ANT COMMUNITIES (HYMENOPTERA: FORMICIDAE) IN A PRIMARY TROPICAL RAINFOREST OF TAWAU HILLS PARK, SABAH AND ADJACENT OIL PALM PLANTATION AREA

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I hereby declare that the work in this project is my own except for the quotations and summaries which have been fully acknowledged.

10th May 2008

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ABSTRACT

This study was carried out within the primary forest at Tawau Hills Park, Sabah, Malaysia and an adjacent oil palm plantation. The objectives of this study were to determine the effect of forest conversion to oil palm plantation area on ant diversity and to determine the effectiveness of all sampling methods used to sample ants at both study sites. Five sampling methods were used: arboreal baited pitfall trapping, extraction of ants from arboreal *Asplenium nidus*, Winkler bags, terrestrial baited pitfall trapping and hand collection using forceps through 100m belt transect. A total of 126 species of ants belonging to 47 genera and ten subfamilies were sampled in the primary forest of Tawau Hills Park meanwhile 82 species of ants belonging to 36 genera and seven subfamilies were sampled in the oil palm plantation. A total of 62 species of ants appeared exclusively in primary forest of Tawau Hills Park (i.e. not found in oil palm plantation). Assumption was made that some ant species were lost when primary forest was converted into oil palm plantation. In this research, ant species of *Tapinoma melanocephalum* and *Anoplolepis gracilipes* were recorded in oil palm plantation and *Anoplolepis gracilipes* was recorded in the primary forest of Tawau Hills Park. For terrestrial primary forest ants, manual transects gave the best results yielding 77 species whereas terrestrial pitfall method and Winkler's bags method yielded 42 and 44 species respectively. For arboreal ants in the primary forest, pitfall trap yielded 26 species meanwhile, extraction from *Asplenium nidus* root only recorded seven species. For terrestrial oil palm ants, manual transects gave the best results yielding 48 species whereas terrestrial pitfall method and Winkler's bags method yielded 21 and 24 species respectively. For arboreal ants in oil palm plantation, pitfall trap yielded 35 species meanwhile extraction from *Asplenium nidus* root only recorded 13 species. Based on the values of Shannon-Weiner diversity index and Evenness index, not all sampling methods in primary forest of Tawau Hills Park will record a higher value of these indexes compared with the indexes of oil palm plantation. This was mainly due to baited trapping method as this method recorded high abundance of *Pheidologeton affinis* and *Lophomyrmex bedoti*. Shannon-Weiner diversity index tend to be lower with these ant species of high abundance. In conclusion, this study showed that land conversion of primary forest into oil palm plantation decrease the total ant species number. Besides that, this land conversion also changes the species composition of the ant community, accompanied by an increase of invasive ant species in the oil palm plantation. Based on sampling efficiency that above 80% given by at least one species richness estimator for all the sampling methods used in this study, the conclusion that can be made is that all the sampling methods are effective to sample ants in both the primary forest of Tawau Hills Park and oil palm plantation.

