A DISSERTATION FOR THE MASTER DEGREE OF FOREST SCIENCE

Difference in small mammals and forest structures between primary and secondary forests subjected to two different post-fire management practices in the Phou Khao Khauy National Protected Area, Lao PDR

라오스 푸카오 쿠아이 보호지역에서 산불 후 처리에 따른 산림 구조 및 소형포유류의 차이

BY

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UNDER THE SUPERVISION OF ADVISOR
PROFESSOR DR. WOO-SHIN LEE

SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL OF SEOUL NATIONAL UNIVERSITY

MAJOR IN FOREST ENVIRONMENTAL SCIENCE

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APPROVED AS A QUALIFIED DISSERTATION OF

SOUNYVONG BOUNTHAN

FOR THE MASTER DEGREE OF SCIENCE
BY THE EXAMINING COMMITTEE

CHAIR	**:**	**HYUN SEOK KIM**	________________
VICE CHAIR	**:**	**WOO-SHIN LEE**	________________
EXAMINER	**:**	**EUN JAE LEE**	________________

Abstract

This study was conducted to clarify the difference in small mammal community and habitat structure between two different post-fire management practices. Small mammals were captured ten consecutive nights from nine study plots in each of the three different stands, namely 1) natural forest stand, 2) post-burned rice field stand (4-6 years after abandonment), and 3) post-burned rubber plantation stand (< 5years post-burned and planted) in Phou Khao Khauy National Protected Area, Lao PDR. Small rodents were captured using live traps during two seasons following the rainy season in August 2015 and dry season in December 2015 to January 2016. In addition, to a capture-mark-release data nine factors related to the forest structure of the study plots were also recorded.

Five species and 456 individuals of small mammals were captured in rainy seasons and dry season including *Niviventer fulvescens, Maxomys surifer, Leopoldamys sabanus*, *Mus musculus* and *Rattus rattus*. Total number of individuals captured from the natural forest stand area was the highest among the three stands, which was possibly due to the hight cover and food availability in relation to the increased sub-overstory and downed coarse woody debris. The number of individuals captured from the post-burned rubber plantation stand was the lowest among the three forest stands. This result showed that the rubber plantation after fire can have negative effects on habitat conditions for small mammal communities.

The home range sizes of small rodents were affected by stands and season with different post-fire management practice. The home range size of individuals was estimated by each individual captured with more than three times, and the home rang of the individuals captured in the natural forest stand was smaller in size than that in the post-burned rice field stands. The home range size of individuals captured in the post- burned rubber plantation stand was the smallest among the three stands because the post-burned rubber plantation was slightly captured individuals during trapped session, especially in the dry season. Thus, the home range size was the smallest in this type of stands. The home range size was larger in the rainy season and smaller in the dry season. It showed that in the dry season, food quantity and quality are suitable than in rainy season.

Small mammal communities were related with forest variables were significant in relationships between the numbers of small mammal individuals captured for *N. fulvescens* which had overstory coverage, sub-overstory, the number of tree stems, ground coverage, the volume of coarse woody debris (CWD) and the number of snag variables. *M. musculus* and *R. rattus* had an association with the number of tree stems and mid-story cover; *M. surifer* had number of tree stems, sub-overstory coverage and number of woody seeding and *L. sabanus* had positive association with overstory coverage and sub-overstory coverage. This result of the study showed that forest structure has an influence on small mammal communities, and that variations in small mammal species require different forest values for communities.

Keywords: dry season, forest structure, natural forest stand, post-burned rice field stand, post-burned rubber plantation stand, rainy season, small mammals

Student ID: 2014 - 25179

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I. Introduction

The Lao People's Democratic Republic (Lao PDR) is mostly composed of hills and plateaus as well as mountainous terrain over 80% of its territory. Approximately, more than 40% of its total land area is under forest covers (FAO, 2001). Laos has the most remaining initial tropical rainforests when compared to other countries in Southeast Asia, with over 10% of its forest classified as primary forests. In recent decades, however, researches showed that the characteristics of tropical forests have been highly disturbed and primary forests continue to decrease (Ashton, 2008). An addition to further 600 million ha of area is the logged-over forests, and secondary forests, with an average of more 9 million ha generated every year (Brown & Lugo 1990, Emrich et al., 2000). In particular, Southeast Asia has the highest annual deforestation, with a rate of 1.9 %, whereas the average global rate is 0.2-0.3 % (Matthews, 2001). The effect of changing habitat in tropical rain-forest ecosystem on biodiversity of wildlife is an urgent subject for appropriate forest management and species conservation. The forest in Southeast Asia is utilized for various human purposes, including traditional utility. As a result, both deforestation and anthropogenic uses are dispersed at the landscape-level. In Laos, the forest cover is estimated to have declined from 70% in 1943, 49 % in 1982, 47.2 % in 1992, 45 % in 2002 and 40.3 %

in 2010 (DoF, 2010). With this rapid rate of deforestation, it is estimated that the forest cover of Laos would approach 30% by the year 2020 (MAF, 2005). To prevent the rapid loss of forest cover, Lao PDR initiated a reform program in natural resource management in the early 1990s. The loss of forest cover caused major changes in land use, including the development of hydropower, mining, slash-and-burn agriculture and industrial plantations (MAF, 2010). In addition, Lao PDR is experiencing extensive and uncontrolled expansion of industrial rubber plantation. This expansion has been motivated by the strong requirement for natural rubber in key rubber producing and processing countries such as China, India and Vietnam. Several industry experts predict that the existing estimate of 180,000 ha to 200,000 ha of rubber plantations in Lao will increase to about 300,000 ha by 2020 (Hicks, et al., 2009). Hence, the policies mandated to protect and conserve Lao biodiversity is in conflict with reality.

Changes in the forest composition as a result of forest destruction have effects on populations of various animals, such as rodents (Dunstan and Fox, 1996; Kelt, 2000), bats (Schulze, et al., 2000), birds (Sieving and Karr, 1997; Ferraz, et al., 2003), and insects (Brown and Hutchings, 1997). In particular, changes in land-use as a result of anthropogenic use may have effects on the composition of small mammal communities. The best-known examples concern agriculture such slash-and-burn and plantation. One of three responses of small mammals may show the changing conditions. First, small mammals that can fully use the new conditions will survive and possibly increase in numbers. Second, ones that can only partially use the new conditions will decline in numbers, and third, some small mammals may become extinct because the new habitat does not provide the resources required for survival (Happold, 1987). Within small mammal communities, one or more of these responses may happen. The results reveal that the mammals are highly influenced by the species diversity and species composition, and the total numbers have also changed from those of natural habitats. The exact nature of the changes depends largely on the previous vegetation and land-use, climate, crop (monoculture or polyculture), the species of small mammals, and the method of cultivation.

Therefore, the objectives of this study are to compare the abundance of small mammal community and species richness in different forest stand among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand and to identify the relationship between small mammal communities and forest variables in different forest stand in the Phou Khao Khauy National Protected Area. Because small mammals have potential as indicator of sustainable forest management (Pearce & Venier, 2004) and they also play an important role as seed dispersers in forest ecosystems and forming the basis of the mammalian food chain (Eisenberg, 1980; Compton, et al., 1996; Shine, et al., 1998; Shanahan and Compton, 2000), comprehending the effects of forest utilized on small mammals is required to determine appropriate forest management strategies. The area was not studied previous to the difference in small mammal and forest structure among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand so there is no comparative information. This study was designed to test hypotheses that (i) forest structure may be different among primary forest and post-burned rice field and rubber plantation practices, and (ii) small mammal population would decline after post-burned rice field and rubber plantation practices affecting forest structure.

II. Literature Review

2.1 The National Protected Areas (NPA) System Related to the Biodiversity Conservation in Lao PDR.

Lao PDR has a rich of fauna and flora than in most countries of the Southeast Asia (Berkmuller, et al., 1995; Duckworth and Salter, et al., 1999; Robichaud et al, 2001). An extensive ranking of ecoregions by the World Wide Fund for Nature (WWF) identified the country as having four global priority ecosystems. Laos also supports important habitat for a diversity of wildlife species and, some endemic species that are known to be highly important populations in conservation concern globally, regionally or nationally, including elephant, tiger, Eld's deer and large water birds etc. In addition, it is home to several new species of large mammals and rediscovered species such as Saola (*Pseudoryx nghetinhensis*), Large-antlered Muntjac (*Megamuntiacus vuqua- ngensis*), and the Indochinese Warty Pig (*Sus bucculentus*). Over the past two decades, the government of Lao PDR has taken important steps to conserve forests, wildlife and aquatic animals and envisioned of the significance of its rich biodiversity. In line with this, in 1993 the 20 National Protected Area (NPA) system was implemented where 8 were legally established through the Prime Minister's Decree No. 164, together with several other protected areas designated at provincial and district levels. At the present, there are 24 designated NPAs with a total area of over 4.7 million ha, covering more than 19 % of the country's total land area (MoNRE, 2012). The objectives of the establishment of the NPAs are to:

1. Protect forest, wildlife and water;
2. Maintain natural abundance and environmental stability; and
3. Protect natural beauty for leisure and research; and

A series of regulations regarding biodiversity conservation and PA management were issued to guide management interventions, most notably, the forestry and wildlife laws (GoL, 2007). Several national strategies were also developed, including national biodiversity and forestry strategies. In addition, the country is a signatory to several international treaties, the most notably ones of which are the Convention on Biodiversity in 1996, and the Convention on International Trade of Endangered Species of Wild Fauna and Flora (CITES) in 2004. However, very few of these NPAs are currently managed, and it has been largely dependent on financial support from international organizations. As a result of limited financial support, all protected areas are now understaffed and lack the necessary of training and skills to effectively manage the protected areas and conserve their biodiversity (Vongkhamheng and Johnson, 2009).

