DISTRIBUTION OF WOOD FEEDING TERMITES IN THE PRIMARY AND REGENERATING FORESTS OF DANUM VALLEY, LAHAD DATU, SABAH

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ABSTRACT

The tendency of wood feeding termites selecting types of tree species as their food source is still unclear. This study was aimed to understand the distribution patterns of termites especially wood feeding termites and the types of tree species which are infested from the primary and regenerated forest of Danum Valley. The objectives of this study were to i) determine the species of wood feeding termites associated with trees in the forest of Danum Valley; ii) identify the types of trees in the primary and regenerated forest associated with termites; iii) map the distribution patterns of termites in the forest of Danum Valley; iv) find the relationship between termites and abiotic factors from the forest of Danum Valley. This research was carried out in two types of forest namely primary and regenerated forest in Danum Valley, Lahad Datu, Sabah. A total of six plots were sampled in this study. Three plots with an area of 0.25 hectare (50 meters X 50 meters) were placed in each, primary and regenerated forest. Trees in each plot with a diameter breast height, (dbh) of more than 10 cm were examined. Examination for termites on trees included examination of tree barks, runways and termite mounds. Trees with and without termites were tagged and labeled accordingly using GPS. Overall a total of 23 termite species were sampled from the forest of Danum Valley. However, only 16 species (69.6%) of termites sampled were wood feeding termites. Shannon-Wiener Diversity Index and Simpson's Index of Diversity indicates that termites in the regenerated forest (H' = 2.5909; D = 0.9374) were higher compared to the primary forest (H' = 2.5335; D = 0.9312). There were a total of 66 interactions of which involved 23 termite species and 31 tree species. Termites in Danum Valley were found in association with tree families of Alangiaceae, Annonaceae, Burseraceae, Dipterocarpaceae, Ebenaceae, Euphorbiaceae, Fabaceae, Fagaceae, Lauraceae, Magnoliaceae, Meliaceae, Myrsinaceae, Sapindaceae and Sapotaceae. *Macaranga gigantea* was the highest recorded tree species with 16 hits found associating with nine different termite species. This tree species was only sampled in the regenerating forest with 54 hits. *Macrotermes malaccensis* is the termite species which are abundantly found in the forest of Danum Valley. This species was found associated with six different tree species. Eight termite pest species which have been identified as potential pest in Danum Valley include *Heterotermes tenuior, Coptotermes curvignatus, Schedorhinotermes medioobscurus, Schedorhinotermes sarawakensis, Microcerotermes dubius, Macrotermes gilvus, Odontotermes javanicus and Nasutitermes matangensis*. Statistical analysis showed that termites association with trees in the forest of Danum Valley are influenced by dbh ($p = 0.000$) and canopy density ($p = 0.006$). However, the presence of pest termites is statistically influenced by dbh ($p = 0.001$) and soil pH ($p = 0.002$).