ABSTRAK

Kajian ini dijalankan di hutan hujan primer Taman Bukit Tawau, Sabah, Malaysia dan habitat ladang kelapa sawit yang berdekatan. Objektif kajian adalah untuk mengkaji kesan ke atas kelimpahan spesies semut akibat pemusnahan hutan hujan tropika primer dan bertukar kepada penanaman kelapa sawit. Lima kaedah digunakan dalam kajian ini: kaedah lubang berumpan arborel, pengekstrakkan semut dari *Asplenium nidus* arborel, kaedah bag Winkler, kaedah lubang berumpan terrestrial dan kaedah pungutan semut secara manual sepanjang transek 100m. Sejumlah 126 spesies semut dalam 47 genus dan 10 subfamili telah dikumpul di hutan primer; manakala 82 spesies semut dalam 36 genus dan tujuh subfamili telah dikumpul di ladang kelapa sawit. Sebanyak 62 spesies semut hanya dijumpai di hutan primer Taman Bukit Tawau dan tidak terdapat di ladang kelapa sawit. Anggapan yang dibuat adalah bahawa sebahagian spesies semut ini telah pupus apabila hutan primer ditukar kepada ladang kelapa sawit. Spesies semut *Tapinoma melanocephalum* and *Anoplolepis gracilipes* dijumpai di ladang kelapa sawit dan *Anoplolepis gracilipes* di Taman Bukit Tawau. Bagi semut terrestrial di hutan primer, kaedah pungutan semut secara manual mencatatkan rekod terbaik sebanyak 77 spesies, manakala kaedah lubang berumpan terrestrial dan kaedah bag Winkler masing-masing merekodkan sebanyak 42 dan 44 spesies. Bagi semut arborel di hutan primer, kaedah lubang berumpan arborel merekodkan 26 species manakala, pengekstrakkan semut dari *Asplenium nidus* hanya merekodkan tujuh spesies. Bagi semut terrestrial di ladang kelapa sawit, kaedah pungutan semut secara manual mencatatkan rekod terbaik sebanyak 48 spesies, manakala kaedah lubang berumpan terrestrial dan kaedah bag Winkler masing-masing merekodkan sebanyak 21 dan 24 spesies. Bagi semut arborel di ladang kelapa sawit, kaedah lubang berumpan arborel merekodkan 35 species manakala, pengekstrakkan semut dari *Asplenium nidus* hanya merekodkan 13 spesies. Berdasarkan nilai indeks diversiti Shannon-Weiner and indeks Evenness, tidak semua kaedah persampelan di hutan primer Taman Bukit Tawau merekodkan nilai indeks yang lebih tinggi berbanding dengan nilai indeks ladang kelapa sawit. Ini adalah disebabkan kaedah lubang berumpan terutamanya merekodkan kelimpahan spesies *Pheidologeton affinis* dan *Lophomyrmex bedoti* yang tinggi. Nilai indeks diversiti Shannon-Weiner cenderung lebih rendah nilainya dengan kehadiran spesies semut yang mempunyai kelimpahan yang tinggi. Sebagai kesimpulan, kajian ini menunjukkan bahawa pertukaran tanah dari hutan primer kepada ladang kelapa sawit megurangkan jumlah bilangan spesies semut. Selain daripada itu, penukaran kegunaan tanah ini juga menyebabkan pertukaran komposisi spesies semut and struktur dominasi komuniti semut selain juga peningkatan dari segi kelimpahan spesies semut yang diperkenalkan di ladang kelapa sawit. Berdasarkan keberkesanan kaedah persampelan yang melebihi 80% yang dicatatkan oleh sekurang-kurangnya satu nilai anggaran kelimpahan spesies bagi semua kaedah persampelan yang telah digunakan dalam kajian ini, kesimpulan yang boleh dibuat adalah kesemua kaedah persampelan adalah efektif untuk mendapat sample semut dari hutan primer Taman Bukit Tawau dan ladang kelapa sawit.

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%	percent
km	kilometer
km^2	square kilometer
m	meter
m^2	square meter
ha	hectare
THP	Tawau Hills Park
OP	oil palm plantation

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CHAPTER 1

INTRODUCTION

1.1 Ecological Research

The ant fauna of Borneo Island have nine subfamilies, 94 genera and more than 1000 described species. Though Borneo covers less than 0.2 percent of the earth's land surface, it may have representatives of about 30 percent of ants genera and about seven percent of its species, (Maryati *et al.*, 2004). In Indo-Australian region, which include Malaysia, Philippines, Indonesia, New Guinea and Pacific islands, 22 endemic genera were found (Bolton, 1995). Thus, about 27 percent of them are Bornean ants.

Tropical rainforests represent a store of living renewable natural resources, by virtue of their richness in both animal and plant species, have contributed a wealth of resources for the survival and well-being of humankind. These resources have included basic food supplies, clothing, shelter, fuel, spices, industrial raw materials and medicine.

