THE VALUE OF RIPARIAN RESERVES FOR NON-VOLANT SMALL MAMMAL CONSERVATION IN DISTURBED AND CONVERTED FOREST LANDSCAPES IN SABAH, MALAYSIA

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DECLARATION

I hereby declare that the material in this thesis is my own except for quotations, equations, summaries and references, which have been duly acknowledged.

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ABSTRACT

Logging and forest conversion to oil palm plantations are two of the main factors affecting South-East Asia's rich tropical rainforests biodiversity. Retaining forest fragments flanking streams, i.e. the riparian reserves, within disturbed and converted habitat matrix is generally recognized to be useful practice for enhancing biodiversity or mitigating biodiversity loss, although the usefulness of such forest fragments for the conservation of non-volant small mammals is still poorly known. A study was conducted at the Stability of Altered Forest Ecosystem project area (SAFE) located in and around Kalabakan Forest Reserve, in south central part of Sabah, Malaysian Borneo, by using live-cage traps arranged in a grid, to study the non-volant small mammal communities in riparian reserves located within unlogged forests, repeatedly logged forests and in oil palm plantations. To compare the effects of retaining riparian reserves within oil palm plantations, the small mammals were also sampled in the oil palm plantations without any riparian reserves. In this study, the species richness, diversity, abundance and community composition of the small mammals were compared between the different riparian reserve treatments. A total of 1,446 individuals of small mammals were captured over 13,440 trap-nights, represented by 23 species from 3 orders and 5 families at all of the sampling sites combined. The riparian reserves within the logged forest sites (6 sites) recorded an average of 12.33 ± 2.42 (s.d.) species of small mammals, compared to an average of 11.50 ± 0.71 species in the unlogged forest sites (2 sites) and 12.33 ±1.15 species in oil palm plantation sites (3 sites). Sites in oil palm plantation without riparian reserves (3 sites) recorded an average of 7.67 ±1.15 species. Small mammals in unlogged forest sites showed the highest species similarity with the logged forest sites (Sørensen similarity coefficient= 45%), while the lowest species similarity was recorded between unlogged forest sites and oil palm plantation without riparian reserve (37%). Although, species richness was higher in logged forest than in unlogged forest, the species diversity (based on Simpson's inverse diversity index) was recorded to be higher in the unlogged forest than in the logged forest. The small mammal species richness and abundance were lower in the oil palm without riparian reserves compared with oil palm with riparian vegetation; and the commensal species, i.e., rats (*Rattus exulans* and *R. rattus*), dominated (67% of total individuals caught) the habitat in the oil palm without

riparian vegetation. Increase in the understory vegetation appeared to significantly increase the presence of small mammals. Conversely, increase in the bare ground cover decreases the presence of the small mammals. As coverage of understorey vegetation is generally positively associated with foraging and nesting sites for small mammals, as well as refuge sites from predators, the findings of this study generally suggest that retaining riparian reserves in oil palm plantations can help in the conservation of the non-volant small mammal community. This finding may have important implications for future riparian reserves management particularly in oil palm plantation with a view to increase the biodiversity within this converted landscape.

ABSTRAK

NILAI RIZAB SUNGAI UNTUK PEMULIHARAAN MAMALIA KECIL TIDAK-TERBANG DALAM LANDSKAP HUTAN YANG TERGANGGU DAN TERUBAH SUAI DI SABAH, MALAYSIA