2.2 Small mammal abundance in Lao PDR

Recent knowledge of rodent ecology in Laos comes from regular systematic trapping activities conducted in various habitats in four provinces (Luang Prabang, Oudomxay, and Houaphanh in northern Laos and Sekong in the south) between 1999 and 2002 (Khamphoukeo, et al., 2003), these were done through extensive farmer interviews, excavation of burrow systems, observations made while participating in "rat hunts," and a restricted study of rodent movement in Luangprabang, using the techniques of radio tracking and line-spooling (see Aplin, et al., 2003 for an explanation of these methods). The house rat is the most abundant rodent in all habitats within the upland agricultural landscape of Laos. In the village habitat, it is probably the only resident rodent, with other species (e.g., *Bandicota indica*) encountered only as occasional visitors. In field areas, the house rat is likewise dominant, although in these habitats it occurs alongside several other resident species. In lowland rice fields, along valley floors, house rats are found together with *Bandicota indica*, *Berylmys berdmorei*, and two or more species of house mouse. In upland fields, whether under crop or weedy fallow vegetation, house rats appear together with resident populations of *Berylmys berdmorei* (mainly in moister gully habitats), *Mus cookii*, and *Cannomys badius*. House rats also existent in forest habitats but they appear to be less abundant in such contexts. Other resident species in forests include *Rattus nitidus*, *Rattus* *sikkimensis*, *Berylyms berdmorei*, *Berylyms bowersi*, *Chiromyscus. chiropus, Leopoldamys* spp, *Maxomys surifer*, *Mus pahari, Niviventer* spp, and the bamboo rats *Cannomys badius* and *Rhizomys pruinosus.* How far the house rat penetrates away from the forest edge into progressively less disturbed habitats is not yet known. However, it is clear that it becomes less abundant away from field habitats.

2.3 Response in small mammals community on fire

Fire is a key force in maintaining many ecosystems (Hulbert, 1969; Old, 1969; Axelrod, 1985; Briggs, et al., 2002; Bowman, et al., 2009). As a physical force fire can change nutrient cycling, plant community composition and structure of forest (Collins and Steinauer, 1998), as well as apply direct and indirect pressure on small mammals (Kaufman, et al., 1990). Direct effects include required emigration, reduced reproductive effort and increased mortality due to burns, heat stress, physiological stress, asphyxiation and predation. Indirect effects may be caused by changes in the forest structure, quantity and quality of food, availability of nest sites, predation pressure, parasitism and disease and by changing competitive and social interactions (Kaufman, et al., 1990; Briggs, et al., 2002, Kirchner, et al., 2011).

Forest structure and various microhabitat variables can also affect small mammal diversity and abundance. The quantity of grass, snag, shrub, rock, and coverage are some microhabitat variables which may play significant roles in influencing small mammal abundance and diversity (Dueser and Shugart, 1978; Coppeto et al, 2006), while microhabitat variables associated with the coverage vegetation may possibly affect small mammals after a burn by changing their relative populations and species diversity. Small mammals relate with the flora and fauna through levels of multiple tropics and are significant fragments of forest ecosystems (Coppeto, et al., 2006; Krefting and Ahlgren, 1974). Their function is seeds dispersers, parasitic organisms and consumers of plant material, and as prey for other mammalian and avian predators (Coppeto, et al., 2006).

Post-burned forests for silviculture are interrupted to a magnitude by want of clear information on the efficacy of different alternative. Currently, we want information on the quality of post-burned forest or how resident wildlife species respond to the fire in case of a change in the availability of altered structural element (Bury, et al., 2000). Change in small mammal communities by post-fire are normally connected with the change in vegetation composition and vegetation structure (Price & Waser, 1984; Ojeda, 1989). Fire incident may also create robust change in population as well as in the small mammal community structure (Whelan, 1995). Small mammal populations can be classified by their numerical responses to fire. Populations that increase in size after fire are called fire-positive, whereas those that decrease are fire-negative (Kaufman, et al., 1990).

Many studies have examined community structure and biomass of small mammals in tropical forests in many parts of the world (Fleming, 1975). Other studies emphasized on the effects of human activities such as fire, mining and logging on the community structure of small mammals (e.g. Fox & Fox, 1984; Fox & McKay, 1981; Martell, 1983; Wu & Luo, 1993). Kirkland (1990) reviewed 21 published studies on initial responses of small mammal communities to conventional clear-cutting and burned forests. He found significant increases of the overall relative abundance of small mammals and abundance of some microtone rodents. More than half of the studies in his review showed increases of species richness and diversity after clear-cutting and burned, but the overall pattern of increase was not significant.

Wu & Luo (1993) reported the effects of human disturbance of different magnitudes on small mammal communities in a mountainous area north of Xishuangbanna reserve (China). They found that species richness, diversity, abundance and biomass decreased as the magnitude of disturbance increased. In Brazil, Fonseca (1989) found that species richness and diversity were greater in secondary forest than in primary tropical forest. Beck and Vogl (1972) and Sullivan, et al., (1999) carried out studies on unburned areas and controlled burned areas. These studies concluded that there was no statistically significant difference in abundance and diversity between the unburned areas and the controlled burned areas but they did find an increase in deer mice abundance. Monreo & Converse (2006) studied the effects of fire on wildlife populations at the conifer forests where fire has been suppressed over the last century. The result of studies predicted that fire effects altered depending on the season of fire received only limited support for each of the four metrics. In this study it showed that initially prescribed fires set during the early season will have similar impacts with late season fires on deer mouse populations, chipmunk populations, and total small mammal biomass in Sierra Nevada mixed conifer forests.

Lee, et al., (2008) conducted studies on the difference in the abundance of mammals in post-fire silvicultural management stands within the pine forest. The results of the study found that the post-fire silvicultural practices are the main cause of the forest structure change. In addition to the unburned forests, an average number of small rodents were highly captured more than the area of burned forests with or without trees removed. Lee, et al., (2012) conducted studies on different small mammals and stand structures between unburned and burned pine stands subjected to two different post-fire silviculture management practices. These of studies concluded that the forest composition was significantly different among the different management stands but the abundance of small mammals captured was not significantly different among the different management stands.

2.4 Description target species in study site

2.4.1 House rat (*Rattus rattus*) and House mouse (*Mus musculus*)

The house rat (*Rattus rattus*) and the house mouse (*Mus musculus*) have been widely introduced to terrestrial environments across the planet; more than 80% of island groups have been invaded (Atkinson, 1985; Towns, 2009). All two rodent species are voracious predators of a wide range of plants and animals, and are probably the invasive animals responsible for the greatest number of plant and animal extinctions on islands (Towns, et al., 2006; Angel, et al., 2009). The extent to which introduced rodents have invaded island habitats is variable, and almost certainly depends upon numerous interacting factors, including temperature, precipitation, food availability, predator populations, vegetation structure, and the presence of other rodents (King, et al., 1996; Yom-Tov, et al., 1999; Blackwell, et al., 2003; Harper, 2006; Atkinson and Towns, 2005; Harris and Macdonald, 2007; Stokes, et al., 2009). Some of these introduced rodents are found only in distinct habitats even when adjacent habitats are rodent-free or have smaller-bodied rodents that are more likely to succumb to the larger species (Lindsey, et al., 1999; Harper, 2006). Although the House rats are of typically the dominant rodent of the two introduced species (Innes, 2005; Harper, 2006), and as a result house rats are generally more abundant and 34 occur in a wider range of habitats than the others (Innes, 2005). Similarly, the house mouse may be suppressed by all introduced *Rattus* spp. (Russell and Clout, 2004; Angel, et al., 2009).

2.4.2 Indomalayan niviventer (*Niviventer fulvescens*)

Indomalayan niviventer is found in Nepal, possibly Pakistan, northern India (Arunchal Pradesh, Assam Himachal Pradesh, Manipur, Meghalaya, Sikkim, Uttarachal and West Bengal), possibly Bangladesh, southern China (Xizang, Yunnan, Guizhou, Hunan, Guangxi, Guangdong, Hainan, Jiangxi, Fujian, Zhejiang, Anhui, Henan, Shaanxi, Gansu, Sichuan, Hongkong, Macao), Lao PDR, Vietnam (including a number of offshore islands such as Con Son), Thailand, Malaysia and Indonesia (Sumatra, Java and Bali) (Molur, et al., 2005; Musser and Carleton, 2005; Francis, 2008; Smith and Xie, 2008). It is absent from Borneo and other islands on the Sunda Shelf (Musser and Carleton, 2005). This species is found in the subtropical evergreen broadleaved forest in Dujiangyan Region of Sichuan Province, China. In Lao PDR, it is found in evergreen, pine, deciduous, and secondary forests (Marshall, 1977). In Southeast Asia, it occurs in tropical evergreen, temperate broadleaf, grass and bushy land, riverbeds in the hilly forest (Francis, 2008; IUCN, 2008).

2.4.3 Long-tailed giant rat (*Leopoldamys sabanus*)

Long-tailed giant rats are found in both primary and secondary closed canopy moist lowland evergreen and montane forest. It has been recorded at the forest edge and can be found in disturbed habitats close to forested areas (IUCN, 2008). This widespread species ranges from northeastern South Asia, into central and southern China, and parts of Southeast Asia. In South Asia, it has been recorded from Arunachal Pradesh, Meghalaya, Nagaland and West Bengal in India (Molur, et al., 2005). In China, the species has been recorded from Guizhou to Zhejiang and Guangdong, Sichuan, south Gansu, south Shaanxi, Hubei and Hainan (Smith and Xie, 2008). In Southeast Asia, it has been recorded from northern Myanmar, northern Lao PDR, northern and central Viet Nam, with an isolated population present in northern Thailand, Cambodia, Malaysia (Musser and Carleton, 2005).

2.4.4 Red spiny maxomys (*Maxomys surifer*)

Red spiny maxomys is widespread throughout Southeast Asia including, southern Myanmar, Thailand, Lao PDR, southern and southwestern Cambodia, throughout Vietnam (including Thom and Phu Qoc Islands off the south coast), extreme southern Yunnan, China, the Malay Peninsula, Borneo, Sumatra, Java, and many smaller islands (Musser and Carleton, 2005). It is a lowland species that ranges from around sea level to 1,680 m (Mount Kinabalu) (Nor, 2001). The abundance of this species ranges from locally common to quite rare depending on the population surveyed (Aplin, et al., 2006).

III. Materials and Methods

3.1 Description of the study area

Phou Khao Khauy National Protected Area (Log. 18º 14' -18º 32' N, Lat. 102º 38' – 102º 59' E) is one of the 24 protected areas of Lao PDR. It was declared in 1993 by Prime Minister's Decree 163 (ICEM, 2003) and was under the Ministry of Defense in 1994. Now the aims of the management are to restore, enhance the biodiversity and maintain the habitat and the ecosystem value of the area, with an approximate area of 2000 km^2 (Figure 1). The topological characteristics in this area are generally steep sloping in the low elevation central portion of the area and on the Phou Khao Khauy plateau, where elevation varies from less than 100 m to nearly 1700 m above sea level (Lucas, et al., 2013). Most of the areas are found on rough mountain slopes, cliffs of steep sandstone, flat uplands or hilly terrains. This steep topography characterizing the area has been figured by the exposure and uplifting of the underlying sediments (Salter & Phanthavong, 1990).