The chemical and morphological heterogeneity of tropical trees can affect the species richness of some insect groups (Huston, 1994). In these circumstances, insect species richness would be causally related to tree species richness, so that logging and forest clearance would have a direct impact on insect diversity (Samways, 1994; Basset *et al.*, 1998). Different groups of tropical insects respond in different ways to the same type of disturbance, but frequently insect species peak over intermediate disturbance levels (Spitzer *et al.*, 1997).

Based on Khoo and Chandramohan (2002), palm oil is the second largest oils and fats produced after soybean oil, accounting for 20% of the world oils and fats production in the year 2001. Malaysia alone contributed 30% to the global oils and fats exports last year, making it the largest oils and fats exporting country in the world.

World population is expected to grow to 7.54 billion in 2020, and palm oil play an important part to supply the demand.

So, despite oil palm plantation being very important to Malaysia's economy, it may produce negative impact to our country rich biodiversity. So, the practice of sustainable agriculture undergoing which is not just environmentally sound land management practices but an integration of the three main goals of environmental health, economic profitability and social responsibility. This means that modern agriculture must now be more encompassing, with stewardship of natural and human resources being equally important as economic viability.

1.2 Problem Statement

The research problem is to identify the degree of changes in ant diversity when a tropical rainforest is converted into oil palm plantation and also to discuss the consequences of this action on ant diversity.

This research is to compare ant diversity of Tawau Hills Park as primary tropical rainforest with Golden Hope Table Estate as oil palm plantation in both terrestrial and arboreal ants. Collection of terrestrial ants using three methods: pitfall traps, Winkler's bags and hand collection using forceps through 100 x 2m belt transect. Meanwhile, for collection of arboreal ants, baited pitfall traps and extraction of ants from *Asplenium nidus* will be used.

1.3 Importance Of Study

This research will provide a reliable baseline for counting populations and determining ant species. This can contribute to our country oil palm plantation objectives which are economically viable, socially equitable and environmentally sustainable.

Next, this inventory provides baseline documentation of natural occurrence of ant species in Tawau Hills Park and adjacent oil palm plantation, and is a crucial first step in mapping conservation priorities. This inventory is essential to advance understanding of ant ecology and to take full advantage of their demonstrated value in conservation priority setting, bio-monitoring in the primary tropical rainforest, and biological control in oil palm plantation.

1.4 Objectives

The objectives of this study are:

1. To determine the effect of forest clearing to convert into oil palm plantation area on ant diversity.

2. To determine the effectiveness of all sampling methods used to sample ants in both study sites of Tawau Hills Park and Golden Hope Table Estate.

1.5 Hypothesis

In this study, the hypothesis made is that forest conversion into oil palm plantation area will record lower ant diversity compared to primary tropical rainforest. Next, no single collection method of ants is the most effective in both study sites of Tawau Hills Park and Golden Hope Table Estate.

CHAPTER 2

LITERATURE REVIEW

2.1 Importance Of Ants

Ants are ecologically dominant in almost every terrestrial environment around the world. Ant species, although they constitute only 1.5% of the known global insect fauna, make up as much as 10% or more of the total animal biomass in tropical forests, grasslands, and probably other major habitats (Wilson, 2000).

Ants have many attributes that make them ideal for biodiversity studies. These attributes include ants have high diversity, numerical and biomass dominance in almost every habitat throughout the world, a nearly good taxonomic knowledge base, ease of collection, stationary nesting habits that allow them resample over time, sensitivity to environmental change and important functions in ecosystem that include interactions with other organisms at every trophic level. Ground-dwelling ants, in particular, can represent a subset of ants that can be fairly completely sampled using only a few target methods. The ground-dwelling ants' communities of relative stability, moderate diversity and sensitivity to microclimate make them a good candidate to use in biodiversity inventory and monitoring programs (Alonso and Agosti, 2000).