ABSTRAK

TABURAN ANAI-ANAI PEMAKAN KAYU DALAM HUTAN PRIMER DAN REGENERASI DI LEMBAH DANUM, LAHAD DATU, SABAH

Kecenderungan anai-anai memilih spesies pokok sebagai sumber makanan masih tidak jelas. Kajian ini bertujuan untuk memahami corak taburan anai-anai terutamanya anai-anai pemakan kayu serta jenis spesies kayu yang dimakan oleh anai-anai dari hutan primer dan hutan regenerasi daripada Lembah Danum. Objektif kajian ini adalah untuk i) menentukan spesies anai-anai pemakan kayu di Lembah Danum; ii) mengenal pasti jenis pokok di hutan primer dan hutan regenerasi yang berhubungkait dengan anai-anai pemakan kayu; iii) pemetaan taburan spesies anai-anai di hutan Lembah Danum; iv) mengkaitkan persamaan antara kehadiran anai-anai dengan faktor-faktor abiotik di hutan Lembah Danum. Kajian ini telah dijalankan di dua jenis hutan iaitu hutan primer dan hutan regenerasi di Lembah Danum, Lahad Datu, Sabah. Sebanyak enam plot dikaji dalam kajian ini. Tiga plot dengan keluasan 0.25 hektar (50 meter X 50 meter) telah ditempatkan, masing-masing dalam hutan primer dan hutan regenerasi. Pokok-pokok yang hanya mempunyai diameter lebih daripada 10 cm pada ketinggian paras dada (dbh) dikaji. Kehadiran anai-anai ditentukan dengan menjalankan pemeriksaan pada bahagian kulit pokok, laluan dan sarang anai-anai. Penandaan GPS dibuat pada pokok-pokok untuk membezakan pokok-pokok yang terdapat anai-anai dengan yang tidak. Sejumlah 23 spesies anai-anai telah disampel dari hutan Lembah Danum. Walau bagaimanapun, hanya 16 spesies (69.6%) daripada sampel anai-anai yang dikumpul merupakan anai-anai pemakan kayu. Indeks Kepelbagaian Shannon-Wiener dan Indeks Kepelbagaian Simpsons menunjukkan bahawa diversiti anai-anai di hutan regenerasi (H' = 2.5909; D = 0.9374) lebih tinggi berbanding di hutan primer (H' = 2.5335; D = 0.9312). Terdapat sejumlah 66 interaksi antara 23 spesies anai-anai dengan 31 spesies pokok. Anai-anai yang ditemui di Lembah Danum mempunyai hubungkait dengan keluarga-keluarga pokok; Alangiaceae, Annonaceae, Burseraceae, Dipterocarpaceae, Ebenaceae, Euphorbiaceae, Fabaceae, Fagaceae, Lauraceae, Magnoliaceae, Meliaceae, Myrsinaceae, Sapindaceae dan Sapotaceae. Macaranga gigantea merupakan spesies pokok yang tertinggi yang direkodkan dengan 16 pokok menunjukkan interaksi dengan sembilan spesies anai-anai yang berbeza. Pokok ini hanya ditemui di hutan regenerasi dengan sejumlah 54 pokok. Manakala, Macrotermes malaccensis merupakan spesies anai-anai yang paling banyak disampel di hutan Lembah Danum. Spesies anai-anai ini ditemui pada enam species pokok yang berbeza. Sejumlah lapan spesies serangga perosak anai-anai telah dikenalpasti daripada hutan Lembah Danum. Anai-anai perosak di Lembah Danum terdiri daripada Heterotermes tenuior, Coptotermes curvignatus, Schedorhinotermes medioobscurus, Schedorhinotermes sarawakensis, Microcerotermes dubius, Macrotermes gilvus, Odontotermes javanicus dan Nasutitermes matangensis. Analisis statistik menunjukkan bahawa interaksi anai-anai dan pokok di hutan Lembah Danum dipengaruhi oleh dbh (p = 0.000) dan ketumpatan kanopi (p = 0.006). Manakala, kehadiran anai-anai perosak dipengaruhi oleh dbh (p = 0.001) dan pH tanah (p = 0.002).

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%	Percentage
m	Meter
mm	Millimeter
cm	Centimeter
ha	Hectare
km^2	Kilometer square
m^3 ha	Cubic meter per hectare
kg ha^{-1} a^{-1}	Kilogram per hectare per annual
CH_4	Methane
CO_2	Carbon dioxide
F	Felling
H'	Shannon-Wiener Index
H"	Shannon-Wiener Evenness Index
D	Simpson's Diversity Index
Sp	Species
Mt	Mount
2D	Two dimension
pH	Potential of Hydogen
TPA	Total Protected Area
PFE	Permanent Forest Estate
SLF	State Land Forest
RIL	Reduce Impact Logging
WWF	World Wide Fund for Nature
DBH	Diameter Breast Height
RDC	Research Development Centre
MUS	Malayan Uniform System
SMS	Selective Management System
RIFS	Regeneration Improvement Felling System
Pre-F	Pre Felling
Post-F	Post Felling
DVCA	Danum Valley Conversation Area
DVMC	Danum Valley Management Committee
IBTC	Institute for Tropical Biology and Conversation
SPSS	Statiscal Package for Social Science
ANOVA	Analysis of Variance
ARCGIS	Geographic Information System Software
SEARRP	South East Asia Rainforest Research Programme

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CHAPTER 1

INTRODUCTION

1.1 Background

Termite is an insect classified under Insecta and often referred to as 'white ants' (Eggleton et al., 1994). However, termites are not related to ants. Instead previous and recent studies showed that termites and cockroaches have similar molecular phylogenetic. Thus, termites are known to be social cockroaches (Inward et al., 2007; Eggleton et al., 2007). Termites can be found from the temperate regions to the rainforest of Africa, South America and Asia. In addition, termites are also vastly populated in the tropical rainforest as the best sites to examine tropical termites are in Peninsular Malaysia, Sumatra, Borneo and Java. In Malaysia, good taxonomic accounts exists for Peninsular Malaysia (Tho, 1992) and Sabah (Thapa, 1981).