Pembalakan dan penukaran hutan kepada ladang kelapa sawit adalah dua faktor utama yang mempengaruhi biodiversiti hutan hujan tropika di Asia Tenggara. Pengekalan fragmen hutan di tebing sungai, atau rizab sungai, dalam habitat hutan yang terganggu dan terubah suai secara umumnya diakui sebagai salah satu kaedah yang berguna dalam meningkatkan biodiversiti atau mengurangkan kemusnahan biodiversiti. Namun demikian, keberkesanan fragmen hutan ini dalam usaha pemuliharaan mamalia kecil tidak-terbang masih kurang diketahui. Satu kajian telah dijalankan di kawasan projek Stability of Altered Forest Ecosystem (SAFE) yang terletak di dalam dan sekitar Hutan Simpan Kalabakan, Sabah, Borneo Malaysia, dan telah menggunakan kaedah pemerangkapan dengan perangkap mammalia kecil yang disusun dalam grid, untuk mengkaji komuniti mamalia kecil tidak-terbang dalam rizab sungai di hutan tak dibalak, hutan yang dibalak dan ladang kelapa sawit. Persampelan telah dijalankan di dalam ladang kelapa sawit yang tidak mempunyai rizab sungai, untuk membandingkan kesan pengekalan rizab sungai dalam ladang kelapa sawit. Dalam kajian ini, perbandingan kekayaan spesies, kepelbagaian, kelimpahan dan komposisi komuniti mamalia kecil di antara habitat-habitat rawatan telah dilakukan. Sebanyak 1,446 individu mamalia kecil yang mewakili 23 spesies, 3 order dan 5 famili telah berjaya ditangkap dengan usaha perangkapan keseluruhan sebanyak 13,440 malam-perangkap di semua lokasi persampelan secara keseluruhan. Rizab sungai hutan yang pernah dibalak (6 lokasi) mencatat 12.33 ± 2.42 (s.d.) *purata spesies mamalia kecil, manakala hutan tidak dibalak (2 lokasi) mencatat* 11.50 ± 0.71 *purata spesies dan ladang kelapa sawit (3 lokasi) mencatat purata spesies sebanyak 12.33 ±1.15. Kawasan persampelan dalam ladang kelapa sawit yang tidak mempunyai rizab sungai (n=3 lokasi) mencatat purata spesies sebanyak 7.67 (±1.15). komuniti mamalia kecil dalam hutan yang tidak dibalak mempunyai persamaan spesies yang tertinggi dengan hutan yang pernah dibalak (Pekali Sørensen= 45%), manakala persamaan spesies yang paling rendah adalah antara hutan tidak dibalak dengan ladang kelapa sawit yang tidak mempunyai rizab sungai (37%). Kekayaan dan kelimpahan spesies*

mamalia kecil telah berkurang dalam ladang kelapa sawit yang tidak mempunyai rizab sungai, dan spesies tikus komensal (Rattus exulans and R. rattus), adalah dominan di habitat ini (67% daripada keseluruhan hasil tangkapan). Kelimpahan spesies di hutan yang dibalak adalah lebih tinggi berbanding hutany yang tidak dibalak, namun demikian, hutan yang tidak dibalak mencatatkan nilai kepelbagaian spesies (berdasarkan index songsang kepelbagaian Simpson) yang lebih tinggi berbanding hutan yang dibalak. Peningkatan kepadatan vegetasi bawah kanopi meningkatkan kehadiran spesies mamalia kecil. Sebaliknya, peningkatan litupan kawasan lantai hutan yang terdedah (i.i. tiada vegetasi) mengurangkan kehadiran mamalia kecil. Memandangkan litupan vegetasi kanopi bawah pada umumnya berkolerasi secara positif dengan kawasan pencarian makanan dan lokasi membuat sarang, dan juga kawasan pelindungan daripada pemangsa oleh mamalia kecil, keputusan kajian ini mencadangkan bahawa pengekalan rizab sungai boleh membantu dalam pemuliharaan komuniti mamalia kecil tidak-terbang. Penemuan kajian ini mempunyai implikasi yang penting dalam pengurusan rizab sungai di dalam ladang kelapa sawit dalam usaha meningkatkan biodiversiti di dalam landskap yang diubah.