Knowledge of the diversity of ants in an area can provide a great deal of useful information for conservation planning. The number and composition of ant species in an area can indicate the health of an ecosystem and provide insight into the presence of other organisms, since many ant species have obligate interactions with plants and other animals (Alonso and Agosti, 2000). Ants are one of the terrestrial invertebrates used as bioindicators. They are included in monitoring programs associated with human activities in Australia (Andersen, 1993).

The impact of ants on the terrestrial environment is correspondingly great. In most terrestrial habitats they are among the leading predators of other insects and small invertebrates (Wilson, 1971; Sorensen and Schmidt, 1987). Ants also alter their physical environment profoundly. In the temperate forest of New York, ants are responsible for the dispersal of nearly one-third of the herbaceous plant species, which in turn constitute forty percent of the aboveground biomass (Handel *et al.*, 1981).

Ants as a whole have achieved dominance across many land habitats enjoyed by few other groups of insects. Their numerical success has allowed them to alter not just their nest environments but the entire habitats in which they live. Harvesting ants, species that regularly include seeds in their diet, have an especially high impact. They consume a large percentage of the seeds produced by plants of many kinds in nearly all terrestrial habitats, from dense tropical forest to deserts. Their influence is not wholly negative. The mistakes they make by losing seeds along the way also disperse plants and compensate at least in part for the damage caused by their predation (Holldobler and Wilson, 1994).

The construction of ant nests changes the physical and chemical properties of the soil increasing its drainage and aeration through the formation of underground galleries, and transforming organic matter and incorporating nutrients by food storage, aphid (Homoptera) cultivation, and the accumulation of feces and corpses (Brian, 1978). These bioturbation effects occur in the topsoil as well as in the subsoil whether the ant nest is subterranean or forms a mound (Folgarait, 1998).

Ants transport plant and animal remains into their nest chambers, mixing these materials with excavated earth, the nest area is often charged with high levels of carbon, nitrogen and phosphorus. The soil surface is consequently broken into a mosaic of nutrient concentrations, and this in turn creates patchy distributions of plant growth, especially during the early stages of succession (Beattie and Culver, 1977; Petal, 1978; Briese, 1982).

Ants have a major influence on other organisms in many tropical dryland habitats where some predatory species are important biological control agents (Way and Khoo, 1992). Cocoa plantation ants may control some pests by predation, repellency or by their behavior toward intruders. Efficient predators, like *Pseudomyrmex* spp which nest in dried shoots, some Ponerinae and some Ecitoninae, live on Bahia cocoa plantations in Amazonian Basin (Delabie, 1990). Based on Delabie (1990) too, *A.chartifex spiriti*, essentially nocturnal, controls undesirable insects through its aggressive behavior or by its repellency. According to Giesberger (1983), ant species of *Dolichoderus bituberculatus* Mayr in Indonesia has been successfully utilized as biological control agents for cocoa plantation.

In Malaysia, black cocoa ant, *Dolichoderus thoracicus* Smith and *Oecophylla smaragdina* Fabr both can be used to control *Helopelthis theobromae* which is the main organisms caused damages in cocoa plantation of Peninsular Malaysia (Khoo and Chung, 1989). Again, *Dolichoderus thoracicus* plays an important role in controlling mosquito of *Helopelthis theivora* (Khoo and Chung, 1989; Khoo and Ho, 1992). *Dolichoderus thoracicus* also been proven its ability to reduce the impact of attack by some mammals pests and reduce the negative impact caused by *Phytopthora palmivora* which cause cocoa black pod disease (Khoo and Ho, 1992).

