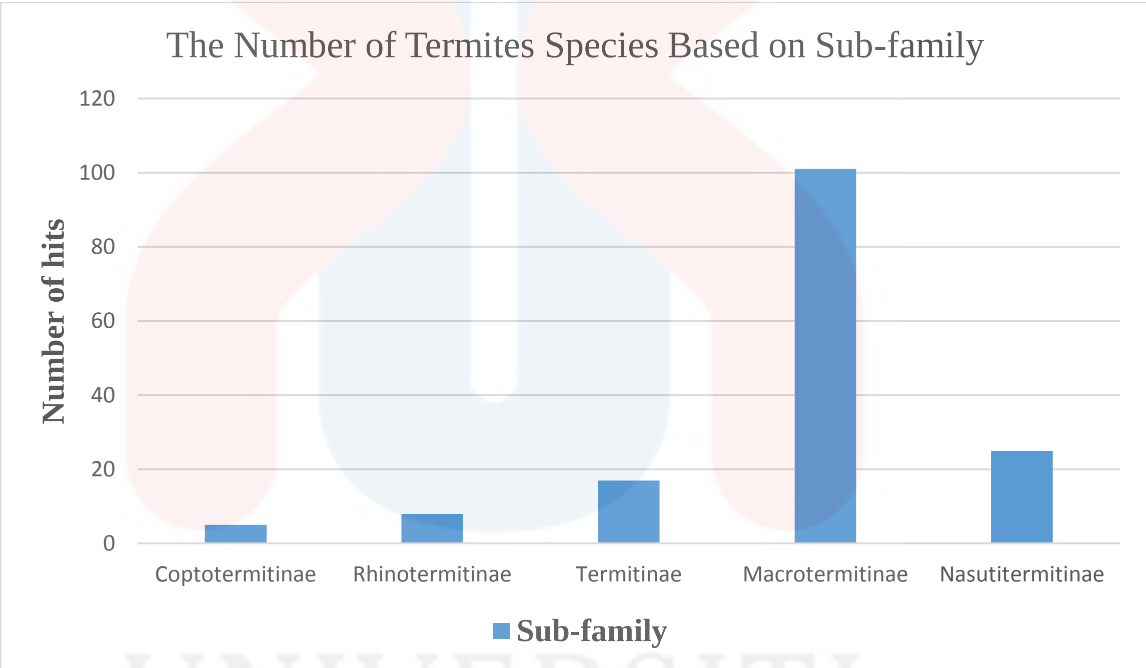

Figure 4.2: The number of termite species based on sub-family

4.2.1 Shannon-Wiener Index and Species Evenness

Based on Table 4.2, the value of Shannon-Wiener Index, H' (Appendix A) recorded in this study is H'=2.707 which was represent species diversity in this study. This indicated that termite diversity in Hutan Lipur Bukit Bakar are high. Meanwhile, maximum diversity calculated using formula $\ln(\frac{1}{s})$ was $H'_{max} = 3.219$. The value shows for all species collected at three different transect lines. Then, the range of evenness,

H_E was between ‘0’ to ‘1.0’ which means low evenness and complete evenness respectively. The evenness for all species in the sample which gave value of H_E = 0.841. This shows the evenness of termite species collected in Hutan Lipur Bukit Bakar are high. The evenness index for termite species collected at Agropark UMK, Jeli Campus in previous study also shows high evenness by H_E = 0.837 (Kori & Arumugam, 2017).

Table 4.4: The Shannon-Wiener Index and Evenness value

Total number of species	Shannon-Wiener Index, H’	Maximum Diversity, H'_{max}	Evenness, E_H
156	2.707	3.219	0.841

4.2.2 Rarefaction curve

According to Figure 4.3, the curve of species diversity was displayed in three different transect lines which gave different pattern for distribution of termite. Furthermore, the number of hits of termite species in T3 was the highest among three transect lines with 57 hits. Then, it followed by T1 with 53 hits and 46 hits at T2.

The termite distribution at those three difference are shows in rarefaction curve. The rarefaction curve shows most diverse area were T3 with 57 hits which had the higher abundance of termite. Meanwhile, the less average of diversity area which is T2. Other than that, the termite diversity are influence by weather and environmental surrounding. The forest condition at T2 are quite disturbed because of the location of sampling area was near the riverside and suitable spot for human activity such as picnic and other recreation activities. The disturbance of natural habitat of termite causes by human activity had been caused declining of termite abundance and function (Ackerman et al., 2009). However, some studies were shows that some termite groups were less affected to which some even respond positively to disturbance (Eggleton et al., 1995).

