HABITAT USE AND THE POPULATION TREND OF KITTI'S HOG-NOSED BATS (*CRASEONYCTERIS THONGLONGYAI*) IN DISTURBED HABITATS IN WESTERN THAILAND

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A THESIS SUBMITTED IN PERTIAL FULFILLMENT
OF THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF SCIENCE
(ENVIRONMENTAL BIOLOGY)
FACULTY OF GRADUATE STUDIES
MAHIDOL UNIVERSITY
2000

ISBN 974-664-827-6

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was submitted to the Faculty of Graduate Studies, Mahidol University
For the degree of Master of Science (Environmental Biology)

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ACKNOWLEDGEMENT

I would like to thank the following people

Dr. Sompoad Srikosamatara, who served as major advisor, for his guidance, helpful suggestion on the working and writing of this thesis. He gave me a chance to work on the thesis quite independently, and also corrected the manuscript.

Dr. Warren Y. Brockelman for invaluable knowledge he gave me in many course works. He also corrected the drafts and provided many helpful suggestions.

Mr. Surapon Duangkhae, who help me so much about the field work, this work could not have been carried out without his valuable suggestion and his kindness. He also loan me a bat detector when I started working the thesis.

Mr. Sawai Wanghongsa for his kindness and his suggestion and Mrs. Kalyanee Boonkird for inviting to survey a bat with her, also Mr. Adrian R. Hillman who gave me an information concerning *Craseonycteris* and corrected the drafts.

Dr. Ben Verboom for his literature that not available in Thailand.

My parents who supported me during the long term study and my sister who gave me many books, send me a literature that not available in Thailand, and helped purchasing some equipment. Miss Piyathip Piyapan who assisted me in many ways, also in some field trips and Mr. Karn Lekagul who surveyed some of the caves with me and loan me some equipment.

Mr. Chong Cho-snab and Ju-sa-wat family, the local villagers, for their hospitality and field assistance.

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3836539 SCEB/M: MAJOR: ENVIRONMENTAL BIOLOGY;
M.Sc. (ENVIRONMENTAL BIOLOGY)
KEY WORDS : *CRASEONYCTERIS*/ DISTURBANCE/ ENDANGERED/ ENDEMIC/ POPULATION TREND

MEDHI YOKUBOL: HABITAT USE AND THE POPULATION TREND OF KITTI'S HOG-NOSED BATS (*CRASEONYCTERIS THONGLONGYAI*) IN DISTURBED HABITATS IN WESTERN THAILAND. THESIS ADVISORS: SOMPOAD SRIKOSAMATARA, Ph.D., WARREN Y. BROCKELMAN, Ph.D., SURAPON DUANGKHAE, M.Sc., 67 p. ISBN 974-664-827-6.

Craseonycteris thonglongyai, also known as Kitti's hog-nosed bats and Bumblebee bats, is the smallest mammal of the world that is distributed only in confined area of western Thailand and was listed as an endangered species by The World Conservation Union (IUCN). There has been no study on the status and population trend of *Craseonycteris* for more than ten years. Also there has been no study on the ecology of these endemic bats in areas where the habitat is being altered to determine whether the bats can adapt themselves to this change in habitat. The purposes of this study were to determine the population trend and to determine if there were any human activities that might affect the survival of *Craseonycteris*.

This study was carried out in three steps: population monitoring and cave survey, studying the flight paths and microhabitat use, and examining habitat preferences of the bats in patchy habitats composed of forest and cassava plantations.

The total population of *Craseonycteris* was found to be higher than the previous study with 2,656 bats compared with 2,000 bats due to the discovery of new caves, while the number in original caves has not changed significantly (1,536 to 1,382 bats). However, disturbance levels tended to decrease the percentage of presence and the numbers per cave of *Craseonycteris*.

Craseonycteris foraged along specific flight paths, which were interconnected with other caves and could be adapted in relation to the change of landscape. The bats could forage in suburban and many kinds of plantation areas preferring edges and small clearings, but avoided foraging in large open areas of cassava plantations eventhough insects were similarly abundant.

3836539 SCEB/M : สาขาวิชา: ชีววิทยาสภาวะแวดล้อม: วท.ม (ชีววิทยาสภาวะแวดล้อม)

เมธี หยกอุบล: แนวโน้มการเปลี่ยนแปลงประชากรและการเลือกใช้พื้นที่ในการหากินของค้างคาวกิตติ (*Craseonycteris thonglongyai*) ทางตะวันตกของประเทศไทย (HABITAT USE AND THE POPULATION TREND OF KITTI'S HOG-NOSED BAT (*CRASEONYCTERIS THONGLONGYAI*) IN DISTURBED HABITATS IN WESTERN THAILAND). คณะกรรมการควบคุมวิทยานิพนธ์: สมโภชน์ ศรีโกสามาตร, Ph.D., วรเรณ บรอคเคลแมน, Ph.D., สุรพล ดวงแข, M.Sc. 67 หน้า. ISBN 974-664-827-6

ค้างคาวกิตติ (*Craseonycteris thonglongyai*) เป็นสัตว์เลี้ยงลูกด้วยน้ำนมที่มีขนาดเล็กที่สุดในโลกซึ่งพบกระจายอยู่เฉพาะในพื้นที่จำกัดในภาคตะวันตกของประเทศไทยและถูกจัดเป็นสัตว์ป่าที่ตกอยู่ในภาวะใกล้สูญพันธุ์ (Endangered Species) โดยสหพันธ์นานาชาติว่าด้วยการอนุรักษ์ธรรมชาติ (IUCN) การศึกษาเพื่อประเมินสถานภาพและแนวโน้มการเปลี่ยนแปลงจำนวนประชากรของค้างคาวชนิดนี้ได้ขาดหายไปเป็นระยะเวลากว่าสิบปี และไม่เคยมีการศึกษานิเวศวิทยาของค้างคาวชนิดนี้ในพื้นที่ที่มีการเปลี่ยนแปลงหรือรบกวนจากกิจกรรมต่างๆโดยมนุษย์เพื่อตรวจสอบความสามารถในการปรับตัวต่อการเปลี่ยนแปลงนั้นๆ

การศึกษาครั้งนี้เป็นการศึกษาเพื่อประเมินแนวโน้มการเปลี่ยนแปลงจำนวนประชากรและตรวจสอบหาปัจจัยคุกคามซึ่งอาจเกิดขึ้นจากกิจกรรมต่างๆของมนุษย์ โดยดำเนินการเป็นสามขั้นตอน ได้แก่ ประเมินจำนวนประชากรและการสำรวจถ้ำ, ศึกษาพฤติกรรมการใช้พื้นที่หากินและเส้นทางบินเฉพาะ, และตรวจสอบการเลือกใช้พื้นที่หาอาหารในพื้นที่ผสมระหว่างป่าเต็งรังเสื่อมโทรมและไร่มันสำปะหลัง

การศึกษาครั้งนี้พบจำนวนประชากรโดยรวมของค้างคาวกิตติมากกว่าในอดีตเนื่องจากมีการสำรวจพบถ้ำใหม่ๆเพิ่มขึ้น โดยพบเพิ่มจากจำนวนประมาณ 2,000 ตัวเป็น 2,656 ตัว ในขณะที่จำนวนประชากรในกลุ่มถ้ำเดิมไม่มีการเปลี่ยนแปลงอย่างชัดเจนโดยพบจำนวน 1,382 ตัวจากจำนวนเดิม 1,536 ตัว แต่พบว่าจำนวนค้างคาวในแต่ละถ้ำและอัตราส่วนของถ้ำที่พบค้างคาวมีแนวโน้มลดลงตามระดับการรบกวนในถ้ำที่เพิ่มขึ้น

ค้างคาวกิตติบินหาอาหารโดยใช้เส้นทางบินเฉพาะซึ่งพบว่ามีการเชื่อมต่อกันระหว่างถ้ำและสามารถเปลี่ยนแปลงได้ตามการเปลี่ยนแปลงของสภาพพื้นที่ ค้างคาวชนิดนี้สามารถบินหาอาหารในพื้นที่กึ่งเมืองกึ่งชนบทและพื้นที่สวนผลไม้และไม้ยืนต้นหลายประเภทแต่หลีกเลี่ยงพื้นที่โล่งของไร่มันสำปะหลังแม้ว่าปริมาณแมลงจะไม่แตกต่างกัน

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CHAPTER I

INTRODUCTION

Craseonycteris thonglongyai (Kitti's hog-nosed bat, Bumblebee bat) is a smallest mammal so far known in the world with a weight of 2 g, it was discovered in 1973 by a team led by Mr. Kitti Thonglongya and classified as a new species in a new genus and family of mammal by Dr. John Edwards Hill of the British Museum the following year (1).

Soon after being discovered, most studies focussed on the distribution and population sizes of the bat, researcher found an extremely low populations distributed in only a few caves near the River Khwae in Sai Yok district, Kanchanaburi Province (2, 3, 4). There were no intensive studies on ecology of the bat at that time but only some observations by Lekagul and McNeely (1977) (2) and description of the structure of premaxillae, wing morphology, and the kinds of insects found in the stomach of one specimen by Hill (1974) (1) and Hill and Smith (1981) (5). It is suggested that the bat is a gleaner (catches insects on the ground and foliage), and might catch insects on the wing.

Many years later, a more intensive study on ecology, population size and distribution of the bats was conducted by Duangkhae (1990, 1991) (3, 4), and on echolocation call characteristic and feeding behaviour by Surlykke et al. (1993) (6). Both studies observed the bats in open-canopy forest areas.

Craseonycteris has two brief activity periods, one in the evening just after sunset and one in the morning before sunrise (3, 6). The bat forages at the time when insects are most abundant to optimize their energy gain. The foraging period of the bats varies seasonally but not more than one hour on each day (3). This is not common behaviour among bats, especially in small insectivorous bats, which normally have three feeding periods (7).

Duangkhae (1990) (3) found that *Craseonycteris* used specific flight paths (or flyways) to reach their foraging areas, which were less than 1 km from their roost cave. The numbers of bats in each flyway varied daily and seasonally. The major purpose of the flyways might be for minimizing the energy cost of foraging.

While hunting, *Craseonycteris* usually circled, often swooping up and down, in a small patch of foraging area about 10 m in diameter (3). Their hunting areas were uncluttered, open field, and not semi-cluttered, and far from all vegetation within the detection range in open areas, around 2-5 m above the ground. They flew fast and fluttered with many sharp turns, showing high maneuverability. The echolocation call of the bats in the search phase is a high intensity, constant frequency (CF) signal with a peak at 73 kHz (6). Surlykke et al. (1993) (6) suggested that the bats are not gleaners but seize insects directly on the wing in the open. They also noticed that the bat had an unusual echolocation call structure for gleaning.

The observations that the bat are open aerial feeders in unobstructed area are contradicted to previous studies by Hill and Smith (1981) (5) and Nabhitabhata (1986) (8), which suggested the possibility of foliage gleaning in cluttered or semi-cluttered areas from examination of stomach contents, and also contradicted to Lekagul and

McNeely (1977) (2) who observed that the bats flew around the tops of bamboo clumps and teak trees, suggesting that *Craseonycteris* was a foliage gleaner.

