MAMMAL SPECIES RICHNESS AND COMMUNITY COMPOSITION ACROSS A GRADIENT OF HABITAT DISTURBANCE IN KALABAKAN FOREST RESERVE, SABAH, MALAYSIA

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ABSTRACT

A short term camera-trapping study was carried out within the logged forest of Kalabakan Forest Reserve within the Stability of Altered Forest Ecosystem (SAFE) experimental area located in south central part of Sabah, Malaysia. The study was performed from 16th August to 4th September 2014. Secondary camera trapping data based on a study conducted within the primary forest of Maliau Basin Conservation Area, located approximately 60km to the west of the Kalabakan FR were used as a control treatment. The objectives of the study were to determine the effects of habitat disturbance in the form of selective logging on the mammal species richness and community composition, as well as to describe the relationship between certain habitat features and the mammal species recorded in the logged forest sites using a multivariate approach. The habitat features recorded were also used to characterize the level of disturbance of the different sampling sites. Randomized camera trapping survey was conducted using 31 units of camera-traps distributed across three sampling sites within Kalabakan FR. A total camera trapping effort of 587 trap-nights was achieved during the study and has yielded 280 independent photographs of medium- to large-sized mammals representing 13 species belonging to 16 genera, 13 families and five orders. The disturbance level of the three sampling sites in this study was determined to vary from each other. Sampling saturation was not achieved at all sites. However, based on extrapolated data, the number of mammal species appeared to be the highest at sampling site in Maliau. The similarity of mammal species between unlogged (Maliau) and logged (Kalabakan FR) forests was assessed to be 80%. This study shows that mammal species continued to persist in logged forest habitats and while not equivalent to areas of primary forests, regenerating secondary forests have a valuable role to play in terms of mammal species conservation.

KEKAYAAN SPESIS DAN KOMPOSISI KOMUNITI MAMMALIA SEPANJANG KECERUNAN GANGGUAN HABITAT DI HUTAN SIMPAN KALABAKAN, SABAH, MALAYSIA

ABSTRAK

Sebuah kajian jangka masa pendek menggunakan kamera perangkap telah dilaksanakan dalam kawasan eksperimental *Stability of Altered Forest Ecosystem* (SAFE), yakni hutan bekas pembalakan di Hutan Simpan Kalabakan, yang terletak di selatan tengah Sabah, Malaysia, bermula daripada 16 Ogos sehingga 4 September 2014. Sebagai rawatan kawalan, data sekunder pemerangkapan berdasarkan kajian yang dijalankan dalam hutan primer di Kawasan Pemuliharaan Lembangan Maliau, terletak kira-kira 60km ke barat daripada Hutan Simpan Kalabakan, telah digunakan. Objektif kajian ini adalah untuk mengkaji kesan gangguan habitat berbentuk pembalakan selektif terhadap kekayaan spesies dan komposisi komuniti haiwan mammalia dan juga untuk menjelaskan hubungan antara sesetengah ciri-ciri habitat dengan beberapa spesies mammalia yang telah direkod menggunakan pendekatan multivariat. Ciri-ciri habitat tersebut turut digunakan untuk mencirikan aras gangguan di ketiga-tiga kawasan kajian. Pemerangkapan rawak menggunakan 31 unit kamera perangkap telah dipasang di sekitar tiga kawasan persampelan. Hasil pemerangkapan kamera yang berjumlah 587 perangkap-malam telah berjaya direkod sepanjang kajian dijalankan dan telah menghasilkan 280 jumlah gambar mammalia bersaiz sederhana sehingga yang bersaiz besar, dan mewakili 13 spesies yang berasal daripada 16 genera, 13 famili dan 5 ordo. Tahap gangguan habitat didapati berbeza di ketiga-tiga kawasan kajian. Kepenuhan persampelan tidak tercapai di kesemua kawasan kajian. Meskipun demikian, berdasarkan data yang diekstrapolasi kawasan persampelan di Maliau memberi jumlah spesies yang tertinggi. Persamaan komposisi spesies mammalia antara hutan yang tidak mengalami pembalakan dengan hutan yang telah dibalak adalah sebanyak 80%. Kajian ini menunjukkan bahawa haiwan spesies mammalia mampu hidup secara terus dalam hutan yang telah diganggu dan meskipun tidak bersamaan dengan kawasan hutan primer, hutan sekunder yang sedang melalui proses pemulihan mempunyai peranan yang penting dalam pemuliharaan haiwan spesies mammalia.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Logging, deforestation, agricultural expansion, and urbanization are now becoming all too common in the Southeast Asian region, with threats from deforestation growing ever higher (Sodhi *et al.*, 2010). Although the region houses a great multitude of endemic species, more than 70% of the species' original habitat is subjected to habitat loss and degradation (Sodhi *et al.*, 2010, Sodhi and Brook, 2006). The tropical rainforest of northern Borneo is no less affected by this impending disaster. There has been previous research done on the impacts of forestry and agricultural activities on the biodiversity of the forest in Borneo, particularly mammals (Hiromitsu *et al.*, 2012; Johns, 1988; Wells, 2005).

