RESPONSES TO BURNING AND EDGE EFFECTS OF SMALL MAMMALS AT KLONG E TAO SUBSTATION, KHAO YAI NATIONAL PARK

MISS WARAPORN KAEWPROM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE (NATURAL RESOURECS MANAGEMENT)

SCHOOL OF BIORESOURCES AND TECHNOLOGY
KING MONGKUT'S UNIVERSITY OF TECHNOLOGY THONBURI

2004
ISBN 974-184-496-4

โครงการพัฒนาองค์ความรู้และศึกษานโยบายการจัดการทรัพยากรชีวภาพในประเทศไทย
c/o ศูนย์พันธุวิศวกรรมและเทคโนโลยีชีวภาพแห่งชาติ
อาคารสำนักงานพัฒนาวิทยาศาสตร์และเทคโนโลยีแห่งชาติ
73/1 ถนนพระรามที่ 6 เขตราชเทวี
กรุงเทพฯ 10400

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T-346005

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① OVERVIEW, ② manuscript, ③ รายงานการเงิน
④ File

Responses to burning and edge effects of small mammals at Klong E Tao substation, Khao Yai National Park

Miss Waraporn Kaewprom B.Sc. (Agricultural Science)

A Thesis Submitted in Partial Fulfillment of the Requirements for the

Degree of Master of Science (Natural Resource Management)

School of Bioresources and Technology

King Mongkut's University of Technology Thonburi

2004

Thesis Committee

.... (Lect. George A. Gale, Ph.D.)	Chairman
.... (Antony J. Lynam, Ph.D.)	Co-Chairman
.... (Philip D. Round)	Member
.... (Anak Pattanavibool, Ph.D.)	Member

ISBN 974-184-496-4

Thesis Title	Responses to Burning and Edge Effects of Small Mammals at Klong E Tao Substation, Khao Yai National Park
Thesis Credits	12
Candidate	Miss Waraporn Kaewprom
Thesis Advisors	Dr. George A. Gale
	Dr. Antony J. Lynam
Program	Master of Science
Field of Study	Natural Resources Management
Department	Natural Resources Management
Faculty	School of Bioresources and Technology
B.E.	2004

Abstract

Fire management can have both positive and negative impacts on the survival and behavior of a variety of small mammals. In this study, live-trapping techniques and capture-recapture estimation models were used to determine the effects of fire and edges on small mammal abundance in forest, edge, and grassland habitat of Klong E Tao substation, Khao Yai National Park, northeastern Thailand. There were eight species of rodents trapped during this study; seven species (*Maxomys surifer, Niviventer bukit, Rattus rattus, Leopoldamys sabanus*, *Crocidura estrusca*, *Tupaia belangeri*, and *Mus caroli)* in the forest, six species (*Maxomys surifer, N. bukit, R. rattus*, *L. Sabanus, T. belangeri*, *Mus caroli*) at the edge, and five species (*Maxomys surifer*, *N. bukit*, *R. rattus*, *C. horsefieldi* and *Mus caroli*) in the grassland. In addition to more species, there were significantly higher densities of small mammals in the forest than in the grassland. Diversity (Shannon index) was also lower in the grassland than the forest, but the difference was not statistically significant due to small sample size. The most common species in the forest, *Maxomys surifer* was unaffected in the forest by the grassland fire, but declined significantly in the edge and grassland. In contrast, *Mus caroli* the most common species in the grassland, significantly increased in density in the grassland after fire. *R. rattus* which showed a clear preference for edge habitat, significantly increased in density in the forest after fire. Survival rate before the fire tended to be higher compared to after fire for both *M. surifer* and *M. caroli* (Paired-sample Wilcoxon-tests, p=0.066 and p=0.070 respectively). However, all of these changes in abundance in response to fire were temporary, and while no long-term data was collected, it appears that most species probably return to pre-fire densities within 6 months after a burn. Although *R. rattus* does not appear to be a pest, it appears to be desirable to reduce the abundance of this invader species.

As fire is the form of disturbance used to maintain grassland habitats in Khao Yai, I recommend reducing the frequency of burns since repeated fire sustains and reinforces forest fragmentation which in turn leads to reduced small mammal diversity and increased abundance of *R. rattus*. Further study of the effect of burning on small mammal abundance is encouraged.

Keywords: Small mammals / *Maxomys surifer* / *Mus caroli* / *Rattus rattus* / Fire Effects / Edge Effects / Khao Yai National Park / Tropical Forest Management

หัวข้อวิทยานิพนธ์	การตอบสนองของสัตว์เลี้ยงลูกด้วยนมขนาดเล็กต่อไฟและผลกระทบจากแนวขอบป่า ณ บริเวณคลองอีเฒ่า อุทยานแห่งชาติเขาใหญ่
หน่วยกิต	12
ผู้เขียน	นางสาววราภรณ์ แก้วพรหม
อาจารย์ที่ปรึกษา	ดร.จอร์จ เอ เกล
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คณะ	ทรัพยากรชีวภาพและเทคโนโลยี
พ.ศ.	2547

บทคัดย่อ

การใช้ไฟเผาในการจัดการทุ่งหญ้าสามารถส่งผลกระทบทั้งทางบวกและทางลบต่อความอยู่รอดและพฤติกรรมของสัตว์เลี้ยงลูกด้วยนมขนาดเล็กหลายชนิด ในการศึกษานี้ได้ใช้กับดักสัตว์ยังมีชีวิตอยู่ติดเครื่องหมาย และจับซ้ำ (Capture-recapture method) สำหรับประเมินแบบจำลองประชากร เพื่อระบุผลกระทบโดยที่ ประเมินผลกระทบจากไฟและแนวขอบป่าต่อความชุกชุมของสัตว์ฟันแทะในสามพื้นที่คือป่า แนวขอบป่า และทุ่งหญ้า บริเวณหน่วยพิทักษ์ป่าคลองอีเฒ่า อุทยานแห่งชาติเขาใหญ่ ประเทศไทย พบว่าในพื้นที่ป่ามีสัตว์ฟันแทะจำพวกหนูอยู่ 7 ชนิดได้แก่ หนูฟานเหลือง (*Maxomys surifer*) หนูขนเสี้ยนดอย (*Niviventer bukit*) หนูท้องขาว (*Rattus rattus*) หนูหวาย (*Leopoldamys sabanus*) หนูผีจิ๋ว (*Crocidura estrusca*) กระแตธรรมดา (*Tupaia belangeri*) และหนูผีป่าเล็กขนเกรียน (*Mus caroli*) ในพื้นที่แนวขอบป่าพบ 6 ชนิด คือหนูฟานเหลือง หนูขนเสี้ยนดอย หนูท้องขาว หนูหวาย กระแตธรรมดา และหนูหริ่งนาหางยาว และในพื้นที่ทุ่งหญ้าพบ 5 ชนิด คือหนูฟานเหลือง หนูขนเสี้ยนดอย หนูท้องขาว หนูผีป่าเล็กขนเกรียน และหนูหริ่งนาหางยาว พบว่าในพื้นที่ป่ามีความหนาแน่นของประชากรมากกว่าในทุ่งหญ้าอย่างมีนัยสำคัญ ถึงแม้ว่าความหลากชนิดจากการทดสอบโดยวิธี (Shannon index) ในทุ่งหญ้าจะน้อยกว่าในป่า แต่ไม่มีนัยยะทางสถิติเนื่องจากมีจำนวนตัวอย่างน้อย หนูฟานเหลืองเป็นชนิดที่พบมากที่สุดในพื้นที่ป่าซึ่งไม่ได้รับผลกระทบจากการเผาทุ่งหญ้า แต่ในพื้นที่แนวขอบป่า และทุ่งหญ้า พบว่าค่าความหนาแน่นลดลงอย่างชัดเจน ในทางกลับกัน หนูหริ่งนาหางยาวพบมากที่สุดในบริเวณทุ่งหญ้าโดยความหนาแน่นประชากรเพิ่มขึ้นหลังจากการเผาทุ่งหญ้า ส่วนหนูท้องขาวชอบอาศัยอยู่ในบริเวณแนวขอบป่าและมีความหนาแน่นเพิ่มขึ้นในพื้นที่ป่าอย่างมีนัยสำคัญหลังการเผา จากการเปรียบเทียบโดยวิธี Paired-sample Wilcoxon-tests พบว่า อัตราการรอดชีวิตของหนูฟานเหลืองและหนูหริ่งนาหางยาวก่อนเผาสูงกว่า

หลังเผา (*p*=0.066 และ *p*=0.070 ตามลำดับ) ถึงแม้ว่าการเผาจะมีผลต่อความความชุกชุมแต่ก็เป็นผลในระยะสั้น หากไม่มีการเก็บข้อมูลในระยะยาวต่อไป เป็นไปได้ว่าความหนาแน่นของสัตว์เหล่านี้จะกลับมาเหมือนเมื่อตอนก่อนเผาอีกภายใน 6 เดือน ถึงแม้ว่าหนูบ้านจะไม่ได้เป็นสัตว์ที่รบกวนสัตว์ชนิดอื่น แต่การศึกษานี้ชี้ให้เห็นว่ามีความจำเป็นต้องลดความชุกชุมของสัตว์ผู้บุกรุกชนิดนี้อยู่

เนื่องจากการใช้ไฟเผาในการจัดการทุ่งหญ้าของอุทยานแห่งชาติเขาใหญ่ ซึ่งเป็นการรบกวนสัตว์ป่ารูปแบบหนึ่ง ดังนั้นจึงขอเสนอแนะว่าควรลดความถี่ในการเผาทุ่งหญ้าลง เพราะนอกจากการเผาซ้ำจะทำให้พื้นที่ป่าแยกกันอย่างถาวรมากขึ้นแล้วยังส่งผลให้ความหลากชนิดของสัตว์เลี้ยงลูกด้วยนมขนาดเล็กลดลง และเพิ่มความหนาแน่นของหนูบ้าน ดังนั้นจึงขอสนับสนุนให้มีการศึกษาเพิ่มเติมเกี่ยวกับผลกระทบจากการเผาทุ่งที่มีต่อความชุกชุมของสัตว์เลี้ยงลูกด้วยนมขนาดเล็กต่อไป

คำสำคัญ: สัตว์เลี้ยงลูกด้วยนมขนาดเล็ก / หนูท้องขาว / หนูฟานเหลือง / หนูหริ่งนาหางยาว / ผลกระทบจากไฟ / ผลกระทบจากแนวขอบป่า / อุทยานแห่งชาติเขาใหญ่ / การจัดการป่าเขตร้อน

ACKNOWLEDGEMENTS

I would like to thank my advisor Dr. George A. Gale for guidance and suggestions throughout the course of my study and my Co-advisor Dr. Antony J. Lynam, for giving me the opportunity to work on this project. Also, I would like to thank my committee, Mr. Philip D. Round and Dr. Anak Pattanavibool for their suggestions. I also want to thank the Wildlife Conservation Society (WCS)-Thailand program staff. Special thanks to Dr. Chompol Sukkasem, former Superintendent of Khao Yai National Park for allowing me the use of facilities and giving permission to conduct the field work. Thanks to Mr. Noppalerk Kaewprom, Mr. Sumran Cherchan and Mr. Kantachard Merngchompol for assisting in the field, I also would like to thank Mr. Prawat Wohandee the current Superintendent of Khao Yai National Park and Mr. Prawatsart Chan-teph Coordinator and Ranger of National Park for their help. Thanks also to the Director of National Laboratory Animal Centre (NLAC) to allow me to borrow equipment to use in the field and Mr. Phanya from the NLAC for training me how to use an ear punch. I would also like to thank Mr. Niwech Nadee from the National Research Council of Thailand for his help with species identifications, Dr. Ulrich Reichard for generously providing rainfall data from Khao Yai and Mr. Christopher Atwood for his help and advice, particularly with my English. I would like to thank all my good friends for giving me their help and encouragement and most of all special thanks to my parents, brother and relatives who supported and encouraged me throughout my life. I couldn't have done it without you. This work would not been completed without financial support from the WCS- Thailand Program and the TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_346005.

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CHAPTER 1 INTRODUCTION

1.1 Background

The habitats for many tropical forest species have become increasingly fragmented and lost due to increasing human populations and changes in land use. For example, each year roughly 0.6 to 1.1% of tropical forest is lost (FAO, 1993). Fragmentation is the process by which habitats become reduced in size, increasingly isolated, with the proportion of edge to interior habitat increasing (Reed et al, 1996; Schelhas and Greenberg, 1996; McGarigal and Cushman, 2002; Yates et al. 1997). In addition, the effects of fragmentation can be magnified by changes in the remnant fragments (reviewed by Lindenmayer et al. 1999). Organisms that remain in the fragments are exposed to different surrounding habitat types and their responses to this change have been termed edge effects (Murcia 1995). For example, alterations to the microclimate within the fragments caused by the proximity of the matrix around the fragments to the forest system are edge effects (Laurance 1991b, Lovejoy et al.1983, Saunders et al.1991, Turton & Freiburger 1997). Edge effects can be subtle, such as at the boundary of mature and secondary forest or perennials and annual grassland. Alternatively, edge effects may be abrupt changes such as those at urban – wildland interfaces (Kristan et al. 2003).

Edges may affect the organisms in a fragment in different ways. For example, changes in species, distribution and abundance may occur near forest edges because of differences among species in their physiological tolerances (Murcis, 1995) Density and activity of forest animals may vary among species from avoidance to preference for edges (Liebhold, et al., 2005). In most cases, mammals are more abundant on the edge (e.g., the ecotonal area between forest and non-forest areas) than in any other type of landscape feature investigated. The species inhabiting the edge are provided with a greater amount of food and cover than they would obtain from any single type of habitat (Yoakum and Dasmann, 1969).

Edges can also influence a variety of ecological processes such as dispersal and the community composition of both animals and plants (Hansen and di Castri 1992; Pickett and Cadenasso 1995; Risser 1995). Small mammals are highly sensitive to plant growth forms and other associated variables such as structural complexity (M'Closkey and Fieldwick 1975; Adler 1985), as this may alter the risk of predation for these organisms (Lima and Dill 1990; Kristan et al. 2003). Fire is a perturbation that may affect species use of edges by changing microhabitat structure. For example, frequent fires may produce a very narrow ecotone while less frequent fires produce a more diffuse ecotone (Ash 1988, Unwin et al. 1985). Fires affect population densities principally by altering habitat (Higgins, Kruse and Piehl, 2000). The decrease of vegetative cover results in fewer microhabitats available for use by wildlife, especially rodents (USGS, 2003).

In Thailand, natural habitats for wildlife are heavily fragmented. Many forest reserves and protected areas feature 'hard edges' where human modified lands meet wildlands. In these landscapes fire is a regular form of disturbance which may affect distribution and abundance of wildlife. However, there has been very little research about the effects of fragmentation, in particularly effects of edges and fire on wildlife. This study attempted to examine the influence of edges and fire on the community of small mammals at Klong E Tao, Khao Yai National Park, Thailand.

1.2 Objectives and hypothesis

1.2.1 To compare species richness and abundance of small mammals in the forest-grassland edge at Klong E Tao, Khao Yai National Park.

1.2.2 To determine the distribution of small mammals in forest- grassland edges after fire at Klong E Tao, Khao Yai National Park.

Hypothesis 1

H0: There are no differences in species richness and diversity of small mammals between forest and grassland habitats at Klong E Tao, Khao Yai National Park.

H1: There are differences in species richness and diversity of small mammals between forest and grassland habitats at Klong E Tao, Khao Yai National Park.

Hypothesis 2

H0: Burning has no effect on the small mammal communities in either habitat at Klong E Tao, Khao Yai National Park.

H1: Burning has significant effects on the species richness, diversity and abundance of individuals of the small mammal communities in either or both habitats at Klong E Tao, Khao Yai National Park.

1.3 Study Scope

This project was established in one site at Klong E Tao substation (KET) of Khao Yai National Park. This study site was created by slash-and-burn farmers who settled on the mountains before the park was established in 1962. Grassland and secondary growth make up the remaining vegetation types. This experiment was conducted along the edges of natural forest and grasslands. This forest has a sharp boundary with the adjacent grassland. The grassland is burned annually which prevents succession back into forest, but maintains grazing habitat where deer can be easily seen (Srikosamatara and Hansel, 2000). A total of 5 transect lines were used to sample 3 different habitats forest, grassland, and forest edge. Each line was sampled three times before the grassland was burned and three times after it was burnt.

1.3.1 Study species

There are a total of 20 small mammal species in Khao Yai National Park (list of KY by Conservation Centre Database see Table 3.1).

1.3.2 Survey design

1.3.2.1 Preliminary collection

Preliminary, before and after burn data collection: the preliminary survey took 7 days to develop a species accumulation curve which reached an asymptote after 4 days.

1.3.2.2 Before burn / after burn data collection

Before burn surveys were conducted 8 nights per month. This was done in two periods of 4 nights each. In each period 2 trap lines were set. These trap lines were then rotated to new positions and re-laid 2 weeks later. Before fire lines were surveyed from January to April 2003 and after the burn from May-July 2003.

1.3.3 Data Analysis

A relative abundance index (RAI) was calculated for each species as the number of captures of individuals of that species scaled for trapping effort (Tanaka, 1960; Caughley, 1977). Density was estimated using Program CAPTURE software run on the Patuxent Wildlife Research Center web site (http://www.mbr-pwrc.usgs.gov/

software/capture.html). The Shannon index of diversity (H'; Magurran 1988) was used to estimate species diversity for each species in each habitat.

A t-test (Hutcheson 1970) was used to test the null hypothesis that H' did not differ among forest and grassland habitat and before and after fire. Comparisons of distributions before and after fire were done using t-tests and Sorenson tests were used to compare species composition before and after fire.

1.4 Expected benefits

This study will provide knowledge about the ecological effects of fire and edges on small mammals. This information could be used in combination with other forest fire knowledge for developing more effective forest management techniques.