According to Krishna et al., (2013), there are currently 3105 living and fossil termite species around the world. These species consist of 330 of living and fossil genera from twelve main termite families. The twelve termite families which have been accounted for in the world are Cratomastotermitidae (fossil family), Mastotermitidae, Termopsidae (fossil family), Archotermopsidae, Hodotermitidae, Stolotermitidae, Kalotermitidae, Archeorhinotermitidae (fossil family), Stylotermitidae, Serritermitidae, Rhinotermitidae, and Termitidae. However, there are only four of these families of termites which have been recorded in Malaysia. They are Kalotermitidae, Rhinotermitidae, Stylotermitidae and Termitidae (Thapa, 1981; Collins, 1988; Tho, 1992). About 323 species out of 52 genera of termites have been recorded in the region of Indo-Malaysia (Thapa, 1981; Tho, 1992). In Peninsular Malaysia, there are 175 species of termites consisting of 42 genera and three families which have been identified (Tho, 1992; Jones and Brendall, 1997).

However, in Sabah there are lesser species sampled compared to Peninsular Malaysia with 103 species of 33 genera from four families (Thapa, 1981).

Termite can be categorized into five known trophic groups according to their food intake, colour of the abdomen, known biology and foraging columns (Eggleton et al., 1997; Jones and Brendell, 1997). The five trophic groups are namely soil feeders; soil-wood interface feeders; wood feeders; litter foragers and micro-epiphyte feeders. The termite feeding habits consists of plant tissue from all stages of decay, living trees and mineral soils. These five trophic groups are related to the four types of termite habitats. Termite nest ranges from small to huge subterranean and epigeal nest system. The construction materials of the nests are mostly from faeces mixed with saliva (Eggleton, 1999). The four types of termite nesting group are wood nesters, subterranean nesters (termites found below the soil), epigeal mounds (termites found above the soil) and arboreal nester (termite nest which are attached outwards from trees) (Eggleton et al., 1997; Homathevi and Noel, 2003).

Wood feeding termites feed on wood and woody litter and are sometimes looked up as pest. Termites become pest when humans alter the natural habitats of these termites such as logging practises and forest destruction. Examples of termite species which infest on standing trees in the tropical rainforest of South East Asia are Coptotermes curvignathus and Microcerotermes dubius (Aihetasham and Iqbal, 2012). However, not all termites are pest species. Most termites benefit the ecosystem greatly as they act as natural decomposers (Bignell and Eggleton, 1999). In addition, termites are also involved in contributing gases exchange such as carbon influx and nitrogen fixation (Eggleton et al., 1997). Activities involving termites includes mound building, subterranean tunnelling and soil feeding of which actually improves the quality and soil structure (Jones and Prasetyo, 2002). Termites also play an important role in the food chain. This is as termites become prey for birds and various types of mammals like sun bears, pangolins and sloth bears (McGavin, 2001).

Termites can also be classified into 'higher termites' and 'lower termites'. This classification is based on the composition of the symbiotic protists and bacteria

living in the termites gut. All termite families carry a dense and diverse array of prokaryotes. Lower termites have flagellated protists while higher termites generally lack flagellated protists. Example of higher termite is from the family of Termitidae. This is the only family which is classified as a higher termite however, this family comprises of more than three quarter (75 % - 80 %) of all termite species (Matsui et al., 2009). Higher termites mostly live in the tropical ecosystem in which several termites have been known to maintain the soil fertility. The presence of the flagellated protists on the lower termites allows cellulose digestion in the termite gut.

