THE EFFECTS OF LOGGING ON ORGANISMS USING BEARDED PIG'S (*Sus barbatus*) MUD WALLOWS IN DANUM VALLEY FIELD CENTRE, LAHAD DATU, SABAH

YEAH WAI YUIN

DISERTATION SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF BACHELOR OF SCIENCE

CONSERVATION BIOLOGY PROGRAMME
SCHOOL OF SCIENCE AND TECHNOLOGY
UNIVERSITY MALAYSIA SABAH

APRIL 2007

UNIVERSITI MALAYSIA SABAH

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Ijazah: Sarjana Muda Sains

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I declare that this is the result of my own reseach except as cited in reference. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any degree.

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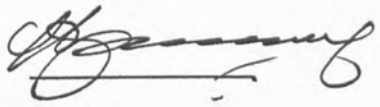

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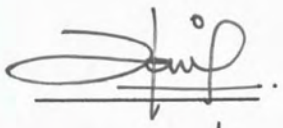

3. **EXAMINER 2**

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ACKNOWLEDGEMENT

First of all, I would like to express my greatest gratitude to my supervisor, Dr. Henry Bernard for his supervisions, advises, patience guidance and endless support during the period of completion for this project. I would like to thank Institute for Tropical Biology and Conservation (ITBC) for providing field equipements and for allowing me to use the collections in BORNEENSIS for identification of species collected in my studies.

Not forgetting, I would like to thank Mr. Wong Siew Te for his advises, guidance and support during the sampling period in Danum Valley and also to all the research assistants whom had lend a helping hand in my study, especially Mr. Teo Shu De, Mr. Dominic and Mr. Remmy. I would also like to take this opportunity to thank Professor Matsui for assisting me in the identification of Amphibians collected. Besides that, I would love to thank Mr. Noel Beltran-Tawatao for his kind guidance and advises.

Finally, I would like to thank my beloved family for their understanding and support. A very deep appreciation goes to two of my fellow friends, Miss Wong Yit Kuan and Mr. Gan Chin Keong who have went through thick and thin with me during the whole sampling period in Danum Valley and also during the completion of this disertation.

ABSTRACT

This study focused on the effects of logging on organisms using bearded pig's mud wallows in Danum Valley Field Centre (DVCA), Lahad Datu, Sabah. The study was conducted in unlogged and logged forest at Danum Valley from June 2006 to July 2006. Thirty two bearded pig's wallows, of which 18 were from unlogged forest and 14 were from logged forest, were sampled and a total of 865 individuals of invertebrates and vertebrates were collected at both sites combined. From the total number of individuals caught, 660 individuals belonged to class Insecta, 52 individuals were from class Amphibia and 153 individuals were captures of other invertebrates. Insecta were the dominant group found in bearded pig's wallows, consisting of five orders, 14 families and 25 species. Amphibia was represented by one order, three families and six species, while other invertebrates were from the class Arachnida, Crustacea, Oligochaeta and Chilopoda. Species richness of organisms associated with bearded pig's wallows were found very similar between sites (Insects; Unlogged forest: 19 species, Logged forest: 21 species) (Amphibia; Unlogged forest: four species, Logged forest: five species) (Other invertebrates; Unlogged forest; seven species, Logged forest: five species). Shannon-Wiener and Simpson's Diversity Index showed no significant difference of diversity between both sites (Insects; Shannon-Wiener: $P = 0.4359$, Simpson's: $P = 0.5723$) (Amphibia; Shannon-Wiener: $P = 0.9457$, Simpson's: $P = 0.9436$) (Other invertebrates; Shannon-Wiener: $P = 0.7053$, Simpson's: $P= 0.4167$). A high percentage of similarity (0.60) of composition of species between both sites was obtained. Species were also found to be evenly distributed in unlogged and logged forest (Insects; Unlogged forest: $E = 0.7448$, Logged forest: $E = 0.7264$) (Amphibian; Unlogged forest: $E = 0.8958$, Logged forest: $E = 0.7851$) (Other invertebrates; Unlogged forest: $E = 0.7934$, Logged forest: $E = 0.9321$).

KESAN PEMBALAKAN TERHADAP ORGANISMA YANG MENGGUNAKAN KUBANG BABI HUTAN DI LEMBAH DANUM, LAHAD DATU, SABAH.