CHAPTER 2 LITERATURE REVIEW

2.1 Habitat Fragmentation and edge effects

Habitat fragmentation is a threat to wildlife populations for many reasons (Soulé 1986; Lande 1988; Robinson et al 1995; Leach and Givnish 1996). The effects of forest fragmentation include habitat changes and changes in ecological processes, enhanced predation and brood parasitism near edges (Laurance and Bierregaard, 1997), and local extinction of small populations in isolated habitats (Gilpin and Diamond, 1982; Harris, 1984; Wilcove et al, 1986; Saunders et al, 1991; and Lidicker, 1999). From 1981 to 1990 the total overall loss of tropical forest was 154 million ha, 25% of that loss occurred in Asia. Currently, Thailand's remnant forests have decreased from 70% to around 30% of the total area or 153,780 km^2, with protected areas covering approximately 16% of the land area (Arbhabhirama et al., 1988; Prayurasiddhi et al., 1999; and Pattanavibool & Dearden, 2001).

Habitat edges area consequence of fragmentation. Positive features of ecotones include their high productivities and enhanced biodiversity, particularly from the presence of edge adapted species that live between two community types (Leopold 1933). Laurance (1997), and Yahner (1988) however have shown that habitat edges make movements between habitat patches more difficult. In fact habitat edge can enhance the dispersal of exotic species due to affects from solar radiation changing the microclimate between the two sides of an edge. This is likely to create a gradient of temperature from the edge with reduced soil moisture and relative humidity near the edge (Kapos 1989; Murcia 1995).

2.2 Fire

Fire is an environmental factor that may strongly influence composition and community dynamics of plants and animals worldwide (Mutch 1970, Bendell 1974, Crowner & Barret 1979, Catling et al. 1982, Happold 1983, Simons 1991). Fire can be, and often is, a disaster for animals dwelling in forests or other places where fires are infrequent. But mammals living in environments exposed to frequent fires, as in grasslands, survive because of their adaptations (Handley 1969). However, forests that are adjacent to fire-maintained pastures and agricultural lands are at high risk from fire (Cochrane 2001).

2.3 Effects of fire on small mammals

Fire may affect animal populations by causing (1) loss of preferred habitats and food sources, (2) some rodent species to increase and invade habitats of native species, and (3) an increase in the risk of predation. The lack of cover immediately after a fire produces an exposed environment and improves accessibility to avian and mammalian predators (Motobu, 1978). Post-burn predation may be more restrictive to rodent populations than the burning itself (Lawrence 1966). Motobu (1978) estimated 20% mortality from predation in mountain beaver (*Aplodontia rufa*) on an area of patchy burn with few of the surviving animals showed signs of burn injury.

Fires affect population densities principally by altering habitat. The decrease of vegetative cover results in fewer microhabitats available for use by wildlife, especially rodents (Hinggins, Kruse, and Piehl, 2003). However, with the reduction of ground litter, primary production is enhanced. Within 2 to 4 years after a fire, litter gradually increases again, with a decrease in primary production (Dix 1960; Vogl 1965; McGee

1982). Based upon these habitat changes and the habitat and food preferences of rodents, major shifts in species composition and density should also occur within the first few years after a fire. For the first year, granivorous and omnivorous rodents are abundant (Ahlgren 1966; Kaufman et al 1983). Species considered herbivorous are limited especially on complete burns (Hinggins et al. 2003). Many rodents are opportunistic omnivores (Johnson 1961), often shifting diets according to the availability of seeds and invertebrates (Williams 1959; McGee 1976). Their food and habitat preferences make them particularly suited to exploit burned areas. Omnivores that require litter cover (*Peromyscus* spp., *Niviventer bukit, Mus caroli, Maxomys surifer*, and *Leopoldamys sabanas* for example) are favored (USGS, 2003). As vegetative cover increases on burned areas, species such as *Rattus rattus* also invade (Lynam, 1999).

Numerically, most of the rodents unintentionally introduced by people in inhabited areas belong to the muridae species *Mus musculus, Rattus rattus* and *R. norvegicus*. They do not easily penetrate primary systems, however, and this limits their impact on wild habitats. Omnivores will usually invade an area within 2-4 weeks after a fire (Cook 1959; Tevis 1956; Sims and Buckner 1973). This immigration is a response to the availability of a new food source and to the open space in which a home range may be established (Tevis 1956). Within 3 years, deer mouse (*Peromyscus* spp.) populations on a burned area will increase greatly over that of an unburned area (Cook 1959; Tevis 1956; McGee 1976; Bock and Bock 1983; Kaufman et al 1983). These increases may be caused by additional immigration or increased reproductive rates in response to favorable environmental conditions (Lawrence 1966; McGee 1976). The western harvest mouse, a granivore, will also inhabit a burn, but tends not to invade until some vegetative cover is established (Cook 1959; Kaufman et al 1983). House mice (*Mus* *musculus*) also show a preference for habitat created by fire (Cook 1959). Other species may utilize a burned area depending upon the surrounding habitat types and the amount and type of vegetation that becomes established after a burn. But not all rodent species are positively affected by fire. The small mammal response is not considered a direct response to fire but a reaction to fire-altered habitat. Fire alters the composition of rodent species from those associated with the climax community to those considered early succession species (McGee 1982). For example in the Northern Great Plains (USA) there is a predominant shift from chaparral species (Cook 1959; Lawrence 1966) and forest species (Beck and Vogl 1972) to prairie and grassland species. Most invasive mammals are Rodentia (*Rattus rattus*), house mouse (*Mus musculus*), which were introduced for biological disturbance and then became pests.

The lethal temperature tolerance of rodents is 122-145 F (50-63 °C) at 22% relative humidity (Howard et al 1959); however, at 60% relative humidity, the lethal temperature drops to 120 F (49 °C) (Lawrence 1966). To escape the heat of a fire many rodents take refuge in unburned islands (Motobu 1978), in rock outcroppings (Howard et al 1959), by running ahead of flames (Erwin and Stasiak 1979), or by taking refuge in burrows (Lawrence 1966; Quinn 1979). Beneath the soil surface, temperatures are reduced (Lawrence 1966) and rodents are able to survive.

CHAPTER 3 STUDY AREAS

3.1 Study areas

Khao Yai National Park (KYNP) (18° 52'N, 94° 51'E) was established as Thailand's first national park in 1962; with an area of 2,168 km^2. The major vegetation types include hill evergreen forest (>1000 msl); moist evergreen forest covering more than 60% of the area between 500-1000 msl; dry mixed deciduous (300-600 msl); dry evergreen forest (200-400 msl) and grassland or secondary forest. Wildlife with in KYNP includes more than 333 species of birds and 70 species of mammals (Srikosamatara and Hansel, 2000) such as Asian elephant, Tiger, Gaur, Serow, Asiatic black bear, Malayan sunbear, Asian wild dog, Gibbon, civets, pheasants and hornbills. This includes 20 species of small mammals and mammals in Khao Yai National Park. (see Table 3.1).

Table 3.1 List of small mammals at KYNP. (From the Mahidol University Conservation Centre Database, Bangkok Thailand)

No.	Scientific name	Common name
1	*Hylomys suillus*	Pig-tailed Shrew
2	*Crocidura horsifieldi*	Horsfield's Shrew
3	*Suncus etruscus*	Dwarf Shrew
4	*Tupaia belangeri*	Common Treeshrew
5	*Ratufa bicolor*	Black Giant Squirrel
6	*Callosciurus finlaysoni*	Variable Squirrel
7	*Callosciurus caniceps*	Grey-bellied Squirrel
8	*Tamiops macclellandi*	Burmese Striped Tree Squirrel
9	*Menetes berdmorei*	Indochinese Ground Squirrel
10	*Dremomys rufigenis*	Red-cheeked Squirrel
11	*Petaurista petaurista*	Red Giant Flying Squirrel
12	*Hylopetes lepidus*	Red-cheeked Flying Squirrel
13	*Petinomys setosus*	White-bellied Fly Squirrel
14	*Bandicota savilei*	Lesser Bandicoot

No.	Scientific name	Common name
15	*Mus caroli*	Ryukyu Mouse
16	*Maxomys surifer*	Yellow Rajah Rat
17	*Niviventer bukit*	Chestnut Rat
18	*Rattus sillimensis*	Sladen's Rat
19	*Rattus rattus*	Roof Rat
20	*Leopoldamys sabanus*	Noisy Rat
21	*Cynopterus sphinx*	Great Short-nosed Fruit Bat
22	*Rousettus leschenaulti*	Leschenault's Rousette
23	*Macroglossus sobrinus*	Great Long-tongued Fruit Bat
24	*Eonycteris spelaea*	Cave-dwelling Nectar-eating Bat
25	*Taphozous theobaldi*	Tomb Bat
26	*Megaderma spasma*	Lesser False Vampire
27	*Rhinolophus malayanus*	North Malayan Horseshoe Bat
28	*Rhinolophus stheno*	Lesser Brown Horseshoe Bat
29	*Rhinolophus thomasi*	Thomas' Horseshoe Bat
30	*Thinolophus affinis*	Intermediate Horseshoe Bat
31	*Rhinolophus pearsoni*	Pearson's Horseshoe Bat
32	*Hipposideros bicolor*	Bicolored Roundleaf Bat
33	*Hipposideros diadema*	Large Malay Roundleaf Bat
34	*Hipposideros armiger*	Great Roundleaf Bat
35	*Hipposideros larvatus*	Intermediate Roundleaf Bat
36	*Chaerephon plocata*	Wrinkled-lipped Bat
37	*Nycticebus coucang*	Slow Loris
38	*Lutra pespicillata*	Smooth-coated Otter
39	*Aonyx cinerea*	Small-clawed Otter
40	*Tragulus javanicus*	Lesser Mouse Deer
41	*Hystrix brachyura*	Malayan Porcupine
42	*Atherus macrourus*	Bush-tailed Porcupine
43	*Lepus peguensis*	Siamese Hare

3.1.1 Klong E Tao substation (KET)

The Klong E Tao substation is approximately 4 km from park headquarters and is comprised of a mix of primary, secondary forest and grassland habitats (Figure 3.1). This experiment was conducted along the edges of natural forest and grasslands. The grassland in the study area, are burned annually, which prevents succession back into forest, to attract Sambar deer, and other herbivores such as Common muntjac, Elephant, and Wild Pig to make such animals easier to see for tourists. This grassland was originally created by slash-and-burn farmers who settled in the area before the park was established in 1962, and many of the old fields are now secondary forest. I divided the study area into three habitats. (1) Forest which includes both primary and secondary evergreen forest (2) grassland defined by the tall grass and (3) edge areas between grassland and forest, which in this area, are quite sharp and occur over a distance of a few meters.

3.1.2 Climate and Topography

KYNP has a monsoonal climate and receives about 2,270 mm of rainfall annually (FIGURE 3.1). The park has three seasons: cool, hot, and rainy. The cool season (November-February) is rather dry and has an average low temperature of 17 °C. Nights are usually clear and cool. The hot season (March-May) has an average temperature of 28 °C, during this period many animals will congregate near remaining water sources. The rainy season (June-October) brings 84% of KY's precipitation. During this period it will rain nearly every day (Srikosamatara and Hansel, 2000).

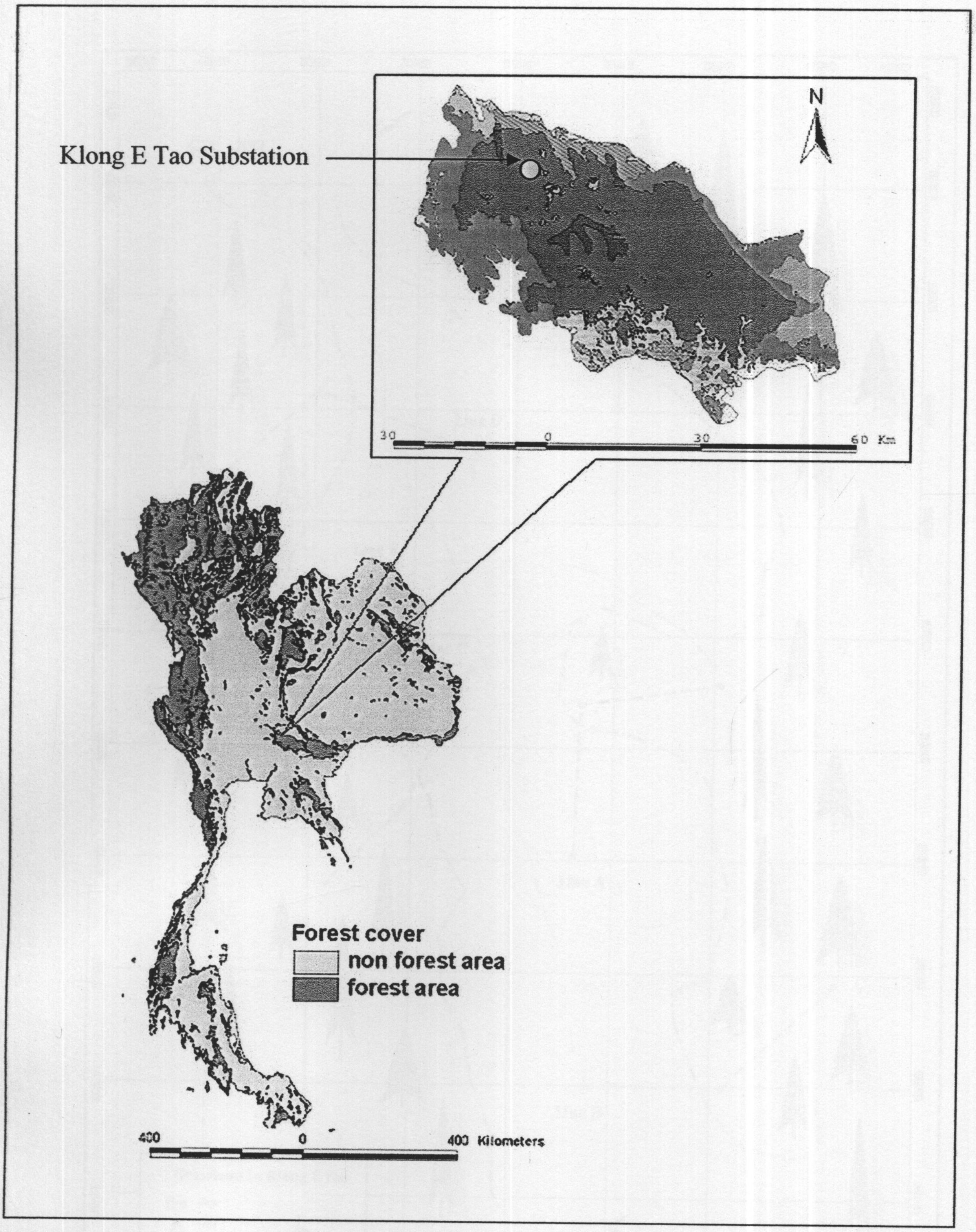


Figure 3.1 Klong E Tao Substation, Khao Yai National Park.

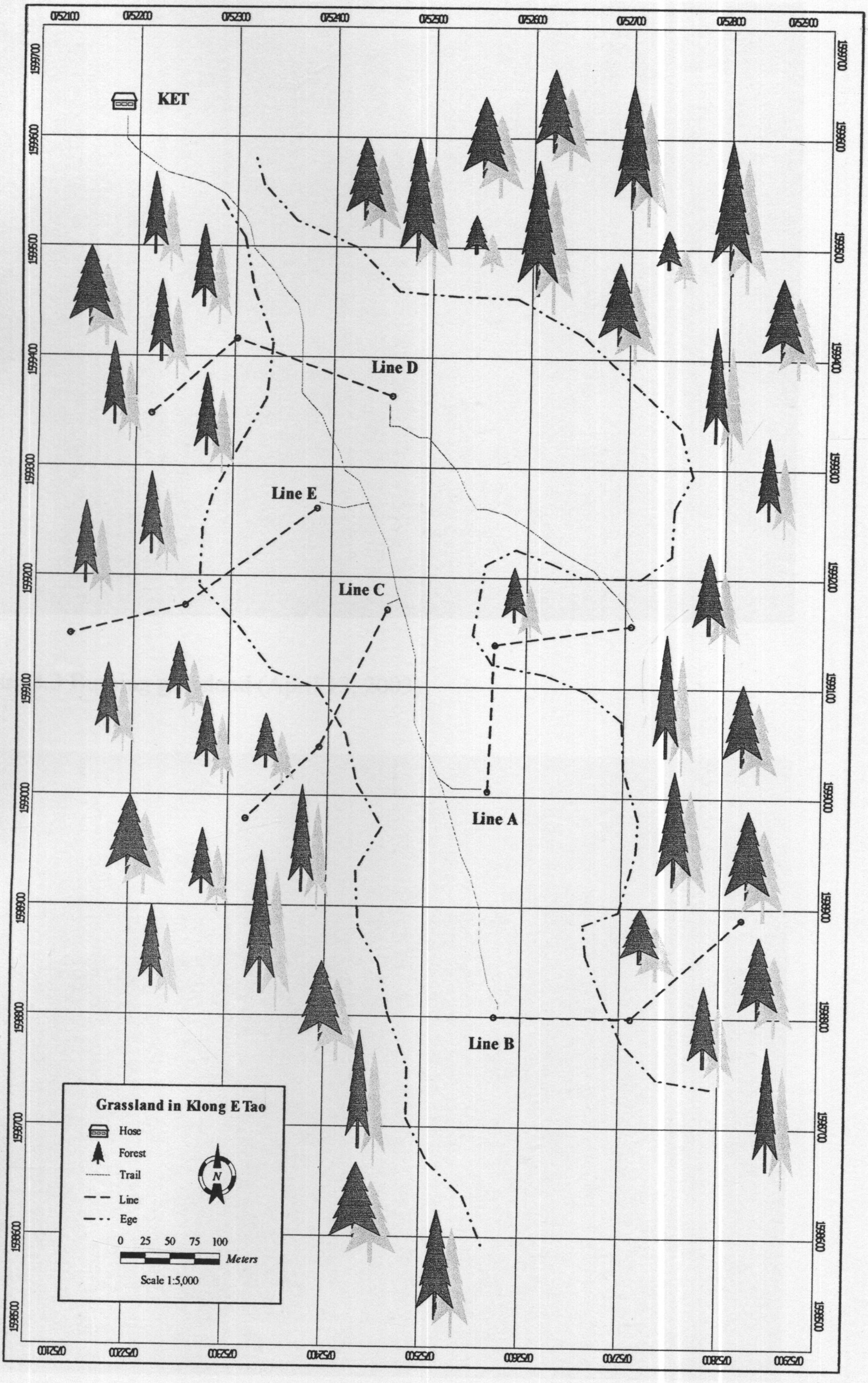


Figure 3.2 Transect locations near the Klong E Tao substation, Khao Yai National Park.