For the climate in this site, it is the tropical monsoonal climate that is similar to the kind of central Laos, with rainy season starting in May and - ending in October, and a different dry season from November to April. On the lowland of this site, the average precipitation is about 2049 millimeters with 92% of rains in May–October. Temperatures are highest just in the beginning of the rainy season, making April, the hottest month with an average temperature of about 39°C. Meanwhile, December is the coldest month with 10°C at low-level terrain (DMH, 2011).

This study was conducted in different forests type as nature forest stand were originally primary forest dominated by *Hopea* spp, *Dipterocarpus* spp, *Vatica dyeri*, *Anisoptera robusta* although some selective cutting of tree species for hose or coffin contracture has occurred historically but this area was not unburned. Post- burned rice field stand was secondary forest at a developmental stage after slash-and-burn agriculture as young fallow (4-6 years after abandonment). The dominant trees in young fallow were *Cratoxylum cochinchinensis, Mesua ferrea, Aporosa villosa, Oxytenanthea parviflora*, *Gigantichloa albociliata*, and post-burned rubber plantation stand, like cultivated agricultural areas, differ from natural communities by having low plant species diversity. Most forest plantations tend to be formed by a single species of tree; where the dominant tree species was the rubber tree (*Hevea brasiliensis*). These trees were planted 3-5 years ago after the abandonment of slash-and-burn agriculture by small landholders.

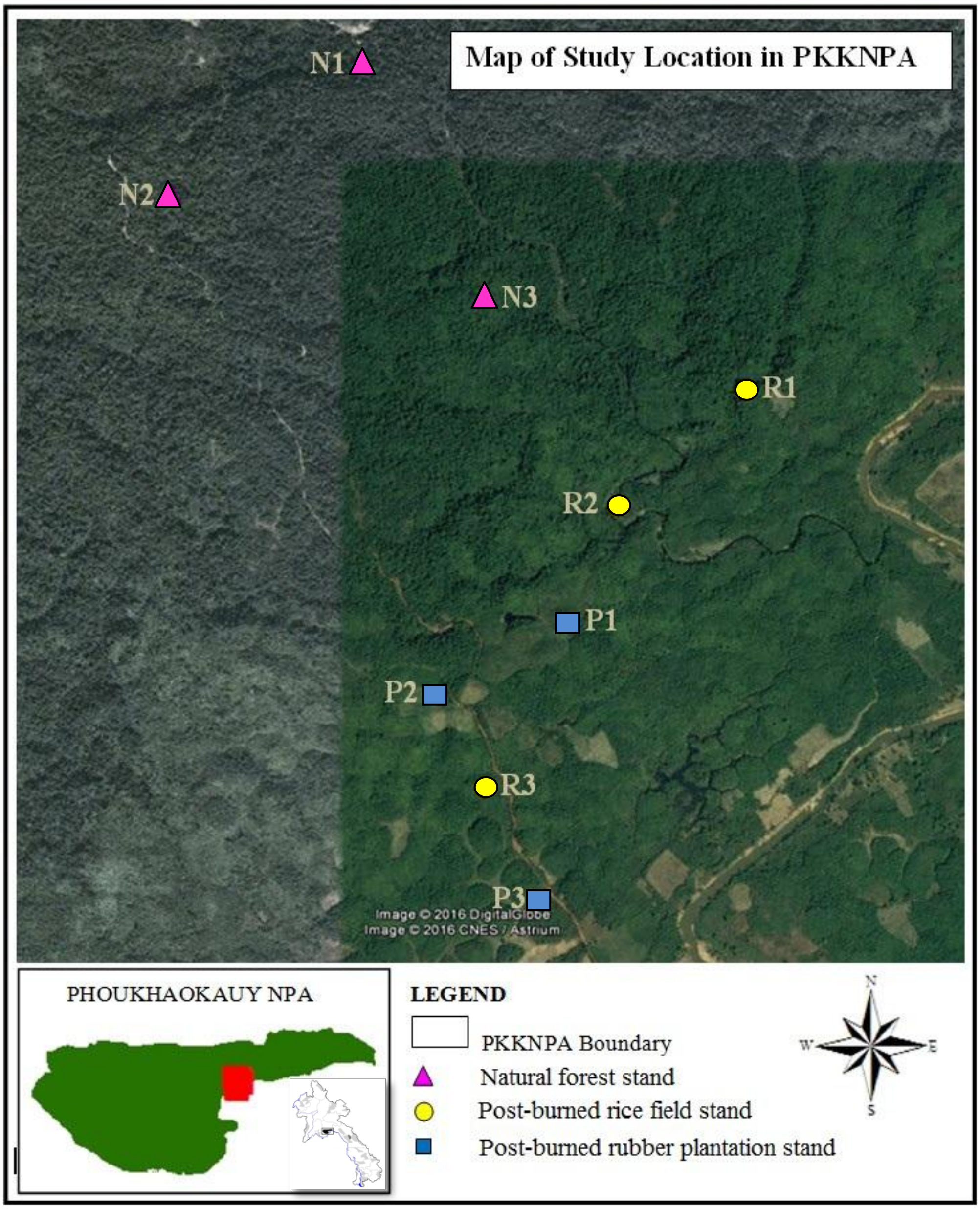

Figure 1. Location of the study plots in and around the Phou Khao Khauy National Protected Area, Lao PDR. Symbols indicate the forest stands: primary forest as a nature forest stand (solid triangle), secondary forest as a post-burned rice field stand (4-6 years after abandonment; solid circle), and post-burned rubber plantation stand (solid square).

3.2 Forest variables sampling

Forest variables data were gathered at each trap station. I used the circle method following Lee, et al., 2008 for the survey environment factor. I measured the forest conditions at each trap station (108 stations/ stand) within circle 2.5-m in radius. The stand characteristics within each circle was recorded including species, the number of shrubs, snags, woody seedlings, diameter at breast height (DBH) for each tree and the volume of down coarse woody debris within 2.5 m radius circle was also recorded. I divided the vertical layers within the circles into overstory (20-50 m), sub-overstory (8-20 m), mid-story (2-8 m) and ground (0-2 m) (Kang, et al., 2013). Coverage was classified into four categories on the basis of the percentage of cover in each vertical layer within the circle, following Rhim and Lee, 1999; 0 (percent coverage = 0%), 1 (1-33%), 2 (34-66%), and 3 (67-100%). I did the survey in December 2015 for the forest condition. The positions of each point were marked with GPS (GARMIN- GPS map 62S).

Table 1. Description of the forest variables for representing the habitat structures of the small mammals in this study area.

Variables	Description
Overstory cover	Coverage over 20 m on scale 0-3
Sub-overstory cover	Coverage over 8-20 m on scale 0-3
Mid-story cover	Coverage over 2-8 m on scale 0-3
Ground cover	Coverage over 2-0 m on scale 0-3
Downed CWD★	Total of volumes of downed CWD★ (≥ 10cm in diameter) within 2.5 m radius circle
Tree stems	Number of tree stems (DBH★ > 5 cm) within 2.5 m radius circle
Shrub stems	Number of shrub stems (DBH★<5 cm and height >1 m Woody seeding stems) within 2.5 m radius circle
Woody seeding stems	Number of woody seeding (height < 1 m) within 2.5 m radius circle

★CWD: coarse woody debris, ★DBH: diameter at breast height

Table 2. The geographical and ecological information of the study plots

Description	Natural forest stand			Post-burned rice field stand			Post-burned rubber plantation stand		
	Plot1	Plot2	Plot3	Plot1	Plot2	Plot3	Plot1	Plot2	Plot3
Altitude (m)	354	380	197	196	168	180	184	180	162
Dominant over-story species	*Hopea* spp., *Hydnocarpus anthelmintica, Vatica dyeri*	*Hopea* spp., *Dipterocarpus* spp., *Anisoptera robusta*	*Hopea* spp., *,Anisoptera robusta*	-	-	-	-	-	-
Dominant sub-overstory species	*Vatica dyeri, Hydnocarpus anthelmintica, Hopea* spp.,	*Aporosa villosa, Arytera litoralis blume,*	*Dipterocarpus* spp., *Vatica dyeri, Arytera litoralis blume*	-	-	-	-	-	-
Dominant mid-story species	*Vatica dyeri ,Oxytenanthea parviflora, Gigantichloa albociliata*	*Hopea* spp., *Commelina zeylamica ,Oxytenanthea parviflora,*	*Hopea* spp., *Arytera litoralis blume, Aporosa villosa*	*Cratoxylum cochinchinensis, Mesua ferrea Oxytenanthea parviflora, Gigantichloa albociliata*	*Cratoxylum cochinchinensis , Mesua ferrea, Oxytenanthea parviflora*	*Cratoxylum cochinchinensis, Aporosa villosa, Oxytenanthea parviflora*	*Hevea brasiliensis*		

Number of trees stem/ha	221	165	258	253	263	248	34	17	21
Number of shrubs/ha	145	109	301	435	388	783	0	0	202
Number of woody seeding/ha	177	143	260	113	74	280	173	55	226

3.3 Small mammal trapping studies

To avoid the pseudo-replication, each plot was distanced as least more than 300 meters from other plots. Three hectares represented in each type of forest and designated as natural forest stand, post-burned rice field stand and post-burned rubber plantation stand. Each site of three hectares was divided into three subplots and each subplot was divided into a grid pattern consisting of a 20 x 20 m array, for trapping and surveying habitat. The trapping of small mammals was conducted for two seasons between September 2015 as rainy season and December 2015 to January 2016 for the dry season and used a capture-mark-release technique. Trapping was conducted for a minimum of ten consecutive nights per season using Sherman live-traps (7.5 x 9.2 x 29.2 cm) baited with peanuts, and checked in the morning (Lee, et al., 2012). The traps were placed in six lines in the plot, each lines consisting of 6 traps, and approximately 20 m intervals at each station. Trapping grids of three hectares had 108 trap stations (20 x 20 arrays at 20 m intervals) with a live trap at each forest types. All small mammals captured had the following recorded data: sex, adult or juvenile (based on whether testes were scrotal or vaginas were perforate), mass (using a Pasola 300 g and 100 g hanging balance), trap location, new or recapture, and release condition (Lee, et al., 2012). For individual identification, each small mammal captured had an ear tag number and immediately released at the point of capture (Saitoh, 1991; Rhim and Lee, 2001; Lee, et al., 2008).