Mammals are receiving much attention from both the scientific and non-scientific community around the world and some are even raised to flagship species status (e.g. Sumatran Rhinoceros, Bornean Orangutans, Malayan Tapir, Sumatran Tiger, and the Proboscis Monkey). With the increased threat from deforestation, illegal logging, monoculture plantation, and wildlife trade and hunting, it is crucial that these species are properly managed and protected (Williams *et al.*, 2000). Most mammals with large body sizes require larger home ranges – foraging across wider areas. Large-sized to medium-sized mammals roam at a greater range than do small mammals and this natural trend makes them good indicator species of the habitat's condition (O'Brien *et al.*, 2010). A study regarding the species richness of mammals inhabiting a degraded habitat suggested that the species richness does not undergo significant alterations after logging, but the community composition does (Bennett and Gumal, 2001). Other research showed that both species richness and community composition are affected when faced with a gradient of habitat disturbance (Bernard *et al.*, 2014b). With rapid increase in habitat disturbance and fragmentation in the tropics, there is a need to understand the exact effects of these environmental stresses on the mammal community.

This research used camera-trapping techniques, to study the mammals (Ancrenaz *et al.*, 2012). Camera-traps are becoming more reliable and popular in studies pertaining to biodiversity and free-ranging animals, including birds (Hiromitsu et al., 2012), and small to large-sized mammals (Ancrenaz,*et al.*, 2012; Bernard et al., 2013; Foreman and Pearson, 1998; Trolle and Kery, 2005). Camera-trapping studies on rare and elusive mammals such as the clouded Leopard, *Neofelis diardi*, and the Malayan tapir, *Tapirus indicus* have proven to be beneficial and the method is frequently used in tandem with other methods such as live-trapping, radio-telemetry, and direct observation, to increase sample size and reliability of results (Ahumada *et al.*, 2011; Bernard *et al.,* 2014; Trolle and Kery, 2005). In this study, microhabitat characterization (Sum, 2011) was conducted to study the relationship between different aspects of vegetation structure on the absence/presence and preferences of the medium to large sized mammals (above 1kg) in the sampling location. The aim of this study was to investigate the influence of different levels of habitat disturbance on the mammal community with particular emphasis on the large-sized to medium-sized terrestrial species.

1.2 Justification

There is limited published information pertaining to the changes in mammal community living under the effect of disturbed habitats, there still exists a gap in our understanding of how or what changes that occur to these communities with respect to the different intensity of habitat disturbances at a local scale, and how the mammal species richness and community composition are affected under such conditions (Ahumada *et al.*, 2014, Bernard *et al.*, 2013). Therefore, on a short term scale, the present study will be conducted to provide useful information to bridge this gap as much as possible. Additionally, the information can be helpful for wildlife management and planning for the future of tropical mammal conservation.

1.3 Objectives

1. To compare species richness and diversity of mammals between the varying levels of habitat disturbance.
2. To compare the species composition of mammals between the varying levels of habitat disturbance.
3. To describe the differences in the disturbance levels of the different sampling sites in terms of vegetation structure.
4. To study the correlation between some aspects of habitat structure on the presence or persistence of medium- to large-sized terrestrial mammals.