Figure 3.3 Burning grassland (April 13, 2003)

Figure 3.4 Grassland after the burn.

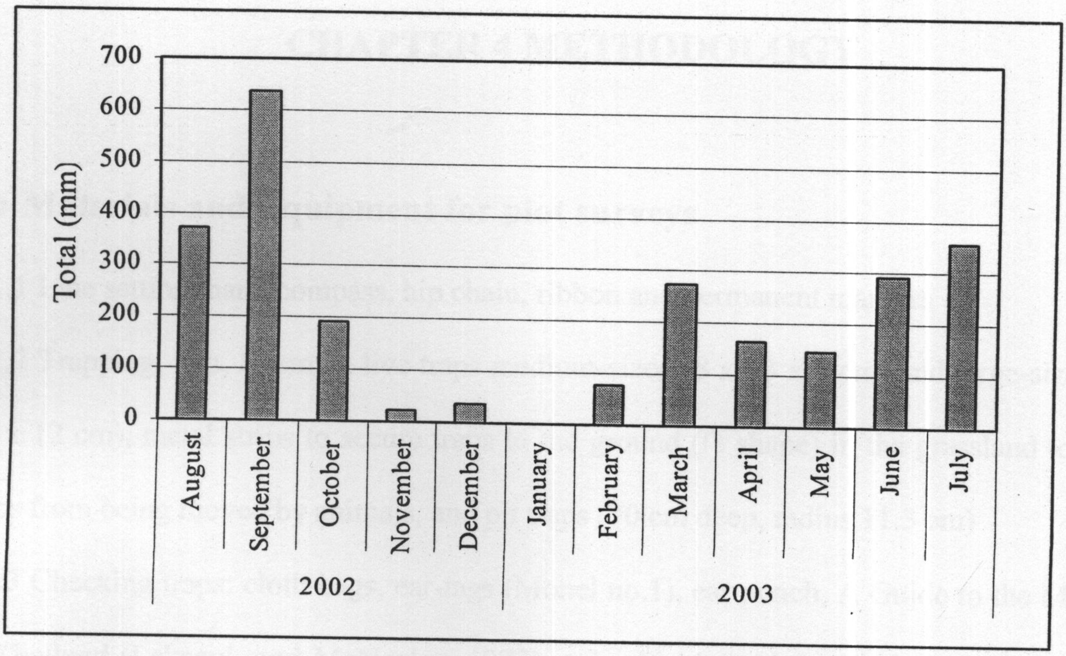


Figure 3.5 Rainfall (average per month) at Khao Yai National Park between August 2002 and July 2003 (from Reichard *unpubl. data*)

CHAPTER 4 METHODOLOGY

4.1 Materials and Equipment for plot surveys

4.1.1 Line setting: hand compass, hip chain, ribbon and permanent markers

4.1.2 Trapping: bait, Sherman live traps medium-sized (8 x 23 x 9 cm) and large-sized (10 x 38 x 12 cm), metal strips to secure traps to the ground (∩ shape) in the grassland to protect traps from being moved by animals, and pit traps (70 cm deep, radius 11.3 cm)

4.1.3 Checking traps: cloth bags, ear-tags (Monel no.1), ear punch, A Guide to the Mammals of Thailand (Lekagul, and McNeeley. 1977) and a Field Guide to the Mammals of Borneo (Payne, Francis, and Phillipps. 1985).

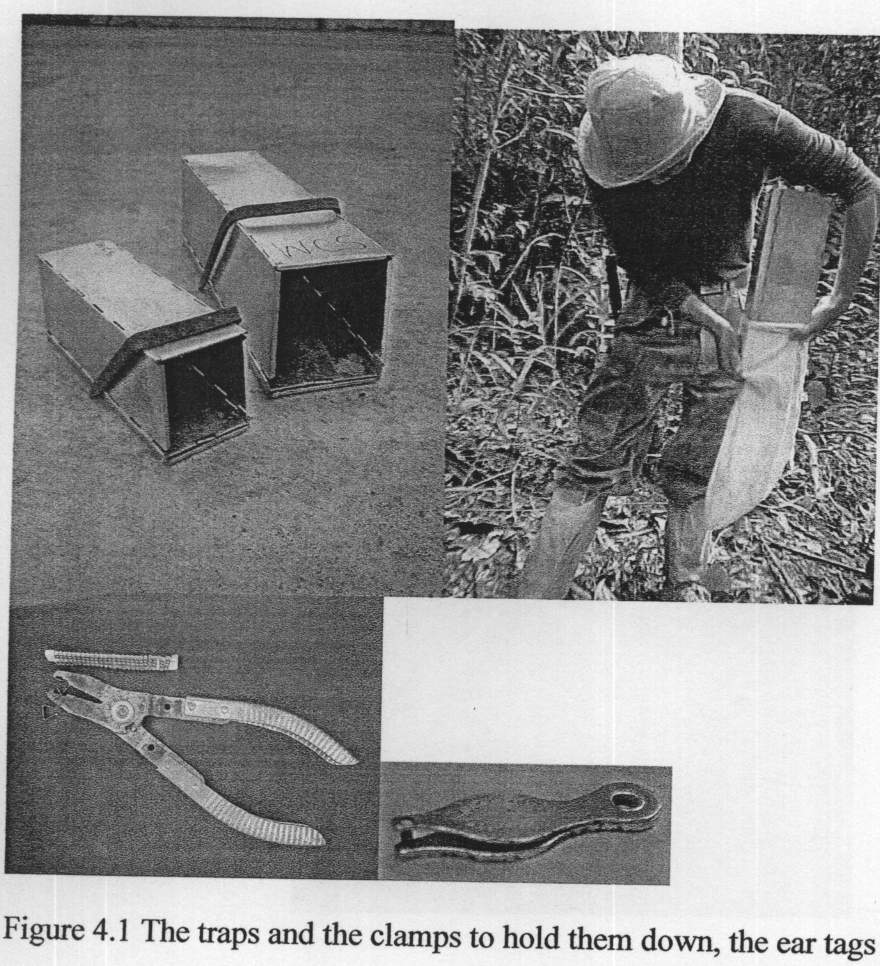


Figure 4.1 The traps and the clamps to hold them down, the ear tags and ear punch.

4.2 Methods

4.2.1 Trapping methods

A total of 100 trapping stations were used on five trap-lines 270 m long, which covered both forest and grassland habitats. Ten stations were set in each habitat, located at 15 meter intervals for a total of 135 meters into the forest and into the grassland for another 135 meters from the edge. The edges were sharply defined by fire and was set as distance 0 m. At each trap station a single medium-sized Sherman live trap (23 x 8 x 9 cm) was placed on the ground. In addition, a single large-sized Sherman live trap (38 x 10 x 12 cm) was placed at trap stations at the edge (0 m) and at., 30 m., 60 m., 90 m., and 120 m. Traps were baited with fresh banana and fried coconut pieces covered in peanut butter. Traps were checked once daily, between 07.00-12.00 hrs. Captured mammals were identified, sexed, weighed, individually marked with ear tags, while smaller animals (mice and small-sized rats) were marked by ear punching, and released at the point of capture (Harrington et al. 2001). Initially, for small species such as *M. caroli* I used permanent markers to paint the inside of the ears, but this quickly faded, thus ear punching was used which had almost no problems. For *T. belangeri* we clipped hair from the tail.

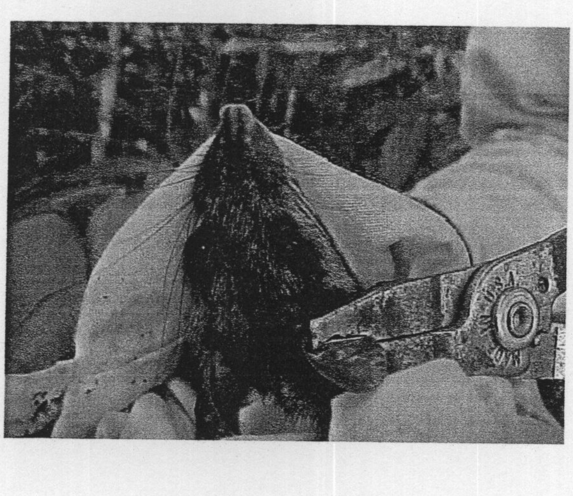


Figure 4.2 Ear tag to mark individuals.

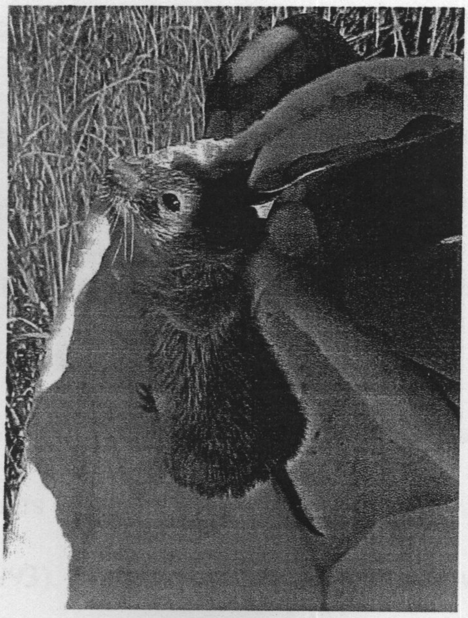


Figure 4.3 Ear punch to mark mice and small sized mammals

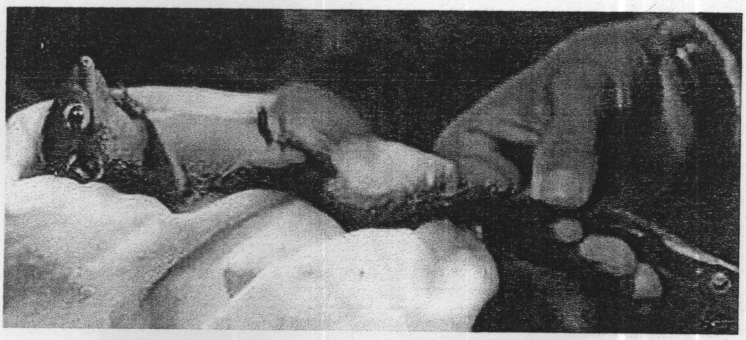


Figure 4.4 Fur clipping the tail to mark a Common tree shrew

4.2.2 Pit trap methods

A total of 20 pit-fall trap stations on one line were set specifically to catch shrews. A pitfall trap is a container (usually ≥ 40 cm deep and 20 to 40 cm in diameter; Jones et al. 1996), that has smooth vertical walls and is placed in the ground. Pitfalls are effective devices to capture the smallest (< 10 g) terrestrial mammals such as shrews. Animals may be attracted to pitfall traps with bait or may fall into traps because they are placed along travel-ways or equipped with drift fences (barriers designed to direct small mammals into traps; Bury and Corn 1987; Handley and Kalko 1993). In this study the pit-fall traps were baited but were not used with drift fences.

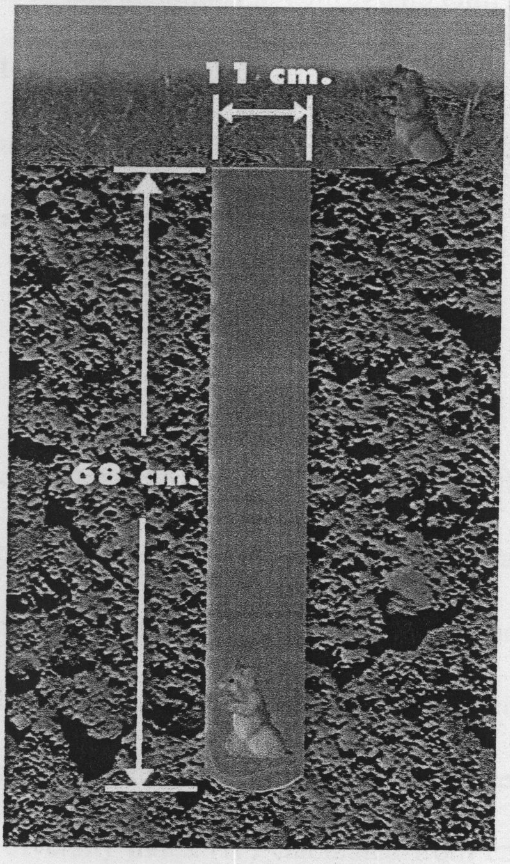


Figure 4.5 Diagram of a pit fall trap

4.2.3 Burning Methods

Burning was started in the afternoon on 13 April 2003, after checking the wind; burning was initiated from south to north. The next day I set transects and stations on the same lines and points as before the burn.

4.2.4 Small Mammal Surveys / Data Collection

4.2.4.1 Preliminary collection

Preliminary surveys took 7 days to develop species accumulation curves, and after 4 days the curve remained constant. The species number at a site was determined when the cumulative species number reached an asymptote with trapping effort. I started to collect data in September 2002 and continued to collect data until the end of July 2003.

4.2.4.2 Before burn / after burn collection

I took 4 days for each survey. The before-burn survey was defined as the period January-April 2003 and after burn May-July 2003

4.3 Data Analysis

4.3.1 A relative abundance index (RAI) was used to estimate the relative abundance of all species based on capture rates. Two estimates of relative abundance were used. The RAI was a simple animal abundance index defined by the number individuals caught per 100 trap-nights. Standardized measures of diversity and abundance (Magurran, 1988) were used to facilitate direct comparisons between grassland and forest sites. The Shannon diversity index (H') calculated from captures on the 5 lines was used to measure diversity before and after the fire.

4.3.2 Program CAPTURE for density estimation

In capture-recapture studies, the animals are marked or tagged for future identification, and then returned to the population, particularly at the same point. Program CAPTURE is a comprehensive computer program that contains eight models but five are concerned with estimators for estimating population size when the sources of variation in capture probabilities act individually or in combination. All models in CAPTURE assume demographic closure and include: a constant capture probability model, M_o, the time variation model, M_t the behavioral response model, M_b, the individual heterogeneity model, M_h, and combination of the last three models M_{bh}, M_{th}, M_{tb}, and M_{tbh}. Program CAPTURE is used to test the assumption of whether a population is closed and to detect the sources of variation in capture probabilities of the animals. Program CAPTURE was used to estimate survival and population density. The CAPTURE software was run on the Patuxent Wildlife Research Center web site (http://www.mbr-pwrc.usgs.gov/ software/capture.html). I used model M_h: whereby capture probabilities vary by individual animal. The model assumes individual heterogeneity which permits each member of a population to have its own probability of capture independent of all other members of the population; it assumes no difference between trapping occasions and no behavioral response to capture. Heterogeneity may be due to age, species, sex (White and et al, 1982).

4.3.3 Statistical Analysis

T-tests were used to compare distributions in each habitat before and after fire. Paired-sample Wilcoxon-Tests were used to compare survival rates in each species before and after fire. Sorenson test of similarity was used to compare the species community among habitats before and after the burn. Sorensen's test = 2 x (the sum of the smaller value of abundance of each species in the two habitats being compared)/ (sum of abundance of all species in habitat 1 + sum of abundance of all species in habitat 2) Capture rates per 100 trap nights of all species for each of the three habitats was also used to compare among habitats before and after fire.

CHAPTER 5 RESULTS

5.1 Trapping effort

Live-trapping was repeated three times at roughly one month intervals (Table 5.1). At each of five trap lines, trapping was done over a period of four days. Live trapping from September 2002 to July 2003 resulted in 481 captures of 8 small mammal species from 3,600 trap-nights of sampling. Before fire there were 279 captures representing 71 individuals of 8 species, while the total after the fire was 202 captures representing 81 individuals of 6 species (Figure 5.1). Prior to 9 March 2002, *Mus caroli* could not be reliably marked because it could not be ear tagged. After 9 March 2002 ear punching was shown to be a reliable method for marking. In a few cases *M. surifer* and *R. rattus* ear tags were pulled off by perhaps getting caught on vegetation and tearing the pinna (see Table 5.2).

Table 5.1 Trapping schedule for five replicate trap lines (A-E) at Klong E-Tao, Khao Yai National Park.