In particular, "green islands" surround colonies of *Formica polyctena* during outbreaks of the lepidopteran *Panolis flammea;* the ants disturb ovipositing adults, kill larvae on the trees and on the ground, and kill pupae beneath the soil (Way and Khoo, 1992). In fact, *Formica* spp. kill many different defoliating pests in European forests, from which tree growth may benefit (Whittaker and Warrington, 1985). *F. polyctena* and *F. lugubris* are particularly useful for artificial establishment in different climatic zones (Pavan, 1979). They are favored because they reach high population densities, are facultative predators active over a long season day and night at all levels of the forest, and are capable of killing both active and quiescent stages of different prey species, notably the caterpillar pests on which they concentrate during outbreaks.

The territorial patterns within an ant mosaic might influence also the pattern of pest insect species that occur on the respective plants. In some experiments, the researcher found that *Oecophylla smaragdina* was able to kill larvae of *Setothosea asigna*, an important pest insect on oil palms. Therefore we expect less larvae of *S. asigna* in trees that are dominated by the *O. smaragdina*, which is one of the largest and most aggressive ant species on palms within the plantations (Pfeiffer, 2008). In several other crop plantations *Oecophylla smaragdina* is successfully used as a control agent against pest insects (Peng *et al.* 1997, Peng and Christian 2004). Apart from protecting *Eucalyptus* and other timber trees, *Oecophylla smaragdina* control all major pests and improve the yield and quality of citrus and cashew (Van and Thi, 2003).

2.2 Importance Of Oil Palm, *Elaeis guineensis* To Malaysia

Oil palm, *Elaeis guineenis* is a monocotyledon plant of the order Spadiciflotae. It is from the Palmae family and the Cocoineae tribe. The oil palm in Malaysia is over a century old. Introduced as an ornamental in 1871, the oil palm was commercially exploited as an oil crop only from 1911 when the first oil palm estate was established (Yusof Basiron *et al.*, 2000).

In year 1960, oil palm plantings covered 60 000 ha and reached 1.07 and 3.38 million hectares in year 1980 and 2000 respectively. In year 2001, oil palm covered 3.5 million hectares and is expected to increase to 4.72 and 5.10 million hectares in year 2010 and 2020, respectively. With the expansion of the oil palm area, palm oil production rose from 91793 tonnes in year 1960 to 11.80 million tonnes in year 2001 and is expected to reach 18.81 million tonnes in year 2020 (Jalani *et al.*, 2002). The industry had in the past generated about RM 22.6, 19.2, 14.9 and 14.1 billion in foreign exchange in year 1998, 1999, 2000 and 2001, respectively (Yusof Basiron and Chan, 2004).

From its home in West Africa, the oil palm (*Elaeis guineensis* Jacq.) has spread throughout the tropics and is now grown in 16 or more countries. However, the major centre of production is in South East Asia (SEA) with Malaysia and Indonesia together accounting for around 83 % of world palm oil production in 2001. Malaysia is presently the world's leading exporter of palm oil having a 60% market share and palm oil is second only to soybean as the major source of vegetable oil. Oil palm production in Malaysia presently occupies around 3.7 million hectares of which over two million are in Peninsular Malaysia and the rest in the East Malaysian states of Sabah and Sarawak (Mohd. Basri Wahid *et al.,* 2004)

According to Yusof Basiron and Mohd Arif Simeh (2005), the four main traditional uses of palm oil in food products are for cooking or frying, shortenings, margarines and confectionary fats. Palm oil is popularly used in both solid fat products as well as liquid form as cooking oil sector especially for industrial frying applications. New applications for palm oil in foods include its use in emulsion-based powdered and consumer foods such as pourable margarine, mayonnaise, soup mixes, imitation cheese and microencapsulated palm oil. Each year, the oil palm industry in Malaysia generates more than 30 million tonnes of biomass in the forms of empty fruit bunches, oil palm trunks and oil palm fronds. Palm biomass such as empty fruit bunches and trunks are being used for commercial products (*e.g.* pulp and paper, medium density fiberboard, automotive components *etc.*).