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LIST OF ABBREVIATIONS

GHG	-	Green House Gas
FAO	-	Food and Agriculture Organization of the United Nations
RSPO	-	Roundtable of Sustainable Palm Oil
MEC	-	Malaysian Environmental consultants
SAFE	-	Stability of Altered Forest Ecosystem
NG0	-	Non-profit organization
MBCA	-	Maliau Basin Conservation Area
Ha	-	Hectare
USFR	-	Ulu Segama Forest Reserve
VJR	-	Brantian Tantulit Virgin Jungle Reserve
NMDS	-	Non-metric Multidimensional Scaling
GLM	-	Generalised Linear Model
AICc	-	Akaike Information Criterion
UF	-	Unlogged forest
LF	-	Logged forest
OPR	-	Oil palm plantation riparian reserve
OP	-	Oil palm plantation without riparian reserve
DS	-	Dead or alive stumps
CH	-	Canopy height
CC	-	Canopy cover
UVG	-	Understory vegetation density
BGC	-	Bareground cover
GLC	-	Ground leaf litter cover
PC	-	Palm climber
LDG	-	Leaf litter depth
CCm	-	Canopy cover at the middle of the river
WR	-	Width of the river
DBH	-	Diameter at breast height

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CHAPTER 1

INTRODUCTION

1.1 General Overview

Borneo's tropical forests are some of the richest on the planet (Myers *et al.*, 2000). However, the demand of the timber industry and conversion of forest for agriculture, as well as the urbanization process to cater for the increasing number of human population, has led to rapid deforestation (MacMorrow & Talip, 2001). Rapid deforestation as a result of economic development activities by humans have reduced this island's natural forest cover into a disjointed matrix of regenerating secondary forest and agricultural establishments with very few patches of old growth forest or primary forest remaining outside of protected areas (MacMorrow & Talip, 2001).

In 2010, only 54% of the native forests of Borneo were reported to be intact, and in Sabah; northern part of Borneo, where deforestation and logging have been reported to be the highest, only 19.1% of the forest remain intact (Gaveau *et al.*, 2014). In recent years, the combined effects of the timber and agro-industries have resulted in an annual deforestation rate of close to 1.3% (FAO, 2010). The conversion of tropical forests into agricultural areas, particularly oil palm (*Elaeis guineensis*) plantation in South-East Asia, is rapidly increasing (Gray *et al.*, 2015; Phalan *et al.*, 2013). Because the oil palm's range is limited to the humid tropics, the expansion of oil palm plantations has been, at the expense of species rich tropical forests (Koh & Wilcove, 2008; Gunarso *et al.*, 2013). Many studies have documented the negative effects of oil palm expansion on the biodiversity and ecosystem functions of tropical forests (e.g. Gray *et al.*, 2015; Cusack *et al.*, 2015; Fitzmaurice, 2014; Bernad *et al.*, 2009). The loss of

biodiversity as the aftermath of rapid ongoing loss of forests attributed to logging concession and conversion of forest into agricultural landscape, has escalated a great deal of concern among ecologists, conservation scientists and the public in general.

Logging concession and conversion of forest into agricultural landscape have led to many negative impacts; for example increase in Green House Gas (GHG) emissions, soil nutrient depletion, drought and desertification and water pollution from toxic waste and severe habitat fragmentation. All these in turned have led to significant loss of biodiversity and the ecosystem services. Over the last 10 years, approximately 40% of oil palm expansion in Malaysia and Indonesia, both countries of which produce over 80% of the global palm oil production (FAO, ;2015), has been on the expense of forested land (Koh & Wilcove, 2008; Gunarso *et al.*, 2013). Oil palm is a typical tropical tree crop which is grown for the industrial production of vegetable oil. Previously, palm oil was considered as low-value edible oil because of the difficulty of manipulating its fatty acid profile, resulting in the lower energy content and lower levels of digestible amino acids which are essential for human growth (Verheye, 2010). However, oil palm has now become the most important source of vegetable oil in the world (Verheye, 2010).

Generally, oil palm plantation can only support less than 40% of species found in undisturbed or logged forest (Fitzherbert *et al.*, 2008). The main reasons are attributed to the simplified vegetation structure, higher diurnal temperature, and lower humidity in oil palm plantation as compared to natural forest (Gray, *et al.,* 2015). To enhance biodiversity conservation or mitigate biodiversity loss in the oil palm plantation, several efforts have been endeavoured. These include the Roundtable of Sustainable Palm Oil (RSPO) certification initiative; a global, multi-stakeholder initiative that seeks to promote the production and use of sustainable palm oil through a set of uniform and universally-accepted sustainability standards, otherwise known as the RSPO Principles and Criteria (RSPO 2006).