1.2 Forest Land in Malaysia

Malaysia has an approximately 32.86 million ha of total land area, in which Peninsular Malaysia has 13.16 million ha, Sarawak has 12.33 million ha while Sabah has 7.37 million ha of land. Peninsular Malaysia is separated with the island of Borneo (Sabah and Sarawak) by 720 km of the South China Sea. In Malaysia, there are a total of 18.67 (56.8%) million ha of land gazetted as forested area. Based on policy and administrative framework, the forest resources in Malaysia are categorised according to Permanent Forest Estate (PFE), State Land Forest (SLF), and Totally Protected Area (TPA). In Sabah, there are 3.35 million ha of PFE, 0.84 million ha of SLF and 0.26 million of TPA. The PFE in Sabah are divided into seven different classes which comprises of Protection Forest, Commercial Forest, Domestic Forest, Amenity Forest, Mangrove Forest, Virgin Jungle and Wildlife (Reynolds et al., 2011).

In Malaysia, forestry plays a major role in the socio-economic development by contributing significantly towards foreign exchange earnings, Gross Domestic Product (GDP), government revenue, employment and livelihood of rural population (United Nations Development Programme, 2008). The timber industry has shown a remarkable strength and resilience in exports. Thus for the timber industry to continue growing, continuous harvesting is required. However, with an increase of logging in the tropical rainforest, it is known to cause an effect towards the ecosystem. The behaviour of termites can also be affected due to changing environments. Termites have been known to be affected by intensity, temperature, humidity, altitude and longitude, soil and leaf litter (Gathorne-Hardy et al., 2002).

1.3 Justification

The tropical rainforest of Borneo is known to be rich with a diversity of flora and fauna. Different types of studies have been conducted in Borneo. This includes the study pertaining termites which have been well documented especially in Sabah (Eggleton et al., 1997; Jones et al., 1998; Homathevi and Bignell, 1999; Homathevi et al., 2002a). However, no particular study has been conducted to relate the infestation of wood feeding termites with different species of trees especially in the primary and how it changes in disturbed habitat or forest.

Intensive study of termite assemblages has been conducted in the forest of Danum Valley, Lahad Datu (Eggleton et al., 1997; Eggleton et al., 1999). However, the current study differs as this study looks into the distribution of wood feeding termites which are only present on the tree stand. This study shows patterns of termite infestation towards living trees. In addition, this study identifies the types of termites which infest trees and the types of tree species which are infested by pest termite species. Furthermore a comparison of termites and tree species infested from the primary and regenerated forest was undertaken to show the effectiveness of Reduce Impact Logging, RIL.

The abiotic factors and environmental variables were taken to determine the relationship towards the presence of wood feeding termites on certain tree species. These factors would provide better understanding of the feeding preferences and behaviour of the wood feeding termites. It would also show the criteria of standing trees of which wood feeding termites pick. A species checklist of termite pest found in Sabah can be made from this study and can become beneficial to all walks of life.

This study would benefit logged over forest as the infestation of wood feeding termites will be better understood. Indigenous tree species which are infested can be identified and protected. From this study, better forest management can be implemented especially in areas of afforestation and reforestation. Tree species which are abundantly infested by termites can be monitored or reduced. This study will also provide better knowledge of the feeding behavior of these termites. In which durability of processed log can last longer.

This will also provide furniture manufacturers with better understanding of certain tree and termite species affiliated for better treatment if needed.

1.4 Research Objectives

The objectives of this research were:

- **a.** To determine the species of wood feeding termites which are associated with the trees in primary and regenerated forest of Danum Valley.
- **b.** To identify the types of trees in primary and regenerated forest which are associated with termites in Danum Valley.
- **c.** To map the distribution patterns of termites in the forest of Danum Valley.
- **d.** To find the relationship between termites and abiotic factors from the forest of Danum Valley

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Termites were initially placed under the order of Isoptera which comes from the Greek Language in which '*iso*' means same while '*ptera*' means wing (CSIRO, 1991). It is believed that termites have evolved about 120 million years ago (Collins, 1988). There has been evidence that relates the phylogenetic of a termite to cockroaches (Kambhampati *et al.*, 1996). It is said that termites are derived from a primitive group of wood-dwelling cockroaches (Bignell and Eggleton, 1999). In recent phylogenetic studies, it has been proposed that termites and cockroaches are to be placed under the same order which is Blattodea. This is because from the extraction of a molecular phylogenetic analysis, it showed that termites are social cockroaches. It was also suggested that termites be classified under a new family of cockroaches called Termitidae and the order of Isoptera is no longer valid (Inward *et al.*, 2007).