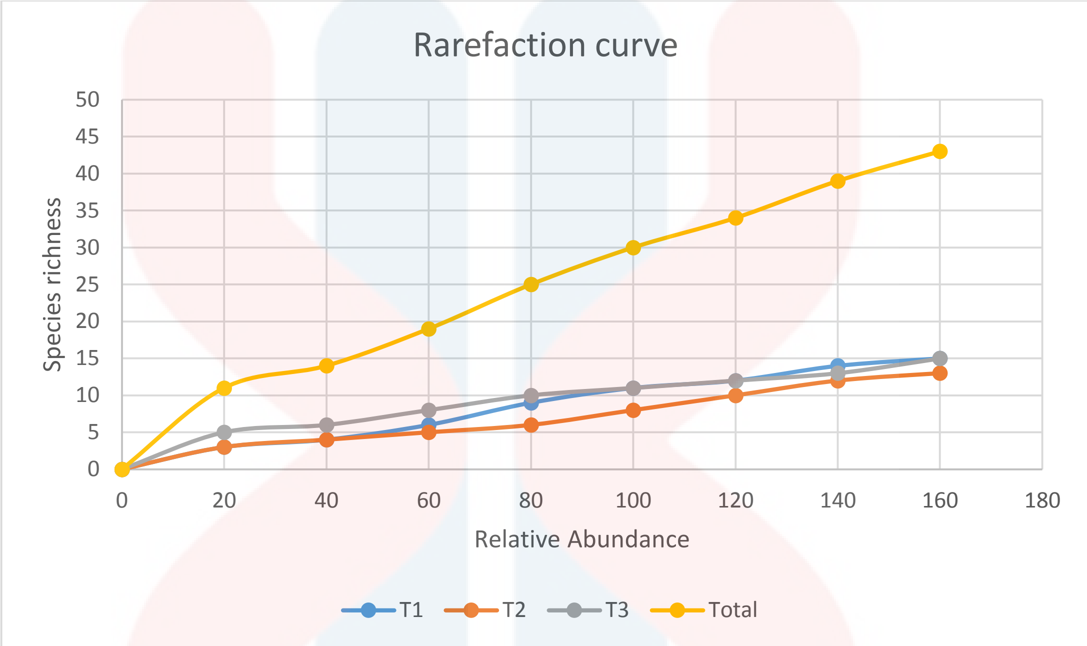

Figure 4.3: Rarefaction curve shows the species richness in the study areas

4.3 Relative abundance of termite

Based on Figure 4.3, the data gathered below was the relative abundance of termite species in each transect lines. Relative abundance of termite species was referred to the total number of hits collected. The graph below shows *Odontotermes* sp. was dominating with 14 hits and highly distributed species in T3. This species were well distributed in Hutan Lipur Bukit Bakar and were encountered at those three different type of forest in Hutan Lipur Bukit Bakar. The high distribution of *Odontotermes* sp. was at T3 (lowland forest) and topography of T3 were hilly. Then, it was followed by *M. carbonarius* from T1 with 13 hits. Termite species that had most abundance of diversity was from sub-family Macrotermitinae and in litter-foraging trophic group. The least abundance of termites' species was from sub-family

Coptotermitinae with *C. kalshoveni* (1 hit) at T1, *C. curvignathus* (4 hits) at T2 and no any hits in T3.

Furthermore, the termite distribution at Pasoh Forest Reserve and Belum-Temenggor Forest Reserve were higher compared to Hutan Lipur Bukit Bakar. This is because of the influenced by forest type and effect of seasonal rainfall on termite diversity. Pasoh Forest Reserve were lowland evergreen rain forest (Jones & Eggleton, 2000) while Belum-Temenggor Forest were primary hill dipterocarp forest (Aiman et al., 2014). High annual rainfall and seasonal flooding caused difficulty to foraging and nesting (Martius, 1994). Diversity of termite at T2 in Hutan Lipur Bukit Bakar were done near to the river and less diverse compared to other transect lines.

The highest in number of termite species recorded are at lowland forest (T3). There have distribution of higher termite and lower termite in this area. There were more dead wood, branches and leaf litter found in the area. The higher termite presented in T3 comprise four species from sub-family Termitinae which are *Prohamitermes mirabilis*, *Globitermes sulphureus*, *Termes propinquus*, and *Discuspiditermes nemorosus*. There are six species from sub-family Macrotermitinae (*Macrotermes gilvus*, *Odontotermes oblongatus*, *O. sarawakensis*, *Odontotermes* sp., *Hypotermes xenotermitis*, and *Microtermes obesi*) and four species from sub-family Nasutitermitinae which are *Nasutitermes longinasus*, *Bulbitermes constrictiformis*, *Longipeditermes mandibulatus* and *Aciculitermes* sp. The lower termite recorded are from sub-family Rhinotermitinae which is *Schedorhinotermes medioobscurus*.