ABSTRAK

Tujuan kajian ini adalah untuk menentukan kesan pembalakan terhadap organisma yang menggunakan kubang babi hutan di sekitar hutan primer dan hutan sekunder di Lembah Danum, Lahad Datu, Sabah. Perbandingan kepelbagaian dan kelimpahan spesies dilakukan di antara kedua-dua hutan dari Jun 2006 sehingga Julai 2006. Sebanyak 32 kubang babi hutan, di mana 18 dari hutan primer dan 14 dari hutan sekunder, telah disampel dan 865 vertebrata dan invertebrata diperolehi daripada hasil persampelan. Daripada jumlah keseluruhan hasil persampelan, sebanyak 660 individu adalah dari kelas Insecta, 52 organisma dari kelas Amphibia dan 153 individu dari kumpulan lain-lain. Kelas Insecta merupakan kumpulan majoriti di dalam kajian ini dan ia terdiri daripada lima order, 14 famili dan 25 spesies. Kelas Amphibia pula terdiri daripada satu order, tiga famili dan enam spesies. Organisma yang tergolong di dalam kumpulan lain-lain terdiri daripada kelas Arachinida, Crustacea, Oligochaeta dan Chilopoda. Kepelbagaian dan kelimpahan spesies di kubang babi hutan didapati tidak banyak berbeza di antara hutan primer dan hutan sekunder (Insecta; Hutan primer: 19 spesies, Hutan sekunder: 21 species) (Amphibia; Hutan primer: empat spesies, Hutan sekunder: lima spesies) (Lain-lain; Hutan primer; hutan sekunder: lima spesies). Indeks kepelbagaian Shannon-Wiener dan Simpson tidak menunjukkan perbezaan yang ketara di antara kedua-dua kawasan (Insecta; Shannon-Wiener: P = 0.4359, Simpson's: P = 0.5723) (Amphibia; Shannon-Wiener: P = 0.9457, Simpson's: P = 0.9436) (Lain-lain; Shannon-Wiener: P = 0.7053, Simpson's: P= 0.4167) Peratusan kesamaan yang tinggi iaitu sebanyak 0.60 didapati untuk komposisi spesies di antara hutan primer dan sekunder. Taburan spesies yang seragam didapati di kedua-dua lokasi kajian (Insecta; Hutan primer: E = 0.7448, Hutan sekunder: E = 0.7264) (Amphibia; Hutan primer: E = 0.8958, Hutan sekunder: E = 0.7851) (Lain-lain; Hutan primer: E = 0.7934, Hutan sekunder: E = 0.9321).

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ft	feet
%	percent
°	degree
'	minute
N	North
E	East
Mm	millimeter
°C	degree Celsius
km^2	kilometer square
H'	Shannon-Weiner Diversity Index
D	Simpson's Diversity Index
Cj	Jaccard's Similarity Index
E	Evenness value
P	Estimated probability that diversity at both sites is equal
sp.	Species
s.d	Standard deviation
$\sum$	Sigma
ln	log e
pp	page
UF	Unlogged forest
LF	Logged forest

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

Borneo tropical rainforest, a hotspot for scientists and nature lovers is particularly rich in flora and fauna. The valuable Dipterocarpaceae tree species that are present in this tropical rainforest at relatively high densities are experiencing the highest rate of forest loss in the tropical world due to the high export demand (Brooks & Spencer, 1997). Habitat alteration or fragmentation is recognized as one of the most important threats to species diversity, particularly in tropical zones where diversity is high and forests are being transformed at ever-increasing rates (Eduardo & Gonzalo, 2004). In the state of Sabah, the undisturbed tropical rainforest has been reduced from 60.1% in 1986 to 21.6% in 1992 due to the effect of selective logging (Marsh & Greer, 1992). The impact of logging not only disturbed the ecosystems of living organisms in the forest but it is also known to affect the forest structure. Hamer and Hill (2000), reported that selective logging has affect the forest structure and the amount of light reaching ground level through changes in canopy cover which later disrupt the vertical stratification of species and affect the estimate of biodiversity on the forest floor.

The mosaic of disturbance produced by selective logging, ranging from heavily disturbed and compacted areas to patches of intact forest, has received little attention (Clarke & Walsh, 2006). Furthermore, the response of organisms to logging focused on birds and mammals and there is a critical lack of information on invertebrate communities (Sutton & Collins, 1991). Invertebrates are another major group of inhabitants in the forest and they react dramatically to changes in environmental conditions. According to Tawatao (2005), invertebrates are potential indicators for monitoring forest disturbances, regeneration and habitat condition in respond to selective logging. Invertebrates are found almost everywhere in the forest, from occupying the canopy area to inhabiting the forest floor. A rich community of invertebrates was found in the wallows created by bearded pigs but there are no related studies being conducted to investigate the impacts of selective logging to the communities in bearded pig's wallows.