Before fire	A	B	C	D	E
Rep. 1	10-13 Jan 03	26-29 Jan 03	9-12 Feb 03	6-9 Jan 03	26-29 Jan 03
Rep. 2	23-26 Feb 03	23-26 Feb 03	23-26 Mar 03	9-12 Feb 03	9-12 Mar 03
Rep. 3	23-26 Mar 03	9-12 Apr 03	4-7 Apr 03	9-12 Mar 03	4-7 Apr 03
After fire					
Rep. 1	4-7 May 03	4-7 May 03	18-21 May 03	18-21 May 03	4-7 Jun 03
Rep. 2	4-7 Jun 03	19-22 Jun 03	19-22 Jun 03	23-26 Jun 03	23-26 Jun 03
Rep. 3	7-10 Jul 03	7-10 Jul 03	11-14 Jul 03	11-14 Jul 03	23-26 Jul 03

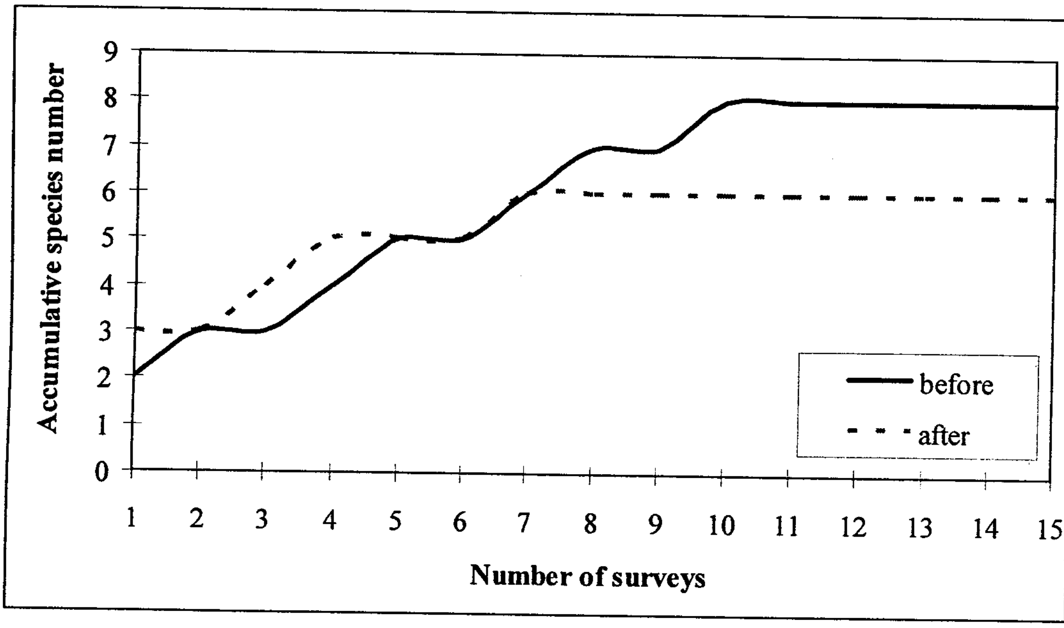


Figure 5.1 Small mammal species accumulated in three habitats before and after fire. Each survey consisted of 4 nights of trapping on 1 trap line.

5.2 Patterns of species occurrence

A total of 8 species were recorded in the traps during the study period: 7 species from the forest, 6 from the edge, and 5 in the grassland. Yellow Rajah Rat (*Maxomys surifer)* Chestnut Rat *(Niviventer bukit),* Ryukyu Mouse (*Mus caroli*), and Roof Rat *(Rattus rattus)* were recorded in all three habitats. Noisy Rat *(Leopoldamys sabanus)* was recorded in the forest and in the edge. Two insectivores recorded were Horsefield's Shrew (*Crocidura horsefieldi*) caught in the grassland only, and Dwarf Shrew (*Crocidura estrusca*) caught in the forest only. Northern treeshrew (*Tupaia belangeri*) was recorded in the forest and the edge (Table 5.2).

M. surifer were most frequently recorded in the forest though small numbers of individuals were found in edge and grassland. *M. caroli* most frequently occurred in the grassland. *T. belangeri* was mostly caught in the forest, although at least one individual was caught in the edge. *C. horsfieldi*, *C. estrusca* and *L. sabanus* were rare species, the former occurring in grassland, the latter two species occurring in forest. After fire, *N. bukit* were also caught in the grassland where it had previously not been trapped. *C. horsefieldi* and *C. estrusca* were not found after fire. *M. surifer, R. rattus* and *T. belangeri* were recorded in the same habitats after fire.

Table 5.2 Species list and number of individuals of Klong E Tao substation before and after the burn.

Taxonomy	Sciencetific name	No.	Common name	Diet	Thai name	Species found in each habitat						Total number of individuals
						Forest		Edge		Grassland		
						Before	After	Before	After	Before	After	
Order Insectivora												
Suborder Menotyphla												
Family Tupaiidae												
Genus Tupaia	*Tupaia belangeri*	1	Common Treeshrew	insectivore	กระแตธรรมดา	4	3	1	1	0	0	14***
Suborder Lipotyphla												
Family Soricidae												
Subfamily Crocidurinae												
Genus Crocidura												
Subgenus Crocidura	*Crocidura horsfieldi*	2	Horsefield's Shrew	insectivore	หนูผีป่าเล็กขนเกรียน	0	0	0	0	1	0	1
Subgenus Suncus	*Crocidura estrusca*	3	Dwarf Sherw	insectivore	หนูผีจิ๋ว	1	0	0	0	0	0	1
Order Rodentia												
Suborder Myomopha												
Family Muridae												
Subfamily Murinae												
Genus Mus												
Subgenus Mus	*Mus caroli*	4	Ryukyu Mouse	omnivore	หนูหริ่งนาหางยาว	1	1	1	0	9	14	29**
Genus Rattus												
Subgenus Maxomys	*Maxomys surifer*	5	Yellow Rajah Rat	omnivore	หนูฟานเหลือง	32	34	12	8	1	1	72*
Subgenus Niviventer	*Niviventer bukit*	6	Chestnut Rat	omnivore	หนูขนเสี้ยนดอย	5	5	1	2	0	1	14
Subgenus Rattus	*Rattus rattus*	7	Roof Rat	omnivore	หนูท้องขาว	1	6	1	1	2	4	14
Subgenus Leopoldamys	*Leopoldamys sabanus*	8	Noisy Rat	omnivore	หนูหวาย	0	1	1	0	0	0	1
Total number of individuals						44	50	15	12	19	11	146
Number of species						6	6	6	4	4	4	8
Total species found in each habitat						7		6		5		8

* Estimated number of individuals as some ear tags were lost. **Estimated number of individuals as some permanent pen ink mark were lost. *** Estimated number of individuals because this species could not be ear tagged. Initial marks with permanent pen faded quickly, so animals were marked by cutting patches of fur.

5.3 Similarity of species composition before and after fire.

Sorensen's test was used to assess the degree of species similarity between and within habitats before and after fire (Table 5.3). Before fire there was a relatively high degree of similarity of species between the forest and the edge whereas species in the forest and grassland and the grassland and edge were highly dissimilar. After fire the similarity of species between the forest and the edge increased 62%, while the similarity between the forest and grassland increased 68%, but the similarity was still low. The level similarity between the grassland and edge was unchanged after the fire.

Within habitats there were changes in similarity of species before and after fire (Table 5.3). The species similarity in the forest habitat decreased by 10% whereas the similarity in the other two habitats approximately halved.

Table 5.3 Similarities (based on Sorensen's index) between and within habitats before and after the burn.

Period	Comparison	Sorenson's test
Habitat/before burn	forest and grassland	0.12
	forest and edge	0.52
	grassland and edge	0.18
Habitat/after burn	forest and grassland	0.20
	forest and edge	0.84
	grassland and edge	0.18
Fire	Forest before and forest after	0.89
	Edge before and edge after	0.54
	Grassland before and grassland after	0.61

5.4 Species accumulation before and after fire

I separated the data into two time periods; before fire (December 2002 to April 2003), and after fire (April 2003 to July 2003) (Figure 5.2). When the accumulated species catch for the five trap lines before and after fire was compared the number of species caught decreased after fire and the overall accumulation rate appeared to be somewhat slower.

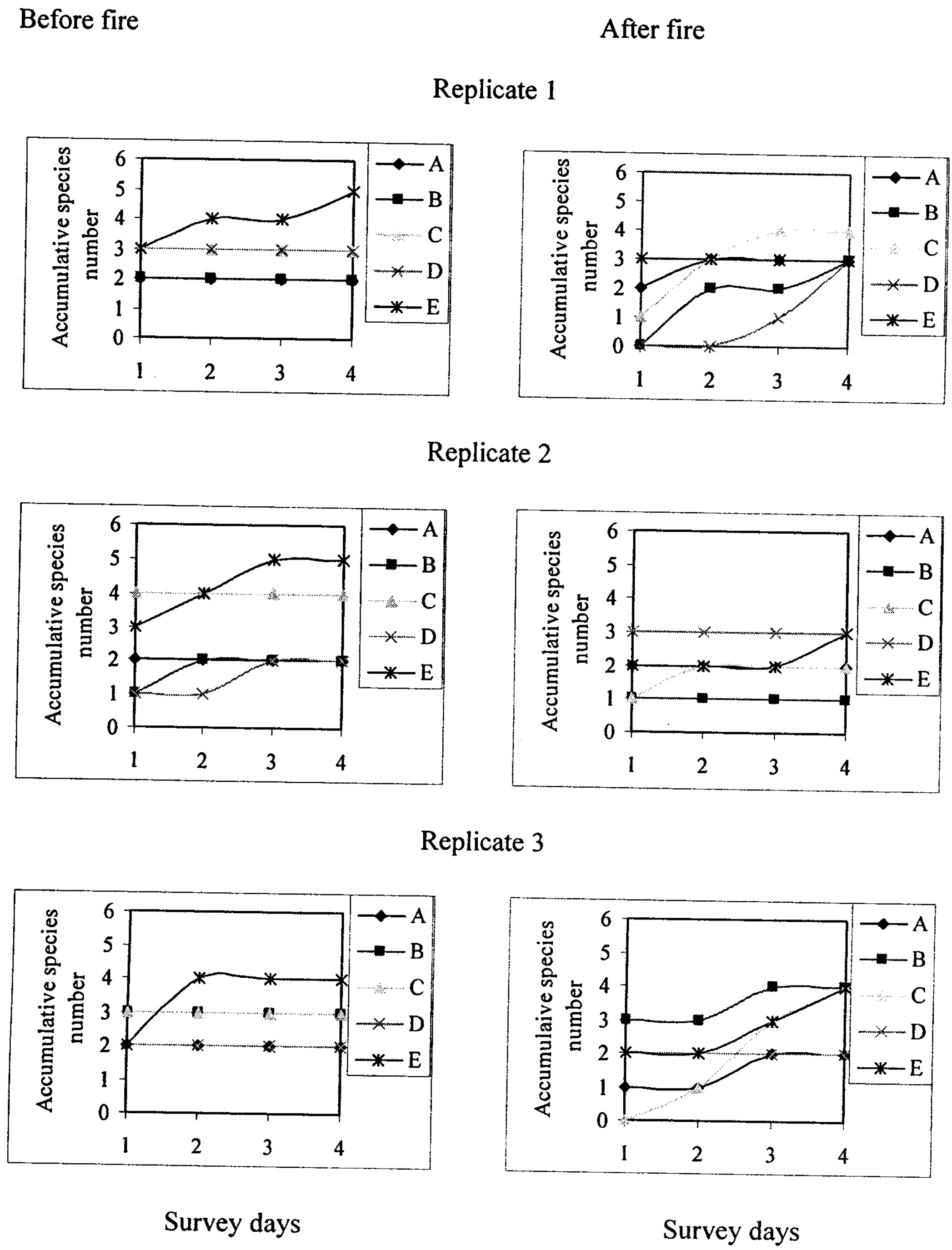


Figure 5.2 Accumulation of species from live-trapping at Klong E-Tao at three replicate sampling periods and five trap lines.

The three graphs below (Figure 5.3) show the accumulated number of different species captured in each habitat over time both before and after fire. The number species caught before and after the fire was the same in the forest and grassland habitats but two species recorded before fire (*Mus caroli* and *Leopoldamys sabanus*) were not observed after fire in the edge habitat.

In the forest habitat before fire the number of species caught accumulated to 6 after 23 days. After fire, however, it took just 16 days to capture the same number of species. In contrast, in the edge the accumulative capture was much slower after fire. Before fire 6 different species were caught within 25 days but after fire only 4 species had been caught during the entire capture period. In the grassland habitat the accumulative capture was quite similar both before and after fire with 4 different species being caught in 12 and 16 days respectively.

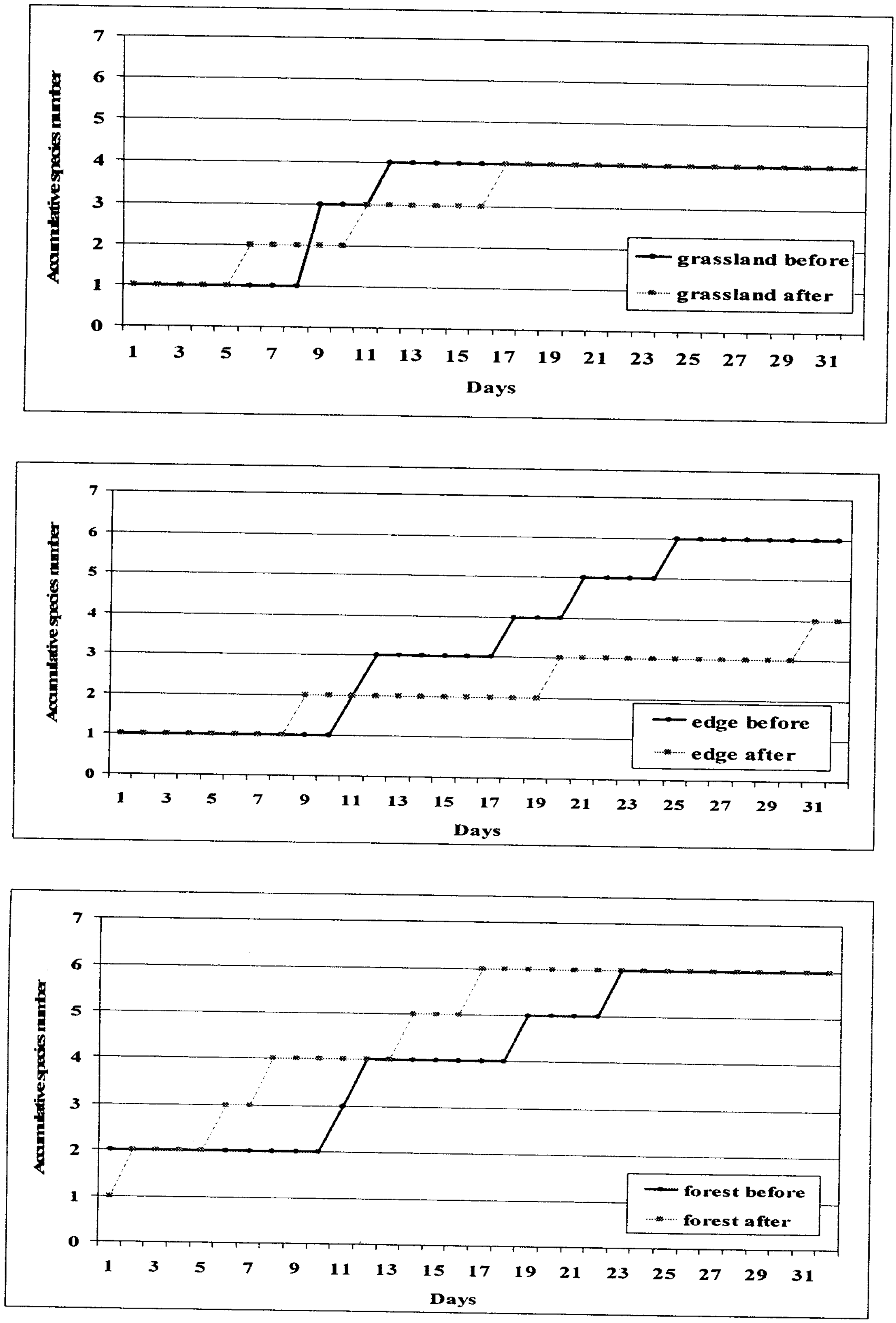


Figure 5.3 Accumulative species number in each habitat before and after fire. The days are total days traps were set for all lines combined.

5.5 Diversity before and after fire

The Shannon diversity index (H') calculated from captures on the 5 lines was used to measure diversity before and after fire. For each habitat, there was no significant difference in diversity before and after fire (t-test, $p>0.05$, df=8, t=0.40, mean in the forest before =0.17, mean in the forest after =0.21; t-test, $p>0.05$, df=8, t=0.25, mean in the edge before =0.11, mean in the edge after =0.13; t-test, $p>0.05$, df=8, t=0.23, mean in the grassland before =0.12, mean in the grassland after=0.10).

Table 5.4 Shannon diversity index in the different habitats together before and after fire.

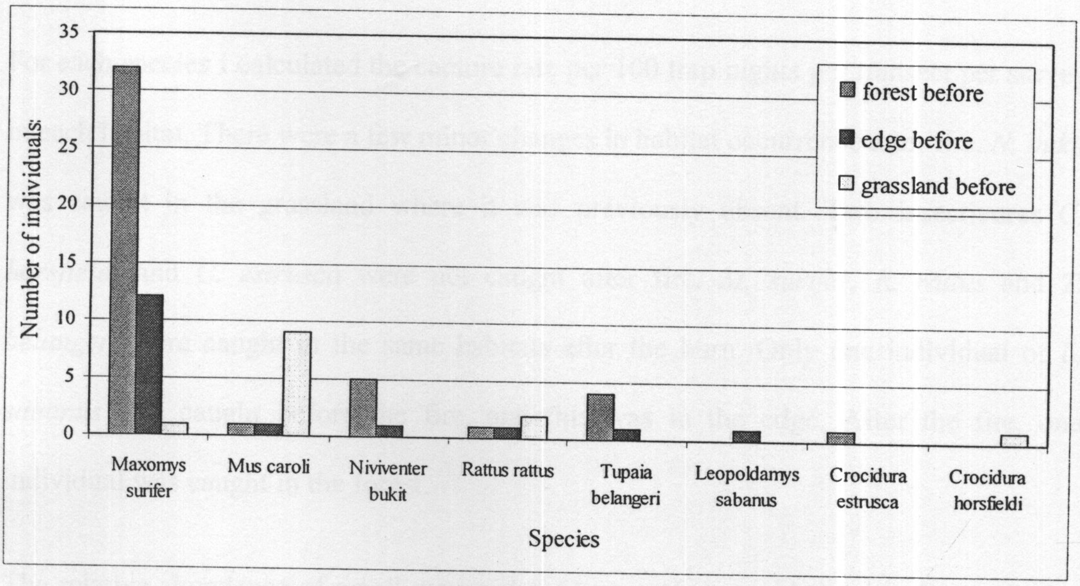
Shannon index	H' before fire	H' after fire
Three habitats combined	0.50	0.59
Forest	0.38	0.47
Edge	0.23	0.43
Grassland	0.21	0.27

5.6 Comparative abundance in habitats

The overall abundance of all small mammals in the forest was greater than in the grassland (t-test, $p=0.001$, df=8, t=4.09, mean in the forest=73.46, mean in the grassland=34.62). Also there was a significant difference in abundance between forest and edge (t-test, $p=0.04$, df=8, t=1.95, mean in the forest=73.46, mean in the edge=51.25). However, there was no significant difference in abundance between the grassland and the edge (t-test, $p=0.13$, df=8, t=1.21, mean in the grassland=34.62, mean in the edge=51.25).