1.4 Hypothesis

1. Species richness increase in unlogged forest and decrease in logged forest according to the gradient of habitat disturbance.
2. Unlogged forest habitat will have a greater mammal species composition compared to logged forest habitat.
3. Based on vegetation structure, site E will be most disturbed, followed by D and then B, forming a gradient of habitat disturbance in the logged forest habitat.
4. Habitat generalists such as the bearded pig and the lesser mouse deer may be found to occupy a wide range of habitat types; tall-closed canopy forest to low-open canopy forest habitat.

CHAPTER 2

LITERATURE REVIEW

2.1 Deforestation across Southeast Asia

Biodiversity across the tropical regions of the world is under serious threat; rapid deforestation, industrial logging, forest degradation and landscape conversion for agricultural expansion, and urbanization takes its toll on both the fauna and flora of regions in the Americas, Africa and worse of all in Asia (Laurance, 1999; Sodhi *et al.*, 2006; Sodhi *et al.*, 2010; Koh *et al.*, 2013; Wilcove *et al.*, 2010). It was once estimated that tropical forests support more than half of the world's biodiversity, although covering less than 7% of the Earth's total land surface (Wilson, 1988). Today, however, only a quarter of the Earth's terrestrial area is covered by forests and 50% of these occur in the equatorial region, the tropical rainforests (Global Deforestation, 2010). Deforestation is the term to describe 'an activity whereby intact forest is clear-cut and not allowed or able to regenerate as forest, or is replaced with a non-forest land cover, such as agriculture' (Wilcove *et al.*, 2013). In a review done by Laurance (1999) on the tropical deforestation crisis, he stated that four key emerging drivers are responsible for the increasing forest destruction in these regions; the rising-human-population induced pressure, weak government institutions and poor policies, increasing trade liberalization, and rampant industrial logging.

In the Southeast Asian tropics, four biodiversity hotspots overlap; the Sundaland, Indo-Burma, Philippines, and the Wallacea region (Myers *et al.*, 2000; Sodhi and Brook, 2004). The threat is greatest in this region, and particularly the Sundaland because it houses high proportion of endemic species that are endangered (Sodhi *et al.*, 2010a), higher relative rates of deforestation and logging (Laurance, 1999; Sodhi and Brook, 2004; Wilcove *et al.*, 2013), and the proliferous increase in habitat conversion into agricultural land contributed by the lucrative oil-palm industry (Koh, 2013) and pulp and paper production in this region (Wilcove *et al.*, 2013). Myers (2001) showed that, besides Madagascar, the Philippines and the Sundaland region are two of the 'hottest' hotspots. In the Sundaland and in some parts of the Wallacea region, oil palm is widely cultivated (Koh and Wilcove, 2008). Forest cover in the Southeast Asian tropics has gone down by 0.35% and 0.67% per year respectively for both primary and secondary forests, in the year 2000 to 2010 (FAO, 2010) and in those 10 years, areas in Sundaland which are under oil palm plantations has increased by 87% - a staggering rise which has consumed differing percentages of intact, logged and agro forests in the region (FAO, 2012).

It is now evident that the loss of biodiversity that results from even intensive logging is less than the loss resulting from the conversion of primary or logged forest into cropland, in particular, oil palm plantations which are devoid of forest-dwelling species (Koh and Wilcove, 2008; Wilcove and Koh, 2010; Wilcove *et al.*, 2013). With this understanding, logging now seems secondary in its threat to biodiversity as compared to the effects of oil-palm expansion in the tropics. Though it was argued that oil palm companies do not clear away and plant the seedlings in pre-existing forested area, Koh and Wilcove (2008) found that in the year 1990 till 2005, 55%–59% and 56% of the time, forests are being clear-cut and converted for oil palm plantations in both Malaysia and Indonesia, respectively. The presumptuous idea that logged forests no longer hold any value for conservation and biodiversity as held by most developers and individuals in this industry are now being put to the challenge.