3.4 Data analysis

For the analysis of stand structure, small mammal abundance and species diversity, each subplot of three different forest stand variables through randomized-block Analysis of Variance (ANOVA) was conducted to compare with coverage of forest, number of tree stems, number of shrub, number of snag, number of woody seeding for the trees, volume of downed CWD and abundance of small mammal (Zar, 1984). I used analysis of variance (ANOVA) to compare abundance and, weight of small mammal community. As an additional part to this environment factor analysis, cover and height of understory vegetation in the three forest type were compared using a one-way ANOVA. When the variable was significantly different among the stand ($P<0.05$), Least-Significant Different multiple-comparison test was used to compare mean values.

Utilizing multiple regressions analyzed the relationship between the number of small mammal captured in each point and forest variables. To examine the influence of forest variables and species composition, the dependent variable was the number of small mammal capture in each point and forest variables which of nine stand-structures were the independent variables. I utilized stepwise multiple regression models to determine which of nine forest variables accounted for the greatest amount of variation in small mammal abundance in each point. Stepwise multiple regressions identified which variables explain the greatest amount of variation in each species capture. The first variable entered into the stepwise model accounts for the greatest variability.

A variable may be removed if the variables are appropriately correlated. The variable was selected for the model if the $p<0.10$. After first employing the stepwise process to identify significant variables, I analyzed each overall model again using multiple regressions. Statistical analyses were performed through software SPSS package version 22 and Microsoft Excel 2007.

IV. Results

4.1 Comparison of forest variables between nature of forest and two different post-fired management practices.

There were significant differences in forest structure among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand. Overstory vegetation coverage (one-way ANOVA, F = 134.721, P<0.001) and sub-overstory (F = 52.112, P <0.001) were the highest in the natural forest stand but not have coverage in the post-burned rice field stand and post-burned rubber plantation stand, while mid-story (F = 60.677, P<0.001) vegetation coverage was the highest in the post-burned rubber plantation stand and lowest in the nature forest stand. However, ground vegetation coverage was higher in the post-burned rice field stand than the other forest types (F = 159.518, P<0.001). Also, the number of tree stems (F = 288.142, P<0.001) and volume of downed CWD (F = 11.615 P<0.001) were highest in the natural forest stand, while the number of woody seedlings (F = 2.779, P= 0.064) did not show significant difference in the natural forest stand, post-bred rice field stand and post-burned rubber plantation stand. Therefore, there were more snags in the nature forest stand (F = 13.795, P<0.001). In the natural forest stand, the overstory and sub-overstory vegetation were higher than in both forest types and mid-story vegetation of the post-burned rice field stand was more developed than in the other stands (Table 3).

Table 3. Differences in forest variables with between nature forests and secondary forests with two different post-fire management practices at the Phou Khao Khauy National Protected Area, Lao PDR. Different letters indicate significantly different value (*p<0.05*)

Variables	Forest types					
	Natural forest stand (n=108)	Post-burned rice field stand (n=108)	Post-burned rubber plantation stand (n=108)	df	*F*	*P* value
Coverage of overstory vegetation	1.43± 1.277 [a]	0 [b]	0 [b]	2	134.721	<0.001
Coverage of sub-overstory vegetation	0.72 ± 1.040 [a]	0 [b]	0 [b]	2	52.112	<0.001
Coverage of mid-story vegetation	0.66 ± 0.888 [a]	1.57 ± 0.919 [a]	1.90 ± 0.760 [a]	2	60.677	<0.001
Coverage of ground vegetation	0 [a]	1.46 ± 0.766 [b]	0.68 ± 0.708 [c]	2	159.518	<0.001
No. of tree stems/survey point	6.24 ± 2.055 [a]	0.98 ± 3.66 [a]	0.48 ± 0.502 [b]	2	288.142	<0.001
No. of shrub stems/survey point	5.17 ± 2.578 [a]	14.83 ± 5.138 [b]	2.02 ± 3.840 [c]	2	302.319	<0.001
No. of woody seedlings/survey point	5.50 ± 4.045	4.35 ± 3.624	4.56 ± 3.710	2	2.779	0.064
No. of snags/survey point	0.16 ± 0.366 [a]	0.03 ± 0.165 [b]	0 [c]	2	11.424	<0.001
Volume of downed CWD★ (m3/ha)	1.189 ± 3.502 [a]	0.106 ± 0.455 [ab]	0.022 ± 0.127 [b]	2	11.615	<0.001

Coverage indices: 0 (coverage percentage = 0%), 1 (1–33%), 2 (34–66%), and 3 (67–100%).

★CWD = Coarse Woody Debris; (Mean ± S.E)

4.2 Comparison of small mammal communities among three different forest types

The trapping was conducted in August 2015 as rainy season and December 2015 to January 2016 as dry season, for a minimum of ten consecutive nights per season. In rainy season, 216 individuals belonging to four small mammal species were captured for a total of 476 times, indomalayan niviventer (*Niviventer fulvescens*) was recaptured 69 times, house mouse (*Mus musculus*) 76 times, house rat (*Rattus rattus*) 71 times, red spiny maxomys (*Maxomys surifer*) 44 times for a recaptured total of 260 time. The number of captured small mammal was highest in natural forest stand, with a total of 252 times including 123 individuals captured, post-burned rice field stand with 63 individuals captured for a total of 166 times and total of small mammal captured having the lowest in the post-burned rubber plantation stand with a total of 58 times including 30 individuals.

In the dry season, 240 individuals comprised of five species were captured a total of 544 times, indomalayan niviventer (*N. fulvescens*) was recaptured 161 times, house mouse (*M. musculus*) 51 times, house rat (*R. rattus*) 36 times, red spiny maxomys (*M. surifer*) 47 times, long tailed giant rat (*L. sabanus*) recaptured 9 times. The number of small mammal captive population was highest in natural forest stand with a total of 387 times, including a capture of 175 individuals, and post-burned rice field stand with 54 individuals captured for a total of 137 times, while the lowest captured small mammal was in the post-burned rubber plantation stand with a total of 20 times including 11 individuals (Table 4). Four species were captured in the rainy season, while five species were captured in the dry season. Two species were caught in three different forest types in both seasons. During trapping session, the species richness was greater in the dry season than rainy season. The *N. fulvescens* was the most abundant species captured in both seasons. The next more commonly trapped species were *M. musculus*, *R. rattus, M. surifer* and *L. sabanus* (Table 4). And also, comparison proportion number of small mammal captured among three study site during the rainy season and dry season. The *N. fulvescens* had higher proportion of the number of captured in the dry season than other species, and the proportion of number of captured was higher in natural forest satnd than post-burned rice field stand and post-burned rubber plantation stand (Figure 2). When compared between rainy season and dry season, most of small mammals captured were significantly different in forest types and season (Table 5).

When a total of 5 small mammals species were analyzed, all species showed two or more significant correlations with forest variables according to stepwise approach. Indomalayan niviventers (Bonferroni test: $P = 0.001$) were most sensitive to overstory coverage, sub-overstory, the number of tree stems, ground coverage, the volume of coarse woody debris (cwd) and number of snag variables. *M. musculus* and *R. rattus* had a positive association with number of tree stems ($P = 0.001$) and mid-overstory coverage ($P = 0.001$). *M. surifer* did with number of tree stems, sub-overstory coverage and number of woody seeding (*P*= 0.001) and *L. sabanus* had positive association with overstory coverage and sub-overstory coverage (*P*= 0.001).

Table 4. Number of small mammals captured by the capture-mark and release method among natural forest stand, post-burned rice field stands, and post-burned rubber plantation stand in rainy season and dry season

Season	Species*	Forest types			Total
		Natural forest stand	Post-burned rice field stand	Post-burned rubber plantation stand	
Rainy	Nf	35 (89,54)**	7 (22,15)	0	42 (111,69)
	Ms	25 (49,24)	25 (60,35)	18 (35,17)	68 (144,76)
	Rr	37 (61,24)	21 (57,36)	12 (23,11)	70 (141,71)
	Rs	26 (53,27)	10 (27,17)	0	36 (80,44)
	Total	123 (252,129)	63(166,103)	30 (58,28)	216 (476,260)
Dry	Nf	104 (249,145)	15 (31,16)	0	119 (279,161)
	Ms	10 (23,13)	16 (48,32)	9 (15,6)	35 (86,51)
	Rr	18 (35,17)	12 (28,16)	2 (5,3)	32 (68,36)
	Rs	33 (61,28)	11 (30,19)	0	44 (91,47)
	Ls	10 (19,9)	0	0	10 (19,9)
	Total	175 (387,212)	54 (137,83)	11 (20,9)	240 (544,304)

* Abbreviation of species: Nf: *Niviventer fulvescens*, Ms: *Mus musculus*, Rr: *Rattus rattus*, Rs: *Maxomys surifer*, Ls: *Leopoldamys sabanus*.

** The no. of captured individuals (no. of total time captures, no. of recaptures)

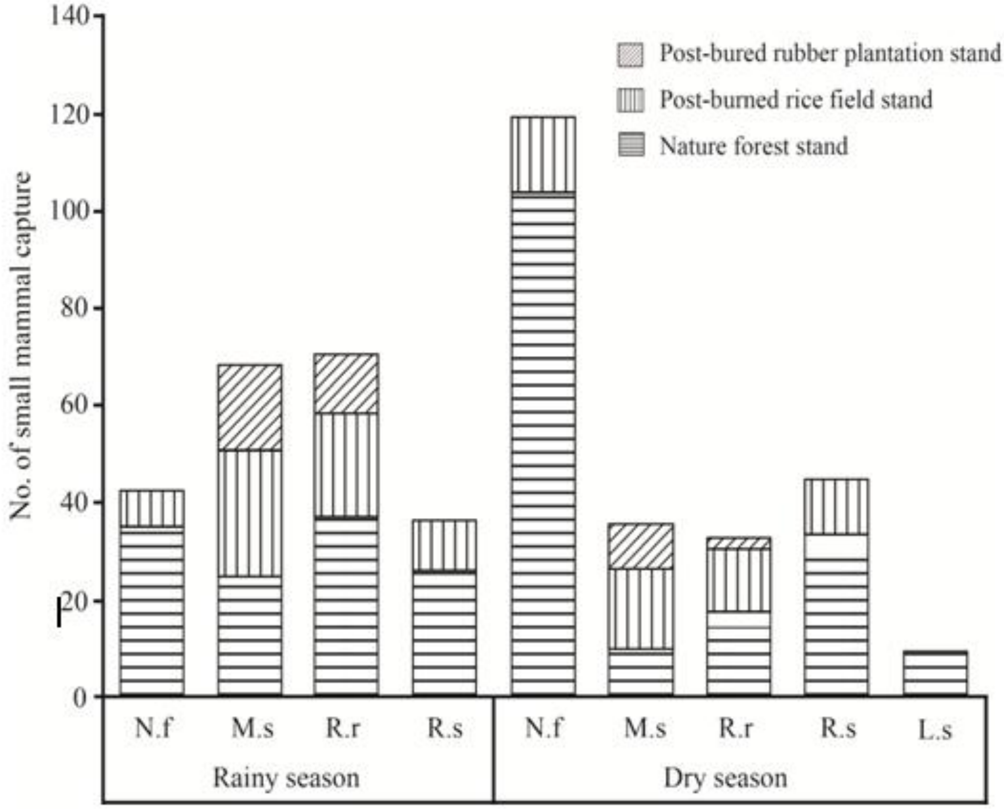

Figure 2. Comparison proportion number of small mammal captured in each study site during rainy season and dry season.