Part of the RSPO criteria in the sustainable oil palm management practices includes retaining epiphytes or undergrowth in the plantations. However, this

practice has been shown to only marginally increase the number of bird and butterfly species, and does not significantly improve the biodiversity value in general (Yaap *et al.,* 2010.). Other criteria is improving land use planning by retaining and maximising the natural habitat cover and connectivity of forest within oil palm plantation such as the narrow strips of natural forests flanking rivers i.e. the riparian forests.

Riparian reserves are strips of natural forest vegetation retained along waterways with permanent above ground water flow (Naiman *et al.*, 1993). According to the Malaysian Environmental consultants (MEC), a riparian reserve is a physical area that borders a stream and river. It begins from the waters' edge to three meters above the water level. The current legal and regulatory status of riparian areas in Malaysia is diverse (Parish *et al.,* 2012). For instance, in Sabah, 20 m reserves on each side of the river is required for rivers that are more than three meters wide (Sabah Water Resources Enactment, 1998), whereas in Peninsular Malaysia and Sarawak, five meters reserves are required on rivers less than five meters wide; 10 meters reserves on rivers five to 10 meters wide; 20 meter reserves for rivers 10 to 20 meters wide; and 40 meters reserves for rivers 20 to 40 meters wide (Parish *et al.*, 2012). Globally, there are significant differences in how riparian areas are treated depending on whether they are publicly or privately owned; and whether the condition of the land is agricultural, silvicultural, rangeland, or urban (Committee on riparian zone functioning and strategies for management, 2002).

Riparian reserves are important due to their hydrological reasons, their roles in conserving functionally important taxa and also the processes they support which include reducing run-off into streams (Tabacchi *et al,*. 2000), nutrient regulation and pest control (Naiman *et al.*, 2010). As species richness increases in the oil palm plantation adjacent to forest fragments by species spillover (Lucey & Hill, 2012), there is a possibility that pest (i.e., bagworm) and predator species (i.e., barn owl) also increases (Naiman & Decamps, 1997). They maintain forest-dependent species and processes (i.e. nutrient cycling, reduces soil erosion and flood damage) in these landscapes and can therefore limit the negative impacts on farm land

landscapes (Gray *et al.,* 2015). Furthermore, riparian reserves allocate non-crop environment and movement corridors for species that would not live in, or move through, agrarian zones, such as large mammals e.g. banteng (*Bos javanicus*) (Marczak, 2010). Nevertheless, our knowledge about the effects of retaining riparian forests within agricultural land for biodiversity conservation is still insufficient, although it is considered as a useful practice to enhance biodiversity conservation or mitigate biodiversity loss in oil palm plantation (Gray *et al.,* 2014). Specifically, our knowledge on the effect of retaining riparian reserve in oil palm plantation on the non-volant terrestrial small mammal community is still generally poor. Moreover, the differences in the small mammal community living in riparian reserves in disturbed habitat (i.e. logged forest) versus in primary forests are not known.

Therefore, the primary aim of the present study was to assess the value of retaining riparian reserves in oil palm plantation for non-volant small mammal conservation by using small mammal communities in primary forest and logged forest riparian reserve, and riparian vegetation in oil palm plantation as treatments for comparisons. Understanding how the small mammal communities in riparian reserves within oil palm plantation differ from that in oil palm habitat without riparian reserves and in continuous natural forests is essential, because small mammals play crucial roles in the forest ecosystems, such as acting as both seed predators and dispersers, therefore affecting forest regeneration and recovery (Asquith *et al.,* 1997, Wells & Bagchi, 2005, Wells *et al.,* 2009). Moreover, small mammals are important prey items for large avian and mammalian predators (Wilting *et al.*, 2006, Puan *et al.*, 2011). Therefore, changes in the abundance of this functionally important group in altered forests may cause cascading effects on other animals in different trophic levels (Grassman *et al.*, 2005).