In recent years, secondary or logged forests have received increased attention. There is mounting evidence that these forest types – which are prime target for further loss through agriculture and landscape conversion (Fitzherbert *et al.*, 2008; Wilcove *et al.*, 2013) – ought to be protected, conserved for its ability to retain a good amount of the original biodiversity in the area even after undergoing significant and repeated disturbance from logging (Peh *et al.*, 2006; Koh and Wilcove, 2008; Martin and Blackburn, 2013; Struebig *et* al., 2013; Bernard *et al.*, 2014). However, this issue with our demand for biofuel as a product that is an alternative to fossil fuels is a much wider problem that involves various stakeholders at every level, and cannot be curbed through boycott or direct top-down approaches alone (Koh and Ghazoul, 2008). It is also indicated that 'environmental apathy, corruption, poor natural resource governance, poverty and lack of conservation funding' are to be blamed for impeding effective conservation works in this biologically diverse region (Sodhi *et al*, 2010). Therefore, without proper mitigation guidelines and informed policies on future expansions of oil palm, the high concentrations of globally endemic species in these areas will be further threatened if not extinct (Koh and Ghazoul, 2008; Koh and Wilcove, 2008; Sodhi *et al.*, 2004).

2.2 Habitat disturbance and Degradation

Habitat disturbance may be defined as a condition when "potentially damaging forces are applied to habitat space occupied by a population, community or ecosystem" and the magnitude of these forces may kill or displace organisms, deplete consumable resources, and degrade or destroy the habitat structure (Lake, 2000). In a natural context, habitat disturbance may be derived from flash floods, forest fires, tsunamis and even landslides. However, with the increased human population (increased density) across the globe, more and more land is demanded for resource acquisition, particularly for agriculture – to grow food and feed the world's population – at the expense of forests (Sodhi *et al.*, 2010b).

With the increase in this anthropogenic phenomenon, there is also a proportional increase in research that aimed to understand the effects of habitat disturbance or degradation on classes of animals such as the avifauna (Peh *et al.*, 2006; Soh *et* al., 2006; Gomes *et* al., 2008; Martin and Blackburn, 2013), mammals (Wells, 2005; Samejima *et* al., 2012; Bernard *et al.*, 2014a; Bernard *et al.*, 2014b), amphibians (Sodhi *et* al., 2004; Gillespie *et* al., 2012) and even on soil micro and macro-fauna (Hasegawa *et al.*, 2014). There is also a large pool of research on a the insect taxa, for instance, parasitoids (Idris *et al.*, 2001), Bees (Williams *et al.*, 2010), beetles (da Silva *et* al., 2008; Slade *et al.*, 2011), and butterflies (Cleary *et al.*, 2009; Bonebrake *et* al., 2010; Houlihan *et al.*, 2013) and their observed responses to reduced or degraded habitat quality were significantly explored. The effects are species-dependent; some are negatively affected by the increased disturbance, whilst other species showed positive response, with a certain range of tolerance depending on the magnitude of the disturbance factor in the respective habitats.

The common understanding on habitat disturbance has been a term widely accepted by many to indicate the ecological effects that arises from the introduction of a destructive, natural or anthropogenic factor into the spatial surrounding of an organism. Habitat fragmentation, on the other hand, has been found to be defined and understood by authors differently in their research, as one study by Fahrig (2003) has discovered. Habitat fragmentation can be conceptualized as a process, but can sometimes be mistaken to be the product of disturbance and loss of habitat. It is a process because "a large expanse of habitat is transformed into a number of smaller patches of smaller total area, isolated from each other by a matrix of habitats unlike the original" (Wilcove *et al.*, 1986), where the original habitat undergoes reduction of its coverage over time due to continuous disturbance and degradation. Habitat fragmentation is marked by, 1) increased number of patches, 2) decreased patch sizes, and 3) increased isolation of patches (Fahrig, 2003; Sodhi *et al.*, 2010a). The effects of fragmentation are based on concepts from island biogeography, where a dynamic equilibrium in the number and composition of the species of flora or fauna in any continuous or fragmented habitat is constantly at play (Wilcove *et al.*, 1986). The dispersal abilities and population densities may determine what type of species can be found in any of these remnant habitats.