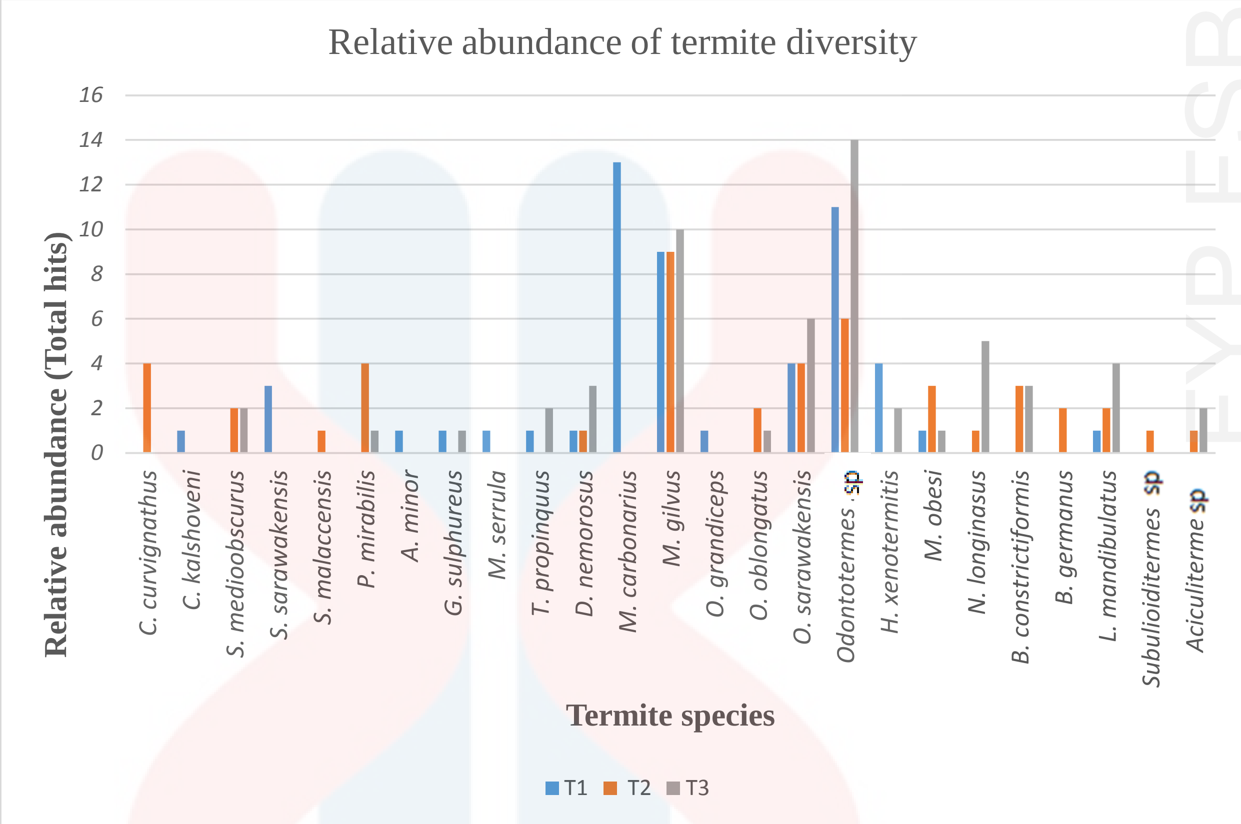

Figure 4.4: Relative abundance of termite diversity in three different transect lines

4.4 Composition of Tropic Groups and Nesting Groups

The observation at the location of termite foraging whether on the ground, above ground, under trees, branches, decay wood, dead stumps or nest are the characteristic that classified termite trophic groups. Termite assemblages in forest ecosystem comprised of five trophic groups, varying in abundance and species composition.

Wood feeders were termite that consume on wood litter which also dead woods, log or branches (Eggleton et al., 1996; 1997). Based on gathered data, there were 3.2% of Coptotermitinae, 5.1% of Rhinotermitinae, and 0.6% of Termitinae that classified as wood feeders. Total percentage of wood feeders collected in three different areas is 9% from three sub-families.