The diet of *Craseonycteris* was investigated on two occasions using stomach contents analysis, once by Hill and Smith (1981) (5), and also by Nabhitabhata et al. (1982) (9 cited by 10) and Nabhitabhata (1986) (8). The data showed a variety of taxonomic classes of insect including Diptera, Hymenoptera, Psocoptera, Hemiptera, Orthoptera, Coleoptera and Homoptera, and also fragments of spiders. Sizes of insects found also varied from 2-3 mm to 10-12 mm. Unfortunately, these data were obtained from only two specimens, and provided no possibility of determining whether the bats were specialists on some certain groups or sizes of insects or were generalists/opportunists.

In his study of population size and distribution, Duangkhae (1990, 1991) (3, 4) searched 51 caves in the limestone range in the west of Thailand between 1983 and 1984 and found approximately 2,000 individuals of *Craseonycteris* in 21 caves confined to a relatively small area in dry evergreen forest, mixed deciduous forest, and dry deciduous dipterocarp forest. No cave with the presence of bat was found above latitude 14°45'N or below latitude 13°45'N. The presence or absence of the bats could be predicted by three cave characteristics with about 88% certainty. The bats preferred roosting in complex caves with many chambers. The colony size of the bats per cave was about 100 individuals on average, while the maximum number was not greater than 500. There was no correlation between actual numbers per cave and cave characteristics in those caves where *Craseonycteris* were present, but the number of bats per cave was greater in caves located in the dry evergreen forest near the river than in caves located farther from the river in the mosaic forest composing of both mixed and dry deciduous forest.

Craseonycteris are very sensitive to disturbance in their roost cave; they usually fly immediately after being disturbed. This meant that the very small bats could not survive in caves where tourism was promoted, since frequent disturbance may prevent them from conserving the energy that they must gain in a very short period of feeding time on each day, the numbers of bats in the two original caves where they were discovered at Sai Yok and Wang Pra cave decreased significantly after tourism was promoted, from 200 individuals to 50 and then 20, and many years later, no *Craseonycteris* could be found either of these caves anymore (3, 4, 11).

The data above suggest some unique characteristics of *Craseonycteris*. They are the smallest mammal in the world, can be found only in a confined area of western Thailand at low densities. They have only two brief foraging periods, and are very sensitive to disturbance in the roost caves. They are only the species in the newest family of bats to be named in the world. Some of these characteristics make them valuable for collectors, both scientists and non-scientists, and also make them vulnerable to habitat change around their roost caves, and disturbance within the caves.

Craseonycteris has been listed as an endangered species by The World Conservation Union (IUCN) for a long time, because the total population was less than 2,500 bats and distributed in small groups, with most groups smaller than 250 individuals. They were also found in a very confined area where habitat has been continuously destroyed by human activities and the population was recognized to be declining continuously (12).

There has been no study on the status and population trends of *Craseonycteris* for more than ten years, while the alteration and destruction of habitats and caves by a variety of human activities continues in these areas. In fact, there has been no study on the ecology of this bat in areas where habitat is being altered, to determine whether the bats can adapt themselves to change in habitats.

The purpose of this study was to determine the population trends by comparing the data with the previous study in 1983-1984 by Duangkhae (1991) (4) and to determine if there are any human activities that might affect the survival of this endemic and endangered bat in its foraging habitats and also in the roost caves. This study was done in three steps.

The first step was to search for and monitor populations of the bats in association with type of habitats around the caves and disturbance level within the caves. The second step was studying the flyways and microhabitat use by the bats in three different habitats. The third step was examining habitat preferences of the bats in patchy habitat composed of forest and cassava plantation.

The following is some general information about bats. It is given here as a background for anybody who is interested in *Craseonycteris*, but is not familiar with the biology of bats.

Most insectivorous bats use echolocation calls for navigation and detection of their prey. The sounds emitted by bats are species-specific; each species has its own frequencies and structure which are related to body size and wing morphology. Both echolocation calls and wing morphology are related to flight style, feeding habit, and the habitat/microhabitat preference of the bats. Many bat researchers have predicted habitat preference, flight style and echolocation call characteristics of bats from their morphology, and vice versa: some researchers predicted characteristics of bats from the type of habitat and found that observations in the field fitted the prediction. This means that bats are physically and behaviourally adapted for different kinds of foraging areas (13, 14, 15, 16, 17).

Most bat species, however, are flexible feeders and can show considerable plasticity in their foraging style. They can forage in a wide range of microhabitats, shift their habitat use, and eat a variety of insects, especially if there is influx/efflux of species due to season, or the area undergoes long term habitat change (18, 19). In addition, they might change their style according to situation or time. Arlettaz (1996) (19) found that mouse-eared bats (*Myotis myotis* and *Myotis blythii*) change their strategy from gleaner to aerial hawker when insects were present in huge concentration and Neuweiler (2000) (20) suggested that the horseshoe bat (*Rhinolophus rouxi*) employs a combination of aerial and gleaning strategies depending on the time of day.

There have been few studies on food preferences of insectivorous bats. The studies support the bats as both selective and opportunistic foragers. Several workers have noted that insectivorous bats foraging in the same place consume the same kinds of insects (21, 22) and most have concluded that most bats are generalists/opportunists (7, 8, 15, 18). However, some workers have suggested that some bats are specialists. They select their prey by size or species, and may change their food or feeding area in relation to the abundance of certain kinds of insects (23, 19).

The general prey foraging model predicts that small insectivorous bats which catch insects on the wing should be generalists or opportunists since the handling time is so small in relation to searching time (24, 18). By this prediction, and given the fact that *Craseonycteris* fed on wide variety of insects (5, 9 cited by 10, 8), this bat may be considered to be a generalist. They should eat all edible prey of the right size that they can be detected.

CHAPTER II

DESCRIPTION OF STUDY AREAS

2.1 Step 1: Population Monitoring and Cave Survey

The study area was located in the west of Thailand, the only area where *Craseonycteris* has been reported to exist, in Sai Yok and Thong Pha Phum District, Kanchanaburi Province. The location of surveyed caves is presented with the limestone range and topographic map in figures 2.1 and 2.2 The overall region covered by the survey was about 440 km², and can be divided into four areas (Figure 2.2).

The first area is located in and around the border area between the east side of Sai Yok National Park and west side of Erawan National Park between 98°53'-99°04'E and 14°12'-14°21'N. The area covered was about 124 km². The hill areas are composed of mixed deciduous and bamboo forests while most areas in the plain are degraded and invaded by local villagers for agriculture and settlement. Local villagers grow rice, cotton, cassava, corn, lemon, orange, sesame, castor, and kapok. They still clear the jungle for expansion of their agricultural area, and slash-and-burn occurs every year in the dry season (Figures 2.3, 2.4).

The second area is located close to the first area, in the area around Sai Yok National Park headquarters between 98°48'-98°52'E and 14°24'-14°26'N. The area covered was about 22 km². This area contains the original cave where *Craseonycteris* was discovered. The area contain mixed deciduous forest with bamboo clumps, dry evergreen forest, teak plantations, some abandoned agricultural areas, and human

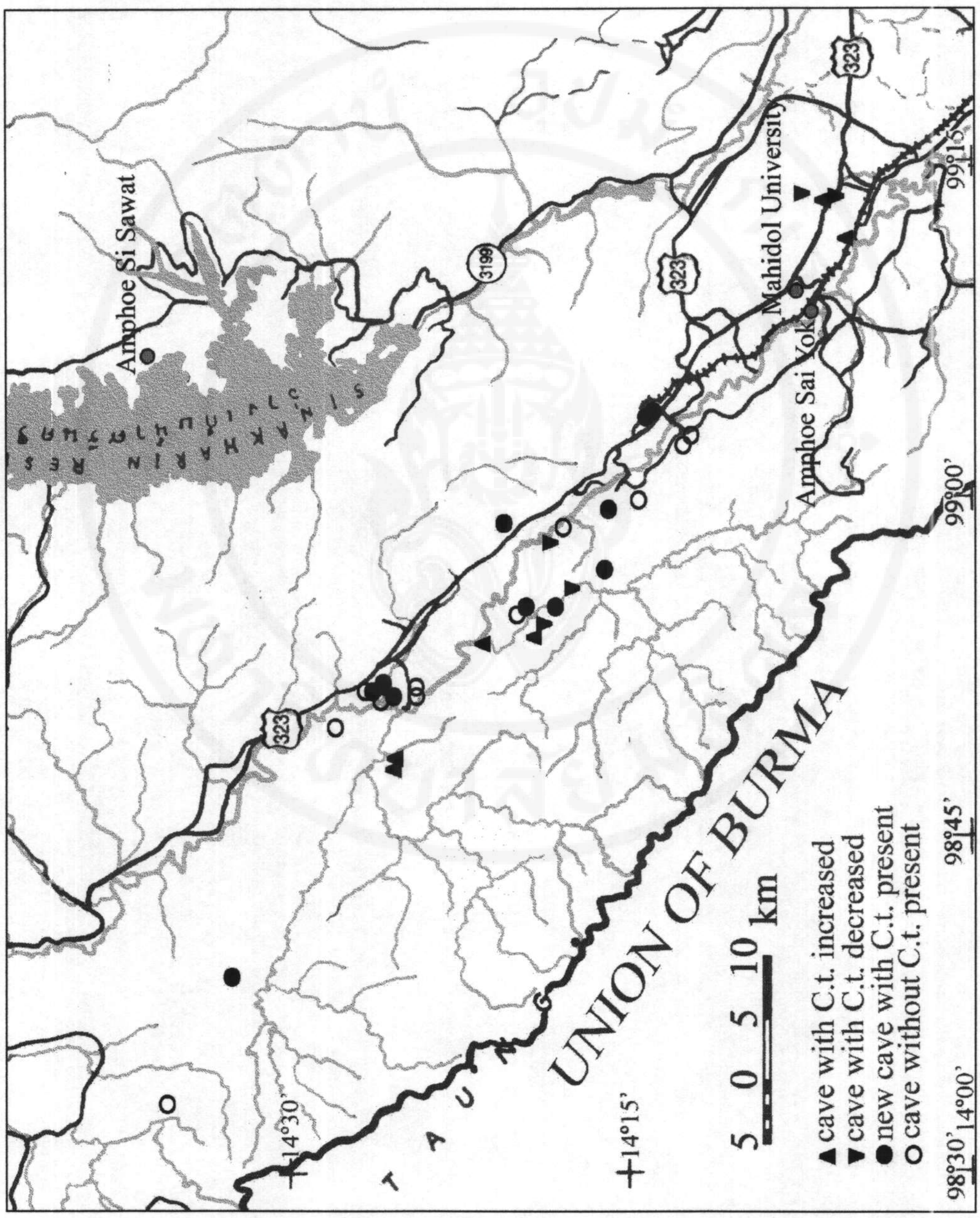


Figure 2.1 Location of the surveyed caves. The change in the population and presence/absence were compared with the study of Duangkhae (1991). C.t. is *Craseonycteris*.

