WILDLIFE RESPONSE TO HABITAT FRAGMENTATION AND OTHER HUMAN INFLUENCES IN TROPICAL MONTANE EVERGREEN FORESTS, NORTHERN THAINAND

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Wildlife Response to Habitat Fragmentation and other Human Influences in Tropical Montane Evergreen Forests, Northern Thailand

by

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ABSTRACT

Montane evergreen forests in northern Thailand have been severely fragmented and converted to agricultural lands and other forms of development that affect wildlife. The objectives of this study were to examine patterns and changes in montane evergreen forest patches, and document wildlife responses in terms of species diversity, abundance, and distribution. The study was conducted in Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak Provinces. LANDSAT TM imagery, aerial photographs, GIS, and the spatial pattern analysis program FRAGSTATS were employed to examine landscape patterns and changes. I found that Om Koi still maintained large patches (> 400ha) with connectivity while Mae Tuen was comprised mainly of small isolated patches (< 100 ha). Mae Tuen lost 2,640 ha of montane evergreen forest within 50 years compared to 888 ha in Om Koi. Road development and cabbage cultivation in Mae Tuen played a major role in accelerating forest loss. For the wildlife survey, I compared 4 forest patches in Mae Tuen, which are heavily fragmented and disturbed, with another 4 in Om Koi, where human influences are less. I used 1-km transects to survey animals in each patch. For mammals, 156 5×1m track recording stations were set up in each location for recording footprints. Over a 9-month period from September 1997 to June 1998 I found 9 species of mammals in Mae Tuen and 19 in Om Koi. I also found 89 species (1,238 detections) of birds in Mae Tuen and 119 (1,192) in Om Koi. Large patches (> 400 ha) with connectivity still supported large mammals, primates, and a high diversity of birds. Bird diversities were significantly greater ($P = 0.011$) in large patches in Om Koi than in the small patches in Mae Tuen. Large frugivorous birds such as

hornbills were found in Om Koi but there were none in Mae Tuen. Small patches (< 100 ha) in Mae Tuen were still valuable for forest birds and virtually no penetration by clearing birds was found. Track counts gave 886 mammal tracks in Mae Tuen and 2,016 in Om Koi. Om Koi patches still support large mammals such as the Asian elephant (*Elephas maximus*), tiger (*Panthera tigris*), Asiatic black bear (*Selenarctos thibetanus*), and sambar (*Cervus unicolor*) but there were none in Mae Tuen. Three species of primates existed in Om Koi but they were virtually extinct from Mae Tuen. There were traces of a positive relationship between bird and mammal diversities and patch size. The distribution model for elephants suggests that villages in the middle of elephant seasonal migratory paths must be restricted from development and slash-and-burn cultivation to reduce the impact on elephant populations. The small population of bantengs (*Bos javanicus*) was confined to a small area as revealed by the distribution model. These animals need urgent and effective protection to avoid extirpation. Hunting, burning, and domestic cattle dispersing into the forest are other influences threatening wildlife in the areas.

Examiners:

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To my friends at RFD who lost their lives
trying to sustain other life forms

CHAPTER 1
INTRODUCTION

> "More than ever, our effect on the biological systems of the planet will rebound to affect us. A slash and burn approach to the biosphere is no longer viable. Indeed the planet already has a reduced capacity to support Man. We need a populace and politicians aware that all decisions have a biological component, and that biology is inextricably interwoven with sociology and economics. As the planet becomes simpler biologically, it becomes more expensive economically: fish are smaller and dearer; lumber is narrower, shorter, and more expensive; dwindling natural resources fuel inflation. The planet also is more vulnerable to disaster, and the quality of life inevitably declines.
>
> Conservation is sometimes perceived as stopping everything cold, as holding whooping cranes in higher esteem than people. It is up to science to spread the understanding that the choice is not between wild places or people. Rather it is between a rich or an impoverished existence for Man."
>
> Thomas E. Lovejoy
> (in Baskin 1997)

The above quotation demonstrates clearly the outcomes of careless human utilization of natural biological resources. Increasing human exploitative pressures on natural biota have led to a severe degradation of biological diversity. The pressures are acute in the tropics where a large proportion of species occurs. The situation has prompted scientists and resource managers worldwide to engage different techniques and approaches in order to sustain biodiversity. Monitoring the impacts of human land use on flora' and fauna' elements is a major direction undertaken to guide management activities.

Thailand is a tropical country located in a transition zone of the Indo-Chinese, and Indo-Malayan zoogeographic subregions (Wallace 1876). Thailand supports a high diversity of living organisms: 280 species of mammals, 917 species of birds, 300 species of reptiles, 107 species of amphibians, and 1,900 species of fishes. Unfortunately, forest cover, as well as animal species, has declined remarkably. Slash-and-burn agriculture, logging, and various forms of development (e.g., road construction, irrigation and hydro-electric dams, mining) contribute significantly to the deterioration of biodiversity. The conservation actions taken by the government include banning logging, enforcing forest and wildlife protection laws, and establishing protected areas in the form of national parks and wildlife sanctuaries. Approximately 15 % of the total land area is already protected.

Unfortunately, almost all protected areas are not pristine. Protected area managers have to deal with ongoing human pressures such as village expansion, slash-and-burn agriculture, hunting, and cattle grazing. Mostly, habitat is already fragmented or facing an ongoing fragmentation. To learn how to conserve wildlife species in fragmented habitat influenced by various human pressures is a must for protected area managers if biodiversity conservation is to be effective. This thesis addresses the issue of wildlife conservation in fragmented forests. It is also designed to provide guidance and tools to monitor and conserve wildlife under various patterns and rates of human landuse and other inextricable influences.

This thesis outlines the effects of habitat fragmentation and other related human influences on wildlife with the focus on birds and mammals. The methodology for the thesis was designed to gather information at different levels of ecological organization including landscape, community, population, and species. Patterns and changes at the landscape scale can shape the biota from the community, population, down to species level. Management of protected areas such as national parks and wildlife sanctuaries that encompass large areas with complex biological and social components must recognize patterns and changes in every level of organization. Adoption of technology to aid decision-making is also important to keep pace with changes caused by increasing human pressures.

The goal of this study was to initiate ecological monitoring in areas where solutions for the conflict between humans and biodiversity have been desperately needed for managing protected areas in northern Thailand. The main purposes are to emphasize the concepts of wildlife response to habitat fragmentation, and to introduce the techniques to monitor fragmented landscapes and wildlife distributions. The expectation is to aid protected area managers in the conservation of wildlife and its habitat in areas experiencing similar situations as the study area.

The study area was in Om Koi and Mae Tuen Wildlife Sanctuaries located in Chiang Mai, and Tak Provinces in northern Thailand. These two areas together are among few protected areas in the region that still support remnants of several wildlife species. However, they have experienced human influences in the forms of fragmentation, hunting, and burning. The sanctuary managers are badly in need of information and techniques to effectively manage biological and social components within the area.

1.1 Research Objectives

Research objectives can be categorized into two sections as follows.

1.1.1. Wildlife responses to habitat fragmentation and other influences; The objectives were to:

i. examine the patterns and changes of habitat fragmentation in montane evergreen forest landscape within the Om Koi and Mae Tuen Wildlife Sanctuaries,

ii. document the diversity, abundance, distribution, and movement of mammals and birds over the fragmented landscape.

iii. examine the relationship between patch characteristics (size, shape, core areas, edge and interior zones) and bird and mammal species assemblages,

iv. compare bird and mammal diversity and density between forest patches with different fragmentation patterns and intensity of human influences,

v. determine the patterns that cause least impact on wildlife

vi. document other human influences related to habitat fragmentation.

1.1.2. Establish a monitoring system that can be used for ongoing research and management of wildlife in the sanctuaries. The objectives were to:

i. establish a baseline GIS database that can be used for further inventory of wildlife diversity and abundance in the area,

ii. introduce a technique to quantify fragmentation patterns,

iii. introduce a technique to map wildlife distributions for key species in the area.

The thesis provides information and techniques for protected area managers and researchers. Chapter 2 reviews the literature on the effects of habitat fragmentation on wild animals with the focus on birds and mammals. Other subjects related to fragmentation such as hunting, road development are also briefly mentioned. The basis for ecological monitoring is addressed in Chapter 2 as well. Chapter 3 introduces northern Thailand and the study area. It explains how the region has been transformed from an area rich in biodiversity to the current degraded status. It also overviews the study area and its biological significance in the region.

The study detail begins with Chapter 4. This chapter shows the quantitative configurations of habitat fragmentation between Om Koi and Mae Tuen montane forest landscapes. FRAGSTAT, a spatial pattern analysis program for quantifying landscape structure, was used and various fragmentation indices such as largest patch index, patch size, edge contrast, and core area index were compared between the two landscapes. Such indices were also used to compare the landscape between 1954 and 1996. Chapter 5 is the key chapter for this thesis. The study details on bird and mammal diversity, density, and abundance related to habitat fragmentation and other human influences are shown in this chapter. The findings from the study are also discussed in comparison to other studies. Chapter 6 introduces how GIS technology can combine the information from the literature with field surveys to build model maps of animal distributions. Only two large mammals endangered in the area were selected as examples, the Asian elephant (*Elephas maximus*) and banteng (*Bos javanicus*).

The last two chapters conclude and give recommendations from the findings. Management recommendations are made specifically to Om Koi and Mae Tuen Wildlife Sanctuary managers, and broadly to all protected area managers faced with similar conditions. The conclusions and recommendations are divided into sections to facilitate the readers' understanding of each individual result of this study.

CHAPTER 2
WILDLIFE RESPONSE TO HABITAT FRAGMENTATION AND OTHER HUMAN INFLUENCES: A REVIEW

A main theoretical underpinning for research and management applications regarding habitat fragmentation is *the theory of island biogeography* introduced by McArthur and Wilson (1967). The theory has two major theses: 1) species number varies directly with island size; 2) species number varies inversely with distance of an island from the mainland. When McArthur and Wilson first introduced the theory they stated that the same principles apply to formerly continuous natural habitats being broken up by the encroachment of civilization. Although some of the details of the theory have been subject to controversy the theory stimulated concern regarding the effect of habitat fragmentation in terrestrial ecosystems (Temple and Wilcox 1986).

Knowledge of the effects of habitat fragmentation has been expanded to cover a wide range of physical and biological components in various types of habitats (e.g., Wilcox 1980, Brittingham and Temple 1983, Lovejoy et al. 1986b, Yahner 1988, Saunders et al. 1991, Bierregaard et al. 1992, Laurence and Bierregaard 1997, Marsh and Pearman 1997). This review, however, focuses mainly on the effects of habitat fragmentation on birds and mammals. First an overview of the principal notions of fragmentation and ecological components related to wildlife is introduced. Then more detailed effects on birds and mammals are discussed. Other influences related to fragmentation such as hunting, and road development are also briefly reviewed. The review ends with a summary of the need for ecological monitoring.

2.1. Fragmentation and Wildlife Responses

The problem of habitat fragmentation has two components; a decrease in total habitat area, and an increase in isolation (Wilcove et al. 1986, Noss 1987). These components are mainly influenced by human land-use activities (Bierregaard and Dale 1996). Human-caused fragmentation generally changes a landscape from a large intact forest to small remnant patches of native vegetation isolated from each other by a matrix of habitats such as agricultural or other developed lands (Wilcove et al. 1986, Saunders et al. 1991). These developments lead to changes in structure – the spatial relationships among ecosystem elements – and function – the interactions among spatial elements (Forman and Godron 1986). The consequences of fragmentation also vary with the time since isolation, distance from other fragments, and degree of connectivity with other remnant patches. Abrupt edges with a sudden transition from forest to pastures, crops, or other modified habitats are mainly a result of fragmentation that can lead to other consequences (Laurence and Bierregaard 1997). Changes in these structures can affect microclimate such as radiation, wind and water fluxes (Saunders et al. 1991). Structures and functions within remnant patches are also dependent upon the dynamics of the surrounding matrix. These physical changes will undoubtedly affect plant and animal species and their interactions (Bierregaard and Dale 1996).

Positive relationships between forest patch size and wildlife diversity have been shown by a substantial number of authors (e.g. Galli et al. 1976, Ambuel and Temple 1983, Opdum et al. 1985, Bierregaard et al. 1992, Kattan and Alvarez-Lopez 1996, Waburton 1997). Isolation is also a key aspect of habitat fragmentation affecting the movement of animals (Wiens 1997). Patch shape affects the dispersal and foraging of animals (Forman and Godron 1986). Also important are fragmentation effects on species composition (Waburton 1997) and the types of species that fragmented habitat will support (Saunders et al. 1991). Populations of some species increase in fragments, some are unaffected, and yet others decline or disappear (Warburton 1997). Effects of patch size and isolation on bird and mammal species will be specifically examined in sections 2.1.1 and 2.1.2 respectively.

Fragmentation may disrupt many of the important ecological interactions of a community, including predator-prey, parasite-host, plant-pollinator relations, and mutualism (Wilcove et al. 1986). Mawdsley et al. (1998), for instance, suggest that many fig species in the tropics are declining partly as a result of fragmentation causing local extinctions of species-specific wasps that act as pollinators. Fig trees are considered a "keystone resource" for many wild animals (Terborgh 1986). The phenomenon called "mesopredator release", for example, happens when the disappearance of large predators has led to an over-abundance of medium-sized predators such as raccoons and opossums for example in North American forest patches which prey on nesting song birds and therefore adversely affect song bird population (Soule et al. 1988). Because fragmentation limits dispersal activities for many seed-dispersing animals, effects on plant communities are unavoidable. There is evidence that among rain-forest trees, animal dispersal of seeds is more effective than dispersal by wind (Whitmore 1984). Bierregaard et al. (1992), for instance, confirmed that a high percentage (approximately 90%) of forest tree species in Paragominas, Brazil, depend on animals to disperse their seeds, and few potential animal dispersers are likely to carry seeds into large open tracts. In other cases when populations of carnivores are extirpated or decline by fragmentation and hunting combined there could be a dramatic increase in seed predators. Increasing seed predation in small remnants will affect regeneration of tree species (Redford 1992, Corlett and Turner 1997).

A phenomenon reported after the forest has been recently fragmented is a substantial influx of individuals displaced from their former habitat. This packing phenomenon has been called "crowding effects" (Bierregaard and Lovejoy 1988). Lovejoy et al. (1986b), for instance, demonstrated this effect on understory birds in newly isolated fragments in an Amazonian forest. This effect is likely to be ephemeral but it depends upon the suitability of the new matrix to species from the original habitat (Bierregaard and Stouffer 1997). Remnant patches encircled by denuded pastures or croplands are likely to suffer far more severe changes than those surrounded by mosaics of habitat types that include corridors of mature second growth (Laurance and Bierregaard 1997). Species assemblages in remnant patches therefore are strongly influenced by composition of the surrounding matrix (Bierregaard and Stouffer 1997, Warburton 1997). Some primary-forest species can persist in, or use, second-growth forests (Bierregaard and Dale 1996).

One of the most extensive studies regarding habitat fragmentation and wildlife is the study of "edge effects". Leopold (1933) is a pioneer ecologist who documented greater wildlife diversity at edges. Afterwards, various authors (e.g., Gates and Gysel 1978, Brittingham and Temple 1983, Wilcove 1985) have revealed some adverse edge effects with higher nest predation and parasitism and a decrease in the populations of songbirds. Suarez et al. (1997) found that nest predation rates along agricultural and abrupt edges were higher than rates along more gradual edges where plant succession occurs. Gates and Gysel (1978) stress that edge may function as an "ecological trap" by attracting individuals to areas in which predation losses are great. Edges may also be detrimental to species requiring large undisturbed areas because increases in edge are generally connected with reduction in size of remnant patches (Yahner 1988). In many cases of habitat fragmentation, species richness does not seem to change, or may even increase. Species composition, however, often shifts towards taxa with low area requirements or high edge affinities (World Resource Institute 1994). Eventually, a very small forest may be entirely edge habitat (Forman and Godron 1986).

Although forest fragmentation affects different species differently (Terborgh 1992), habitat loss is the main factor driving the present extinction crisis of many species (Wilcox and Murphy 1985). In this case the nature of the animals such as home range size and dispersal characteristics can also contribute to survival ability and recolonization (Wilcove et al. 1986, Fahrig and Merriam 1994). Species with restricted habitat types are also among the most vulnerable to become extinct as a result of fragmentation (Bierregaard and Dale 1996). Frequently, the first species to be extirpated from remnant patches are high on the trophic pyramid or are the larger or more specialized members of feeding guilds (Terborgh 1992).

Fragmentation can subdivide populations and create spatial patterns, called metapopulation dynamics. In such dynamics Hanski and Simberloff (1997) explain that populations are spatially structured into assemblages of local breeding populations and that migration among the local populations has some effect on local dynamics, including the possibility of populations reestablishing following extinction. Small forest patches in agricultural landscapes are generally thought to be population "sinks" where the reproductive success is too low to sustain populations (Donovan et al 1995). Large patches, on the other hand, have the capacity to sustain populations and therefore are considered as "sources" (Pullium 1988). However, Friesen et al. (1999) found that some forest bird populations were self-sustaining within small forest patches (3-14 ha) in farmed landscape.

2.1.1. Effects on Birds

Patch size is an important factor determining bird diversity (e.g., Ambuel and Temple 1983). Small patches (Lovejoy et al. 1986a) can lead to extinction of some forest birds. Bierregaard et al. (1992), for instance, found that small forest remnants less than 10 ha lost the many army-ant-following birds and mixed-species flocks. More penetration of nonforest birds was also reported in small patches of temperate old-growth forest (Schieck et al. 1996). However, very low penetration of generalist species was found in tropical forest patches in the Amazon by Lovejoy et al. (1986b). Some bird species such as understory hummingbirds (Stouffer and Bierregaard 1996), and Eurasian nuthatches (*Sitta europaea*) (Matthysen and Adriaensen 1998) are not effected by small forest patches. Small isolated populations would become extinct due to the effects of inbreeding (Karr 1982). However, other bird populations are known to exist at extremely low genetic effective population sizes (Walter 1990) and, thus, inbreeding should not be regarded as a dominant cause of avian extinction over the ecological time scale (Sieving and Karr 1997). Sieving and Karr (1997) suggest that short-term (< 100 years) causes of extinction are more likely to be ecological factors.

Isolation resulting from fragmentation can affect species distribution and reduce the productivity or survival of nesting birds (e.g., Donovan et al. 1995) and thus result in population decline on local and regional scales. Juvenile and adult song birds, for instance, prefer moving through woodland than open areas of agricultural fields, forestry, and other human activities (Haas 1995, Desrochers and Hannon 1997). Songbirds crossing open areas can increase the chance of being preyed on by raptors (Desrochers and Hannon 1997). Laurance and Bierregaard (1997) suggest that the most vulnerable species are often those that avoid the matrix of modified habitats surrounding fragments or respond negatively to edge effects or other ecological changes in fragments. Bierregaard et al. (1992) found that a break of as little as 80m is a strong barrier to movement by the vast majority of understory birds in the Amazon forest, for example. Dunning et al. (1996) also showed that Bachman's sparrow (*Aimophila aestivalis*) rarely colonized isolated patches.

One of the most studied topics occurs in the temperate zone where fragmentation has led to bird nest predation and brood parasitism on migratory song birds by the brown-headed cowbird (*Mulothrus ater*) and caused song birds to decline (Robinson 1992, Paton 1994). High nest predation was reported in fragmented forests with agricultural matrix compared to contiguous forest landscapes (Bayne and Hobson 1997).

Natural history plays an important role in determining species survival. Larger birds may be more subject to extinction than smaller species because their large territories dictate smaller populations that are sensitive to environmental change in the remnant patches (Shaffer 1981). Large frugivorous birds of the Central Colombia forest, for instance, have been found vulnerable to fragmentation (Kattan 1992, Kattan et al. 1994).

2.1.2. Effects on Mammals

Effects of fragmentation on mammals are less intensively studied than birds. Many studies (e.g., Lynam 1997, Malcolm 1997, Wolff et al. 1997) have focused on small mammals and found both positive and negative reponses of small mammals to fragmentation. Laurance and Gascon (1997) showed that the lemuroid ringtail possom (*Hemibelideus lemuroides*) in Australia disappears from forest fragments of less than 600 ha in only a few decades. They also suggest that dispersal and migration between forest patches will help to reduce the extinctions. Mammal communities were found to be more diverse and complex in large reserves (> 20,000 ha) compared to medium (>2,000 ha) and small (< 200 ha) reserves in Brazilian forest (Chiarello 1999). Yahner and Mahan (1997) showed that fragmentation can affect behaviors of some mammal species such as white-tailed deer (*Odocoileus virginianus*), red squirrels (*Tamiasciurus hudsonicus*), etc. Primates have also been investigated. Branch (1981) reported that many primates require different habitats over the course of a year; therefore, if a forest fragment does not contain the appropriate selection of habitats it would not be able to support the species. Schwarzkopf and Rylands (1989) revealed that primate diversity in an Amazonian forest was dependent upon structural complexity of habitat patches. Some primate species, such as howler monkeys (*Alouatta seniculus*), survive well in small fragments (< 10ha) because they have small home ranges (Lovejoy et al. 1986b).

However, most large mammals have large home ranges and fragmented habitats may be too small to support them (Robinson 1996). Newmark (1996), for example, shows that large mammals in Tanzania are becoming locally extinct from small forest parks insularized by human settlement, agricultural cultivation, and the active elimination of wildlife. Large mammals, especially those at high trophic levels, have an earlier chance of being extinct than smaller ones (Lomolino et al. 1989, Corlett and Turner 1997). Corlett and Turner (1997), for instance, indicate that carnivores such as tiger (*Panthera tigris*) and leopard (*Panthera pardus*) were among the first species being extirpated following severe fragmentation and hunting in Hong Kong and Singapore. Severe fragmentation together with hunting in the eastern United States eliminated many mammal species including the gray wolf (*Canis lupus*), mountain lion (*Felis concolor*), and elk (*Cervus elaphus*) (Wilcove et al. 1986). The length of time that a species can persist is largely due to the population size supported by the remnant patches (Pimm et al. 1988); however, large-body species also tend to occur at lower densities (Robinson and Redford 1986). Such species can be susceptible to inbreeding, demographic instabilities, and unpredictable catastrophes (Robinson 1996).

2.2 Other Human Influences

Study of fragmented systems must not exclude consideration of other ongoing human influences (Bierregaard et al. 1992). Robinson (1996) emphasized that this is important because of the following reasons. First, the influence of human activities is much more immediate than that of the biological processes stimulated by fragmentation. Second, human influence on biological communities is different from the effects of fragmentation alone.

Hunting is an important activity determining the diversity and abundance of large-bodied wildlife species in tropical forest patches (Robinson 1996). The conversion of forest into agricultural land allows people to get easy access to wildlife (Robinson 1996). The combination effects of hunting and fragmentation probably have devastating effects on some wildlife species, and as forests are reduced in area, there will be increasing pressures on fauna in isolated reserves and other remnants (Laurance and Bierregaard 1997). The impacts of hunting are greater in small isolated fragments because fragmentation prevents hunted populations from being restored by immigration and limits movements across the landscape. On the other hand, fragments with connectivity with each other or with the intact forest, wildlife can withstand some degree of hunting but not when hunting is prolonged and intense (Robinson 1996). Hunting depresses species densities and often results in local extinction. Species with large body size are the main target for hunters (Redford 1992, Robinson 1996). A species in a community when reduced to very low abundance can no longer interact significantly with other species and therefore this situation is called "ecological extinction" (Estes et al. 1989). Redford (1992) characterized such situations as "empty forests". Dearden (1996a) has suggested that this situation exists in most areas of northern Thailand.

Cutting trees for building material and firewood within the forest gaps is common in tropical forest patches. This activity causes declines in understory, canopy, and forest-gap bird species. The loss of forest-gap species, which are generalists, is probably because the rapid removal of large trees inside the forest patch may not mimic the more patchy occurrence of natural gaps (Greenberg 1996).

Road construction and other development can lead to more fragmentation and exploitation of natural resources due to socioeconomic changes in local communities (Dearden 1995, 1996b, Fox et al. 1995). Roads add to forest fragmentation by dissecting large patches into smaller pieces and by converting forest interior habitat into edge habitat (Reed et al. 1996). Roads and power lines cutting through the forest have a variety of effects on native fauna including: (1) destruction or alteration of habitats, (2) disturbances, edge effects, and intrusions of animals alien to the natural habitats, (3) increased mortality due to vehicle traffic, and (4) fragmentation of habitats and wildlife populations (Goosem 1997).

2.3. Ecological Monitoring

Understanding how fragmented communities and ecosystems are structured is the basis for maintaining biological diversity in human-influenced landscape (Malcolm 1997). Knowledge of the dynamics and patterns of tropical forest loss and fragmentation may be useful for answering questions related to the long-term sustainability of human-forest interactions and for developing management policies that protect and enhance tropical forests (Fox et al. 1995). Monitoring should serve as a feedback mechanism to promote better integration of conservation and development. Monitoring change in fragmentation patterns and remaining forest cover is one of the simplest ways to monitor changes in biodiversity and ecological health (Kremen et al. 1994). Noss (1990) suggested that monitoring at multiple levels of biological organizations is important because biological structures, compositions, and functions are organized in different levels ranging from gene to landscape and affecting each other. This study seeks to contribute to this literature by establishing monitoring baselines and procedures as related to the impacts of fragmentation in the Om Koi and Mae Tuen Wildlife Sanctuaries in northern Thailand. The remaining chapter will provide a broader regional context for the study.

CHAPTER 3
NORTHERN THAILAND AND THE STUDY AREA

Thailand has shown the highest rate of deforestation of all South East Asian countries in recent years (Hirsch 1990). Royal Forest Department reports (Royal Forest Department 1985, 1993), based on aerial surveys and LANDSAT images, suggest a reduction in forest area from 53.32% of the whole country area in 1961 to 26.02% in 1993. However, many sources estimate the current percentage of the true forest area at under 20% of the country. (e.g., TDRI 1986 in Hirsch 1990). The forest area has been reduced substantially by a combination of legal and illegal logging, encroachment by lowland settlers and shifting cultivators and through infrastructural projects (Hirsch 1990). Associated biological diversity, specifically wildlife, is also suffering from the depletion of the forest resources. Tigers (*Panthera tigris*) and elephants (*Elephas maximus*), for example, have disappeared throughout most of the country (Dearden and Chettamart 1997). Populations of all hornbill species are sharply declining and have been made locally extinct from many areas by deforestation and hunting (Poonswad and Kemp 1993). Northern Thailand is a region where the activities of local people supported by development programs have severely reduced the diversity and abundance of biological resources particularly wildlife, resulting in a reduction in the welfare of the people and their environment (Dearden 1995). The purpose of this chapter is to provide some background to the environment and people of northern Thailand.

3.1 Northern Thailand

In northern Thailand, some 23 different tribal ethnic groups, normally called "hilltribes", have occupied vast area of upland forests (Bhruksasri 1989). This region was originally rich in biodiversity. Doi Suthep National park, for example, as described by Elliott and Beaver (1993), is home to 329 bird species, 61 mammals, 28 amphibians and 50 reptiles. However, despite the efforts of the Royal Thai Government to protect biodiversity through the establishment of national parks, wildlife sanctuaries and non-hunting areas, many species have either been extirpated from the region, or remain in such low numbers as to be considered ecologically extinct. There are many causes behind these declines including the building of state infrastructure such as roads and reservoirs, expansion of agricultural activities, commercial logging and hunting. Also a topic of major concern in this region is the impacts of the hilltribes in protected areas such as national parks and wildlife sanctuaries on the remaining biodiversity in the region (e.g., see Elliott and Beaver 1993, Dearden et al. 1996)

Most hilltribes have traditionally employed slash-and-burn or shifting cultivation. The technique involves felling large trees and other living vegetation, burning them to release mineral nutrients to the soil, planting crops for some period, followed by a fallow period to replenish the impoverished soil fertility, and then cultivating again (Forman and Godron 1986). Over the last few decades, their cultivation systems have been influenced by market forces and development projects transforming many areas into permanent cash crops (Renard et al. 1988). Fox et al. (1995) studied changes in three upland watersheds occupied mainly by hill peoples and reported that within three decades forest cover declined, agricultural cover increased, population and population density grew, and agriculture changed from subsistence to cash crops, confirming earlier reports over the years by researchers such as Kunstadter (1980), Keen (1983), Cooper (1984), Kunstadter (1990). Fox et al. (1995) concluded that these changes resulted in increase in forest fragmentation and loss of biological and cultural diversity. This connection between biological and cultural impoverishment has been examined in some more detail by Dearden (1995). However, there is little empirical evidence in northern Thailand for the relationship between fragmentation and other human influences on loss of biodiversity.

On the whole, geographical and ecological information to maintain and restore the diversity of wildlife is desperately needed in Northern Thailand. Dearden (1996b) concludes that "Of the millions of dollars that have been spent on development assistance in the region, there is no record of any that have been explicitly directed toward understanding and conserving ecosystem processes" (p 337). These processes must be understood if biodiversity is to be maintained and restored.

3.2. Study Area

The study was conducted in Om Koi and Mae Tuen Wildlife Sanctuaries, in the provinces of Chiang Mai and Tak. These two contiguous sanctuaries are located in the northwestern part of Thailand (Figure 3.1) and together they encompass an area of 2,397 km^2 – 1,224 and 1,173 km^2 for Om Koi and Mae Tuen respectively. The area falls between latitude 17° 00′ – 17° 55′ N and longitude 98° 30′ - 98° 55′ E. The topography is mountainous with the elevation ranging from 200 to 1,926m. The highest peak in Om Koi is Doi Mon Chong with an elevation of 1,929m whereas Doi Soi Ma Lai in Mae Tuen is 1,664m high.

The climate is subtropical. Average rainfall in Om Koi is 1,060.1 mm/year with the highest average rainfall (254.1 mm) in September. The rainfall record is higher in Mae Tuen with 1,926 mm/year. Three seasons can be distinguished. The rainy season normally covers 6 months (May – October), the cool season 3 months (November – January), and the hot season 3 months (February – April). The highest average temperature is between 34.1° – 37.9° C while the average lowest is between 19.5° – 24.9° C. Average relative humidity is 74.9% with the highest 92.7% and lowest 53.9% (Thailand Forest Research Center 1991, 1992).

3.2.1. Vegetation Cover

Vegetation types are as characterized by the Thailand Forest Research Center (1991, 1992) and are influenced by elevation, soil type, and human activities and classified into 4 main types.

i. Hill evergreen forest or lower montane forest – This forest type covers mainly from 1,200m to higher elevations (see Figures 3.2, and 3.3). Trees in the Family Fagaceae mainly dominate tree species composition. The upper canopy layer includes such species as *Quercus brandisiana, Lithocarpus sootepensis, L. truncatus, Castanopsis argyrophylla, C. hystrix, Toona ciliata, Cinnamomum ilicioides, Fraxinus floribunda, Michelia floribunda*. The lower layer is composed of *Symplocos macrophylla, Litsea cubeba, Eugenia thumra,*

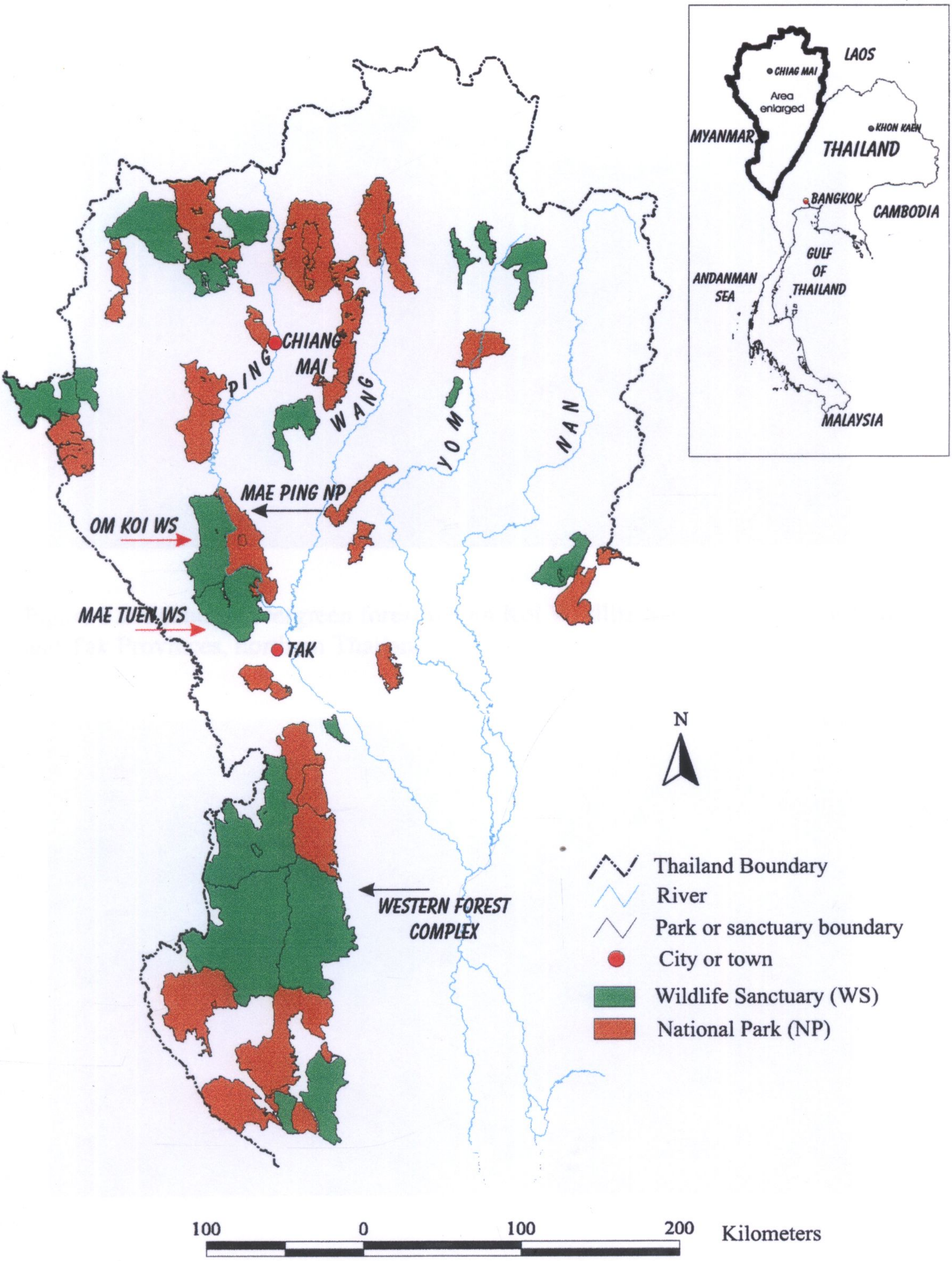

Figure 3.1 The study area and nearby protected areas in northern and western Thailand

Figure 3.2. Montane evergreen forest in Om Koi Wildlife Sanctuary, Chaing Mai and Tak Provinces, northern Thailand.

Figure 3.3 Montane evergreen forest in Mae Tuen Wildlife Sanctuary, Tak Province, northern Thailand.

Schima wallichii, etc. Some temperate species from the Himalayan region are also found in this forest, such as *Betula alnoides*, and *Prunus ceracoides*. The undergrowth is mainly ferns, lianas, and annual plants such as Family Zingiberaceae. Mosses, lichens, and epiphytes cover most tree trunks and limbs.

ii. Dry evergreen forest – This forest occurs from about 980 to 1,200 m. Although it is mainly closed canopy, there are fewer species in the Family Fagaceae and more spacing between trees than in the hill evergreen forest. Canopy trees comprise *Actocarpus lanceifolius*, *Eugenia cumini*, *Dialium cochinchinense*, *Michelia floribunda*, *Anisoptera costata*, etc.

iii. Mixed deciduous forest – This type occurs on lower elevations than the evergreen formations described above. It can be classified into two subtypes, mixed deciduous with teak, and mixed deciduous without teak. A variety of bamboos is also characteristic of this forest. The canopy is broken and trees such as *Tectona grandis* (Teak), *Pterocarpus macrocarpus*, *Vitex* spp., *Largerstroemia* spp., *Terminalia bellerica* dominate.

iv. Dry dipterocarp forest – This is the main forest type for Om Koi and Mae Tuen in terms of areal coverage and occupies mainly dry sites with sandy soil. Trees in the Family Dipterocarpaceae dominate. Other characteristics include an open canopy and lack of bamboos with tree species such as *Dipterocarpus tuberculatus*, *Shorea obtusa*, *S. siamensis*, and *Terminalia alata*. The undergrowth includes grasses and shrubs. Very often there is an extensive mixture of pine (*Pinus merkusii*) with this forest type in this area.

v. Old clearing and shifting cultivation areas – This kind of habitat is caused mainly by the hilltribes including the Karen, Mussur, and Hmong. The area is mostly covered with *Imperata cylindrica* if the soil is very degraded. In the areas with higher moisture, *Eupatorium odoratum*, *Thysanolaena maxima* and *Tithonia deversifolia*, are dominant.

3.2.2. Zoogeographic Significance of the Study Area

The Om Koi and Mae Tuen forests fall within the Indo-Chinese Subregion of the Oriental Region in terms of faunal realm (Wallace 1876). They are on the Downa Range, which is a long mountain range, dividing Thailand and Burma. The area supports animal species distributed in not only the two countries but also northern Laos and southern China. They also support species from the Sino-Himalayan Subregion, which includes Nepal, Putan, Assam, and northern Burma. Animals in this range are, for example, goral (*Naemorhedus goral*), Assamese macaqa (*Macaca assamensis*) and many bird species (Thailand Forest Research Center 1992).

Furthermore, these two sanctuaries are located on the west side of the Ping River which is one of the main rivers in northern Thailand while to the east side lies another national park named "Mae Ping National Park". These reserves together constitute a significant capacity in supporting wildlife populations in the region.

3.2.3. Wildlife Records

The Thailand Forest Research Center (1991) reported 43 species of mammals, 181 birds, 31 reptiles, and 13 amphibians in Om Koi Wildlife Sanctuary. Almost the same numbers were found in Mae Tuen Wildlife Sanctuary with 41 mammals, 192 birds, 32 reptiles, and 13 amphibians (Thailand Forest Research Center 1992). The sanctuaries still support many species listed as endangered and threatened by IUCN (1978, 1979a, 1979b) and Humphrey and Bain (1990) (see Figures 3.4, and 3.5). Examples of such species are given below.

i. Mammals – Tiger (*Panthera tigris*), leopard (*Panthera pardus*), elephant (*Elephas maximus*), goral (*Naemorhidus goral*), white-handed gibbon (*Hylobates lar*), serow (*Capricornis sumatraensis*), etc.
ii. Birds – Peregrine falcon (*Falco peregrinus*), black Eagle *(Ictinaetus malayensis*), great hornbill (*Buceros bicornis*), kalij pheasant (*Lophura leucomelena*), etc.

Figure 3.4. Remnant populations of Gorals (*Naemorhedus goral*) still exist in Om Koi and Mae Tuen Wildlife Sanctuaries (Photograph taken on April 23,1998 at Doi Mon Chong).

Figure 3.5. Serows (*Capricornis sumatraensis*) are one of the endangered species that Om Koi and Mae Tuen Wildlife Sanctuaries still support (Photograph taken on January 21,1998 at Doi Mon Chong).

iii. Reptiles – Yellow tree monitor (*Varanus bengalensis*), giant Asiatic tortoise (*Testudo emys*)

iv. Amphibians – Asiatic giant frog (*Rana blythii*)

3.2.4. Human Settlements and Agricultural Practices

Different hilltribe groups including Karen, Mussur, Hmong, and Lisaw have been in the area for various time periods. Currently within the sanctuaries there are at least 12 main villages (9 are Karen, 2 Mussur, and 1 Thai) in Om Koi WS and 25 (15 Karen, 9 Thai, 2 Hmong) in Mae Tuen WS (Mae Tuen Wildlife Sanctuary 1998, Thailand Forest Research Center 1991,1992) (Figure 3.6). There are also satellite villages located near the main village which is a common pattern of settlements in northern Thailand among some ethnic groups. Further strings of villages from all ethnic groups can be found along the western boundary of each sanctuary. In 1992, there were 720 households with a total population of 2,702 inside Om Koi WS whereas some 16 villages with a population of over 8,000 were along the boundary (Thailand Forest Research Center 1992). In 1998, Mae Tuen WS contained 832 households with a population of about 3,998 while 8 villages with a population of 562 were on the boundary (Mae Tuen Wildlife Sanctuary 1998).

People generally employ slash-and-burn cultivation. The Karen main crops include wet and dry rice, peppers, corns, sesame, and beans. The Hmong and Musser currently grow mainly cabbages for the commercial market. Tungittiplakon (1998) has discussed the spread of such commercial crops in the Highlands. Most of the old clearings at higher elevations in Om Koi and Mae Tuen are grasslands created more than 50 years ago (evidence from aerial photographs). The Hmong, Lisaw, and Musser are the main groups of people using such clearings in Om Koi mainly for growing opium and dry rice at various points in time. The Hmong moved out of the area some 20 years ago. Some local people mentioned that they were driven out of the area by local Thais because of conflicts (pers. comm. with local people). The Lisaw were relocated out of the sanctuary between 1993-1994 (perr. pomm. with sanctuary officers).

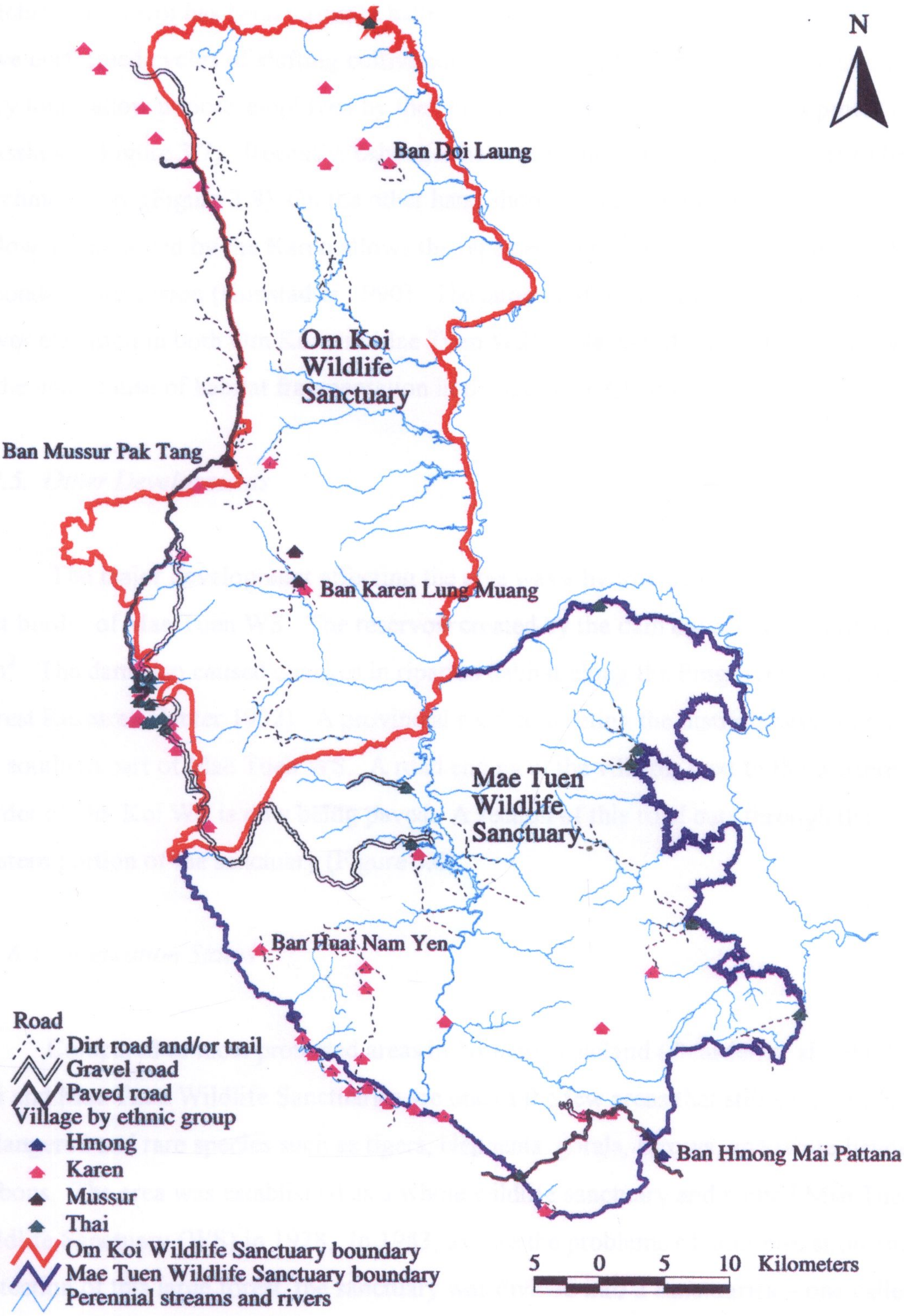

Figure 3.6. Human settlements and road development in Om Koi and Mae Tuen Wildlife Sanctuaries

Since then slash-and-burn shifting cultivation around the montane evergreen forest patches in Om Koi has been virtually halted. In Mae Tuen at high elevations, the Hmong have performed cycles of shifting cultivation without interruption. Long cultivation and very long fallow periods employed by the Hmong and Lisaw promote development of grasslands (Figure 3.7). Recently, cabbages have predominated cash crops in the Hmong catchment area (Figure 3.8). On the other hand short cultivation with relatively long fallow as employed by the Karen allows the repeated development of forest and bush as secondary succession (Kunstadter 1990). The latter kind of succession can be found at lower elevation in both Om Koi and Mae Tuen WS's. Slash-and-burn shifting cultivation is the main cause of habitat fragmentation in the area (see Chapter 4).

3.2.5. Other Developments

The major development affecting the area was a hydroelectric dam next to the east border of Mae Tuen WS. The reservoir created by the dam covers an area of 318 Km^2. The dam also caused changes in riparian habitat along the Ping river (Thailand Forest Research Center 1992). A provincial road connecting the districts was cut through the southern part of Mae Tuen WS. A road ending at the villages next to the western border of Om Koi WS is now being paved. A section of this road cuts through the western portion of the sanctuary (Figure 3.6).

3.2.6. Conservation Status

Compared to most protected areas in northern Thailand (Dearden et al. 1996), Om Koi and Mae Tuen Wildlife Sanctuaries are one of the few areas that still support several endangered and rare species such as tigers, elephants, gorals, serows, and white-handed gibbons. The area was established as a whole wildlife sanctuary and named Mae Tuen Wildlife Sanctuary (WS) in 1978. In 1983, to ease the problems of administration and protection of this large forest, the sanctuary was divided into 2 sanctuaries – one called Om Koi WS and another Mae Tuen WS. The areas are protected under the Wildlife Preservation and Protection Act (1960). By law, hunting, fishing, burning, illegal

Figure 3.7. Old clearings surround the montane evergreen forest patches in Om Koi Wildlife Sanctuary.

Figure 3.8. Cabbage fields are the main type of crop fields surrounding the montane evergreen forest patches in Mae Tuen Wildlife Sanctuary.

logging, encroaching, grazing are prohibited. In reality, however, all these activities seriously threaten wildlife populations within the areas.

The Wildlife Conservation Division, Royal Forest Department is in charge of administration. Currently there are 10 ranger stations permanently established in Om Koi WS and 8 in Mae Tuen WS. More than 100 officials and local guards have been employed to protect the forest and wildlife in the area.