Soil and wood interface feeders was a termite that consume decay wood, the soil under logs or soil plastered to logs, or soil mixed with leaf litter in stilt-root complexes (Eggleton et al., 1996; 1997). Total percentages of termite species that collected classified under soil and wood interface feeders was 19%. There were 10% of Termitinae and 9% of Nasutitermitinae according to Figure 4.5.

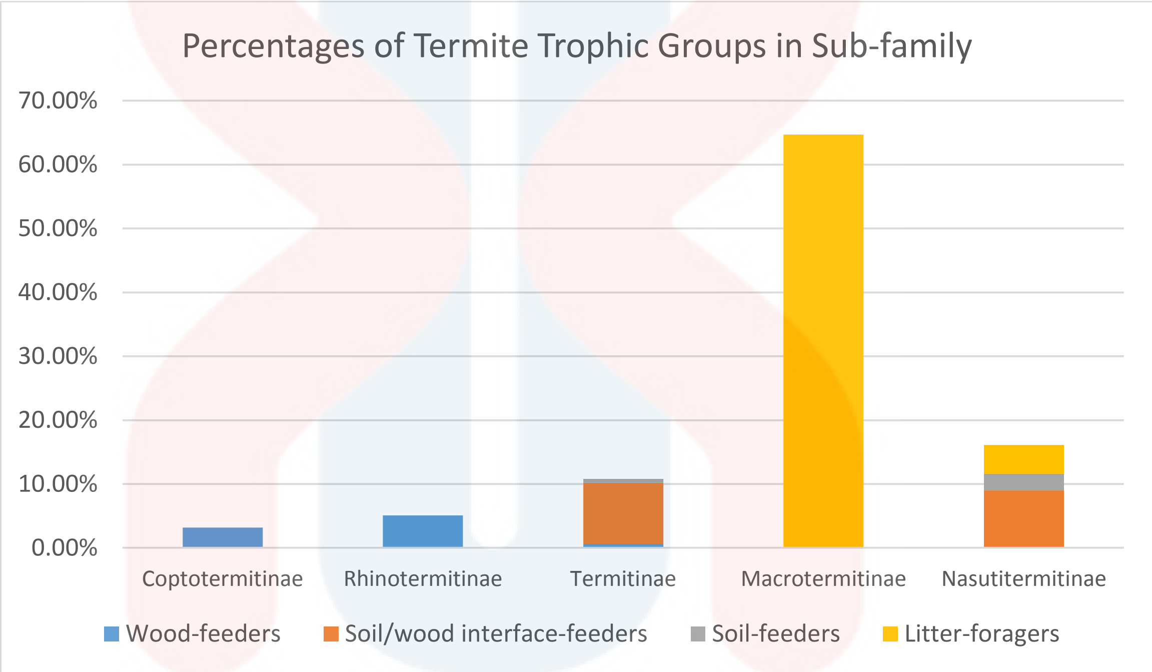

Figure 4.5: The percentages of termite trophic groups based on sub-family

Soil feeders are termites that feed on mineral soil and majority of them ingest topsoil rich in organic matters (Sleaford et al., 1996). This type of feeders usually dominated by Termitinae, certain species of Nasutitermitinae and Apicotermitinae (Abe, 1978). Based on Figure 4.4 and 4.5, there was 3% of soil feeders that represented from two sub-families which were Termitinae and Nasutitermitinae. This type of trophic group is the lowest compared to other trophic groups because they are sensitive and weak to habitat disturbance. The termite species in this group also prefer soil with high moisture content with dense canopy cover in the forest (Eggleton et al., 2002).

Litter forager are termite that consume leaf litter and small items trash of wood decay. Usually Macrotermitinae were dominated this this of feeders due to their consumption of litter in certain circumstances (Lepage et al., 1993). Based on this study, litter forager dominated the assemblages compared to other trophic groups. According to Figure 4.5, the percentages of litter forager is 69% which is higher than other trophic groups. They were from sub-families Macrotermitinae (64%) and Nasutitermitinae (5%). This is due to forest floor at the sampling area had many wood and leaves litter which this trophic group used to consume.

Micro-epiphyte feeders were termite's species that forage for moss, algae, lichens and fungi on tree barks. For example, *Hospitalitermes hospitalis* is known to feed on lichen in Southeast Asia (Eggleton et al., 1997; Collins, 1981). However, there are no any termite species recorded in this type of trophic group based on Figure 4.4 and Figure 4.5. This is because sampling period was during morning till afternoon. This type of feeder were foraging from 46% to 72% of the night (Jones & Gathorne-Hardy, 1995).