Abbreviation of species, Nf: *N. fulvescens*, Ms: *M. musculus*, Rr: *R. rattus*, Rs: *M. surifer*, Ls: *L. sabanus*.

Table 5. Comparison of small mammal communities among the natural forest stands, post-burned rice field stands, and post-burned rubber plantation stands during rainy season and dry season.

Species	Description	df	*F*	*P* value
Rattus rattus	forest	2	75.55	0.01
	season	1	16.64	0.01
	forest*season	2	4.36	0.03
Mus musculus	forest	2	3.82	0.05
	season	1	48.69	0.01
	forest*season	2	1.65	0.23
Niviventer fulvescens	forest	2	48.09	0.01
	season	1	0.19	0.67
	forest*season	2	0.79	0.48
Maxomys surifer	forest	2	59.53	0.01
	season	1	15.74	0.01
	forest*season	2	4.15	0.04
Leopoldamys sabanus	forest	2	100	0.01
	season	1	100	0.01
	forest*season	2	100	0.01
Total	forest	2	51.73	0.01
	season	1	40.93	0.01
	forest*season	2	2.59	0.12

4.3 Comparison of age and gender between three different forest types

For capture individuals in each study areas were separated by juvenile and adult, male and female. Comparison among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand of age and gender are shown in Table 6. Through the age and gender caught during the two seasons, the proportion of female juvenile population was higher than that of male in the rainy season and male population was higher than juvenile population in the dry season. Comparing between rainy season and dry season of age ratio of each individual captured was mostly higher in proportion of juvenile than in proportion of adult. The ratio of juvenile individuals was the highest in natural forest stand and lowest ratio in post-burned rubber plantation stand (Figure 3). Also, when it comes to the ratio of gender in each species during trapping session, the proportion of female was mostly higher than male, while the ratio of female was the highest in natural forest stand and lowest in post-burned rubber plantation stand (Figure 4).

In each study area between rainy season and dry season of age and gender, the ratio of age was mostly higher in juvenile than adult, while the ratio of gender was higher in females than males. But the expected significant differences in age and gender between the study areas with a comparison of different types of age and gender by each of study site, results did not show a great feature. Therefore, habitat quality, when compared according to gender and age between forest types that looks into different small mammals captured in each study area is expected to be included in more researches in the future.

Table 6. Difference in the age and sex ratio of *N. fulvescens, M. musculus, R. rattus, M. surifer* and *L. sabanus* in rainy season and dry season.

Forest types	**Species**	**Age ratio** ⋆		**Sex ratio** ⋆⋆	
		Season		Season	
		Rainy	Dry	Rainy	Dry
Natural forest stand	Nf	1 : 2.50	1 : 1.21	1 : 1.33	1 : 1.60
	Mm	1 : 1.08	1 : 0.42	1 : 1.08	1 : 0.66
	Rr	1 : 4.28	1 : 2.60	1 : 0.94	1 : 2.6
	Rs	1 : 0.73	1 : 0.82	1 : 0.85	1 : 0.55
	Ls	0 : 0	0 : 0	0 : 0	1 : 0.66
Post-burned rice field stand	Nf	1 : 2.5	1 : 1.14	1 : 1.33	1 : 1.50
	Mm	1 : 1.27	1 : 1.14	1 : 0.66	1 : 1
	Rr	1 : 9.50	1 : 30	1 : 0.9	1 : 1.40
	Rs	1 : 4	1 : 1.20	1 : 1	1 : 2.66
Post-burned rubber plantation stand	Mm	1 : 0.63	1 : 3.50	1 : 1.25	1 : 1.25
	Rr	1 : 3	1 : 1	1 : 0.71	1 : 1

⋆ Age ratio = adult: juvenile, ⋆⋆ sex ratio = male: female

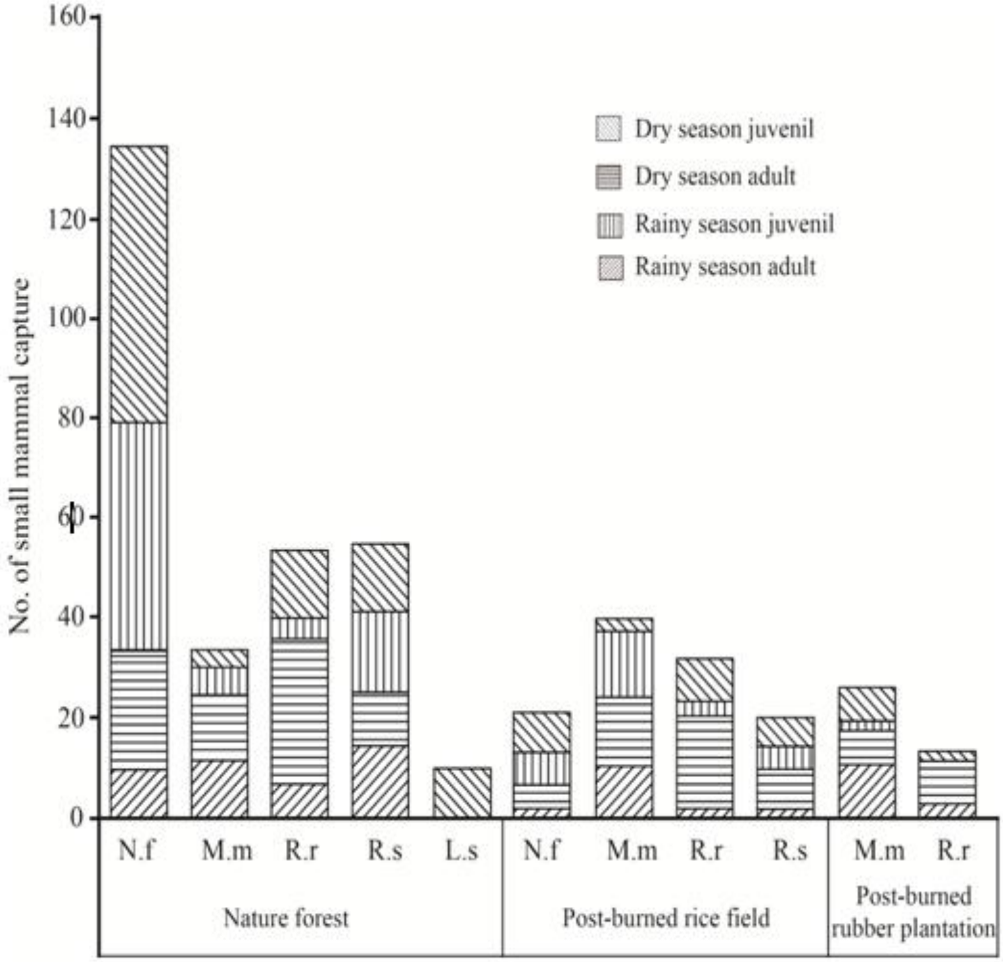

Figure 3. Comparison of proportion of age (adult and juvenile) in each forest type between rainy season and dry season, Nf: *N. fulvescens,* Mm: *M. musculus,* Rr: *R. rattus,* Rs: *M. surifer*, Ls: *L. sabanus*

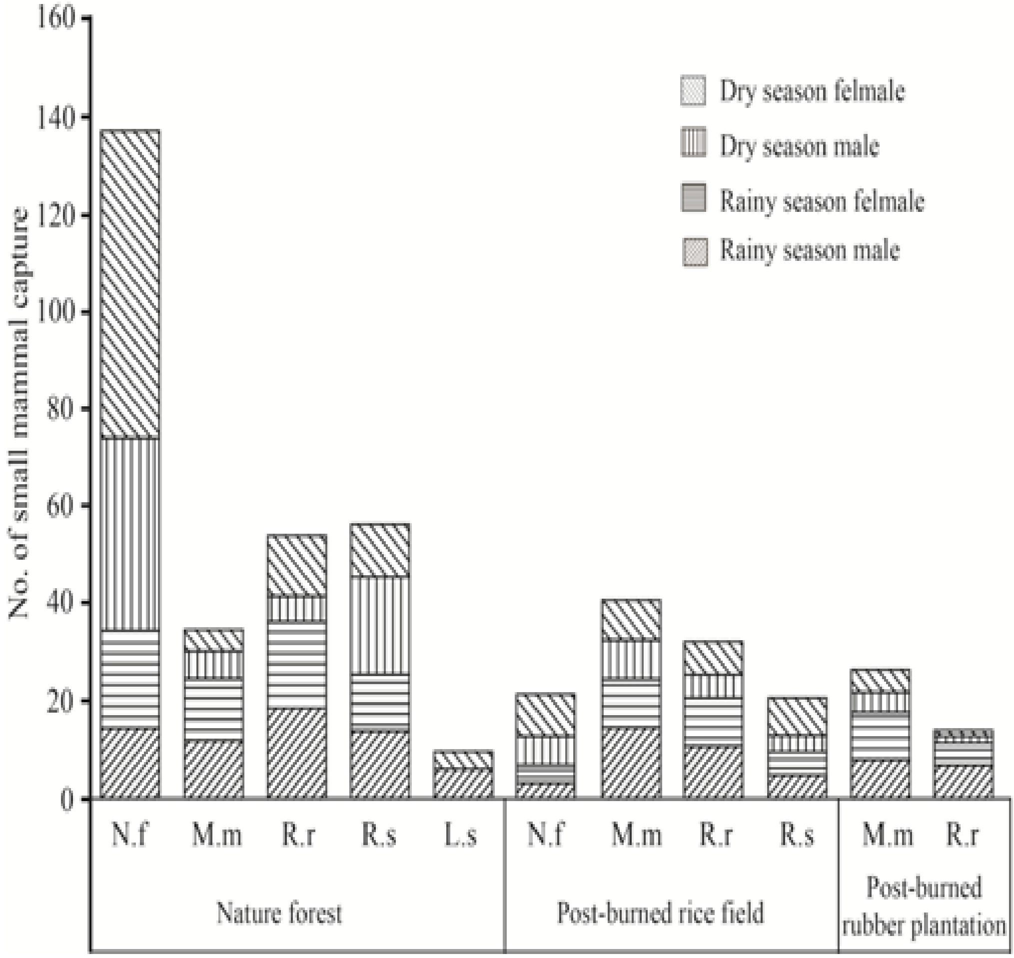

Figure 4. Comparison of proportion of sex (male and female) in each forest type between rainy season and dry season, Nf: *N. fulvescens*, Mm: *M. musculus*, Rr: *R. rattus*, Rs: *M. surifer*, Ls: *L. sabanus*