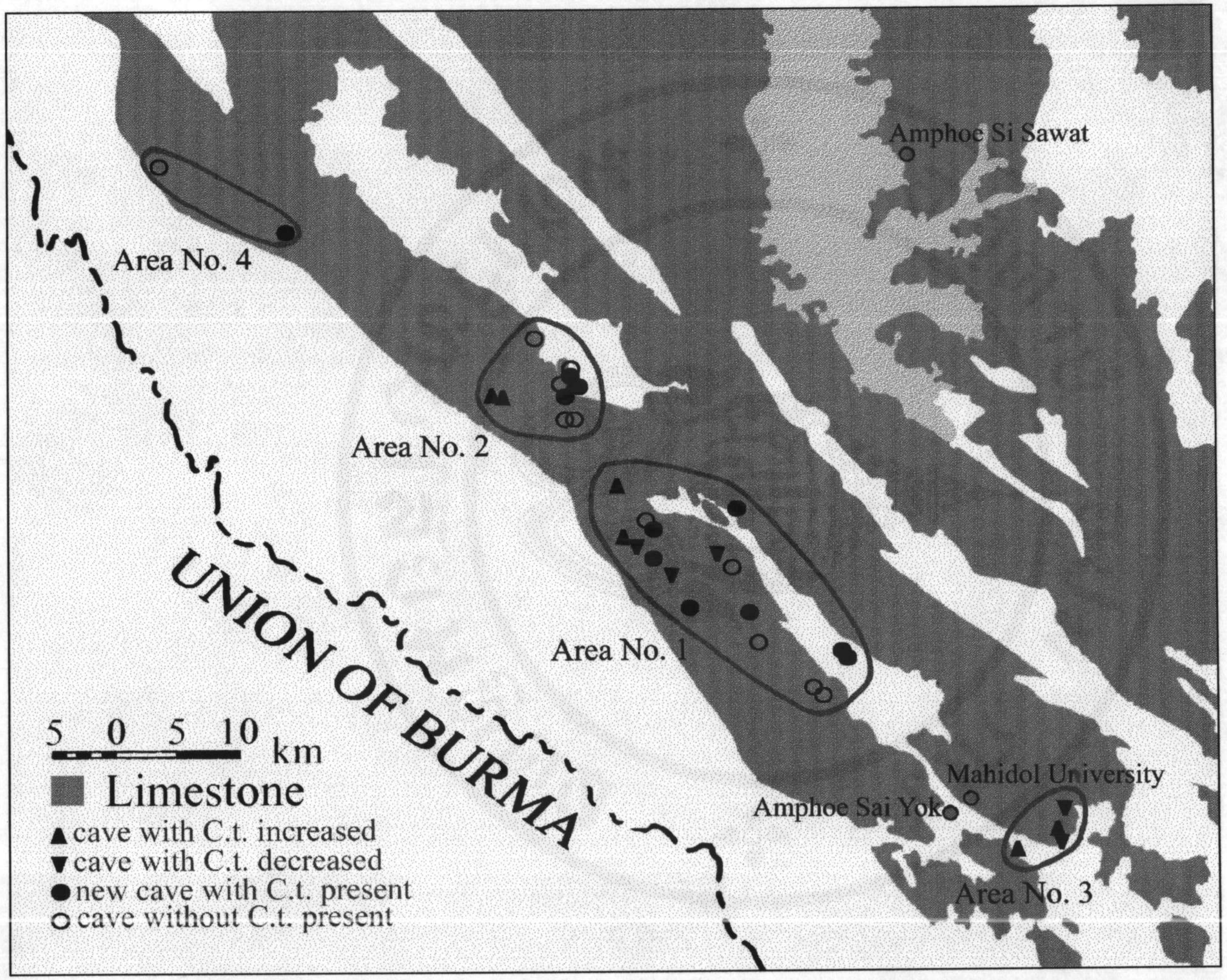


Figure 2.2 Location of the surveyed caves in the limestone range and study area in the west of Thailand. The change in the population and presence/absence were compared with the study of Duangkhae (1991). C.t. is *Craseonycteris*.

Figure 2.3 Forest in Area No. 1, wildfire occurs every year in dry season.

Figure 2.4 Bamboo forest in Area No. 1, local villagers continue to clear the forest for expansion of agriculture area.

settlements. This area is faced with heavy tourism, especially on holidays and weekends. Tourists' activities are picnicing, swimming, rafting, camping, sightseeing, and cave exploring. However, most caves were not heavily visited except Cave No. 63, which is located very close to Pu Ton Num, campground and National Park headquarters.

The third area is located near Amphoe Sai Yok at 99°10'-99°14'E and 14°06'-14°08'N. The covered area was about 8.5 km². Survey caves in this area can be divided into two groups. The first group is located in the plain and comprises mostly degraded dry deciduous dipterocarp forest (Figure 2.5) and cassava plantation (Figure 2.6). The second group contains of only one cave located in a separate area where tourism is promoted. Around the area of the second group, humans occupy most areas in the plain and there are buildings, resorts, railway, houses, and agricultural areas. Mixed deciduous forest and bamboo clumps are left only on the hills.

The fourth area is located north of Sai Yok National Park between 98°33'-98°39'E and 14°32'-14°35'N in Huai Khayeng forest reserved area, the area proposed to be declared as Thong Pha Phum National Park. Only two caves, which located around 11.5 km apart, were found in this area and the area is composed of dry evergreen forest, bamboo forest, mixed deciduous forest, teak plantation, agricultural area and human settlement. Most areas where the survey was conducted are located not far from the Yadana gas pipeline of the Petroleum Authority of Thailand (PTT).

Most of the study areas are located outside of protected areas of the Royal Forest Department and are degraded and invaded by human activities. Habitat alterations have created a landscape mosaic of the remaining forest, agricultural areas, and structure for human amenities. The forest area was dominated by mixed

Figure 2.5 Degraded dry deciduous dipterocarp forest in Area No. 3.

Figure 2.6 Cassava plantation in Area No. 3.

deciduous forest and bamboo forest, but most has been disturbed and now remains mainly on the hills. Local villagers continue to clear the forest for expansion of agriculture area, and slash-and-burn farming occurs in nearly all areas, both on the hills and in the plain.

Many caves in the survey area were disturbed or altered by a variety of human activities; some were occupied by monks, some were promoted for tourism and some for other activities. The details of the surrounding habitat, human activities, and disturbance frequency in each cave are shown in Table 2.1.

2.2 Step 2: Habitat/Microhabitat Use and Flight Paths

Some sites around the caves were chosen for studying the use of habitat and microhabitat by *Craseonycteris*. Each selected site had different surrounding habitat including degraded dry deciduous dipterocarp forest to mosaic cassava plantation and mosaic village area. The details of each site are described below.

2.2.1 Site No. 1 was the area around Cave No. 30 (Figure 2.7), the only cave where flight paths or flyways of *Craseonycteris* were examined thoroughly in the past by Duangkhae (1990) (3). The area in the plain is degraded dry deciduous dipterocarp forest while on the hill degraded mixed deciduous forest with bamboo clumps are found. In general, the habitat has not changed much from the time when the study of Duangkhae (1990) (3) was conducted, but primary tall trees are more scattered due to logging. All weeds, herbs, and shrubs are burned in dry season and regrew in the rainy season each year. The vegetation type and climate of this area were described in more details by Duangkhae (1990) (3).

Table 2.1 Surrounding area, human activities and disturbance frequencies (Disturbance) of the surveyed caves in 1997.

Cave No.	Surrounding area	Human activities in cave	Disturbance
1	MD with BC, PT, human settlement, stream	occupying by monk in the past	1
5	MD with BC, PT, dirt road, stream	bat guano were harvested in the past	1
7	MD with BC, abandon area of PT	bats were hunted (less than 1 month before survey)	1
8	MD with BC, open area of PT	occupying by villagers in the past	1
10	MD with BC, DE, abandon area of PT		1
11	MD with BC, DE, abandon area of PT	occupying by monk in the past	1
16	BC, Eucalyptus PT, river	cave digging and occupying by villagers in the past	1
17	BC, Eucalyptus PT, river	cave digging and occupying by villagers in the past	1
18	BC, PT, river	tourism, alteration* for tourism	4
22	MD with BC, river, resort	occupying by monk	3
29	MD with BC, PT, human settlement		1
30	MD with BC, DD, cassava PT, human settlement		1
34	MD with BC, DD, cassava PT, human settlement, road	tourism, alteration* for tourism	3
35	MD with BC, PT, human settlement, railway, resort	tourism, alteration* for tourism	4
36	MD with BC, DD, cassava PT, human settlement, road	cave digging and occupying by villager in the past	2
52	MD with BC, PT, dirt road, human settlement		1
53	MD with BC, PT, dirt road, human settlement		1
54	MD with BC, DE, PT, village, railway, road, stream	bat guano collecting, tourism	3
55	MD with BC, DE, PT, village, railway, road, stream	monk activities, tourism	2
56	MD with BC, abandon area of PT, stream, dirt road	bat guano collecting	1
57	MD with BC, PT, lawn, human settlement, dirt road	occupying by monk in the past	1
58	BC, cassava PT, human settlement	occupying by monk	2

Continued on next page

Table 2.1 (continued)

Cave No.	Surrounding area	Human activities in cave	Disturbance
59	MD with BC, PT	bat guano collecting	1
60	MD with BC, abandon area of PT	tourism	1
61	MD, BC, river	tourism	2
62	MD ,BC	tourism	2
63	MD with BC, DE, PT, stream	tourism, alteration* for tourism	4
64	PT, abandon area of PT, near PTT gas pipeline	cave digging and occupying by villager in dry season	2
65	MD with BC, DE, near PTT gas pipeline		1
66	BC, PT, road	alteration* and occupying by monk	4
67	MD with BC, PT	occupying by monk/nun in the past	2
68	MD with BC	tourism	4
69	MD with BC, DE, PT, stream		1

Numbers of the cave before Cave No. 52 are original number of Duangkhae (1991).
DE: dry evergreen forest, MD: mixed deciduous forest, DD: dry deciduous dipterocarp forest, BC: bamboo clump, PT: plantation
*Permanent alteration with concrete, electric light and wire

Disturbance frequency

1 : none or rarely used
2 : used, but not frequently
3 : frequently used but not everyday
4 : heavily used, almost everyday

Almost all the area is occupied by proprietor or monks but is still not developed for anything except for a forest temple, which is located about 700 m from the cave.

2.2.2 Site No. 2 is located about 2 km southward from Cave No. 30 in the area around Cave No. 36. The forest area is connected with area of Site No. 1 and the habitat types are similar, both on the hill and in the plain. However, in this area, the villagers grow cassava in a vast area of the plain, and they also made a dirt road for maintaining their crops. This has generated a landscape mosaic of forest, cassava, eucalyptus, some mangoes and tamarind, and dirt roads. Local villagers continue to invade the jungle to expand their cassava area every year, and almost the entire area is burned in every dry season (Figure 2.8).

2.2.3 Site No. 3 was selected at about 22 km northwest from Site No. 1 and Site No. 2 in a small village near Sai Yok Noi Waterfall. The area comprises of a habitat mosaic of forest, plantation, orchard, and human amenity structures such as building, houses, railway station, temple, schools, bungalow, highway road etc. Mixed deciduous forest and bamboo forest is on the hill where Cave Nos. 54 and 55 are located, and on the hills nearby in the border area of Erawan National Park, where a small area of dry evergreen forest can be found in some areas close to the stream. Villagers occupy almost all areas in the plain; where they grow mangoes, tamarind, custard apple, coconut, corn, and cassava in some area near the hill and have constructed buildings, houses and other structures beside the road at the front of the hill (Figures 2.9, 2.10, and 2.11).