2.3 Mammals under the effect of Habitat Disturbance

Mammals occupy only a small portion of the overall biodiversity in our biosphere (less than 0.004%), yet they are the most complex in many forms; physiologically, psychologically, and behaviorally to note a few. Mammals occupy third place in the measure of most endangered and threatened taxa in the wild, with amphibians ranking first, followed by birds (IUCN, 2014). More than 5490 species of mammals have been assessed and described, and about 90% of the total described species inhabit the tropical region. This rich biome is facing mass destruction since recent years and thus the threat that this taxa experience has also increased. No less than 1131 described species of mammals are classified as endangered, threatened or vulnerable, which is close to a fifth of the species of mammals in the world. With rampant habitat loss and degradation in the tropics, together with the majority of mammals inhabiting this region, mammals are threatened now more than ever (Sodhi *et al.*, 2004; Sodhi and Brook, 2006; Koh, 2013). Increased disturbance induced by human activities such as logging and deforestation changes the natural landscape, increasing edge effects, patchiness, and reduced connectivity of the forest habitat.

Generally, taking into consideration the size and degree of isolation, degraded or fragmented habitats which may be remnants of logged over forest or regenerating secondary forest has been shown to support less mammal diversity compared to those found in a contiguous primary forest, and in areas which experience extreme habitat degradation (oil palm plantation), the species richness is much lower (Bernard *et al.*, 2014b). In Maliau Basin Conservation Area, a report by Brodie and Giordano (2011) on the diversity of small carnivorous mammals in the area has revealed that more species existed in primary dipterocarp forest than in logged forest. On the contrary, though not geographically far apart, all nine primate species (including the endangered Bornean orangutan, *Pongo pygmaeus p.*, the Bornean gibbon, *Hylobates muelleri*, and the Proboscis monkey, *Nasalis larvatus*) were found to still utilize secondary forest types (Bernard *et* al., 2014a). There is still little research findings to go by to determine whether these mammals; to the species level consideration, actually persists in these habitats as a result of preference or pressure. The long-term values of these habitat types for terrestrial forest mammals are still poorly understood (Sampaio *et al.*, 2010; Bernard *et al.*, 2014a).

2.4 Camera-trapping: Species Richness and Community Composition

Camera-traps have been in existence since the 1950s, where one of the earliest quantitative ecological studies that used camera-traps was conducted by Pearson (1959). Following then was the use of camera traps as surveillance tool for hunters and later developed for commercial use (Sunarto *et al.*, 2013). Modern technologies have enabled scientists to assimilate statistical analyses with the use of camera-traps into methods of estimating population size and density of wildlife, wildlife monitoring and determination of species richness, abundance and activity patterns (O'Brien *et al.*, 2003; Ancrenaz *et al.*, 2012). Most literature on camera-trapping research has been focused on the faunas of the tropical rainforest (Trolle and Kery, 2005; Ahumada *et al.*, 2011; Bernard *et al.*, 2013; Linkie *et al.*, 2013; Sunarto *et al.*, 2013; Bernard *et al.*, 2014b) because of the immediate threat to biodiversity in the region (Sodhi *et al.*, 2004). Camera traps are excellent at knowing what species of large to medium sized animals are present in an area, because these animals have greater need to forage to support their metabolic requirements, and therefore travel more often (O'Brien *et al.*, 2003). The more these animals move, the more likely it is that they are photo-captured in one of the camera-trap points. It is important to note that greater sampling effort (camera-trap nights) would yield higher species richness (Ahumada *et al.*, 2014; Bernard *et al.*, 2013) and for rarer species such as the Asian Tapir, *Tapirus indicus*, sampling done across its known geographical range would be beneficial to increase species detection probability and to confirm sightings of the species in the area (Linkie *et al.*, 2013).

Camera-trapping does not require frequent maintenance once its placed in the field, and because it does not involve physical contact (as in most traps) with the animal, it is considered non-invasive, except to some more inquisitive groups of mammals such as the pig-tailed macaque, *Macaca nemestrina* (Ancrenaz *et al.*, 2012). Maintenance costs were reduced with the development of longer lasting and rechargeable Li-ion batteries, and memory cards with greater storage capacity. Now camera-traps can be a reliable tool in monitoring studies, even in remote areas. Other advantages include; ability to analyze spatial patterns of species' occurrence (GPS coordinates of the camera-trap location) and allows observations of certain activity patterns and behavior of the species of interest. The images can also help generate public awareness for a particular project or conservation movement. Other than that, problems that may arise from the use of camera-traps are thievery or loss (from alarmed poachers and uninformed villagers), battery shortage, full-memory storage, improper positioning (unsuitable angle), and technical failures due to high humidity that is common in the tropics (Mohamed, 2009; Ancrenaz *et al.*, 2012; Sunarto *et al.*, 2013).