Om Koi WS has received extra protection and management from a royal project on conservation initiated in 1992. The project covers Om Koi WS and a national reserve forest outside the sanctuary boundary. The purposes of the project include: 1) protecting Om Koi forest and wildlife from further encroachment; 2) restoring the degraded areas for protected and multiple use forest; 3) improving the availability of life for local people in a way harmless to Om Koi's remaining forest (Utayan 1998). Major activities regarding wildlife conservation from the project are, for example: establishing a wildlife breeding station to breed native rare wildlife for future reintroduction; relocating villages located in the middle of the elephant range to a new settlement on the boundary of the sanctuary (Om Koi Forest Conservation Project 1997).

CHAPTER 4
FRAGMENTATION STRUCTURE AND CHANGE BETWEEN TWO MONTANE EVERGREEN FOREST LANDSCAPES IN NORTHERN THAILAND

4.1. Introduction

Forman and Godron (1986) defined landscape as "a heterogeneous land area composed of a cluster of interacting ecosystems that is repeated in similar form throughout" (p11). The repeated similar forms include (1) the cluster of ecosystem type, (2) the flows of interactions among the ecosystems of a cluster, (3) the geomorphology and climate, and (4) the set of disturbance regimes (Forman and Godron 1986). Forman and Godron (1986) define disturbance as "an event that causes a significant change from the normal pattern in an ecological system" (p591). They also suggest that the study of ecology at the landscape scale can be addressed in 3 fundamental ways:

- Structure – the spatial relationships among the distinctive ecosystems or "elements" present --- more specifically, the distribution of energy, materials, and species in relation to the sizes, shapes, numbers, kinds, and configurations of the ecosystems.
- Function – the interactions among the spatial elements; that is, the flow of energy, materials, and species among the component ecosystems
- Change – the alteration in the structure and function of the ecological mosaic over time.

Important ecological processes affecting wildlife populations and communities operate at local spatial scales (Dunning et al. 1992). Forest fragmentation is a landscape-level process in which forest tracts are subdivided into smaller and more isolated forest fragments (Harris 1984). The importance of coarse-scale habitat patterns, based on landscape ecology (Forman and Godron 1986), to wildlife has been increasingly documented. McGarigal and McComb (1995), for example, reported that bird species' abundance was generally greater in more heterogeneous landscapes. However, the abundance of forest interior species generally declines, whereas the abundance of forest edge species generally increases in response to habitat fragmentation caused by agricultural development and urbanization (e.g. Terborgh 1989).

Patch is a main element in landscape structure. For individual patches, patch size, edge, shape, isolation, age, environmental heterogeneity, and disturbance (e.g, agricultural fields) play a role in determining animal diversity. Large forest patches support more animal species than smaller patches (e.g., Bierregaard and Lovejoy 1989). Also, high levels of animal activity along the patch edges have been a concept in wildlife management (e.g., Leopold 1933, Gate and Gysel 1978). A landscape with many large patches plus small patches and corridors can support both interior and edge species. Patch shape is important to the dispersal and foraging of animals. Patch shape in a landscape can be estimated by comparing these characteristics with the interior-to-edge ratio of a patch (Forman and Godron 1986).

Matrix is another element in a landscape structure. If a type of landscape element covers more than 50% of the landscape it is very likely to be a matrix. There are 3 criteria for determining the matrix – (1) it has a greater portion of the landscape, (2) it is the most connected portion of the landscape, and (3) it plays a predominant role in the dynamics of landscape (Foreman and Godron 1986).

Other aspects of landscape structures include (Foreman and Godron 1986)

- Patchiness is a measure of density of patches of all type .
- Landscape configuration is a pattern of landscape and refer to the physical distribution of spatial character of patches within the landscape (McGarigal and Mark 1995),
- Landscape contrast is strong if adjacent landscape elements are very different from each other and the transitions between them are narrow or absent. By aerial photographs the intact tropical evergreen forests may appear homogeneous and have a low contrast between landscape elements. However, the dispersion of common tropical forest trees indicates aggregations and clusters within continuous forests (Hubbell 1979). Therefore, scale is very important in understanding structures of landscape. Cultivated plots within the tropical forests are high contrast landscape elements.

In many tropical forest landscapes, the main disturbance regime involves a slash-and-burn cultivation employed by local people to transform the forest landscape into agricultural lands (Forman and Godron 1986). This technique can be viewed as a perturbation to forested landscape that results in the formation of cleared patches, patches undergoing natural succession, and mature forest. The severity of perturbation is a function of the rate of patch formation, the size and shape complexity of the patches, the length of fallow or successional period for each patch, and the size and shape complexity of the mature forest (Fox et al. 1995). A key component of slash-and-burn techniques is the potential for recovery and the reliance upon the forested landscape to promote the recovery process (Krummel et al. 1987). However, it also compounds the effects of fragmentation by continually setting the forest succession back to the beginning stage (Fox et al. 1995).

Few studies on landscape structure and change have been conducted in Thailand. Fox et al. (1995) conducted an extensive study on land use and landscape dynamics in montane forest sites occupied and altered by hilltribes and local Thai people using slash-and-burn cultivation techniques in northern Thailand. They found that between 1954 and 1992, forest cover declined, agricultural cover increased, population and population density grew, and agriculture changed from subsistence to cash crops. They also showed that the landscape changes were controlled not only by physical parameters such as topographic complexity but also by social and economic forces. The purpose of this section of the study is to examine landscape patterns and change between the montane evergreen forest landscapes of Om Koi and Mae Tuen Wildlife Sanctuaries and how they differ in degree of fragmentation and human disturbance. The results will help to understand the responses of wildlife to landscape change in the area.

4.2. Methods

4.2.1. Data Acquisition

Maps and images already available for the study included

- Topographic maps with scale 1:50,000

- Satellite imagery of the study area – a LANDSAT-5 TM acquired on February 15, 1996.
- Aerial photographs taken in 1954 and 1996 with scale 1:50,000
- Digital forest type and landuse map of Om Koi (Juntakat 1999)

4.2.2. Database Building

4.2.2.1. Forest Type and Land Use Maps

Because Mae Tuen and Om Koi Wildlife Sanctuaries are contiguous I used the forest type and landuse map classification in Om Koi (Juntakat 1999) as baseline information to build the digital map for Mae Tuen. I built a forest type and landuse map of Mae Tuen by visually interpreting the LANDSAT TM image. The digital maps were built in ARC/INFO format by digitizing. Ground truthing was conducted and the classification adjusted as needed.

The classification of forest types for both areas, however, was modified from Juntakat's (1999) version to suit the purpose of this study in which I tried to make more detailed classification of forest remnant patches in montane evergreen areas on both sites. Hill evergreen and dry evergreen forest types classified by Thailand Forest Research Center were combined into one category called montane evergreen forest (Groom 1994). This type of forest can be found from the elevation around 800m to the peak. I also separately classified montane evergreen forest with disturbed and open canopy visible in aerial photographs as another class called "Disturbed/open montane evergreen forest". Under the patch scale, patches of montane evergreen forest are better recognized in aerial photographs than in LANDSAT TM images because of the distinct crown cover texture. I therefore visually overlaid rectified maps of montane evergreen forest remnants interpreted from aerial photographs with the forest type and land use maps from LANDSAT TM to correct the boundary of the forest patches. Methods for building the rectified maps of forest remnants from aerial photos are later explained in section 4.2.2.3. The following is the vegetation classification used for Om Koi and Mae Tuen Wildlife Sanctuaries.

i. Montane evergreen forest
ii. Disturbed/Open montane forest
iii. Mixed deciduous forest
iv. Dry dipterocarp forest
v. Crop field
vi. Old clearing area
vii. Water bodies

The forest type and land use maps for Om Koi and Mae Tuen Wildlife Sanctuaries are shown in Figures 4.1

4.2.2.2. Landscape Maps

The LANDSAT TM images for Om Koi and Mae Tuen Wildlife Sanctuaries were used for selecting and drawing landscape boundaries. A montane forest landscape was selected from each of the sanctuaries. For the landscape analysis purpose, I demarcated the boundary of each selected landscape to cover the remaining montane forest area.

4.2.2.3. Montane Evergreen Forest Maps in Different Periods.

This step used aerial photographs taken in 1954 and 1996 with 1:50,000 scale. First, I scanned each photo with the 250 dpi (resolution ~ 5 m) to get a digital image of photographs. Then with PCI, a remote sensing software, I used the hydrology coverage as a reference map to rectify each image by collecting and matching Ground Control Points (GCPs). The mathematical model selected for rectification was "Thin plate spline" because this model, together with the large numbers of GCPs needed, work well for areas with high relief (PCI 1997). Because of the high relief, I collected as many as 20 to 40 GCPs, depending on the proportion of montane evergreen forest in each image. GCPs were located mainly on the montane evergreen forest area for each photograph. Photo mosaicking was performed after the rectification. The final product was a photo mosaic for each landscape in each year. The photomosaics were used to draw the boundary of the montane evergreen forests. The boundaries were digitized under ARC VIEW version 3.0. During digitizing I also used the hardcopies of aerial photographs with a stereoscope to get 3D image and texture of the area as guidance for forest

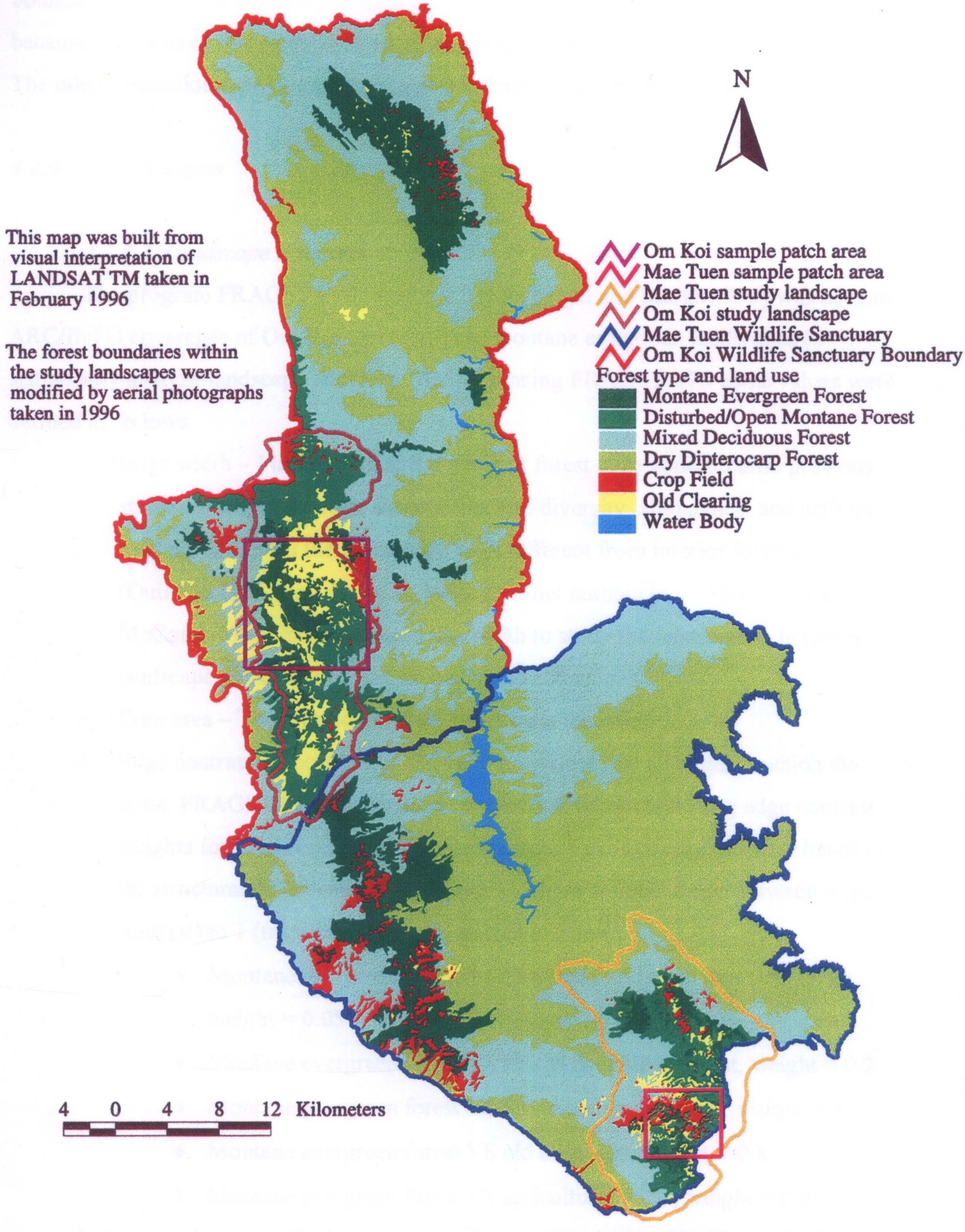

Figure 4.1. Forest types and land use in Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak Provinces, with the boundaries of sample landscapes, and sample patch areas for transect surveys with the details in Chapter 5.

boundaries. I focused my interpretation only on montane evergreen forest patches because the focus of this study is on montane evergreen forest change by fragmentation. The other vegetation types were not interpreted from the aerial photographs.

4.2.3 Data Analysis

4.2.3.1. Landscape Structure

The program FRAGSTATS version 2.0 (McGarigal and Marks 1995) was used on ARC/INFO coverages of Om Koi and Mae Tuen montane evergreen landscapes to statistically analyze landscape structure. Before running FRAGSTATS some values were defined as follows

i. Edge width – I used 100m as the width of forest edge zone because previous studies in tropical forests showed that bird diversity, abundance, and activity within 100m from the forest edge were different from interior forests (Quintela 1985, Lovejoy et al. 1986b). Other authors (e.g., McGarigal and McComb 1995) have also used this width to study the relationship between landscape structure and bird diversity and abundance.

ii. Core area – The area deeper than 100m from the edge,

iii. Edge contrast – Because it is not valid to assume that all edges function the same, FRAGSTATS allows users to specify a value containing edge contrast weights for each combination of patch types. I defined edge contrast based on the structural differences of forest types. These weights range between 0 (no contrast) to 1 (maximum contrast) as shown below.

- Montane evergreen forest VS Disturbed and open montane forest, weight = 0.05
- Montane evergreen forest VS Mixed deciduous forest, weight = 0.2
- Montane evergreen forest VS Dry dipterocarp forest, weight = 0.3
- Montane evergreen forest VS old clearings, weight = 0.8
- Montane evergreen forest VS agricultural areas, weight = 0.9

Indices used to quantify the structures of the two landscapes are shown in Table 4.1.

Table 4.1. Indices used to quantify the landscape structures of Om Koi and Mae Tuen montane evergreen forest landscapes built from interpretation of 1996 LANDSAT TM and aerial photographs with 1:50,000 scale.

Acronym	Index name (units)	Description*
%LAND	Percent of landscape (%)	Percentage of a landscape occupied by each forest type
LPI	Largest patch index (%)	Percentage of a landscape occupied by the largest patch
NP	Number of patches	Number of patches for each type
PD	Patch density (no./100ha)	Density of patches
MPS	Mean patch size (ha)	Average size of patch
PSSD	Patch size standard deviation (ha)	Patch size standard deviation for each forest type
PSCV	Patch size coefficient of variation (%)	Relative measure of patch size variability
TE	Total edge (m)	Total length of edge involving the corresponding patch type
ED	Edge density (m/ha)	Density of edge involving the corresponding patch type
CWED	Contrast-weighted edge density (m/ha)	Density of edge involving the corresponding patch type weighted by the degree of structural contrast between adjacent patches; equals ED when all edge is maximum contrast and approach 0 when all edge is minimum contrast
TECI	Total edge contrast index (%)	Total edge contrast as a percent of maximum contrast; equals 100% when all edge is maximum contrast and approaches 0 when all edge is minimum contrast
MECI	Mean edge contrast index (%)	Mean patch edge contrast as a percent of maximum contrast; equals 100% when all edge is maximum contrast and approaches 0 when all edge is minimum contrast
AWMECI	Area-weighted mean edge contrast index (%)	Similar to mean patch edge contrast, but patch edge contrast weighted by patch area
LSI	Landscape shape index	Landscape shape complexity; equals 1 when the landscape consists of a single circular patch and increases as landscape shape becomes noncircular and the amount of internal edge increases
MSI	Mean shape index	Mean patch shape complexity; equals 1 when all patches are circular and increases as patches become noncircular
AWMSI	Area-weighted mean shape index	Similar to MSI, but patch shape index weighted by patch area
MPFD	Mean patch fractal dimension	Mean patch shape complexity; approaches 1 for simple geometric shapes (e.g., circle) and 2 for complex shapes
C%LAND	Percent of core area (%)	Percentage of the landscape composed of core area (as defined above) of the corresponding patch type
TCA	Total core area (ha)	Total amount of core area of the corresponding patch type; core areas were defined by eliminating a 100m wide buffer along the perimeter of each patch

Acronym	Index name (units)	Description*
NCA	Number of core areas	Number of core areas, as defined above
CAD	Core area density (no./100ha)	Density of core areas, as defined above
MCA	Mean core area (ha)	Average size of core area per patch, as defined above
MCAI	Mean core area index	Average percentage of a patch that is core area, as defined above
TCAI	Total core area index (%)	Total percentage of the landscape that is core area, as defined above
CASA	Core area standard deviation (ha)	Absolute measure of core area variability, as defined above
CACV	Core area coefficient of variation (%)	Relative measure of core area variability, as defined above

* Modified from McGarigal and McComb (1995) and See McGarigal and Marks (1995) for a complete description and definition of each index

4.2.3.2. Landscape Change

To standardize the process of quantifying landscape structure, I used only the maps of remaining montane evergreen forest interpreted from aerial photographs in 1954 and 1996. No forest type map from LANDSAT TM was used in this process. Therefore, the 1996 forest areas calculated from aerial photographs appear a bit different from those from the LANDSAT TM images of the same year of 1996 (as discussed in the Result section). FRAGSTATS was used to analyze spatially the forest coverages of Mae Tuen and Om Koi montane evergreen forest patches in 1954 and 1996. Because there is only one type of vegetation on the coverages, edge contrast analyses were not available. A summary of the steps taken in processing data is shown in Figure 4.2.

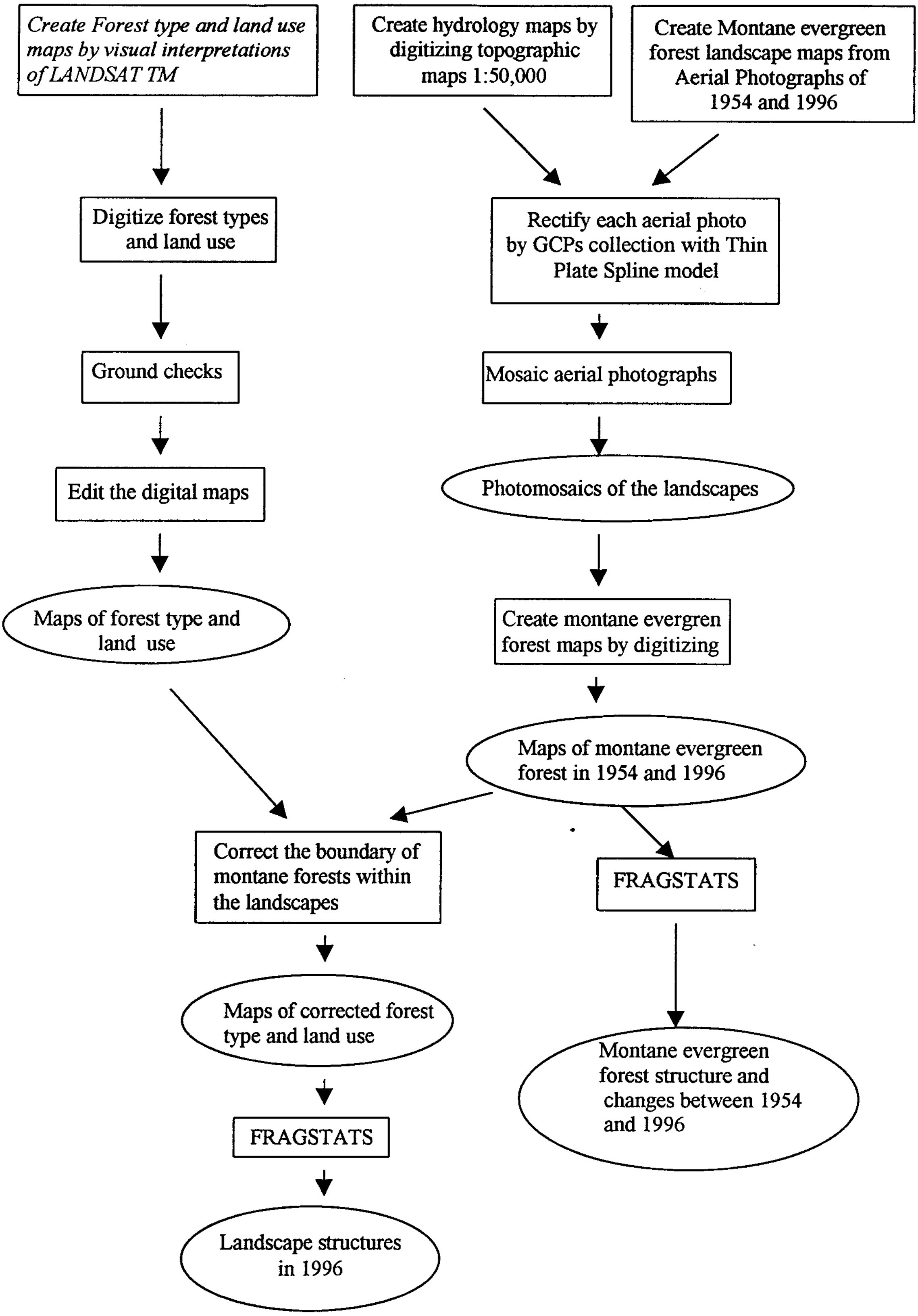

Figure 4.2. Flow diagram of processing procedure

4.3. Results

4.3.1. Landscape Structure

The structure and configuration of Om Koi and Mae Tuen evergreen forest landscapes are shown in Figures 4.3, 4.4, and Table 4.2. The Om Koi landscape is composed of ~ 17 % of montane evergreen forest, ~ 38 % of disturbed and open montane forest, ~ 3 % of crop fields, and ~ 25 % of old clearing. The Mae Tuen landscape was composed of ~ 13 % of montane evergreen forest, ~ 23 % of disturbed and open montane forest, ~ 6 % of crop fields, and ~ 6 % of old clearing. Only the major indices are shown in this section as follows. The Om Koi landscape contained some 3,400 ha of montane evergreen forest compared to 2,475 ha in the Mae Tuen landscape. The percentage of largest patch index was almost 17 % in Om Koi but there was only around 4 % in Mae Tuen. Mean patch size in Om Koi was ~ 77 ha while it was ~ 57 ha in Mae Tuen. Total core area in Om Koi was 1,623 ha whereas only 890 ha was in Mae Tuen.

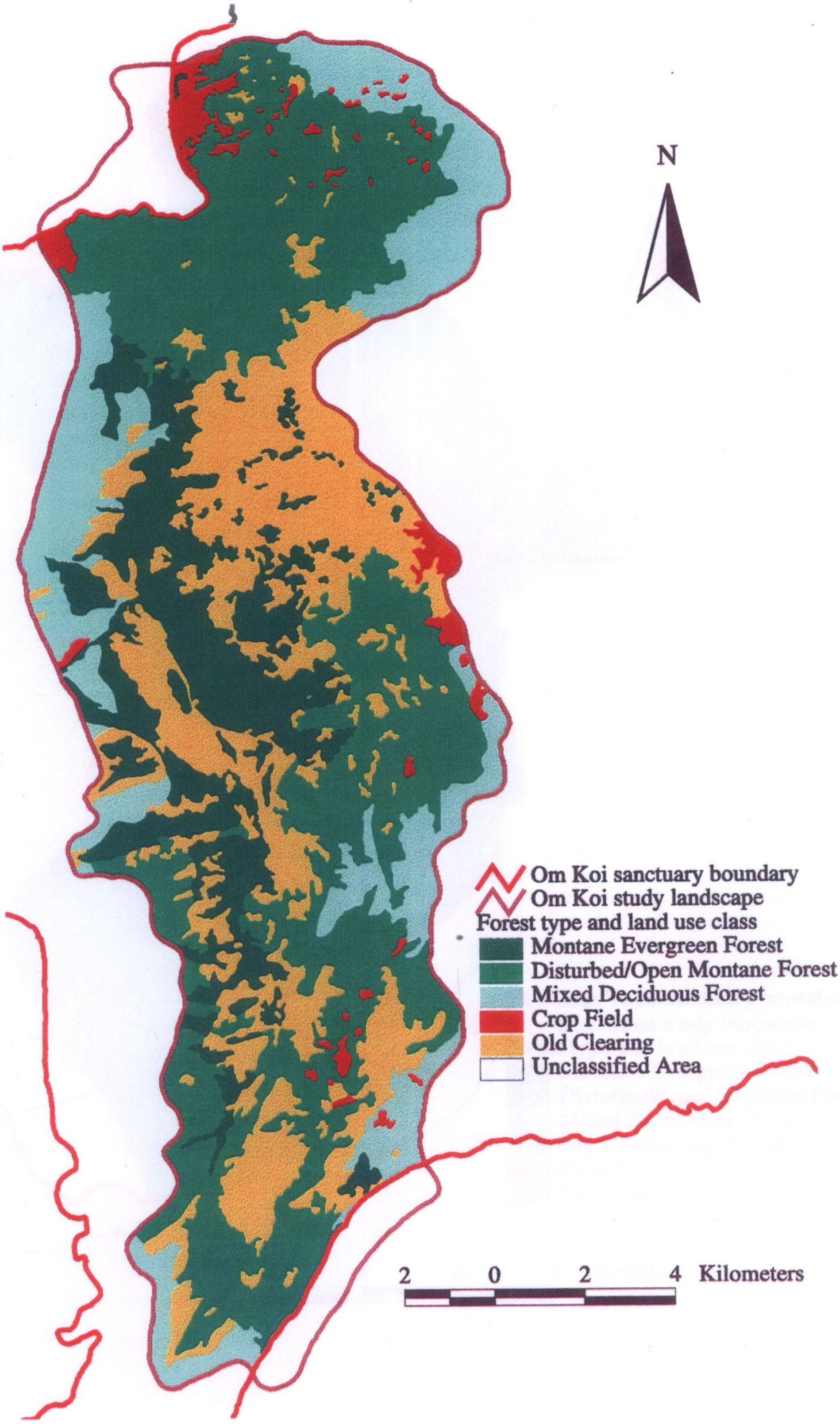

Figure 4.3. Forest and land use type in the study landscape in Om Koi Wildlife Sanctuary

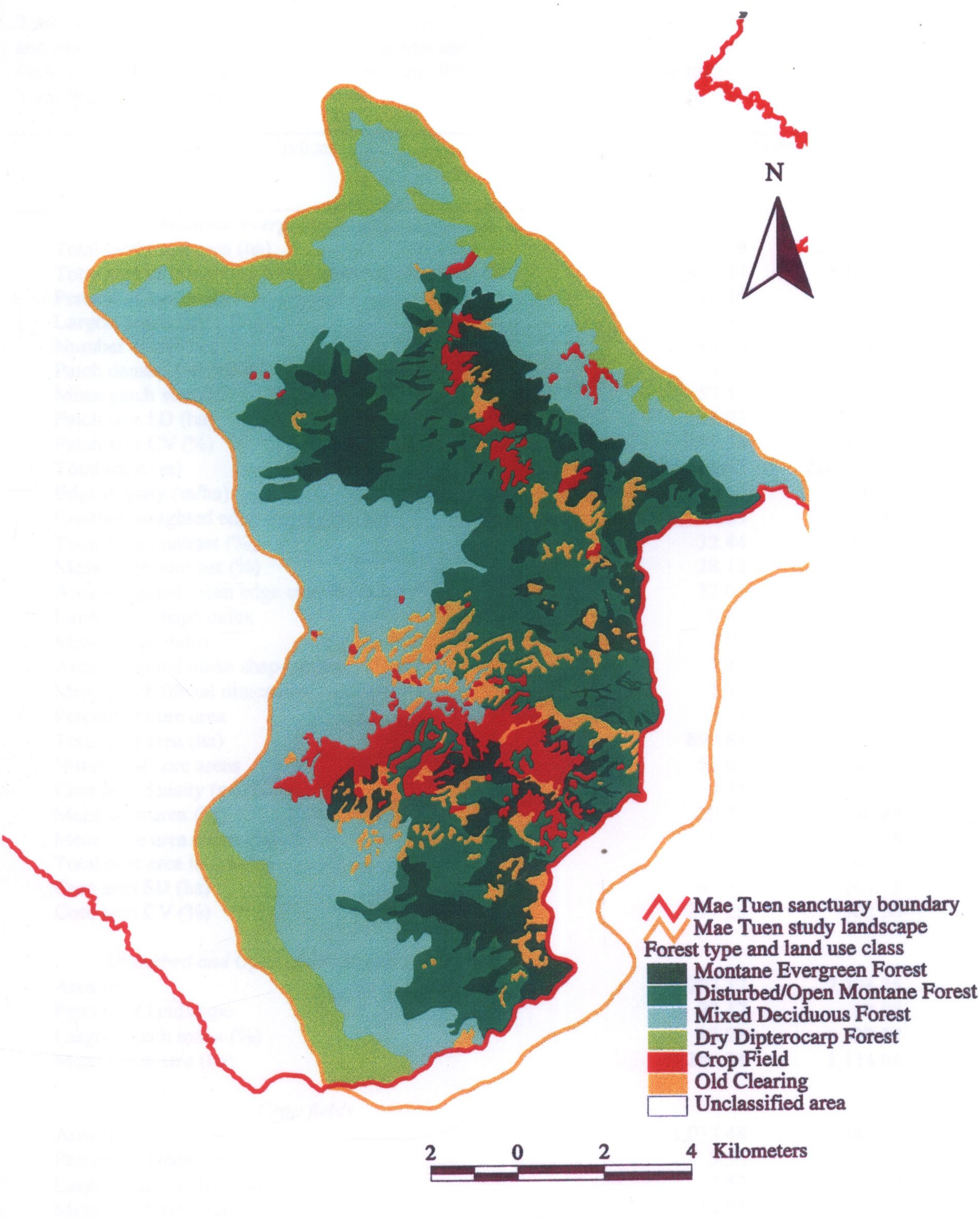

Figure 4.4..Forest and land use type in the study landscape in Mae Tuen Wildlife Sanctuary

Table 4.2. Structure and patterns of Om Koi and Mae Tuen montane evergreen forest landscapes, Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak Provinces, northern Thailand, using FRAGSTATS (McGarigal and Marks 1995) on 1996 forest types and landuse maps of Om Koi and Mae Tuen Wildlife Sanctuaries.

Indices	Landscape	
	Mae Tuen	Om Koi
Montane evergreen forest patches		
Total landscape area (ha)	18,530.79	20,481.08
Total area of remaining montane evergreen forest (ha)	2,475.33	3,403.79
Percent of landscape	13.36	16.62
Largest patch index (%)	3.94	16.62
Number of patches	43.00	44.00
Patch density (no./100ha)	0.23	0.22
Mean patch size (ha)	57.57	77.36
Patch size SD (ha)	132.02	377.77
Patch size CV (%)	229.34	488.33
Total edge (m)	216,062.47	220,793.09
Edge density (m/ha)	11.66	10.78
Contrast-weighted edge density (m/ha)	3.89	6.82
Total edge contrast (%)	32.44	62.54
Mean edge contrast (%)	28.12	70.66
Area-weighted mean edge contrast index (%)	32.01	60.25
Landscape shape index	6.43	6.26
Mean shape index	2.09	1.66
Area-weighted mean shape index	3.43	5.88
Mean patch fractal dimension	1.33	1.30
Percent of core area	3.28	7.93
Total core area (ha)	890.88	1,623.26
Number of core areas	51.00	42.00
Core area density (no./100ha)	0.28	0.21
Mean core area (ha)	20.72	36.89
Mean core area index (%)	9.35	7.78
Total core area index (%)	35.99	47.69
Core area SD (ha)	61.59	209.73
Core area CV (%)	297.26	568.50
Disturbed and Open montane evergreen forest		
Area (ha)	4,293.17	7,798.25
Percent of landscape	23.17	38.08
Largest patch index (%)	13.71	20.37
Mean patch size (ha)	286.21	1,114.04
Crop fields		
Area (ha)	1,033.48	585.17
Percent of landscape	5.56	2.86
Largest patch index (%)	2.57	0.89
Mean patch size (ha)	16.94	12.91
Old Clearings		
Area (ha)	1086.79	5,161.86
Percent of landscape	5.87	25.20
Largest patch index (%)	0.43	10.80
Mean patch size (ha)	10.55	62.95

4.3.2. Landscape Change

The structure and configuration of the Om Koi montane forest area in 1954 and 1996 are shown in Figures 4.5, 4.6 and Table 4.3. Change in the montane evergreen forest area is shown in Figure 4.7. The montane evergreen forest area lost is ~ 888 ha within 50 years. The number of patches increased from 20 to 36. The mean patch size decreased from ~ 178 ha to 74 ha. The core area lost was ~ 750 ha.

The structures and configurations of the Mae Tuen montane forest area in 1954 and 1996 are shown in Figures 4.8, 4.9 and Table 4.4. Change in the montane evergreen forest area is shown in Figure 4.10. The montane evergreen forest area lost was ~ 2,640 ha from 1954 to 1996. The number of patches increased from 6 to 43. The mean patch size decreased from ~ 829 to 54 ha. The core area lost was ~ 1,719 ha.

Again some of the indices on 1996 may appear different than the same indices in section 4.4.1. This is because the landscape changes analysis was based on maps interpreted directly from the photomosaics without LANDSAT TM being involved.

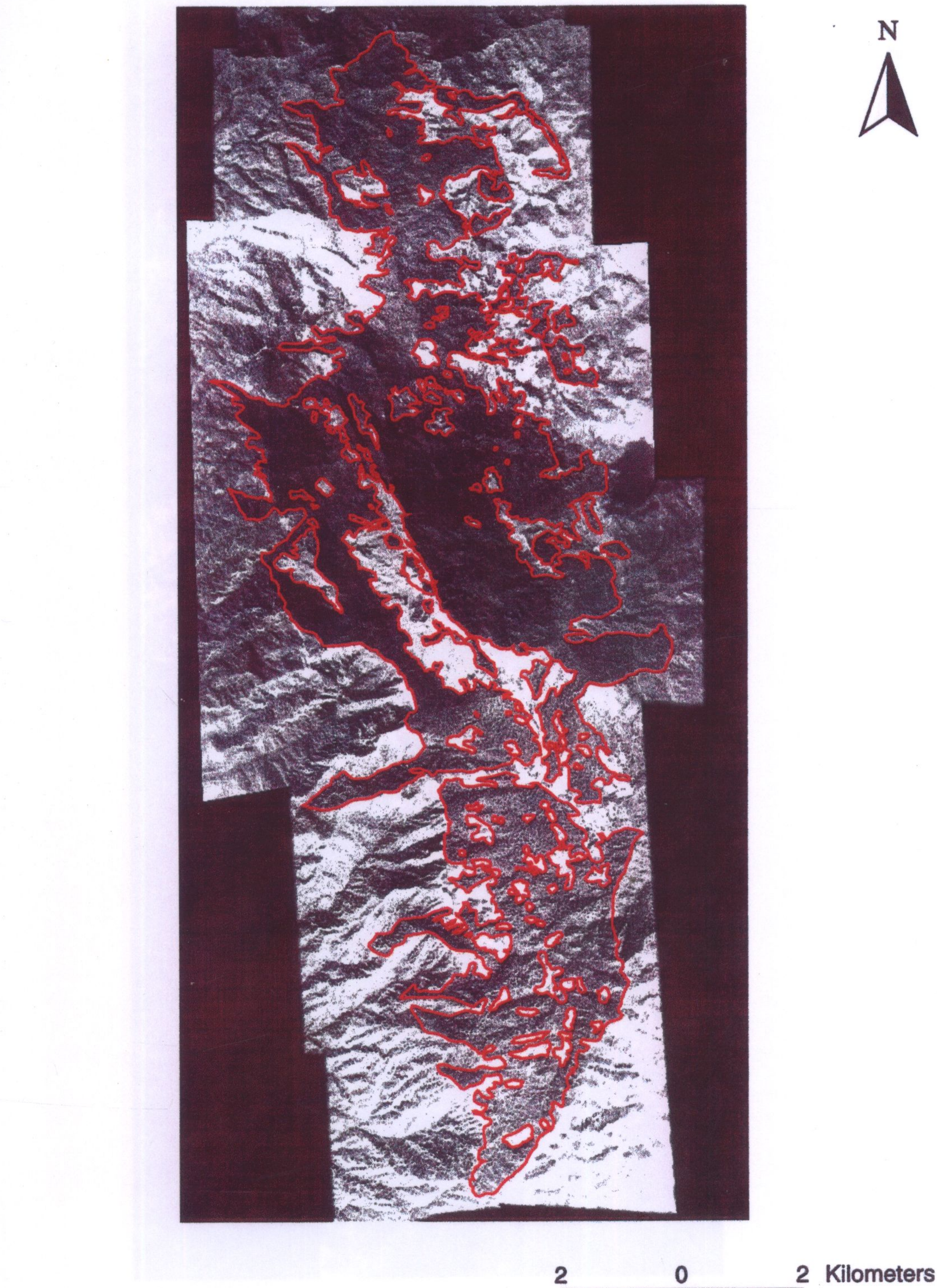

Figure 4.5. A photomosaic of the study landscape in 1954 showing montane evergreen forest, Om Ḳoi Wildlife Sanctuary

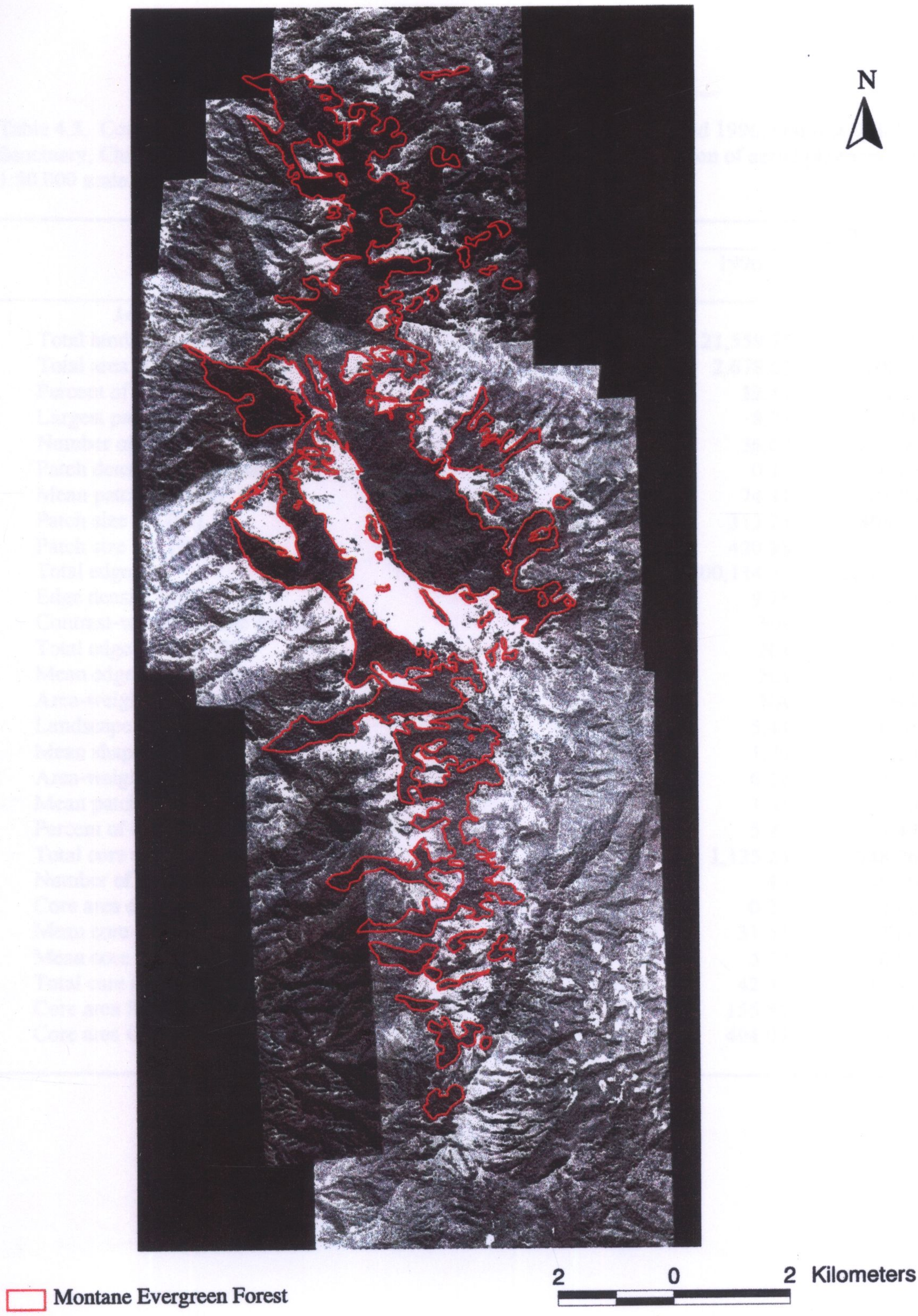

Figure 4.6. A photomosaic of the study landscape in 1996 showing existing montane evergreen forest, Om Koi Wildlife Sanctuary

Table 4.3. Comparisons of montane evergreen forest change between 1954 and 1996, Om Koi Wildlife Sanctuary, Chiang Mai and Tak Province, northern Thailand, from interpretation of aerial photographs with 1:50,000 scale.

Indices	Year		Difference
	1954	1996	
Montane evergreen forest patches			
Total landscape area (ha)	21,559.75	21,559.75	0
Total area of remaining montane evergreen forest (ha)	3,567.04	2,678.62	888.42
Percent of landscape	16.54	12.42	4.12
Largest patch index (%)	15.35	8.77	6.58
Number of patches	20.00	36.00	-16.00
Patch density (no./100ha)	0.09	0.17	-0.08
Mean patch size (ha)	178.35	74.41	103.94
Patch size SD (ha)	718.28	313.23	405.05
Patch size CV (%)	402.73	420.98	-18.25
Total edge (m)	202,897.28	200,114.33	2,782.95
Edge density (m/ha)	9.41	9.28	0.13
Contrast-weighted edge density (m/ha)	NA	NA	NA
Total edge contrast (%)	NA	NA	NA
Mean edge contrast (%)	NA	NA	NA
Area-weighted mean edge contrast index (%)	NA	NA	NA
Landscape shape index	5.49	5.44	0.05
Mean shape index	1.99	1.76	0.23
Area-weighted mean shape index	7.55	6.12	1.43
Mean patch fractal dimension	1.31	1.31	0
Percent of core area	8.74	5.27	3.47
Total core area (ha)	1,884.01	1,135.25	748.76
Number of core areas	36	45	-9.00
Core area density (no./100ha)	0.17	0.21	-0.04
Mean core area (ha)	94.20	31.54	62.66
Mean core area index (%)	4.89	5.72	-0.83
Total core area index (%)	52.82	42.38	10.44
Core area SD (ha)	408.62	155.81	252.81
Core area CV (%)	433.77	494.09	-60.32

Figure 4.7. Change in montane evergreen forest area between 1954 and 1996 in the study landscape interpretated from aerial photographs, Om Koi Wildlife Sanctuary

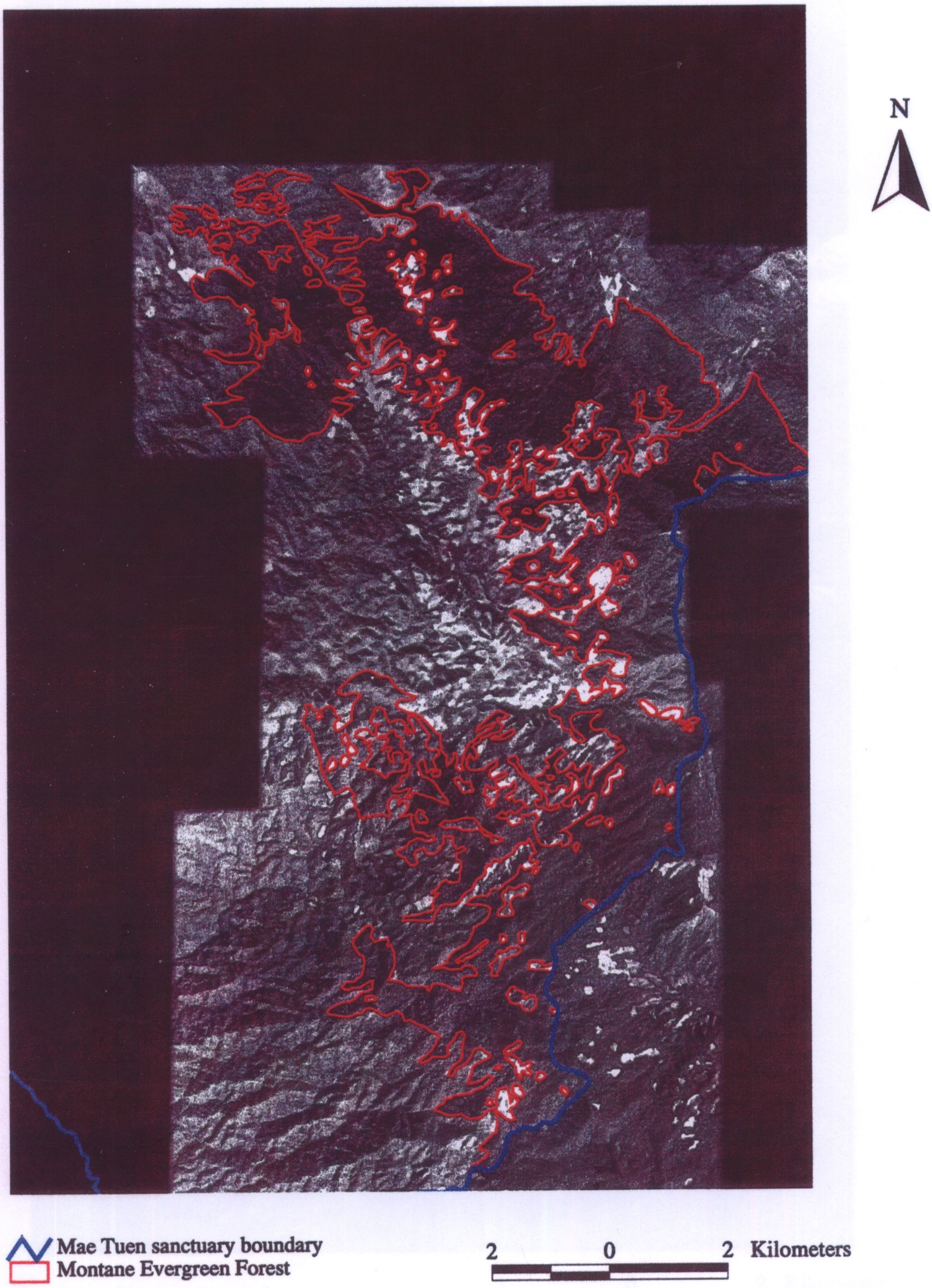

Figure 4.8. A photomosaic of the study landscape in 1954 showing existing montane evergreen forest patches, Mae Tuen Wildlife Sanctuary

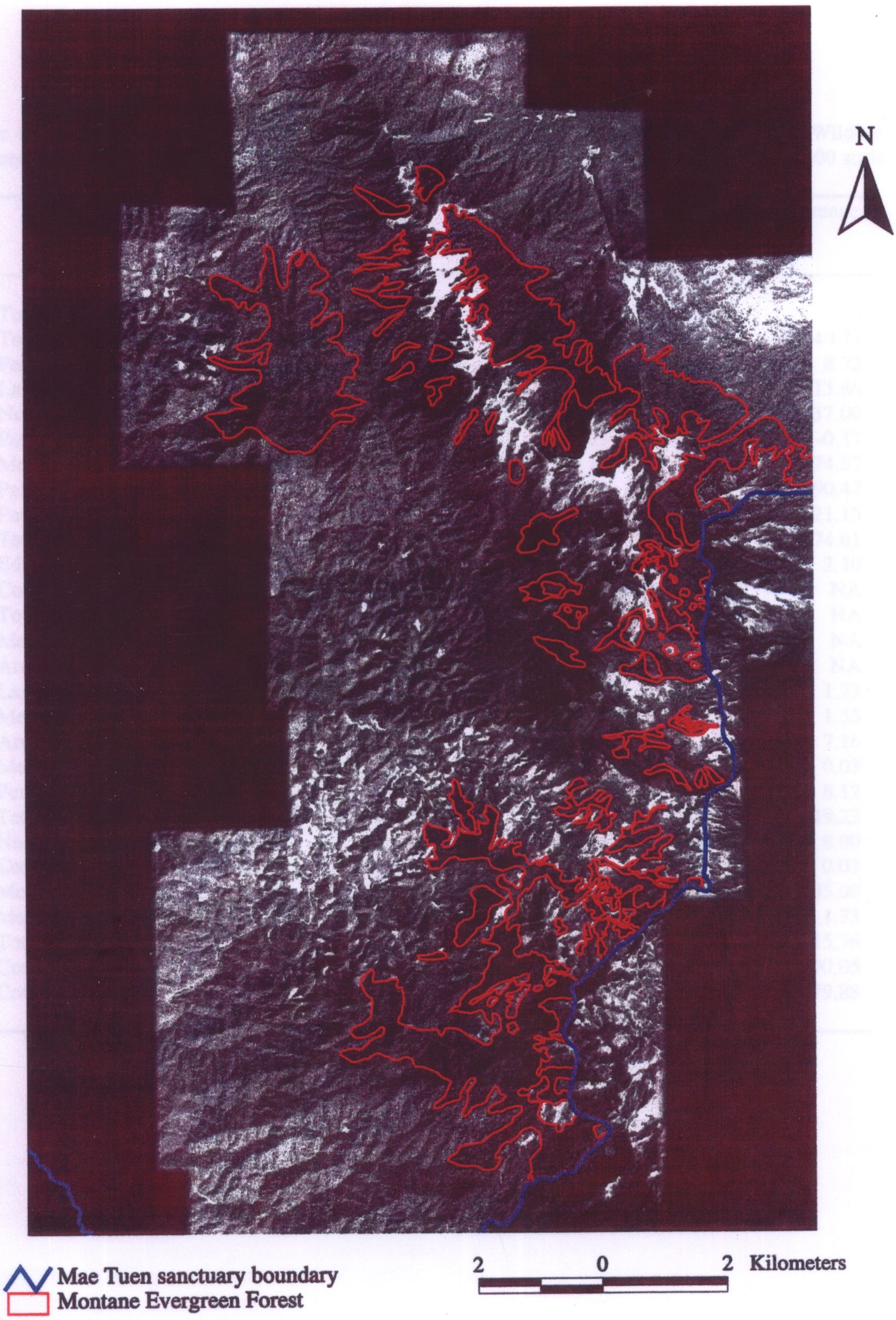

Figure 4.9.. A photomosaic of the study landscape in 1996 showing existing montane evergreen forest patches, Mae Tuen Wildlife Sanctuary

Table 4.4. Comparisons of montane evergreen forest change between 1954 and 1996, Mae Tuen Wildlife Sanctuary, Tak Province, northern Thailand, from interpretation of aerial photographs with 1:50,000 scale.