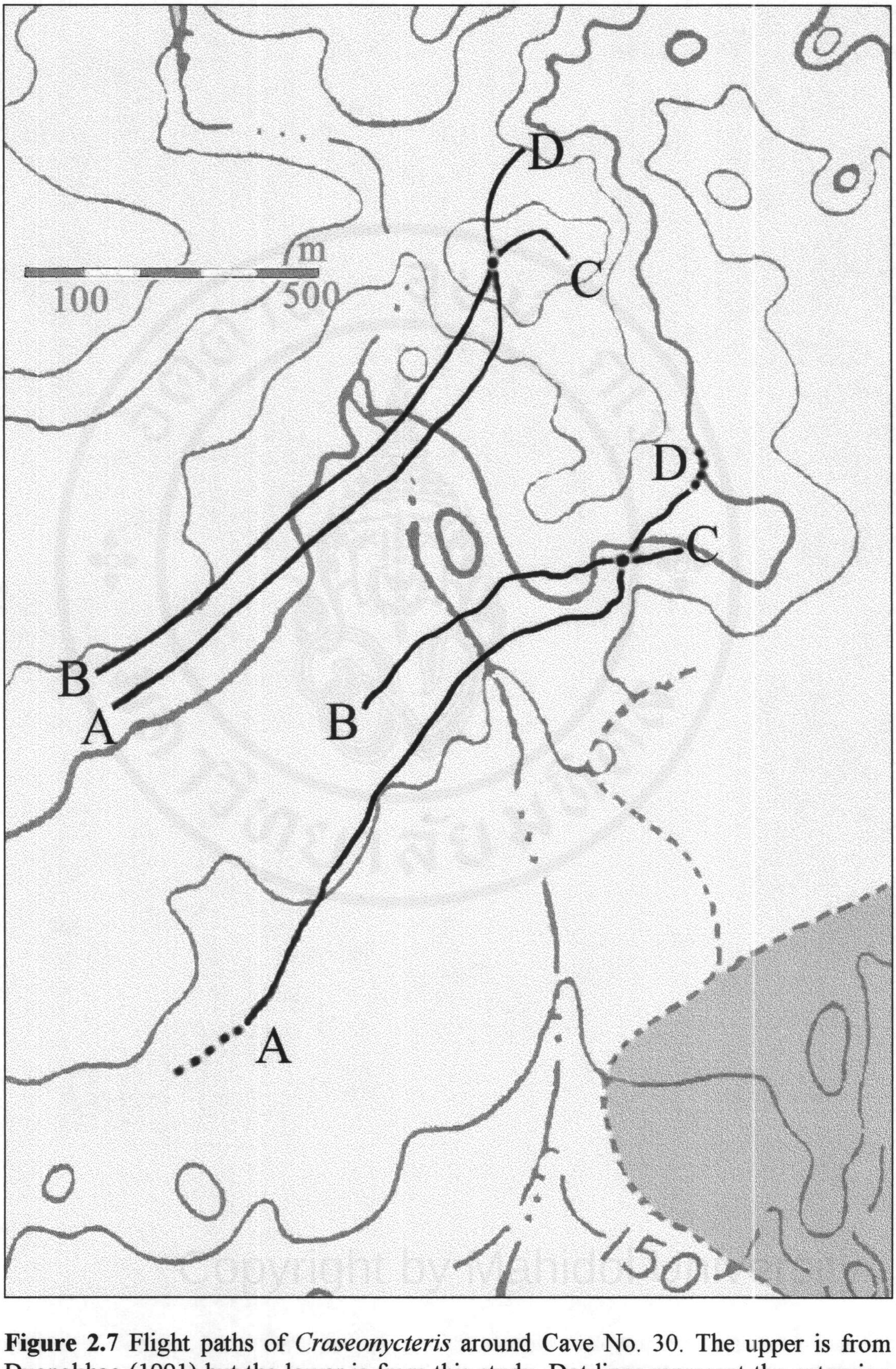


Figure 2.7 Flight paths of *Craseonycteris* around Cave No. 30. The upper is from Duangkhae (1991) but the lower is from this study. Dot lines represent the extension of flight paths from the past and gray area is area of forest temple. Difference in location of cave is due to better equipment (GPS).

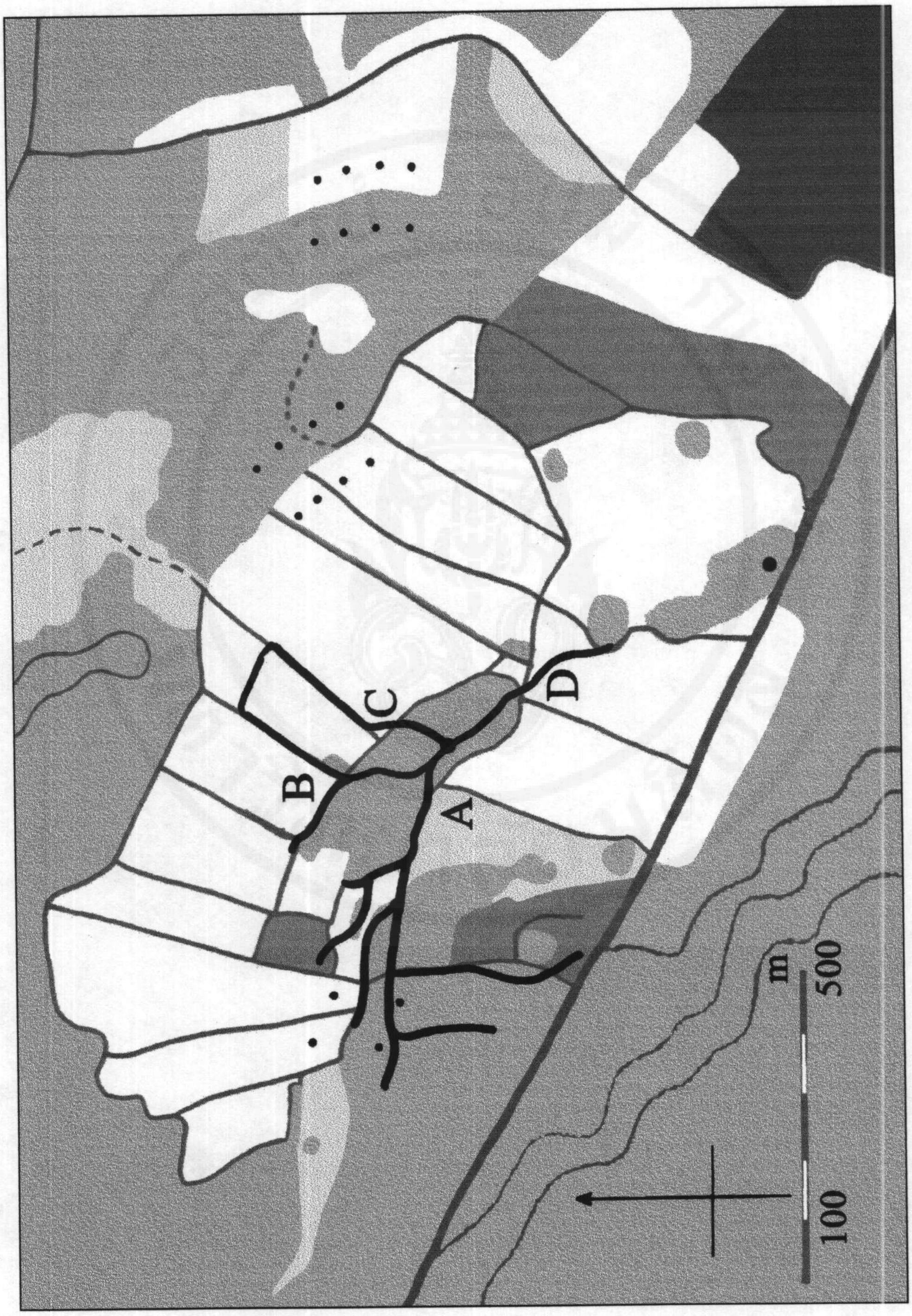


Figure 2.8 Flight paths of *Craseonycteris* around Cave No. 36 and the surrounding area. Large dots represent caves, small dots represent observation points in Step 3. White area is cassava plantation, light gray is weeds field with small shrub, gray is forest, dark gray is tree plantation (eucalyptus or fruit tree), and black area is human settlement.

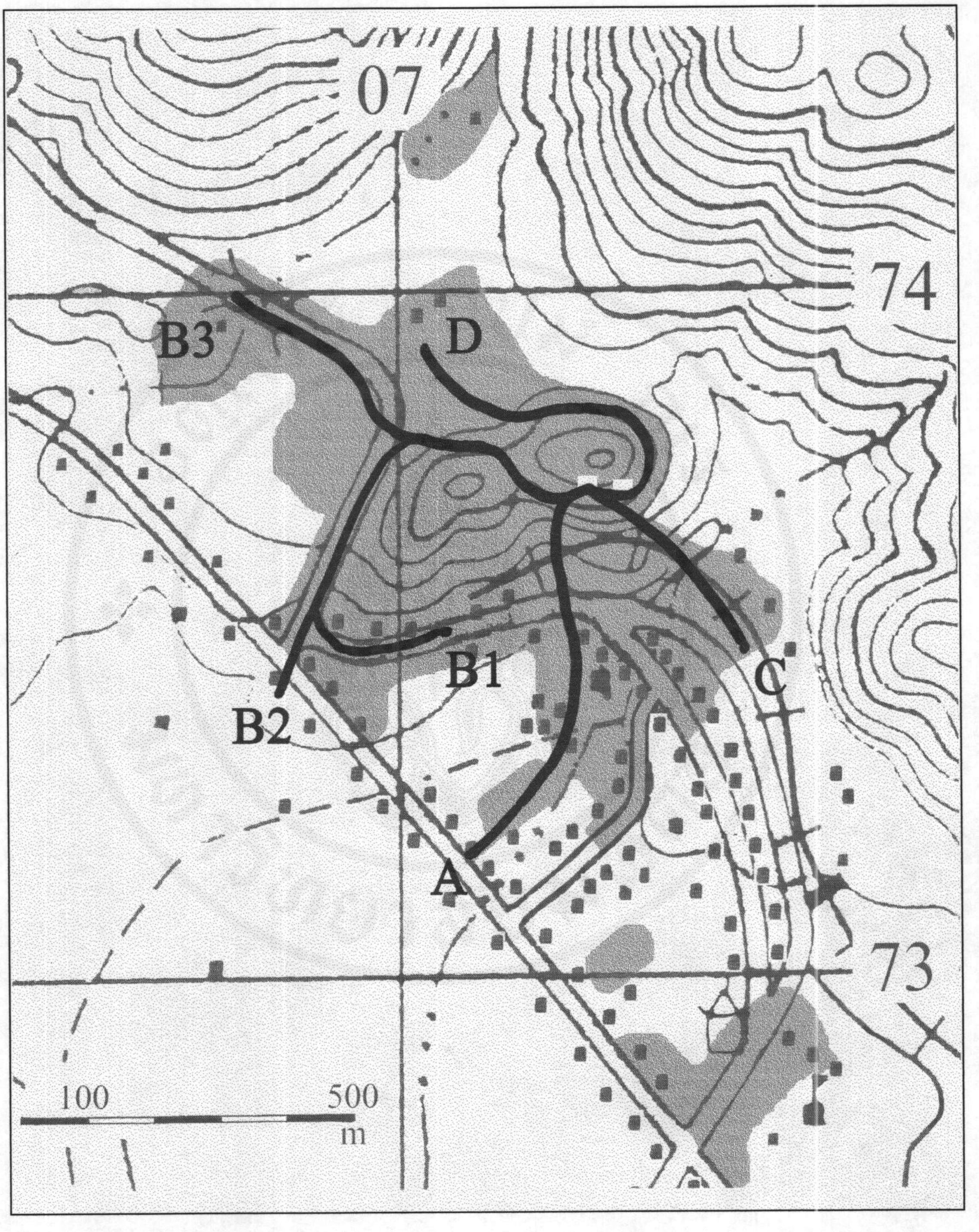


Figure 2.9 Flight paths (solid line) and feeding area (gray area) of *Craseonycteris* around cave No 54 and No 55. White rectangle on the hill represents cave No 54 (right) and No 55 (left).