There was no significant difference in abundance of small mammals per transect in the grassland before and after fire (t-test, $p=0.09$, df=8, t=1.47, mean per transect before fire=22.69 and mean per transect after fire=11.92. In the forest there was no significant difference in abundance before and after fire (t-test, $p>0.05$, df=8, t=1.33, mean per transect before fire=40.77 and mean per transect after fire=32.69). In the edge there was no significant difference in abundance of small mammals before and after fire (t-test, $p=0.08$, df=8, t=1.54, mean per transect before fire=32.5 and mean per transect after fire=18.75).

Before the fire



After the fire

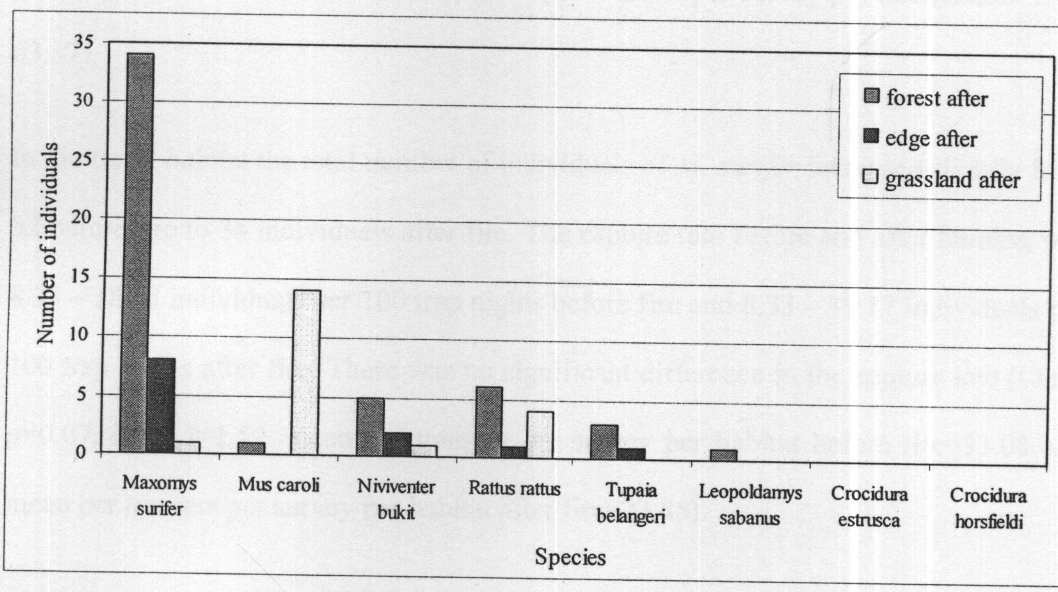


Figure 5.4 The total number of individuals before and after the fire in three different habitats.

5.7 Habitat associations and relative abundance before and after fire.

For each species I calculated the capture rate per 100 trap nights per transect per survey in each habitat. There were a few minor changes in habitat occurrence after fire. *N. bukit* was caught in the grassland where it was previously absent. Two insectivores *C. horsfieldi* and *C. estrusca* were not caught after fire. *M. surifer*, *R. rattus* and *T. belangeri* were caught in the same habitats after the burn. Only one individual of *L. sabanus* was caught before the fire, and this was in the edge. After the fire, one individual was caught in the forest.

The relative abundance of small mammal per transect/ survey/ habitat before and after fire was significantly different (t-test, p=0.01, df=8, t=2.46, mean per transect per survey per habitat before fire=95.96, mean per transect per survey per habitat after fire= 63.37).

In the forest habitat the total number of individuals of *M. surifer* increased slightly from 32 before fire to 34 individuals after fire. The capture rate before and after burning was 8.33 – 18.33 individuals per 100 trap nights before fire and 8.33 – 19.17 individuals per 100 trap nights after fire. There was no significant difference in the capture rate (t-test, p=0.07, df=8, t=1.59, mean per transect per survey per habitat before fire=33.08 and mean per transect per survey per habitat after fire=23.85).

The number of *M. caroli* individuals caught was the same (n=1) before and after the fire. In contrast, the number of individuals of *R. rattus* increased from 1 to 6 individuals (Figure 5.4). The relative abundance increased from 0.83 individuals per 100 trap nights before fire to between 1.67 – 5 individuals per 100 trap nights after fire. The capture rate was not significantly different, but nearly so (t-test, p=0.06, df=8, t=1.69, mean per transect per survey per habitat before fire =0.38 and mean per transect per survey per habitat after fire=4.62).

In the grassland habitat the number of individuals of *M. caroli* increased from 9 to 14 before and after fire. The relative abundance before and after fire was 2.5 – 13.33 and 0.83 – 10 individuals per 100 trap nights respectively. The difference in capture rate was almost significant (t-test, p=0.07, df=8, t=1.55, mean per transect per survey per habitat before fire =20.38 and mean per transect per survey per habitat after fire =8.85). The number of individuals of *T. belangeri* in the forest before fire and after fire was 4 and 3 individuals, the relative abundance was between 0.83 – 3.33 before fire and after the fire between 0.83 – 1.67 individuals per 100 trap nights. There was no significant difference in the capture rate (t-test, p=0.14, df=8, t=1.16, mean per transect per survey per habitat before fire=3.85 and mean per transect per survey per habitat after fire=1.15). *N. bukit* the number of individuals in the forest before and after fire in the forest was 0.83 – 5 individuals per 100 trap nights and after fire 0.83 – 2.5 individuals per 100 trap nights, there was not a significant difference in the capture rate (t-test, p=0.38, df=8, t=0.32, mean per transect per survey per habitat before fire=2.69 and mean per transect per survey per habitat after fire=2.31).

5.8 Small mammal distribution relative to the forest – grassland edge

Figures 5.5 and 5.6 shows the capture distribution of all 8 species in each habitat for a distance of 135 meters from the edge into the forest and into the grassland before and after fire. For all species except *R. rattus,* the total number of captures decreased in all 3 habitats after the fire. *M. caroli* was only found in the grassland and here too the total number of captures decreased after fire. In contrast, the number of *R. rattus* increased after the fire. Changes in capture distribution of the main species are described in more detail below.

M. surifer was by far the most common species in the edge and forest habitats. Before fire this species was evenly distributed throughout these two habitats with the total number of captures ranging from approximately 8 to 30. After fire, although distribution remained uniform, the maximum value of the capture range decreased to less than 20. These differences were significant (t-test, $p<0.05$, df=16, t=2.72, mean per habitat per distance before fire= 19.44 and mean per habitat per distance after fire=12.68).

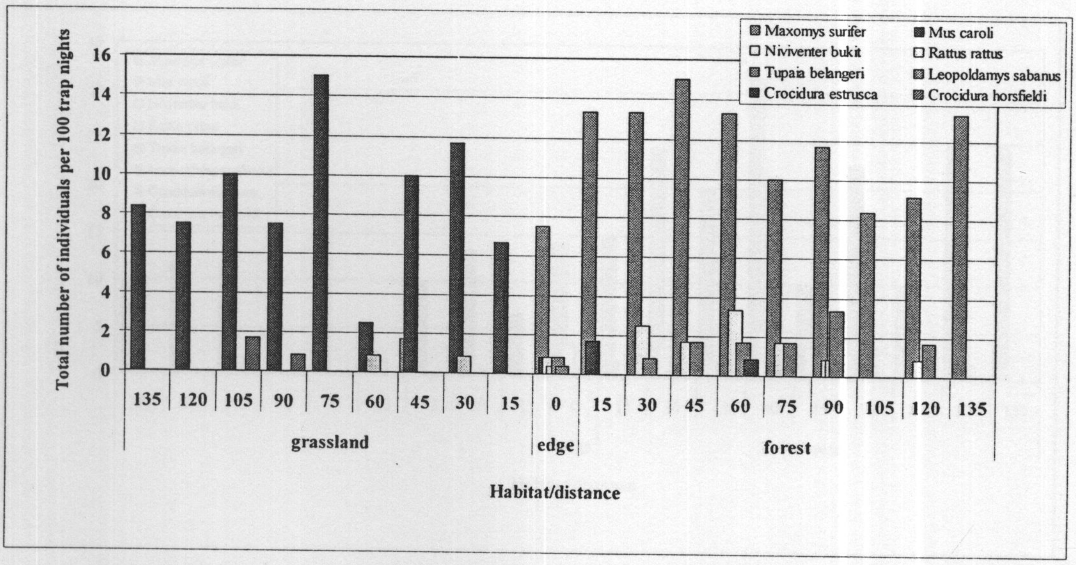
M. caroli was the most common species in the grassland. Before the fire it was also present in the edge habitat and was found sporadically in the forest. Before fire the total number of captures ranged from about 3 to 15 in the grassland and the capture distribution was uniform throughout this habitat. After the fire the number of captures was significantly less in grassland particularly within 45 meters from the edge (t-test, $p<0.05$, df=15, t=1.83, mean per habitat per distance before fire=9.25 and mean per distance after=6.04).

Though less common, *N. bukit* and *T. belangeri* were evenly distributed throughout the forest and in the edge habitats before the fire. The total number of captures per 100 trap nights of *N. bukit,* which ranged from 1 to 7, was not significantly different after fire (t-test p=0.08, df=14, t=1.44, mean before fire=2.19 and mean after fire=1.15) but the distribution changed. After fire the capture rate went up to 7 in the grassland where the species had not been found before while capture rates in the forest and edge went down. Before fire the capture rate of *T. belangeri* ranged between 1 and 4 individuals but after fire the *T. belangeri* was rarely captured in the forest habitat. Both these species remained present in the edge. *L. sabanus, C. horsfield, and C. estrusca* were rare species and were each only captured once before the fire. After fire no shrews were captured, and only 1 new individual of *L. sabanus* was recorded.

In contrast with the other species the capture rate of *R. rattus* increased but not significantly after fire (t-test, p=0.14, df=4, t=1.24, mean before=0.83 and mean after=3.16). Before fire *R. rattus* was mostly captured in the edge and grassland habitats up to 60 meters from the edge and one individual at 90 m into the forest. The capture rate ranged from 1 to 3 captures per 100 trap nights per habitat per each distance. After the fire, however, *R. rattus* captures appeared to increase, particularly in the forest while the upward limit of the capture range increased to 3 captures per 100 trap nights. *R. rattus* also used the edge habitat before and after the burn.

Figure 5.5 shows the distribution of each species along all the transects combined. The center of distribution of *M. caroli* was in the grassland. The centers of distribution of *M. surifer* and *T. balangeri* were in the forest while that of *R. rattus* was around the edge.

Before fire



After fire

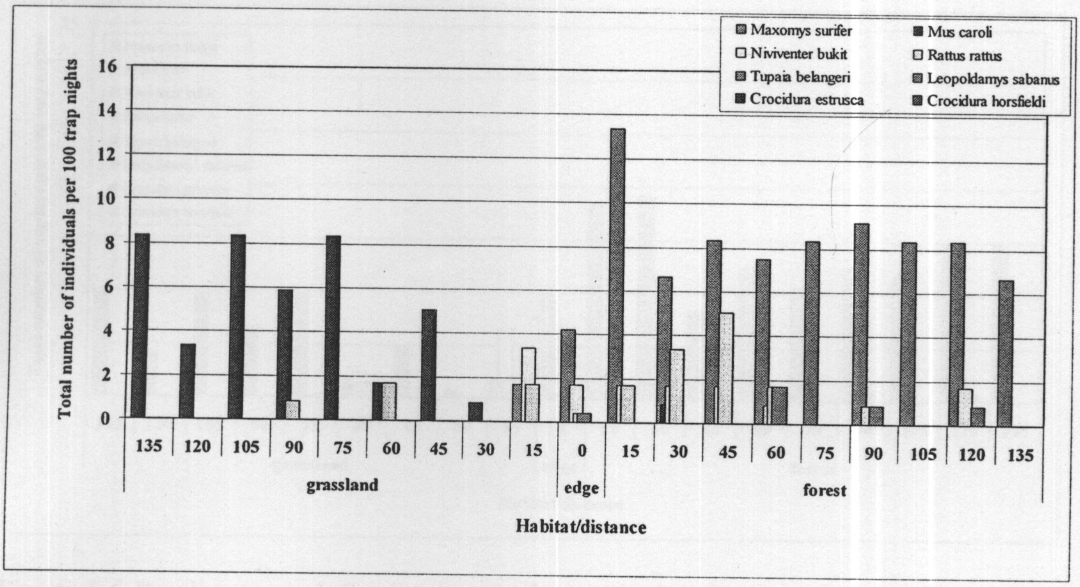
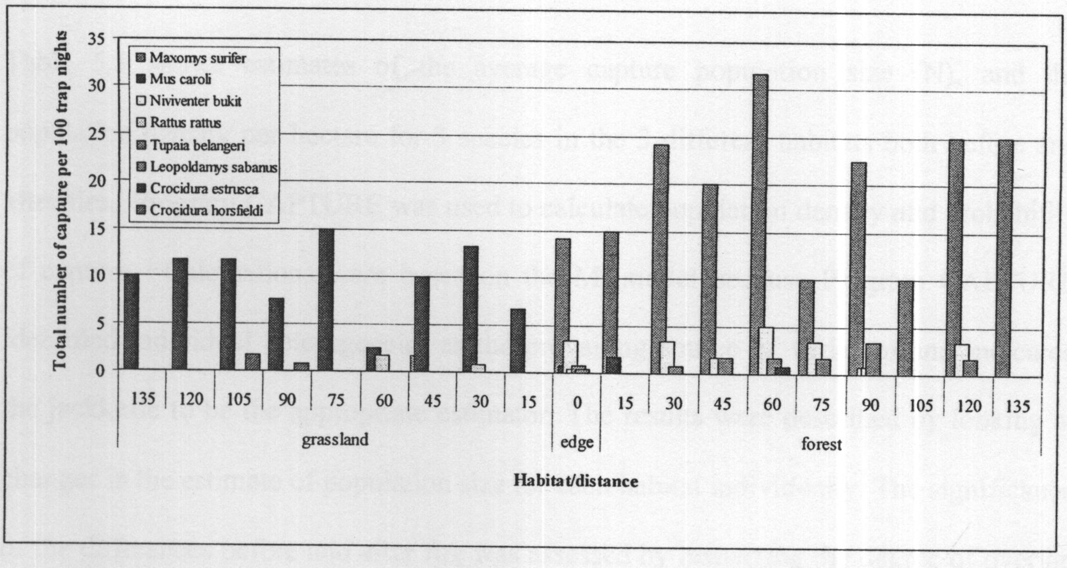


Figure 5.5 Small mammal distributions before and after fire based on number of different individuals captured.

Before fire



After fire

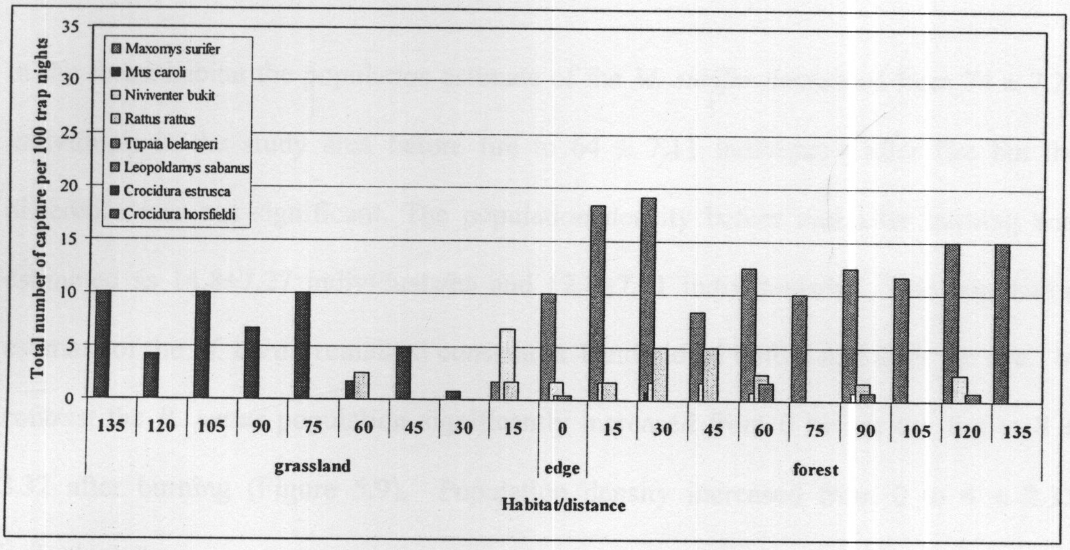


Figure 5.6 Small mammal distributions before and after fire based on total number of captures

5.9 Density

Table 5.5 shows estimates of the average capture population size (N), and the population density per hectare for 3 species in the 3 different habitats both before and after fire. Program CAPTURE was used to calculate population density and probability of capture. Calculations were based on the M_h model because Program CAPTURE identified individual heterogeneity as the prevailing source of variation and indicated the jackknife to be the appropriate estimator. The results were described by looking at changes in the estimate of population size for each habitat individually. The significance of the differences before and after fire was assessed by inspecting the degree of overlap of standard error bars (Figures 5.7-5.9).