4.4 Differences in the adult body weight among three different forest types and seasons.

The mean body weight of the captured small mammal in each forest type was calculated by adult weight of each species on the site because the body weight was a considerable variation among three different forest types, and the body weight of each species was compared between adult male and adult female in each forest type during rainy season and dry season. The result of the study found that only *R. rattus* and *M. musculus* species were captured in each forest type. The body weight of *R. rattus* was larger in the natural forest stand than in both forest types in dry season. The body weight of male and female tended to be lower at post-burned rubber plantation stand relative to post-burned rice field stand and natural forest stand, while the weight of the male tended to be larger than those of the female (Table 7). The weight of *M. musculus* was larger in the natural forest stand than in the both of forest types in the rainy season. The weight of male and female tended to be lower at post-burned rubber plantation stand relative to post-burned rice field stand and natural forest stand. Also, the weight of the male tended to be larger than that of female. Comparison of adult body weight of *R. rattus* was not significantly different in three different forest types, season and sex but was significantly different in adult body weight in *M. musculus* (Table 8). The *N. fulvescens, M. surifer* and *L. sabanus* were not captured in the rubber plantation stand. Only *N. fulvescens* and *M. surifer* were captured in the natural forest stand and post-burned rice field stand in both seasons and *L. sabanus* was present only in dry season in the natural forest stand (Table 7).

Table 7. The mean adult body weights of small mammals among three different forest types in PKKNPA, Lao PDR, NFS= Natural forest stand, PRFS= Post-burned rice field stand, and PRPS= Post-burned rubber plantation stand. Means (± SE) are base on captured individuals from each forest type.

Species	Sex	NFS		PRFS		PRPS	
		Season		Season		Season	
		Rainy	Dry	Rainy	Dry	Rainy	Dry
Nf	Male	50.66 ± 5.77	68.40 ± 10.47	--	65 ± 1.41	--	--
	Female	50.57 ± 4.85	65.13 ± 18.77	52 ± 2.84	57.4 ± 3.57	--	--
Mm	Male	40 ± 0	36 ± 1.87	39.4 ± 2.60	39.66 ± 1.96	37.75 ± 2.87	33 ± 2.82
	Female	30.28 ± 1.09	27.5 ± 0.70	32 ± 3.34	29.25 ± 3.10	27.66 ± 3.05	--
Rr	Male	72 ± 2.82	113.33 ± 34.19	--	74.6 ± 7.40	70 ± 0	--
	Female	64.80 ± 5.40	97.5 ± 38.89	71 ± 1.41	71.75 ± 10.24	60.5 ± 6.36	89 ± 0
Rs	Male	131 ± 19.29	152.61 ± 22.49	--	96 ± 0	--	--
	Female	126.55 ± 11.43	145.75 ± 18.33	117 ± 18.38	90.25 ± 3.94	--	--

Abbreviation of species: Nf: *N. fulvescens*, Mm: *M. musculus*, Rr: *R. rattus*, Rs: *M. surifer*, Ls: *L. sabanus*.

Table 8. Comparison of adult weights of small mammals in three different forest types, and the result of Univariate Analysis of Variance (two-ways ANOVA) among forest, sex and season.

Species	**Description**	**df**	***F***	***P* value**
Mus musculus	Forest	2	3.432	0.040
	Season	1	10.41	0.002
	Sex	1	95.027	0.001
	Forest*season	2	0.958	0.391
Rattus rattus	Forest	2	0.317	0.734
	Season	1	7.457	0.018
	Sex	1	1.04	0.328
	Forest*season	2	1.186	0.339
Total	Forest	2	1.322	0.273
	Season	1	3.126	0.081
	Sex	1	8.497	0.005
	Forest*season	2	2.625	0.080

4.5 Comparison home range size of small mammal

Home range was estimated for each individual captured with at least three or more times on a trapping session (Stickel, 1954). The small mammals were captured ten consecutive nights per season from the nine study plots in each three forest types. In the rainy season, a total of 9 individuals were captured more than three times: 6 individuals in the natural forest stand, and in the post-burned rice field stand, while 3 individuals in the home range were estimated (Figure 5-9). The size of home range was 350 m^2 /individual in the nature forest stand, and 300 m^2 /individual in the post-burned rice field stand, while there was no home range size in the post-burned rubber plantation stand in the rainy season (Table 9). In the dry season, a total of 19 individuals were captured more than three times: the natural forest stand had 12 individuals, post-burned rice field stand had 7 individuals and post-burned rubber plantation stand had 1 individual in the home range (Figure 5-9). The size of home range was 283.3 m^2/individual in the nature forest stand, 433.3 m^2/ individual in the post-burned rice field stand and post-burned rubber plantation stand was 200 m^2/ individual (Table 9). Therefore, when the size of home range was compared between rainy season and dry season, it was found that the home range of size in dry season was smaller than in rainy season. During rainy season and dry season, home range adjacent and overlap between male and female were estimated. Results revealed that male and male had overlapped to differ from the entire study site but overlapping between female and female did not happen (Figure 5-9). The greatest numbers in overlapping home range were between males and females, most of which were in the dry season. Female range rarely overlapped with each other, while male overlapped with each other mostly in the dry season. There was a significant difference in home range size between each species and forest types but not significant difference in home range size between season and sex (Table 9; 10). For each species, home range of males was larger than those of females, though not all differences were statistically significant. The only exception was *M. musculus*, where home ranges of male were smaller than females but the difference was not significant. Also, several other researchers showed that males have larger home ranges than females (Zejda & Pelikan, 1969; Wierzbowska, 1972; Andrzejewski & Mazurkiewicz, 1976; Mazurkiewicz, 1981, Chelkowska, et al., 1985).

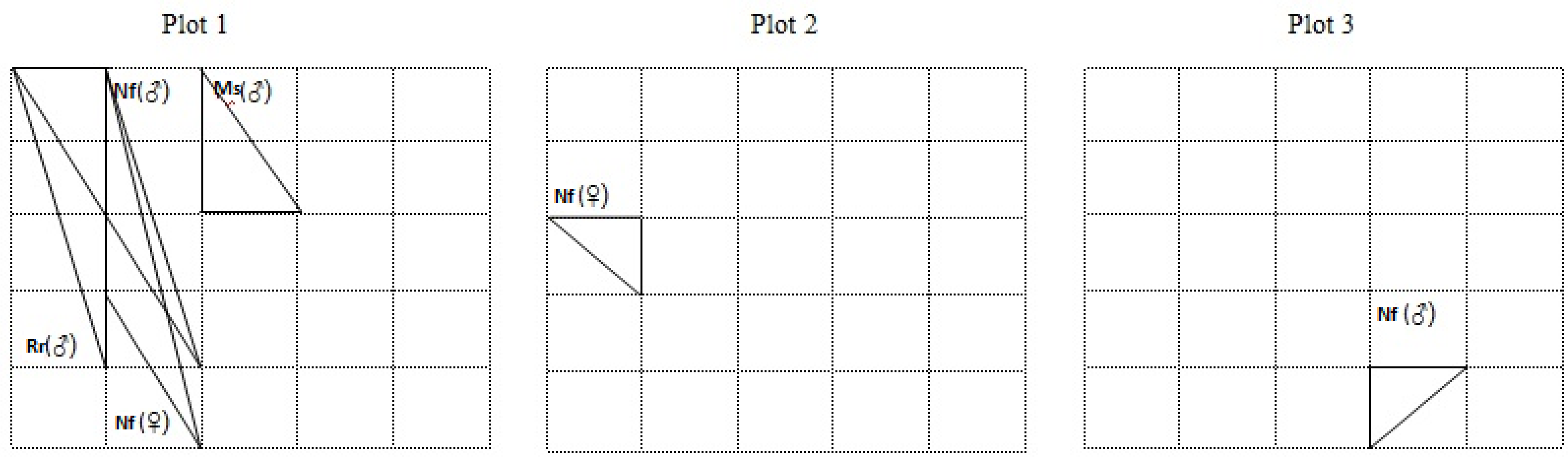

Figure 5. Home range map of the small mammals in the natural forest stand in rainy season (♂ male : ♀female), Nf = *N. fulvescens*, Rs = *M. surifer*, Rr = *R. rattus*