Figure 2.10 Suburban area in Site No. 3 of Step 2.

Figure 2.11 Plantation area in Site No. 3 of Step 2.

2.3 Step 3: Examining Habitat Preference in Cassava-Forest Area

Examining habitat preference of *Craseonycteris* between cassava and forest area was carried out in the area around Cave No.36 (Site No. 2 of the last step). Forest area is degraded dry deciduous dipterocarp forest with scatter trees not taller than 5-10 m, most of the area has been logged and creating many open gaps covered with weeds, herbs, and small shrubs. At the time when the study was conducted, weeds were approximately 60-90 cm long and shrubs were not taller than 1.5 m (Figure 2.5). The plantation area comprised only cassava with a height around 60 cm, but almost all other plants were eradicated by the farmers (Figure 2.6).

CHAPTER III

METHODOLOGY

3.1 Step 1: Population Monitoring and Cave Survey

This work was done in two periods, the first period in Area Nos. 1, 2, 3 during Feb - May 97 and the second period in Area No. 4 in Oct 97.

Searching of the caves in the first period used the same key helper, Mr. Chong Cho-snab, who assist Mr. Surapon Duangkhae's study in Duangkhae (1991) (4) in order to find the original caves as many as possible, and also accompanied by local villagers if necessary. Searching for caves in the second period was conducted together with researchers from the Royal Forest Department in order to find *Craseonycteris* in the area near Yadana gas pipeline project, where the helper was an officer from the Royal Forest Department.

Geographical location at each cave entrance was recorded using handheld GPS (Global Positioning System) receiver (Magellan GPS 4000). Locations of surveyed cave were then compared with the locations of cave recorded by Duangkhae (1991) (4) to determine whether they were a new caves or cave where survey was conducted in the past. Number of the cave was recorded using the same number of Duangkhae (1991) (4) if it was the original cave, but Cave No. 52 was the beginning of new caves.

The following information was recorded in each cave: date of survey, number and local name of the cave, coordination in UTM (Universal Transverse Mercator), surrounding area/habitat, human activities and intensities within the cave, number and species of bats found, general characteristic and sketchy map of the cave.

Surrounding area and habitat type was determined within the distance of 1 km from each cave. Human activities and disturbance frequencies within each cave were determined by visual inspection and interviews with local guides and villagers nearby. Frequency of disturbance Type 1, the interruption of tranquillity (25), was categorized to four levels from level 1:never or rarely used, 2:used but not frequently, 3:used frequently but not everyday, and 4:heavily used almost everyday.

Numbers of *Craseonycteris* and other bats in each cave were estimated using a photographic method, direct counts, or visual emergence counts. The photographic method was used in caves containing not too complex caverns and crevices or in caves where direct counts and visual emergence counts were not possible. Photos of groups of the bats were taken using 35 mm SLR camera attached with wide angle lens and flash, the numbers of bats were counted from the photos after enlargement. Visual emergence counts were used in more accessible caves or caves where direct counts and the photographic method were not possible. Direct counts was the most preferred method since the bats were not disturbed much and yielded the most accuracy data but it could be used in only a few caves.

The population trend of *Craseonycteris* was determined by comparing the data in this study with previous data of Duangkhae (1991) (4). Numbers of *Craseonycteris* in each cave and percentage of caves with *Craseonycteris* presence in each disturbance level were plotted in comparison with human disturbance intensity in order to determine the tolerance of *Craseonycteris* to human activities within the cave.

3.2 Step 2: Habitat/Microhabitat Use and Flight Paths

This work was conducted during Feb - Oct 98 in three sites selected around Cave Nos. 30, 36, 54 and 55. *Craseonycteris* were traced to determine their flight paths when they emerged from their caves after sunset and when they returned to their caves before sunrise. This work was done when ambient light was bright enough for visual observation. Pettersson Ultrasound Detector model D230 was used to detect any *Craseonycteris* flying in the observed area accompanied with visual observation. The next *Craseonycteris* was followed immediately if it flew in the same direction to the previous bat in order to confirm the flight path. The bats were followed as far as possible until all of them had flown passed. Signs were marked along the track mostly with flagging. The flight paths were extended day by day; the terminal point of the previous day being the beginning point of the subsequent day. The map of flight paths at Cave No. 30 which had been examined by Dunagkhae (1990) (3) was ignored in this study while the bat was traced.

After all *Craseonycteris* had flown passed and tracing was no longer possible, feeding behaviour of *Craseonycteris* was observed. The height where *Craseonycteris* foraged above the ground were recorded corresponding to the type of habitat and microhabitat use such as above or below tree canopy, distance between bat and nearest landscape element, and the flight pattern of the bat; circling or flying through. Observation was done in ambient light; flashlight was used only when necessary to eliminate disturbance.

The flight paths were mapped later in daytime using optical bearing compass and laser rangefinder (Bushnell Lytespeed 400™) projected from the cave entrance associated with handheld GPS. A map of the area around Cave No. 36 was also drawn by the same method.

The flight paths at Cave No. 30 was compared with the paths in the previous study done by Duangkhae (1990) (3) to determine the change in the flight paths during 13 years period. While flight paths and habitat/microhabitat use at Cave Nos. 36, 54 and 55 were studied to determine the adaptability of foraging behaviour of *Craseonycteris* in altered landscape.

3.3 Step 3: Examining Habitat Preference in Cassava-Forest Area

This work was carried out during June - July 99 in the area near Cave No. 36 to examine habitat preference of *Craseonycteris* between cassava and degraded forest area. The 20 observation points were set up in 10 pairs along the forest-cassava interface. Each pair was located 50 m apart and each point in each pair was located 50 m perpendicular to the forest-cassava interface line; one in the forest and one in the plantation, the two point are therefore located 100 m apart (Figure 2.8).

A bat detector was tuned at 73 kHz in heterodyne mode and mounted to a pole at approximately 1 m above the ground. *Craseonycteris* activity was observed during 50 min period starting at 5 min after local sunset and 55 min before local sunrise. Local sunset/sunrise time was obtained from handheld GPS. *Craseonycteris* were observed using one-zero sampling with 5 sec time interval. Activity recorded in each time interval was scored if the sound of a bat could be heard through the bat detector without considering of numbers of sound emitted.

Two blacklight traps were set up together at distance around 40 m behind the observing point, or around 90 m perpendicular to forest-cassava interface line. The traps were hanged on two poles at 1.7 m above the ground and switched on at the time of local sunset and one hour before sunrise; these traps were operated for one hour before being switched off. Insects were collected in every time when the observation of *Craseonycteris* was conducted and were killed and dried before categorizing into 2 mm size classes from smaller than 2 mm (group A) to larger than 10 mm (group F).

The bat detector battery was replaced after using three times and the battery of the insect traps was recharged every time after use to eliminate any error that might occur from the voltage dropping.

Data were recorded in the darkness using light pen and illuminating digital watch for preventing disturbance to *Craseonycteris* that might occur from flashlight. Observations of *Craseonycteris* activity was done during nights with no strong moonlight or rain to prevent error from suppression of bat activity that has been found to occur in some bat species (7, 26).

Habitat use intensity that implies habitat preference of *Craseonycteris* was determined from the total score of interval times when the sound of a bat could be heard. Wilcoxon match-pairs signed ranks test was used for examining the differences of both *Craseonycteris* intensity and dryweight of insects between cassava and forest area. Correlation between habitat use intensity and dryweight of insects was examined using Spearman rank correlation.

These two statistical analyses were used to determine the importance of insect abundance as one factor which possibly determines patch selection and habitat preference of *Craseonycteris*.

CHAPTER IV

RESULTS

4.1 Step 1: Population Monitoring and Cave Survey

4.1.1 Population and distribution of *Craseonycteris*

Of 33 caves surveyed, 15 are original caves studied previously by Duangkhae (1991) (4) and 18 are new caves. Most of the caves up to 19 caves are located outside protected area while 11 are located in, and 3 caves are at boundary.

At least 2,656 *Craseonycteris* were found in 22 caves range from 1 to 560 individuals per cave with the median at 66. Among the caves where *Craseonycteris* were found, 50% or 11 caves contained fewer than 100 individuals, 40% or 8 caves had less than 30 individuals while only 20% or 4 caves have more than 180 individuals roosting therein. Hence the number of *Craseonycteris* in each cave was generally low (Table 4.1, Figure 4.1).

The distribution of *Craseonycteris* was clumped (Figure 4.2). Most of the bats up to 1,896 (71%) with a mean of 158 individuals per cave, were found in the first study area. The mean numbers were lower at 74, 94, and 15 individuals per cave in the second, the third, and the fourth area, respectively. In addition, most of the bat up to 1,590 individuals roosted in the caves outside protected area and 581 individuals were at boundary while only 385 individuals roosted in protected area.

Numbers of *Craseonycteris* in some caves varied by time of estimations but not all the bats abandoned their roost cave at the same time, this suggests that the bat might have more than one roost cave and a partial movement between caves by *Craseonycteris* might occur throughout the year (Table 4.2).

Among the 15 original caves of Duangkhae (1991), numbers of *Craseonycteris* had decreased in 5 caves, still no bat in 3 caves, increased in 4 caves, and had changed from negative to positive or the bat was present in 2 caves (Table 4.3). The highest number of increase was 98 individuals with a mean of 50, while the highest number of decrease was 294 individuals with a mean of 90. From these numbers, the population of *Craseonycteris* has slightly changed overall from 1,536 to 1,382 individuals with a mean of −14 individuals per cave. However, it is not possible to conclude that the population of *Craseonycteris* has actually declined due to the partial movement of the bats, which led to the fluctuation of numbers of the bat in each cave.

4.1.2 Human activities in the caves

Human activities found in the caves were tourism, bat guano collecting, hunting the bats for food, and living in some caves by monks (Figures 4.3, 4.4). Most of the surveyed caves are disturbed infrequently, mostly by local villagers for bat guano collecting. A frequently used cave was the caves promoted for tourism and caves occupied by monks. Some of these caves were altered permanently by concrete structures, electric wires and lights. Some caves had some signs of other human activities in the past such as digging the ground to find treasure, digging the soil for sale, and being lived in by humans (Table 2.1).