In the forest habitat the population estimate of the *M. surifer* decreased from 74 ± 7.27 individuals in the study area before fire to 64 ± 7.11 individuals after fire but the difference was not significant. The population density before and after burning was estimated as 14.8±7.27 individuals/ha and 12.8±7.11 individuals/ha. The population estimate of the *M. caroli* remained constant at 1 individual before and after the fire. In contrast the *R. rattus* population significantly increased from 0 before the fire to 8 ± 2.32 after burning (Figure 5.9). Population density increased from 0 to 4 ± 2.32 individuals/ha.

In the edge habitat the estimated population of the *M. surifer* almost halved from 25 ± 4.61 before the fire to 14 ± 3.02 after fire and this difference was significant (Figure 5.7). The population density decreased proportionately from 5.0 ± 4.61 individuals/ha to 2.8 ± 3.02 individuals/ha.

The *M. caroli,* which had an estimated population of 1 individual before the fire, was not captured in this habitat after the fire while the *R. rattus* population remained the same at 1 individual with a population density of 0.5 ± 0.00 individuals/ha.

In the grassland habitat the estimated population and population density of *M. surifer* was 3 times higher before the burn than after. Its population significantly decreased from 3 ± 0.16 to 1 while its population density decreased from 0.6 ± 0.16 individual/ha to 0.2 ± 0.00 individual/ha (Figure 5.7). In contrast the population of the *M. caroli* and the *R. rattus* both significantly increased after fire (Figures 5.8-5.9),. The *M. caroli* population rose from 3 ± 0.16 to 5 ± 1.52 individuals while the *R. rattus* population went up from 3 ± 1.07 to 4 ± 2.17. Population density increased proportionality from 0.5 individuals/ha to 0.8 individuals/ha for *M. caroli* and from 1.5 individuals/ha to 2.0 individuals/ha for *R. rattus.*

To summarize, the *M. surifer* population dropped significantly in the edge and grassland habitats after the burn. In contrast both the *M. caroli* and *R. rattus* populations increased in the grassland habitat. Also the *R. rattus* population increased dramatically in the forest habitat.

Table 5.5 Estimated population size (N) and density derived from Program CAPTURE

Model used (Mh)		p	N	SE	*Nci*	individuals/ha
Maxomys surifer	Forest before	0.3919	74	7.2657	64-93	14.8
	Forest after	0.3073	64	7.1066	54-82	12.8
	Edge before	0.2933	25	4.6149	20-39	5.0
	Edge after	0.3571	14	3.0233	12-24	2.8
	Grassland before	0.7778	3	0.1639	3-3	0.6
	Grassland after	0.6667	1	0.0000	1-1	0.2
Mus caroli	Forest before	0.6667	1	0.0000	1-1	0.2
	Forest after	0.6667	1	0.0000	1-1	0.2
	Edge before	0.6667	1	0.0000	1-1	0.2
	Edge after	0.0000	0	0.0000	0	0.0
	Grassland before	0.7778	3	0.1639	3-3	0.5
	Grassland after	0.4000	5	1.5174	5-11	0.8
Rattus rattus	Forest before	0.0000	0	0.0000	0	0.0
	Forest after	0.3333	8	2.3200	7-18	4.0
	Edge before	0.3333	1	0.0000	1-1	0.5
	Edge after	0.3333	1	0.0000	1-1	0.5
	Grassland before	0.3333	3	1.0723	3-8	1.5
	Grassland after	0.3333	4	2.1695	4-4	2.0

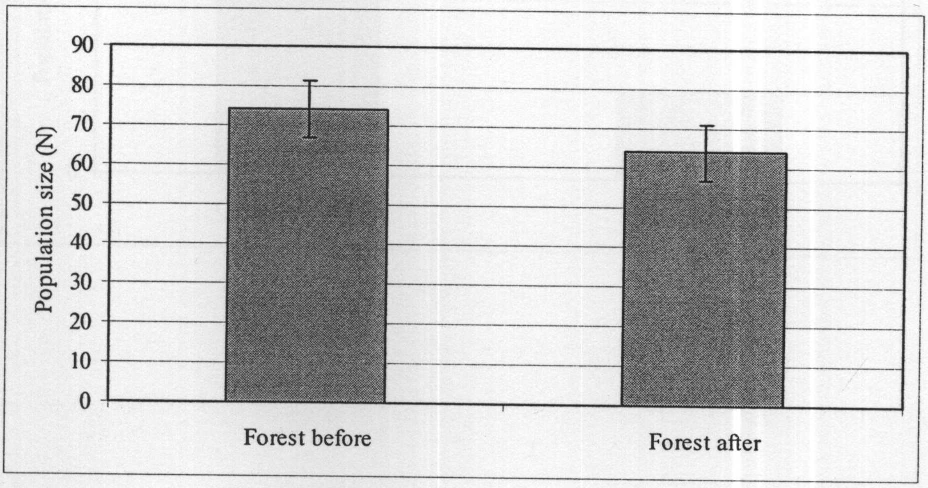
P; Estimated probability of capture

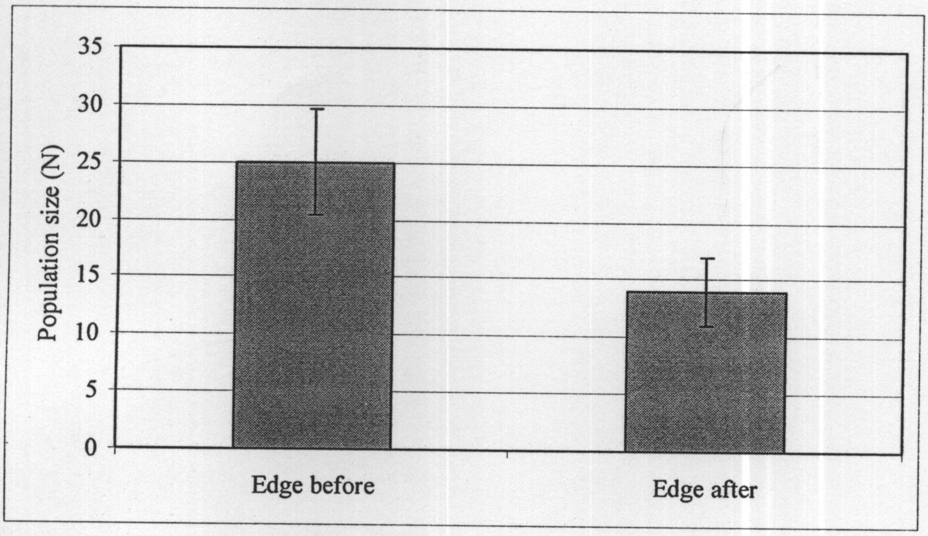
N; Population size

SE; Standard error of N

N_{ci}; 95% confidence

Figure 5.7 Population sizes of *Maxomys surifer* in three habitats based on estimates from the Program CAPTURE. Estimates with non-overlapping standard errors are considered significantly different.





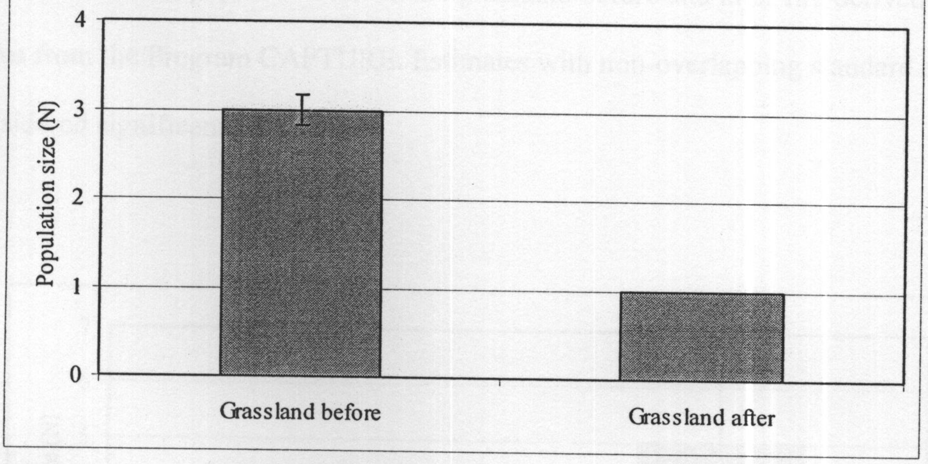

4
3
2
1
0
Population size (N)
Grassland before
Grassland after

Figure 5.8 *Mus caroli* population size in the grassland before and after fire derived from estimates from the Program CAPTURE. Estimates with non-overlapping standard errors are considered significantly different.

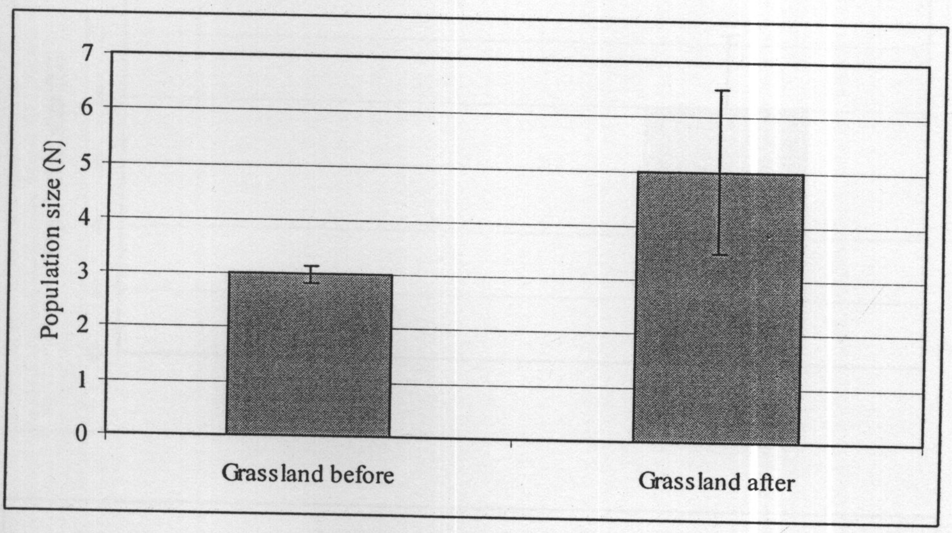
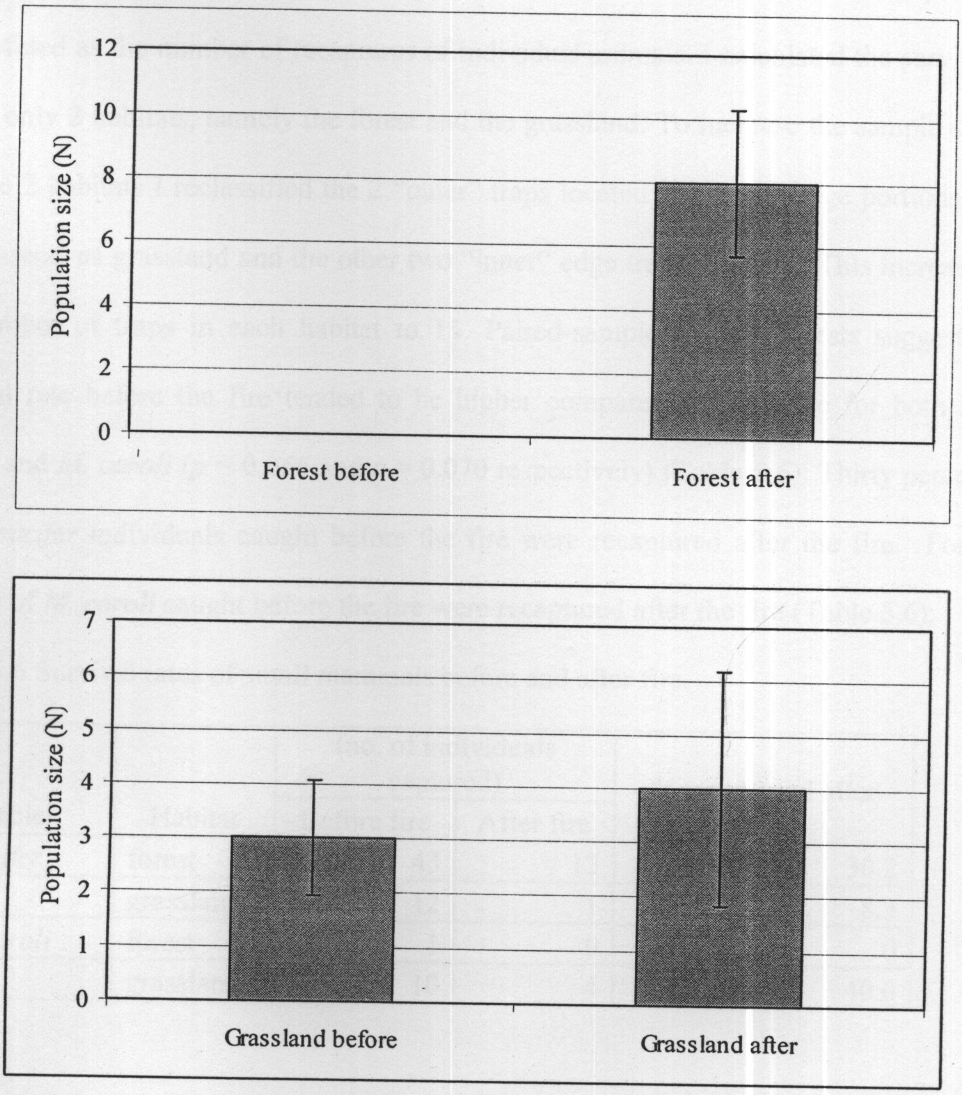


Figure 5.9 Population sizes *Rattus rattus* in two habitats based on estimates from the Program CAPTURE. Estimates with non-overlapping standard errors are considered significantly different.



5.10 Survival rates

I compared the survival rates of forest-dwelling *Maxomys surifer* and grassland-dwelling *Mus caroli* before and after fire. An index of survival rate for each species was defined as the number of recaptures of individual animals. I calculated the survival rate in only 2 habitats, namely the forest and the grassland. To increase the sample size in these 2 habitats I reclassified the 2 "outer" traps located in each of edge portions of the transects as grassland and the other two "inner" edge traps as forest. This increased the number of traps in each habitat to 15. Paired-sample Wilcoxon-tests suggested survival rate before the fire tended to be higher compared to after fire for both *M. surifer* and *M. caroli* (p = 0.066 and p = 0.070 respectively) (Table 5.6). Thirty percent of *M. surifer* individuals caught before the fire were recaptured after the fire. Forty percent of *M. caroli* caught before the fire were recaptured after the fire (Table 5.6).

Table 5.6 Survival rates of small mammals before and after fire.

Species	Habitat	(no. of individuals captured)		% recaptured after fire
		Before fire	After fire	
M. surifer	forest	43	13	30.2
	grassland	12	1	8.3
Mus caroli	forest	1	0	0
	grassland	10	4	40.0

CHAPTER 6 DISCUSSION

6.1 Species composition

A total of eight species of small mammal were captured during this study. Seven species (M. surifer, T. belangeri, N. bukit, R. rattus, C. estrusca, M. caroli and L. sabanus) occurred in forest habitat. Six of these (M. surifer, T. belangeri, N. bukit, R. rattus, Mus caroli and L. sabanus) also occurred in edge habitat. Five species (Mus caroli, M. surifer, C. horsfieldi, N. bukit and R. rattus) occurred in grassland habitats with four species, Mus caroli, N. bukit, M. surifer and R. rattus, occurring in all three habitats. Although previous lists indicated that Khao Yai National Park had 20 species of small mammals, there are a number of reasons for the low number of species captured in this study. Firstly, the grassland appeared to be a relatively poor quality habitat for small mammals, having lower species richness, diversity, and abundance than either forest or edge habitats. Secondly, my trapping methods were designed for ground dwelling and ground-frequenting species. Therefore, none of the nine species of mostly arboreal squirrel found in Khao Yai were caught (Pasho, 2000). The other three species that were not caught included the pig-tailed shrew (Hylomys suillus), Sladen's Rat (Rattus loratensis) and Lesser bandicoot (Bandicota savilei). Although pig-tailed shrews are known to inhabit evergreen forest (Lynam 1997), the species' status at Khao Yai is currently unknown (Srikosamatara and Hansel, 2000). Sladen's Rat is a medium-sized (129g.) murid rodent and is rare in Khao Yai (Srikosamatara and Hansel, 2000). Lesser bandicoot (Bandicota savilei) occurs in foothill localities including Korat, Nakhon Nayok, Tak and Ubon Ratchathani. It lives in grass beneath teak forest in Tak province, along with M. surifer. The species is also found in cleared foothill areas in cornfields and tall grass (Lekagul and McNeely 1988). I did not record this species at Khlong E-Tao but Soontompitakkool, (1996) found it commonly in evergreen forest at Khao Yai quite near my study site, although exact locations were not provided. Surprisingly, Soontompitakkool (1996) caught Bandicota savilei and R. rattus but no other species of small mammals. However, measurement data from Lekagul and McNeely (1988) and my study suggest that the animals caught during Soontompitakkool's 11-day study may have been misidentified. Third, although I also used pit-fall traps specifically to catch shrews, none were caught. Perhaps this type of trap would have been more successful if it were used together with a fence to guide animals towards the trap, such as Oguge, et al. (2004) who used it successfully to catch Crocidura cf. selina.