Indices	Year		Difference
	1954	1996	
Montane evergreen forest patches			
Total landscape area (ha)	21,182.33	21,182.33	0
Total area of remaining montane evergreen forest (ha)	4,974.92	2,334.19	2,640.73
Percent of landscape	23.49	11.02	8.72
Largest patch index (%)	23.14	3.33	13.86
Number of patches	6.00	43.00	-37.00
Patch density (no./100ha)	0.03	0.20	-0.17
Mean patch size (ha)	829.15	54.28	774.87
Patch size SD (ha)	1,821.18	130.71	1,690.47
Patch size CV (%)	219.64	240.79	-21.15
Total edge (m)	291,230.06	227,555.45	63,674.61
Edge density (m/ha)	13.75	10.73	2.10
Contrast-weighted edge density (m/ha)	NA	NA	NA
Total edge contrast (%)	NA	NA	NA
Mean edge contrast (%)	NA	NA	NA
Area-weighted mean edge contrast index (%)	NA	NA	NA
Landscape shape index	7.00	5.77	1.23
Mean shape index	3.72	2.17	1.55
Area-weighted mean shape index	10.99	3.83	7.16
Mean patch fractal dimension	1.36	1.33	0.03
Percent of core area	12.02	3.90	8.12
Total core area (ha)	2,545.90	826.67	1,719.23
Number of core areas	58.00	50.00	8.00
Core area density (no./100ha)	0.27	0.24	0.03
Mean core area (ha)	424.32	19.23	405.09
Mean core area index (%)	9.11	7.38	1.73
Total core area index (%)	51.18	35.42	15.76
Core area SD (ha)	948.38	58.33	890.05
Core area CV (%)	223.51	303.39	-79.88

Figure 4.10. Change in montane evergreen forest areas between 1954 and 1996 in the study landscape, Mae Tuen Wildlife Sanctuary

4.4. Conclusions and Discussion

The conclusion and discussion in this chapter focus mainly on the effects of the structure and configuration of landscape on wildlife. More discussion of the landscape structures and change affecting local wildlife species and communities in Om Koi and Mae Tuen montane evergreen forest landscapes is later addressed in Chapter 5 on wildlife responses to habitat fragmentation and other influences following the wildlife species and community survey.

4.4.1. Landscape Structure

From Figure 4.3 and 4.4 it appears that the two montane evergreen forests have been heavily fragmented. Om Koi contains large areas of old clearings which indicate heavy human use in the past. Chronic disturbance by slash-and-burn cultivation of the area in Mae Tuen has left many small forest patches surrounded by disturbed forest, regrowth, and agricultural areas. Some of the quantitative indices of fragmentation in Table 4.2 will now be discussed.

Although the landscape boundaries were drawn based on the areas of montane forest in each sanctuary, it turns out that the study landscapes of montane forest in Om Koi and Mae Tuen are not greatly different in area, thereby facilitating comparisons. The Om Koi landscape contained 3,403.79 ha of montane evergreen forest compared to 2,475.33 ha in Mae Tuen. There was a small difference in the percentage of the landscape (%LAND) remaining in montane evergreen forest between the Mae Tuen (13.36%) and Om Koi (16.62%) landscapes. However, a more severe indicator of fragmentation is the largest patch index (LPI). The LPI in Om Koi comprised almost 17% of the landscape, whereas in Mae Tuen it was only 4% of the landscape. The LPI indicates that the Mae Tuen montane evergreen forest has been fragmented severely into smaller patches. The larger patches in Om Koi may play a significant role in maintaining species diversity following island biogeography theory (McArthur and Wilson 1967). Many authors have confirmed a positive relationship between forest patch size and species diversity (e.g., Bierregaard and Lovejoy 1989, Warburton 1997). Mae Tuen patches are also less likely to contain large mammals mainly because many large mammals have large home ranges, and, thus, the patches are too small to support them (Robinson 1996). The number of patches (NP) and patch density (PD) are very similar for both landscapes (Table 4.2). NP can be important in determining the number of subpopulations in a spatially dispersed population, or metapopulation, for species exclusively associated with that habitat type (McGarigal and Marks 1995). Although mean patch size (MPS) in Om Koi (77 ha) was greater than Mae Tuen MPS (57 ha) patch size variability (SD and CV) was greater in Om Koi. This indicates that the human-altered landscape in Mae Tuen contains more uniformity of small patch size than the Om Koi landscape, which has a mixture of large and small patches.

The montane evergreen forest patches in the two landscapes contained almost the same numbers of total edge (TE) and edge density (ED). The degree of edge contrast as indicated by four indices including contrast-weighted edge density (CWED), total edge contrast index (TECI), mean edge contrast index (MECI), and area-weighted mean edge contrast index (AWMECI) indicates more edge contrasts in Om Koi. This is mainly because the montane forest patches in Om Koi are adjacent to patches of old clearings distributed all over the landscape. Although high-contrast edges may prohibit or inhibit some animals from seeking supplementary resources in surrounding patches, some species prefer high contrast edge (Dunning et al. 1992).

The mean shape index (MSI) values of both landscapes are greater than 1, indicating that the average patch shape in the two landscapes is noncircular (McGarigal and Marks 1995). Montane evergreen forest patches in Om Koi (MSI = 1.66) were less irregular in shape than Mae Tuen's (MSI = 2.09). However when weighted by patch area, patches in Om Koi became more irregular than patches in Mae Tuen. The small irregular patches in Om Koi probably cause this discrepancy. Patch shapes may influence animal foraging strategies (Forman and Godron 1986). The primary significance of patch shape in a landscape can also be related to edge effects (McGarigal and Marks 1995).

Core areas (C%LAND) in Om Koi comprised almost 8% of the landscape compared to only 3% in Mae Tuen (Table 4.2). The difference in core area is clearly shown in the total core area (TCA) statistic in which Om Koi is almost twice as large as the TCA in Mae Tuen. These indices including the higher number of core areas (NCA) in Mae Tuen indicate that the Mae Tuen landscape is more fragmented than Om Koi. Mean core area (MCA) values were also higher in Om Koi. The lower core area variability (SD and CV) in Mae Tuen indicates more uniformity of landscape. The large core areas remaining in Om Koi may support some habitat specialists which prefer deep forest. Core area has been found to be a much better predictor of habitat quality than patch area for forest interior specialists (Temple 1986).

The remaining Om Koi montane evergreen forest was also contiguous to a large area of disturbed and open montane forest. Although this type of habitat still exists in Mae Tuen, forest patch sizes are much smaller than those in Om Koi. Nevertheless forest areas were still the matrix for the two landscape, according to Forman and Godron (1986), because they comprised more than 50% of the total landscape areas at both sites. The total area of crop fields in Mae Tuen is almost twice as large as the total area of crop fields in Om Koi. Old clearing areas in Om Koi are almost 5 times as large as Mae Tuen. However, the areas were not totally cleared. There are some small dots and bands of remaining forest interspersed in the clearings. Also, the pattern of forest clearing in Om Koi is very large patches (MPS = 62.95) compared to Mae Tuen (MPS = 10.55). This indicates the difference in the land use pattern between the two landscapes. Also, old clearings in Om Koi are likely enlarged by chronic fires.

4.4.2. Landscape Change

The conclusion and discussion on landscape change in Om Koi are based on Figures 4.5 – 4.7 and Table 4.3 whereas Figures 4.8 – 4.10 and Table 4.4 are for the Mae Tuen montane forest landscape.

The amount of montane evergreen forest loss of 2,640 ha (53% of montane evergreen forest existed in 1954) in Mae Tuen within 40 years (1954-1996) is dramatically high compared to the 888 ha (25% of montane evergreen forest existed in 1954) in Om Koi. Closed canopy montane forest was converted to disturbed and open montane forest, crop fields, and old clearings. The percentage of the landscape (%LAND) covered by montane evergreen forest dropped from 23% in 1954 to 11% in

1996. Severe fragmentation in Mae Tuen is shown in the following indices. The largest patch index (LPI) was greatly reduced from ~23% (1954) of the landscape to ~3% (1996). The number of patches (NP) increased from 6 to 43. Mean patch size (MPS) dropped from ~ 830 ha to 54 ha. Variability indices for patch size (PSSD and PSCV) were greatly reduced, which indicates more uniformity of small patch size after the severe fragmentation. Om Koi montane evergreen forest changed at a less severe rate. The percentage of montane evergreen forest cover in the Om Koi landscape changed from ~16% (1954) to ~12% (1996). There was a 6% change in largest patch index (LPI) from 1954 (~15%) to 1996 (~9%). The number of patches (NP) increased from 20 to 36. Mean patch size (MPS) changed from 178 to 74 ha. More uniform patch size was indicated by patch size standard deviation (PSSD) that changed from 718 to 313 ha.

For patch shape indices MSI and AWMSI values were reduced from 1954 to 1996 for both landscapes. Mean shape index (MSI) measures the average perimeter to area ratio and therefore after fragmentation the perimeters in the landscapes may be reduced because of the large areas of forest loss. This reasoning is supported by the lower values of total edge and edge density in 1996 than in 1954 for both landscapes. It also means that the average patch shape became simpler, closer to a circular shape, in 1996 than 1954. This result agrees with that of Fox et al. (1995) who found that slash-and-burn agriculture resulting in the production of simple shapes as opposed to irregular patch shapes resulted from physical and biological processes under natural conditions.

There was great change in core areas in Mae Tuen between the years. The percentage of core area of the landscape (C%LAND) was greatly reduced from 12% (1954) to almost 4% (1996). A smaller change occurred in Om Koi, a change of ~ 3%. Total core area (TCA) dropped sharply from 2,545 ha (1954) to 826 ha (1996) in Mae Tuen. TCA in Om Koi was reduced from 1,884 ha (1954) to 1,135 ha (1996). The large reduction of core area SD between 1954 to 1996 in both areas means that current landscapes are more uniform compared to the past landscape structure.

The main reasons for the more severe montane evergreen forest loss and fragmentation, and larger areas of crop fields in Mae Tuen compared to Om Koi include the influences of turning to cash crops and constructing a paved road right through the area. A paved road has opened the villages to markets as far away as Bangkok. Dearden

(1995) emphasized that road and other development programs have contributed significantly to the forces of homogenization in the highlands of northern Thailand.

In conclusion, both the Om Koi and Mae Tuen montane forest landscapes have been heavily fragmented. However, Om Koi still contains more large patches and larger core areas than Mae Tuen and this may be an important determinant of survival of many species. Furthermore, slash-and-burned activities in Om Koi landscape have been virtually halted, whereas they are still going on in Mae Tuen. Such chronic use of areas by humans may keep many wild species less tolerant of human disturbance away from the area. Also the faster pace of forest loss in Mae Tuen from 1954 to 1996 may lead to local extinction of many species. Development and urbanization has also contributed to the more rapid change in the montane forest areas in Mae Tuen compared to Om Koi.

CHAPTER 5
MAMMAL AND BIRD DIVERSITY AND ABUNDANCE IN MONTANE EVERGREEN FOREST PATCHES IN NORTHERN THAILAND

5.1. Introduction

Some studies regarding wildlife response to habitat fragmentation in the tropics do not fully conform to mainstream results on fragmentation. Species loss from fragmentation is less than predicted for many tropical forest birds. On Cebu Island in the Philippines, for example, 7 of 15 endemic bird species survived in a total area of 15 km^2, comprising 0.3% of the original forest (Magsalay et al. 1995). A major influence on the degree of survival could be the proximity of the fragment to large reservoirs of primary forest. Another result in Amazonian forest remnant patches indicated that very few second-growth species appear to colonize or invade remnant patches of native vegetation (Bierregaard and Stouffer 1997, Lovejoy et al. 1986b). Time since fragment isolation is also a relevant factor (Whitmore 1997).

Many fragmentation studies have examined fauna and flora in recently fragmented landscapes (e.g., Bieeregaard et al. 1992, Malcolm 1997). However, many areas of tropical forests have been fragmented before the turn of the century (Whitmore 1997). Remaining forest patches in the tropics mainly serve as "islands of biodiversity" in agricultural landscapes and as a source of colonizers for many animals (Viana and Tabanez 1996). Corlett and Turner (1997) conducted a study in Singapore, which has faced a long history of fragmentation and other development, and produced lists of forest birds and mammals extirpated from hundred-year old forest remnants. The extinct animals in Singapore are mainly large birds, carnivores, and herbivores and the surviving species are mainly small and very abundant species adaptable to disturbed environments. Corlett and Turner (1997) also point out that hunting accelerated extinction in the country. All carnivores in Hong Kong faced the same fate as indicated in Singapore. More studies on old fragments are necessary in order to conserve biological diversity in landscapes shared with humans (Corlett and Turner 1997).

Fragmentation effects on wild animals in Thailand rarely have been documented. Lynam (1997) studied the effects on small mammals from ecological changes on evergreen forest islands created by a hydroelectric reservoir in southern Thailand. He found that fragmentation plus continuous burning and logging resulted in loss of evergreen forest and disturbance-sensitive species such as lesser gymnure (*Hylomys suillus*), and murid rodent (*Leopoldamys sabanus*) on the islands, while the exotic house rat (*Rattus rattus*) dramatically increased. He suggested that primary forest fragments of 100 ha or less may be too small to maintain intact assemblages of small mammals unless they are connected to larger relatively undisturbed tracts of forest. No study on habitat fragmentation has been conducted in montane evergreen forest in Northern Thailand where local Thai and hilltribes have used many areas for decades.

This study is designed to document bird and mammal use of montane evergreen patches some of which have been fragmented for more than 50 years. It is also intended to compare the wildlife using forest patches between two areas that differ in fragmentation patterns and degree of human disturbance.

5.2. Methods

5.2.1. Data Collection

5.2.1.1. Site Selection

Since aerial photographs and GIS maps of forest types were not available at the beginning of the field work, I conducted several site surveys with topographic maps to locate sample montane evergreen forest sites, one in Om Koi Wildlife Sanctuary and another in Mae Tuen Wildlife Sanctuary. Then, 4 remnant patches (replicates) were selected for each site based on similarity of vegetation cover, accessibility, and time available for survey. The two sites are somewhat different in elevation and differ greatly in surrounding human activities. Although there are no pre-fragmentation baseline studies on wildlife in both areas, there are reasons supporting the comparison study. These include: (1) these two sites are montane evergreen forest; (2) the sites are one large tract of forest at the regional scale (see Figures 3.1 and 4.1); and (3) historically the two sanctuaries contain almost exactly the same wildlife species from the records of sanctuary-wide surveys conducted by the Thailand Forest Research Center (1991, 1992) (see section 3.2.3 in Chapter 3).

For sampling purposes, each sample patch was given a code as P1 to P4 for patches in the Mae Tuen site and P5 to P8 for Om Koi. The location of each patch is shown in Figures 5.1 and 5.2. Photographic examples of the sampled patches are shown in Figures 5.3 – 5.6. Some sample forest patches were still connected with the other sample patches by narrow forest remnants (< 300 m wide) which I arbitrarily defined as forest corridors. For analysis of species using edge and interior, patches were roughly divided into edge and interior zone. According to the literature, penetration of edge effects on bird abundance and diversity varies between 50 to > 100m (e.g., Burke and Nol 1998, Lovejoy et al. 1986b). Quintela (1985) showed that avian activity level in Amazonian forest fragments was lower at 100m from the forest edges than in deep forest areas. Many authors (e.g., Gates and Gysel 1978, Brittingham and Temple 1983) have also showed that at distances of over 100 m from the edge many negative impacts associated with edge habitat have ameliorated. Therefore I defined edge zone as 100 m from forest edge to measure effects. Areas deeper than 100m were considered as interior zone.

5.2.1.2. Sampling Protocols

I used line transect methods (Buckland et al. 1993) to survey diversity and estimate the abundance of birds and mammal tracks within each sampled patch. The total length of transect set up in each patch was 1 km. However, due to the small area of P1 and P7 the transect total lengths in those two cases were only 0.9 and 0.8 km respectively. Each transect was broken into half. One half, 500 m in length, was set up deeper than 100 m away from the forest edge to measure species using the interior zone. The other half was broken again into 4-5 100 m transects located perpendicular from the forest edge into the interior and at 200-300 m apart to ensure independence of the data (Thiollay 1993). A compass and measurement tape were used for direction and distance of transects. I marked the transects with flagging tape at 10 m intervals. Wherever the undergrowth was dense the trails were cut wide enough only for an individual to pass. Otherwise I applied only flagging tape for marking to keep the disturbance to a minimum.

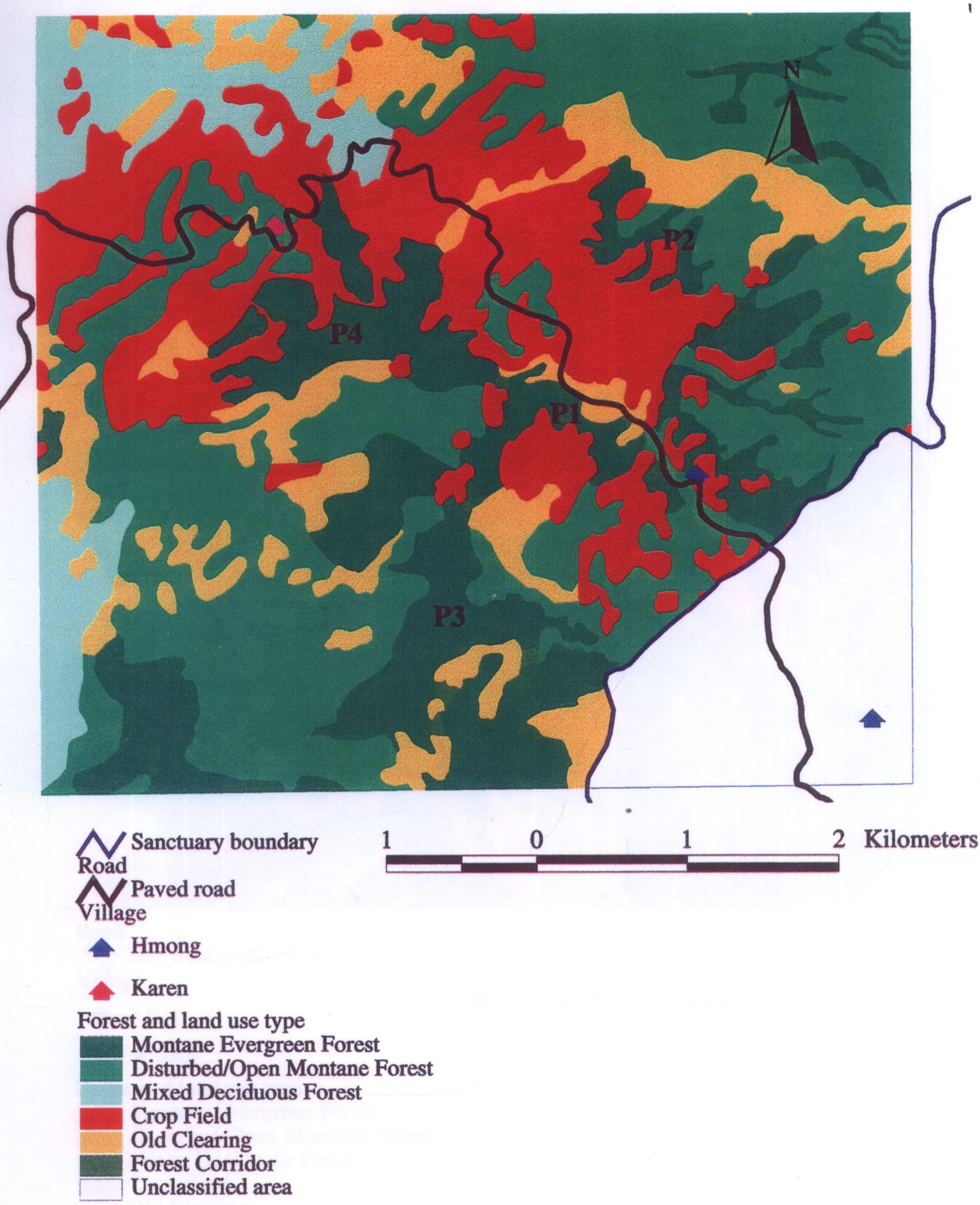

Figure 5.1. Sample patches (P1-P4) of montane evergreen forest, Mae Tuen Wildlife Sanctuary (also see Figure 4.1 for the location in the landscape).

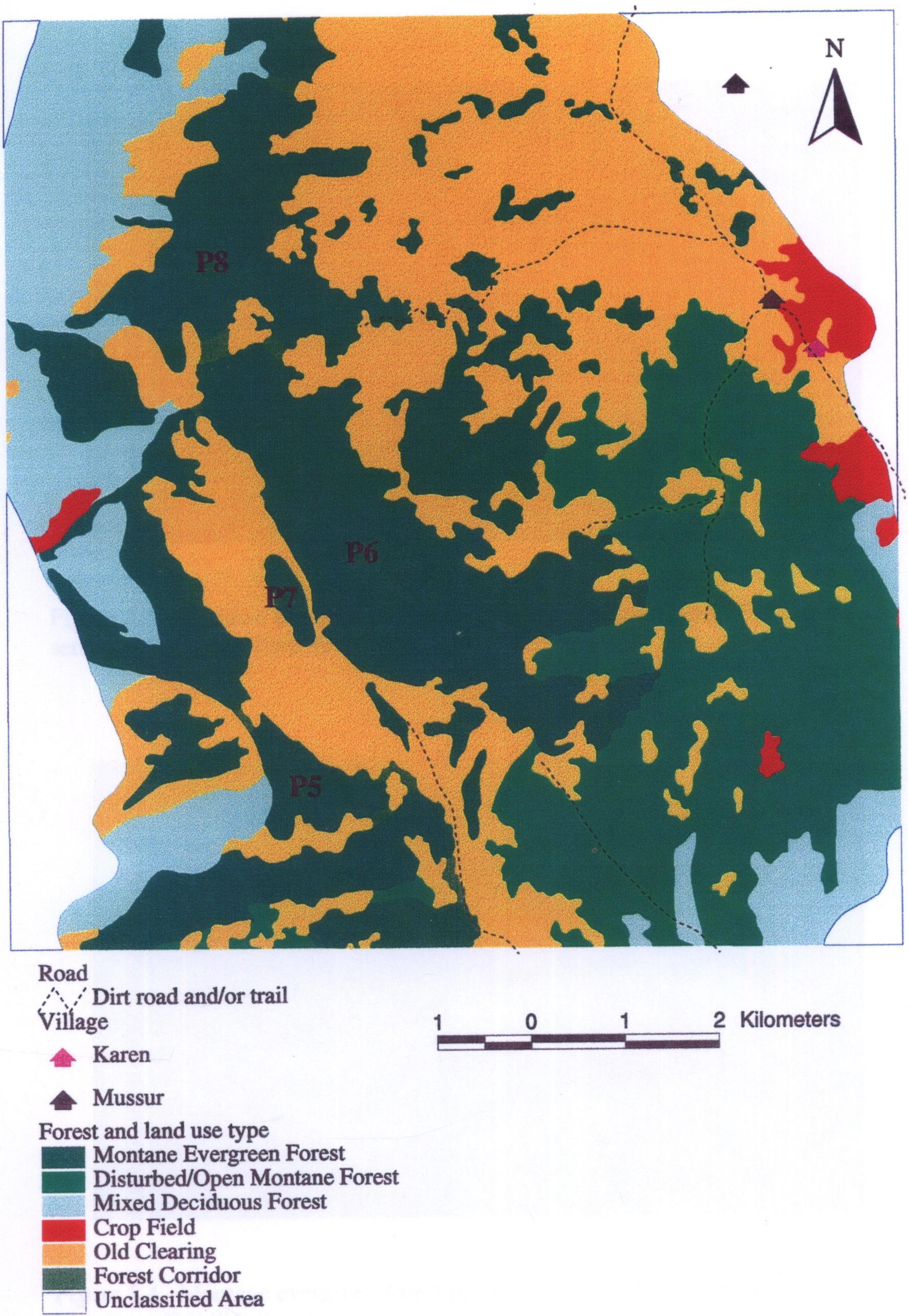

Figure 5.2. Sample patches (P5 - P8) of montane evergreen forest, Om Koi Wildlife Sanctuary (also see Figure 4.1 for the location in the landscape).

Figure 5.3. Montane evergreen forest patches surrounded by crop fields and near settlements in Mae Tuen Wildlife Sanctuary.

Figure 5.4. Montane evergreen forest patch # 2 surrounded by cabbage fields in Mae Tuen Wildlife Sanctuary.

Figure 5.5. Patch # P6, the largest montane evergreen forest patch with an area of 796 ha in the sample landscape in Om Koi Wildlife Sanctuary.

Figure 5.6. Patch # P7, the smallest evergreen forest patch sampled with an area of 27 ha in Om Koi Wildlife Sanctuary.

The transect survey was started in September 1997 and ended in June 1998. There were 7 site visits during the period. This period covered one wet season to another. I utilized transects differently between the bird and mammal surveys. The details are as follows.

i. Bird survey – I focused my survey only on diurnal species. A bird survey was conducted from 7-11 am and 2-5 pm in each trip. Many times I had to wait until there was enough light under the dense canopy of montane forest to be able to sight and identify birds. I tried to avoid performing the survey when there was light rain or low rain clouds covering the area. I walked slowly searching for birds and listening for calls. I recorded species, number of individuals, and perpendicular distance from the transect line for birds sighted or calls recognized. Birds found or heard before or after on-transect surveys were also recorded in separate data sheets.

ii. Mammal survey – Because the area has been disturbed by humans for so long mammals are elusive and many of them are nocturnal. Therefore besides recording species and number of individuals sighted before, after, and during the transect surveys, I employed the track recording station method (Wilkie and Finn 1990). A track recording stations is an area of 5×1 m where litter is cleared and soil tilled to create a soft zone for recording animal footprints. I set up 4 stations in every 100 m along a transect and each was located 20-25 m apart. During the survey I received help from local guards to identify mammal tracks. I recorded type of animals and numbers of tracks appearing on a track recording station in every site visit. Each time after recording a station was retilled. Mammal tracks found outside the recording stations were recorded in separate data sheets.

iii. Tree profiles – To have a picture of the habitat structure and plant species composition for edge and interior locations for each patch. I, together with a plant specialist, sampled a portion, 50-m long, of edge and interior transects in each patch for the tree profile survey. Then we measured every tree larger than 5-cm dbh along the 50 m section. Trees further than 5 m from the transect line on either side were not measured. We recorded species, dbh, distance on the transect, perpendicular distance from the transect, first limb height, tree height and canopy shape. This information was later used to draw tree profiles. Unfortunately tree profiles are unavailable for the Mae Tuen site because no plant specialist was available to help at the time.

iv. Observations on other human influences – Human activities such as hunting, burning, and cattle grazing around the sample patches were observed. These influences are intermingled with habitat fragmentation and affect wildlife populations in the area.

5.2.2. Data Analysis

5.2.2.1. Patch characteristics

I used FRAGSTATS version 2.0 (McGarigal and Marks 1995) to spatially analyze the sampled patches. The indices used for patch characteristics include

- Patch area (ha),
- Perimeter (m),
- Edge contrast (%) – See definition of edge contrast in section 4.2.3.1 in Chapter 4,
- Shape index – patch shape is evaluated with a circular standard and it is minimum for circular patches and increases as patches become increasingly noncircular,
- Core area (ha) – the area deeper than 100 m from the patch edges.

5.2.2.2. Analyses on Wildlife Diversity and Abundance

Different analytical steps were used for data analysis between birds and mammals. Analysis of bird data was better informative than mammals because more data were obtained. Analysis details are explained by animal group as follows.

❑ Birds

i. Species diversity

Two indices were used to indicate diversity for each remnant patch.

(a) The total number of species found on the transects regardless of the abundance,

(b) Hill's diversity number based on Shannon's index (Ludwig and Reynolds 1988) which incorporates abundance values. Hill's diversity number, like other diversity indices, incorporates richness and evenness into a single value. It is easier to interpret than many other indices because it has a unit of number of species. This number of species, however, is weighted by its abundance, and bases its calculation mainly on abundant species in the sample. As number of species in the sample increases less weight is placed on rare species. The formula for Hill's diversity number is as follow.

$$N1 = e^{H'} \qquad \text{Equation 4.1}$$

Where: $N1$ = Number of species

H' = Shannon's index

Shannon's index has probably been the most widely used index in community ecology. It measures the average degree of "uncertainty" in predicting what species an individual chosen at random from a collection of S species and N individuals will belong to. Two properties that have made it popular are (1) $H' = 0$ if and only if there is one species in the sample, and (2) H' is maximum only when all S species are represented by the same number of individuals. The equation for Shannon's index is as follow.

$$H' = -\sum_{i=1}^{S}\left[\left(\frac{n_i}{n}\right)\ln\left(\frac{n_i}{n}\right)\right] \qquad \text{Equation 4.2}$$

Where: H′ = Shannon's index

S = Number of species in the sample

n = Total number of individuals in the sample

n_i = Number of individuals belonging to ith species

ii. Species' abundance

Two parameters were used to quantify abundance

(a) Density – Bird density (number of birds/ha) in each patch was analyzed by the program DISTANCE version 2.03 (Laake et al. 1993).

(b) Species' abundance – The number of birds/site visit was calculated for each species (because amount of data for each species was not enough to calculate the density by the DISTANCE program).

iii. Species composition

From information derived from *A Guide to the Birds of Thailand* (Lekagul and Round 1991) species composition was analyzed on 2 aspects as follows

(a) Feeding guilds: Groups include (1) Frugivores, (2) Insectivores, (3) Nectarivores, and (4) Omnivores

(b) Resident/Migratory

iv. Statistical analysis and hypothesis testing

I used t-tests to test the hypotheses as follows

(a) Bird diversity and density were equal between montane evergreen forest patches under less human disturbance (Om Koi) and patches with chronic fragmentation with severe human disturbance (Mae Tuen),

(b) Bird diversity and density were equal between anthropogenic grassland/forest edges (Om Koi) and cultivated/forest edges (Mae Tuen),

(c) Bird diversity and density were equal between less human disturbed (Om Koi) and more human disturbed (Mae Tuen) forest patch interior zones,

(d) Bird diversity and density were equal between forest edge and interior zones in low disturbed patches (Om Koi),

(e) Bird diversity and density were equal between forest edge and interior zones in highly disturbed patches (Mae Tuen),

(f) Bird diversity and density were equal between forest edge and interior zones in montane evergreen forest patches for the two sites combined,

(g) Species compositions by feeding guild were equal between low disturbed patches (Om Koi) and highly disturbed patches (Mae Tuen),

- *Mammals*

    i. Species diversity

    Only the number of species sighted in each patch was used. Sighting data were too scarce to use diversity indices.

    ii. Species' abundance

    The number of animals actually sighted was low; therefore, I based my analysis only on the abundance of mammal tracks. Mammal tracks per site visit were calculated for each species.

    iii. Statistical analysis and hypothesis testing

    T-tests were performed to test the hypothesis that there was no difference in the numbers of mammal tracks between less disturbed (Om Koi) and more disturbed (Mae Tuen) patches. Only numbers of tracks for wild pig and barking deer were adequate to use statistics to test the hypotheses of no differences in the numbers of tracks for these animals between the two sites.

5.3. Results

The first part of the results describes the characteristics of the sampled sites and each individual patch. This is followed by the results on birds and mammals. Results on birds contain more detailed comparisons due to the large amount of data obtained compared to mammals. The effects on birds are shown first followed by the effects on mammals.

5.3.1. Site and Patch Characteristics

Descriptive characteristics of Om Koi and Mae Tuen sampled patches are shown in Table 5.1, and quantitative characteristics for each sample patch shown in Table 5.2 (also see Figures 5.1 and 5.2 for patch setting). Tree profiles for Om Koi patches P5-P8 are shown in Appendix A. Tree profiles in Mae Tuen patches are not available. The sample patches in Mae Tuen are mainly smaller than Om Koi with an average patch size of 60 ha, compared with 345 ha in Om Koi.

Table 5.1. Descriptive characteristics between Om Koi and Mae Tuen sites, Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak Provinces, northern Thailand.

Characteristics	Mae Tuen sampled patches (see Figure 5.1)	Om Koi sampled patches (see Figure 5.2)
Elevation	850 – 1,260 m	1,400 – 1,800 m
Clearing type	Mainly cabbage fields, some dry rice and opium fields	Abandoned fields, and anthropogenic grassland
Human settlement proximity	0.7 – 2.4 km	> 5 km
Other developments	- Paved road cut through the valley - Extensive human activities	- No road - Sparse human activities

Table 5.2. Patch characteristics in Om Koi and Mae Tuen montane evergreen forest landscapes, Om Koi and Mae Tuen Wildlife Sanctuaries, Chiang Mai and Tak Provinces, northern Thailand (Analyzed by FRAGSTATS version 2.0 and GIS visual overlay function)

Characteristic	Patch number			
Mae Tuen	***P1***	***P2***	***P3***	***P4***
Area (ha)	37.65	28.76	88.60	85.45
Perimeter (m)	5,670.86	6,050.29	7,610.67	8,229.45
Edge contrast (%)	75.17	64.16	23.33	81.55
Shape index	2.61	3.18	2.28	2.51
Core area (ha)	0.44	0.00	28.99	18.29
Distance to nearest village (km)	0.75	1.60	2.00	2.40
Om Koi	***P5***	***P6***	***P7***	***P8***
Area (ha)	96.84	795.96	27.07	461.78
Perimeter (m)	5,278.79	25,768.67	2,441.89	22,571.37
Edge contrast (%)	66.61	65.50	80.00	69.01
Shape index	1.51	2.58	1.32	2.96
Core area (ha)	49.49	558.96	5.87	268.62
Distance to nearest village (km)	6.90	5.10	6.20	5.90

In Mae Tuen, P1 is small (37 ha) and narrow with a small core area (0.4 ha) available and one side of this patch is adjacent to the paved road. P2 is a small (28 ha) and very convoluted patch with no core area left and it is located near the village. P3 and P4 are almost the same size, 88 ha and 85 ha respectively. P3 still has connectivity with disturbed and open montane forest so that it keeps the edge contrast of P3 at a low value. P4 is further from the Hmong village compared to the rest of the sample patches in Mae Tuen (see Figures 5.3 and 5.4).

In Om Koi, P5 is a medium sized patch (96 ha) with one side next to an anthropogenic grassland. P6 is the largest sample patch (795 ha) with one side next to a cliff-side grassland and remainder surrounded by old clearing areas. P7 is the smallest patch (27 ha) in this study and is surrounded by grassland at the foothill of the cliff. P8 is a large patch (461 ha) with some connectivity with P6 by forest remnant corridor (see Figures 5.5, and 5.6).

5.3.2 Bird Responses

The results for birds in the montane evergreen forest patches begin with analyses of diversity and density. Within each of these components different comparisons were conducted including comparisons of species numbers, Hill's diversity numbers (Ludwig and Reynolds 1988), densities, abundance of birds using fragments, edge, and interior locations between and within sites. These are followed by comparisons between feeding guild and end with relationship trends between patch size and species diversity.

5.3.2.1. Bird Diversity

i. Bird Diversity between Sites

A total of 2,433 detections of 149 species were made overall comprising: 1,238 detections of 89 species in Mae Tuen patches and 1,192 detections of 119 species in Om Koi patches. For each forest patch the number was 50 species (289 counts), 54 (304), 51 (340), and 61 (305) in Mae Tuen P1 to P4 respectively while 68 (310), 64 (356), 54 (241), and 67 (285) were from P5 to P8 respectively in Om Koi (Figures 5.7 and 5.8). Comparisons between the two sites are addressed below.

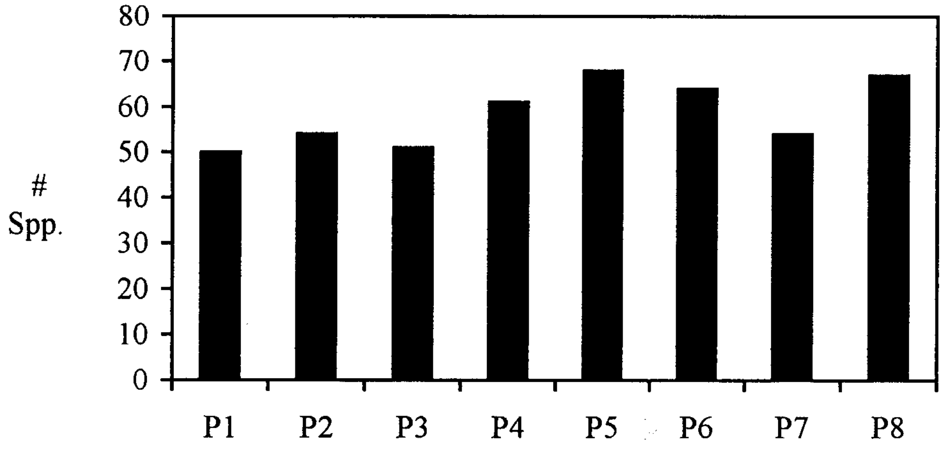

Figure 5.7. Numbers of bird species found in montane evergreen forest patches P1 – P4 in Mae Tuen and P5 – P8 in Omkoi (From the survey between September 1997 to June 1998).

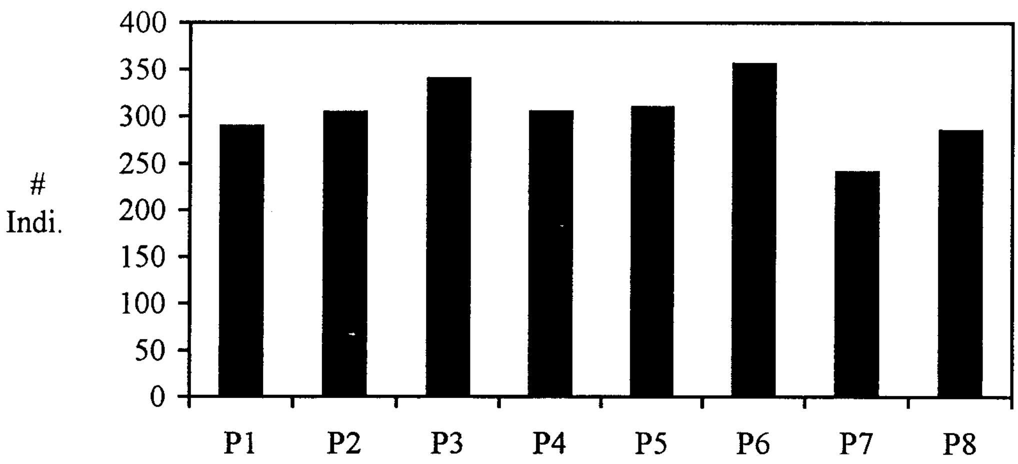

Figure 5.8. Numbers of bird detections in montane evergreen forest patches P1 – P4 in Mae Tuen and P5 – P8 in Omkoi (From the survey between September 1997 to June 1998).

(a) Patch Comparisons

The mean number of species in Om Koi per patch was 63.25 species (SE = 3.20) with 54 species (SE = 2.48) in Mae Tuen. Although not significant, the difference was close to a significant difference (P = 0.062). However when the relatively low species number from the smallest patch (P7) in Om Koi was not included in the analysis, the mean species number in Om Koi was increased to 66.33 species (SE = 1.20) and a significant difference of greater species number in Om Koi was detected (P = 0.011). The difference between mean diversity indices in Om Koi ($\bar{X}$ = 39.83 species, SE = 2.41) and in Mae Tuen ($\bar{X}$ = 32.99 species, SE = 2.82) was not significantly different (P = 0.114) (Table 5.3) (refer to raw data in Appendix B).

(b) Interior Zone Comparisons

The mean species numbers for birds using interior zones in Om Koi ($\bar{X}$ = 32.75 species, SE = 2.43) and in Mae Tuen ($\bar{X}$ = 29.50 species, SE = 2.22) patches were not significantly different (P = 0.361) between sites. There was also a nonsignificant test result (P = 0.287) for the mean diversity indices in Om Koi ($\bar{X}$ = 23.96 species, SE = 3.13) and in Mae Tuen ($\bar{X}$ = 19.31 species, SE = 2.46) patch interior zones (Table 5.3) (refer to raw data in Appendix B).

(c) Edge Zone Comparisons

The test for species number using edge also gave nonsignificant differences (P = 0.833) between mean species numbers in Om Koi ($\bar{X}$ = 38.0 species, SE = 0.91) and in Mae Tuen ($\bar{X}$ = 37.25 species, SE = 3.28) patches. No significant differences (P = 0.748) were detected in mean diversity indices between Om Koi ($\bar{X}$ = 27.15 species, SE = 1.34) and Mae Tuen ($\bar{X}$ = 26.34 species, SE = 2.02) patch edges (Table 5.3) (refer to raw data in Appendix B).

ii. Bird Diversity between Edge and Interior Within Sites and Overall Sites

(a) Om Koi

The mean species number using patch edges ($\bar{X}$ = 38.0 species, SE = 1.83) was not significantly different (P = 0.089) from the patch interior ($\bar{X}$ = 32.75 species, SE = 2.43). The test result for mean diversity indices also indicated no significant difference (P = 0.384) between patch edge ($\bar{X}$ = 27.16 species, SE = 2.68) and interior ($\bar{X}$ = 23.96 species, SE = 3.13) (Table 5.4)(refer to raw data Appendix B).

(b) Mae Tuen

The test between mean species number for patch edge ($\bar{X}$ = 37.25 species, SE = 3.28) and interior ($\bar{X}$ = 29.50 species, SE = 2.22) gave a nonsignificant result (P = 0.098). This was also the same result (P = 0.069) for mean diversity indices in edge ($\bar{X}$ = 26.34 species, SE = 2.02) and interior ($\bar{X}$ = 19.31 species, SE = 2.46). However, the P-values are close to significant level (0.05) for these comparisons (Table 5.4) (refer to raw data in Appendix B).

(c) Overall

When comparing mean species numbers between edge ($\bar{X}$ = 37.63 species, SE = 1.58) and interior overall ($\bar{X}$ = 31.13 species, SE = 1.64) there are significantly more bird species (P = 0.013) using edge than interior. The diversity index was also greater (P = 0.046) in patch edges ($\bar{X}$ = 26.75 species, SE = 3.21) than in interior ($\bar{X}$ = 21.63 species, SE = 2.04) (Table 5.4)(refer to raw data Appendix B).

5.3.2.2. Bird Density

The density of birds in Mae Tuen patches, P1 – P4, was 9.51 birds/ha, 8.67, 8.92, and 8.10 respectively. In Om Koi patches, P5 – P8, the densities were 5.92, 7.89, 9.06, 4.75 respectively (Figure 5.9).

i. Densities between Sites

The variance ratio test between the mean density of all species combined in Mae Tuen ($\bar{X}$ = 8.80 birds/ha, SE = 0.29) and in Om Koi ($\bar{X}$ = 6.91 birds/ha, SE = 0.97) indicated a severe and adverse affect by sampling nonnormal populations (F = 9.282, P = 0.023) so a Mann-Whitney test was used instead of a T-test (Zar 1984). The test result indicated no significant difference ($P > 0.20$) between mean densities of the two sites.