The financial benefits from the palm oil industry had indeed helped the country to weather the effects of the melt down of the Asian Financial Crisis in the year 1997 and 1998. All these pointed to the beneficial effect of the palm oil industry as a vehicle to eradicate rural poverty. Landless people were placed as settlers in the newly opened land schemes. The government provided them housing and infrastructure including community halls, schools, health clinics, shops and roads. Initially, the government supported their livelihoods until the oil palm matured when the income from the crop was sufficient to pay off their loans. In doing so, the government was able to alleviate rural poverty using the oil palm as the vehicle to do so (Yusof Basiron and Chan, 2004).

2.3 Ant Ecology In Tropical Rainforest And Plantation Area

In addition to the potential value of ants as a surrogate group for overall diversity, they have great promise as indicators of ecological change (Nepstad 1995). Ant community structure has been shown to be sensitive to heterogeneity in a number of environmental factors. For example, data from both within and across site studies have shown relationships between ground dwelling ant communities and soil properties (Bestelmeyer and Wiens 2001), seasonality and climate factors (Kaspari and Weiser 2000), vegetation density (Bestelmeyer and Wiens 2001), vegetation communities (Majer and Delabie 1994; Bestelmeyer and Wiens 2001), and plant productivity (Kaspari, 2000). Many of these factors have been shown to be currently undergoing measurable changes due to climate and land use change (Root and Schneider 2002; Walther *et al.* 2002; Parmesan and Yohe 2003), and these effects are predicted to continue into the foreseeable future (Enquist, 2002).

Ants make their nests in a variety of forms. Most ant colonies are relatively sessile, at most moving their colonies every two weeks, some not moving at all. Ants derive their energy from other organisms – either plants (nectar, leaves, and seeds) or other animals, alive or dead. From a central point, colonies send foragers through the environment, quickly recruit to new food resources, and just as quickly abandon them as the need arises. In this way ants collect and concentrate resources in the environment and are themselves predictable resources for those that exploit them (Andersen, 1991).

Tropical forest and secondary growth habitats may contain a wealth of microhabitats in the form of both nesting sites and food for the great many ant species found in these places. Rates of predation by ants are greater in the tropics than in Temperate Zone areas and that predation rates in dissimilar tropical habitats, such as forest understory and open field, tend to be similar (Young, 1982).

The tropical forest canopy and litter differ in physical structure, resource availability and abiotic conditions. Ant activity (biomass at bait after 32 minutes) was higher in the canopy than litter, and higher on protein baits than carbohydrate baits. Aggressive bait defense occurred more frequently in the canopy (60%) than in the litter (32%), but was not associated with tree species or bait type in either habitat (Yanoviak and Kaspari, 2000).

Species richness at bait was relatively uniform across tree species and habitats. Litter and canopy do not share similar ant species, but overlap among tree species was three times higher in the litter assemblages. Litter assemblages showed less activity, less interference, less differentiation across the landscape, and different size distributions than canopy assemblages (Yanoviak and Kaspari, 2000).

The availability of many kinds of prey and other food sources and a diversity of nesting sites account for a high species richness of ants in both tropical forest and field habitats. Based on study of ant species richness in the forest of Brazil, there are 24 ant species recorded on forest ground. In addition, the researcher managed to find 19 ant species in the twigs and 12 ant species in leaves. A total of 35 ant species recorded in all three habitats which are on forest ground, twigs and in leaves. Meanwhile, trunks sampled in the forest of Brazil recorded a total of 15 ant species. There are a total of 16 ant species in canopy above 15m. Canopy at 15m recorded a total of 17 ant species (Young, 1982).

Based on Kaspari and Weiser (2000), season and habitat exposure, but not time of the day, significantly shaped ant activity. From the dry to the wet season, ant activity increased by 25 percent. However, ant activity increased only marginally from day to night. Ant response to microhabitats differed along humidity gradients. From the dry to the wet season, ant activity increased by 30 percent in shrubs and 20 percent in trees. Ant activity was measured as the number of ants collected at a station during a transect run.