Termites are a type of polymorphic insect which is an organism with more than one adult form. Furthermore, termites like ants are an eusocial insect in which they form an insect society characterized by specialization of tasks and cooperative care of the young (CSIRO, 1991). Termites are also known as "White Ant" which are one of the most abundant insects in the tropical rainforest of Borneo (Horwood and Eldridge, 2005). The term is an unfortunate one as termites are not related to ants. Termites resemble ants in one aspect of they both live in organised communities (Tweedie and Harrison, 1965). Generally, ants are brownish black while termites are pale brownish white. In comparison, termites have straight antennas while ants have elbowed antennas. Reproductive termites have equal length of wings while for ants, the fore and hind wings differ in length (Koehler and

Pereira, 1994). Figure 2.1 shows the general comparison of winged termites and ants.

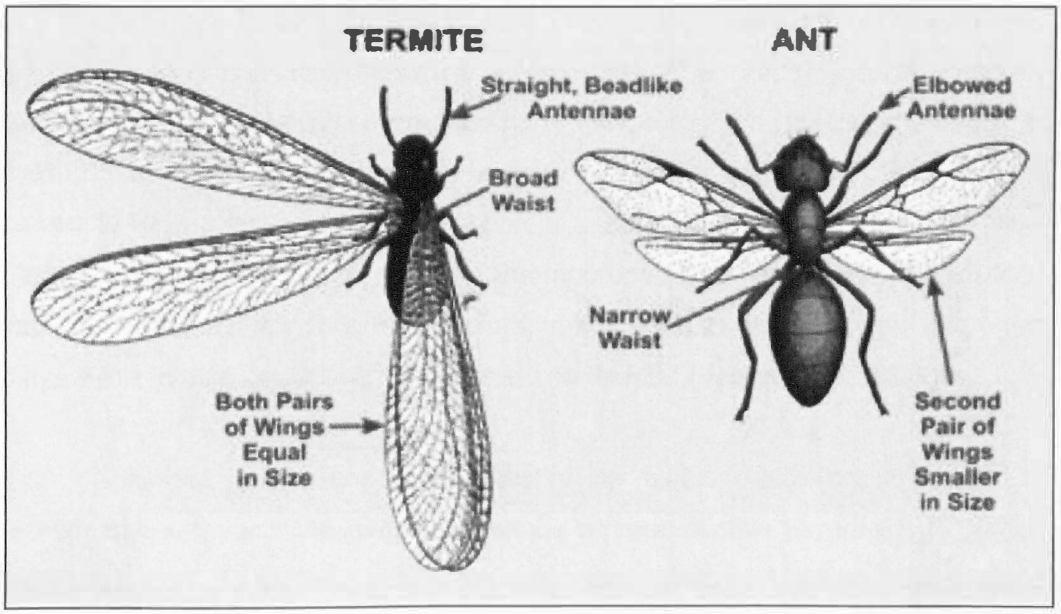

Figure 2.1 : General comparisons of termites and ants.
Source : www.ianrpubs.unl.edu/pages/publicationD.jsp?publicationId=338

Throughout the world, it is known that there are about 3,105 species of 12 families including living and fossil termites Krishna *et al.* (2013). Termites are widely dispersed throughout the tropics and have high diversities and abundance in the rainforest of Africa, South America and Southeast Asia (Bignell and Eggleton, 1999). There are about 150 species in 44 genera which have been recognised in Malaysia (Jones and Eggleton, 2000). In Sabah, about 103 species of termites were collected around the island, in which 38 species were new species (Thapa, 1981).

2.2 Termite Morphology

The termite anatomy can be divided into three segments which are head, thorax and abdomen. However, different castes of termites have different morphology characteristics. Morphology characteristics of a termite include antennas, compound eyes (Amornsak *et al.*, 2003), three pairs of legs and termite alates have two pairs of wings (fore and hind wings).