The mean densities of birds in patch interiors were not significantly different (P = 0.485) between Mae Tuen ($\bar{X}$ = 10.60 birds/ha, SE = 1.49) and Om Koi ($\bar{X}$ = 8.96 birds/ha, SE = 0.85). The mean density along the patch edge in Om Koi ($\bar{X}$ = 10.91 birds/ha, SE = 1.94) was also not significantly different (P = 0.395) than in Mae Tuen ($\bar{X}$ = 8.68 birds/ha, SE = 1.47) (Table 5.3).

ii. Densities between Edge and Interior within Sites, and Overall Sites

In Mae Tuen patches, the mean density of birds using edges ($\bar{X}$ = 8.68 birds/ha, SE = 1.47) was not significantly different (P = 0.437) than the interiors of patches ($\bar{X}$ = 10.47 birds/ha, SE = 1.55). The trend of no difference in density (P = 0.391) was also found between edges ($\bar{X}$ = 10.91 birds/ha, SE = 1.94) and interiors ($\bar{X}$ = 8.96 birds/ha, SE = 0.85) in Om Koi patches. When density of birds between edge and interior for both sites combined was considered the test still gave a nonsignificant result (P = 0.991) (Table 5.4).

Table 5.3. Comparisons with t-test on bird diversity and density in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries (From the survey during September 1997 to June 1998 with 7 site visits).

Comparison	Om Koi		Mae Tuen		t	df	P	Power[a]
	$\bar{X}$	SE	$\bar{X}$	SE				
Diversity								
Patch								
- Species number	63.25	3.20	54.00	2.48	2.28	6	0.062	0.62
- Species number[b] (without F7)	66.33	1.20	54.00	2.48	3.97	5	0.011*	-
- Diversity index[c]	39.83	2.41	32.99	2.82	1.85	6	0.114	0.46
Interior zone								
- Species number	32.75	2.43	29.50	2.22	0.99	6	0.361	0.17
- Diversity index	23.96	3.13	19.31	2.46	1.17	6	0.287	0.22
Edge zone								
- Species number	38.00	0.91	37.25	3.28	0.22	6	0.830	0.06
- Diversity index	27.15	1.34	26.34	2.02	0.34	6	0.748	0.06
Density (no. birds/ha)								
Patch	6.91	0.97	8.80	0.29	-	-	0.200[d]	-
Interior zone	8.96	0.85	10.60	1.49	0.74	6	0.485	0.12
Edge zone	10.91	1.94	8.68	1.47	0.92	6	0.395	0.15

Remarks

*Significant difference

[a]Statistical power at $\alpha = 0.05$

[b]Data from the smallest fragment were left out of the analysis

[c]Hill's diversity number (unit = number of species) (Ludwig and Reynolds 1988)

[d]Mann-Whitney test was used due to nonnormal distribution of data (Zar 1984)

Table 5.4. Comparisons with t-test on bird diversity and density between edge and interior zones within Om Koi and Mae Tuen montane evergreen forest patches (From the survey during September 1997 to June 1998 with 7 site visits).

Comparisons	Edge zone		Interior zone		t	df	P	Power[a]
	$\bar{X}$	SE	$\bar{X}$	SE				
Diversity								
Om Koi								
- Species number	38.00	1.83	32.75	2.43	2.02	6	0.089	0.53
- Diversity index[b]	27.16	2.68	23.96	3.13	0.94	6	0.384	0.16
Mae Tuen								
- Species number	37.25	3.28	29.50	2.22	1.96	6	0.098	0.50
- Diversity index	26.34	2.02	19.31	2.46	2.21	6	0.069	0.60
Overall								
- Species number	37.63	1.58	31.13	1.64	2.85	14	0.013*	-
- Diversity index	26.75	3.21	21.63	2.04	2.19	14	0.046*	-
Density (no. birds/ha)								
Om Koi	10.91	1.94	8.96	0.85	0.92	6	0.391	0.45
Mae Tuen	8.68	1.47	10.47	1.55	0.83	6	0.437	0.39
Overall	9.79	3.40	8.79	2.41	0.01	14	0.991	0.05

Remarks

*Significant difference

[a]Statistical power at α=0.05

[b]Hill's diversity number (unit = number of species) (Ludwig and Reynolds 1988)

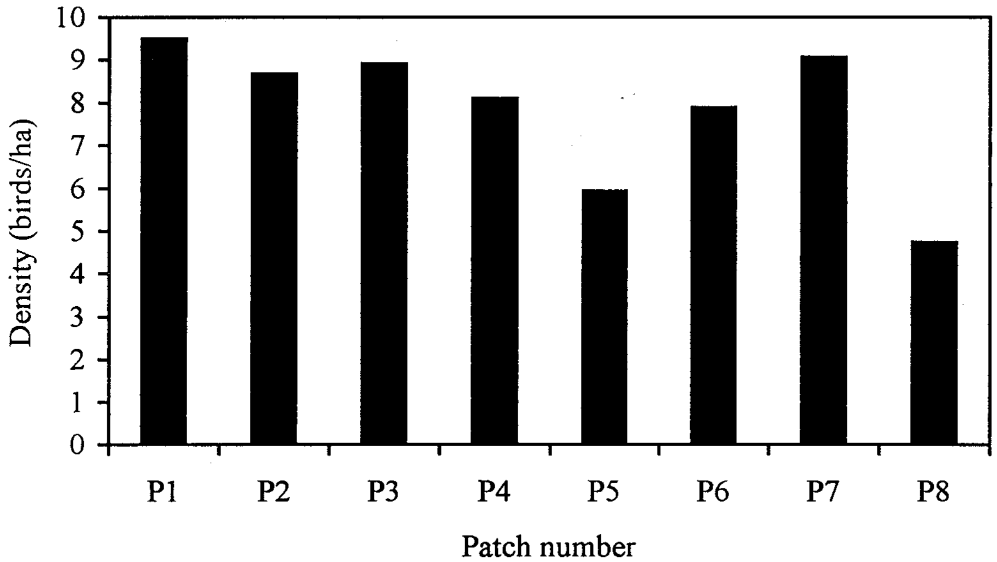

Figure 5.9. Density of bird (birds/ha) in montane evergreen forest patches in Mae Tuen (P1-P4) and Om Koi (P5-P8) Wildlife Sanctuaries (From the survey between September 1997 to June 1998)

5.3.2.3. Species' Abundance

Only bird species found on transects were used to calculate species' abundance to ensure the same search efforts for Om Koi and Mae Tuen sites. The abundance unit is birds/site visit. There are 7 site visits in total. The details on bird habitat requirements presented in this part are based on Lekagul and Round (1991).

i. Species' Abundance in Forest Patches between Sites

Species' abundance (birds/site visit) for Om Koi and Mae Tuen are shown in Tables 5.5 and 5.6. Almost 1/2 of bird species (40 from 89 species) in Mae Tuen were found <1 birds/site visit while virtually 1/3 (42 from 119 species) were in Om Koi. In other words, I found 77 low abundance species (< 1 bird/site visit) in Om Koi and 49 in Mae Tuen. The 5 most abundant species in Om Koi, included the gray-cheeked fulvetta, mountain bulbul, golden-throated barbet, white-tailed leaf-warbler, and black-headed sibia were species all obligate to montane evergreen forests. In Mae Tuen, however, 2 species, the black bulbul and streaked spiderhunter, which can also be found in mixed deciduous and secondary growth, were among the 5 most abundant species. Few black bulbuls and streaked spiderhunters were found in Om Koi. Large frugivorous birds such as the brown hornbill and great hornbill still existed in low abundance, 1.43 and 0.43 birds/site visit respectively, in Om Koi, but none were found in Mae Tuen. This status is similar to the mountain imperial pigeon, which was common in Om Koi, but none were found in Mae Tuen patches. Ground omnivores in the pheasant family such as the Kalij pheasant and rufous-throated partridge were found in Om Koi patches with an abundance of 1 and 3 birds/site visit respectively. However, bar-backed partridge with the same size and feeding guild as rufous-throated partridge was found in very low abundance (0.57 bird/site visit) in Mae Tuen patches. Red-jungle fowls were rarely seen on either site, with an abundance of 0.14 bird/site visit in Mae Tuen and 0.43 in Om Koi.

Table 5.5. Species' abundance of birds in montane evergreen forest patches in Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

No.	Common name	Scientific name	Abundance (birds/site visit)
1.	Gray-cheeked fulvetta	*Alcippe morrisonia*	11.00
2.	Mountain bulbul	*Hypsipetes mcclellandii*	11.00
3.	Golden-throated barbet	*Megalaima franklinii*	10.86
4.	White-tailed leaf-warbler	*Phylloscopus davisoni*	8.71
5.	Black-headed sibia	*Heterophasia melanoleuca*	7.57
6.	White-throated fantail	*Rhipidura albicollis*	6.14
7.	Gray-headed flycatcher	*Culicicapa ceylonensis*	5.86
8.	Mountain imperial pigeon	*Ducula badia*	5.43
9.	Lesser racket-tailed drongo	*Dicrurus remifer*	5.29
10.	Great barbet	*Megalaima virens*	3.86
11.	Gray-chinned minivet	*Pericrocotus solaris*	3.57
12.	Golden-spectacled warbler	*Seicerus burkii*	3.29
13.	Silver-eared mesia	*Leiothrix argentauris*	3.29
14.	Large niltava	*Niltava grandis*	3.14
15.	White-necked laughing-thrush	*Garrulax strepitans*	3.14
16.	Yellow-cheeked tit	*Parus spilonutus*	3.14
17.	Rufous-throated partridge	*Arborophila rufogularis*	3.00
18.	Flavescent bulbul	*Pycnonotus flavescens*	2.57
19.	White-browed shrike-babbler	*Pteruthius flaviscapis*	2.14
20.	Black bulbul	*Hypsipetes madagascariensis*	2.00
21.	Long-tailed broadbill	*Psarisomas dalhousiae*	2.00
22.	Little-pied flycatcher	*Ficedula westermanni*	1.86
23.	Brown-throated treecreeper	*Certhia discolor*	1.71
24.	Chestnut-crowned laughingthrush	*Garrulax erythrocephalus*	1.71
25.	White-crowned forktail	*Enicurus leschenaulti*	1.71
26.	Gray treepie	*Dendrocitta formosae*	1.57
27.	Gray-sided thrush	*Turdus feae*	1.57
28.	Rufous-winged fulvetta	*Alcippe castaneceps*	1.57
29.	Brown hornbill	*Ptilolaemus tickelli*	1.43
30.	Chestnut-crowned warbler	*Seicercus castaniceps*	1.43
31.	Red-whiskered bulbul	*Pycnonotus jocosus*	1.43
32.	Bronzed drongo	*Dicrurus aeneus*	1.29
33.	Gray nightjar	*Caprimulgus indicus*	1.29
34.	Streaked spiderhunter	*Arachnothera magno*	1.29
35.	White-headed bulbul	*Hypsipetes thompsoni*	1.29
36.	Black-throated parrotbill	*Abroscopus albogularis*	1.14
37.	Eurasian jay	*Garrulus glandarius*	1.14
38.	White-browed scimitar-babbler	*Pomatorhinus shisticeps*	1.14
39.	Inornate warbler	*Phylloscopus inornatus*	1.00
40.	Kalij pheasant	*Lophura leucomelana*	1.00
41.	Streaked wren-babbler	*Napothera brevicaudata*	1.00
42.	Two-barred warbler	*Phylloscopus plumbeitarsus*	1.00
43.	Blyth's leaf-warbler	*Phylloscopus reguloides*	0.86
44.	Maroon oriole	*Oriolus traillii*	0.86
45.	Short-billed minivet	*Pericrocutus brevirostris*	0.86
46.	Striated bulbul	*Pycnonotus striatus*	0.86
47.	Wedge-tailed pigeon	*Treron sphenura*	0.86
48.	White-necked laughingthrush	*Garrulax strepitans*	0.86
49.	Chestnut-fronted shrike-babbler	*Pteruthius aenobarbus*	0.71

No.	Common name	Scientific name	Abundance (birds/site visit)
50.	Eyebrowed thrush	*Turdus obscurus*	0.71
51.	Green-billed malkoha	*Phaenicophaeus tristis*	0.71
52.	Green-tailed sunbird	*Aethopyga nipalensis*	0.71
53.	Hair-crested drongo	*Dicrurus hottentottus*	0.71
54.	Large-tailed nightjar	*Caprimulgus macrurus*	0.71
55.	Mountain scops-owl	*Otus spilocephalus*	0.71
56.	Red-headed trogon	*Harpactes erythrocephalus*	0.71
57.	Scalet minivet	*Pericrocutus flammeus*	0.71
58.	Speckled piculet	*Picumnus innominatus*	0.71
59.	Stripe-breasted woodpecker	*Picoides atratus*	0.71
60.	Verditer flycatcher	*Eumyias thalassina*	0.71
61.	Ashy bulbul	*Hypsipetes flavala*	0.57
62.	Collared owlet	*Glaucidium brodiei*	0.57
63.	Eastern crowned warbler	*Phylloscopus coronatus*	0.57
64.	Golden babbler	*Stachyris chrysaea*	0.57
65.	Lesser yellownape	*Picus chlorolophus*	0.57
66.	Long-tailed minivet	*Pericrocotus ethologus*	0.57
67.	Slaty-bellied tesia	*Tesia olivea*	0.57
68.	Striped tit-babbler	*Macronous gularis*	0.57
69.	White-bellied yuhina	*Yuhina zantholeuca*	0.57
70.	Ashy drongo	*Dicrurus leocophaeus*	0.43
71.	Black-naped monarch	*Hypothymis azurea*	0.43
72.	Burmese yuhina	*Yuhina humilis*	0.43
73.	Dark-sided thrush	*Zoothera marginata*	0.43
74.	Gould's sunbird	*Aethopyga gouldiae*	0.43
75.	Great hornbill	*Buceros bicornis*	0.43
76.	Green magpie	*Cissa chinensis*	0.43
77.	Hill blue flycatcher	*Cyornis banyumas*	0.43
78.	Oriental white-eye	*Zosterops palpebrosus*	0.43
79.	Red Junglefowl	*Gallus gallus*	0.43
80.	Rusty-cheeked scimitar-babbler	*Pomatorhinus erythrogenys*	0.43
81.	Bar-winged flycatcher-shrike	*Hemipus picatus*	0.29
82.	Black-crested bulbul	*Pycnonotus melanicterus*	0.29
83.	Black-throated sunbird	*Aethopyga saturata*	0.29
84.	Ferruginous flycatcher	*Muscicapa ferruginea*	0.29
85.	Greater yellownape	*Picus flavinucha*	0.29
86.	Indian cuckoo	*Cuculus micropterus*	0.29
87.	Mountain tailorbird	*Orthotomus cuculatus*	0.29
88.	Purple cochoa	*Cochoa purpurea*	0.29
89.	Pygmy wren-babbler	*Pnoepyga pusilla*	0.29
90.	Red-throated flycatcher	*Ficedula parva*	0.29
91.	Rufous-bellied niltava	*Niltava sundara*	0.29
92.	Siberian thrush	*Zoothera sibirica*	0.29
93.	Sulfur-breasted warbler	*Phylloscopus ricketti*	0.29
94.	Velvet-fronted nuthatch	*Sitta frontalis*	0.29
95.	Arctic warbler	*Phylloscopus borealis*	0.14
96.	Asian emerald cuckoo	*Chrysococcyx maculatus*	0.14
97.	Black-throated laughingthrush	*Garrulax chinensis*	0.14
98.	Black-winged cuckoo-shrike	*Coracina melaschista*	0.14
99.	Blue rock-thrush	*Monticola solitarius*	0.14
100.	Blue whistling thrush	*Myiophoneus caeruleus*	0.14
101.	Blue-eared barbet	*Megalaima australis*	0.14

No.	Common name	Scientific name	Abundance (birds/site visit)
102.	Blue-throated flycatcher	*Cynornis rubeculoides*	0.14
103.	Brown wood-owl	*Strix leptogrammica*	0.14
104.	Buff-vented bulbull	*Hypsipetes charlottae*	0.14
105.	Crested serpent-eagle	*Spilornis cheela*	0.14
106.	Eye-browed wren-babbler	*Napothera epilepidota*	0.14
107.	Gray-throated babbler	*Stachyris nigriceps*	0.14
108.	Greenish warbler	*Phylloscopus trochiloides*	0.14
109.	Large cuckoo-shrike	*Coracina macei*	0.14
110.	Orange-bellied leafbird	*Chloropsis hardwickii*	0.14
111.	Red-billed scimitar-babbler	*Pomatorhinus ochraceiceps*	0.14
112.	Rosy minivet	*Pericrocotus roseus*	0.14
113.	Rufescent prinia	*Prinia rufescens*	0.14
114.	Rufous-browed flycatcher	*Ficedula solitaris*	0.14
115.	Rufous-gorgetted flycatcher	*Ficedula strophiata*	0.14
116.	Rufous-backed sibia	*Heterophasia annectens*	0.14
117.	Slaty-blue flycatcher	*Ficedular tricolor*	0.14
118.	White-tailed robin	*Cinclidium leucorum*	0.14
119.	Yellow-vented warbler	*Phylloscopus cantator*	0.14

Table 5.6. Species' abundance of birds in montane evergreen forest patches in Mae Tuen Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

No.	Common name	Scientific name	Abundance (birds/site visit)
1.	Gray-cheeked fulvetta	*Alcippe morrisonia*	16.29
2.	Black bulbul	*Hypsipetes madagascariensis*	12.29
3.	Mountain bulbul	*H. mcclellandii*	10.86
4.	Streaked spiderhunter	*Arachnothera magna*	8.00
5.	White-throated bulbul	*Criniger flaveolus*	8.00
6.	Lesser racket-tailed drongo	*Dicrurus remifer*	7.29
7.	Blue-throated barbet	*Megalaima asiatica*	6.29
8.	Golden-throated barbet	*M. franklinii*	5.71
9.	Long-tailed broadbill	*Psarisomus dalhousiae*	5.71
10.	White-throated fantail	*Rhipidura albicollis*	5.71
11.	Hair-crested drongo	*Dicrurus hottentottus*	5.00
12.	Little spiderhunter	*Arachnothera longirostra*	4.71
13.	Great barbet	*Megalaima virens*	4.43
14.	Flavescent bulbul	*Pycnonotus flavescens*	4.14
15.	Buff-vented bulbul	*Hypsipetes charlottae*	3.86
16.	Blyth's leaf-warbler	*Phylloscopus reguloides*	3.71
17.	Gray-headed flycatcher	*Culicicapa ceylonensis*	3.71
18.	White-bellied yuhina	*Yuhina zantholeuca*	3.29
19.	Ashy bulbul	*Hypsipetes flavala*	3.00
20.	Black-crested bulbul	*Pycnonotus melanicterus*	3.00
21.	Golden-spectacled warbler	*Seicercus burkii*	2.86
22.	Gray treepie	*Dendrocitta formosae*	2.86
23.	Bronzed drongo	*Dicrurus aeneus*	2.71
24.	Blue-eared barbet	*Megalaima australis*	2.00
25.	Hill myna	*Gracula religiosa*	2.00
26.	Asian paradise-flycatcher	*Terpsiphone paradisi*	1.71
27.	Two-barred warbler	*Phylloscopus plumbeitarsus*	1.71
28.	Asian fairy-bluebird	*Irena puella*	1.57
29.	White-browed shirke-babbler	*Pteruthius flaviscapis*	1.57
30.	Buff-breasted babbler	*Trichastoma tickelli*	1.43
31.	Barred cuckoo-dove	*Macropygia unchall*	1.29
32.	Emerald dove	*Chalcophaps indica*	1.29
33.	Orange-bellied leafbird	*Chloropsis hardwickii*	1.29
34.	Striped tit-babbler	*Macronous gularis*	1.29
35.	White-browed scimitar-babbler	*Pomatorhinus schisticeps*	1.29
36.	Velvet-fronted nuthatch	*Sitta frontalis*	1.14
37.	White-hooded babbler	*Gampsorhynchus rufulus*	1.14
38.	Black-throated sunbird	*Aethopyga saturata*	1.00
39.	Orange-headed thrush	*Zoothera citrina*	1.00
40.	Rufous-browed flycatcher	*Ficedula solitaris*	1.00
41.	Black-nape monarch	*Hypothymis azurea*	0.86
42.	Gray-thorated babbler	*Stachyris nigriceps*	0.86
43.	Green magpie	*Cissa chinensis*	0.86
44.	Pin-tailed pigeon	*Treron apicauda*	0.86
45.	Red-headed trogon	*Harpactes erythrocephalus*	0.86
46.	Striated yuhina	*Yuhina castaniceps*	0.86
47.	White-crested laughing-thrush	*Garrulax leucolophus*	0.86
48.	Black-winged cuckoo-shrike	*Coracina melaschista*	0.71
49.	Speckled piculet	*Picumnus innominatus*	0.71

No.	Common name	Scientific name	Abundance (birds/site visit)
50.	White-necked laughing-thrush	*Garrulax strepitans*	0.71
51.	Bar-backed partridge	*Arborophila brunneopectus*	0.57
52.	Collared owlet	*Glaucidium brodiei*	0.57
53.	Golden babbler	*Stachyris chrysaea*	0.57
54.	Gray-chinned minivet	*Pericrocotus solaris*	0.57
55.	Green-tailed sunbird	*Aethopyga nipalensis*	0.57
56.	White-crowned forktail	*Enicurus leschenaulti*	0.57
57.	Crested surpent-eagle	*Spilornis cheela*	0.43
58.	Hill blue flycatcher	*Cyornis banyumas*	0.43
59.	Hoopoe	*Upupa epops*	0.43
60.	Silver-breasted broadbill	*Serilophus lunatus*	0.43
61.	Verditer flycatcher	*Eumyias thalassina*	0.43
62.	Blue whistling thrush	*Myiophoneus caeruleus*	0.29
63.	Blue-throated flycatcher	*Cyornis rubeculoides*	0.29
64.	Brown wood-owl	*Strix leptogrammica*	0.29
65.	Eastern-crowned warbler	*Phylloscopus coronatus*	0.29
66.	Greater yellownape	*Picus flavinucha*	0.29
67.	Green-billed malkoha	*Phaenicophaeus tristis*	0.29
68.	Japanese white-eye	*Zosterops japonicus*	0.29
69.	Lesser coucal	*Centropus bengalensis*	0.29
70.	Plaintive cuckoo	*Cacomantis merulinus*	0.29
71.	Scalet minivet	*Pericrocorus flammeus*	0.29
72.	Slender-billed oriole	*Oriolus tenuirostris*	0.29
73.	Streaked wren-babbler	*Napothera brevicaudata*	0.29
74.	Stripe-breasted woodpecker	*Picoides atratus*	0.29
75.	Sulfur-breasted warbler	*Phylloscopus ricketti*	0.29
76.	Asian emerald cuckoo	*Chrysococcyx maculatus*	0.14
77.	Banded kingfisher	*Lacedo pulchella*	0.14
78.	Blue-winged minla	*Minla cyanouroptera*	0.14
79.	Dark-necked tailorbird	*Orthotomus atrogularis*	0.14
80.	Golden-fronted leafbird	*Chloropsis aurifrons*	0.14
81.	Red junglefowl	*Gallus gallus*	0.14
82.	Red-billed scimitar-babbler	*Pomatorhinus ochraceiceps*	0.14
83.	Red-whiskered bulbul	*Pycnonotus jocosus*	0.14
84.	Ruddy kingfisher	*Halcyon coromanda*	0.14
85.	Shikra	*Accipiter badius*	0.14
86.	Sooty-headed bulbul	*Pycnonotus aurigaster*	0.14
87.	Spot-throated babbler	*Pellorneum albiventre*	0.14
88.	Yellow-cheeked tit	*Parus spilonotus*	0.14
89.	Yellow-vented warbler	*Phylloscopus cantator*	0.14

ii. Species' Abundance in Edge and Interior Zones

(a) Om Koi

The total number of bird species using edge zones – less than 100 m from edges – was 82 whereas 73 species were found in interior zones – more than 100m from edges (Table 5.7). The gray cheeked fulvetta, mountain bulbul, golden-throated barbet, white-tailed leaf-warbler, black-headed sibia, and white-throated fantail are montane evergreen forest obligates and were among the most abundant species in edge and interior zones (>1.7 birds/site visit). Large frugivorous birds such as brown hornbills were found only in interior zones although in low abundance (1 bird/site visit). Species using clearings, including flavescent bulbuls and red-whiskered bulbuls, were found along the forest edges in low abundance (1.43 and 0.71 birds/site visits). The clearing species found in interior zones were flavescent bulbuls and blue rock-thrushes, but in very low abundance (0.57 and 0.14 birds/site visits).

(b) Mae Tuen

The total species numbers using edge zones was 68, with 56 species using interior zones (Table 5.8). Black bulbuls and streaked spiderhunters, which use a wide range of habitats from evergreen, mixed deciduous, to secondary growth, were among the most abundant species (7.29 and 4.43 birds/site visit respectively) in the edge zones. These two species were also found using interior zones with abundance values of 3 birds/site visit. In interior zones, however, the 5 most abundant species were montane evergreen forest obligates including gray-cheeked fulvettas, long-tailed broadbills, mountain bulbuls, lesser racket-tailed drongos, white-throated fantails, etc. Long-tailed broadbills were found in high abundance (4.86 birds/site visit) in interior zones but only 0.43 birds/site visit were found in edge zones.

Table 5.7. Species' abundance of birds in edge and interior zones in montane evergreen forest patches in Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits)

No.	Edge zone (<100m from edge)		Interior zone (>100m from edge)	
	Common name	birds/ site visit	Common name	(birds/ site visit)
1	Gray-cheeked fulvetta	5.71	Mountain bulbul	4.71
2	Mountain bulbul	4.29	White-tailed leaf-warbler	4.43
3	Golden-throated barbet	4.00	Golden-throated barbet	3.57
4	White-tailed leaf-warbler	3.86	Gray-cheeked fulvetta	2.86
5	White-throated fantail	3.86	Lesser racket-tailed drongo	2.43
6	Gray-headed flycatcher	3.57	White-necked laughing-thrush	1.86
7	Black-headed sibia	3.43	White-throated fantail	1.86
8	Lesser racket-tailed drongo	2.57	Black-headed sibia	1.71
9	Gray-chinned minivet	2.00	Gray-chinned minivet	1.57
10	White-necked laughingthrush	1.71	Gray-headed flycatcher	1.57
11	Black bulbul	1.57	Mountain imperial pigeon	1.57
12	Large niltava	1.57	Golden-spectacled warbler	1.43
13	Flavescent bulbul	1.43	Gray-sided thrush	1.43
14	Golden-spectacled warbler	1.43	Silver-eared mesia	1.43
15	Chestnut-crowned laughingthrush	1.14	Yellow-cheeked tit	1.43
16	Rufous-winged fulvetta	1.14	Black-throated parrotbill	1.14
17	Silver-eared mesia	1.14	Chestnut-flanked white-eye	1.14
18	White-browed shrike-babbler	1.14	Large niltava	1.14
19	Yellow-cheeked tit	1.14	Brown hornbill	1.00
20	Chestnut-crowned warbler	1.00	Brown-throated treecreeper	0.86
21	Mountain imperial pigeon	1.00	Great barbet	0.86
22	Bronzed drongo	0.86	Little pied flycatcher	0.86
23	Chestnut-flanked white-eye	0.86	Rufous-throated partridge	0.86
24	Long-tailed broadbill	0.86	White-browed shrike-babbler	0.86
25	White-crowned forktail	0.86	White-headed bulbul	0.86
26	Great barbet	0.71	Stripe-breasted woodpecker	0.71
27	Green-tailed sunbird	0.71	Ashy bulbul	0.57
28	Red-whiskered bulbul	0.71	Chestnut-crowned laughing-thrush	0.57
29	Rufous-throated partridge	0.71	Flavescent bulbul	0.57
30	Two-barred warbler	0.71	Lesser yellownape	0.57
31	Wedge-tailed pigeon	0.71	Long-tailed broadbill	0.57
32	Blyth's leaf-warbler	0.57	Short-billed minivet	0.57
33	Eastern crowned warbler	0.57	Slaty-bellied tesia	0.57
34	Golden babbler	0.57	Black bulbul	0.43
35	Inornate warbler	0.57	Black-naped monarch	0.43
36	Long-tailed minivet	0.57	Bronzed drongo	0.43
37	Streaked spiderhunter	0.57	Burmese yuhina	0.43
38	Striped tit-babbler	0.57	Chestnut-crowned warbler	0.43
39	Eyebrowed thrush	0.43	Hair-crested drongo	0.43
40	Green-billed malkoha	0.43	Inornate warbler	0.43
41	Rusty-cheeked scimitar-babbler	0.43	Maroon oriole	0.43
42	Speckled piculet	0.43	Rufous-winged fulvetta	0.43
43	Striated bulbul	0.43	Scalet minivet	0.43
44	Black-crested bulbul	0.29	Streaked spiderhunter	0.43
45	Brown-throated treecreeper	0.29	Ashy drongo	0.29

No.	Edge Common name	birds/ site visit	Interior Common name	(birds/ site visit)
46	Chestnut-fronted shrike-babbler	0.29	Blyth's leaf-warbler	0.29
47	Dark-sided thrush	0.29	Chestnut-fronted shrike-babbler	0.29
48	Gray treepie	0.29	Eyebrowed thrush	0.29
49	Little pied flycatcher	0.29	Greater yellownape	0.29
50	Maroon oriole	0.29	Mountain tailorbird	0.29
51	Purple cochoa	0.29	Pygmy wren-babbler	0.29
52	Red-headed trogon	0.29	Red Junglefowl	0.29
53	Rufous-bellied niltava	0.29	Red-headed trogon	0.29
54	Scalet minivet	0.29	Streaked wren-babbler	0.29
55	Short-billed minivet	0.29	Striated bulbul	0.29
56	Siberian thrush	0.29	Two-barred warbler	0.29
57	Sulfur-breasted warbler	0.29	White-bellied yuhina	0.29
58	Verditer flycatcher	0.29	White-crowned forktail	0.29
59	White-browed scimitar-babbler	0.29	Black-winged cuckoo-shrike	0.14
60	Arctic warbler	0.14	Blue rock-thrush	0.14
61	Ashy drongo	0.14	Blue whistling thrush	0.14
62	Asian emerald cuckoo	0.14	Dark-sided thrush	0.14
63	Black-throated laughingthrush	0.14	Ferruginous flycatcher	0.14
64	Black-throated sunbird	0.14	Gould's sunbird	0.14
65	Blue-eared barbet	0.14	Gray-throated babbler	0.14
66	Blue-throated flycatcher	0.14	Green magpie	0.14
67	Buff-vented bulbull	0.14	Hill blue flycatcher	0.14
68	Collared owlet	0.14	Kalij pheasant	0.14
69	Eye-browed wren-babbler	0.14	Velvet-fronted nuthatch	0.14
70	Ferruginous flycatcher	0.14	Verditer flycatcher	0.14
71	Gray-sided thrush	0.14	Wedge-tailed pigeon	0.14
72	Green magpie	0.14	White-tailed robin	0.14
73	Greenish warbler	0.14	Yellow-vented warbler	0.14
74	Hill blue-flycatcher	0.14		
75	Rosy minivet	0.14		
76	Rufescent prinia	0.14		
77	Rufous-browed flycatcher	0.14		
78	Rufous-gorgetted flycatcher	0.14		
79	Rufous-winged sibia	0.14		
80	Slaty-blue flycatcher	0.14		
81	Velvet-fronted nuthatch	0.14		
82	White-bellied yuhina	0.14		

Table 5.8 Species' abundance of birds in edge and interior zones in montane evergreen forest patches in Mae Tuen Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits)

No.	Edge zone (<100m from edge)		Interior zone (>100m from edge)	
	Common name	birds/ site visit	Common name	birds/ site visit
1	Black bulbul	7.29	Gray-cheeked fulvetta	9.00
2	Mountain bulbul	5.57	Long-tailed broadbill	4.86
3	Gray-cheeked fulvetta	5.14	Mountain bulbul	4.43
4	Sreaked spiderhunter	4.43	Lesser racket-tailed drongo	4.14
5	White-throated bulbul	3.57	White-throated fantail	3.43
6	Blue-throated barbet	2.43	Hair-crested drongo	3.29
7	Blyth's leaf-warbler	2.29	Black bulbul	3.00
8	Flavescent bulbul	2.29	Streaked spiderhunter	3.00
9	Lesser racket-tailed drongo	2.29	Golden-throated barbet	2.43
10	Little spiderhunter	2.29	White-throated bulbul	1.86
11	White-throated fantail	2.29	Flavescent bulbul	1.71
12	Bronzed drongo	2.00	Asian paradise-flycatcher	1.57
13	Gray-headed flycatcher	2.00	White-bellied yuhina	1.57
14	Hill myna	2.00	Asian fairy bluebird	1.29
15	Golden-spectacled warbler	1.57	Blyth's leaf-warbler	1.29
16	Ashy bulbul	1.43	Gray-headed flycatcher	1.29
17	Buff-vented bulbul	1.43	Little spiderhunter	1.29
18	Two-barred warbler	1.43	Golden-spectacled warbler	1.14
19	Black-crested bulbul	1.14	Great barbet	1.14
20	Hair-crested drongo	1.14	Black-crested bulbul	1.00
21	White-bellied yuhina	1.14	Gray Treepie	1.00
22	White-hooded babbler	1.14	Buff-vented bulbul	0.86
23	Golden-throated barbet	1.00	Black-naped monarch	0.71
24	Gray treepie	1.00	Blue-throated barbet	0.71
25	Striped tit-babbler	1.00	Rufous-browed flycatcher	0.71
26	Great barbet	0.86	Ashy bulbul	0.57
27	Orange-bellied leafbird	0.86	Bar-backed partridge	0.57
28	White-crested laughing-thrush	0.86	Black-throated sunbird	0.57
29	Emerald dove	0.71	Bronzed drongo	0.57
30	Orange-headed thrush	0.71	Green magpie	0.57
31	Red-headed trogon	0.71	Golden babbler	0.43
32	White-browed shrike-babbler	0.71	White-browed shrike-babbler	0.43
33	White-necked laughingthrush	0.71	Black-winged cuckoo-shrike	0.29
34	Barred cuckoo-dove	0.57	Blue-eared barbet	0.29
35	Velvet-fronted nuthatch	0.57	Brown wood-owl	0.29
36	Black-throated sunbird	0.43	Buff-breasted babbler	0.29
37	Black-winged cuckoo-shrike	0.43	Eastern-crowned warbler	0.29
38	Gray-chinned minivet	0.43	Emerald dove	0.29
39	Gray-throated babbler	0.43	Gray-throated babbler	0.29
40	Green-tailed sunbird	0.43	Green-billed malkoha	0.29
41	Long-tailed broadbill	0.43	Hill blue flycatcher	0.29
42	Speckled piculet	0.43	Japanese white-eye	0.29
43	Striated yuhina	0.43	Orange-headed thrush	0.29
44	Asian fairy-bluebird	0.29	Speckled piculet	0.29
45	Buff-breasted babbler	0.29	Two-barred warbler	0.29

No.	Edge		Interior	
	Common name	birds/ site visit	Common name	(birds/ site visit)
46	Greater yellownape	0.29	Velvet-fronted nuthatch	0.29
47	Green magpie	0.29	White-browed scimitar-babbler	0.29
48	Hoopoe	0.29	White-crowned forktail	0.29
49	Rufous-browed flycatcher	0.29	Blue-throated flycatcher	0.14
50	Silver-breasted broadbill	0.29	Collared owlet	0.14
51	Stripe-breasted woodpecker	0.29	Gray-chinned minivet	0.14
52	Verditer flycatcher	0.29	Green-tailed sunbird	0.14
53	Asian emerald cuckoo	0.14	Orange-bellied leafbird	0.14
54	Black-naped monarch	0.14	Red-whiskered bulbul	0.14
55	Blue-eared barbet	0.14	Slender-billed oriole	0.14
56	Blue-throated flycatcher	0.14	Sulfur-breasted warbler	0.14
57	Blue-winged minla	0.14		
58	Dark-necked tailorbird	0.14		
59	Golden babbler	0.14		
60	Hill blue flycatcher	0.14		
61	Red junglefowl	0.14		
62	Red-billed scimitar-babbler	0.14		
63	Slender-billed oriole	0.14		
64	Spot-throated babbler	0.14		
65	Sulfur-breasted warbler	0.14		
66	White-crowned forktail	0.14		
67	Yellow-cheeked tit	0.14		
68	Yellow-vented warbler	0.14		

iii. Bird Abundance by Feeding Guilds

When considering bird abundance by feeding guilds, I found that the mean abundance of nectarivorous birds using Mae Tuen patches ($\bar{X}$ = 3.64 birds/site visit, SE = 0.31) was greater (*P* = 0.009) than in Om Koi ($\bar{X}$ = 1.68 birds/site visit, SE = 0.41). The streaked spiderhunter (8 birds/site visit) and little spiderhunter (4.71 birds/site visit) were the most abundant nectarivores in Mae Tuen patches. These species are followed by the black-throated sunbird, green-tailed sunbirds, and Japanese white-eye with abundances of 1, 0.57, and 0.29 birds/site visit respectively (Table 5.9, and also see Table 5.6). In Om Koi, although nectarivorous species were more diverse, they were found in lower abundance. The ranking of nectarivores in Om Koi was chestnut-flanked white-eye, streaked spiderhunter, green-tailed sunbird, Gould's sunbird, oriental white-eye, and black-throated sunbird with abundances of 3.57, 1.29, 0.71, 0.43, 0.43, and 0.29 birds/site visit respectively (Table 5.5).

The difference between frugivores in Mae Tuen ($\bar{X}$ = 16.0 birds/site visit, SE = 1.99) and in Om Koi ($\bar{X}$ = 10.71 birds/site visit, SE = 1.68) was not significant (*P* = 0.088). However, *P*-value is close to significant level. The difference between insectivores in Om Koi ($\bar{X}$ = 29.25 birds/site visit, SE = 2.34) and in Mae Tuen ($\bar{X}$ = 21.79 birds/site visit, SE = 2.11) was not significant (*P* = 0.058). However, *P*-value is also close to significant level. Omnivorous birds were not significantly different (*P* = 0.719) between sites (Table 5.9).

iv. Abundance of Migratory Bird Species

Om Koi fragments were used by 21 migratory birds while 9 used Mae Tuen fragments (Table 5.10).

Table 5.9 Comparisons with t-test on bird abundance by feeding guild in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries (From the survey during September 1997 to June 1998 with 7 site visits).

Feeding guild	Om Koi		Mae Tuen		t	df	P	Power[a]
	$\bar{X}$	SE	$\bar{X}$	SE				
Nectarivores	1.68	0.41	3.64	0.31	3.82	6	0.009*	-
Frugivores	10.71	1.68	16.00	1.99	2.03	6	0.088	0.53
Insectivores	29.25	2.34	21.79	2.11	2.34	6	0.058	0.65
Omnivores	2.10	0.64	2.11	0.50	0.38	6	0.719	0.07

Remarks
*Significant difference
[a]Statistical power at $\alpha = 0.05$

Table 5.10 Abundance of migratory bird species in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries (From the survey during September 1997 to June 1998 with 7 site visits).

No.	Om Koi		Mae Tuen	
	Common name	birds/ site visit	Common name	birds/ site visit
1	Chestnut-flanked white-eye	3.57	Blyth's leaf-warbler	3.71
2	Golden-spectacled warbler	3.29	Golden-spectacled warbler	2.86
3	Gray-sided thrush	1.57	Orange-headed thrush	1.00
4	Inornate warbler	1.00	Eastern-crowned warbler	0.29
5	Two-barred warbler	1.00	Japanese white-eye	0.29
6	Blyth's leaf-warbler	0.86	Slender-billed oriole	0.29
7	Eyebrowed thrush	0.71	Sulfur-breasted warbler	0.29
8	Eastern crowned warbler	0.57	Ruddy Kingfisher	0.14
9	Gould's sunbird	0.43	Yellow-vented warbler	0.14
10	Ferruginous flycatcher	0.29		
11	Red-throated flycatcher	0.29		
12	Rufous-bellied niltava	0.29		
13	Siberian thrush	0.29		
14	Sulfur-breasted warbler	0.29		
15	Arctic warbler	0.14		
16	Blue rock-thrush	0.14		
17	Greenish warbler	0.14		
18	Rosy minivet	0.14		
19	Rufous-gorgetted flycatcher	0.14		
20	Slaty-blue flycatcher	0.14		
21	Yellow-vented warbler	0.14		

5.3.2.4. Bird Diversity and Patch Size

Because there are only 8 patches, with a wide range of sizes and differences in environment, statistical tests on the effects of patch size on bird diversity and abundance are not feasible. Nevertheless bird diversity and density in patches ranging from small to large are represented in Figure 5.10. Although there is no relationship between patch size and bird diversity and density, medium (P5) and large patches (P8, P9) were distinctively higher in bird species number than smaller ones.

When plotted separately for Om Koi and Mae Tuen, there was still no real trend (Figures 5.11, 5.12). In Mae Tuen P3 (89 ha) surprisingly contained the lowest number of species (51 species). The highest species number was in another medium sized patch (P4, 85 ha). P1 and P2 (the smallest patch) supported 50 and 54 species respectively. Densities from small to largest patches were 8.67, 9.51, 8.1, and 8.92 birds/ha respectively. In Om Koi the smallest patch, P7 (27 ha), contained prominently low species numbers with 54 species while P5 (97 ha), P6 (796 ha), and P8 (462 ha) contained 68, 64, and 67 species respectively. Density, however, was high with 9.06 birds/ha, while density in P5, P6, and P8 was 5.93, 7.89, and 4.75 birds/ha respectively.

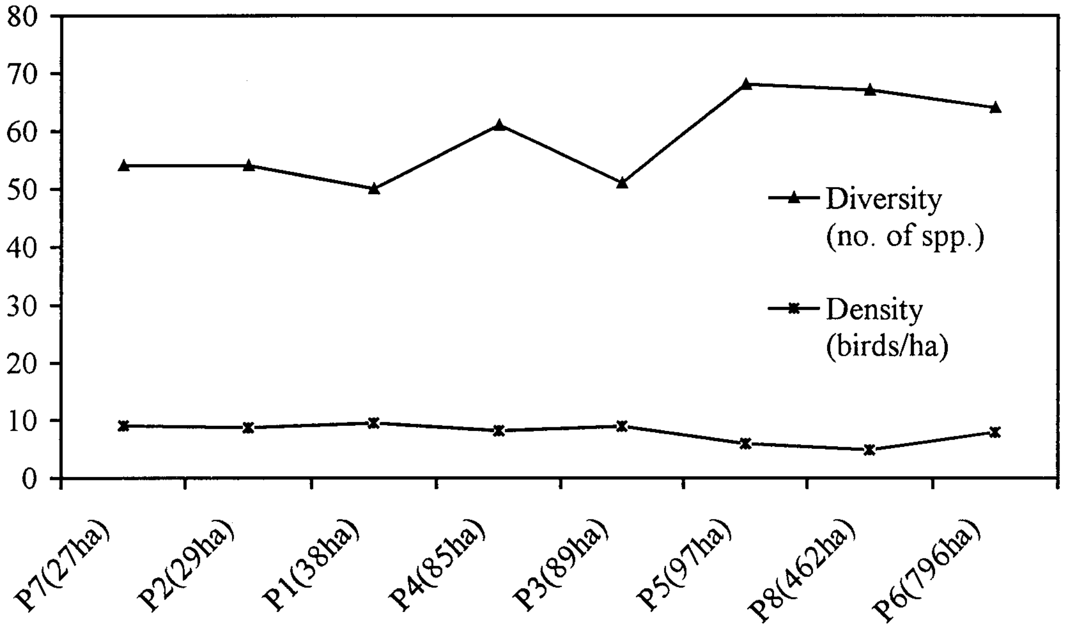

Figure 5.10. Bird diversity (number of bird species) and density (birds/ha) in different patch sizes (ha) ranging from small to large in montane evergreen forests, Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

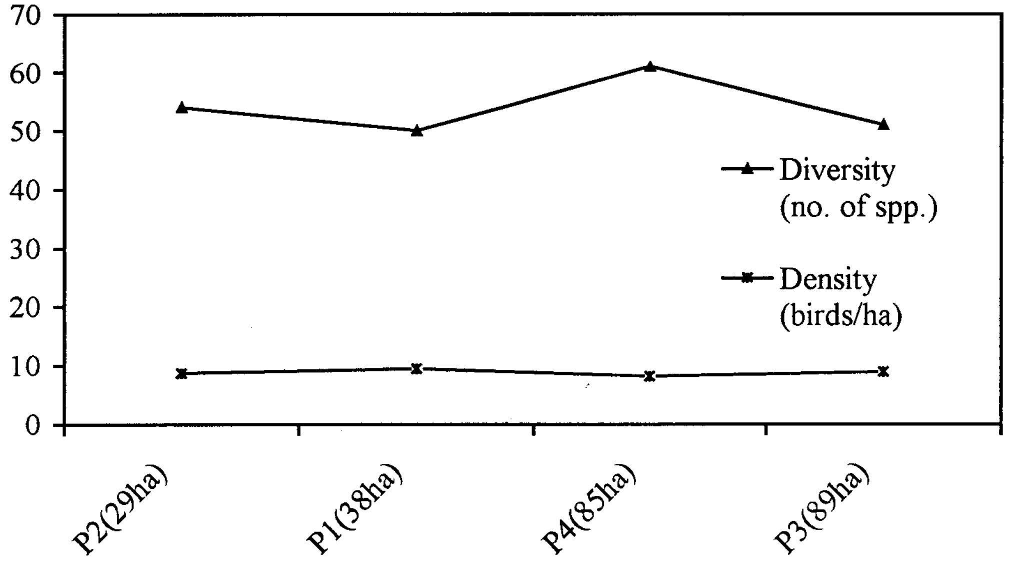

Figure 5.11. Bird diversity (number of bird species) and density (birds/ha) in different patches sizes (ha) ranging from small to large in montane evergreen forests, Mae Tuen Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

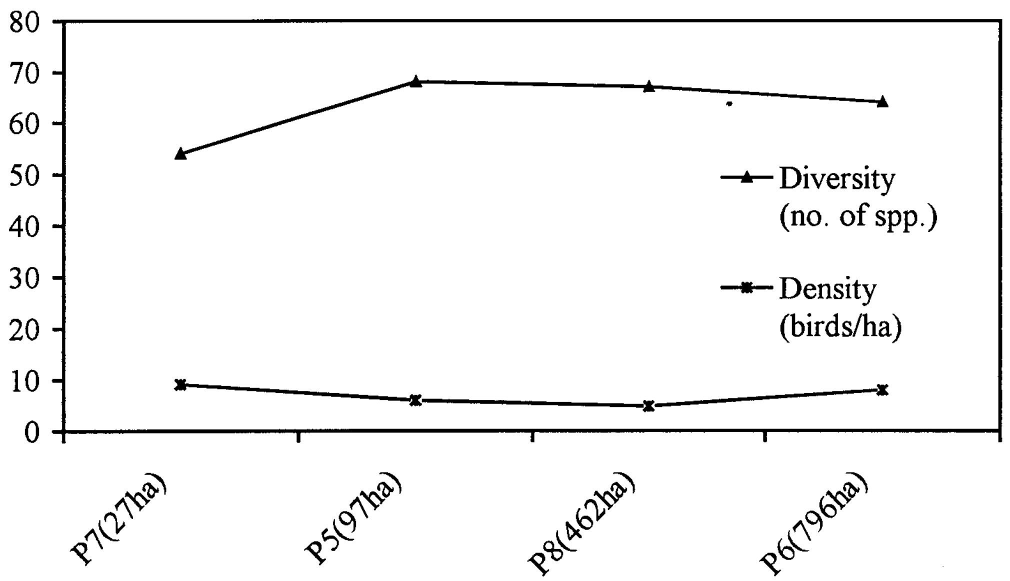

Figure 5.12. Bird diversity (number of bird species) and density (birds/ha) in different patch sizes (ha) ranging from small to large in montane evergreen forests, Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

5.3.3. Mammal Responses

5.3.3.1. Mammal Diversity

A total of 20 species were found, 9 species in Mae Tuen and 19 in Om Koi (Table 5.11). Om Koi fragments support large mammals such as Asiatic elephant, Asiatic black bear, leopard, tiger, sambar and primates such as Assamese macaque, Phayre's langur, and white-handed gibbon. Except for the white-handed gibbon, none of these animals were found in Mae Tuen patches. Smaller size mammals such as black giant squirrel, barking deer, wild pig, hog badger were found on both sites.