Table 4.1 List of caves and numbers of different species of bats. Ct: *Craseonycteris thonglongyai*, Ha: *Hipposideros armiger*, Hb: *Hipposideros bicolor*, Rm: *Rhinolophus malayanus*, Rp.: *Rhinolophus pearsoni*, Tm: *Taphozous melanopogon*, Ml: *Megaderma lyra*, Ms: *Megaderma spasma*, As: *Aselliscus stoliczkanus*, Es: *Eonycteris spelaea*, un: unknown

Cave No	Ct	Ha	Hb	Rm	Rp	Tm	Ml	Ms	As	Es	Un
1	134*	40									
5	19	50									
7	6	8									
8	560					11					1
10	145	159									*Rhinolophus* 1
11	1										*Megaderma* 5
16						121					10
17											*Megaderma* 4
18		506									2
22	142		120			727					
29	>100		un								3
30	66										un
34	4										
35	248*										20
36	57*	46			1						*Rhinolophus* 12
52	380										
53											
54	8										*Megaderma* 12
55	119	120				50					
56	15	93									
57	299	45		1							
58		200		4			1				
59	114	40	60								*Rhinolophus* un
60	10							7			
61											3, *Megaderma* 1
62	175*	63							20		
63	39	1			3						
64	15	108		un		un			20	un	*Megaderma* un
65		104									un
66					1						
67								5			
68		30			un				3		
69					1						*Megaderma* un
Total	2,656	1,613	180	5	6	909	1	12	43		

Numbers of the cave before Cave No. 52 are original number of Duangkhae (1991).
*Numbers of bat vary by time of estimation (see Table 4.2).

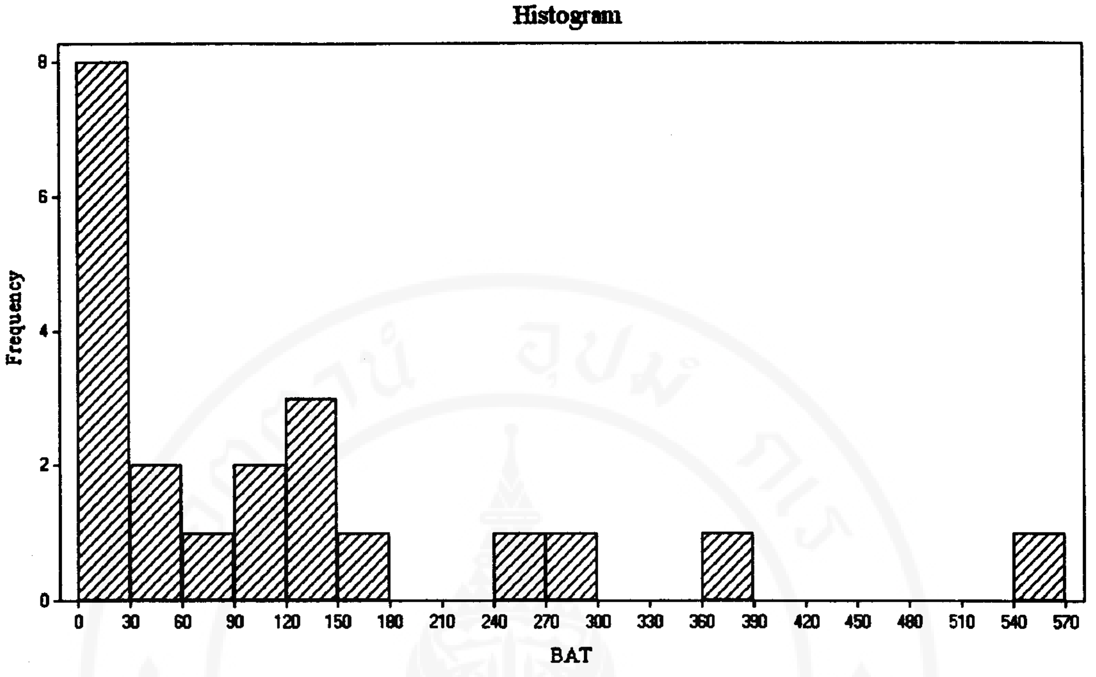


Figure 4.1 Histogram of cave frequency (vertical axis) and number of *Craseonycteris* (horizontal axis) found in each cave.

Table 4.2 Fluctuation of number of *Craseonycteris* in some caves where repeat estimations were conducted.

Cave no.	Jan 97	Feb 97*	Mar 97	Apr 97	May 97	Oct 98
1		106, 134				88
35			150	256	248	149
36			14		57	
62	<100			187	175	

Estimations in Feb 97 were conducted two weeks apart

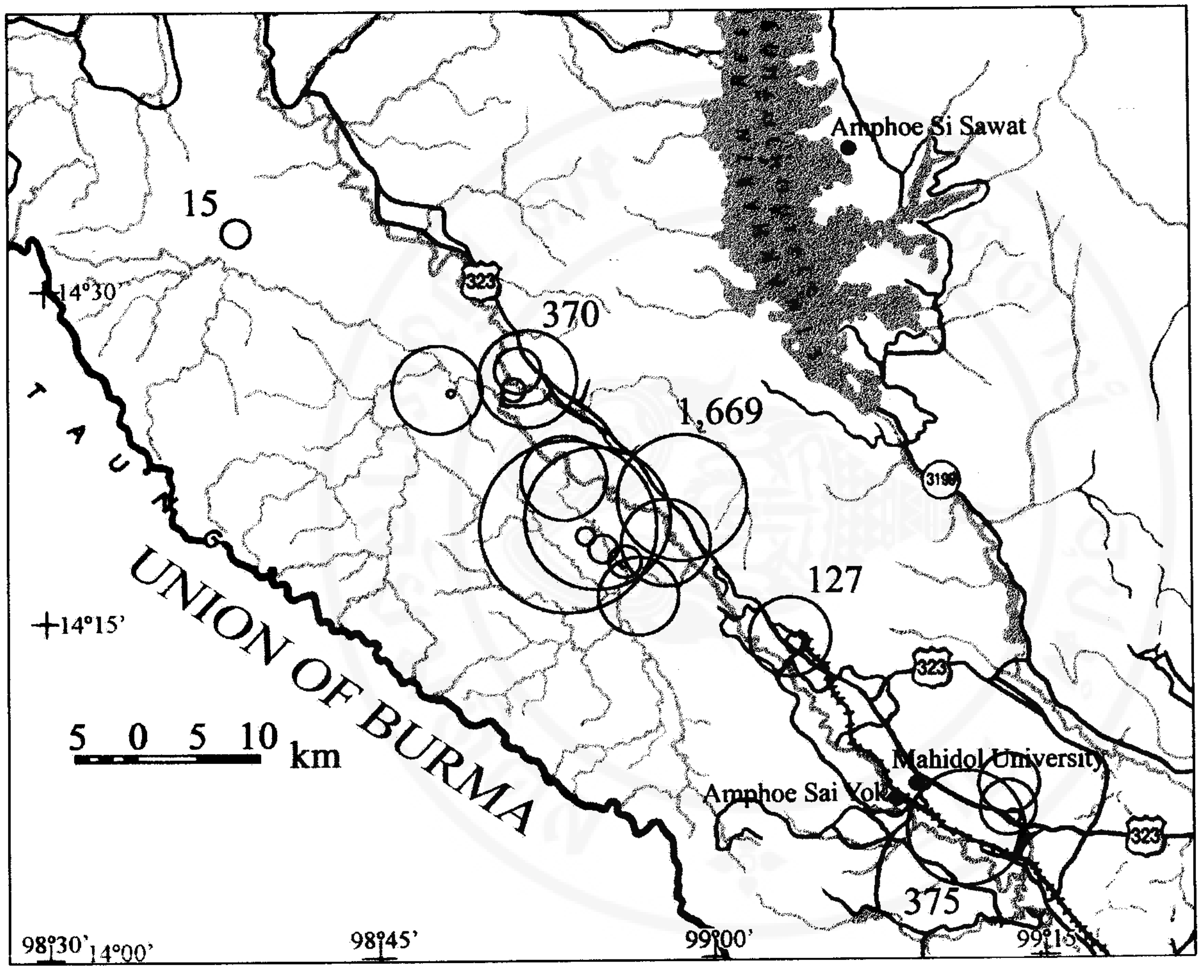


Figure 4.2 Bubble plot (circle) represents distribution and number of *Craseonycteris*; size of circle corresponds to population size of the bat in each cave. The number beside a group of circles is a population size of the bat in each group. The data does not include Cave No. 29.

Table 4.3 Population of *Craseonycteris* in some caves where estimation has been conducted in the past. Total number does not include Cave No. 29.

Cave	No. of bat at present	No. of bat in the past	No. of change	% of change
1	134	130	4	3
5	19	80	-61	-76
7	6	300	-294	-98
8	560	500	60	12
10	145	68	77	113
11	1	0	1	Present
16	0	0		
17	0	0		
18	0	0		
22	142	200	-58	-29
29	>100	Data not available		
30	66	70	-4	-6
34	4	38	-34	-89
35	248	150	98	65
36	57	0	57	Present
Total	1382	1536	-154	-10

4.1.3 *Craseonycteris* and cave disturbance

When *Craseonycteris* are disturbed, they react firstly by emitting echolocation sounds to determine the situation. If the disturbance continues for some certain time or certain degree, such as by strong flashlight or the intruder approaches too close, the bats then fly away from their roosting site within the cave to temporary roosting sites in crevices or small chambers.

Craseonycteris might ignore some potential roosting sites if the disturbance occurs continuously, observation in Cave No. 57 where a monk stayed there intermittently found the bats roosted in more disperse area when the monk abandoned the cave for some certain time but roosted in a more confined area, almost all in only small chambers, when the monk returned to live there. In addition, numbers of *Craseonycteris* changed from negative to positive in two caves when heavy disturbances occurred in the past but they are stopped now, at Cave No. 11 where a monk used to live there, and at Cave No. 36 where the local villagers used to dig the cave ground for sale (Figure 4.5).

Although this study found *Craseonycteris* in caves at all level of disturbance levels, percent of *Craseonycteris* present and numbers of the bats in each cave tend to decrease according to disturbance level (Figure 4.6, 4.7 and Table 4.4). In addition, in four caves where *Craseonycteris* roosted with the highest numbers, three are level 1 (Cave Nos. 8, 52, and 57) and one is level 4 (Cave No. 35) disturbance. Almost all *Craseonycteris* in those caves roosted in isolation from other bat species in chambers or crevices, which were impossible or very difficult for humans to access, and hence the disturbance was minimal.

Table 4.4 Number of caves with and without *Craseonycteris* and disturbance level.

Disturbance level	Number of cave	Bat present	Bat absent
1	18	13	5
2	7	4	3
3	3	3	0
4	5	2	3

Figure 4.3 Some of the surveyed caves were used for religious practices.

Figure 4.4 Hand net, the equipment that some villagers used for catching a bat.

Figure 4.5 Cave No. 36 where local villagers used to dig the cave ground for sale.