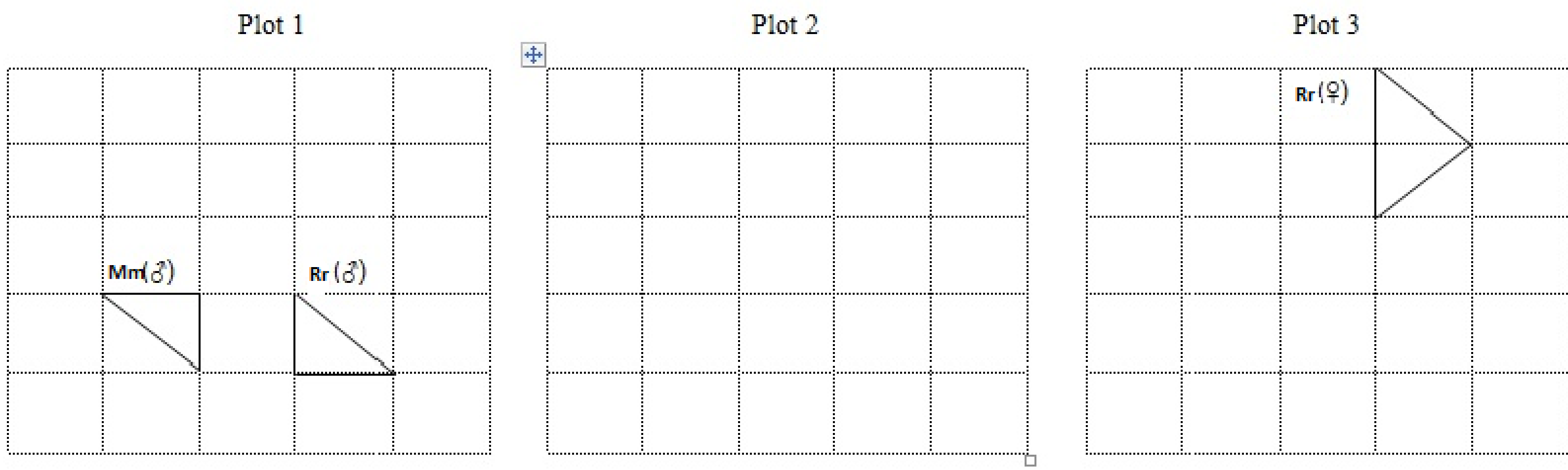

Figure 6. Home range map of the small mammals in the post-burned rice field stand in rainy season (♂ male : ♀female), Mm =*M. musculus*, Rr = *R. rattus*,

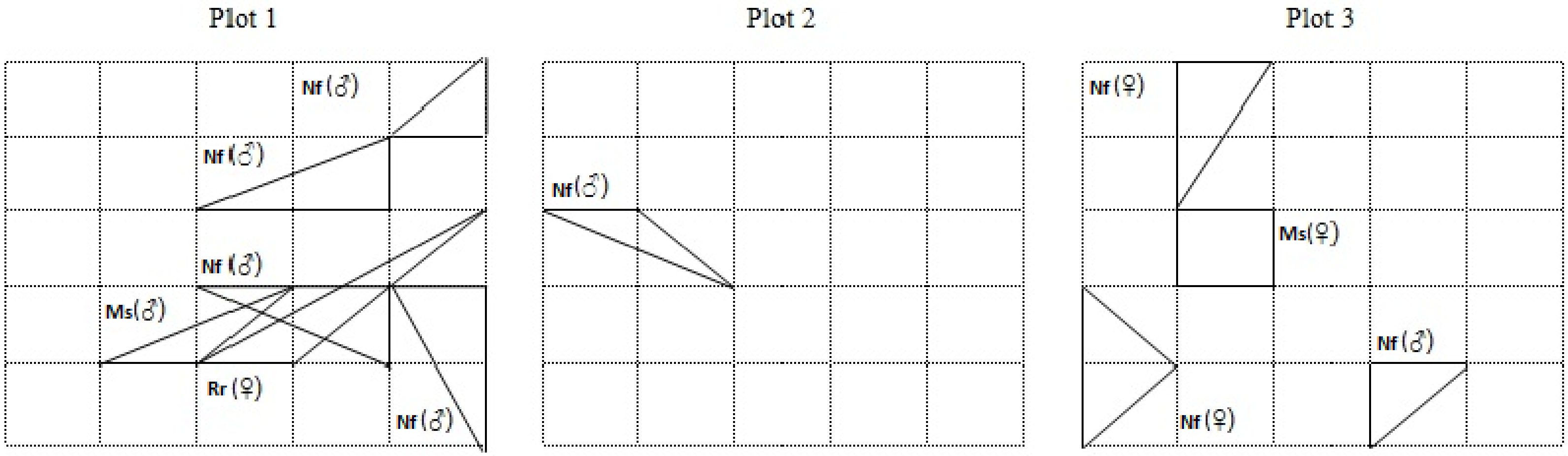

Figure 7. Home range map of the small mammals in the natural forest stand in dry season (♂ male : ♀female), Nf= *N. fulvescens*, Rr = *R. rattus*, Ms = *M. surifer*

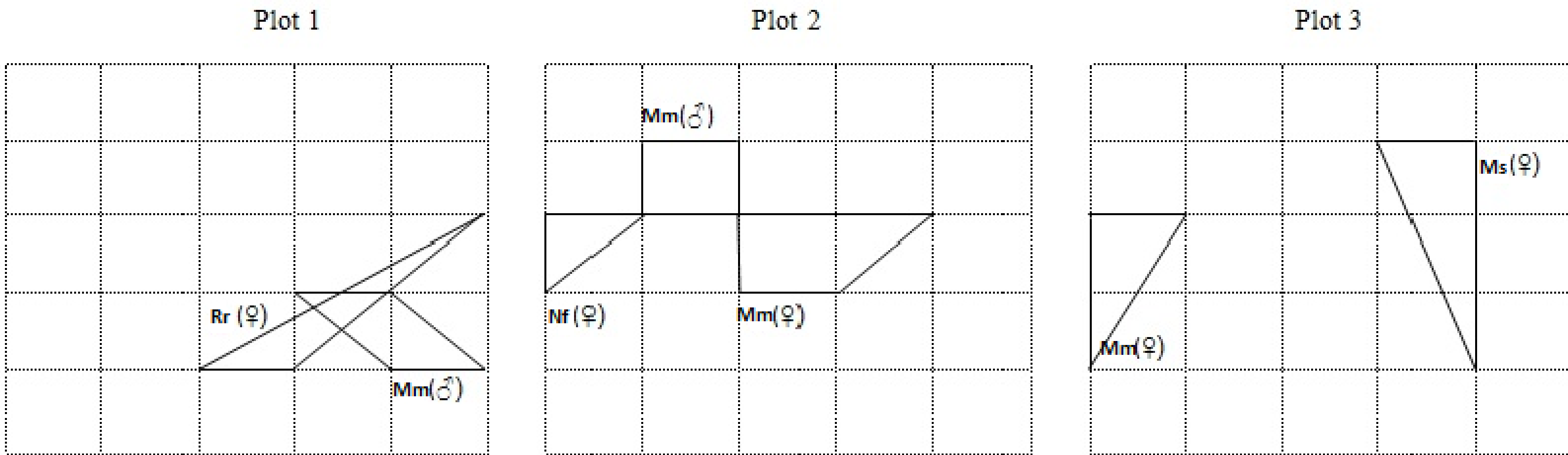

Figure 8. Home range map of the small mammals in the post-burned rice field stand in dry season (♂ male : ♀female), Mm= *M. musculus*; Nf = *N. fulvescens*; Rr = *R. rattus;* Ms = *M. surifer*

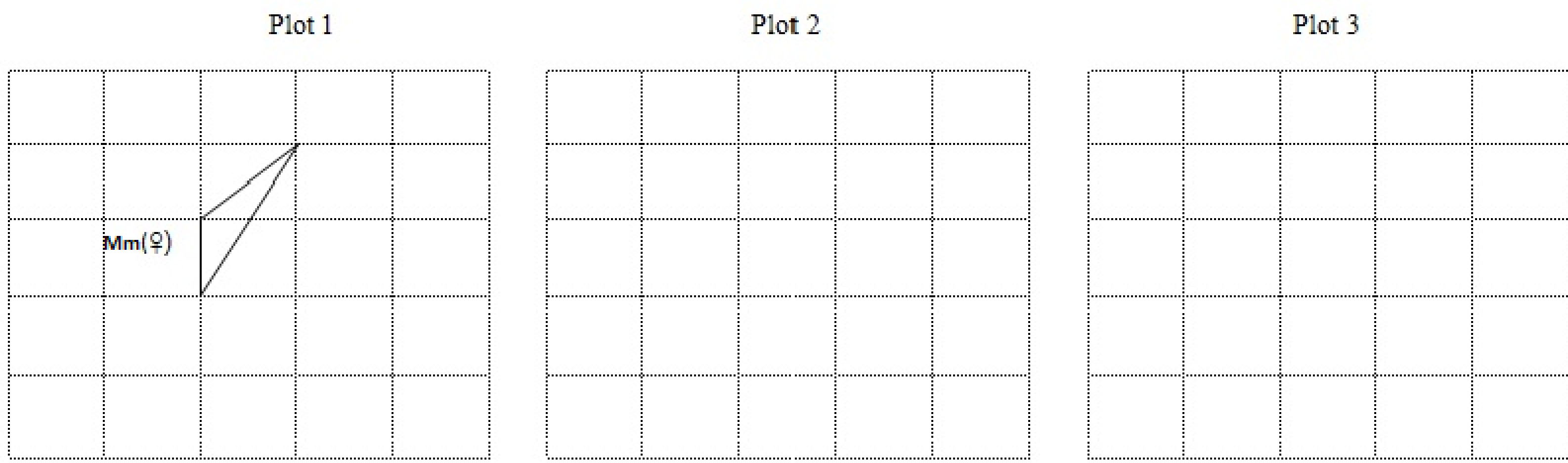

Figure 9. Home range map of the small mammals in the post-burned rubber plantation stand dry season (♂ male: ♀: female), Mm= *M. musculus*

Table 9. Difference in the home range size among different forest type in rainy season

Season	Forest type	Plot 1		Plot 2		Plot 3		Total estimated mean home range (m^2)
		No. of individuals	Estimated mean home range (m^2)	No. of individuals	Estimated mean home range (m^2)	No. of individuals	Estimated mean home range (m^2)	
Rainy	Natural forest stand	4	650	1	200	1	200	350
	Post-burned rice field stand	2	200	-	-	1	400	300
	Post-burned rubber plantation stand	0	-	-	-	-	-	0
Dry	Natural forest stand	6	300	1	200	4	350	283.3
	Post-burned rice field stand	2	400	3	400	2	500	433.3
	Post-burned rubber plantation stand	1	200	-	-	-	-	200

Table 10. Difference in the home range size (m ^{2}) between genders among nature forest stand, post-burned rice stand and post-burned rubber plantation stand in rainy season and dry season.