There was variation in the diversity of species among individual patches (Tables 5.12 and 5.13). P6, that is the largest patch in the area, supported the largest mammal diversity. It also had the highest variety of large carnivores, including tiger, leopard, and Asiatic black bear, and herbivores including elephant and sambar. Elephant used all of the patches in Om Koi. Sambar tracks and pellets were found only in patches P5 and P6. A serow and gorals were found along the edge of P6 and goral pellets were found in P7. Scrape marks of Asiatic black bear were found on tree trunks in patches P5, P6, P7 but not P8. Patches P1 – P4 in Mae Tuen contained mainly smaller sized mammals. I found the fewest species, tracks, and signs in P2. Siberian weasels were found in P1 and P3. Barking deer and wild pigs used all patches in Om Koi and Mae Tuen.

For tree-dwelling mammals I found that P6 had the highest species assemblage (Table 5.14). Assamese macaque used only this patch and has the highest abundance level in tree-dwelling mammals followed by Phayre's langur and white-handed gibbon respectively. I found the white-handed gibbon on almost every site visit to P8. Patches in Mae Tuen (P1-P4) were devoid of tree dwelling mammals of this size with the exception of P3, where a gibbon was heard calling during the last visit. Very low abundance of black giant squirrels was found in P1. The abundance of ground-dwelling mammals as analyzed by track analysis is as follows.

Table 5.11. List of mammal species found in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries (From the survey during September 1997 to June 1998).

Species	Mammal species in Mae Tuen	Mammal species in Om Koi
Family Cercopithecidae		
1. Assamese macaque (*Macaca assamensis*)	Not found	Found
2. Phayre's langur (*Presbytis phayrei*)	Not found	Found
Family Hylobatidae		
3. White-handed gibbon (*Hylobates lar*)	Found	Found
Family Sciuridae		
4. Black giant squirrel (*Ratufa bicolor*)	Found	Found
Family Hystricidae		
5. Malayan porcupine (*Hystrix brachyura*)	Found	Found
Family Ursidae		
6. Asiatic black bear (*Selenartos thibetanus*)	Not found	Found
Family Mustelidae		
7. Hog badger (*Arctonyx collaris*)	Found	Found
8. Siberian weasel (*Mustela sibirica*)	Found	Not found
9. Yellow-throated marten (*Martes flavigula*)	Not found	Found
Family Viverridae		
10. Crab-eating mongoose (*Harpestes urva*)	Not found	Found
11. Civet (unknown)	Found	Found
Family Felidae		
12. Leopard (*Panthera pardus*)	Not found	Found
13. Tiger (*Panthera tigris*)	Not found	Found
14. Cat (*Felis* spp.)	Found	Found
Family Elephantidae		
15. Asiatic elephant (*Elephas maximus*)	Not found	Found
Family Suidae		
16. Wild pig (*Sus scrofa*)	Found	Found
Family Cervidae		
17. Common barking deer (*Muntiacus muntjak*)	Found	Found
18. Sambar (*Cervus unicolor*)	Not found	Found
Family bovidae		
19. Serow (Capricornis sumatraensis)	Not found	Found
20. Goral (*Naemorhedus goral*)	Not found	Found
TOTAL	9 species found	19 species found

Table 5.12. List of mammal species found in montane evergreen forest sample patches (P1-P4) in Mae Tuen Wildlife Sanctuary (From the survey during September 1997 to June 1998)

P1	P2	P3	P4
1. Black giant squirrel	1. Wild pig	1. White-handed gibbon	1. Malayan porcupine
2. Siberian weasel	2. Barking deer	2. Siberian weasel	2. Civet (unknown spp.)
3. Hog badger		3. Civet (unknown spp.)	3. Cat (Felis sp.)
4. Civet (unknown spp.)		4. Cat (Felis sp.)	4. Barking deer
5. Cat (Felis sp.)		5. Barking deer	5. Wild pig
6. Wild pig		6. Wild pig	
7. Barking deer			

Table 5.13. List of mammal species found in montane evergreen forest sample patches (P5-P8) in Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998)

P5	P6	P7	P8
1.Black giant squirrel	1. Assamese macaque	1. Asiatic black bear	1. Phayre's langur
2.Malayan porcupine	2. Phayre's langur	2. Civet (unknown sp)	2. Black giant squirrel
3.Yellow-throated marten	3. White-handed gibbon	3. Yellow-throated marten	3. White-handed gibbon
4. Hog badger	4. Black giant squirrel	4. Asiatic elephant	4. Hog badger
5. Civet (unknown sp.)	5. Malayan porcupine	5. Wild pig	5. Civet (unknown sp)
6. Asiatic elephant	6. Asiatic black bear	6. Barking deer	6. Cat (*Felis* sp)
7. Wild pig	7. Yellow-throated marten	7. Goral	7. Crab-eating mongoose
8. Barking deer	8. Hog badger		8. Asiatic elephant
9. Sambar	9. Civet (unknown sp)		9. Wild pig
	10. Hog badger		10. Barking deer
	11. Cat (*Felis* sp.)		
	12. Leopard		
	13. Tiger		
	14. Asiatic elephant		
	15. Wild pig		
	16. Barking deer		
	17. Sambar		
	18. Serow		

Table 5.14. Abundance of tree dwelling mammals (per site visit) in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries (From the survey with 7 site visits during September 1997 to June 1998).

Species	Mae Tuen patches (individuals/site visit)				Om Koi patches (individuals/site visit)			
	F1	F2	F3	F4	F5	F6	F7	F8
Family Cercopithecidae								
1. Assamese macaque (*Macaca assamensis*)	0	0	0	0	0	7.43	0	0
2. Phayre's langur (*Presbytis phayrei*)	0	0	0	0	0	2.86	0	0.14
3. White-handed gibbon (*Hylobates lar)*	0	0	0.14	0	0	0.71	0	3.43
Family Sciuridae								
4. Black giant squirrel (*Ratufa bicolor*)	0.29	0	0	0	0.14	0.43	0	0.29
Family Mustelidae								
5. Yellow-throated marten (*Martes flavigula*)	0	0	0	0	0.29	0.43	0.14	0

5.3.3.2. Mammal Track Abundance

Total numbers of tracks of all species were 886 in Mae Tuen and 2,016 in Om Koi. The mean number of tracks per site visit for all species combined was significantly higher (t = 2.74, 12df, *P*=0.018) in Om Koi ($\bar{X}$ = 271.57 tracks/site visit, SE = 46.48) than in Mae Tuen ($\bar{X}$ = 123.43 tracks/site visit, SE = 27.78) patches (Table 5.15). The number of barking deer and wild pig tracks came first and second respectively in both sites. Barking deer tracks were significantly more abundant (t = 2.21, 12df, *P* = 0.047) in Om Koi ($\bar{X}$ = 118.86 tracks/site visit, SE = 24.36) than in Mae Tuen ($\bar{X}$ = 51.86 tracks/site visit, SE = 17.99) patches. Wild pig track abundance in Om Koi patches was 95.43 tracks/site visit (SE = 26.54) compared with 66.29 tracks/site visit (SE = 19.87) in Mae Tuen patches. However, there was no significant difference in wild pig track abundance between sites (t = 0.88, 12df, *P* = 0.397; power = 0.14 at α = 0.05). No statistical comparisons were conducted for the rest of species and taxa due to the low numbers of tracks encountered between sites or no tracks at all in one site. I found no tracks of Asiatic black bear, Asiatic elephant, sambar, serow, and goral in Mae Tuen. Elephant tracks were the third highest in abundance ($\bar{X}$ = 34.57 tracks/site visit) in Om Koi. Some sambar tracks ($\bar{X}$ = 11.43 tracks/site visit) were encountered in Om Koi patches. Malayan porcupine tracks were found in small numbers ($\bar{X}$ = 0.29 tracks/site visit) in Mae Tuen patches but more often encountered ($\bar{X}$ = 2.43 tracks/site visit) in Om Koi patches. It was difficult in the field to identify tracks of civets (Family Viverridae), and cats (Genus *Felis*) to species level. Average tracks/site visit of cats, civets, and hog badger in Mae Tuen patches were 0.71, 4.14, and 0.14 respectively compared with 1.57, 3.71, and 0.57 respectively in Om Koi patches (Figure 5.13). I also found a very few tracks of a tiger and leopard in P6 in Om Koi but none were found on the track record stations.

5.3.3.3. Sightings of Mammals Using the Surrounding Habitat

Although I did not spend time extensively searching for animals, tracks and signs outside the forest patches, I found some large mammals using old clearings and anthropogenic grasslands. Elephants were found crossing the large area of grassland between P5 and P7. They were also found feeding and using saltlicks in the old clearings adjacent to P6 and P8. Sambar pellets were found on the old clearings and grassland next to P6 and P5. Barking deer and wild pig also used such habitats. Tracks of these two species were found in seasonally abandoned cabbage fields next to the fragments in Mae Tuen. Goral were regularly found on the ridge and cliff at Doi Mon Chong in Om Koi next to P6. A serow was found near the edge of P6.

5.3.3.4. Mammal Diversity and Patch Size

The relationship between patch size and species diversity was quite fuzzy in the small patches in Mae Tuen but the relationship became more pronounced in Om Koi (Figure 5.14). When separately plotted between the sites, Mae Tuen sites showed no relationship between size and diversity (Figure 5.15). However, mammal diversity indicated a strong relationship with patch size in Om Koi patches as the larger the forest patch the more the species diversity (Figure 5.16).

Table 5.15. Relative abundance (average track counts per site visit) of mammals in hill evergreen forest fragments in Mae Tuen and Om Koi montane evergreen forest patches, Om Koi and Mae Tuen Wildlife Sanctuaries, from track record stations surveyed between September 1997 to June 1998.

Species		Maetuen N=7[a]	Omkoi N=7	T-test
OVERALL SPP.		123.43	271.57	0.018
Family Hystricidae				
Hystrix brachyuca	Malayan porcupine	0.29	2.43	n/a[b]
Family Ursidae				
Selenarctos thibetanus	Asiatic black bear	0	2.14	n/a
Family Mustelidae				
Arctonyx collaris	Hog badger	0.14	0.57	n/a
Family Viverridae				
	Civet	4.14	3.71	0.710[c]
Family Felidae				
Felis spp.	Cat	0.71	1.57	n/a
Family Elephantidae				
Elephas maximus	Asiatic elephant	0	34.57	n/a
Family Suidae				
Sus scrofa	Wild pig	66.29	95.43	0.397
Family Cervidae				
Muntiacus muntjak	Common barking deer	51.86	118.86	0.047
Cervus unicolor	Sambar	0	11.43	n/a
Family Bovidae				
Naemorhedus goral	Goral	0	0.86	n/a

[a] number of site visit

[b] no testing because of not enough data

[c] Man-Whitney test due to unequal sample size.

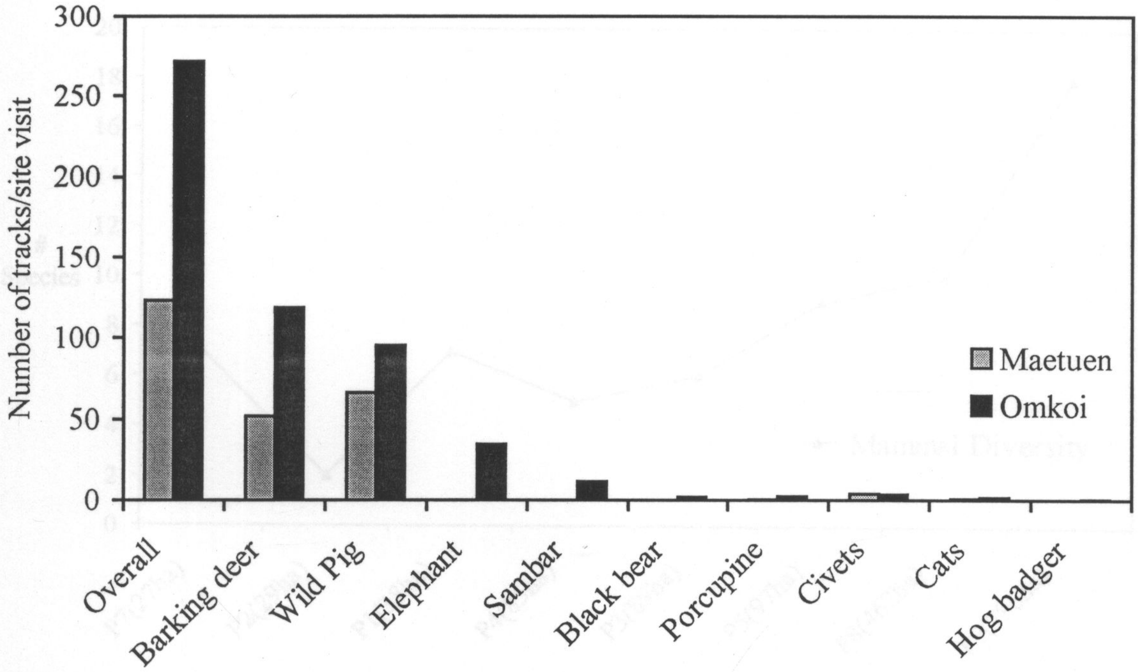

Figure 5.13. Mammal track abundance (number of tracks/site visit) in montane evergreen forest patches in Om Koi and Mae Tuen Wildlife Sanctuaries, from track record stations surveyed between September 1997 to June 1998

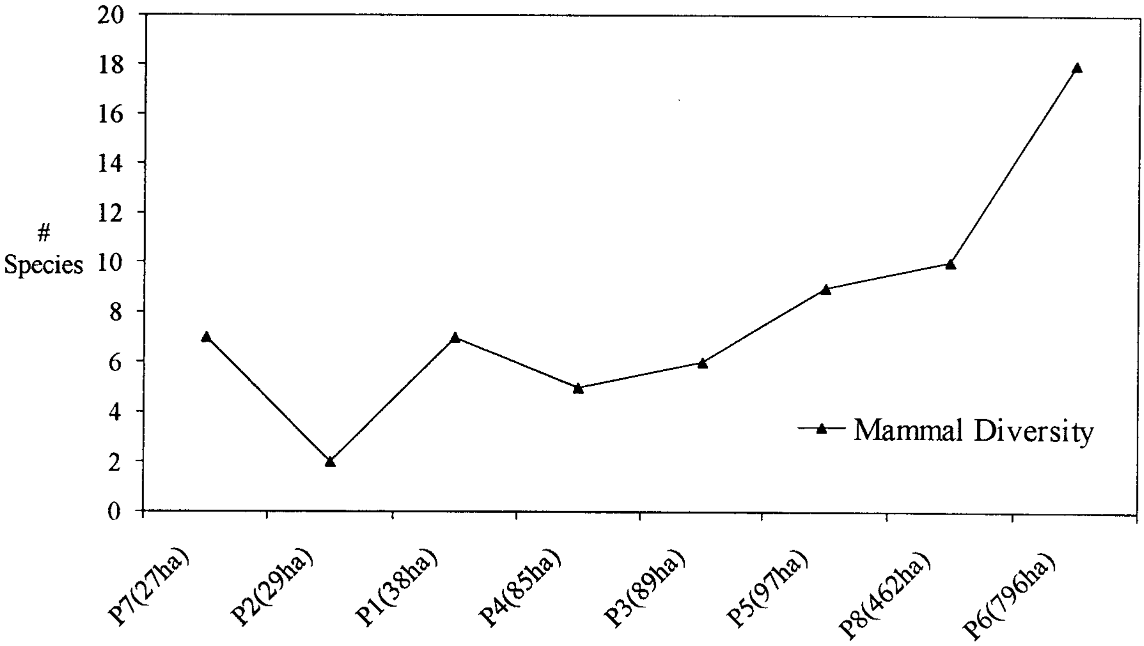

Figure 5.14. Mammal diversity (number of mammal species) in different patch sizes (ha) ranging from small to large in montane evergreen forests, Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

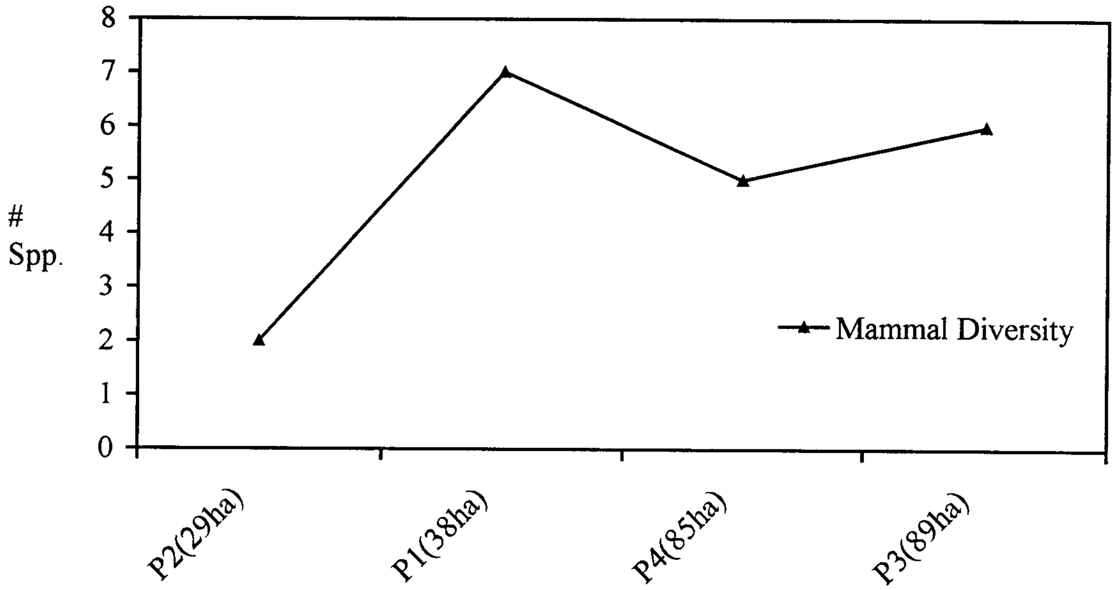

Figure 5.15. Mammal diversity (number of mammal species) in different fragment sizes (ha) ranging from small to large in montane evergreen forests, Mae Tuen Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

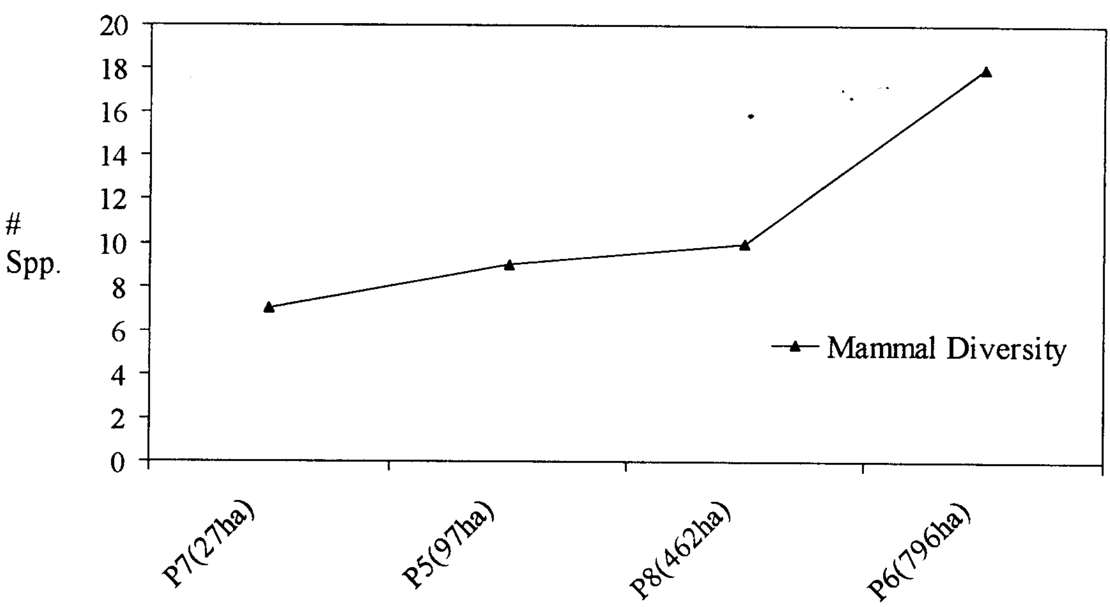

Figure 5.16. Mammal diversity (number of mammal species) in different patch sizes (ha) ranging from small to large in montane evergreen forests, Om Koi Wildlife Sanctuary (From the survey during September 1997 to June 1998 with 7 site visits).

5.3.4. Observations on Other Human Influences

During the surveys of birds and mammals, 3 main human disturbances including hunting, fire, and cattle grazing were also observed. The detail for each influence are as follows.

5.3.4.1. Hunting

Informal interviews with the ex-hunters who at the moment are the sanctuary guards reveal that sambars were the favorite target. The other targets were animals such as elephants, tigers, and bears. At present, law enforcement with regular patrols by guards makes hunting of large animals difficult. Hunting platforms were found during the survey in both Om Koi and Mae Tuen. The most hunted animals are currently barking deer and wild pigs. Hunters often build platforms on the trees to hunt mainly wild pigs and barking deer (Figure 5.17). There was also evidence that local hunters use paved and gravel roads for hunting animals at night. Sometimes the sanctuary guards were able to stop the hunters before they shot animals. Hunters are watchful and try to evade the guards; thus, direct encounters with hunters were rare. Therefore, I counted the number of gunshots heard during the surveys as an indicator of hunting as shown in Table 5.16. Many of the gunshots were heard at night. Other evidence of hunting is also shown in Table 5.16. Hunting in Mae Tuen site was more intense than Om Koi as indicated by number of gunshots. Animal targets for Hmong hunters ranges from barking deer to small birds such as barbets, drongos, pigeons.

5.3.4.2. Fires

The dry season in 1998 was one of the worst years for fires in Om Koi and Mae Tuen WS because fires burned deep into the montane evergreen forest patches and killed many trees (Figure 5.18). Also the large areas of dry dipterocarp and mixed deciduous forests were burned. The origins of these fires are uncertain. However, local people normally set fires to burn the new clearings and fallows and to drive animals for hunting. Therefore local people mainly started fires in this area. Fires are also a significant cause for dense montane evergreen to become more open forests and reduce gradually the size of forest patches (Figure 5.19). More spacing among the trees along the forest edges compared to interior zone is also a result of fires (see Appendix A.)

5.3.4.3. Cattle Grazing and Browsing

Cattle populations within the sanctuary, especially Om Koi WS, have recently increased. Less than a decade ago, with the cooperation of the district office, Om Koi WS successfully prohibited cattle in the area by enforcing a strict regulation including eradication of cattle sighted inside the sanctuary (Pers. comm. with the guards). Unfortunately, after a period of compromise and cattle raising boom, cattle have dispersed all over the area. The sanctuary officers in Om Koi estimated that more than 10,000 cattle are roaming in Om Koi Wildlife Sanctuary. I witnessed in 1998 that the cattle penetrated to the peak where there was no record of cattle before. Large herds of cattle can be found grazing in the old clearings surrounding Patch P5 – P8 (Figure 5.20). People burn such old clearings for new grasses for cattle every year. Cattle also browse deep inside the forest patches and compete for food sources with local wildlife such as sambars and elephants. It is common to see people carrying guns following their cattle in the area. They use such opportunity to hunt wild animals whenever they encounter them.

5.4.5.4. Use of Pesticides

Use of pesticides is intense in Mae Tuen because of the huge areas of cabbage fields (Figures 5.21 and 5.22). Hmong people spray both herbicides and insecticides regularly. They also put high volumes of fertilizers onto their cabbage fields.

Table 5.16. Numbers of gunshots and evidence of hunting observed in Om Koi and Mae Tuen Wildlife Sanctuaries during wildlife surveys from April 1997 – July 1998

Month	Maetuen	Omkoi	Remarks
Apr 97	2	N/A	
Sep 97	N/A	1	
Oct 97	8	1	- Oct 24, 97 Hunters were found skinning 2 barking deer in Maetuen
Nov 97	11	0	- 3 piles of barbet feathers killed by hunters found near P2 in Maetuen - Bamboo rat trap P1, Mae Tuen - A group of local hunters unsuccessfully tried to ambush a goral at Doi Mon Chong area, Om Koi (sighted by Rattanawat Chayarat, a researcher conducting research on goral behavior in the area).
Dec 97	6	6	
Jan 98	N/A	2	- A pile of porcupine quilt was spotted near P6, hunted
Feb 98	4	N/A	- 2 Hmongs carrying guns for hunting in P3 in Mae Tuen - Pulled down 3 hunting platforms in Mae Tuen
Mar 98	N/A	2	
Apr 98	3	1	
May 98	2	2	
June 98	0	0	
July	N/A	1	
TOTAL	36	14	

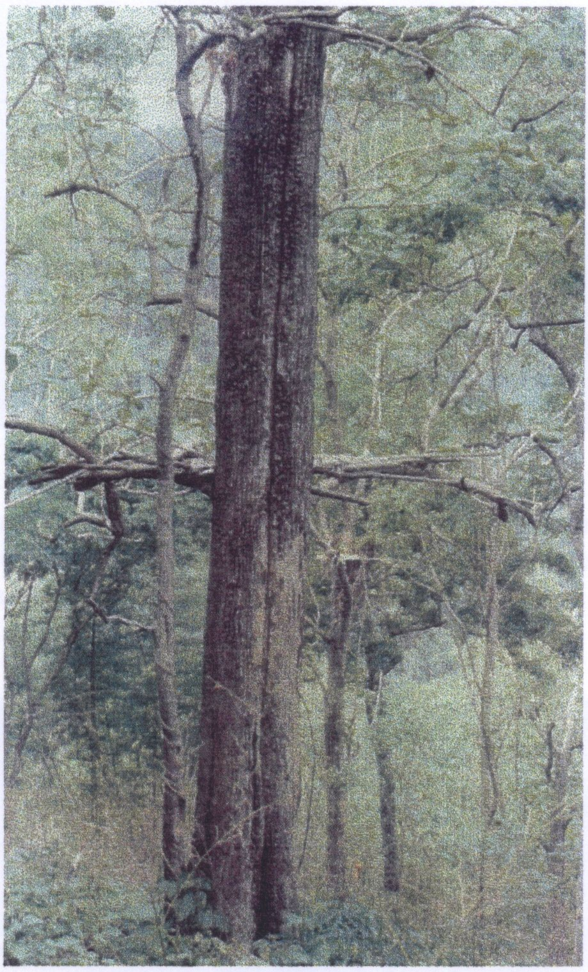

Figure 5.17. Platforms for hunting commonly found in Om Koi and Mae Tuen sample patches, Om Koi and Mae Tuen Wildlife Sanctuaries.

Figure 5.18. Anthropogenic fires burn deep inside the montane evergreen forest patches killing trees appearing as brown canopies in the picture, in Om Koi Wildlife Sanctuary.

Figure 5.19. Fires set by local people have killed the montane evergreen forest trees along the forest edges leading to the reduction in patch size

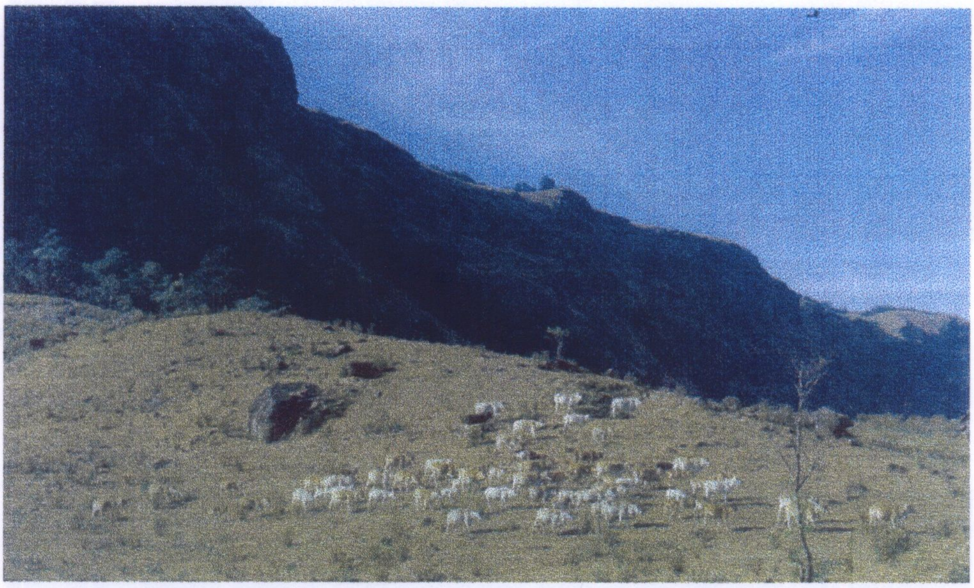

Figure 5.20. Cattle compete with local wildlife for food sources and can transmit diseases to wild ungulates in Om Koi and Mae Tuen Wildlife Sanctuaries.

Figure 5.21. The Hmong use insecticides extensively on the cabbages fields in Mae Tuen Wildlife Sanctuary.

Figure 5.22. Empty bottles of pesticides were commonly found on Hmong's cabbage fields, Mae Tuen Wildlife Sanctuary.

5.4. Discussion

5.4.1. Patch Characteristics and Human Use of the Area

The montane evergreen forest in Mae Tuen is more intensely fragmented with smaller forest patches and lack of, or very small, core areas (interior zones) compared to the Om Koi site (Tables 5.1, 5.2). A paved road and human settlement embedded within the valley in Mae Tuen (Figure 5.1) have made strong contributions to the reduction of forest area. The paved road opened the villages to outside markets as far away as Bangkok, and cabbages now dominate cash crops in Mae Tuen site. I witnessed in 1997-98, when the market price for cabbages was high, that many Hmongs were able to purchase brand-new pick-up trucks to carry cabbages to the market in Bangkok. Different authors (e.g., Fox et al. 1995, Dearden et al. 1996b) reported changes in socioeconomic condition of the local people after road construction and other development programs leading to severe degradation of forest areas.

From the tree profiles, some patch edges show more gaps than interior zones (see Appendix A). This is consistent with Kapos et al. (1997) who found that the increase of gaps near edges has led to more regrowth in understory level in Amazonian forest remnants. Malcolm (1994) studied three primary forest habitats in Brazil and found that understory foliage thickness increased and overstory foliage thickness decreased toward edges. Many studies (e.g., Williams-Linera 1990, Matlack 1994) indicate that older edges are different in abiotic and structural conditions than newly created edges in which vegetation structure gradually changes. The abrupt edges are more pronounced in Mae Tuen forest patches where human activities are intense.

Fires set by local people in the dry season have burned deep into the forest patches in Om Koi and Mae Tuen (see Figures 5.18, and 5.19). Fire intrusions in evergreen forest patches from the surrounding clearings in Om Koi and Mae Tuen may have serious effects on montane evergreen forest patches. Fire intrusion is normally a rare event in tropical evergreen forests (Uhl and Kauffman 1990), and its effects are often lethal to tree species (Uhl and Buschbacher 1985). Kellman et al. (1996) discussed the effects of fire in Belize and explained that fire intrusions were found to be patchily distributed and of a variety of intensities and consequently change the structure of the forests. Kellman et al. (1996) also suggest that the boundaries of forest patches appear able to remain intact at low fire frequencies, but may be unable to sustain increased frequency. For example, savanna fires set by ranchers appear to be causing a gradual retreat of the forest boundary.

5.4.2. Wildlife Responses

Because both areas have been fragmented and disturbed for more than 50 years (see Chapter 4), the current species assemblages and populations are possibly different from those at the pre-fragmentation period. Species that currently exist may be (1) the only species with the ability to adjust to the modified habitats, or (2) and also species vulnerable to local extinction due to demographic and environmental uncertainties influencing small remnant populations (Meffe and Carroll 1994). Especially in the Mae Tuen patches where human disturbances are chronic and fragments have been reduced in size, the current species composition is likely to be different than the past. Study of the old fragments in Singapore and Hong Kong revealed the extinctions of many forest birds and mammals from the fragments (Corlett and Turner 1997). Warburton (1997) found that small remnants tend to converge in composition, supporting locally common species that often survive well in modified habitats. Laurance and Bierregaard (1997) suggest that the long-term survival of much of the tropical biota will depend on the ability of species to persist in highly modified habitats and on human capacity to manage and conserve such degraded landscapes. Also the survival of species as currently seen may conceal the largely invisible erosion of genetic diversity as population numbers decline (Whitmore 1997).

5.4.2.1. Bird Responses

Although they are both montane evergreen forests, the degree of elevation difference between the Om Koi and Mae Tuen sites at first caused uneasiness in comparing the effects of fragmentation on bird diversity. Normally bird species diversity decreases with increase in elevation due primarily to change in forest structure and composition (Whitmore 1984). Many authors (e.g., Diamond 1973, Terborgh 1977, Young et al. 1998) have confirmed this pattern. The opposite result, however, was found in this study with a trend of greater diversity ($P = 0.06$) at higher elevation, Om Koi patches, than lower elevation, Mae Tuen patches. The significant difference ($P = 0.01$) with more bird species in Om Koi than Mae Tuen was detected after excluding the smallest patch F7 – the one with a prominently low species number – out of the analysis (Table 5.3). The comparison with the other studies suggests that elevation should not be a major factor affecting the difference in bird diversity in this study. The effects of habitat fragmentation and other human disturbances can be a major factor in this case as I discuss further below.

The configuration of large remnant patches with natural forest connectivity between patches of the same forest types in Om Koi may be a key factor in maintaining the high numbers of bird species in P5, P6, and P7 (see Figure 5.7). Within Om Koi the distinctively low bird diversity in small and isolated P7 indicates the effects of fragmentation. Reduced patch size and increased isolation reduced bird diversity (e.g., Bierregaard et al. 1992, Kattan and Alvarez-Lopez 1996).

The type of surrounding clearings can also determine species diversity. The clearings around the montane evergreen forest patches in Om Koi are abandoned fields, regrowths, and anthropogenic grasslands. This type of clearing has less contrast compared to Mae Tuen where cabbage fields are the predominant clearing type. The lower contrast between habitat types in Om Koi patches could help maintain the diversity of birds. Bierregaard and Stouffer (1997) describe a number of primary rain forest birds in an Amazonian forest foraging in adjacent secondary forest, and these species have also used secondary forest to recolonize small primary forest fragments nearby. I found some evergreen forest species such as yellow-cheeked tit, black-headed sibia, using the regrowth along the patch edges in Om Koi. Nevertheless, some primary forest specialists avoid the matrix of modified habitats whereas some adapt to the changed landscape (Laurance and Bierregaard 1997). I found no primary forest birds in the cabbage fields next to Mae Tuen patches.

The significantly greater ($P = 0.01$) bird diversity along the edge zone compared to the interior zone conforms to some studies in other habitat types (e.g., Leopold 1933, De Casenave et al. 1998). Gates and Gysel (1978) suggested that birds might be drawn to the edge because of greater food availability. The findings in this case contrast to a study on birds in newly created edges in a tropical forest in the Amazon where bird species richness was depressed (Lovejoy et al. 1986b). Evergreen forest birds were still abundant within 100 meters from the forest edge in Om Koi and Mae Tuen (see Table 5.7 and 5.8). Nevertheless, the species composition along the forest edges between the sites needs to be addressed. The abundant species along the edge in Om Koi were composed of strictly evergreen forest birds such as gray-cheeked fulvetta, mountain bulbul, and golden-throated barbet. For the more disturbed edges in Mae Tuen patches, abundant species include those evergreen forest obligates previously mentioned and black bulbul and streaked spiderhunter, which can be found in both forest and disturbed habitat.

The abundance of nectarivorous birds including the streaked spiderhunter and little spiderhunter in Mae Tuen patches was quite obvious. This may be related to the vegetation type along the edge. Most edges in Mae Tuen patches are covered with dense stands of wild banana (Figure 5.23) and banana flowers are one of the main nectar sources for nectarivorous birds (personal observation). Nectarivores such as spiderhunters may benefit from this food source and locally increase in number. Wild bananas are scarce along the forest edge in Om Koi. Nectarivores such as hummingbirds generally prove to be less vulnerable to fragmentation than insectivores and frugivores (Bierregaard and Stouffer 1997).

Only a few clearing species, including flavescent bulbul and red-whiskered bulbul, were found in low abundance within 100 m from the forest edge in both sites (see Tables 5.7 and 5.8). Lovejoy et al. (1986b) also found that very few second growth bird species invaded tropical forest patches in the Amazon. However, de Casenave et al (1998) studied bird communities in a semiarid forest in Argentina and found that the species assemblage along the edge was similar to second growth species. Therefore, bird response to forest edges may be different among habitat types.

The low abundance (>1 birds/site visit) of most species makes it difficult to decide whether they are edge-avoiding species (Tables 5.7 and 5.8). Sighting of such species in particular locations could happen by chance alone. Therefore interior species with the abundance number ≥ 1 birds/site visit are more certain to be interior zone specialists. In Om Koi patches the brown hornbill, a large frugivorous bird, was found only in interior zones. In Mae Tuen, although there were no birds restricted to interior zones, the long-tailed broadbill was found to be distinctively more abundant in interior zones (4.86 birds/site visit) compared to edge zones (0.43 birds/site visit). Furthermore, ground insectivores were found to be vulnerable or extinct in forest remnants with a decrease in core area (Bierregaard et al. 1992, Burke and Nol 1998). In Om Koi patches 4 species of ground insectivores, including slaty-bellied tesias, pygmy wren-babblers, streaked wren-babblers, and dark-sided thrushes, were found in interior zones, but two, the dark-sided thrush, and eye-browed wren-babbler were found in the edge zone. In Mae Tuen, where patches contain small or no core areas, no ground insectivorous birds were found.

The low abundance of large frugivores such as brown hornbills and great hornbills in Om Koi (see Figure 5.24) and total lack of these species in Mae Tuen are probably the result of prolonged fragmentation effects. Large frugivorous birds require continuous habitat along altitudinal gradients because fruit availability is variable in time and space, and tracking these resources involves seasonal movements that cover large areas. Forest fragmentation separates the connection between foraging areas and may severely restrict access to a year-round food supply (Guindon 1996). Fragmentation also reduces the availability of large trees, which provide holes for hornbills to use for nesting. Reduction of nesting sites can lead to change in nest competition and reproductive success (Poonswad and Kemp 1993). Large frugivorous birds, including 3 species of hornbills, were eliminated from Hong Kong and Singapore by fragmentation and hunting (Corlett and Turner 1997). Hornbills in this study also have affected from hunting. Large birds are a favorite target for local hunters (Redford 1992). I have seen local people use great hornbill heads as a trophy. Bennett and Dahaban (1995) witnessed that many bird species in Sarawak were taken for their feathers and bills, which are used in traditional decorations and ceremonies.

Figure 5.23. Dense stands of wild banana commonly occur along the forest edges of Mae Tuen montane evergreen forest patches in Mae Tuen Wildlife Sanctuary.

Figure 5.24. A pair of great hornbills (*Buceros bicornis*) were found in forest patch # 5 in Om Koi Wildlife Sanctuary (Photograph taken on May 16,1998).

Small cavity nesting birds such as the great barbet, golden-throated barbet, and blue-throated barbet were still abundant in forest patches in both sites (Tables 5.7 and 5.8). Fragmentation at this scale may not have severe effects on small cavity-nesting birds. Matthysen and Adriaensen (1998) found that fragmentation does not affect habitat suitability and reproductive success for Eurasian nuthatches (*Sitta europaea*), which are a small cavity nester. I found that blue-throated barbet and golden-throated barbet used small trees (20 cm DBH) and stumps for nesting in holes < 2 m above the ground.

The existence of game birds such as the rufous-throated partridge in a small forest patch (F7) (see Appendix B. for raw data) implies the capacity of patches of this size (27 ha) to be utilized by this game bird, and hunting on this species is low in this area. This species is much reduced in many areas due to hunting (Lekagul and Round 1991). Hunting may be an influential force causing the low abundance of birds in the family Phasianidae in patches in Mae Tuen. Birds in this family are mainly large and hunted as game species (Robinson 1996). I witnessed Hmongs in Mae Tuen using a domestic cock to trap the red junglefowl. However, even in the absence of hunting, game birds including the family Phasianidae disappeared from small forest patches in Amazon because the forests are too small to support them (Bierregaard and Lovejoy 1989).

Although almost significant, the trend of greater abundance ($P = 0.058$) for insectivores in Om Koi could point to the effects of fragmentation and other disturbance. In many tropical habitats insectivorous birds decreased when elevation increased (e.g., Terborgh 1977). In Mae Tuen, however, the Hmong have extensively used insecticides and herbicides for cabbage fields for a long period. Pesticides that diffuse from the matrix into the fragments may disrupt insect populations in forest patches (Murcia 1996). Therefore the reduction of insects could affect the population of insectivorous birds.

The higher diversity, 21 species, of migratory birds using Om Koi forest patches compared to Mae Tuen patches, 9 species may also be related to fragmentation. Chronic fragmentation and disturbances in Mae Tuen may lead to unsuitable habitat for many migratory species. In Costa Rican montane forests, the diversity of long distance migratory birds was greater at lower elevations (Young et al. 1998).

Diversity index values with Hill's diversity number for both sites showed no sign of significant difference (Table 5.3). Part of the reason is that there may be no significant difference in diversity for the abundant species in both sites because the index is based mainly on abundant species (Ludwig and Reynolds 1988). In other words the diversity of rare species can be the ones that made the sites differ in diversity.

The abundance of birds in terms of density (number of birds/ha) was not significantly different between Om Koi and Mae Tuen forest patches, edges, and interior zones (Table 5.3). Although not statistically significant, most small and medium patches in Mae Tuen supported higher density of forest birds - P7 supported 9.06 birds/ha, P1 (9.51), P2 (8.67), P4 (8.10) compared to large patches P6 (7.89), and P8 (4.75) in Om Koi (see Figure 5.9). This indicates the value of small patches for forest birds especially in Mae Tuen where forest patches are surrounded by harsh environments such as agricultural fields. Forest patches in the tropics serve as "islands of biodiversity" in agricultural landscape and as a source of colonizers for many animals (Viana and Tabanez 1996). The high density of birds in small forest patches may also be a result of excellent foraging conditions (Robinson 1998). But the appearance of high density may not indicate reproductive success for some species (Brown and Robinson 1996). In severely fragmented landscapes, small fragments can also serve as "stepping stones" for faunal movements such as bird species which migrate altitudinally for food sources, and long-distance migratory birds (Greenberg 1996), and thus help to maintain some degree of ecosystem connectivity (Nason et al. 1997).

The non-significant difference in density of birds in edge and interior zones within each site and for overall patches (Table 5.4) did not correspond to some other studies. Bird abundance appeared to be higher in the natural (de Casenave et al. 1998) and anthropogenic (e.g., Yahner 1988) edges. Nevertheless the small sample size in this study could make it difficult to detect differences in density.

5.4.2.2. Mammal Responses

The conspicuously lower number of mammal species in Mae Tuen patches compared to Om Koi can be explained as a result of two main effects, fragmentation and hunting. Large carnivores such as tiger, Asiatic black bear, and leopard, and herbivores such as elephants and sambars were not found in Mae Tuen patches. Large mammals, especially top predators like tigers and leopards, normally have a large home range. A single female tiger, for example, requires at least 20 km^2 for the home range and the male probably at least twice as much (Sunquist 1981). The home range sizes of Asian elephants normally ranges between 34 to 800 km^2 (Stuwe et al. 1998). Fragmented forests may be too small to support large home range animals (Robinson 1996). Many species use a range of different habitats over the course of a year and fragmentation may reduce the appropriate habitat (Robinson 1996). Fragmented forests with intense agricultural clearing are especially of low value to many wild animals (Laurence and Bierregaard 1997) due to difficulties in traversing agricultural fields. The road in Mae Tuen is a provincial freeway with moderate traffic, especially during harvesting season. It likely inhibits some animals from crossing or using the area near the road. In North America, busy highways inhibit the activities of some animals such as red foxes *Canis vulpes*), elk (*Cervus canadensis*) to some distance from the road (Forman and Godron 1986).

Hunting is another factor likely to cause early extinctions from the area. When fragmentation converts forest to agricultural areas, it allows people to increase access to wild animals (Robinson 1996). Robinson (1996) suggests that rural people are exploiting an ephemeral resource made available to them because of forest fragmentation, which will ultimately become exhausted. Development of infrastructure such as construction of the paved road in Mae Tuen may also contribute to species extinction. The development of transportation and infrastructure allows easier transport of forest products to markets (Robinson 1996). In highly developed areas such as Singapore, extinction of large carnivores such as tiger, leopard, large indian civet, and herbivores such as sambars were caused mainly by hunting (Corlett and Turner 1997). Corlett and Turner (1997) also added that currently, despite the control of hunting and protection of forest fragmentation, the extinction rate of forest species has been subsequently high. Only the species that utilize the nonforest matrix can survive under severe habitat degradation like Hong Kong and Singapore (Corlett and Turner 1997). The Om Koi site is more remote and agricultural activities around the montane evergreen forests have been restricted for a long period of time. Some hilltribes villages near the area were relocated out of the sanctuary. Less intense landuse and development within Om Koi may be the key factor for survival of animal species.

Primates were not found in the small forest patch (F7) in Om Koi whereas they were still in large patches (F6 and F8), probably because the sizes are adequate to provide suitable habitats (Robinson 1996). In Amazonian forest fragments, the spider monkey (*Ateles* spp.) and saki (*Chiropotes* spp.) went immediately extinct from small forest patches (Rylands and Keuroghlian 1988). However, Freese et al. (1982) reported that different species of primates still survived in the Peruvian Amazon, though at a reduced density, in small forest patches which were not isolated from one another, and where hunting was light. In Belize, monkeys use small forest patches with several species of strangler figs (*Ficus* spp) (Lyon and Horwich 1996). There are fig trees in P7 that could attract primates such as Assamese macaque but none of them were found during the survey. In some countries such as Singapore and Hong Kong with a long history of fragmentation, hunting, and other land developments, primates such as long-tailed macaque (*Macaca facicularis*) and rhesus macaques (*Macaca mulatto*) can live, but not perform their ecological function (Corlett and Lucas 1990). The almost total lack of primates (only a gibbon call was heard in P3) in Mae Tuen forest patches is likely to be a result of chronic human disturbance mainly from forest fragmentation and hunting.