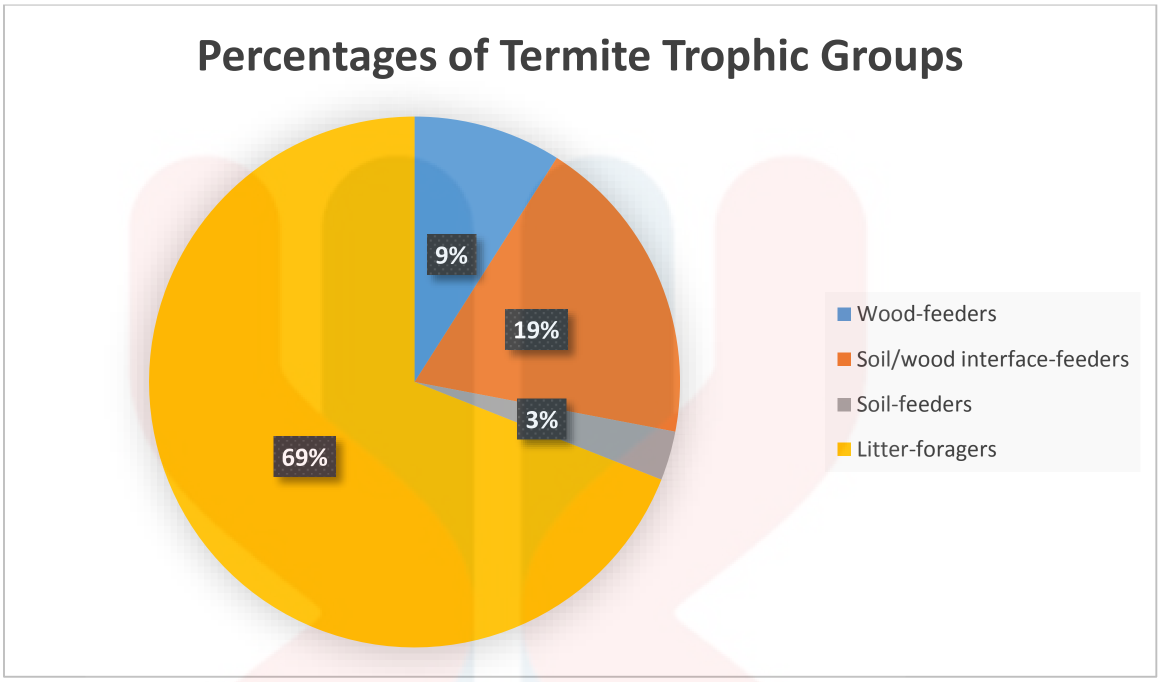

Figure 4.6: The percentages of termite trophic groups

Like ants, termite also had colonies and their specific habitat within confines of excavations, on the ground, or in their own nest system. Nesting groups found at all area were of four types which were arboreal, wood, hypogeal and epigeal nesters. Termites that collected in three different transect lines had different nesting group.

Wood nester were termite species that live in or around standing or dead log (Collins, 1979). The woody substances with in low concentration of nutrient and high levels of lignin and other undigested compound were usually chose by wood nesters as their habitat (Collins, 1979). There were three sub-families that classified under this type of nesting group which were Coptotermitinae (3.2%), Rhinotermitinae (5%) and Termitinae (5.8%). Therefore, total termite species from wood nesters is 14%.

Epigeal nester also known as mound builder. Their nest usually constructed from subsoil with the mixture of organic content and salivary secretion, faeces and macerated wood mixture, or faeces and organic-rich topsoil mixture (Wood and Sand, 1978). The structure of their nest were also well-designated and quite complex.

According to Figure 4.6, this type of nesting group were represented by sub-families Termitinae (5%) and Macrotermitinae (64%). Therefore, the total percentage of termite species classified under epigeal mound builder was 69%. Epigeal nesting termite dominated in nesting group represented by sub-family Macrotermitinae.

The material used to construct nest of hypogeal or subterranean nester was quite similar to epigeal mound builder as they also used their faeces or faeces and mineral soil mixture in the construction (Rahman & Tawatao, 2003). Figure 4.6 shows hypogeal or subterranean nester were from sub-families Termitinae (1%) and Nasutitermitinae (2%) and became 3% in total percentage (Figure 4.7). In the previous study, at Agropark UMK, Jeli Campus, there are 2% of this type of nesting group recorded (Kori & Arumugam, 2017). Meanwhile, there did not had any further discussed about termite nester at Pasoh Forest Reserve and Belum-Temenggor Forest.