Species	**Sex**	**Nature forest stand**		**Post-burned rice field stand**		**Post-burned rubber plantation stand**		**Total estimated mean home range (m ^{2})**
		Rainy season	**Dry season**	**Rainy season**	**Dry season**	**Rainy season**	**Dry season**	
Nf	Male	500	300	-	-	-	-	**400**
	Female	400	400	-	200	-	-	**333.3**
Mm	Male	-	-	200	300	-	-	**250**
	Female	-	-	-	500	-	200	**350**
Rr	Male	800	-	-	-	-	-	**800**
	Female	-	400	-	-	-	-	**400**
Rs	Male	400	200	400	-	-	-	**333.3**
	Female	-	400		600	-	-	**500**

Abbreviation of species: Nf: *N. fulvescens;* Mm: *M. musculus;* Rr: *R. rattus*; Rs: *M. surifer;* Ls: *L. sabanus.*

V. Discussion

Forest structural characteristics are major determinants of habitats for small mammals (Rosenzweig and Winakur, 1969; Yarnell, et al., 2007; Monamy and Fox, 2010). As such, changes in forest structures resulting from fire influence on small mammal community (Wilson and Crarey, 2000; Converse, et al., 2006). Fire and post-fire management practices were dramatically changed in the forest structure in the study areas. Coverage of vegetation, the number of tree stems, and the number of shrubs, the number of snags and the volume of downed coarse woody debris were statistically and significantly different among three different forest types; only the number of woody seedling was not significantly different in the study areas (Table 3). The result of the study showed that fire and post-fire management can create new habitat and microhabitats that represent a function of time following the fire (plant secondary succession) and are preferentially selected by different mammalian species (Fox, 1981). The forest canopy was reduced after forest fire. In addition, the condition of forest canopy became more open due to the post-fire management practices of removing damaged trees. Clearly, there were significant differences observed in forest variables among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand. This data supported the hypothesis that the forest structures are different among primary forest and secondary forests when subjected to two different post-fire management practices.

The number of small mammals captured was high in natural forest stand, which had higher coverage of overstory vegetation, sub-overstory, and higher number of snag and volume of downed coarse woody debris (CWD) than both forests. And also, the CWD was necessary to maintain small mammal population that had been recommended as key to forest factor stand (Hangan & Grove, 1999; Bownan, et al., 2000; Fuller, et al., 2004). Characteristics of the microhabitat variable including number of tree stems, shrubs, snags, volume of woody debris and coverage played an important role in determining small mammal abundance and diversity (Dueser and Shugart, 1978). Similarly, downed woody materials have been suggested to provide habitat for invertebrates, an escape cover from predators (Hayes & cross, 1987; Lee, et al., 2012), a growing surface for fungi (Hagan & Grove, 1999), and a microclimate by maintaining moisture (Fraver, et al., 2002). Management and forest structure influence abundance of small mammals where each of the variables can be managed by forest manager through post-fire management practices. The results of the study indicated that forest components such as coverage of overstory, sub-overstory vegetation, the number of downed trees, and the volume of coarse woody debris had strong influence on small mammal communities (Lee, et al., 2008).

Overall, species richness of small mammal was the lowest in the post-burned rubber plantation stand and higher in the post-burned rice field stand and post-burned highest in the natural forest stand. A total of five species of small mammals were recorded in this study. The species composition and dominance changed with forest types. The natural forest stand contributed to the highest value species diversity and species richness in these forest types. *M. musculus* and *R. rattus* were the most common species captured in each forest type in the rainy season and dry season. Different small mammal species were dominant in the different forest types; *N. fulvescens* and *M. surifur* were most frequency captured in the natural forest stand and post-burned rice field. Interesting *L. sabanus* was found only in the natural forest stand because this species preferred to high forest cover, and number of coarse woody debris. Also, species was captured during the dry season; it might be dry season may provide suitable for this species. The number of small mammals captured during rainy and dry seasons when compared among three different forest types was highest in the natural forest stand and lower in the post-burned rice field stand and the lowest post-burned rubber plantation stand. Because there was no fire disturbance in the natural forest stand, the number of individuals captured was at its highest (Lee, et al., 2008). Also, the high number of individuals in natural forest stand might have reflected the abundance of food sources such as fruits or insects, which might have been more than those in both forest types (Nakagawa, 2006). On the other hand, the post-burned rubber plantation, where the lowest number of small mammals captured and species richness may have an intermediate microhabitat structure, is not enchanting in some small mammal species. In addition, the rubber tree plantation had major effects on small mammal community, especially for population of some species. Also, rubber trees have oil-rich seeds and leaf, and theses seeds with high lipid concentration tend to be more preferable for some mammals (Smallwood & Peter, 1986; Ikwuagwu, et al., 2000; Nakashizuka, 2006). Also, the post-fire silviculture had an impact the on wildlife and changed the vegetation structure, proving spatial variability in microhabitat and resource (Homyack, et al., 2004). It has also been a consequence of increased predation pressure due to decreased vegetation cover and reduced food availability as well as the negative impact of fire on habitat and food source for wildlife (Gordon, 1996).

In this study, I selected the rubber tree plantation that had passed < 5 years since the abandonment of slash-and-burn agriculture and plantation practice. Future accumulation of studies on older rubber tree plantation may be useful for determining the appropriate method for the recuperation of small mammal communities. Furthermore, the effect of forest utilized on other animals, such as large mammals or birds, may be more serious. Under the current conditions of the increasing population and rapid economic development in Southeast Asia, forests are utilized and large-scale deforestation as become a serious concern. To protect small mammals diversity and practice appropriate land-use management, further information about the effects of fire and post-fire management practices on small mammals and an extensive understanding of landscape-level effects are urgently needed.

VI. Conclusion

This study was designed to test the difference of small mammal species richness and abundance among natural forest stand, post-burned rice field stand and post-burned rubber plantation stand in Phou Khao Khauy National Protected Area. The results of this study are described as follows:

1. In comparison with the forest types, the forest structure has significantly different on small mammal community; five species are caught in the natural forest stand, four species in the post-burned rice field stand and two species in the post-burned rubber plantation stand. Only two species, *R. rattus* and *M. musculus* were found in all forest types, while the *N. fulvescens* and *M. surifer* were found in natural forest stand and post-rice field stand, respectively, and *L. sabanus* was found only in dry season in the natural forest stand.

2. The highest number of small mammal species and the number of individuals captured were recorded in the natural forest stand. The lowest numbers of small mammals were captured in the rubber plantation stand.

3. When comparing the sex and weight of each species, the results of this study indicated that the proportion of male weight is higher than female, and the age ratio, and juvenile of the female is higher than male. The home range size of small mammals in post-burned rice field stand is wider than both forest types; because they require a wider habitat in order to obtain the required resource. Therefore, the result of this study indicated that the post-burned rice field and

post-burned rubber plantation have negatives effect on small mammal communities.

4. This research suggested that the natural forest stand may provide more suitable habitat for small mammal species, but *M. musculus* and *R. rattus* also preferred two different post-fire management practices. The results indicate that the two species are no influenced by post-fire management practice. Thus, forest manager (decision-maker) can manage forest structure to maintain sensitive species to the post-fire management practices.

5. Small mammal distribution is very distinct with respect to forest types in the Phou Khao Khauy National Protected Area. The requirement of long-term studies management with food habitat, behavior; activity patterns and seasonal variation have to be implemented to better understand regarding the structure and functioning of these small mammal communities.

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Abstract in Korean

본 연구는 화전 후 처리 방법에 따른 산림 구조 및 소형포유류 군집 구조의 차이를 비교하기 위해 실시되었다. 라오스 푸카오 쿠아이 보호지역(Phou Khao Khauy National Protected Area, Lao PDR)에서 1) 자연림, 2) 화전 후 논 (4-6년 지난 휴경지), 3) 화전 후 고무나무 조림지(최근 5년이내 화전 및 조림 시행), 3종류의 조사지를 선정하였으며, 총 9개의 조사구에서 10일 연속으로 소형 포유류 포획 조사를 실시하였다. 포획 조사는 2015년 8월 우기(rainy season)과 2015년 12월부터 2016년 1월 건기(dry season)동안 생포용 덫(live trap)을 사용해 실시하였으며, 포획-표지 방사법(capture-mark and release)을 적용하여 개체를 식별하였다. 각 조사지 별 산림 구조를 파악하기 위해 9가지 서식지 변수를 선정하여 9개의 조사구에서 산림환경 구조조사를 실시하였다.

전체 조사 기간 동안 5종(*Niviventer fulvescens, Maxomys surifer, Leopoldamys sabanus, Mus musculus, Rattus rattus*)의 소형 포유류에 대해 456 개체를 포획 하였다. 포획 개체 수는 자연림에서 가장 높게 나타났으며, 이는 산림환경 구조조사 결과 다른 지역에 비해 높은 중상층 피도와 수목 잔존물에 따른 소형 포유류의 가용 먹이자원 및 서식지 커버가 높았기 때문인 것으로 판단된다. 화전 후 고무나무 조림지에서 가장 적은 개체가 포획되었으며, 따라서 고무나무 조림이 소형 포유

류 서식에 부정적인 영향을 미치는 것으로 생각된다.

행동권(home range size)은 화전 후 처리 방법과 함께 임분과 시기의 영향을 받는 것으로 나타났다. 행동권 크기는 3번 이상 포획된 개체를 대상으로 추정하였으며, 자연림에서 포획된 개체의 행동권이 화전 후 논보다 작게 나타났다. 고무나무 조림지에서 포획된 개체의 행동권이 세 조사지 중 가장 작게 나타났으나, 이는 이 지역에서 특히 건기 동안 포획된 개체가 가장 적었기 때문으로 생각된다. 조사시기별 행동권의 크기는 우기에 건기보다 큰 것으로 나타났으며, 이는 우기보다 건기에 먹이가 더 풍부하며, 먹이의 질이 높다는 것을 의미하는 것으로 판단된다.

소형포유류 군집과 서식지 변수간 유의한 상관관계가 나타났으며, *N. fulvescens*는 상층 피도, 중상층 피도, 하층 피도, 임분 밀도, 수목잔존물의 부피, 고사목 밀도; *musculus*와 *R. rattus*는 중층 피도 및 임분밀도; *M. surifer*는 중상층 피도, 임분 밀도, 목본 치수 밀도; *L. sabanu*는 상층 피도 및 중상층 피도와 연관이 있는 것으로 나타났다. 따라서 서식지 환경구조에 따라 소형 포유류 군집 구성이 달라지며, 각 종에 따라 선호 서식지가 다른 것으로 판단된다.

Keywords: 건기, 산림 구조, 소형포유류, 우기, 자연림, 화전 후 고무나무 조림지, 화전 후 논

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