2.5 Microhabitat Characterization as Indicator of Habitat Change

Microhabitat structures are important features of the environment that is regularly used in unison with the animal's presence or absence data in a camera-trap study. It can help quantify the anthropogenic habitat disturbance in the study area (Gomes *et al.*, 2008; Sum, 2011). The microhabitat characterization can be used in comparing the species richness in disturbed habitats with species richness in habitats with intermediate or severe levels of disturbance, through the use of statistical analyses such as Principal Component Analysis (Bernard *et al.*, 2014b) and Discriminant Functions. Several variables may be considered altogether, for instance, canopy height, leaf litter cover, diameter-at-breast height, tree counts and others which may help associate and quantify the surrounding vegetation.

CHAPTER 3

METHODOLOGY

3.1 Study site

3.1.1 Kalabakan Forest Reserve

This study was conducted at the Stability of Altered Forest Ecosystem (S.A.F.E.) (Ewers *et al.*, 2011) designated project site, a large span of logged over forest that altogether makes up an area of 7,302 ha, including the 2,200 ha Virgin Jungle Reserve (VJR) that dominates the southwestern part of the project site. The study area is a part of the Kalabakan Forest Reserve, Tawau and located to the far south of the Danum Valley Conservation Area. From the GPS records taken during the study, the range of elevation sampled was between 286m and 506m above sea level (a.s.l.). However, this lowland dipterocarp rainforest has been subjected to intensive logging in the 1970s and even today, therefore the remnant forest cover are mostly highly disturbed or regenerating secondary forest. The Virgin Jungle Reserve is a protected area composed of relatively primary forest growth with minimum disturbance levels, but is not used for sampling during the course of this study.

Amongst the six experimental blocks (A, B, C, D, E, and F) set up within the S.A.F.E Project site (Map 1), blocks B, D, and E were selected to signify the gradient of disturbances from logging in the area (Figure 3.1). Block B represents the least disturbed forest habitat (with 47% forest cover still remaining) compared to the other two experimental blocks, followed by D (35% forest cover) then E (22% forest cover). While deploying the camera-traps in D and E, timber extraction and road clearing was seen to commence actively, indicating the dynamic loss of forest cover in these forests. The standard Split-plot design was used to sample these areas at an equal chance of detection (Ewers *et al.*, 2011). Based on previous camera trap grids used in a research by Oliver Wearn (Wearn *et al.*, 2013) and Amy Fitzmaurice (Fitzmaurice, 2014) randomized camera trapping method was conducted. The sampling was done in such a way that each block is sampled equally (one or two camera-traps placed at each hectares in each grids). The CT points were randomized for each hectares (100, 10 and 1ha) and grids (1 and 2) per experimental fragments (B, D, and E) (Figure 3.3).

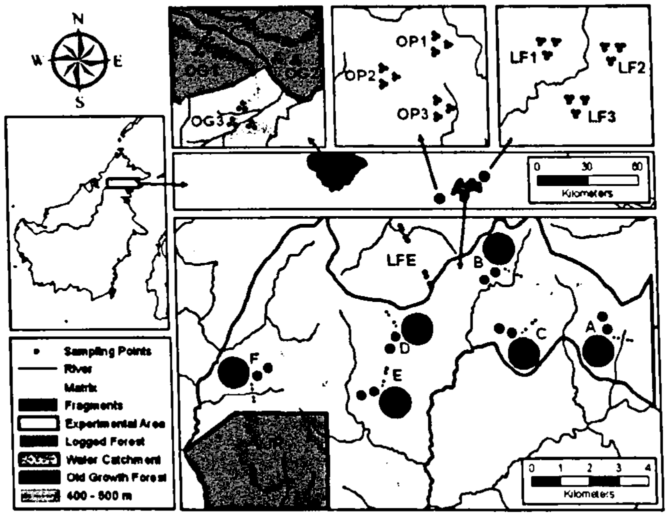

Figure 3.1: Map of Stability of Altered Forest Ecosystem (S.A.F.E) project site (www.safeproject.net), showing all six proposed fragments in the area, and another three sampling site located outside the general experimental area; Oil Palm, OP (1, 2 & 3), Old Growth, OG (1, 2 & 3 – in Maliau Basin Conservation Area (MBCA)), and Logged Forest, LF (1, 2 & 3).