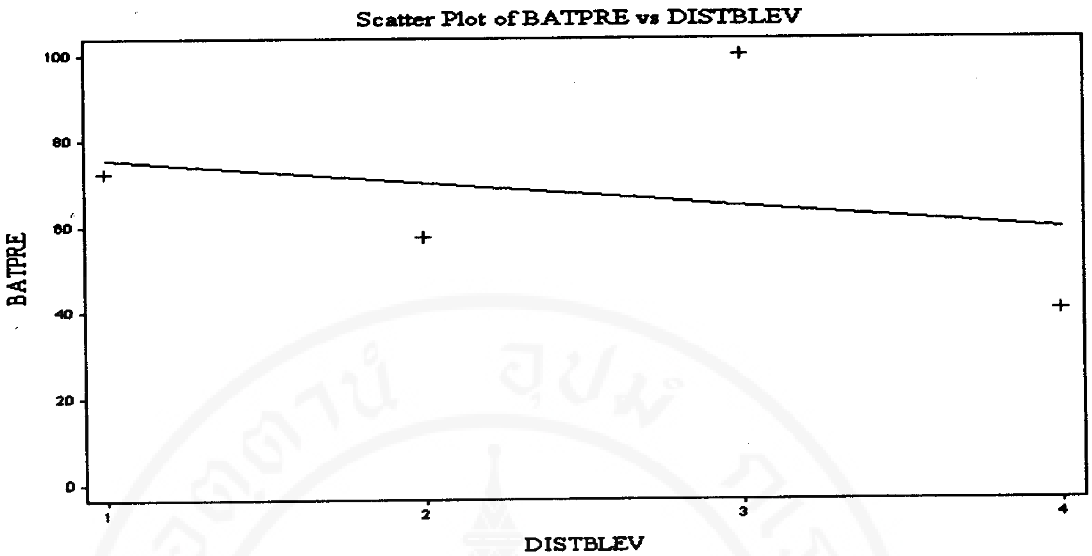


Figure 4.6 Scatter plot of percentage of caves with *Craseonycteris* present in each disturbance level (vertical axis) and disturbance level (horizontal axis).

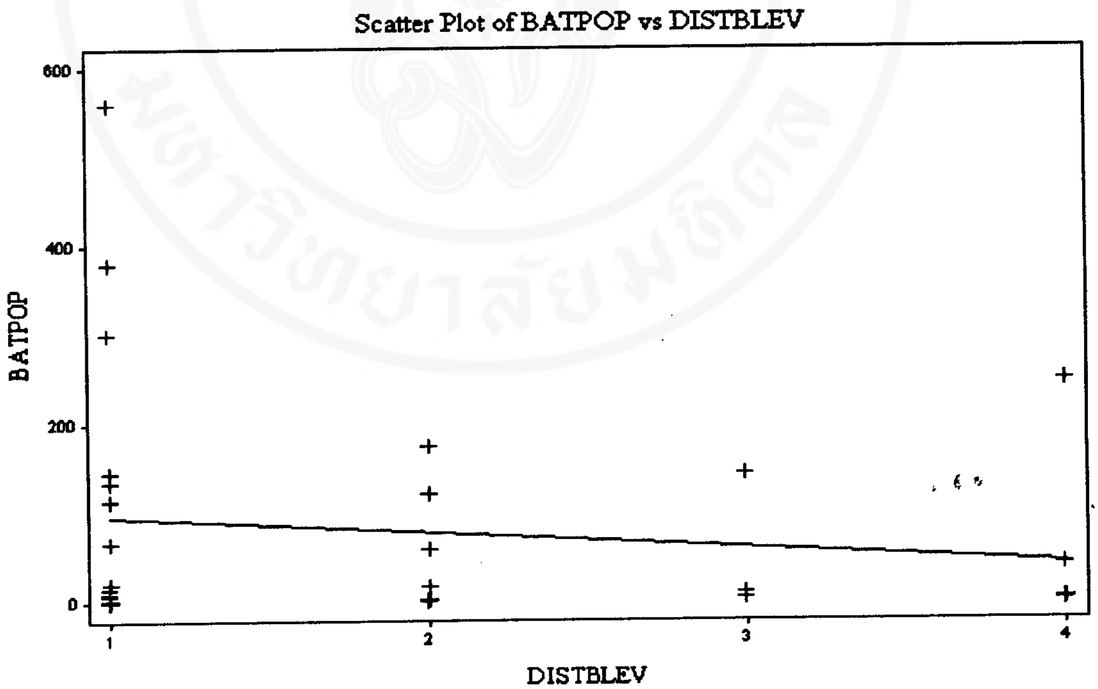


Figure 4.7 Scatter plot of number of *Craseonycteris* (vertical axis) and disturbance level (horizontal axis) in each cave.

The population of *Craseonycteris* in the caves surveyed by Duangkhae (1991) (4) also changed in accordance with disturbance level. Among the four caves where the numbers of *Craseonycteris* have markedly increased, three (Cave Nos. 10, 11, and 36) are disturbed less compared with the previous survey (interview with local guide). In addition, among the four caves where the number of bats have markedly decreased, two are disturbed continuously (Cave Nos. 22 and 34) and one faced with hunting pressure (Cave No. 7).

4.2 Step 2: Habitat/Microhabitat Use and Flight Paths

4.2.1 Flight paths of *Craseonycteris*

Craseonycteris used specific flight paths to commute between roost and feeding area in all sites studied, the details of each site are described below.

4.2.1.1 Site No. 1: Cave No. 30

Four flight paths or routes were found at Cave No. 30 in the same direction as the previous study of Duangkhae (1990) (3). Routes A and D were traced through their terminal points reported in Duangkhae (1990) (3) while Routes B and C were not which was due to a limitation of time and the low number of *Craseonycteris* in those routes during the time of study (Figure 2.7).

At Route A, *Craseonycteris* was found to fly to a point reported as the terminal point where the distance is approximately 1 km from the cave entrances and the landscape looks similar to the point studied by Duangkhae (1990) (3) (Duangkhae pers.com.). However, *Craseonycteris* was not found to fly beyond this point in the previous study but in this study some of the bats at low number around 1-3 individuals flew beyond this point on some days to forage in the area where other

Craseonycteris had arrived from the opposite direction, or from an other cave. Almost all *Craseonycteris*, which were found to forage in this area flew in the opposite direction to Cave No. 30 when feeding was finished, suggesting that Route A might be connected with a flight path of an other cave.

Craseonycteris was also found to fly beyond the terminal point of Route D. But at this route, the bats did not extend their flight path further from the past since it was an unfinished route (Duangkhae pers.com.).

In general, the flight paths of *Craseonycteris* from Cave No. 30 have not changed from 13 years ago, or if so, only slightly. The different shape of flight paths and location of the cave in Figure 2.7 stem from the more sophisticated and precise tools and technique (GPS and laser rangefinder) which have developed more in the time of this study.

4.2.1.2 Site No. 2: Cave No. 36

Flight paths of *Craseonycteris* at this site began in four directions from the cave entrance (Figure 2.8). Path A went to the west along the edge of forest close to a dirt road for around 200 m before splitting into many paths mostly along some linear landscape elements such as cassava-grass field interface, dirt road, border of the jungle, and long gap in the forest area. Path B was located in the same direction as Path A for 60 m before turning to the north along a saddle-back of the hill and then splitting into two paths, one turning left along the forest border and another along the dirt road and connecting with Path C by a dry water course. Some *Craseonycteris* flew along one path (B or C) to forage around the small tree in the course and returned by using either the same or another path. Path D is located along a gap within the forest area on the hill. The bats in this path foraged along the border area on both sides of the hill and some bats flew in the direction of Cave No. 34 in some occasions. On this path, some bats from Cave No. 34 were also found to commute to the area around Cave No. 36.

4.2.1.3 Site No 3: Cave Nos. 54 and 55

Although *Craseonycteris* were found in both caves nearly all the bats roost in Cave No. 55, and since the two caves are located close to each other and are connected together by one flight path, the study focused only on the flight paths of Cave No. 55. *Craseonycteris* flew from the cave entrance in two directions, one to the west and another to the east (Figure 2.9).

The flight path to the west split into two paths at a distance of around 40 m from the cave entrance; one turned right crossing the saddle-back of the hill and split again into three paths along the side of a dirt road (Paths B1, B2, and B3) while another turned left cross the unused railway to the south (Path A).

The flight path to the east was found along the cliff for some distance near the cave entrance before splitting into two paths; one passes Cave No. 54 and turns left along the curve behind the hill (Path D) and another went down to the foothill and extend parallel to the unused railway (Path C).

However, flight paths there seemed not to be too strict; some *Craseonycteris* flew across between paths such as from Path D to path B along the hill and from path B (before split) directly to path B1.

Craseonycteris was mostly found to use linear landscape elements as their flight paths. They flew along vegetation beside dirt roads in Paths A, B1, B2, and B3, along the side of railway in Path C and in the tree lane within plantation in Path D.

Overall, flight paths of *Craseonycteris* in the more natural habitat around Cave No. 30 did not change for over ten years and comprised of only simple, no-split paths, while flight paths in altered landscape mosaic split off into many paths along some linear landscape elements. The bats in altered sites (Site Nos. 2 and 3) also showed less strictness to flying along certain paths, and they frequently flew across between the main paths while foraging.

4.2.2 Habitat/microhabitat use of *Craseonycteris*

Craseonycteris can forage in many kinds of habitat such as in forest, tree plantations, over dirt roads, along tree lines beside a road, around buildings or big trees, and in forest gaps. However, the bat was never found circling in open areas above cassava plantation, lawn, or tree canopy.

The bats always kept some distance from the nearest landscape elements such as ground, vegetation, and buildings, usually around 1-3 m. However, it can fly very close to a surface such as tree bark or dirt road surface, possibly to catch an insect, but the occurrence was rare. The elevation of the flight depended on the landscape elements nearby from around or lower than 1 m above the ground in a forest gap and over a dirt road, up to more than 20 m along a gap between canopy and understorey of tall trees in a dry evergreen forest.

In the degraded dry dipterocarp forest of Sites No. 1 and 2, *Craseonycteris* flew along open space between tree canopy when commuting at a height not higher than the canopy itself mostly around 2-5 m. They circled around 1-3 m above the ground in small gaps not far from nearby trees when feeding. They circled over small areas to feed at a particular point for around 1-5 min before moving to an other point (Figure 4.8).

Craseonycteris did not use open space above the tree canopy as their feeding ground. If the tree canopy is closed and too dense for the bat to fly through, as in an early succession forest, they just flew passed above but did not circle around for feeding. The bats also heavily used the edge of the forest beside a road and a cassava plantation in the area around Cave No. 36. They circled beside a road along the edge of the forest, flying out over the cassava area on some occasions but not further than 5 m from the edge and usually flew back after an instant.

In an area where vegetation is larger and taller such as in the dry evergreen forest of Site No. 3, *Craseonycteris* flew at higher elevation up to 20-25 m in the space between tree canopies. If the canopy was closed and the lower storey was high enough, the bats then circled for feeding with elevation up to 20 m. They did not forage in a dense and cluttered foliage, and also used gaps between trees as their feeding ground like in a degraded dry deciduous dipterocarp forest.

Craseonycteris was never found to circle above cassava plantation but flew passed rapidly at a short distance so that they can cross to other area of a forest. Some of them commuted along a dirt road to feed around small shrubs in a dry water course (Paths B and C, Figure 2.8) and stopped over in some points along their route for feeding, usually for a short period with the height not higher than around 1.5 m above the road surface.

They also heavily used the area around the canopy of big trees standing alone in the cassava near the dirt road close to forest patches as their feeding ground. In this area, *Craseonycteris* flew around but not above the tree canopy and usually kept a certain distance, around 1-2 m, from the vegetation (Figure 4.9).