6.2 Patterns of species occurrence

Although *M. surifer* was mostly found in the forest, Yasuda et al. (2003) also explains that *M. surifer* can survive in edge habitat because they usually nest underground and are not so dependent on the forest to provide nesting sites. This species was found in the edge habitat in this study, but at lower densities. Yasuda et al. (1998) also suggested that this was true for *L. sabanus* which was also found in the edge habitat in this study.

From studies of small mammals in three habitat types in Salak Phra Wildlife Sanctuary, Karnchanaburi Province. *M. surifer* was also the most common small mammal particularly in lowland and upland forest 55-1,210m., and lowland bamboo forest (Wiles 1981). While *R. rattus* was found in all three types of forests and within the vicinity of the sanctuary staff's living quarters; the highest frequency occurred in the dry dipterocarp forest, confirming that open forest may be a favored habitat as also suggested by Klinhorm and Tinarat (1993).

In contrast to *M. surifer, M. caroli* prefers the grassland habitat because its diet is mostly made up of grass seeds and invertebrates (Lekagul and McNeely 1977). Furthermore they are less dependent on the availability of nesting sites because they mostly nest in underground burrows (Adler 1995). Similarly, *R. rattus* prefers the grassland habitat because it feeds largely on grass seeds (Lekagul and McNeely 1977 and AICAF, 1996). However, normally small mammals prefer habitats where there is litter cover (AICAF, 1996).

R. rattus was found in greater numbers in the forest after the fire than before and this may also have been related to loss of litter and other vegetation cover in the grassland as in the above examples. In this case, the loss of accumulated litter cover may have forced *R. rattus, M. surifer* and some *T. belangeri* to seek temporary cover in the forest to protect themselves from predators. I found only one individual of *R. rattus* in the edge and it moved 15m into the forest after fire. However, another individual of *R. rattus* was caught at the same station in the edge after fire.

In this study only two species, *Mus caroli* and *R. rattus* were commonly found in the grassland. Grassland habitat may have been favored by these species because of reduced habitat complexity (Yasuda et al. 1998, Liat et al. 2003, Marcks, 2004) and that few species can tolerate the yearly burning, particularly the removal of litter cover (Wright and Bailey 1982). In general, extensive disturbance has been shown to significantly reduce the richness of small mammal communities in grasslands (AICAF, 1996, Hartnett, 1997, McLeod et al., 1997) and forest habitats (Yasuda et al. 1998, Marcks, 2004, Lim et al. 2003). Similarly in this study after fire, the number of captures *M. caroli*, near the edge fell rapidly and the species essentially disappeared from the edge itself, although it was scarce in this habitat even before fire. The grassland did provide habitat for one rare species in this area, *Crocidura horsfieldi* although more fenced pit-fall trapping would need to be done in all three habitats to understand the distribution of this species.

In general, tropical grasslands appear to support fewer species than nearby tropical forest. According to Yasuda et al. (1998) forest habitat is richer in food resources and nesting sites than grassland. Previous studies indicated that the species richness and overall density of small mammals in primary forest was higher than in regenerating forest (Yasuda et al. 1998, Lim et al. 2003, Marcks, 2004). Three species (*T. glis, L. sabanus* and *M. surifer*) found in this study were also found by Yasuda et al., (2003) and Lim et al., (2003) in Malaysia. In their studies, *L. sabuanus* and *M. surifer* were much more common in primary forest than in regenerating forest while the abundance of *T. glis* was almost the same in both habitats. Likewise, in my study *M. surifer* was much more common in the forest and edge than in the grassland while *L. sabanus* and *T. belangeri* were only found in the forest and the edge.

As in Lim et al. (2003), the results of this study show that the abundance and richness of small mammal species was greater in the forest habitat than in the edge and grassland. This study also suggested that species richness in the forest was higher than in the grassland. This too is consistent with the capture data of Lim et al. (2003), in Malaysia where 26 species were caught in the primary forest compared to only 17 in the regenerating forest. These findings have important implications for park management. They indicate that a policy of creating more grassland to facilitate the viewing of large mammals may be detrimental to the diversity and abundance of small mammal species in the park. The results of Lim et al. (2003) also suggest that the diversity and abundance of small mammals recuperates in regenerating forest if the habitat is left alone without further disturbance. In the light of this, from a small mammal perspective it would seem preferable not only to halt the expansion of grassland in the park but also to burn the existing grassland less frequently.

SPECIES COMPOSITION AMONG HABITATS

Forest vs. grassland before fire.

The Sorensen's index suggested that the small mammal communities of the forest and grassland were quite different (Sorensen's index = 0.12). Specifically, *Mus caroli* were relatively abundant in the grassland while relatively rare in the forest, the opposite for *M. surifer* which was abundant in the forest and scarce in the grassland. Other species common in the forest, but rare in the grassland included *N. bukit*, *L. sabanus* and *T. belangeri.*

Forest vs edge before fire.

Before fire the forest and edge communities were moderately similar (Sorensen's index = 0.52). Species richness was the same, 6 species, in both habitats but there abundances of *M. surifer*, N. bukit, and T. belangeri were much lower in the edge than in the forest.

Grassland vs edge before fire.

In the grassland and the edge before fire the community was quite different (Sorensen's index = 0.18 similarity). The similarity of species composition was low partly because the species richness in the grassland was less than in the edge. Only four species were found in the grassland compared with six in the edge. Furthermore the abundance of *M. surifer* was significantly less in the grassland than in the edge while that of *Mus caroli* was much higher in the grassland, while *R. rattus* abundance was somewhat higher in the grassland.

Species composition among habitats after fire.

Forest before and after fire.

The Sorensen's index suggests that the small mammal communities of the forest before and after fire were very similar (Sorensen's index = 0.89 similarity) as expected. The species richness was the same before and after fire but species abundances changed. *M. surifer* abundance was mostly unchanged after fire while *R. rattus* was significantly more abundant. The abundance of *T. belangeri* appeared to be relatively unchanged after fire. One individual of *L. sabanus* was captured after the fire in the forest and had not been captured in this habitat before the fire.

Edge before and after fire.

The Sorensen's index suggests that the small mammal communities of the edge before and edge after fire were only moderately similar. The Sorensen's index was only 0.54 because the species richness before was higher than after fire. Also, after fire *M. surifer, N. bukit, R. rattus,* and *T. belangeri* were captured more frequently in the edge before than after fire and there were no captures of *M. caroli* and *L. sabanus* after fire.

Grassland before and after fire.

The Sorensen's index suggested that the small mammal community of the grassland before and after fire were moderately similar (Sorensen's index = 0.61). There were no changes in the species richness but after fire *M. surifer* decreased significantly in abundance, while, *M. caroli* although initially decreasing immediately after the burn, did significantly increase after fire. *C. horsfieldi* was not recaptured, while one individual of *N. bukit,* was recorded for the first time in this habitat.

Forest vs grassland after fire

There appeared to be some increased similarity between the forest and grassland habitats after the fire (Sorensen's index = 0.12 before and 0.20 after). This apparent increase in similarity may have been due to *R. rattus* which increased in abundance in the forest after fire and remained about the same or slightly increased in the grassland. Species richness was still the same in both habitats. In any event, the low similarity in species composition shows that there was little overlap in habitat preferences between the species found in the forest and those found in the grassland,

When the grassland was burned some species, particularly *M. surifer* decreased, although the numbers of *M. surifer* were low in the grassland before the fire. Similarly, *M. caroli* had a strong preference for grassland habitat both before and after the fire, and increased in the grassland after the fire.

Forest vs edge after fire.

There appeared to be some increased similarity between the forest and edge habitats after the fire Sorensen's index = 0.52 before and 0.84 after. This apparent increase in similarity may have been due to *M. surifer* which significantly decreased in the edge. There is a sharp boundary between the forest and the adjacent grassland but *M. surifer, N. bukit*, *R. rattus* and *T. belangeri* appeared to have a relatively similar preference for forest and edge habitat. Also, *R. rattus* had increased capture rates in the forest and in the edge after fire and was most abundant near the edge. In the edge after fire, *N. bukit* tended to increase more than in the forest, but the capture rate of *M. surifer* decreased in the forest. These changes were, however, not large and may have been because of the random movement of these species in the area.

Grassland vs edge after fire.

The similarity between the grassland and the edge habitat was low both before and after fire with no change in the Sorensen's index value of 0.18. Whereas the species richness was higher in the edge before fire it was the same in both habitats after fire. After fire there were moderately fewer *M. surifer* but slightly more *N. bukit* in the edge than before fire. *C. horsfieldi*, which was rare before fire, was not recaptured in the grassland after fire but *M. surifer, N. bukit and R. rattus* occurred in the grassland especially within 15m of the edge. These three omnivores may have started using the grassland near the edge after fire because of greater food availability there. The major changes in food availability affect the type of species that will invade after a fire since removal of the litter layer increases availability of seeds and invertebrates for granivores and omnivores (Ahlgren 1966; Stout et al 1971; Kaufman et al 1983).

However, the most significant change was in the abundance of *Mus caroli*. This rodent disappeared from the edge and was much less abundant in the grassland immediately after fire, but nonetheless increased significantly after the burn. The decrease in abundance of this species after fire was perhaps due to the lack of cover immediately after fire which produces an exposed environment and improves accessibility to avian and mammalian predators (Motobu 1978). Beck and Vogl (1972) also suggested that some of the mortality associated with fire may be caused by predation, and that the post-burn predation may be more restrictive to rodent populations than the burning itself (Lawrence 1966).

6.3 Species responses to fire & habitat change

Different species of small mammals may respond differently to fire. There were some significant changes in community composition after the fire. The changes appeared to be mostly in abundance particularly *R. rattus* which increased in the edge and forest. *M. caroli* decreased immediately after the fire, but by the end of the study period had increased significantly after the fire in the grassland habitat compared with pre-burn densities, while *M. surifer* decreased in the grassland and edge. I did not find dead animals after the fire in the burned area, suggesting that direct mortality caused by fire was probably minimal, because vertebrates are typically able to avoid injury by fire (Komarek, 1969). Vieira and Marinho-Filho (1998) also suggested direct mortality by fire was negligible, although sometimes small mammals are killed (Chew et al., 1959;

Simons 1989). Generally, during wildfire rodents can dig burrows below the soil surface to provide temporary shelter (Coutinho 1978; Happold 1983) because the temperatures in burrows a few centimeters below the soil surface rarely increase to a lethal limit if the passage of the fire is rapid (Coutinho 1978, Happold 1983). But fire can have a pronounced effect on the distribution and abundance of small mammals inhabiting grassland (Masters, 1993).

The abundance of *M. surifer* in the forest before fire appeared to be greater than after fire, but the difference was not significant probably because fire did not affect this habitat directly. Although some individuals of *R. rattus* moved into the forest, the movement appeared to be only temporary as found elsewhere (Vieira and Marinho-Filho 1998). Vieira and Marinho-Filho (1998) also suggested this return time might be influenced by the extent of the burned area.

In my study, *M. caroli* was more abundant than before the fire, suggesting this species is already tolerant of this disturbance. In addition several studies have suggested that at least some grassland, small mammals can recover quickly from fire (Monroe, et al. 2005, Range 2003, Yahner 1991). *M. caroli* appeared to be affected only briefly as suggested by the capture of relatively few individuals in the grassland immediately after the fire. This species is also unaffected because they can also live in burrows and quickly reproduce. Data suggests that one 1 pair of *M. caroli* can produce multiple litters per year depending on factors such as food resources, habitat and predators (Tongtawee, at al. 1992).

If the grassland was burned less frequently, the grassland would probably accumulate more species with greater abundance, but presumably it would still be less diverse than the forest. At Khlong E-Tao, *R. rattus* was more abundant in the forest after fire, with animals moving perhaps to hide from the predators and to find food due to the temporary loss of shelter and food, exposure of surface runways, exposure of burrows and increased predation in the grassland habitat (Kaufman and Kaufman 1991). Anecdotal data suggested that predation may have also increased in my study area after the fire as more raptors were observed (*personal observation*). However, *R. rattus* appeared to move back to the grassland habitat presumably due to food availability and competition for food (Graham, 1997).

6.4 Survival rate

Although sample sizes were relatively small, recaptures after the fire suggested that the survival rate of *M. caroli* and *R. rattus* in the grassland was similar at 40% and 33% respectively. The survival rate of *M. surifer* in the grassland was only 8.3%. As mentioned before, the depletion of these species after fire was possibly due to increased avian predation resulting from reduced litter cover.

The survival rate of *M. surifer* in the forest after fire was 30%. The reduction in numbers of *M. surifer* in this habitat is in contrast to the increase in *R. rattus* there.

6.5 Methodological problems

For future studies, multiple marking may be needed to identify individuals because ear tags were sometimes lost, particularly from *M. surifer* and *R. rattus* and also caused occasional injuries to the ears. For *M. caroli* ear punching seemed to be effective while for *T. belangeri* cutting the fur also appeared to be effective.

For this study there were not an adequate number of traps available to lay out all 5 trap lines simultaneously. In order to circumvent this problem the 2 trap lines available were rotated from one position to the next after 4 nights. As I was only able to return to the park for two, 5-day periods a month, the traps lines could only be reset in the new positions after an interval of 2 weeks. This resulted in a complete trapping cycle (traps laid out in 5 lines) taking more than a month. This was not optimal because small rodents have a short lifecycle and are able to produce new litters within this interval of time. This would mean that numbers captured towards the end of the trapping cycle may have been distorted by a population increase of the species resulting from reproduction rather than movement into an area.

Other potential problems including the length of the transects and the duration of the study. For example, the study was not long enough to understand the details how these animals respond to fire and habitat change because some of the different responses may have been related to seasonal changes. Seasonal changes affect the small mammal community directly because they have short life cycles and may have to increase their area of search to find enough food during the dry season. In order to do this, forest dwelling species may need to penetrate deeper into the habitat during the dry season. Capturing these rodents would then require establishing trap sites more than 135 meters into the forest.

To enable all traps lines to be set simultaneously and to have longer trap lines clearly more traps would be required. Each trap line had 30 traps so 120 traps would be required to lay the 5 trap lines together. Comparisons to other studies and on-site experimentation would need to be done to determine the optimal length of these trap lines and to what extent they should ideally penetrate into the forest and grassland habitats.

6.6 Recommendations

Fire can be a disaster for animals living in habitats where fires are infrequent such as tropical rain forest (Dennis et al. 2001). But mammals living in environments exposed to frequent fires, as in grasslands, can survive because of their adaptations. The community and species composition may not change in the first few years after burning, but after a few more years, changes in the composition and community dynamics of plants and animals will occur (Simons 1991).

In this site *R. rattus* is an invader species as it is in other disturbed forest systems (e.g. Lynam 1997; Ganzhorn 2003). Ganzhorn observed that *R. rattus* capture rates increased as forest fragments became smaller, indicating that mosaics of different habitat types are beneficial for introduced rats. However, he found no significant relationship between capture rates of *R. rattus* and the endemic species. It would, however, seem desirable to investigate further whether the same conclusions can be drawn between the interaction between the introduced and endemic species in Ganzhorn's study, which was done in Madagascar, and the small mammal species in Thailand.

In a study by Lynam and Billick (1999) of islands of forest habitat, it was found that of the species that persisted on islands, many had altered abundances, with some increasing and others declining. Specifically three rodents, *L. sabanus*, *M. surifer*, and

N. bukit, and a treeshrew (*Tupaia glis*), had significantly lower abundances on islands than in control areas on the mainland. In contrast *R. rattus* were more abundant on islands. Lynam and Billick concluded that the difference in abundance of species on habitat islands was caused both by differential vulnerabilities of species to local extinction and by varying abilities of species to colonize islands and to thrive in disturbed island habitats. Parallels could be drawn between the islands studied by Lynam and Billick, which were separated from the mainland forest by water, and the primary forest existing in Khao Yai National Park which is adjacent to grassland. If this comparison holds then there is further support for the need to research the possibility of there being negative interactions between introduced rats and the native small mammal fauna in the park.

Ganzhorn also observed that capture rates of endemic rodents declined significantly with increased fragmentation of primary forest. It seems, therefore, that fragmentation of the Khao Yai National Park's primary forest may lead to the depletion of native rodents that are sensitive to forest disturbance. As fire is the form of disturbance used to maintain, if not increase, forest fragmentation in the park, consideration should perhaps be given to minimizing or reducing its use.

Although *R. rattus* does not appear to be a pest in this study, it appears to be desirable to reduce the abundance of this invader species. Therefore, I recommend reducing the frequency of burns in Khao Yai National Park since repeated fire sustains and reinforces forest fragmentation which in turn leads to increased abundance of *R. rattus*. Further study of the effect of burning on small mammal abundance is encouraged. This would also require monitoring different burning regimes for several years to determine if the abundance of *R. rattus* could be reduced and whether the older grasslands would support a more diverse community.

Fire management at KYNP is recommended because the current burning is already influencing the small mammal community. While this effect may be only temporary, converting more forest to grassland could create permanent changes. This is the real problem with the annual burning at Khao Yai. If burning must continue, I suggest fire management may be improved by producing a burn mosaic in time and space, decreasing the area that is burned, and varying periods between prescribed burns (USGS, 2003, Dechant et al. 1998), but I have no long-term data from this study site for making detailed burning regime recommendations.

In conclusion, although for some species small sample sizes and recruitment of new individuals into the population may have affected capture rates, the study generally confirms that grasslands are relatively poorer habitat than forest for small mammals. Only with long-term data and a larger study site would managers be able to determine in more detail how species will be affected by and how they will respond to fire disturbance and habitat changes due to forest loss. Information from this study could be used in combination with other ecological data for developing more effective fire management methods. I tentatively recommend that park management use zones, and that burning should be strictly limited. For example grasslands should be burnt only along the road and/or only the areas that have been burnt before because burning clearly reduces the species richness and abundance of the rodent community. Forest areas should not be burned solely for the purpose of night safaris; and in general managers should reduce forest disturbance and create less edge. Such management changes should result in an increase in the native species richness and diversity.