Bearded pig (*Sus barbatus*), belongs to the order Artiodactyla and family Suidae. Bearded pigs are widely distributed in Borneo but their population can also be found in Peninsular Malaysia, Sumatra, Palawan and Philippines (Payne *et al.*, 1985). Rainforests, mangrove thickets and secondary forests are habitats for bearded pigs. Bearded pigs are large in size (3.3 - 5.5 ft), long-legged and they have a distinguishing character of having two pairs of warts on the face and the first pair is covered with beard hair (Payne *et al.*, 1985). They have the slimmest torso and the longest head compared to other species of pigs. Their diet includes roots, fungi, invertebrates in soil and rotting wood, small vertebrates and agricultural crops (Caldecott *et al.*, 1993). Due to their diet, bearded pigs developed the soil digging behavior. Bearded pig has a prominent snout where they use it to dig for roots and earthworms in the ground.

There are many interesting behaviors of bearded pigs but research on this species is very scarce due to the difficulty of studying them in the field (Hancock *et al.*, 2006). Bearded pig spends much of its time in small groups, but occasionally, they appear to join large-scale migration (Caldecott, 1988). They have a special behavior where they undergo regular migrations to exploit the seasonal fruiting grounds in dipterocarp forests. This regular migration are only observed and the main factor that drives this behavior remains unknown (Hancock *et al.*, 2005).

Mud wallows created by bearded pigs play important roles to bearded pigs and other organisms that can be found near the wallows. Mud wallowing is important to bearded pigs as it is the only way for bearded pigs to get rid of their body heat and other ecto-parasites that stick on their body (Heinken *et al.*, 2006). Usually, water will be trapped in the wallow when rain pours and this creates a small water pond that can cater to the need of other organisms as water sources (Photo 1.1). Elephants, rhinos, and sambar deer are among the frequent visitors of mud wallows as these animals usually drink from the wallow and the behavior of wallowing create a new small habitat for other organisms, such as water striders, water scorpion, tadpoles, frogs, land crabs and dragonflies' larvae (personal communication, Wong, 2006).

Invertebrates such as dragonflies, damselflies and wasps are found at mud wallows as well (personal communication, Wong, 2006). Dragonflies and damselflies make use of the water depression trapped in wallows as their breeding ground to lay their larvae, while wasps visit wallows to collect soil from the wallow's wall to build their nest. Ickes and DeWalt (1999), mentioned in their research on the effects on under story vegetation by the pigs in Malaysia lowland rain forest, that bearded pigs

are considered to be the potential ecosystem engineers as they play an important role in seed dispersing and physical disturbance of the forest ecosystem.

Photo 1.1 A mud wallow that contains stagnant water.

1.2 JUSTIFICATION OF STUDY

The aim of this study is to evaluate the effects of logging on organisms using bearded pig's wallows. It is important to study the biodiversity at mud wallows and to determine whether logging will affect the biodiversity at mud wallows of bearded pigs. Furthermore, this study is important to ecologists and conservationists as more attention should be placed to protect bearded pigs as their population is declining. However, there is not much research carried out on bearded pigs. The lack of attention

is due to the complexity in studying this species as bearded pig's population is highly variable in space and time (Hancock *et al.*, 2005). Thus, this study is more to a basic research as there are no related studies being conducted so far.

1.3 OBJECTIVES OF STUDY

This study focused on the effects of logging to organisms using bearded pig's wallows in Danum Valley Field Centre (DVFC). There are two objectives:

a. To determine the diversity of organisms using or associated with bearded pigs' mud wallows in the forest habitats.

b. To compare patterns of diversity of organisms associated with bearded pigs' mud wallows in logged and unlogged forest.

1.4 HYPOTHESES OF STUDY

The hypotheses of this study are as stated below:

a. There are a wide variety of organisms that make use of wallows created by bearded pigs, especially invertebrates.

b. The organisms found in unlogged forest are more diverse compared to logged forest.

CHAPTER 2

LITERATURE REVIEW

2.1 LOWLAND TROPICAL RAINFOREST OF BORNEO AND THE EFFECTS OF LOGGING

Lowland tropical rainforest of Borneo is considered the most complex terrestrial ecosystem (Konishi *et al.*, 2006) which lack distinct seasonality, and can provide a high food supply to its wildlife communities (Wong, 2002). This type of forest receives high rainfall throughout the year which allows it to have a wide range of flora and fauna, and some of them are endemic to Borneo. Lowland tropical rainforest serves as the natural habitat to a wide variety of animals, ranging from the world's smallest squirrel to the largest terrestrial animal – the Asian elephant (WWF, 2001). This tropical rainforest is also the heart of the world's diversity for dipterocarps. It is reported by WWF that Borneo tropical rainforest contain 267 dipterocarpaceae species, with 155 species endemic to Borneo. Borneo rainforest also have a very unique flora species known as the *Rafflesia arnoldii. R. arnoldii* is the largest flower in the world and it has large red, orange, brown or white flowers with a smell of rotten meat (WWF, 2001).