3.1.2 Maliau Basin Conservation Area (MBCA)

MBCA is chosen as the control treatment for this study due to its unlogged and undisturbed tropical forest structure (Figure 3.2). There have been several expeditions (1988 – 1996 – 25 February 2005 – 24 March 2005) conducted by various parties, including Universiti Malaysia Sabah and the Sabah Foundations, to assess the biodiversity, soil and geomorphology, climate, and human impacts. Later expeditions served to justify the need for the area to be protected and its flora and fauna to be inventoried (Gasis *et al.*, 1998). In 1997, the area became a Class I Protection Forest Reserve, and in 1999 gazetted as Cultural Heritage (Conservation) site. Later in 2003, the protected area was nominated as a World Heritage Site.

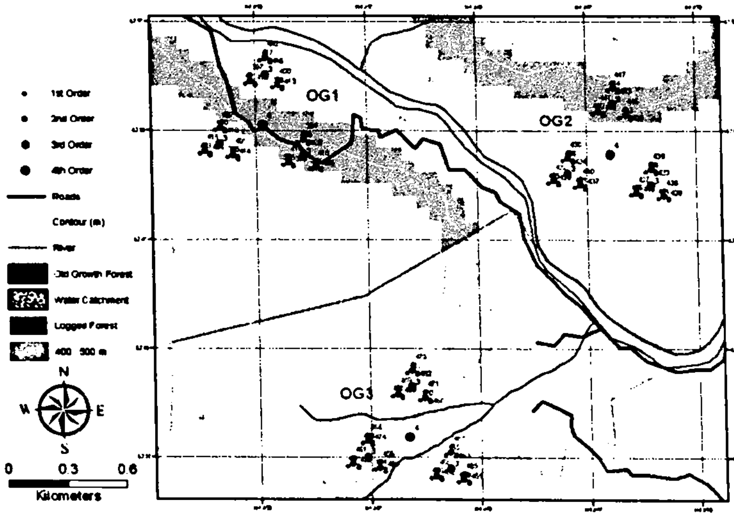

Figure 3.2: Map showing the three fractal sampling plots in Maliau Basin Conservation Area (MBCA) – Old Growth (OG) 1, 2, and 3.

Mammal studies and documentations have also been done in previous years (Mahyudin *et* al., 2010; Brodie and Giordano, 2011). In this study, OG data resembled unlogged or primary forest and therefore act as the control for the study. The data from Blocks B, D, and E in SAFE were tested against the data from MBCA to synthesize a graph showing the relationship between mammal species richness and community composition and the gradient of habitat disturbances level.

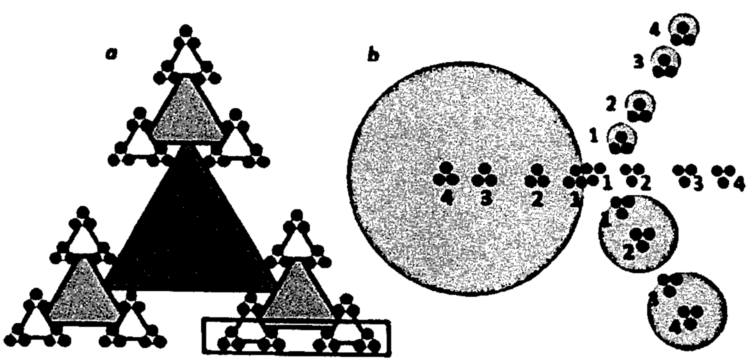

Figure 3.3: Sampling design retrieved from Ewers *et al.*, (2011), showing the (a) Fractal geometry for sampling continuous habitat and (b) the spatial-layout of fragments forming a single block in the split-plot experimental design of the SAFE project.

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