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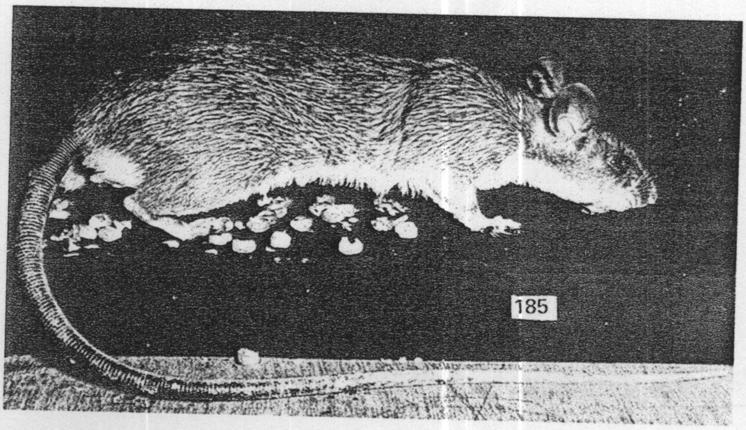
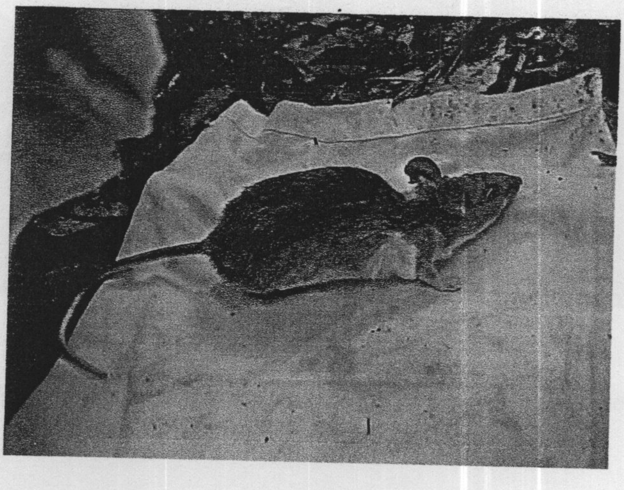
APPENDIX

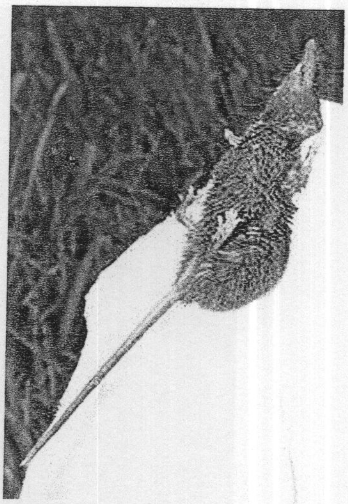
Appendix I Characteristics of small mammals in the study area.



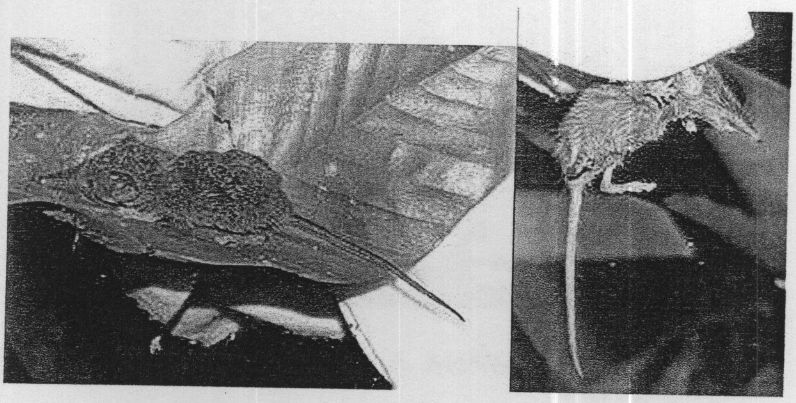
Noisy Rat *(Leopoldamys sabanus)* (Lekagul, B. and J. A. McNeely., 1988)



Yellow Rajah Rat (*Maxomys surifer)* by Waraporn Kaewprom on 26th July 2003

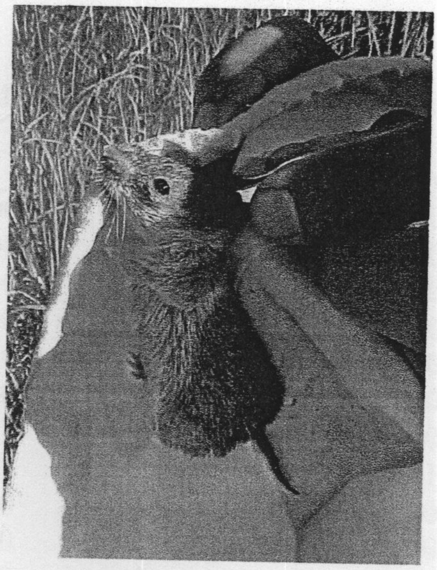


Horsefield's Shrew (*Crocidura hosfieldi)* by Waraporn Kaewprom on 26th January 2003

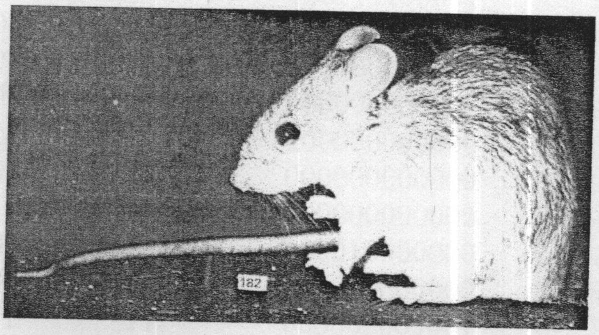


Dwarf Shrew *(Crocidura estrusca*) by Waraporn Kaewprom on 11th March 2003

Common treeshrew (*Tupaia belangeri*) by Waraporn Kaewprom on 26th July 2003



Ryukyu Mouse (*Mus caroli*) by Waraporn Kaewprom on 10th July 2003



Roof Rat *(Rattus rattus)* (Lekagul, B. and J. A. McNeely., 1988)

Chestnut Rat *(Niviventer bukit)* (Lekagul, B. and J. A. McNeely., 1988)

Appendix II

The number of captures of individual *Maxomys surifer* before and after the burn

Id No.	Occasion	Before fire	Occasion	After fire
L030	111111110000	8	000000000000	0
L035	010111101100	7	000000000000	0
L039	110100000000	3	000000000000	0
L040	110011110100	7	000000000000	0
L041	011100000000	3	000000000000	0
L047	111111010000	7	000000000000	0
L053	100001101111	7	000000000000	0
L059	011011011111	9	000010111100	5
L062	101000100100	4	001001000010	3
L064	001111111000	7	000011110000	4
L066	011111111110	10	000101000111	5
L069	000000000000	0	001100000000	2
L077	000000101000	2	000000000000	0
L079	011000000000	2	000000000000	0
L083	000001100100	3	000111100001	5
L086	011000000000	2	000000000000	0
L090	000000000000	0	111100010000	5
L098	110000000000	2	000000000000	0
L099	111100000000	4	000000000000	0
R038	100000000000	1	000000000000	0
R045	101111111110	10	000000000000	0
R046	100010111001	6	100010000000	2
R052	000010001000	2	000000000000	0
R060	111011111111	11	000000001001	2
R067	001000000000	1	000000000000	0
R068	011110101100	7	000000000000	0
R069	011000010111	6	000000000000	0
R072	000010011001	4	100100000000	2
R075	001111101001	7	000000000000	0
R076	000000000000	0	000000000001	1
R081	001010001000	3	000000000000	0
R082	000001011000	3	000000000000	0
R084	000010000000	1	000000000000	0
R085	000010000000	1	000000000000	0
R087	000001000000	1	000000000000	0
R089	000000100000	1	000000000101	2
R093	000010011100	4	000000000000	0
R095	000000001000	1	000000000000	0
R096	000001000000	1	000000000000	0
R100	111011111110	10	010000000000	1
R101	000000001000	1	000000000000	0
R102	000000000010	1	001101100000	4

Appendix II Continued.

The number of captures of individual *Maxomys surifer* before and after the burn

Id No.	Occasion	Before fire	Occasion	After fire
R103	000000010010	2	000100000000	1
R104	000000001110	3	101011000110	6
R107	000000000000	0	000000100010	2
R109	000000000000	0	000001010001	3
R110	000000000000	0	000000111011	5
R111	000000000000	0	000101001000	3
R112	000000000000	0	000000010000	1
R113	000000000000	0	000000010000	1
R114	000000000000	0	000000100000	1
R115	000000000000	0	000001111111	7
R116	000000000000	0	000000101011	4
R117	000000000000	0	000000101110	4
R118	000000000000	0	000000010000	1
R119	000000000000	0	000000010000	1
R120	000000000000	0	000000010001	2
R121	000000000000	0	000000000011	2
R122	000000000000	0	000000000001	1
R123	000000000000	0	000000000001	1
0001	000000000000	0	000010010000	2
0010	000000000000	0	000001000000	1
0011	000000000000	0	000010100000	2
0012	000000000000	0	000000010000	1
0015	000000000000	0	000000010001	2
0017	000000000000	0	000000100000	1
0020	000000000000	0	000000000111	3
0022	000000000000	0	000000000010	1
0024	000000000000	0	000000000010	1
0027	000000000000	0	000000000001	1

Appendix III

The number of captures of individual *Mus caroli* before and after the burn

No.	Occasion	Before fire	Occasion	After fire
0001	000010100100	3	000000000000	0
0002	000001110000	3	000000000000	0
0003	000000010000	1	000000000000	0
0004	000010011011	5	000100000000	1
0005	000000011010	3	000000000000	0
0006	000000001000	1	110000000000	2
0007	000000001101	3	000000000000	0
0008	000000000111	3	000000000000	0
0009	000000001001	2	000000000000	0
0011	000000000001	1	000000000000	0
0012	000000000000	0	001000000000	1
0019	000000000000	0	000010000000	1
0022	000000000000	0	000000000010	1
0023	000000000000	0	000000000001	1
0040	000000000000	0	000011110000	4

Appendix IV Average measurements of all species before fire, by age and sex

Species	Sex	Age	Wt (mg) (SD)	HB (mm) (SD)	TV (mm) (SD)	HF (mm) (SD)	E (mm) (SD)
Maxomys surifer	Female	Adult	153.85	155.80	145.63	35.80	21.84
			19.69	6.70	55.93	1.82	1.67
		Sub Adult	128.39	149.20	139.68	35.73	21.64
			22.56	27.85	39.70	2.57	1.26
		Juvenile	113.83	136.74	145.42	35.58	21.71
			13.57	8.49	43.92	1.65	1.86
	Male	Adult	160.47	163.86	145.48	37.69	22.18
			23.54	25.06	63.83	3.91	1.48
		Sub Adult	135.56	155.37	150.47	35.87	21.62
			23.00	9.78	72.00	2.79	1.58
		Juvenile	119.69	148.94	114.27	36.35	21.47
			33.41	15.24	49.71	3.64	1.84
Mus caroli	Female	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	18.23	72.14	64.21	15.59	11.57
			3.94	7.81	8.10	0.50	0.88
		Juvenile	13.38	65.36	70.26	15.90	13.02
			3.72	7.98	12.61	1.81	1.65
	Male	Adult	14.63	66.73	61.98	15.98	12.55
			0.48	2.32	7.01	1.14	0.64
		Sub Adult	21.61	76.91	75.67	16.95	12.53
			16.61	14.97	28.56	3.89	2.49
		Juvenile	16.15	68.33	67.80	16.22	11.66
			9.87	10.99	20.02	2.11	1.47
Tupaia belangeri	Female	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	153.75	145.00	158.00	38.55	
			23.69	18.38	1.41	0.78	
		Juvenile	142.17	146.00	181.67	38.33	
			5.62	5.20	7.37	2.08	
	Male	Adult	163.25	148.50	176.00	39.75	
			12.37	19.09	0.71	0.35	
		Sub Adult	143.33	131.67	158.33	39.13	
			8.62	2.08	12.74	1.96	
		Juvenile	141.83	149.33	181.00	40.00	
			18.76	12.42	8.72	3.61	
Rattus rattus	Female	Adult	143.50	133.00	203.00	31.00	
		Sub Adult	-	-	-	-	-
			-	-	-	-	-
		Juvenile	-	-	-	-	-
			-	-	-	-	-
	Male	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	109.50	158.00	190.00	31.30	23.00
		Juvenile	84.17	134.33	118.33	29.73	
			27.46	6.11	86.49	1.10	

(to be continued)

Appendix IV (Continued)

Average measurements of all species before fire, by age and sex

Species	Sex	Age	Wt (mg) (SD)	HB (mm) (SD)	TV (mm) (SD)	HF (mm) (SD)	E (mm) (SD)
Niviventer bukit	Female	Adult	76.00	136.82	170.50	26.18	17.72
			10.36	15.73	18.86	0.93	1.92
		Sub Adult	73.81	127.88	134.46	26.02	18.04
			6.84	6.38	43.37	0.71	0.87
		Juvenile	-	-	-	-	-
			-	-	-	-	-
	Male	Adult	86.50	132.00	190.00	27.60	17.30
		Sub Adult	80.15	138.60	186.40	27.74	16.54
			9.24	9.02	9.84	1.51	3.27
		Juvenile	80.50	128.00	193.00	28.50	19.10

Appendix V Average measurements of all species after fire, by age and sex

Species	Sex	Age	Wt (mg) (SD)	HB (mm) (SD)	TV (mm) (SD)	HF (mm) (SD)	E (mm) (SD)
Maxomys surifer	Female	Adult	159.85	164.52	127.91	36.07	22.1
			15.99	8.33	56.57	1.76	1.1
		Sub Adult	84.13	152.72	161.67	34.55	21.3
			8.81	6.68	29.62	1.95	1.1
		Juvenile	84.13	129.92	135.29	33.27	20.0
			21.96	24.58	32.27	1.99	1.4
	Male	Adult	170.39	179.00	148.63	37.35	22.7
			19.78	8.88	56.56	1.19	1.6
		Sub Adult	163.88	178.00	123.40	37.23	22.0
			31.04	10.52	80.81	1.16	1.8
		Juvenile	92.18	140.41	149.33	34.05	27.5
			20.47	14.18	32.71	1.91	34.8
Mus caroli	Female	Adult	17.95	70.90	81.00	16.38	12.1
			0.28	3.11	1.70	0.18	1.3
		Sub Adult	19.26	72.04	60.87	14.81	11.7
			3.44	5.22	17.00	1.50	0.9
		Juvenile	8.97	59.36	58.49	14.81	10.5
			3.12	5.03	11.75	1.37	0.9
	Male	Adult	16.00	76.98	71.82	16.43	12.9
			0.50	1.34	1.65	0.81	0.1
		Sub Adult	17.83	74.71	63.70	15.10	11.4
			3.07	6.70	6.85	0.96	0.5
		Juvenile	21.09	75.25	70.53	16.13	11.8
			4.78	8.54	13.07	2.80	1.9
Tupaia belangeri	Female	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	-	-	-	-	-
			-	-	-	-	-
		Juvenile	54.50	114.60	134.63	35.53	8.5
			26.44	12.49	19.47	3.10	2.1
	Male	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	-	-	-	-	-
			-	-	-	-	-
		Juvenile	144.50	156.00	200.00	42.70	12.0
Rattus rattus	Female	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	-	-	-	-	-
			-	-	-	-	-
		Juvenile	88.77	140.25	170.05	30.34	18.5
			13.11	10.94	17.94	0.76	1.2
	Male	Adult	106.38	156.25	175.63	29.41	20.0
			36.16	6.50	7.16	1.58	1.9
		Sub Adult	98.28	156.00	171.00	29.57	16.9
			12.25	19.92	8.89	2.45	1.9
		Juvenile	56.24	115.50	148.25	28.09	17.1
			17.24	23.22	26.86	3.32	1.1

(to be continued)

Appendix V (Continued)

Average measurements of all species before fire, by age and sex

Species	Sex	Age	Wt (mg) (SD)	HB (mm) (SD)	TV (mm) (SD)	HF (mm) (SD)	E (mm) (SD)
Niviventer bukit	Female	Adult	68.60	129.75	126.96	24.60	16.6
			11.37	8.00	37.14	1.23	1.8
		Sub Adult	63.00	125.90	156.00	25.40	14.7
		Juvenile	42.66	105.36	94.31	25.68	17.4
			11.29	17.14	49.24	3.49	2.3
	Male	Adult	-	-	-	-	-
			-	-	-	-	-
		Sub Adult	74.75	134.00	133.75	25.63	16.2
			6.01	0.00	33.59	0.46	0.8
		Juvenile	58.00	128.00	126.00	30.00	19.1

Wt = Weight (mg)
HB = Head-and body-length measured from the anus to the front of the nose (mm)
T = Tail length measured to the tip of the tail excluding long fur or hairs which project beyond the end (mm)
E = Ear length measured from the external opening to the tip (mm)

CURRICULUM VITAE

NAME	Miss Waraporn Kaewprom
DATE OF BIRTH	17 January 1975
EDUCATIONAL RECORD	
HIGH SCHOOL	High School Graduation Bangkapi School, 1993
BACHELOR'S DEGREE	Bachelor of Science (Agricultural Science) Rajabhat Institute Phanakhorn, 1997
MASTER'S DEGREE	Master of Science (Natural Resources Management) King Mongkut's University of Technology Thonburi, 2004
FUND	WCS- Thailand Program and TRF/BIOTEC Special Program for Biodiversity Research and Training grant BRT T_346005
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