Arboreal nester were termite species that build their nest from wood carton. The structure of nest was quite unique as it was attached outwardly to tree at different height. Mostly Nasutitermitinae was classified under this type of nesting group. This shows on Figure 4.6, Nasutitermitinae with 14% from total termite species recorded in this study.

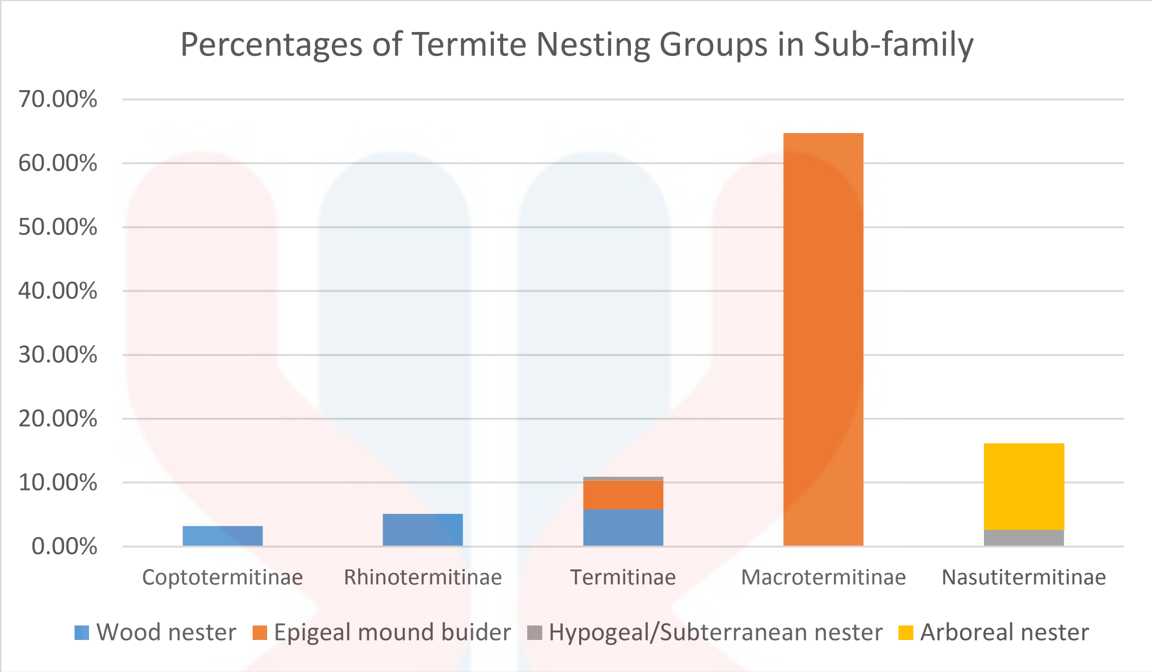

Figure 4.7: The percentages of termite nesting groups based on sub-family

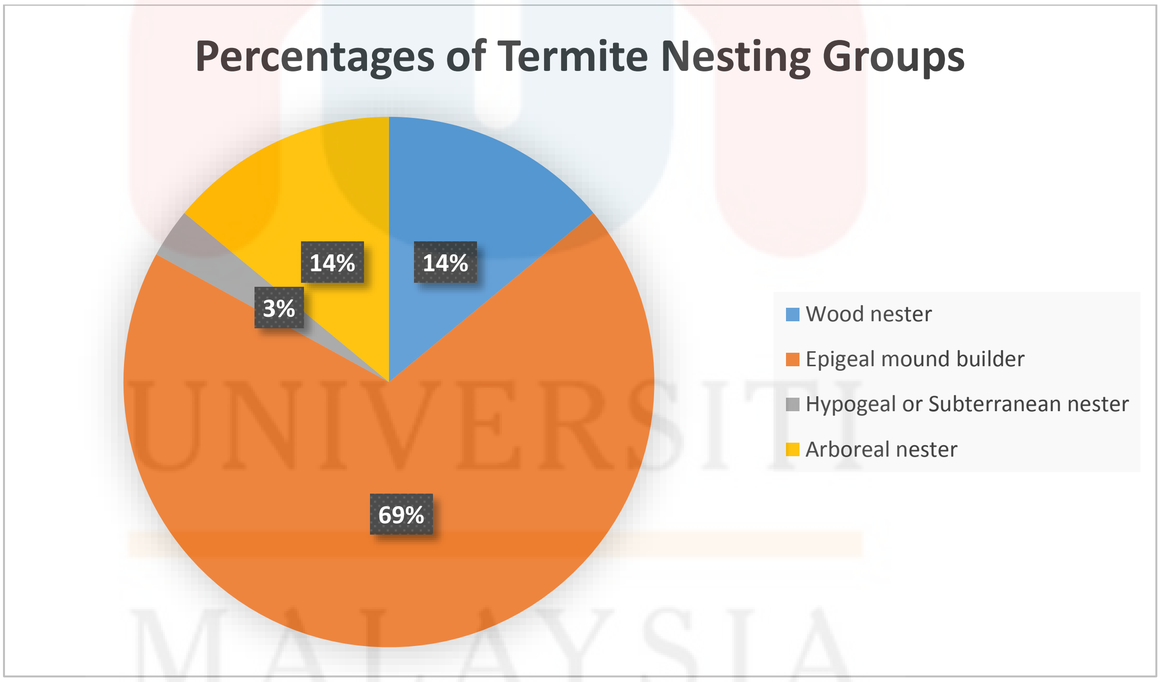

Figure 4.8: The percentages of termite nesting groups

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, this study had provided new records of species diversity of termite fauna in Hutan Lipur Bukit Bakar using standardized line transect. This shows the objective of this study achieved. Termite species was determine according to available taxonomy, key, description and measurement given. This study shows Hutan Lipur Bukit Bakar consist of 25 species from two families, five sub-families and 16 genera.

Based on the gathered data, the total number of sample collected were 156 hits which T1 (53 hits), T2 (46 hits) and T3 (57 hits) at three different sampled location. The difference of sampled locations influenced termite assemblages due to the environmental factors in the area. The parameters that had been recorded were soil pH, soil temperature, depth of leaf litter, percentage of canopy cover, light intensity and elevation in each transect lines. These result of parameters proved when the sample collected in transect 1 and 3 have higher number of hits compared to transect 2 due to the environmental surrounding at both areas are quite similar to each other. Meanwhile, the total number of hits in transect 2 is lower than transect 1 and 3 due to the sampling area is near the riverside. Moreover, there is still more termite species that await to be collect because of the accelerating graph on species accumulative curve.

5.2 Recommendation