The abundance of barking deer and wild pig tracks in Om Koi and Mae Tuen indicates the ability of these species to live in a modified habitat. Pigs have high rates of increase and therefore populations are more resilient to hunting (Robinson 1996). Barking deer are habitat generalists and their solitary behavior (Lekagul and McNeely 1977) may reduce the chance of the population being extirpated by hunting. The significantly greater abundance of barking deer tracks in Om Koi patches than Mae Tuen implies greater barking deer population in Om Koi. Ongoing human disturbances and hunting may be a factor causing the difference. The existence of barking deer and wild pigs in Mae Tuen patches confirmed the observations by Robinson (1996) in Amazonian forest fragments that where forests still retain some connectivity, even preferred species can persist when hunting is light. Only wild pig and barking deer were found in patch P2. This patch is close to village, and human disturbance in terms of hunting and other activities may disrupt other less resilient species. Smith et al. (1997) found that lemur abundance increased with distance from the villages in Madagascar. P2's shape is very convoluted and has no core area, and may not meet the habitat requirements of many species.

The tracks of a male tiger were found at high elevation in Om Koi, which is unusual habitat for tigers (see Figure 5.25). Mountainous areas with severe seasonal fluctuations are not optimal habitats for tigers (Rabinowitz 1993). The presence of tigers at high elevation could indicate the availability of prey species such as sambars, which still exist in Om Koi patches. It could also mean that the tiger is avoiding unsuitable habitat in the lower elevations where human settlements and encroachment are rampant. Rabinowitz (1993) reported that hunting, human settlements, forest degradation from agricultural clearing are the main threats to tiger populations in Thailand. Such threats are more severe in Mae Tuen patches where no tigers were found.

When patch size and diversity were taken into consideration there was a relationship between patch size and mammal diversity in Om Koi but no trends were apparent in Mae Tuen (Figures 5.14 – 5.16). No relationship in Mae Tuen patches is likely because intense human activities may confound the effects of patch size and diversity. With the less disturbed sites in Om Koi, however, the trend of diversity increase with patch size was more pronounced. As mentioned earlier, many authors (e.g., Warburton 1997, Kattan and Alvarez-Lopez 1996, Bierregaard and Lovejoy 1989) have reported a positive relationship between patch size and animal diversity. More diversity on larger patches can be viewed as the result of having more habitat diversity (Buckley 1982) or larger area per se (Simberloff 1976).

In conclusion, Om Koi montane evergreen forest patches are currently less fragmented and disturbed than Mae Tuen patches, which have faced chronic fragmentation and other human disturbances. Om Koi forest patches support more bird and mammal species than Mae Tuen patches. Large remnant patches in Om Koi with a higher degree of connectivity are the key factors maintaining wildlife species requiring interior zones and large home range. A less disturbed environment in Om Koi in terms of low human settlements, no agricultural activities near the patches, and no roads also contributes to the differences in wildlife diversity and abundance between the sites.

Figure 5.25. Tiger tracks were found in montane evergreen forest patch # 6, the largest patch, in Om Koi Widlife Sanctuary (Photograph taken on July 3,1997).

The relationship between patch size and bird and mammal diversities is more pronounced in Om Koi than Mae Tuen patches where the relationship may be confounded by current human influences. In the old forest patches in this study more bird species were found on the edge than interior zones. In every patch the majority bird species composition was montane evergreen forest birds with very low penetration of generalist species. Ground insectivorous birds were absent from Mae Tuen patches mainly because the patches contain no or small core areas. Large frugivorous birds were absent from Mae Tuen patches and they existed in low abundance in Om Koi patches. Nevertheless, small remnant patches in Mae Tuen are still valuable for many forest birds. Bird abundance level in forest patches in Mae Tuen is high compared to Om Koi patches. Therefore, forest patches amid the agricultural landscape are valuable for many forest bird species. Another interesting finding relating to the Mae Tuen patches was the high abundance of the spiderhunters, a group of nectarivorous birds being able to use both forest and secondary growth habitats, that may be related to the great abundance of wild banana and banana flowers along the forest edge of Mae Tuen patches. For large mammal species, habitat loss by fragmentation and hunting following fragmentation may contribute to the reduction of populations in Om Koi forest patches and local extinction in Mae Tuen patches. Most mammals that exist in Om Koi are confined to the very few large remnant patches and their long-term existence remains insecure.

CHAPTER 6
MAPPING WILDLIFE DISTRIBUTIONS IN FRAGMENTED AND HUMAN INFLUENCED LANDSCAPES WITH GIS

6.1 Introduction

In this chapter animal distributions were mapped based on the information regarding mammal use of the forest patches, GPS locations of animals related to other human influences such as roads and villages, and natural history of animals from literature such as home range size and habitat preference. However due to the limitation of data obtained from the field surveys only the distributions of the Asian elephant (*Elephas maximus*) and banteng (*Bos javanicus*) were analyzed. Although bantengs are not obligate to the montane evergreen forest they are currently rare in the forests of northern Thailand. Therefore, their existence in Om Koi Wildlife Sanctuary should be given a priority for protection.

The distribution of animals is regulated by a number of ecological and environmental variables. Currently, distributions of many animal species are controlled by the impact of human change on environmental features (Miller 1994). Habitat features hypothesized to influence species distribution can be mapped and analyzed in relation to individual species (Miller et al. 1989). Data layers necessary for analyzing and identifying priority areas for conservation of animal species include;

- Species data,
- Vegetation types,
- Land use data,
- Human impacts data,
- Administrative data.

Furthermore, literature citing voucher specimens and geographical localities is a major source of data for mapping. By choosing the most reliable data available and having GPS locations from the field collected with the help from people with first-hand knowledge of the area, species ranges can be reliably estimated from the point data (Hall 1994). Distribution maps provide information on where species are located so that both species and their surrounding environment can be better protected and managed (Miller 1994).

GIS capabilities provide many advantages for conservation research and planning. The benefits include (Miller and Allen 1994, p49).

- The ability to regularly edit and update species distribution maps,
- The ability to produce hardcopy, updated maps on a regular basis, and
- The practical and scientific values inherent in the components of a computerized database.

For animal mapping in this study I selected two large mammal species, Asian elephants (*Elaphas maximus*) and banteng (*Bos javanicus*). Asian elephants are an endangered species in Thailand (Thailand Institute of Scientific and Technological Research 1993) and Bantengs are also endangered (IUCN 1994), especially in northern Thailand. The following sections explain the threats to the species and why these two species are urgently in need of protection based on ecological and geographical knowledge. Then, the methods used are described, followed by the result and discussion.

6.1.1 Asian Elephants: Distribution and Threats

Asian elephants are currently distributed over the Indian sub-continent and Southeast Asia. Distributions are restricted mainly to remaining forest tracts where human settlements are sparse (Sukumar 1989). The most serious impact of human activity on elephant habitat has been the reduction and fragmentation of the habitat, resulting in the compression and isolation of elephant populations. Slash-and-burn shifting agriculture is one of the factors depleting Asian elephant habitats in various countries. Elephant habitat in India, for example, has been lost to slash-and-burn agriculture. Elephants in Sumatra also face the same fate by which shifting cultivation is responsible for the loss of 15,000 km^2 of forest every year in Indonesia. Other main threats to elephants include the spread of permanent agriculture, hydroelectric and irrigation dams, and the capture and hunting of elephants (Sukumar 1989).

In Thailand, elephants are patchily distributed in small populations over the remaining forest areas within national parks and wildlife sanctuaries. A large proportion of the remaining elephants is found in the Tenasserim range of northern and western parts of the country (Dobias 1987). Srikrajang (1992) estimated that 1,975 wild elephants existed and also found that between 1986-1990 86 elephants were killed within protected areas. Trisurat et al. (1996) mapped elephant distributions in Khao Yai National Park and found that elephants concentrated near ranger stations probably because of safety from poaching. Dobias (1987) conducted a countrywide survey of elephants and estimated that Om Koi, and Mae Tuen Wildlife Sanctuaries, and Mae Ping National Park (total area 3,400 km^2) hold at least 125-175 elephants. They were one of few protected areas that still support elephants remaining in the North other than the animals that may migrate in from surrounding countries on occasion.

6.1.2. Banteng: Distribution and Threats

The current distribution of banteng ranges mainly in Southeast Asia from Myanma, Thailand, Laos, Vietnam, Cambodia, to Java (Lekagul and McNeely 1977). Srikosamatara and Suteethorn (1995) estimated that 470 bantengs existed in protected areas in Thailand. Bantengs, the same as elephants and many large herbivores, have been faced with habitat loss by deforestation. In many areas bantengs exist in small populations (Prayulrasiddhi 1997) which can readily be wiped out by demographic stochasticity, environmental uncertainty, natural catastrophes, and genetic uncertainty (Meffe and Carroll 1994). Poaching, especially for horns, kills many bantengs every year. Frequent fires set by local people have caused changes in habitat from mixed deciduous forest, with more preferable food source for bantengs, to dry dipterocarp forest with less food sources for banteng (Prayularsiddhi 1997). Domestic livestock heavily distributed into the forest areas can pass disease to bantengs (Ashby and Santipillai 1988).

Prayurasiddhi (1997) extensively mapped the home ranges of banteng in Huai Kha Khaeng Wildlife Sanctuary in western Thailand. He reported that banteng were found in elevations ranging from 200 – 600 m in areas rich in mineral licks. Bantengs can forage away from water where they consume dry grasses, shrubs, herbs, etc.

Although Om Koi Wildlife Sanctuary is known as one of the very last protected areas in northern Thailand that still supports populations of elephants and bantengs distributions of the species have not been intensively studied. The purpose of this section of the project was to build geographical distribution maps based on available data so that those in charge of managing the area can better understand and conserve the species.

6.2. Methods

6.2.1. Database Building

A GIS database on villages, forest types, land-use types, road systems, salt licks, and hydrology was built. Data sources included LANDSAT TM imagery and aerial photographs acquired in 1996, and digitized versions of the 1:50,000 topographic sheets. Data from the sources was combined with information from field surveys to generate maps of *Forest types and land use and fragmentation* (See details in Chapter 4) and the *Digital Elevation Model (DEM).*

6.2.2 Field Surveys

6.2.2.1. Asian Elephant

A Global Positioning System (GPS) was utilized in the field to help adjust the boundaries of sampled forest patches. With the help of local guards who are ex-hunters, elephants were tracked in two main locations including 1) the montane evergreen forest area with elevations between 1,400 m – 1,900 m, and 2) the mixed deciduous and dry dipterocarp forest areas with elevations between 500 – 900 m) (Figure 6.1). The tracking period ranged from April 1997 to June 1998. The locations of elephants sighted, including the sightings of footprints and dung piles, were collected with GPS.

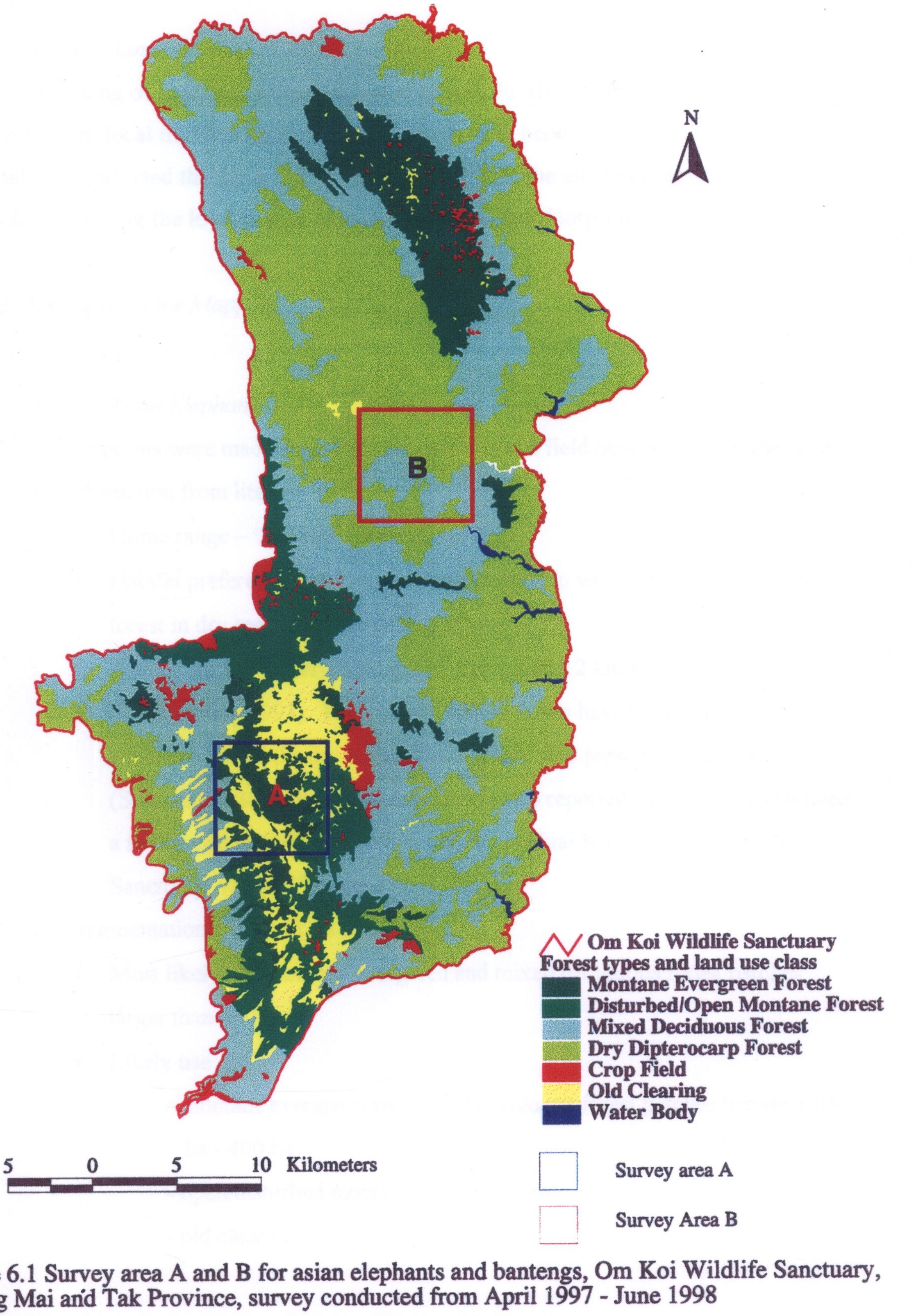

Figure 6.1 Survey area A and B for asian elephants and bantengs, Om Koi Wildlife Sanctuary, Chiang Mai and Tak Province, survey conducted from April 1997 - June 1998

6.2.2.2 Banteng

Tracking of bantengs were conducted only in the Huai Bong area (elevation 500-900 m) where local trackers know locations which have been regularly used by the animals. I conducted the survey at the same period with the elephant survey and used GPS for collecting the locations of physical sightings, and footprints (Figure 6.1)

6.2.3. Assumptions for Mapping

6.2.3.1 Asian Elephant

Assumptions were made from literature reviews and field observations in this study.

i. Information from literature

- Home range – 320 km^2 (Sukumar 1989),
- Habitat preference – Mixed deciduous forest in wet season and montane forest in dry season (Sukmasaung 1993),
- Water sources – Year-round use of areas within 2 km from perennial streams (Sukmasaung 1993). Riverine vegetation zones have the highest elephant concentration in the dry season but elephant also present in wet season (Sukumar 1989). Bhumpakphan (1997) also reported that elephants showed a strong connection to perennial streams in Huai Kha Kheang Wildlife Sanctuary, western Thailand.

ii. Fragmentation effects (This study)

- Most likely use montane evergreen and mixed deciduous forest patches larger than 400 ha
- Likely use
  - montane evergreen and mixed deciduous forest patches between 100 ha - 400 ha
  - open/disturbed montane forest patches
  - old clearings

- Least likely use
  - forest patches < 100 ha
  - crop fields
  - dry dipterocarp forest
  - reservoirs - due to hunting pressure and other human disturbances (Thailand Forest Research Center 1992)

iii. Effects from road development (This study)

- Least likely to use areas within 4 km from paved roads,
- Least likely to use areas within 2 km from gravel roads,

iv. Effects from human settlements (This study)

- Least likely to use areas within 2 km from human settlements,

v. Use wide range of elevation from <500 – 1900m, which almost covers the whole area of the sanctuary. Thus, elevation was not included in the model.

6.2.3.2. Banteng

i. Information from literature

- Home range size 44.8 km^2 in Huai Kha Khaeng Wildlife Sanctuary (Prayurasiddhi 1997),
- Habitat preference – Mixed deciduous and dry dipterocarp forest. Capable of foraging away from water and tolerating more open, dryer areas (Prayurasiddhi 1997),
- Elevation range – Between 200 – 600 m (Prayurasiddhi 1997).

ii. Information from this study

- Habitat preference – Mixed deciduous and dry dipterocarp forests,
- Elevation range – Mostly found between 600 – 900 m,
- Distance from paved road – Found further than 5.5 km from the paved road,
- Distance from villages – Found further than 8 km from the nearest village.

6.2.4. Mapping Steps (also see Figure 6.2)

6.2.4.1. Asian Elephant

i. Buffer and weighed polygon features following the assumptions in section 6.2.3.1. Three values were assigned to each coverage which were

- 1 = Most likely for elephants to use
- 2 = Likely for elephants to use
- 3 = Least likely for elephants to use

ii. Rasterized the coverages to grid layers with 50 m cell size

iii. Combined layers using Arc Grid

iv. Classified the prime habitat (*most likely*) for elephant with most likely value combination, which includes

- Within home range,
- Montane evergreen and mixed deciduous forest with most likely used patch sizes,
- The area > 2 km from villages,
- The area > 4 km from the paved road and > 2 km from the gravel road
- The area < 2 km from the perennial streams

v. Classified the *likely* use value combination which includes the combination of some of the above values plus one of the following values

- Montane evergreen and mixed deciduous patch sizes of likely use,
- Open/disturbed montane forest and old clearings,
- The area > 2 km from perennial streams

vi. Classified the *least likely* use habitat, which includes the combinations of values other than those mentioned earlier. I did not classify the *unlikely* use areas for elephants because elephants use a wide range of habitat, which could cover the whole sanctuary and beyond if there were no effects from humans.

6.2.4.2. Banteng

i. Buffered and weighted the coverage following the assumptions in section 6.2.3.2. Specifically I reclassified or weighed the elevation of the Digital Elevation Model as follows
   - 1 = Most likely use, if 600 m ≥ elevation ≥ 900m,
   - 2 = Likely use, if the elevation < 600 m,
   - 3 = Unlikely use, if the elevation > 900 m.

ii. Rasterized vector coverages to grid layer with 50 m cell size

iii. Combined layers using Arc Grid

iv. Classified the *most likely* use habitat, which includes the combination of
   - Within home range,
   - Mixed deciduous or Dry dipterocarp forests,
   - The area > 5.5 km from the paved road,
   - The area > 8 km from villages,
   - The area 600 m ≥ elevation ≥ 900m.

v. Classified the *likely* use habitat, which includes the combinations of most values above except that the elevation < 600 m

vi. Classified the *least likely* use habitat, which includes some of the above values plus the elevation < 600 m except that the area is out of home range.

vii. Classified the *unlikely* use habitat, which includes the rest of the combinations of
   - Forest types other than mixed and dry dipterocarp forests
   - The area out of home range,
   - The area < 5.5 km from the paved road,
   - The area < 8km from villages,
   - The elevation > 900 m

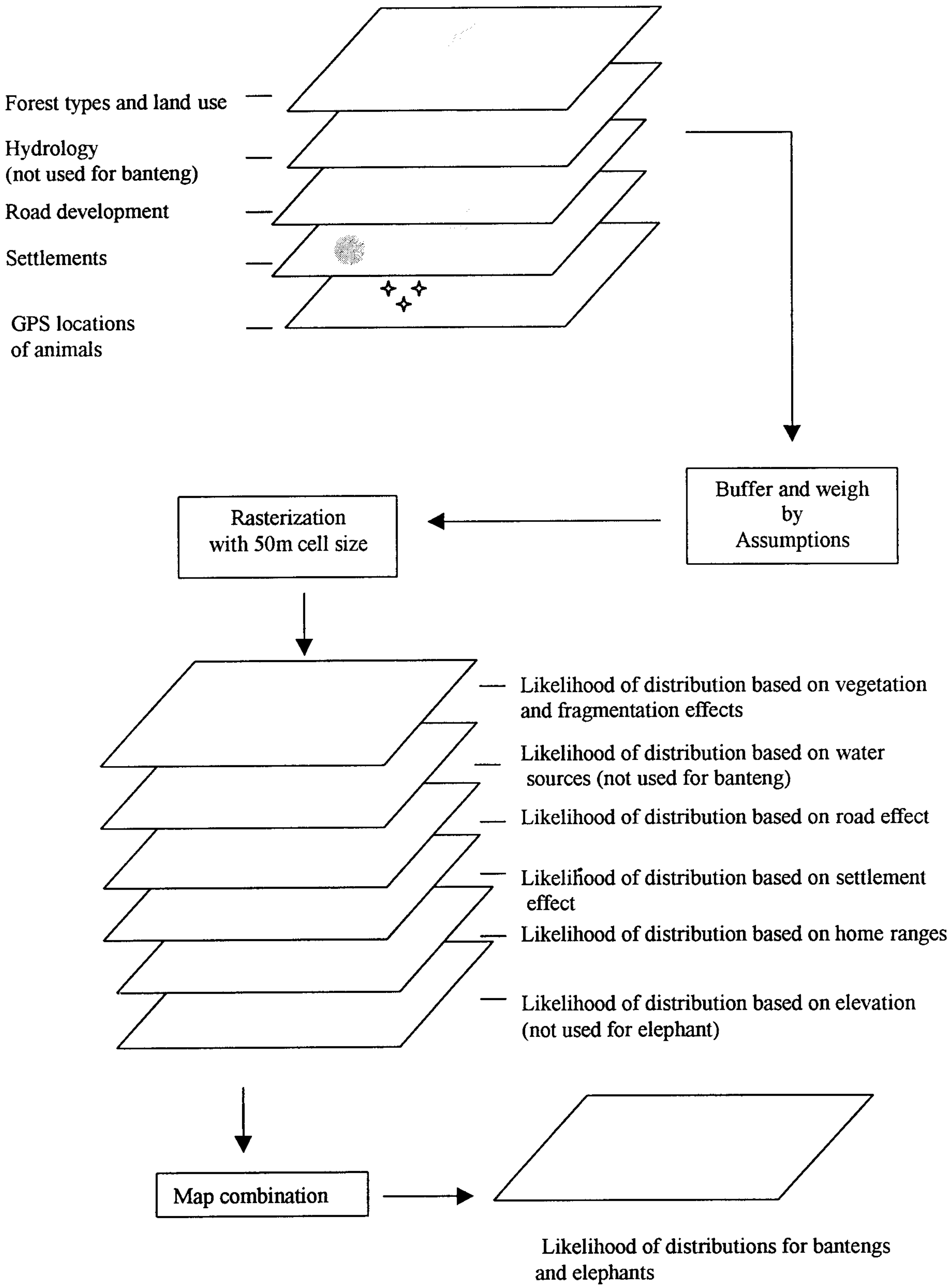

Figure 6.2. Processing steps for spatial distribution models of elephants and bantengs in Om Koi Wildlife Sanctuary, Chiang Mai and Tak Provinces, northern Thailand.

6.3. Results

First, information from the field survey is addressed for elephants and bantengs. This is followed by information derived from the likelihood of distributions built from assumptions for the spatial modeling.

6.3.1. Field Observations

6.3.1.1. Asian Elephant

I collected total of 40 GPS points for elephants from areas A and B (see Figure 6.1). Elephants were found using montane evergreen forest area, open/disturbed evergreen forest, and old clearings (area A.) during the dry and early wet seasons, January to May. Then in the wet and early dry seasons they were found in mixed deciduous and, sometimes, dry dipterocarp forest (area B.) during June to December. Within area B they also used many salt licks distributed in the area. The largest group size spotted was 11 individuals. I found elephants crossed old clearings to reach between evergreen forest patches. Most of the groups contained at least one calf. No males with tusks were seen.

6.3.1.2. Banteng

GPS locations, a total of 17 points, were collected for bantengs in the mixed deciduous and dry dipterocarp forests of area B. GPS points fell between 600 – 900 m elevation. Most of the points were collected from footprints. Mixed deciduous forest and dry dipterocarp forests are the main habitats for bantengs. Throughout the field survey period there were only 2 occasions that the survey teams and I physically spotted bantengs. First a herd of 8 bantengs were sighted on April 7, 1997. Second, the guards spotted 3 bantengs on December 11, 1997. Unfortunately, 2 bantengs were killed by hunters and the carcasses were found on November 7, 1997 with the horns cut off. Bantengs also used salt licks, which in some places they shared with elephants.

6.3.2. Likelihood of Distribution for Elephants

A map of the likelihood of distribution for elephant is shown in Figure 6.3. The area of *"most likely"* value was 164 km^2 in total. It contained the prime vegetation types for elephants including montane evergreen and mixed deciduous forest. This area was supported by a larger area (172 km^2) containing *"likely"* values.

Because some GPS locations were found beyond 2 km from the perennial streams I also combined map layers without the layer of connection with perennial streams. The outcome of this map combination is shown in Figure 6.4. The area of *"most likely"* values was increased to 219 km^2.

6.3.3. Likelihood of Distribution for Bantengs

A map of likelihood of distribution for banteng is shown in Figure 6.5. Habitat of *"most likely"* values encompassed an area of 30 km^2. The *"most likely"* value of habitat was built from the assumptions of home range size, forest type preference, effects from roads, and elevation between 600 – 900 m (see Section 6.2.3.2). The *"likely"* value has almost the same size (29 km^2) as the *"most likely"* value. The *"least likely"* range contained an area of 548 km^2 which contains elevation and vegetation types preferred by bantengs, but the area is out of home range of the current banteng records.

If the assumption of effects from settlements was taken into account, the areas for likelihood of habitat use were reduced in all categories (Figure 6.6). The *"most likely"* use area was reduced to 22 km^2. The great reduction is in the *"least likely"* use area, which was reduced from 548 km^2 to 243 km^2.

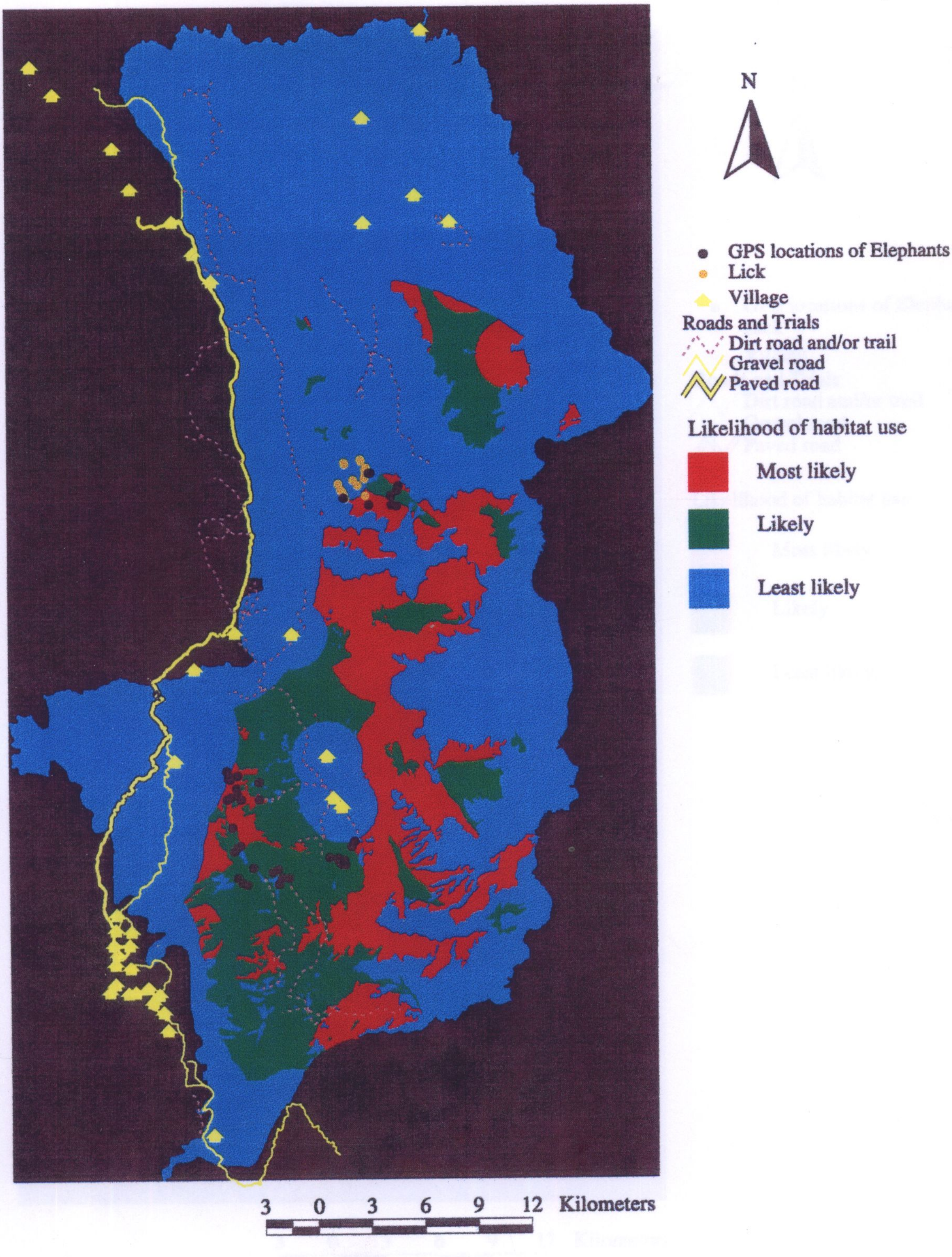

Figure 6.3. Likelihood of habitat use by asian elephants in Om Koi Wildlife Sanctuary (From the survey conducted during 1997-1998)

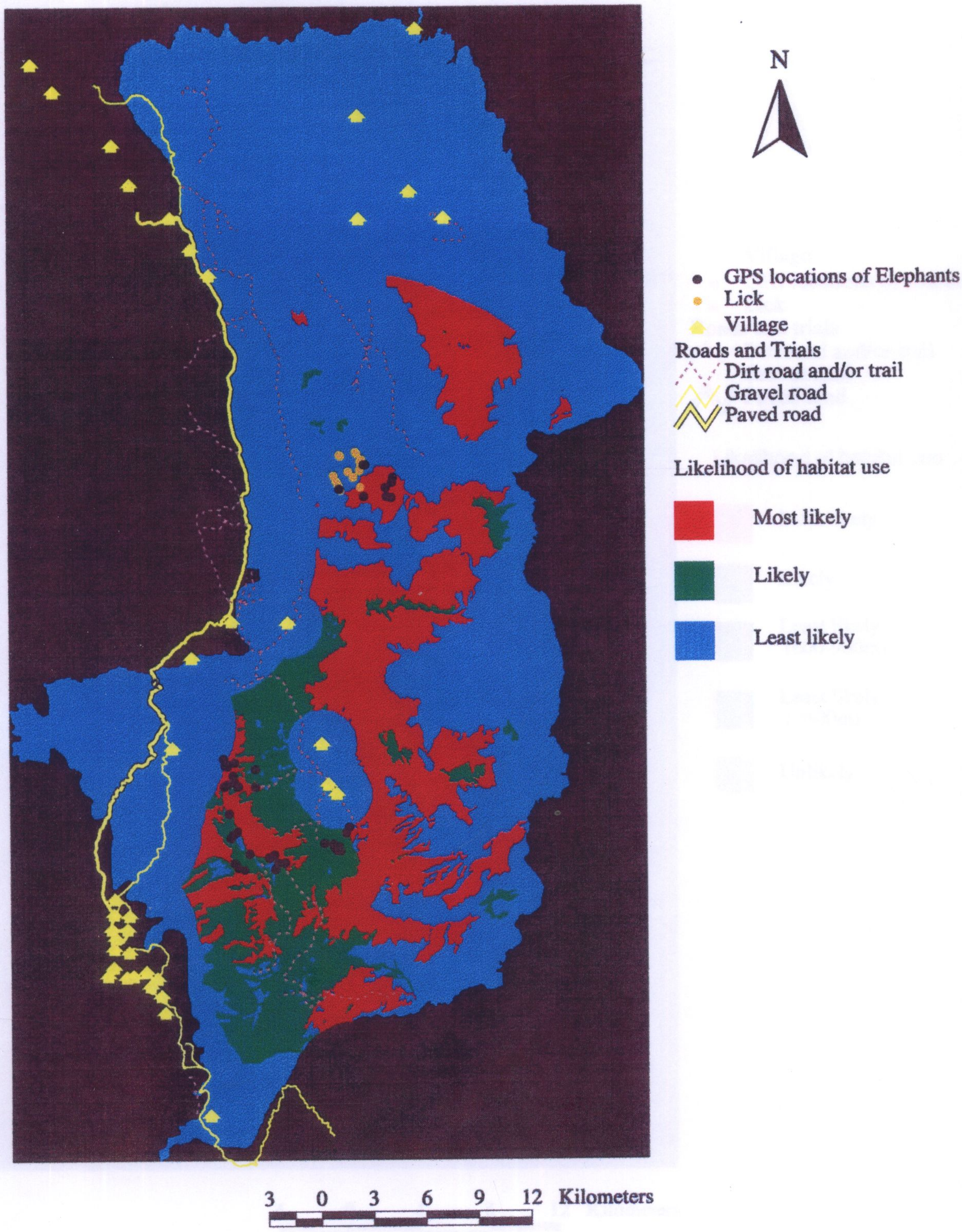

Figure 6.4. Likelihood of habitat use by asian elephants without the assumption of 2 km distance from the perennial streams, Om Koi Wildlife Sanctuary (From the survey conducted between 1997-98)

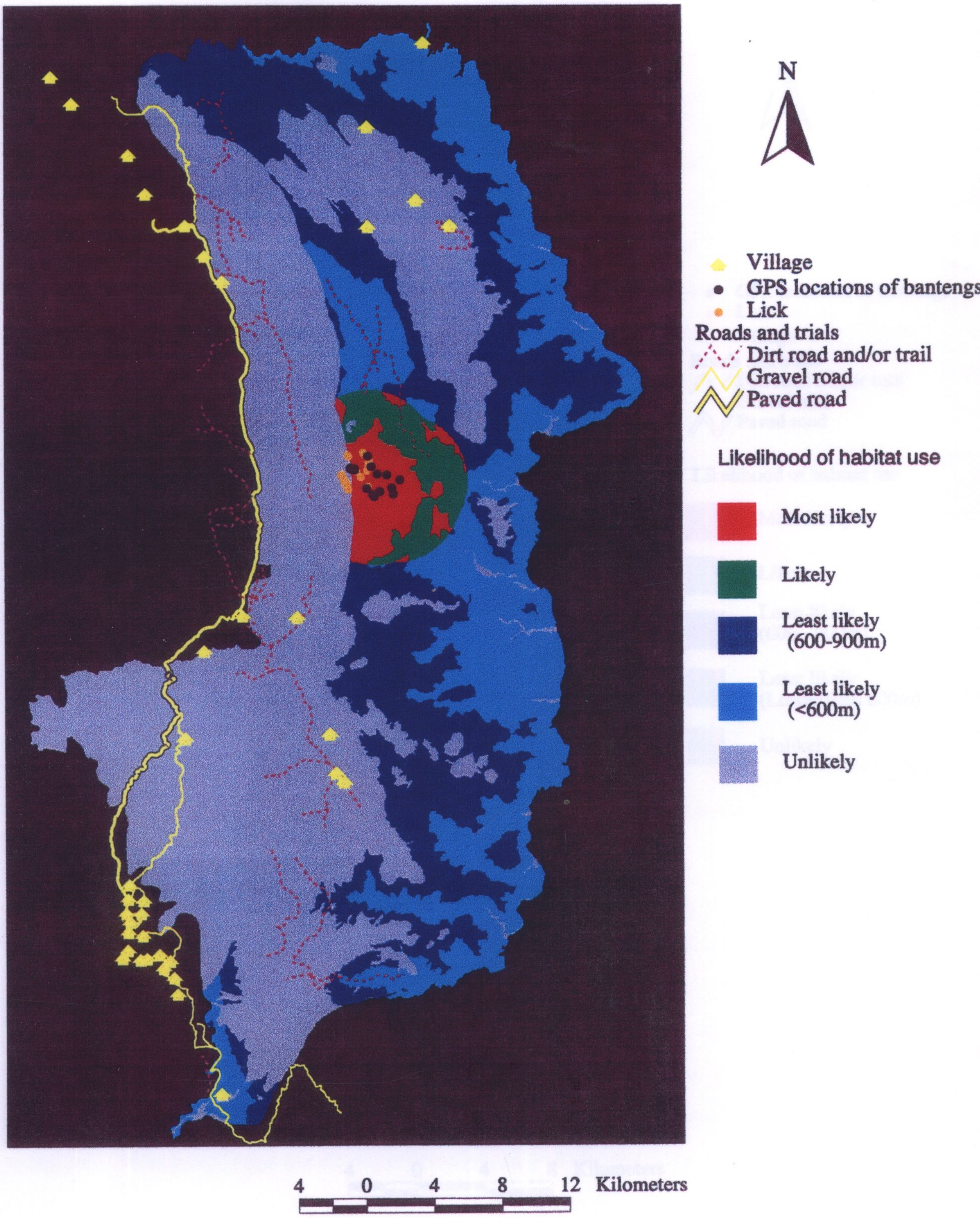

Figure 6.5. Likelihood of habitat use by bantengs without the assumption of the effect from settlements, Om Koi Wildlife Sanctuary (From the survey conducted during 1997-98)

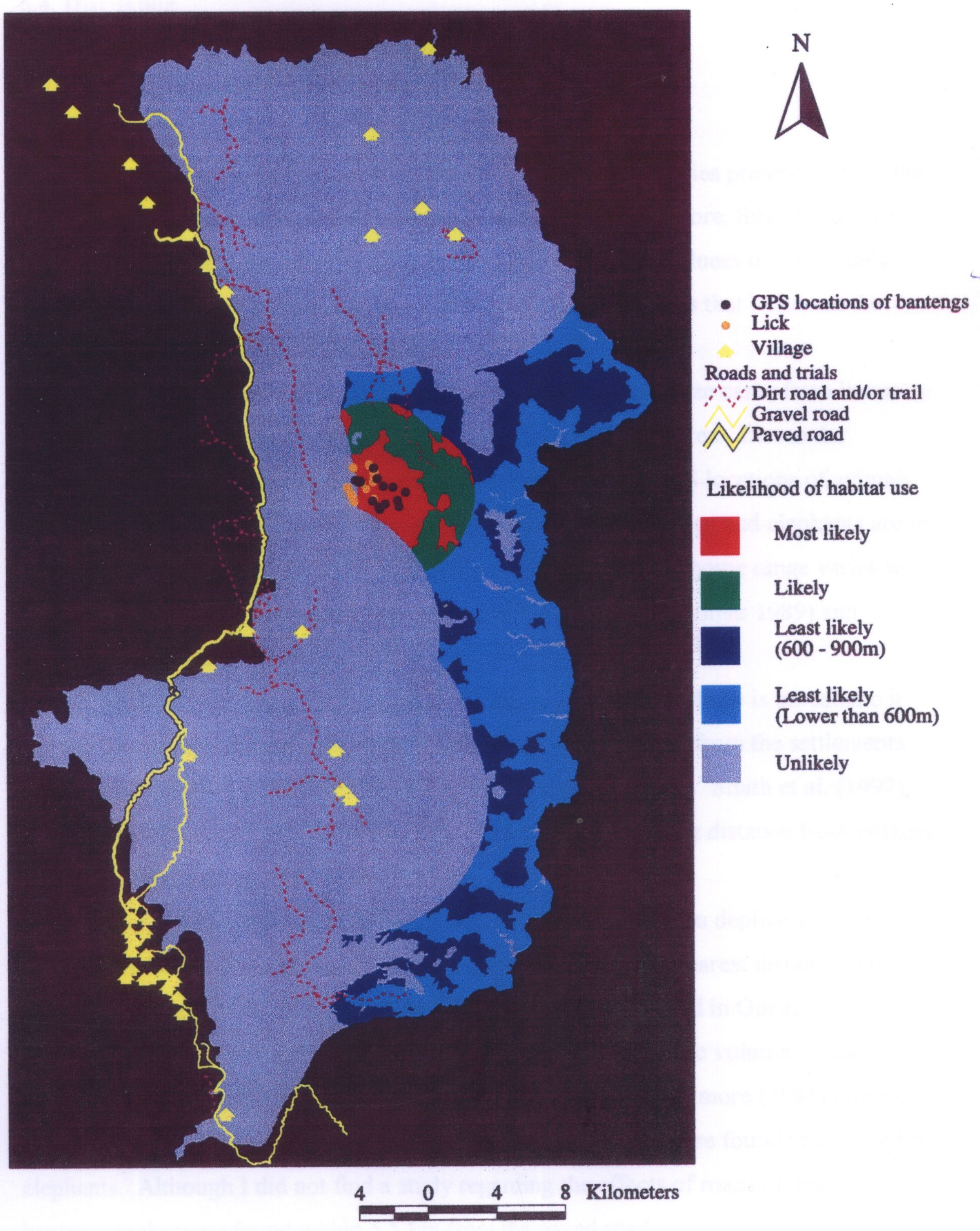

Figure 6.6: Likelihood of habitat use of bantengs with the assumption of the effect from settlements in Om Koi Wildlife Sanctuary (From the survey conducted between 1997- 98)

6.4. Discussion

6.4.1. Map Models

The distribution maps presented in this chapter depict species presence only. The models do not present information on species' abundance. Therefore, further study on species' abundance is another important step to improve the usefulness of the models. Additional map layers concerning important environmental factors that influence the species are required to refine the modeling.

Information used for model assumptions for home range size came from literature which may not reflect the home range size of the animals in this area. Due to the limitations of spatial analysis, I used circular buffers from the GPS locations of animals when building the home ranges. However, home ranges of bantengs and elephants are in fact irregular shapes (Sukumar 1989, Prayulrasiddhi 1997). Also home range varies with season but I used the maximum home range size for elephant (Sukumar 1989) and bantengs (Prayulrasiddhi 1997).

Although buffering distance from villages in a concentric shape is unrealistic it reflects the settlements and related causes that keep wildlife away from the settlements. Distance from villages can be related to degree of hunting activity. Smith et al. (1997), for instance, found that lemur abundance increased with increasing distance from villages in western Madagascar.

As it is with settlements, effects from road development can deplete wild animal ranges. The buffer from the road in this study was based on the nearest distance between the road and the GPS locations of animal sightings. The main road in Om Koi has recently been improved and paved resulting in an increase in traffic volume. This development is a significant disturbance for local wildlife. Michelmore (1994) reported that areas within 7.5 km on each side of roads in central Africa were found to contain few elephants. Although I did not find a study regarding the effects of roads on bantengs, no banteng tracks were found within 5.5 km from the paved road.

6.4.2. Elephant Distribution Models and Applications

The map model permits a picture of the elephant path used for local migration between the dry, area A, and wet, area B, season ranges to be formed (Figures 6.1, 6.3, and 6.4). The path of *most likely* use zone built from this study matches the knowledge of local trackers who have recognized the elephant migration route. In this case, home range and vegetation types are the major factors in modeling elephant habitat (see Figure 6.7). Scott et al. (1993) successfully predicted the distribution of species such as sharp-tailed grouse (*Tympanuchus phasianellus*) based on vegetation types and the knowledge of habitat preference.

A large area of *likely* use, which is composed of open/disturbed montane evergreen forest and old clearings, also supports the tract of *most likely* use area. I witnessed elephants often using this type of habitat around the montane evergreen forest patches (Figure 6.8). Secondary growth forest has good capacity as a food source for elephants (Sukumar 1989) in many areas in India. Therefore old clearings and disturbed/open montane forests play a significant role in maintaining elephant populations in Om Koi Wildlife Sanctuary.

There is a concern among the sanctuary officers about the settlements, which comprise of 2 Mussur and 1 Karen village, in the middle of the elephant ranges (see Figure 6.3). The people still practice slash-and-burn shifting cultivation. Sukumar (1989) confirmed that slash-and-burn shifting cultivation is a major cause in depleting most remaining elephant habitat in India. The Mussur in this area have also started growing commercial cash crops such as cabbages. The expansion of cash crops has proved disastrous to elephant and other large animals (see the results on Chapter 5). Furthermore, study by Sukumar (1989) confirmed that habitat fragmentation has also brought elephant into increased contact and conflict with people in the form of crop raiding. I witnessed that the elephants destroyed the shelters people put up in the crop fields but crop raiding was not confirmed. In order to preserve suitable habitat for elephants, development in terms of road improvement, fragmentation, village and crop field expansion and other activities harmful to elephants within the catchment area of these villages has to be restricted.

Most studies reported the connection of elephant distribution to permanent water sources such as perennial streams (Sukmasaung 1993 and Bhumpakphan 1997). However, I found elephants roamed further than 2 km from the perennial streams especially in the montane evergreen forest areas. Elephants may find other water sources in this type of forest besides perennial streams. After excluding the assumption of 2km from perennial streams the results map better matches with the GPS locations of elephant collected from the montane evergreen forest areas (see Figure 6.4).

6.4.3 Banteng Distribution Models and Applications

The map model for banteng indicates the confined distribution of probably the very last banteng population in the area. Protection must be carefully planned within this area in order to preserve banteng populations. The models also reflect the suitable habitats, the area of *least likely* use, for bantengs if there were no effects from settlements (Figure 6.5). I defined this area as *least likely* only because it was beyond the home range of the existing banteng population. However it is still composed of mixed deciduous and dry dipterocarp forests and elevation from < 900 m which is normally the preferred habitat for banteng (Prayulrasiddhi 1997, this study).

However when I included the effect of settlements in terms of the distance from the villages into the model, it totally masked out the elevation between 600 –900 m which mainly contained mixed deciduous forest considered as a prime habitat for banteng in this sanctuary (Figure 6.6). Intrusion of domestic cattle is widespread in the area. The intensity of domestic cattle intrusion, besides hunting, can be related to the distance from settlements with populations of domestic cattle probably more intense near the villages. I also observed that most bantengs and tracks were encountered in the area where the population of domestic cattle was comparatively light.

Most GPS locations for bantengs were found within 600 m – 900 m in elevation. This elevation range is different from result of Prayulrasiddhi (1997), who studied bantengs in Huai Kha Khaeng Wildlife Sanctuary and found that banteng mostly used the area lower than 600 m. Topography is likely to be a key factor for the difference. Mixed deciduous forest in Om Koi Wildlife Sanctuary mainly occurs between 600 - 900 m, which is higher than in Huai Kha Khaeng Wildlife Sanctuary.

In conclusion, distribution models help wildlife sanctuary managers to be able to produce more effective protection and conservation plans and actions. People settling in the middle of their path have continually altered the remaining prime habitat for elephants. The activities of these people directly affect the elephants and their future. Bantengs are more endangered in this area. The small population is under threat from human activities such as hunting (Figure 6.9) and cattle raising which could easily cause extirpation. To prevent the extirpation of banteng from the sanctuary management must be carefully planned and effective. More information on animal abundance and other factors affecting distribution should be gathered to upgrade the usefulness of the models. Although GIS technology can provide updated map models to cope with ever changing environmental and human influences to animals, it is always important to remember that maps are only as good as the data and interpretation used to produce them (Miller and Allen 1994).

Figure 6.7. Elephants use montane evergreen forest patch # 6 in Om Koi Wildlife Sanctuary (Photograph taken on January 19,1998).

Figure 6.8. Elephants use an old clearing near montane evergreen forest patch # 7 in Om Koi Wildlife Sanctuary (Photograph taken on March 20,1998).