1.2 Justification of the Study

This study focuses on the non-volant terrestrial small mammals living within riparian vegetation in unlogged forest, logged forest and oil palm plantation. To evaluate the effects of retaining riparian vegetation in oil palm plantation, the small mammals living in pure oil palm without any riparian vegetation were also studied.

The study was conducted by using cage traps arranged in a grid (also known as grid trapping) and was carried out in and around the Stability of Altered Forest Ecosystem (SAFE) project area located in Kalabakan Forest Reserve and Maliau Basin Conservation Area (MBCA) in south central part of Sabah, Malaysia.

Many researches have been conducted on biodiversity of small mammals and other group taxa in Sabah and these have greatly provided useful information for future researchers. However, most research to date have been carried out over varying sampling scales and trapping efforts, as well as distinct sampling techniques, making it hard to emphasize clear patterns in the small mammal responses as a result of logging and oil palm plantation development. Existing evidence of faunal studies conducted in forest fragments in oil palm plantation suggest that forest fragments do not conserve biodiversity as well as continuous forest areas, though they can support more bird species (Edwards *et al.,* 2010), dung beetle species (Gray *et al.,* 2014), ant species (Gray *et al.,* 2015) and bat species (especially in forest fragments >300 ha) (Struebig *et al.,* 2008) than in pure oil palm areas.

Studies on mammals in small forest fragments (30-307 ha) located in hilly areas within oil palm plantations by Bernard *et al.,* (2014), indicated that some mammal species use forest fragments in oil palm landscapes, although they may only be transitory in this habitat. Further, Bernard *et al.,* (2014) speculated that many of the mammal species they found in the oil palm habitat and forest fragments within the oil palm plantation may still depend on the existence of a large continuous forest located nearby.

The study subjects in the present study, i.e., the non-volant small mammals, are mainly comprised of species from three families;Tupaiidae (tree shrews), Muridae (rats and mice) and Sciuridae (squirrels). These species formed among the most numerous animal species in the tropical rainforest of Borneo (Payne *et al.*, 1985). As explained in the earlier section in this chapter, the small mammals play important roles in the tropical rainforest ecosystems, for example, as seed consumers (Terborgh *et al.,* 2001; Wells & Bagchi, 2005) and seeds

dispersers, including seeds of many trees that are commercially valuable such as the large lowland dipterocarp tree species (Wells and Bagchi, 2005); as well as acting as an important prey base to many larger predators such as some avian species and charismatic mammals i.e., Sunda clouded leopards (Wilting *et al.,* 2006). So, not only are small mammals important in determining the health of the forest ecosystems by influencing forest regeneration and recovery, but these animals are also crucial in ensuring the persistence of other animal taxa that may be of high conservation value. Evaluating the usefulness of retaining riparian reserves in converted landscapes in the present study can, therefore, provide an insight not only on the importance of retaining riparian reserves in human derived habitats for the small mammal fauna conservation, but also other the biodiversity resources; both plants and animals, in general.

1.3 Research Objectives

To address the main aim of this study, the specific research objectives were as follows:

1. To compare the species richness, diversity, abundance and community composition of the non-volant small mammals in riparian reserves within unlogged forest, logged forest, and oil palm plantation, and within pure oil palm plantation without any riparian reserves.
2. To determine the association between aspects of habitat or vegetation structure of riparian reserves on the non-volant small mammals in unlogged forest, logged forest, and oil palm plantation; and in oil palm without riparian vegetations.

In the present study, it was hypothesized that the community of non-volant small mammals in riparian reserves located within unlogged forest would be the highest in terms of species richness, diversity and abundance. It was expected that the small mammal community in the riparian vegetation within oil palm plantation would be higher in terms of species richness, diversity and abundance compared to the oil palm plantation without riparian reserve. It was also hypothesized that the non-volant small mammal community composition in riparian reserves in oil palm plantation will be more similar with that of the riparian vegetation in unlogged and

logged forest; whereas, the small mammal community composition was expected to be least similar between unlogged forest and oil palm without riparian reserve.

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