The further studies and research on termite diversity are required in order to determine the species richness on this particular areas. This preliminary study in Hutan Lipur Bukit Bakar has created a new baseline data for future research. This data is very useful for planning the conservation activity in this area.

Furthermore, as recreational forest, State Forestry Department should maintain the forest structure of Hutan Lipur Bukit Bakar for ecosystem balanced and secured from disturbance such as development or construction in the area. This is due to Hutan Lipur Bukit Bakar covered large area and different types of topography which lead to different areas for termite distribution. Therefore, it is significant to manage Hutan Lipur Bukit Bakar for future conservation and ecosystem balance.

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APPENDIX

Appendix A

Table A1: Raw data for Shannon-Wiener Index

	No of sample	pi	ln pi	pi ln pi
	4	0.025641026	-3.663561646	0.093937478
	1	0.006410256	-5.049856007	0.032370872
	4	0.025641026	-3.663561646	0.093937478
	3	0.019230769	-3.951243719	0.075985456
	1	0.006410256	-5.049856007	0.032370872
	5	0.032051282	-3.440418095	0.110269811
	1	0.006410256	-5.049856007	0.032370872
	2	0.012820513	-4.356708827	0.055855241
	1	0.006410256	-5.049856007	0.032370872
	3	0.019230769	-3.951243719	0.075985456
	5	0.032051282	-3.440418095	0.110269811
	13	0.083333333	-2.48490665	0.207075554
	28	0.179487179	-1.717651497	0.308296423
	1	0.006410256	-5.049856007	0.032370872
	3	0.019230769	-3.951243719	0.075985456
	14	0.08974359	-2.410798678	0.216353727
	30	0.192307692	-1.648658626	0.317049736
	7	0.044871795	-3.103945858	0.139279622
	5	0.032051282	-3.440418095	0.110269811
	6	0.038461538	-3.258096538	0.125311405
	6	0.038461538	-3.258096538	0.125311405
	2	0.012820513	-4.356708827	0.055855241
	7	0.044871795	-3.103945858	0.139279622
	1	0.006410256	-5.049856007	0.032370872
	3	0.019230769	-3.951243719	0.075985456
Total	**156**	**1**	**-93.45200639**	**2.706519421**