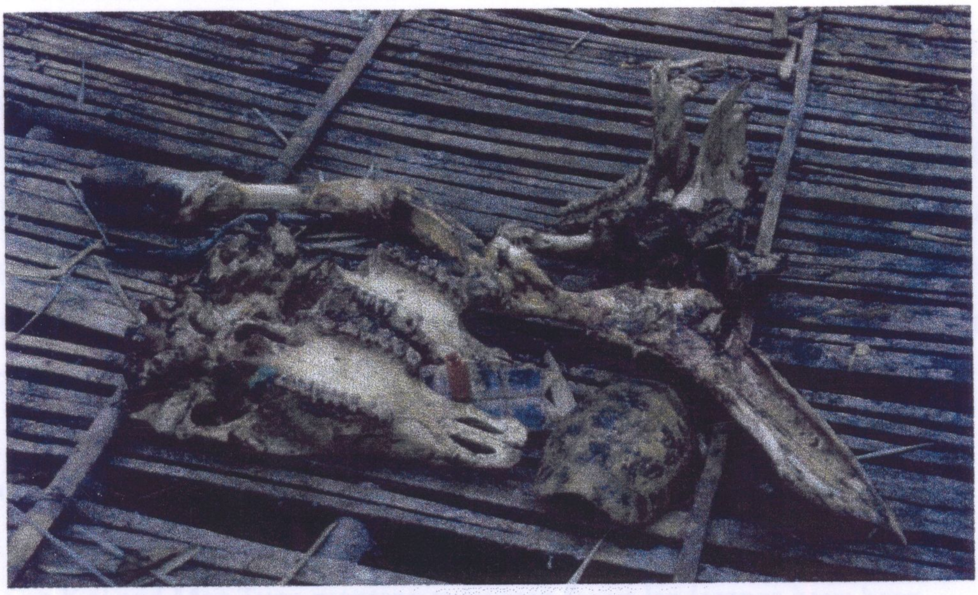

Figure 6.9. Two banteng were killed and the horns cut off in the Huai Bong area, Om Koi Wildlife Sanctuary (Photograph taken on November 8,1997).

CHAPTER 7
CONCLUSIONS

Three different intentions characterized this project. First, the project intended to understand wildlife responses to habitat fragmentation of the two montane evergreen forest landscapes that were different in their pattern of fragmentation and degree of human disturbance. Second, it intended to introduce methodologies to study fragmentation patterns widely used in North America to resource managers in Thailand. Third, it intended to develop a GIS based methodology to build distribution map models for key animals in the area. The goal was to provide information specifically to officers in Om Koi and Mae Tuen Wildlife Sanctuaries and more generally to resource managers in charge of protected areas in Thailand facing similar situations of habitat fragmentation and severe human disturbances. The conclusions of the study will be discussed in this chapter followed by a final chapter that offers some recommendations.

7.1 Fragmentation Patterns and Changes

Om Koi and Mae Tuen montane evergreen forest landscapes have been fragmented for more than 50 years. Within this time span, the amount of montane forest loss in Mae Tuen has been dramatically high with > 2,500 ha of forest loss compared to Om Koi landscape with some 800 ha. The severe fragmentation in Mae Tuen has resulted in a landscape with mainly small isolated forest patches (< 100 ha) with small or a total lack of core areas. The Om Koi landscape, on the other hand, has maintained some large patches (> 400 ha) with connectivity among patches. The Mae Tuen landscape has experienced chronic human disturbance in terms of cash crop cultivation, road development, and settlements. The remoteness of the Om Koi landscape and more effective protection have resulted in currently less human disturbance. Om Koi montane evergreen forest patches are surrounded largely by open and disturbed montane forest, and old clearing areas. The settlements in Om Koi are located away (> 5 km) from the remaining tracts of montane evergreen forests.

7.2 Wildlife Responses to Habitat Fragmentation

7.2.1 Bird Responses

There is a strong suggestion of significantly greater ($P = 0.06$) bird diversity in terms of species number in Om Koi forest patches. The failure to detect larger differences is likely to be a result of the small sample size (n = 4) and mixture of patch size in Om Koi. After excluding the species from the smallest patch in Om Koi a significant difference in bird diversity was detected ($P = 0.011$). There was also a trace of a positive relationship between patch size and bird diversity. Bird diversity was not significantly different between patch edge with crop fields and patch edge with old clearings. Forest birds were more diverse ($P = 0.013$) in edge than interior zones.

Bird densities were not significantly different between Om Koi and Mae Tuen forest patches but bird density tended to be higher in Mae Tuen patches ($\bar{X} = 8.8$ birds/ha) than Om Koi ($\bar{X} = 6.91$ birds/ha). The small forest remnants in a hostile environment such as cabbage fields may function as a refuge for forest birds in Mae Tuen.

Large frugivorous birds such as brown hornbills (*Ptilolaemus tickelli*) and great hornbills (*Buceros bicornis*) still existed in low abundance in Om Koi forest patches but none were found in Mae Tuen patches. The lack of large frugivores in Mae Tuen patches is likely a result of severe fragmentation and hunting. Om Koi forest patches also hosted the remaining population of rufous-throated partridge (*Arborophila rufogularis*) which are regionally much reduced due mainly to hunting. Ground insectivorous birds were virtually not sighted in small forest patches with small or no core areas in Mae Tuen. Ground insectivores such as slaty-bellied tesia (*Tesia olivea*), pygmy wren-babbler (*Pnoepyga pusilla*) were found mainly in interior zone of patches in Om Koi. Small cavity nesters such as golden-throated barbets (*Megalaima franklinii*), great barbet (*M. virens*) are among the birds least affected by fragmentation of this scale.

7.2.2 Mammal Responses

Although statistical testing was not appropriate due to small sample size, mammal diversity in Om Koi forest patches was distinctively higher than Mae Tuen patches. Fragmentation with remaining large remnant patches with connectivity and less human disturbances such as hunting are the key factors for the higher mammal diversity in Om Koi. The trend of positive relationship between patch size and mammal diversity is quite strong. Large herbivores such as elephants (*Elephas maximus*), sambars (*Cervus unicolor*), serow (*Capricornis sumatraensis*) were found mainly in large patches (> 400 ha). Large patches also supported 3 primate species including white-handed gibbons (*Hylobates lar*), Phayre's langur (*Presbytis phayrei*), and Assamese macaque(*Macaca assamensis*). Carnivores such as tiger (*Panthera tigris*), and leopard (*Panthera pardus*) used only large patches in rare abundance. Mae Tuen forest patches with small size and intense human disturbances were devoid of large mammals and virtually lacking in primates – except the rare existence of white-handed gibbons. Barking deer (*Muntiacus muntjak*) and wild pigs (*Sus scrofa*) were tolerant of the current degree of fragmentation and thrived in both sites. The evidence of many mammal species confined to the remaining forest patches with increasing disturbances in terms of domestic cattle raising and hunting cause pessimism regarding the long-term survival of the animals in Om Koi forest patches.

7.3. Mapping Wildlife Distribution with GIS

The distribution models of elephants and bantengs (*Bos javanicus*) allow the wildlife sanctuary managers to set an effective plan and actions to conserve the animals. With the information on animal sightings, home range size, habitat preference, connection to the water sources, elevation range, and effects from settlements and roads, the distribution maps can be effectively built with GIS methodology. By classifying the distribution models into classes including *most likely*, *likely*, *least likely*, and *unlikely* the managers can prioritize the areas to focus conservation efforts amid the limitations of personnel and budget. Elephants in Om Koi are wide ranging and seasonally migrate between dry and wet season ranges. The map model allows the full picture of their path. It also indicates the problems from human settlements that need careful management to maintain the suitable habitat for elephants. Bantengs on the other hand are confined to a small area of mixed deciduous and dry dipterocarp forests and need a very active protection scheme to conserve them amid serious hunting pressure. Bantengs have such a small population that they can easily be eliminated from the area.

CHAPTER 8
RECOMMENDATIONS

Recommendations based on the findings from the project are addressed in 2 aspects – management and research. Management recommendation are divided into sections including specific recommendations for wildlife sanctuary officers in Om Koi and Mae Tuen Wildlife Sanctuaries, and broad recommendations for all protected areas facing similar problems.

8.1.Management Recommendations

8.1.1. Om Koi Wildlife Sanctuary

8.1.1.1. Fragmentation Problems

- Large montane evergreen forest patches (> 400 ha) in Doi Mon Chong area are the last stronghold for many evergreen forest dwelling animals. The area supports > 119 species of birds and > 19 species of mammals and many reptiles and amphibians. Many of them are endangered species such as elephant (*Elephas maximus*), tiger (*Panthera tigris*), goral (*Nemorhaedus goral*), serow (*Capricornis sumatraensis*), rufous-throated partridge, impressed tortoise (*Manouria impressa*), and Himalayan newt (*Tylototriton verrucosus*). The sanctuary should focus their investment in personnel and budget to protect this area as the first priority.
- Connectivity between patches has to be maintained. Animals, particularly primates, move between patches through the narrow forest corridors (< 300 m) connecting patches. Primates can be easily affected by isolation. The main threat to these corridors is anthropogenic fires. Due to the fact that most montane evergreen forest trees are intolerant to fire, fire can gradually eliminate the narrow and small forest corridors and cause more isolation effects to animals. Fire suppression crews should be specifically arranged to guard the area in dry season. Building permanent fire belts is not recommended because it disturbs the area and can do little in preventing fires. Although the sanctuary and fire protection units have conducted extensive fire

protection campaigns and education programs, they should focus more on villages located around montane evergreen forest remnants.

- Small (< 30 ha) montane remnant patches still support a high diversity of birds (>50 species) including such endangered species as the rufous-throated partridge (*Arborophila rufogularis*). Small forest patches should not be considered as low value and, thus, intensive protection plans and actions should include these small patches.
- The seasonal migration path of elephants between high elevation montane evergreen forest and low elevation mixed deciduous forests, although still a continuous forest track, is narrow with ongoing encroachment. Mussur and Karen villages are located in the middle of the elephant range (see Figure 6.3). Following the sanctuary plan these villages have to be relocated out of the elephant path. However if the relocation plan fails, the sanctuary should restrict further developments such as roads, immigration, and further land expansion for cash crops. Engaging in public relation with the villagers is also important for the long-term maintenance of the forest tracts around their area.
- Old clearing areas have been used by herbivores such as elephants, and sambars. The sanctuary has successfully prohibited local people from returning to cultivate many areas for decades. Many species of wild herbivores have benefited from this regulation. This regulation should be strictly maintained.

8.1.1.2. Domestic Cattle Problem

- From the sighting records, the number of Banteng (*Bos javanicus*) in mixed deciduous and dry dipterocarp forests in the Huai Bong area is very small. Their *most likely* habitat is confined to a small area (< 30 km^2) (Figure 6.5). They are in urgent need of a mission to rescue them from extirpation from the area. Hunting and domestic cattle invasion are among the most serious threats to bantengs. After 8 of them were spotted in April 1997, I found 2 carcasses of bantengs killed with the horns cut off. Bovine diseases from domestic cattle such as anthrax, rinderpest, foot-and-mouth can be transmitted to bantengs and easily eradicate this small population.

- In the montane evergreen forest area, the number of domestic cattle intruding in the area is increasing the threats to wild animals in terms of competing for food and carrying bovine diseases. The former administration of the sanctuary successfully prohibited the cattle in this area. Unfortunately, after a decade of weak control, the cattle have been roaming all over the area. 1998 was the first year to witness cattle grazing up to the peak and browsing deep into the forest patches. The sanctuary manager should work intensively with local people and the district administration to reduce or prohibit cattle in this prime habitat for wildlife.

8.1.2. Mae Tuen Wildlife Sanctuary

- Although devoid of large mammals, primates, and large frugivorous birds, small and medium size (30 – 90 ha) forest patches in Mae Tuen still support high diversity and density of forest birds. Most species are high elevation evergreen forest dwellers such as pin-tailed pigeon (*Treron apicauda*), barred cuckoo-dove (*Macropygia unchall*), and the green-tailed sunbird (*Aethopyga nipalensis*). These patches should be maintained by not allowing further expansion of agricultural fields. However, it would be difficult to use only a protection policy alone to work against the tide of cash cropping and further developments in these Hmong occupied areas. Communication with Hmong people who have been receiving monetary benefits from forest clearing and cash crops to cease hunting and encroachment has proved very difficult, and mainly a failure, for the sanctuary officers. Most sanctuary guards feel despair about protecting the remaining montane evergreen forest in this area. Other alternatives must be considered to protect the area and improve the morale of the guards. Because the area is accessible by a paved road and only 70 km away from Tak Province, promoting the area for ecotourism aiming at bird watchers might help turn the tide from destruction to conservation. Furthermore, collaboration with local and regional educational institutes to create conservation-based educational programs is an alternative to better educate Hmong people to utilize the natural resources with care.

- Forest corridors among small forest patches in Mae Tuen are important to maintain linkage among the patches. Black giant squirrel (*Ratufa bicolor*), and barking deer (*Muntiacus muntjak*) are among the remaining mammal species found using the corridors. Fragmented forests with connectivity can help reduce hunting pressure by allowing animals to move away from patches with intense hunting.
- The high utilization of pesticides in Hmong cabbages fields may be harmful to forest bird populations that live in the forest patches next to the agricultural fields, although this has not yet been proved. Pesticides diffusing over into the forest patches could severely affect forest insects and birds. Impact assessments and strategies to reduce the intensity of pesticides are needed. To ask people to reduce pesticide application might be unrealistic because cabbage fields need a lot of insecticides as a cost-effective way of cultivation. Convincing local people to set up a project to plant some native plants such as wild banana along the forest edges might help filter the diffusion of chemicals. Wild bananas grow in dense stands along many forest edges in montane evergreen forest patches in Mae Tuen. They can also function as a fire break in the dry season. The first group of people to be recruited into this type of project might be students from public schools surrounding the sanctuary. This can be done together with more education on conservation and reduction of pesticides.

8.1.3. Overall Protected Areas

- Large forest patches (> 400 ha) with connectivity to larger tracts of forest must be maintained in fragmented montane evergreen forest landscape to allow large mammals and primates to use,
- Small (< 30 ha) montane evergreen forest patches should be recognized as a likely habitat to support a high density of evergreen forest birds and they can function as habitat sinks in metapopulation models and stepping stones for species distribution.
- Corridors linking forest patches should be preserved to help animals with limited dispersal ability to disperse and avoid hunting pressure.
- Preserving core areas (area > 100 m from the forest edge) in fragmented landscapes is necessary to manage for species that need core areas,

- Fragmentation could lead to more intense hunting activity due to accessibility to the area. Preventing fragmentation may also help limit hunting pressure,
- Road development and cash crop promotion in areas already facing harsh encroachment are likely to boost habitat fragmentation and, as a result, extinction to many species especially large mammals and primates. Therefore, managers should try to prevent these developments in their areas of responsibility. However, if it is unavoidable, special restrictions must be issued for such developments in protected areas.
- Knowledge of wildlife responses to fragmentation should be embedded in the campaigns for public relations.

8.2 Research Recommendations

- Research on wildlife responses to habitat fragmentation should be ranked among the most urgent issues in wildlife conservation research in Thailand because most protected areas are faced with fragmentation problems.
- Long term study on species response to fragmentation is needed to confirm the pattern of species loss and reestablishment.
- Study of microclimate change and change in plant communities in fragmented forests will help predict the long-term effects on animals.
- Study of impacts of fragmentation on amphibians and reptiles needs attention,
- Use of remote sensing and GIS is a necessary tool to keep track of fragmentation patterns and changes. More refined methodology should be developed to study fragmentation in areas where encroachment is ongoing.
- Mapping species distributions can help resource managers have concrete evidence to manage and protect wildlife in the area. Methodologies must be further explored. Classification of habitat requirements should be improved by field knowledge.
- Study of population level such as density and abundance can complement mapping efforts.

- Research on effects of other human influences such as cattle raising, hunting, burning, using pesticides that are related to habitat fragmentation are important to guide management of the protected areas.
- Use of sanctuary officers and guards to be better integrated in research effort and more investigation of the efficient use of sanctuary guards in monitoring of bird and mammal indicators should be taken into account.

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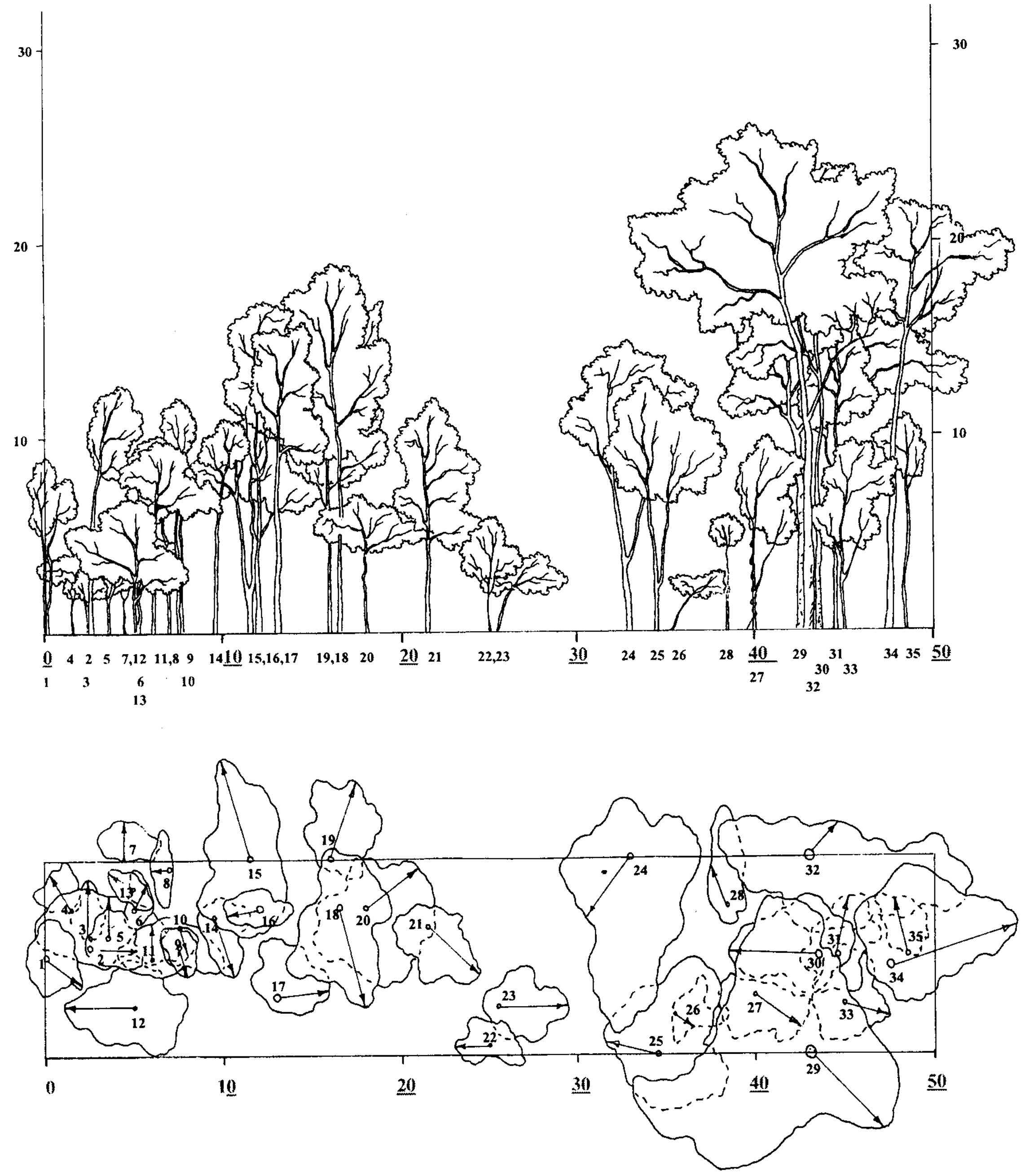
APPENDIX A.

TREE PROFILES AND SPECIES LISTS

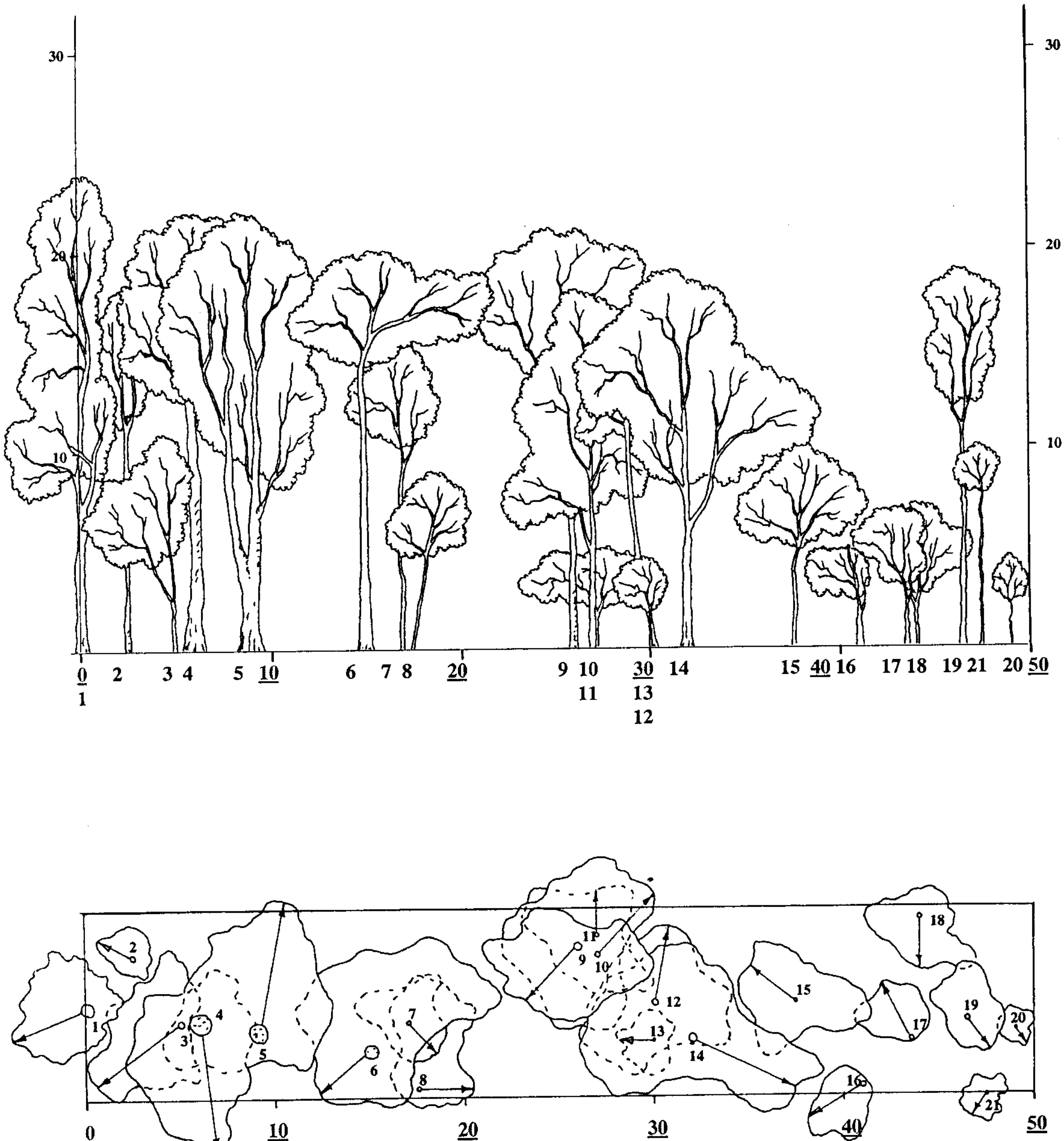


Tree Profile 1 - Edge zone of montane evergreen forest patch # 5 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 1 for Tree Profile 1

Tree No.	Thai name	Scientific Name	Family
Plot T5 in Patch # P5 – Edge zone			
1.	เฉียงพร้านางแอ	*Carallia bravhiata*	Rhizophoraceae
2.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
3.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
4.	กำยาน	*Styrax benzoides*	Styracaceae
5.	Unknown 5	Unknown	Unknown
6.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
7.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
8.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
9.	จำปีหลวง	*Michelia rajaniana*	Magnoliaceae
10	สุราแทพ	*Litsea martabanica*	Lauraceae
11.	กำยาน	*Styrax benzoides*	Styracaceae
12.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
13.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
14.	ตองแตบ	*Macaranga denticulata*	Euphorbiaceae
15.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
16.	โพบาย	*Sapium baccatum*	Euphorbiaceae
17.	มณฑาป่า	*Manglietia garrettii*	Magnoliaceae
18.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
19.	ก่อพ่วง	*Lithocarpus fenestratus*	Fagaceae
20.	เฉียงพร้านางแอ	*Carallia bravhiata*	Rhizophoraceae
21.	มะยาง	*Sarcosperma arboreum*	Sapotaceae
22.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
23.	Mollutus 1	*Mallotus* sp.	Euphorbiaceae
24.	Euphorbiaceae	Unknown	Euphorbiaceae
25.	Mollutus 1	*Mallotus* sp.	Euphorbiaceae
26.	Dehaasia	*Dehaasia* spp.	Lauraceae
27.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
28.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
29.	Unknown 1	Unknown	Unknown
30.	Dehaasia	*Dehaasia* spp.	Lauraceae
31.	Rubiaceae	Unknown	Rubiaceae

Tree No.	Thai name	Scientific Name	Family
32.	มณฑาป่า	*Manglieta garrettii*	Magnoliaceae
33.	ตาเสือ	*Aphanamixis polystachya*	Meliaceae
34.	Dehaasia	*Dehaasia* spp.	Lauraceae
35.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae

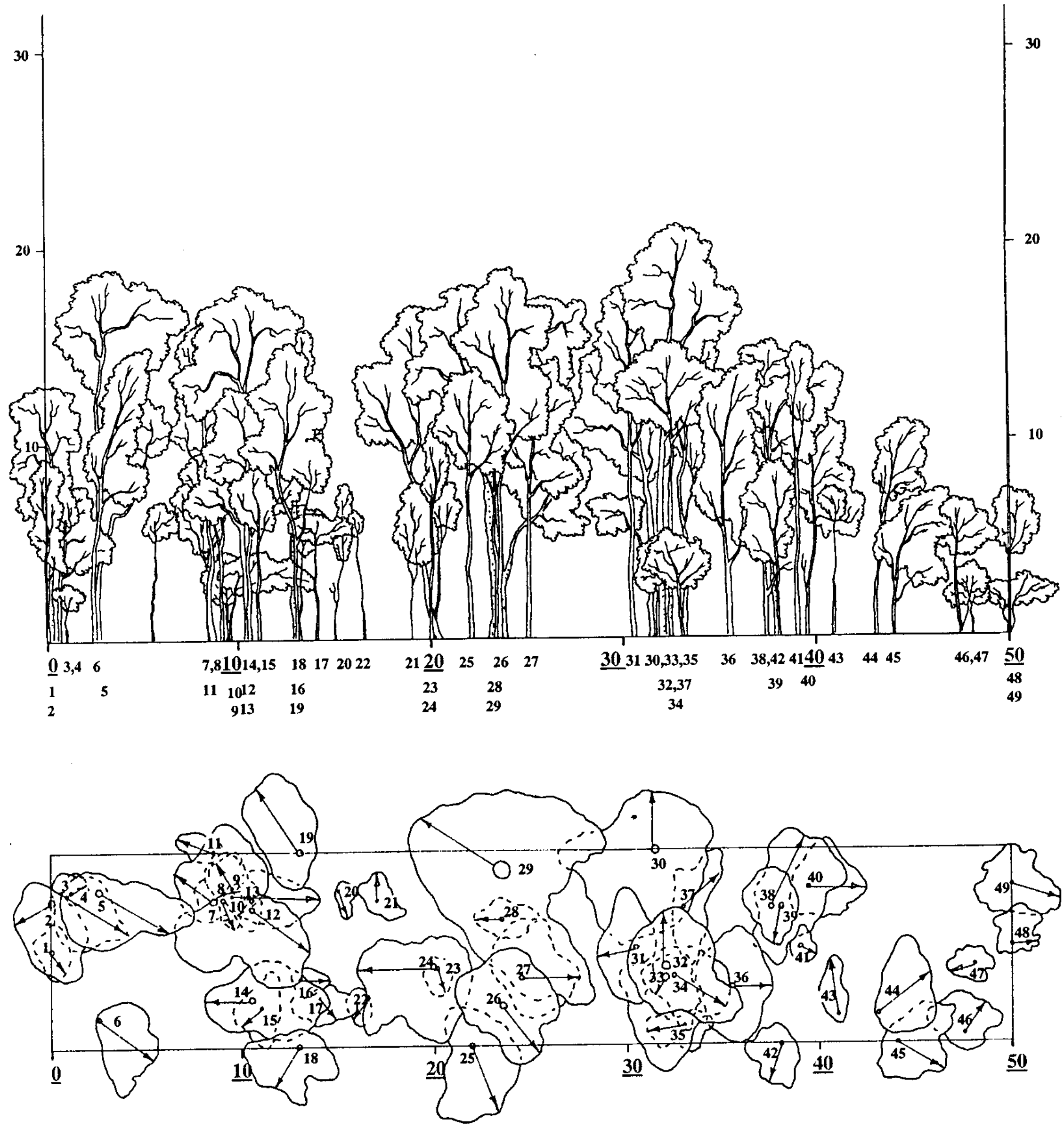


Tree Profile 2 - Interior zone of montane evergreen forest patch # 5 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 2 for Tree Profile 2

Plot TC in Patch # P5 – Interior Zone

Tree No.	Thai name	Scientific Name	Family
1.	Litsea sp.	*Litsia* sp.	Lauraceae
2.	Unknown 6	Unknown	Unknown
3.	หว้าแขา	*Cleistocalyx operculatus*	Myrtaceae
4.	มณฑาป่า	*Manglietia garrettii*	Magnoliaceae
5.	มณฑาป่า	*Manglietia garrettii*	Magnoliaceae
6.	ตองแตบ	*Macaranga denticulata*	Euphorbiaceae
7.	Unknown 7	Unknown	Unknown
8.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
9.	Dehaasia	*Dehaasia* spp.	Lauraceae
10.	หว้าแขา	*Cleistocalyx operculatus*	Myrtaceae
11.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
12.	Elaeocarpus	*Elaeocarpus* spp.	Elaeocarpaceae
13.	Mollutus 1	*Mallotus* sp.	Euphorbiaceae
14.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
15.	ตาเสือ	*Aphanamixis polystachya*	Meliaceae
16.	Mollotus 1	*Mollotus* sp.	Euphorbiaceae
17.	Mollotus 1	*Mollotus* sp.	Euphorbiaceae
18.	Mollotus 1	*Mollotus* sp.	Euphorbiaceae
19.	Walsura sp.	*Walsura sp.*	Meliaceae
20.	หว้าแขา	*Cleistocalyx operculatus*	Myrtaceae
21.	Walsura sp.	*Walsura* sp.	Meliaceae



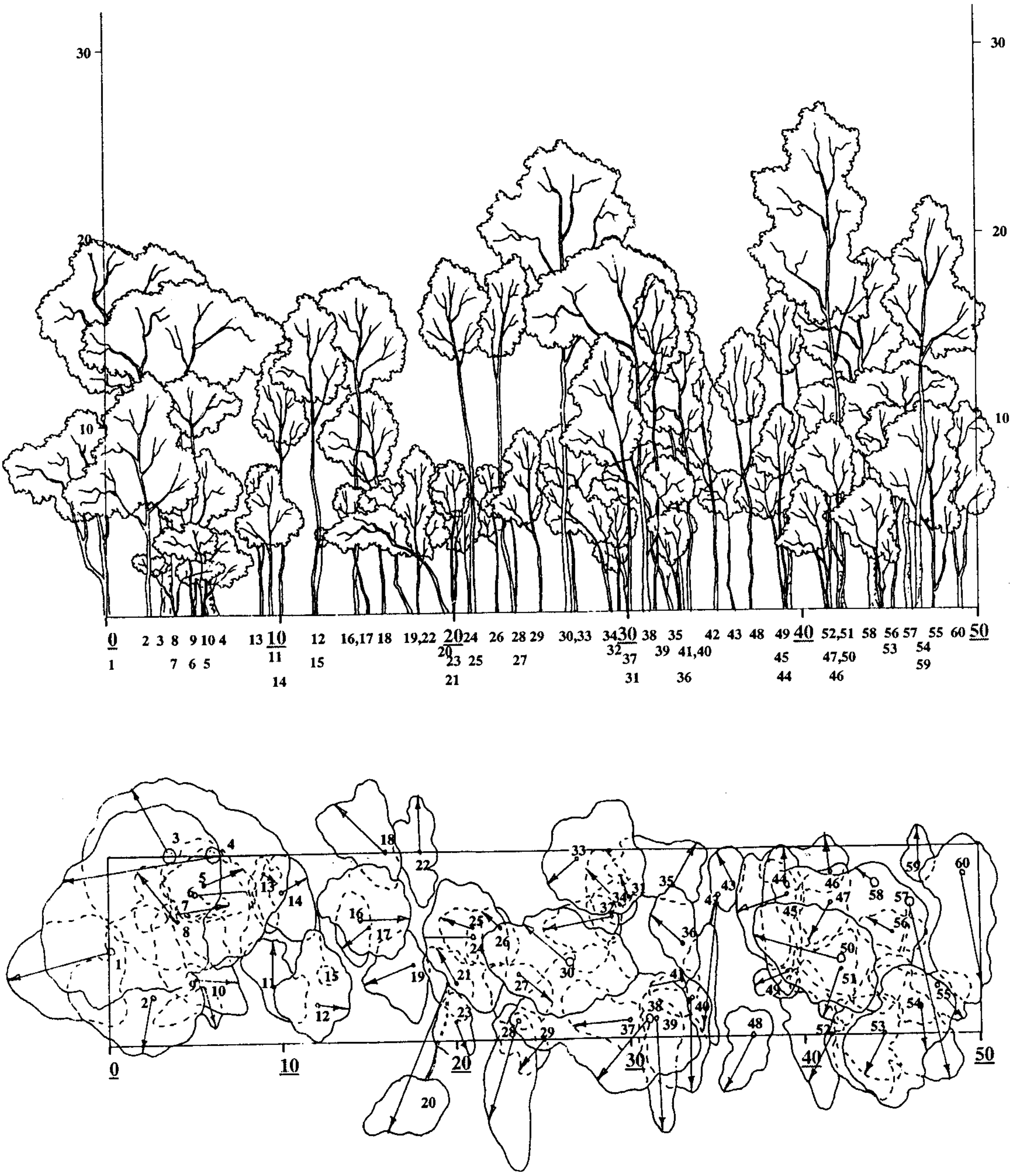
Tree Profile 3 - Edge zone of montane evergreen forest patch # 6 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 3 for Tree Profile 3

Plot T3 in Patch # P6 – Edge Zone

Tree No.	Thai name	Scientific Name	Family
1.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
2.	กระโดงแดง	*Bhesa robusta*	Celastraceae
3.	แมงเม่านก	*Eurya nitida*	Theaceae
4.	แมงเม่านก	*Eurya nitida*	Theaceae
5.	โพธิ์สามหาง	*Symingtonia populnea*	Hammamelidaceae
6.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
7.	Lauraceae 4	Unknown	Lauraceae
8.	พะอง	*Callophylum polyanthum*	Guttiferae
9.	พญาไม้	*Podocarpus nerriifolius*	Podocarpaceae
10.	ทะโล้	*Schima wallichii*	Theaceae
11.	แมงเม่านก	*Eurya nitida*	Theaceae
12.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
13.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
14.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
15.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
16.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
17.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
18.	ก่อหยุม	*Castanopsis argyrophylla*	Fagaceae
19.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
20.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
21.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
22.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
23.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
24.	Unknown 4	Unknown	Unknown
25.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
26.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
27.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
28.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
29.	มณฑาป่า	*Manglietia garrettii*	Magnoliaceae
30.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
31.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae

Tree No.	Thai name	Scientific Name	Family
32.	โพธิ์สามหาง	*Symingtonia populnea*	Hammamelidaceae
33.	โพธิ์สามหาง	*Symingtonia populnea*	Hammamelidaceae
34.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
35.	ม่วงก้อม	*Turpinia cochinchinensis*	Staphyleaceae
36.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
37.	หว้าใบใหญ่	*Syzygium* spp.	Myrtaceae
38.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
39.	Unknown 4	Unknown	Unknown
40.	โพธิ์สามหาง	*Symingtonia populnea*	Hammamelidaceae
41.	Ardiasia sp.	*Ardisia* sp.	Myrsinaceae
42.	Unknown 4	Unknown	Unknown
43.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
44.	ก่อแหลม	*Castanopsis ferox*	Fagaceae
45.	แมงเม่านก	*Eurya nitida*	Theaceae
46.	สุราเทพ	*Litsea martabanica*	Lauraceae
47.	ม่วงก้อม	*Turpinia cochinchinensis*	Staphyleaceae
48.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
49.	ม่วงก้อม	*Turpinia cochinchinensis*	Staphyleaceae



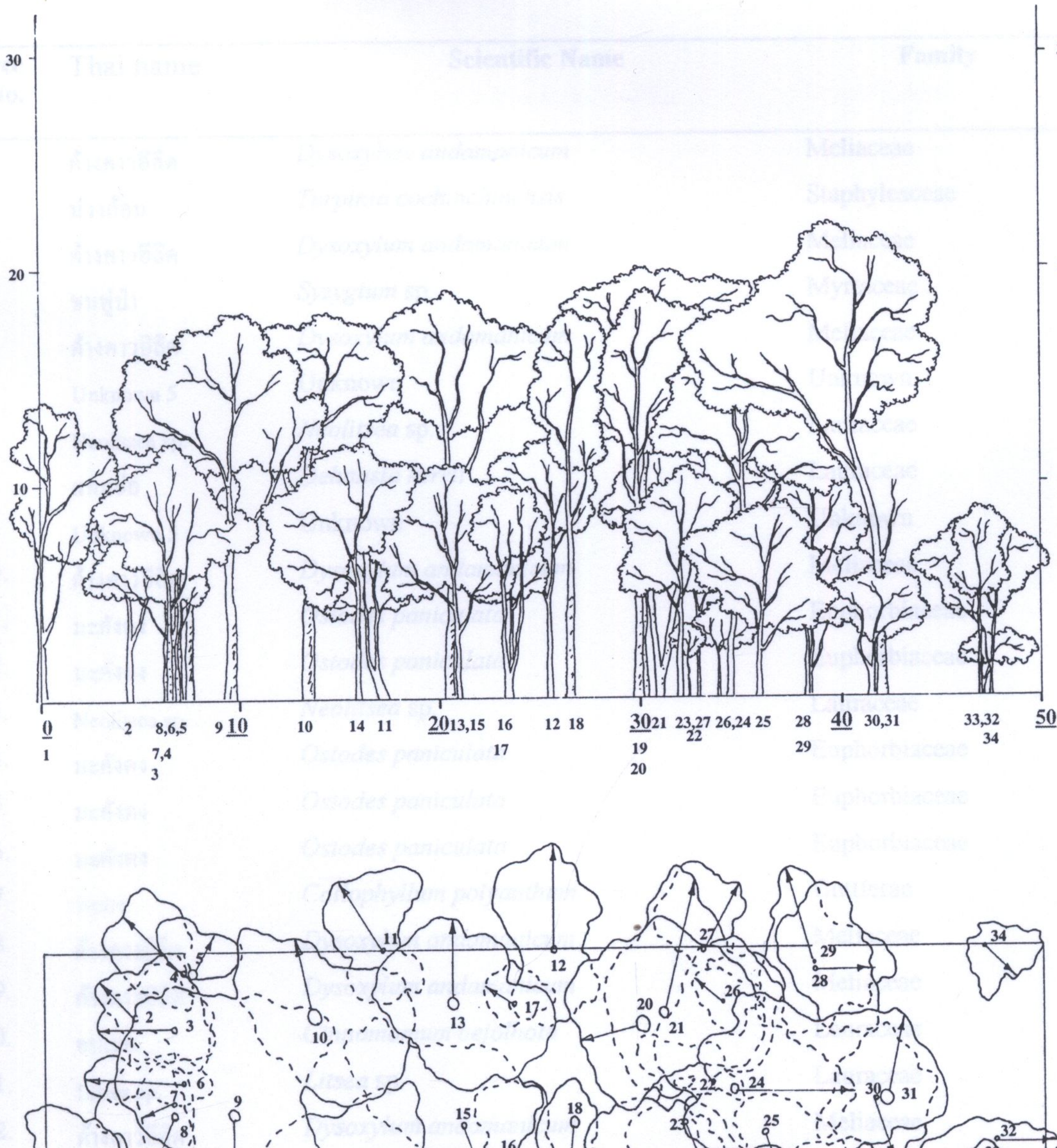
Tree Profile 4 - Interior zone of montane evergreen forest patch # 6 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 4 for Tree Profile 4

Plot TC in Patch # P6 – Interior Zone

Tree No.	Thai name	Scientific Name	Family
1.	เมี่ยง	*Camellia sinensis (var. assamica)*	Theaceae
2.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
3.	Lithocarpus sp.	*Lithocarpus* sp.	Fagaceae
4.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
5.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
6.	Unknown 1	Unknown	Unknown
7.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
8.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
9.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
10.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
11.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
12.	จวงหอม	*Cinnamomum caudatum*	Lauraceae
13.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
14.	Lauraceae 2	Unknown	Lauraceae
15.	Lauraceae 2	Unknown	Lauraceae
16.	พะอง	*Callophylum polyanthum*	Guttiferae
17.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
18.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
19.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
20.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
21.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
22.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
23.	พะอง	*Callophylum polyanthum*	Guttiferae
24.	เอียน	*Neolitsea zeylanica*	Lauraceae
25.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
26.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
27.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
28.	Unknown 3	Unknown	Unknown
29.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
30.	จวงหอม	*Cinnamomum caudatum*	Lauraceae
31.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae

Tree No.	Thai name	Scientific Name	Family
32.	Theaceae	Unknown	Theaceae
33.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
34.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
35.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
36.	จวงหอม	*Cinnamomum caudatum*	Lauraceae
37.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
38.	ก่อ	*Lithocarpus echinophorus*	Fagaceae
39.	ก่อ	*Lithocarpus echinophorus*	Fagaceae
40.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
41.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
42.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
43.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
44.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
45.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
46.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
47.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
48.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
49.	Lauraceae 4	Unknown	Lauraceae
50.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
51.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
52.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
53.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
54.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
55.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
56.	พะอง	*Callophylum polyanthum*	Guttiferae
57.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
58.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
59.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
60.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae



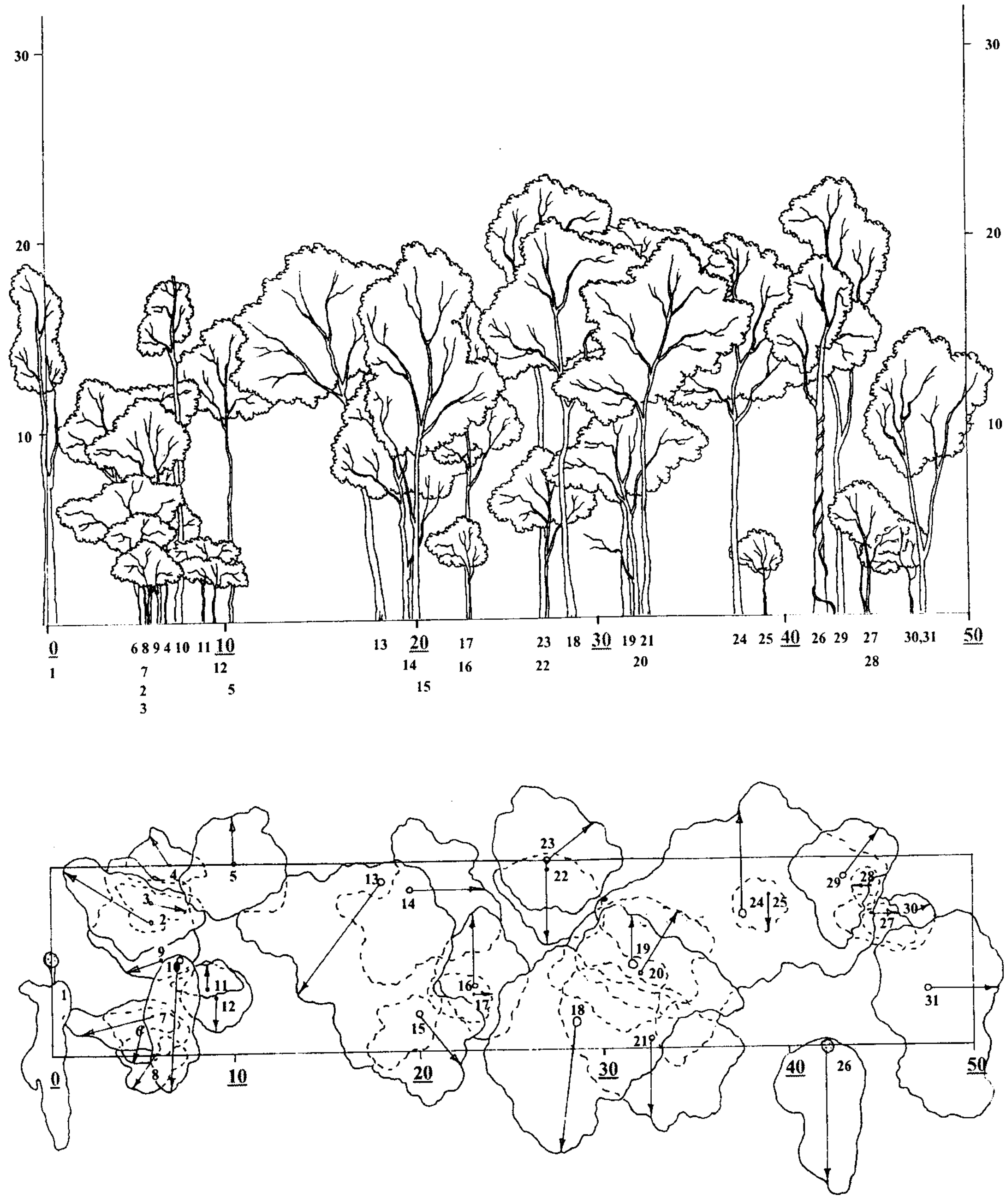
Tree Profile 5 - Edge zone of montane evergreen forest patch # 7 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 5 for Tree profile 5

Plot T2 in Patch # P7 – Edge Zone

Tree No.	Thai name	Scientific Name	Family
1.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
2.	ม่วงก้อม	*Turpinia cochinchinensis*	Staphyleaceae
3.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
4.	ชมพู่ป่า	*Syzygium* sp.	Myrtaceae
5.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
6.	Unknown 5	Unknown	Unknown
7.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
8.	แหลช่อ	*Dehaasia kerrii*	Lauraceae
9.	Unknown 5	Unknown	Unknown
10.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
11.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
12.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
13.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
14.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
15.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
16.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
17.	พะอง	*Callophyllum polyanthum*	Guttferae
18.	ค้างคางอีลิด	*Dysoxylum andamanicum*	Meliaceae
19.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
20.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
21.	Litsea sp.	*Litsea* sp.	Lauraceae
22.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
23.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
24.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
25.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
26.	หนามชิงชี่	*Capparis micracantha*	Capparidaceae
27.	ค้างคางอีลิด	*Dysoxylum andamanicum*	Meliaceae
28.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
29.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
30.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
31.	ก่อ	*Lithocarpus echinophorus*	Fagaceae