Lowland tropical rainforest of Borneo is also very much valued for its timber production (Wong, 2002). One of the major timber producing areas within Sabah is the 927 800 hectares Yayasan Consession Area (YSCA), which covers 21% of the state's forested land (David *et al.*, 2005). In addition, Malaysia and Indonesia are the world's leading exporters of tropical hardwoods (Wong, 2002). There are a wide range of high quality woods in this forest and logging is a very normal scenario throughout the year. The rampant logging and revenue earned by Malaysia had made it the world's largest exporter of tropical woods for the past three decades (Tawatao, 2005).

The lowland tropical rainforest of Borneo is seriously exploited in timber harvesting and it has become increasingly fragmented due to human's activities (Brühl *et al.,* 2003). Human has long invaded forests and convert the landscape into agricultural plantations, for example, conversion of forest land into oil palm plantations in a wide scale (Brühl *et al.,* 2003). Over a million hectares of forest land was converted into large-scale monocultures of oil palm (Brühl *et al.,* 2003). In 1989, Sabah's forest covered an area of 4.7 million hectares, which covered around 63% of the total land mass, including forest reserves, state land and park forests (Sabah Forestry Department, 1989), but in 1996, Sabah is only covered with 3.6 million hectares (Mannan & Awang, 1997).

Besides logging and fragmentation, the rainforest of Borneo is also threatened by forest fire. In 1997-1998 fires are intentionally set to clear the forest for commercial agriculture such as oil palm ravaged a large area in Kalimantan, Indonesia (WWF, 2001). All these disruption will eventually affect the survival rate of wildlife

communities in the tropical rainforest as they are slowly losing their natural habitats. Logging also leads to significant disturbance of soil and water catchments caused by felling of trees and the construction of logging roads and skid trails (Van Gardingen *et. al.*, 1998). Wong (2002) reported that the large scale of timber harvest in the rainforest of Borneo cause both direct and indirect effects on habitats and survival of bearded pigs.

Although tropical rainforest of Borneo is known to yield a high abundance of food, it does experience high seasonal variable of fruits production which can drive some wild animals into starvation. This feature does explain the nomadic behavior of some animals that migrate to other places in search of food. Wong (2002), reported a famine event where the Malayan Sun Bears and bearded pigs are observed to be driven by starvation due to the disrupted fruit production cycle in the Borneo rainforest. Malayan Sun bears and bearded pigs are sympatric in the lowland tropical rainforest of Borneo (Wong, 2002). Bearded pigs are rare to other regions except in Borneo as the rainforest provide a suitable condition and habitat for them. Hancock *et al.*, (2005) mentioned that the pig's population is adapted to exploit the regional scale of fruiting regimes in the Borneo's forest.

According to Wells (2005), rainforest can provide a wide range of challenges and opportunities for researchers and scientists to carry out basic research. It is important to understand the species richness and abundance in undisturbed forest and also how conversion and loss of undisturbed rainforests can affect conservationists to carry out their basic conservation research on the wildlife in undisturbed rainforests (Wells, 2005).

2.2 BEARDED PIGS

Bearded pig (*Sus barbatus*), a wild pig native to the island of Borneo (Hancock *et al.*, 2006) belonged to the order Artiodactyla and from the family Suidae. This species is listed under the IUCN Red List of Threatened Species in 1996. Bearded pig can be found in Brunei Darussalam, Kalimantan, Sumatera, Peninsular Malaysia, Sabah, Sarawak and the Philippines. However, the population of bearded pig is rarely seen in other regions except in Borneo and their number is declining (Caldecott *et al.*, 1993). Bearded pig is the most preferred and most consumed species of wild meat in Sabah and Sarawak, and it is reported that around 72% of animals hunted in Sarawak comprised of bearded pig (Bennett *et al.*, 1999). Although the population is declining, there is not much conservation effort being put up to conserve this threatened species. The lack of research on bearded pig's ecology is due to the difficulty to study them in the field as bearded pig has a high variability of population dynamics (Hancock *et al.*, 2006).

Bearded pig has the slimmest torso and the longest head compared to other species of pigs. It has a dark brown-gray coat with a distinctive white beard on the face. Bearded pigs are large in size (3.3 - 5.5 ft), long-legged and they have a distinguishing character of having two pairs of warts on the face and the first pair is covered with beard hair (Payne *et al.*, 1985). Bearded pig has a prominent snout where they use it to dig for food in the ground. Their diet includes roots, fungi, invertebrates in soil and rotting wood, small vertebrates and agricultural crops (Caldecott *et al.*, 1993). Bearded pig is considered as an ecosystem engineer due to their role in seed dispersing (Ickes & DeWalt, 1999). Furthermore, bearded pig is well known for their

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