H' = 2.707

H'_{max} = 3.219

Appendix B

Table B1: Raw data for forest ecology in three different transect lines

Transect 1

Section	Soil pH	Soil temperature (°C)	Depth of leaves litter (cm)	Canopy cover	Light intensity (lux)
T1S1	7	26.3	4.6	59	4780
T1S3	6.83	24.3	5.2	54	5136.7
T1S5	7	23	3.8	54.7	626.7
T1S7	7	24	3.5	55.9	2246.7
T1S9	7	23	4.5	49.2	850
T1S11	6.83	27.7	6.3	39.2	1393.3
T1S13	6.83	26	3.6	60.6	2010
T1S15	6.97	24	3.3	49.5	1006.7
T1S17	7	24.7	4.2	44.1	563.3
T1S19	7	25	3.9	37.5	853.3

Transect 2

Section	Soil pH	Soil temperature (°C)	Depth of leaves litter (cm)	Canopy cover (%)	Light intensity (lux)
T2S1	7	27.3	4.2	42.8	1213.3
T2S3	6.83	27	5.3	47	2490
T2S5	6.7	27.3	3.3	43.4	3733.3
T2S7	6.83	27.3	2	46.8	8363.3
T2S9	6.7	27.3	2.2	47.1	1880
T2S11	7	26.7	4.2	43	726.7
T2S13	7	27.7	7.3	49.9	1746.7
T2S15	6.83	27.3	4.7	54.2	1356.7
T2S17	7	27.3	2.3	36.2	5316.7
T2S19	7	27	5.2	44.3	2690

Transect 3

Section	Soil pH	Soil temperature (°C)	Depth of leaves litter (cm)	Canopy cover	Light intensity (lux)
TS31	6.7	25.3	4.2	42.4	1180
T3S3	6.93	26	3.1	63.6	340
T3S5	7	27	3.8	60	376.7
T3S7	6.97	28.3	2.5	48.3	2426.7
T3S9	6.7	27.3	3.9	41	543.3
T3S11	7	24.3	3.6	48.8	733.3
T3S13	6.83	25.7	3	50.6	810
T3S15	6.83	25.7	4.2	55.3	966.7
T3S17	6.5	24.7	4.3	54.2	1040
T3S19	6.83	26	3.7	43.4	1060

Appendix C

Table C1: Planning of Final Year Project

Project Activities	Date
Proposal Writing	February 2018
Submission of research proposal and Proposal Defences	Jun 2018
Completion of data collection	August 2018
Completion of data analysis	October 2018
Submission and presentation of full report	December 2018

Appendix D

Figure D1: Collecting termite in the sampling area

Figure D2: Termites' foraging in the sampling area

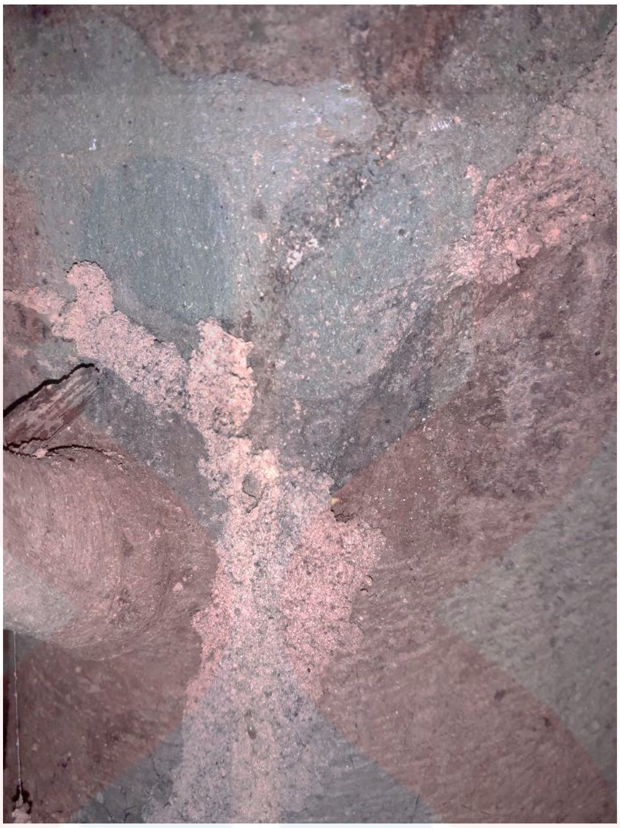

Figure D3: Type of termite nesting (Wood nester)

Figure D4: Type of termite nesting (Epigeal mound builder)

Figure D5: Type of termite nesting (Arboreal nester)