Tree No.	Thai name	Scientific Name	Family
32.	Mollotus 1	*Mallotus* sp.	Euphorbiaceae
33.	มะยาง	*Sarcosperma arboreum*	Sapotaceae
34.	หนามชิงชี่	*Capparis micracantha*	Capparidaceae



Tree Profile 6 - Interior zone of montane evergreen forest patch # 7 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 6 for Tree profile 6

Plot TC in Patch # P7 – Interior Zone

Tree No.	Thai name	Scientific Name	Family
1.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
2.	Litsea sp.	*Litsea* sp.	Lauraceae
3.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
4.	เข็มคอย	*Pavetta* sp.	Rubiaceae
5.	มะยาง	*Sarcosperma arboreum*	Sapotaceae
6.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
7.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
8.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
9.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
10.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
11.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
12.	Unknown	Unknown	Unknown
13.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
14.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
15.	Annonaceae	Unknown	Annonaceae
16.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
17.	มะเว๋อ	*Citrus* sp.	Rutaceae
18.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
19.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
20.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
21.	ก่อหยุม	*Castanopsis argyrophylla*	Fagaceae
22.	Mollotus sp.	*Mallotus* sp.	Euphorbiaceae
23.	Neolitsea sp.	*Neolitsea* sp.	Lauraceae
24.	ก่อพวง	*Lithocarpus fenestratus*	Fagaceae
25.	เข็มคอย	*Pavetta* sp.	Rubiaceae
26.	ค้างคาว	*Aglaia pirifera*	Meliaceae
27.	ลำไยป่า	*Dimocarpus longan*	Sapindaceae
28.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
29.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
30.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
31.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae

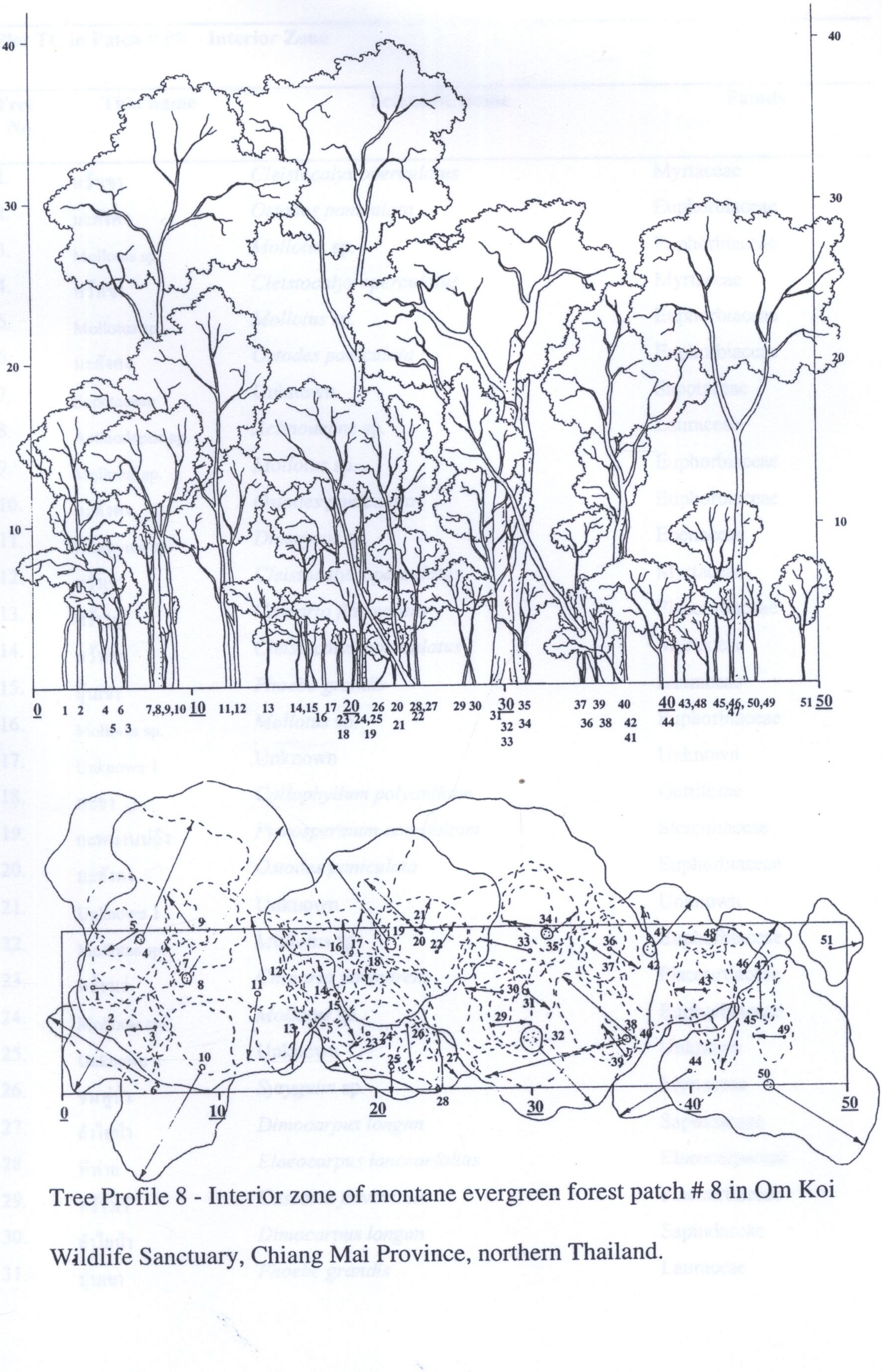
Tree Profile 7 - Edge zone of montane evergreen forest patch # 8 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 7 for Tree profile 7

Plot T4 in Patch # P8 – Edge Zone

Tree No.	Thai name	Scientific Name	Family
1.	มุ้นเขา	*Phoebe grandis*	Lauraceae
2.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
3.	หวีดป่า	*Walsura* sp.	Meliaceae
4.	ไข่เน่า	*Vitex glabrata*	Verbennaceae
5.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
6.	เข็ดช้างสารเขา	*Lasianthus longisepalus*	Rubiaceae
7.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
8.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
9.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
10.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
11.	เดื่อดิน	*Ficus scortechinii*	Moraceae
12.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
13.	ยมหิน	*Chukrasia venlutina*	Meliaceae
14.	ค่าหด	*Engelhardtia spicata*	Juglandaceae
15.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
16.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
17.	ช้างเผือก	*Xanthophyllum siamensis*	Xanthophyllaceae
18.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
19.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
20.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
21.	ชุมแสง	*Xanthophyllum glaucum*	Xanthophyllaceae
22.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
23.	ชุมแสง	*Xanthophyllum glaucum*	Xanthophyllaceae
24.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
25.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
26.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
27.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
28.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
29.	เข็ดช้างสารเขา	*Lasianthus longisepalus*	Rubiaceae
30.	พะอง	*Callophyllum polyanthum*	Guttiferae
31.	มุ้นเขา	*Phoebe grandis*	Lauraceae

Tree No.	Thai name	Scientific Name	Family
32.	พะบ้าง	*Mischocarpus pentapetalus*	Sapindaceae
33.	ก่อนายเร็ก	*Quercus rex*	Fagaceae
34.	ก่อ Rex	*Quercus rex*	Fagaceae
35.	อบเชย	*Cinnamomum bejolhota*	Lauraceae
36.	เดื่อดิน	*Ficus scortechinii*	Moraceae
37.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
38.	มะคังคง	*Ostodes paniculata*	Euphorbiaceae
39.	ลำไยป่า	*Dimocarpus longan*	Sapindaceae
40.	มุ้นเขา	*Phoebe grandis*	Lauraceae
41.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
42.	เดื่อดิน	*Ficus scortechinii*	Moraceae
43.	Termelia sp.	*Termelia* sp.	Combretaceae
44.	Aglaia sp.	*Aglaia* sp.	Meliaceae



Tree Profile 8 - Interior zone of montane evergreen forest patch # 8 in Om Koi Wildlife Sanctuary, Chiang Mai Province, northern Thailand.

Tree list 8 for Tree profile 8

Plot TC in Patch # P8 – Interior Zone

Tree No.	Thai name	Scientific Name	Family
1.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
2.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
3.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
4.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
5.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
6.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
7.	Sopotaceae	Unknown	Sapotaceae
8.	Actinodapne sp.	*Actinodepne* sp.	Lauraceae
9.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
10.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
11.	Diospyros sp.	*Diospyros* sp.	Ebenaceae
12.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
13.	พร้าวเร่	*Casearia flavovirens*	Flacourtiaceae
14.	หว้าเขา	*Cleistocalyx operculatus*	Myrtaceae
15.	มุ้นเขา	*Phoebe grandis*	Lauraceae
16.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
17.	Unknown 1	Unknown	Unknown
18.	พะอง	*Callophyllum polyanthum*	Guttiferae
19.	กะหนานปลิง	*Pterospermum acerifolium*	Sterculiaceae
20.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
21.	Unknown 1	Unknown	Unknown
22.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
23.	พร้าวเร่	*Casearia flavovirens*	Flacourtiaceae
24.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
25.	Unknown 2	Unknown	Unknown
26.	ชมพู่ป่า	*Syzyguim* sp.	Myrtaceae
27.	ลำไยป่า	*Dimocarpus longan*	Sapindaceae
28.	พีพ่าย	*Elaeocarpus lanceaefolius*	Elaeocarpaceae
29.	พร้าวเร่	*Casearia flavovirens*	Flacourtiaceae
30.	ลำไยป่า	*Dimocarpus longan*	Sapindaceae
31.	มุ้นเขา	*Phoebe grandis*	Lauraceae

Tree No.	Thai name	Scientific Name	Family
32.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
33.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
34.	ก่อนายเร็ก	*Quercus rex*	Fagaceae
35.	พร้าวเร่	*Casearia flavovirens*	Flacourtiaceae
36.	มะคังดง	*Ostodes paniculata*	Euphorbiaceae
37.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
38.	ค้างคาวอีลิด	*Dysoxylum andamanicum*	Meliaceae
39.	ก่อ Castanopsis	*Quercus rex*	Fagaceae
40.	ม่วงก้อม	*Turpinia cochinchinensis*	Staphyleaceae
41.	ชมพู่ป่า	*Syzygium* sp.	Myrtaceae
42.	มณฑาป่า	*Manglietia garrettii*	Magnoliaceae
43.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
44.	ไคร้มด	*Eurya nitida (var. siamensis)*	Theaceae
45.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
46.	ก่อ	*Lithocarpus echinophorus*	Fagaceae
47.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
48.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
49.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae
50.	Actinodapne sp.	*Actinodapne* sp.	Lauraceae
51.	Mollotus sp.	*Mollotus* sp.	Euphorbiaceae

APPENDIX B

BIRD SPECIES AND NUMBER OF DETECTIONS IN THE SAMPLE PATCHES

Patch # 1: Number of bird dectections by species from 7 site visits

No.	Species in the patch	#	Species in edge zones	#	Species in interior zones	#
1	Gray-cheeked fulvetta	51	Mountain bulbul	18	Gray-cheeked fulvetta	36
2	Mountain bulbul	24	Black bulbul	11	Lesser racket-tailed drongo	8
3	White-throated bulbul	23	Streaked spiderhunter	9	White-throated fantail	7
4	Black bulbul	16	White-throated bulbul	7	Asian paradise-flycatcher	6
5	Lesser racket-tailed drongo	14	Lesser racket-tailed drongo	6	Gray-headed flycatcher	6
6	Streaked spiderhunter	13	White-throated fantail	6	Mountain bulbul	6
7	White-throated fantail	11	Gray-cheeked fulvetta	5	Black bulbul	5
8	Gray-headed flycatcher	10	Little spiderhunter	5	Golden-spectacled warbler	5
9	Asian paradise-flycatcher	7	Gray-headed flycatcher	4	Rufous-browed flycatcher	4
10	Blue-throated barbet	7	Two-barred warbler	4	Streaked spiderhunter	4
11	Golden-spectacled warbler	7	White-bellied yuhina	4	Blyth's leaf-warbler	3
12	Little spiderhunter	7	Bronzed drongo	3	Green magpie	3
13	Blyth's leaf-warbler	6	Flavescent bulbul	3	White-throated bulbul	3
14	Buff-vented bulbul	6	Gray treepie	3	Ashy bulbul	2
15	White-bellied yuhina	6	Striped tit-babbler	3	Bronzed drongo	2
16	Bronzed drongo	5	Ashy bulbul	2	Long-tailed broadbill	2
17	Buff-breasted babbler	5	Blue-throated barbet	2	White-crowned forktail	2
18	Rufous-browed flycatcher	5	Blyth's leaf-warbler	2	Black-throated sunbird	1
19	Ashy bulbul	4	Golden-spectacled warbler	2	Blue-throated barbet	1
20	Gray treepie	4	Gray-chinned minivet	2	Gray-thorated babbler	1
21	Striped tit-babbler	4	Hill myna	2	Orange-headed thrush	1
22	Two-barred warbler	4	Hoopoe	2	Speckled piculet	1
23	Blue-eared barbet	3	Orange-bellied leafbird	2	Sulfur-breasted warbler	1
24	Flavescent bulbul	3	Velvet-fronted nuthatch	2		
25	Great barbet	3	Asian fairy-bluebird	1		
26	Green magpie	3	Black-throated sunbird	1		
27	Long-tailed broadbill	3	Black-winged cuckoo-shrike	1		
28	White-crowned forktail	3	Blue-winged minla	1		

No.	Species in the patch	#	Species in edge zones	#	Species in interior zones	#
29	Barred cuckoo-dove	2	Buff-vented bulbul	1		
30	Black-throated sunbird	2	Emerald dove	1		
31	Gray-chinned minivet	2	Great barbet	1		
32	Hill myna	2	Rufous-browed flycatcher	1		
33	Hoopoe	2	Silver-breasted broadbill	1		
34	Orange-bellied leafbird	2	Stripe-breasted woodpecker	1		
35	Silver-breasted broadbill	2				
36	Velvet-fronted nuthatch	2				
37	White-browed scimitar-babbler	2				
38	White-browed shrike-babbler	2				
39	Asian fairy-bluebird	1				
40	Banded kingfisher	1				
41	Black-winged cuckoo-shrike	1				
42	Blue-winged minla	1				
43	Crested surpent-eagle	1				
44	Emerald dove	1				
45	Gray-thorated babbler	1				
46	Orange-headed thrush	1				
47	Plaintive cuckoo	1				
48	Speckled piculet	1				
49	Stripe-breasted woodpecker	1				
50	Sulfur-breasted warbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 2 (Mae Tuen): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Gray-cheeked fulvetta	26	Black bulbul	15	Mountain bulbul	18
2	Mountain bulbul	26	Gray-cheeked fulvetta	9	Gray-cheeked fulvetta	15
3	Black bulbul	19	Bronzed drongo	8	White-bellied yuhina	7
4	Little spiderhunter	15	Streaked spiderhunter	8	Little spiderhunter	6
5	Streaked spiderhunter	14	White-throated bulbul	8	White-throated fantail	6
6	Ashy bulbul	13	Little spiderhunter	7	Black bulbul	4
7	Golden-throated barbet	13	Ashy bulbul	6	Black-crested bulbul	4
8	White-bellied yuhina	13	Black-crested bulbul	6	Golden-throated barbet	4
9	White-throated bulbul	13	Buff-vented Bulbul	5	Gray Treepie	4
10	Black-crested bulbul	11	Mountain bulbul	5	Lesser racket-tailed drongo	4
11	Buff-vented Bulbul	11	White-throated fantail	5	Streaked spiderhunter	4
12	White-throated fantail	11	Flavescent bulbul	4	White-throated bulbul	3
13	Lesser racket-tailed drongo	9	Gray-headed flycatcher	4	Ashy bulbul	2
14	Bronzed drongo	8	Hair-crested drongo	4	Black-naped monarch	2
15	Blue-throated barbet	7	Lesser racket-tailed drongo	4	Black-throated sunbird	2
16	Gray Treepie	7	White-bellied yuhina	4	Blyth's leaf-warbler	2
17	Great barbet	7	Blyth's leaf-warbler	3	Buff-vented bulbul	2
18	Flavescent bulbul	6	Emerald dove	3	Emerald dove	2
19	Blyth's leaf-warbler	5	Orange-bellied leafbird	3	Golden-spectacled warbler	2
20	Emerald dove	5	Speckled piculet	3	Hill blue flycatcher	2
21	Gray-headed flycatcher	5	Blue-throated barbet	2	Velvet-fronted nuthatch	2
22	Hair-crested drongo	4	Golden-throated barbet	2	Black-winged cuckoo-shrike	1
23	Speckled piculet	4	Red-headed trogon	2	Blue-throated barbet	1
24	White-browed scimitar-babbler	4	Black-naped monarch	1	Blue-throated flycatcher	1
25	Black-naped monarch	3	Blue-throated flycatcher	1	Collared owlet	1
26	Golden-spectacled warbler	3	Buff-breasted babbler	1	Flavescent bulbul	1
27	Orange-bellied leafbird	3	Dark-necked tailorbird	1	Gray-throated babbler	1
28	Striated yuhina	3	Golden-spectacled warbler	1	Long-tailed broadbill	1
29	Velvet-fronted nuthatch	3	Great barbet	1	Rufous-browed flycatcher	1
30	Black-throated sunbird	2	Orange-headed thrush	1	Speckled piculet	1

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
31	Blue whistling thrush	2	Two-barred warbler	1	White-browed scimitar-babbler	1
32	Blue-throated flycatcher	2	Velvet-fronted nuthatch	1		
33	Buff-breasted babbler	2	Verditer flycatcher	1		
34	Gray-throated babbler	2	White-browed shrike-babbler	1		
35	Hill blue flycatcher	2	Yellow-vented warbler	1		
36	Red-headed trogon	2				
37	Streaked wren-babbler	2				
38	Barred cuckoo-dove	1				
39	Black-winged cuckoo-shrike	1				
40	Blue-eared barbet	1				
41	Collared owlet	1				
42	Dark-necked tailorbird	1				
43	Lesser coucal	1				
44	Long-tailed broadbill	1				
45	Orange-headed thrush	1				
46	Plaintive cuckoo	1				
47	Ruddy kingfisher	1				
48	Rufous-browed flycatcher	1				
49	Sooty-headed bulbul	1				
50	Striped tit-babbler	1				
51	Two-barred warbler	1				
52	Verditer flycatcher	1				
53	White-browed shrike-babbler	1				
54	Yellow-vented warbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 3 (Mae Tuen): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Long-tailed broadbill	32	Gray-cheeked fulvetta	18	Long-tailed broadbill	29
2	Black bulbul	28	Black bulbul	12	Hair-crested drongo	19
3	Gray-cheeked fulvetta	27	Mountain bulbul	10	Golden-throated barbet	11
4	Hair-crested drongo	23	Flavescent bulbul	7	Black bulbul	10
5	Golden-throated barbet	21	White-throated bulbul	7	Lesser racket-tailed drongo	9
6	Mountain bulbul	18	Blyth's leaf-warbler	6	Flavescent bulbul	8
7	Lesser racket-tailed drongo	17	Golden-spectacled warbler	5	Gray-cheeked fulvetta	7
8	Flavescent bulbul	15	Streaked spiderhunter	5	White-throated bulbul	7
9	White-throated bulbul	15	White-necked laughingthrush	5	White-throated fantail	6
10	Streaked spiderhunter	11	Barred cuckoo-dove	4	Asian paradise-flycatcher	5
11	Gray treepie	9	Golden-throated barbet	4	Mountain bulbul	5
12	White-throated fantail	9	Gray treepie	4	Streaked spiderhunter	5
13	Blyth's leaf-warbler	8	Lesser racket-tailed drongo	4	Asian fairy bluebird	4
14	Great barbet	7	Gray-throated babbler	3	Bar-backed partridge	4
15	Asian paradise-flycatcher	5	Green-tailed sunbird	3	Buff-vented bulbul	4
16	Barred cuckoo-dove	5	Hair-crested drongo	3	Great barbet	4
17	Buff-vented bulbul	5	Red-headed trogon	3	White-bellied yuhina	4
18	Golden-spectacled warbler	5	Striated yuhina	3	Golden babbler	3
19	Little spiderhunter	5	Two-barred warbler	3	Gray treepie	3
20	White-necked laughing-thrush	5	Black-throated sunbird	2	Blue-throated barbet	2
21	Asian fairy-bluebird	4	Long-tailed broadbill	2	Blyth's leaf-warbler	2
22	Bar-backed partridge	4	Orange-headed thrush	2	Bronzed drongo	2
23	Blue-throated barbet	4	White-throated fantail	2	Green-billed malkoha	2
24	White-bellied yuhina	4	Asian emerald cuckoo	1	White-browed shrike-babbler	2
25	Black-crested bulbul	3	Blue-throated barbet	1	Black-crested bulbul	1
26	Black-throated sunbird	3	Bronzed drongo	1	Black-throated sunbird	1
27	Bronzed drongo	3	Green magpie	1	Blue-eared barbet	1
28	Golden babbler	3	Little spiderhunter	1	Gray-headed flycatcher	1
29	Gray-throated babbler	3	Spot-throated babbler	1	Green magpie	1
30	Green-tailed sunbird	3	Verditer flycatcher	1	Little spiderhunter	1
31	Orañge-headed thrush	3	White-browed shrike-babbler	1	Orange-bellied leafbird	1

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
32	Red-headed trogon	3	White-crowned forktail	1	Orange-headed thrush	1
33	Striated yuhina	3	Yellow-cheeked tit	1	White-browed scimitar-babbler	1
34	Two-barred warbler	3				
35	White-browed shrike-babbler	3				
36	Crested surpent-eagle	2				
37	Green magpie	2				
38	Green-billed malkoha	2				
39	Verditer flycatcher	2				
40	White-browed scimitar-babbler	2				
41	Asian emerald cuckoo	1				
42	Blue-eared barbet	1				
43	Collared owlet	1				
44	Emerald dove	1				
45	Gray-headed flycatcher	1				
46	Lesser coucal	1				
47	Orange-bellied leafbird	1				
48	Shikra	1				
49	Spot-throated babbler	1				
50	White-crowned forktail	1				
51	Yellow-cheeked tit	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 4 (Mae Tuen): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Blue-throated barbet	26	Black bulbul	13	Lesser racket-tailed drongo	8
2	Black bulbul	23	Blue-throated barbet	12	Streaked spiderhunter	8
3	Sreaked spiderhunter	18	Hill myna	12	Asian fairy bluebird	5
4	Great barbet	14	Sreaked spiderhunter	9	Gray-cheeked fulvetta	5
5	Hill myna	12	White-hooded babbler	8	White-throated fantail	5
6	Lesser racket-tailed drongo	11	Gray-headed flycatcher	6	Great barbet	4
7	Gray-cheeked fulvetta	10	Mountain bulbul	6	Hair-crested drongo	4
8	Gray-headed flycatcher	10	White-crested laughing-thrush	6	Black-naped monarch	3
9	Blue-eared barbet	9	Blyth's leaf-warbler	5	Flavescent bulbul	3
10	White-throated fantail	9	Buff-vented bulbul	4	Black bulbul	2
11	Hair-crested drongo	8	Gray-cheeked fulvetta	4	Black-crested bulbul	2
12	Mountain bulbul	8	Great barbet	4	Blyth's leaf-warbler	2
13	White-hooded babbler	8	Striped tit-babbler	4	Brown wood-owl	2
14	Black-crested bulbul	7	Golden-spectacled warbler	3	Buff-breasted babbler	2
15	Blyth's leaf-warbler	7	Little spiderhunter	3	Eastern-crowned warbler	2
16	Asian fairy-bluebird	6	White-browed shirke-babbler	3	Golden-throated barbet	2
17	Golden-throated barbet	6	White-throated bulbul	3	Gray-headed flycatcher	2
18	Little spiderhunter	6	White-throated fantail	3	Japanese white-eye	2
19	Pin-tailed pigeon	6	Ashy bulbul	2	Little spiderhunter	2
20	White-crested laughing-thrush	6	Black-crested bulbul	2	Long-tailed broadbill	2
21	Buff-vented bulbul	5	Black-winged cuckoo-shrike	2	Mountain bulbul	2
22	Flavescent bulbul	5	Bronzed drongo	2	Two-barred warbler	2
23	Golden-spectacled warbler	5	Flavescent bulbul	2	Black-winged cuckoo-shrike	1
24	White-browed shirke-babbler	5	Greater yellownape	2	Blue-eared barbet	1
25	White-throated bulbul	5	Lesser racket-tailed drongo	2	Blue-throated barbet	1
26	Ashy bulbul	4	Orange-headed thrush	2	Golden-spectacled warbler	1
27	Long-tailed broadbill	4	Two-barred warbler	2	Gray-chinned minivet	1
28	Striped tit-babbler	4	Asian fairy-bluebird	1	Green-tailed sunbird	1
29	Two-barred warbler	4	Blue-eared barbet	1	Red-whiskered bulbul	1
30	Black-nape monarch	3	Buff-breasted babbler	1	Slender-billed oriole	1

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
31	Black-winged cuckoo-shrike	3	Emerald dove	1	White-browed shrike-babbler	1
32	Bronzed drongo	3	Golden babbler	1		
33	Buff-breasted babbler	3	Golden-throated barbet	1		
34	Orange-bellied leafbird	3	Gray-chinned minivet	1		
35	Velvet-fronted nuthatch	3	Green magpie	1		
36	Brown wood-owl	2	Hair-crested drongo	1		
37	Collared owlet	2	Hill blue flycatcher	1		
38	Eastern-crowned warbler	2	Long-tailed broadbill	1		
39	Emerald dove	2	Orange-bellied leafbird	1		
40	Gray-chinned minivet	2	Red-billed scimitar-babbler	1		
41	Greater yellownape	2	Red junglefowl	1		
42	Japanese white-eye	2	Rufous-browed flycatcher	1		
43	Orange-headed thrush	2	Silver-breasted broadbill	1		
44	Scalet minivet	2	Slender-billed oriole	1		
45	Slender-billed oriole	2	Stripe-breasted woodpecker	1		
46	Barred cuckoo-dove	1	Sulfur-breasted warbler	1		
47	Golden babbler	1	Velvet-fronted nuthatch	1		
48	Golden-fronted leafbird	1				
49	Green-tailed sunbird	1				
50	Green magpie	1				
51	Hill blue flycatcher	1				
52	Hoopoe	1				
53	Red-billed scimitar-babbler	1				
54	Red-headed trogon	1				
55	Red-whiskered bulbul	1				
56	Red junglefowl	1				
57	Rufous-browed flycatcher	1				
58	Silver-breasted broadbill	1				
59	Stripe-breasted woodpecker	1				
60	Sulfur-breasted warbler	1				
61	White-browed scimitar-babbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 5 (Om Koi): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Mountain imperial pigeon	20	Lesser racket-tailed drongo	12	Mountain imperial pigeon	10
2	Golden-throated barbet	17	Gray-headed flycatcher	9	Gray-chinned minivet	9
3	Lesser racket-tailed drongo	16	Black-headed sibia	8	White-tailed leaf-warbler	6
4	Black-headed sibia	15	Golden-throated barbet	8	Brown-throated treecreeper	5
5	Long-tailed broadbill	12	Long-tailed broadbill	6	Golden-throated barbet	5
6	Gray-headed flycatcher	11	Mountain bulbul	6	Great barbet	5
7	Great barbet	11	White-crowned forktail	6	White-necked laughing-thrush	5
8	White-necked laughing-thrush	11	Blyth's leaf-warbler	4	Ashy bulbul	4
9	Chestnut-flanked white-eye	10	Golden-spectacled warbler	4	Flavescent bulbul	4
10	Gray-chinned minivet	9	Mountain imperial pigeon	4	Gray-cheeked fulvetta	4
11	Gray treepie	9	Flavescent bulbul	3	Lesser racket-tailed drongo	4
12	White-crowned forktail	9	Rufous-throated partridge	3	Lesser yellownape	4
13	Mountain bulbul	8	Striped tit-babbler	3	Long-tailed broadbill	4
14	White-tailed leaf-warbler	8	Two-barred warbler	3	Black-naped monarch	3
15	Flavescent bulbul	7	White-necked laughing-thrush	3	Bronzed drongo	3
16	Golden-spectacled warbler	7	White-throated fantail	3	Golden-spectacled warbler	3
17	Red-whiskered bulbul	7	Chestnut-crowned warbler	2	Maroon oriole	3
18	Rufous-throated partridge	7	Golden babbler	2	Yellow-cheeked tit	3
19	Maroon oriole	6	Gray treepie	2	Ashy drongo	2
20	Brown-throated treecreeper	5	Great barbet	2	Black-headed sibia	2
21	Yellow-cheeked tit	5	Large niltava	2	Chestnut-crowned warbler	2
22	Ashy bulbul	4	Maroon oriole	2	Gray-headed flycatcher	2
23	Blyth's leaf-warbler	4	Red-whiskered bulbul	2	Hair-crested drongo	2
24	Bronzed drongo	4	White-tailed leaf-warbler	2	Inornate warbler	2
25	Chestnut-crowned warbler	4	Yellow-cheeked tit	2	Little pied flycatcher	2
26	Gray-cheeked fulvetta	4	Bronzed drongo	1	Mountain bulbul	2
27	Large-tailed nightjar	4	Chestnut-crowned laughingthrush	1	Rufous-throated partridge	2
28	Lesser yellownape	4	Collared owlet	1	Scarlet minivet	2
29	Black-naped monarch	3	Eastern-crowned warbler	1	Short-billed minivet	2
30	Collared owlet	3	Eye-browed wren-babbler	1	Striated bulbul	2
31	Great hornbill	3	Ferruginous flycatcher	1	Stripe-breasted woodpecker	2

No. Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
32 Large niltava	3	Green magpie	1	White-browed shrike-babbler	2
33 Mountain scops-owl	3	Hill blue-flycatcher	1	Black-winged cuckoo-shrike	1
34 Striped tit-babbler	3	Red-headed trogon	1	Ferruginous flycatcher	1
35 Two-barred warbler	3	Rufous-bellied niltava	1	Gray-throated babbler	1
36 White-throated fantail	3	Rufous-browed flycatcher	1	Large niltava	1
37 Ashy drongo	2	Sulfur-breasted warbler	1	Rufous-winged fulvetta	1
38 Ferruginous flycatcher	2	Velvet-fronted nuthatch	1	Silver-eared mesia	1
39 Golden babbler	2	White-bellied yuhina	1	Streaked spiderhunter	1
40 Gray nightjar	2			White-bellied yuhina	1
41 Green-billed malkoha	2				
42 Hair-crested drongo	2				
43 Inornate warbler	2				
44 Little pied flycatcher	2				
45 Red-headed trogon	2				
46 Scarlet minivet	2				
47 Short-billed minivet	2				
48 Striated bulbul	2				
49 Stripe-breasted woodpecker	2				
50 White-bellied yuhina	2				
51 White-browed scimitar-babbler	2				
52 White-browed shrike-babbler	2				
53 Black-winged cuckoo-shrike	1				
54 Brown hornbill	1				
55 Chestnut-crowned laughingthrush	1				
56 Eastern-crowned warbler	1				
57 Eye-browed wren-babbler	1				
58 Gray-throated babbler	1				
59 Green magpie	1				
60 Hill blue-flycatcher	1				
61 Indian cuckoo	1				
62 Rufous-bellied niltava	1				
63 Rufous-browed flycatcher	1				
64 Rufous-winged fulvetta	1				

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
65	Silver-eared mesia	1				
66	Streaked spiderhunter	1				
67	Sulfur-breasted warbler	1				
68	Velvet-fronted nuthatch	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 6 (Om Koi): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Mountain bulbul	37	White-tailed leaf-warbler	15	Mountain bulbul	22
2	Golden-throated barbet	31	Mountain bulbul	13	Golden-throated barbet	14
3	Gray-cheeked fulvetta	28	Golden-throated barbet	12	Gray-cheeked fulvetta	14
4	White-tailed leaf-warbler	24	Black bulbul	9	Gray-sided thrush	10
5	Black-headed sibia	18	Gray-headed flycatcher	9	Black-headed sibia	8
6	Black bulbul	12	Gray-cheeked fulvetta	8	White-tailed leaf-warbler	8
7	Chestnut-flanked white-eye	11	Black-headed sibia	7	Chestnut-flanked white-eye	5
8	Gray-headed flycatcher	11	Chestnut-flanked white-eye	6	White-throated fantail	4
9	Gray-sided thrush	11	White-necked laughingthrush	6	Black bulbul	3
10	White-throated fantail	10	White-throated fantail	6	Burmese yuhina	3
11	Little pied flycatcher	9	Green-tailed sunbird	5	Large niltava	3
12	Silver-eared mesia	9	Silver-eared mesia	5	Little pied flycatcher	3
13	Eurasian jay	8	Wedge-tailed pigeon	5	Rufous-throated partridge	3
14	Great barbet	8	Chestnut-crowned laughing-thrush	3	Silver-eared mesia	3
15	Gray nightjar	7	Chestnut-crowned warbler	3	Slaty-billied tesia	3
16	Large niltava	6	Eyebrowed thrush	3	Chestnut-crowned laughing-thrush	2
17	Rufous-throated partridge	6	Bronzed drongo	2	Chestnut-fronted shrike-babbler	2
18	White-necked laughingthrush	6	Golden-spectacled warbler	2	Eyebrowed thrush	2
19	Chestnut-crowned laughing-thrush	5	Inornate warbler	2	Gray-headed flycatcher	2
20	Eyebrowed thrush	5	Purple cochoa	2	Mountain tailorbird	2
21	Green-tailed sunbird	5	Rufous-winged fulvetta	2	Red Junglefowl	2
22	Kalij pheasant	5	Speckled piculet	2	Brown-throated treecreeper	1
23	Wedge-tailed pigeon	5	Striated bulbul	2	Chestnut-crowned warbler	1
24	Yellow-cheeked tit	5	Yellow-cheeked tit	2	Golden-spectacled warbler	1
25	Chestnut-crowned warbler	4	Black-throated sunbird	1	Great barbet	1
26	Flavescent bulbul	4	Buff-vented bulbull	1	Hair-crested drongo	1
27	Burmese yuhina	3	Gray-sided thrush	1	Inornate warbler	1
28	Golden-spectacled warbler	3	Great barbet	1	Lesser racket-tailed drongo	1
29	Inornate warbler	3	Green-billed malkoha	1	Red-headed trogon	1

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
30	Mountain imperial pigeon	3	Greenish warbler	1	Rufous-winged fulvetta	1
31	Rufous-winged fulvetta	3	Large niltava	1	Yellow-cheeked tit	1
32	Slaty-billied tesia	3	Little pied flycatcher	1		
33	Streaked wren-babbler	3	Long-tailed minivet	1		
34	White-headed bulbul	3	Rufous-bellied nilvata	1		
35	Black-throated sunbird	2	Rufous-gorgetted flycatcher	1		
36	Bronzed drongo	2	Two-barred warbler	1		
37	Brown hornbill	2	White-browed shrike-babbler	1		
38	Brown-throated treecreeper	2				
39	Chestnut-fronted shrike-babbler	2				
40	Lesser racket-tailed drongo	2				
41	Mountain tailorbird	2				
42	Purple cochoa	2				
43	Red Junglefowl	2				
44	Red-throated flycatcher	2				
45	Speckled piculet	2				
46	Striated bulbul	2				
47	Brown wood-owl	1				
48	Buff-vented bulbull	1				
49	Crested serpent-eagle	1				
50	Gould's sunbird	1				
51	Green-billed malkoha	1				
52	Greenish warbler	1				
53	Hair-crested drongo	1				
54	Hill blue flycatcher	1				
55	Large cuckoo-shrike	1				
56	Large-tailed nightjar	1				
57	Long-tailed minivet	1				
58	Orange-bellied leafbird	1				
59	Red-headed trogon	1				
60	Rufous-bellied nilvata	1				
61	Rufous-gorgetted flycatcher	1				

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
62	Two-barred warbler	1				
63	Verditer flycatcher	1				
64	White-browed shrike-babbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 7 (Om Koi): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Golden-throated barbet	15	Gray-cheeked fulvetta	13	Black-throated parrotbill	8
2	White-tailed leaf-warbler	15	Gray-chinned minivet	11	White-tailed leaf-warbler	8
3	Gray-cheeked fulvetta	14	Black-headed sibia	7	Silver-eared mesia	6
4	Gray-chinned minivet	12	White-throated fantail	7	White-headed bulbul	6
5	White-throated fantail	12	Flavescent bulbul	6	Golden-spectacled warbler	5
6	Black-headed sibia	11	Large niltava	6	White-throated fantail	5
7	Gray-headed flycatcher	10	Rufous-winged fulvetta	6	Golden-throated barbet	4
8	Mountain bulbul	10	White-tailed leaf-warbler	6	White-browed shrike-babbler	4
9	Large niltava	9	Golden-throated barbet	4	Chestnut-flanked white-eye	3
10	Mountain imperial pigeon	9	Gray-headed flycatcher	4	Gray-headed flycatcher	3
11	Black-throated parrotbill	8	Mountain bulbul	4	Large niltava	3
12	Silver-eared mesia	8	Eastern crowned warbler	3	Black-headed sibia	2
13	Golden-spectacled warbler	7	Lesser racket-tailed drongo	3	Chestnut-crowned laughing-thrush	2
14	Rufous-winged fulvetta	7	Long-tailed minivet	3	Lesser racket-tailed drongo	2
15	White-browed shrike-babbler	7	Mountain imperial pigeon	3	Mountain bulbul	2
16	Flavescent bulbul	6	Red-whiskered bulbul	3	Pygmy wren-babbler	2
17	Rufous-throated partridge	6	Rusty-cheeked scimitar-babbler	3	Short-billed minivet	2
18	White-headed bulbul	6	White-browed shrike-babbler	3	Stripe-breasted woodpecker	2
19	Lesser racket-tailed drongo	5	Yellow-cheeked tit	3	Dark-sided thrush	1
20	Chestnut-crowned laughing-thrush	4	Black-crested bulbul	2	Gould's sunbird	1
21	Chestnut-flanked white-eye	3	Chestnut-crowned laughing-thrush	2	Gray-cheeked fulvetta	1
22	Eastern crowned warbler	3	Chestnut-crowned warbler	2	Gray-chinned minivet	1
23	Long-tailed minivet	3	Golden-spectacled warbler	2	Hill blue flycatcher	1
24	Red-whiskered bulbul	3	Inornate warbler	2	Kalij pheasant	1
25	Rusty-cheeked scimitar-babbler	3	Rufous-throated partridge	2	Little pied flycatcher	1
26	Scalet minivet	3	Scalet minivet	2	Rufous-throated partridge	1
27	Verditer flycatcher	3	Verditer flycatcher	2	Rufous-winged fulvetta	1

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
28	White-browed scimitar-babbler	3	White-browed scimitar-babbler	2	Scalet minivet	1
29	Yellow-cheeked tit	3	Arctic warbler	1	Slaty-bellied tesia	1
30	Black-crested bulbul	2	Great barbet	1	Verditer flycatcher	1
31	Chestnut-crowned warbler	2	Green-billed malkoha	1		
32	Great barbet	2	Little pied flycatcher	1		
33	Inornate warbler	2	Rosy minivet	1		
34	Little pied flycatcher	2	Rufescent prinia	1		
35	Pygmy wren-babbler	2	Rufous-winged sibia	1		
36	Short-billed minivet	2	Slaty-blue flycatcher	1		
37	Stripe-breasted woodpecker	2	Streaked spiderhunter	1		
38	Arctic warbler	1	Striated bulbul	1		
39	Dark-sided thrush	1	Sulfur-breasted warbler	1		
40	Gould's sunbird	1	Two-barred warbler	1		
41	Green-billed malkoha	1				
42	Hill blue flycatcher	1				
43	Kalij pheasant	1				
44	Red junglefowl	1				
45	Red-billed scimitar-babbler	1				
46	Rosy minivet	1				
47	Rufescent prinia	1				
48	Rufous-winged sibia	1				
49	Slaty-bellied tesia	1				
50	Slaty-blue flycatcher	1				
51	Streaked spiderhunter	1				
52	Striated bulbul	1				
53	Sulfur-breasted warbler	1				
54	Two-barred warbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

Patch # 8 (Om Koi): Number of bird dectections by species from 7 site visits

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
1	Gray-cheeked fulvetta	31	Gray-cheeked fulvetta	19	White-tailed leaf-warbler	9
2	Mountain bulbul	22	White-throated fantail	11	White-necked laughing-thrush	8
3	White-throated fantail	18	Mountain bulbul	7	Brown hornbill	7
4	Lesser racket-tailed drongo	14	Golden-throated barbet	4	Mountain bulbul	7
5	White-tailed leaf-warbler	14	White-browed shrike-babbler	4	Yellow-cheeked tit	6
6	Golden-throated barbet	13	White-tailed leaf-warbler	4	Gray-headed flycatcher	4
7	White-necked laughing-thrush	11	Bronzed drongo	3	White-throated fantail	4
8	Black-headed sibia	9	Gray-chinned minivet	3	Blyth's leaf-warbler	2
9	Gray-headed flycatcher	9	Gray-headed flycatcher	3	Golden-throated barbet	2
10	Yellow-cheeked tit	9	Lesser racket-tailed drongo	3	Greater yellownape	2
11	Brown hornbill	7	Silver-eared mesia	3	Streaked spiderhunter	2
12	Streaked spiderhunter	7	Streaked spiderhunter	3	Streaked wren-babbler	2
13	Golden-spectacled warbler	6	White-necked laughingthrush	3	Two-barred warbler	2
14	Great barbet	6	Black-headed sibia	2	White-crowned forktail	2
15	Mountain imperial pigeon	6	Black bulbul	2	Blue rock-thrush	1
16	Brown-throated treecreeper	5	Brown-throated treecreeper	2	Blue whistling thrush	1
17	Silver-eared mesia	5	Chestnut-crowned laughting-thrush	2	Golden-spectacled warbler	1
18	White-browed shrike-babbler	5	Chestnut-fronted shrike-babbler	2	Gray-cheeked fulvetta	1
19	Gray-chinned minivet	4	Dark-sided thrush	2	Gray-chinned minivet	1
20	Large niltava	4	Golden babbler	2	Green magpie	1
21	Streaked wren-babbler	4	Golden-spectacled warbler	2	Large niltava	1
22	Bronzed drongo	3	Large niltava	2	Mountain imperial pigeon	1
23	Chestnut-fronted shrike-babbler	3	Short-billed minivet	2	Red-headed trogon	1
24	Oriental white-eye	3	Siberian thrush	2	Stripe-breasted woodpecker	1
25	Speckled piculet	3	Ashy drongo	1	Velvet-fronted nuthatch	1
26	White-browed scimitar-babbler	3	Asian emerald cuckoo	1	Wedge-tailed pigeon	1
27	White-crowned forktail	3	Black-throated laughingthrush	1	White-bellied yuhina	1
28	Bar-winged flycatcher-shrike	2	Blue-eared barbet	1	White-tailed robin	1
29	Black bulbul	2	Blue-throated flycatcher	1	Yellow-vented warbler	1
30	Blyth's leaf-warbler	2	Flavescent bulbul	1		

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
31	Chestnut-crowned laughing-thrush	2	Great barbet	1		
32	Dark-sided thrush	2	Green-billed malkoha	1		
33	Golden babbler	2	Red-headed trogon	1		
34	Gray treepie	2	Speckled piculet	1		
35	Greater yellownape	2	Striped tit-babbler	1		
36	Green magpie	2	Yellow-cheeked tit	1		
37	Hair-crested drongo	2				
38	Long-tailed broadbill	2				
39	Mountain scops-owl	2				
40	Red-headed trogon	2				
41	Rufous-throated partridge	2				
42	Short-billed minivet	2				
43	Siberian thrush	2				
44	Two-barred warbler	2				
45	White-bellied yuhina	2				
46	Ashy drongo	1				
47	Asian emerald cuckoo	1				
48	Black-throated laughingthrush	1				
49	Blue rock-thrush	1				
50	Blue whistling thrush	1				
51	Blue-eared barbet	1				
52	Blue-throated flycatcher	1				
53	Chestnut-flanked white-eye	1				
54	Collared owlet	1				
55	Flavescent bulbul	1				
56	Gould's sunbird	1				
57	Green-billed malkoha	1				
58	Indian cuckoo	1				
59	Kalij pheasant	1				
60	Striated bulbul	1				
61	Stripe-breasted woodpecker	1				
62	Striped tit-babbler	1				
63	Velvet-fronted nuthatch	1				
64	Verditer flycatcher	1				

No.	Species in the patch[a]	#	Species in edge zones[b]	#	Species in interior zones[c]	#
65	Wedge-tailed pigeon	1				
66	White-tailed robin	1				
67	Yellow-vented warbler	1				

[a]from on- and off-transect surveys
[b]from on-transect survey only
[c]from on-transect survey only

APPENDIX C

LIST OF REPTILES AND AMPHIBIANS FOUND DURING THE SURVEYS

During the surveys of birds and mammals some reptiles and amphibians were encountered as follows.

REPTILES

No.	Common name	Scientific name	Om Koi	Mae Tuen
A. Montane evergreen forests (elevations 900 – 1,800 m).				
	Snake			
1.	Pope's pit-viper	*Trimeresurus popeiorum*	✓	✓
2.	White-lipped pit-viper	*T. alborabris*	-	✓
3.	Oriental whip snake	*Ahaetulla prasina*	✓	✓
4.	Speckle-bellied keelback	*Rhabdophis chrysargus*	✓	-
5.	Common mock viper	*Psammodynastes pulverulentus*	-	✓
6.	Red mountain racer	*Elphe porphyracea*	✓	-
	Lizard			
7.	Cross-bearing tree lizard	*Acanthosaura crucigera*	✓	✓
	Tortoise			
8.	Impressed tortoise	*Manouria impressa*	✓	-
B. Mixed deciduous and dry dipterocarp forests (elevations 500 – 800 m).				
	Snake			
9.	Recticulated python	*Python recticulatus*	✓	-
	Lizard			
10.	Common butterfly lizard	*Leiolepis belliana*	✓	-
	Skink			
11.	Streamside skink	*Sphenomorphus maculatus*	✓	-

AMPHIBIANS

No.	Common name	Scientific name	Om Koi	Mae Tuen
A. Montane evergreen forests (elevations 900 – 1,800 m).				
12.	Himalayan Newt	*Tylototriton verrucosus*	✓	-
13.		*Megophrys lateralis*	✓	✓
B. Mixed deciduous and dry dipterocarp forests (elevations 500 – 800 m).				
13.	Agustic frog	*Rana kuhlii*	✓	-
14.	Common stream frog	*R.Pileata*	✓	-
15.	Common brown frog	*R. nigrovittata*	✓	-
16.	Smith's frog	*R. cubitalis*	✓	-

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Pattanavibool, A., and P. Dearden. 1999. Wildlife response to habitat fragmentation and other human influences in tropical forests, northern Thailand. A paper presented at Society for Conservation Biology Annual Meeting, June 17 – 21, 1999, College Park, Maryland.

Dearden, P., A. Pattanavibool, and P. Uttayan. 1998. Wildlife conservation in Om Koi Wildlife Sanctuary, Thailand. A paper presented at Society for Conservation Biology Annual Meeting, July 13-16, 1998, Sydney, Australia.

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Title of Dissertation:

Wildlife Response to Habitat Fragmentation and other Human Influences in Tropical Montane Evergreen Forests, Northern Thailand

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