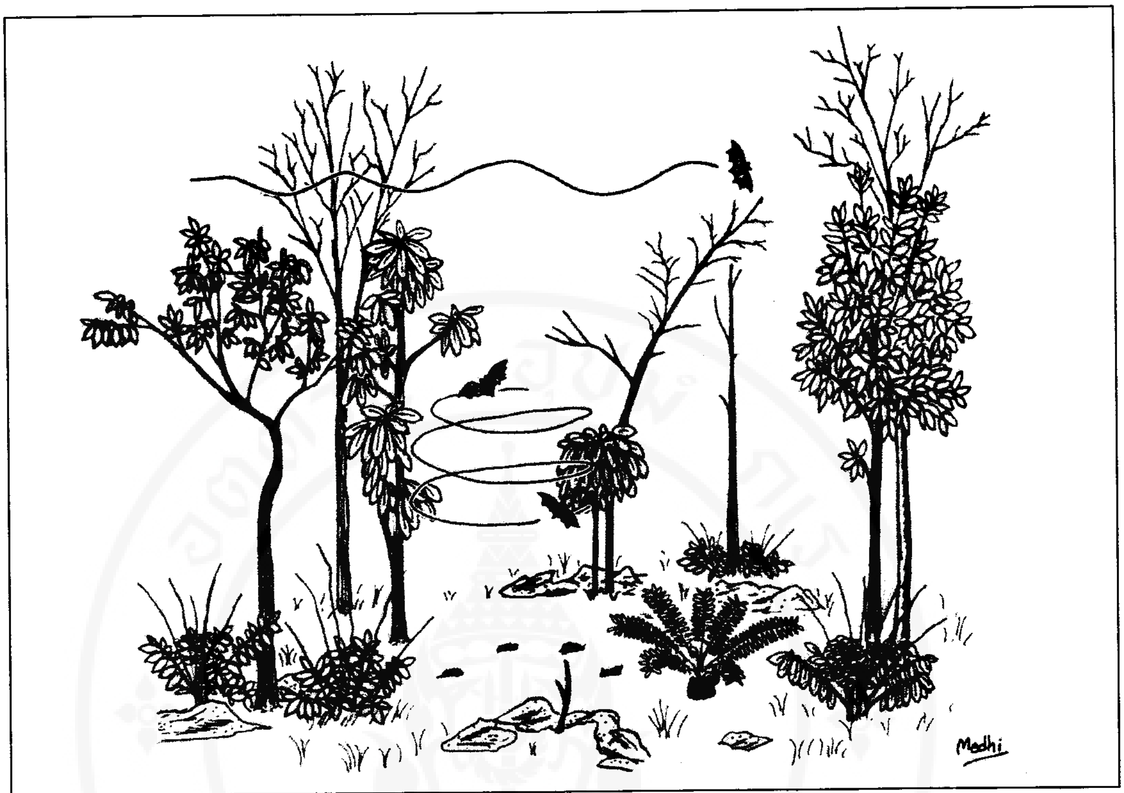


Figure 4.8 Foraging (circling above the ground) and commuting (flying along space between trees canopy) of *Craseonycteris* in degraded dry dipterocarp forest habitat. Note the bats are drawn oversized.

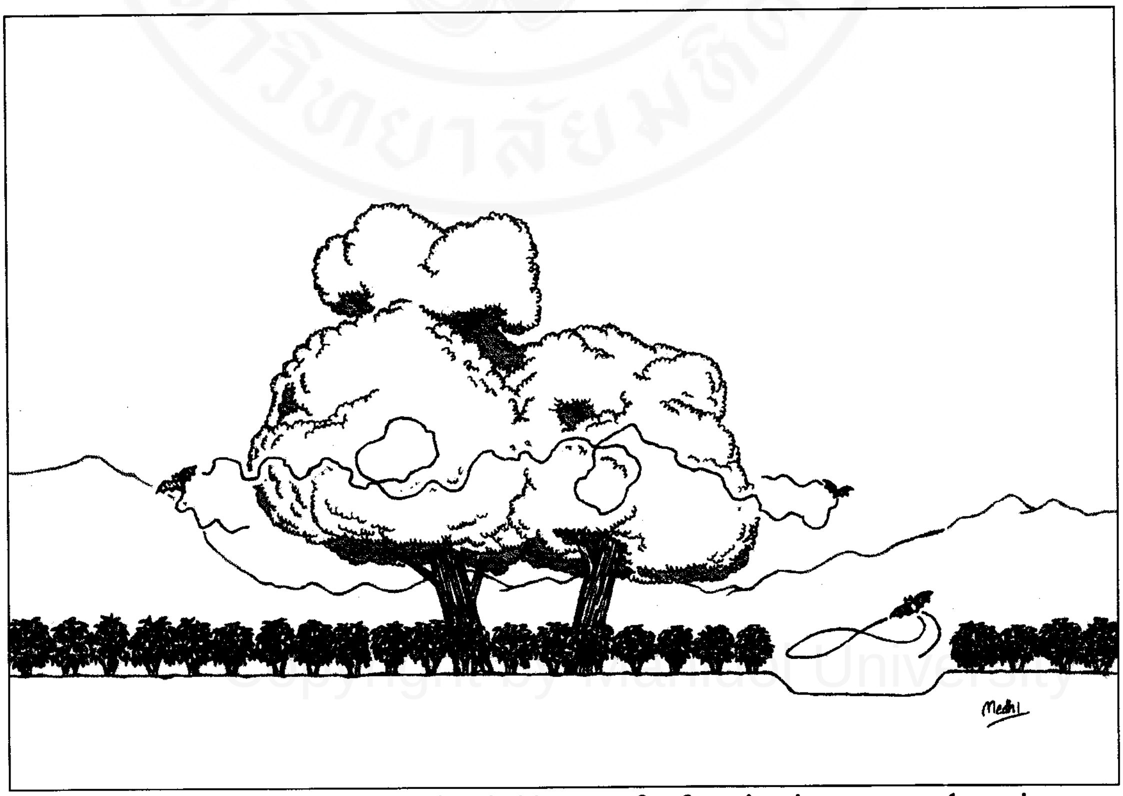


Figure 4.9 *Craseonycteris* and microhabitat use for foraging in cassava plantation. Note the bats are drawn oversized.

Unlike in cassava plantation, however, *Craseonycteris* was found commuting and feeding in other kinds of plantation. The bats flew and circled around eucalyptus, mangoes, tamarind, and coconut trees. Elevation of its flight also depended on the height of nearby vegetation, usually not above tree canopy level.

Although the bats used a dirt road for commuting and foraging but this was not hold for a highway. *Craseonycteris* can fly across a 3-4 lanes highway but did not forage along at both Site Nos. 2 and 3 (Figure 2.8, Path A and Figure 2.9, Path B2) moreover, one flight path was terminated beside the road (Path A, Figure 2.9).

Craseonycteris can fly along and around buildings beside the road in suburban areas for feeding but was found more in areas where there were some trees. They showed no fear and sometimes foraged quite close to humans. The bats avoided flying across an open area of football field but instead commuted along vegetation beside it to forage in other areas.

4.3 Step 3: Examining Habitat Preference in Cassava-Forest Area

4.3.1 Habitat preference of *Craseonycteris*

Craseonycteris was found to forage at all observation points and times in the forest habitat, but in the cassava plantation, the bat was present in only 9 out of 20 times of observation and only 6 out of 10 observation points. Furthermore, the highest, lowest, and total numbers of interval time with the bat present were markedly higher in the forest (Figure 4.10, Table 4.5).

The Wilcoxon match-pairs signed ranks test showed significant differences between the intensity of the bat entering forest and cassava habitat both in evening and morning ($p<0.01$, Table 4.6)

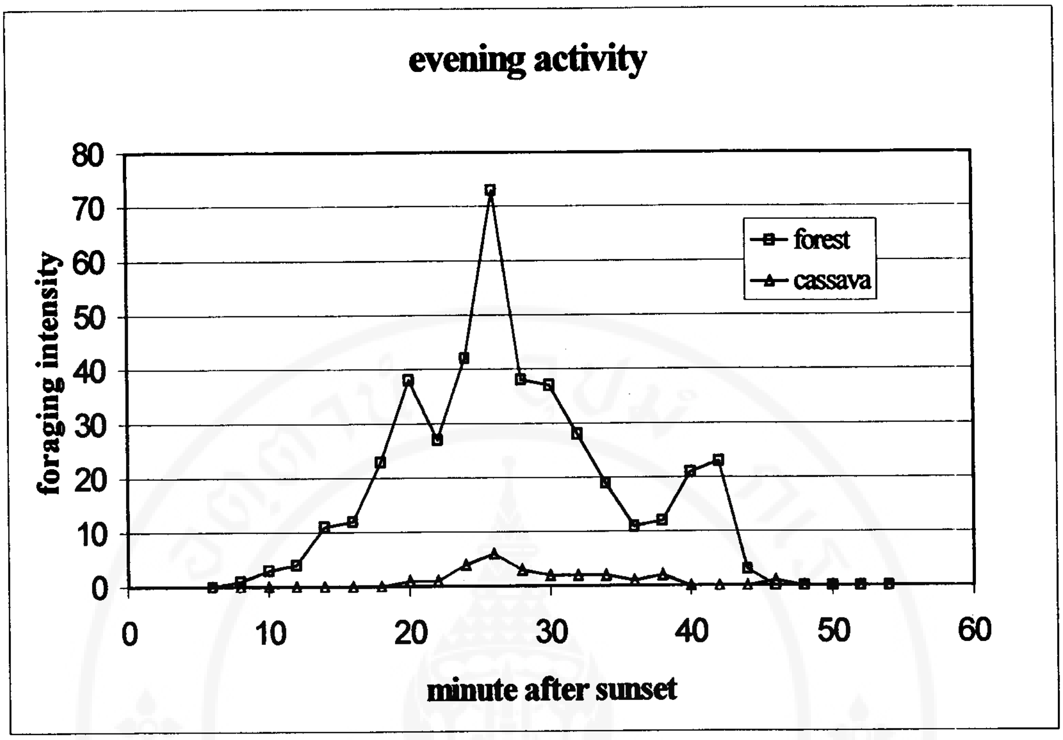
It was obvious that *Craseonycteris* preferred to forage in the degraded dry deciduous dipterocarp forest rather than the cassava plantation habitat.

4.3.2 Relationship between *Craseonycteris* presence and dry weight of insects

While there were significant differences between *Craseonycteris* entering forest and cassava areas but not between morning and evening time, the test results were opposite for dry weight of insects, which were found significantly more abundant in the evening than in the morning and with no significant difference between forest and cassava habitat (Table 4.6). This means that the presence of *Craseonycteris* and insects are not correlated in either time or space.

The Spearman rank correlation indicated no correlation between dry weight of insects and the intensity of the bat presence both overall and in almost all size classes except for size Class F in the forest during the morning which showed a positive correlation (Table 4.7). However, in this class, other categories showed no correlation and moreover, showed a negative trend between the presence of bat and the abundance of insect in the forest during the evening and in the cassava plantation during the morning, which suggests that this significant is by chance so that there was no correlation between the bat intensity and insect abundance.

The lack of correlation between the presence of *Craseonycteris* and insects suggest that insect abundance might not be a major factor determining habitat selection by the bat.



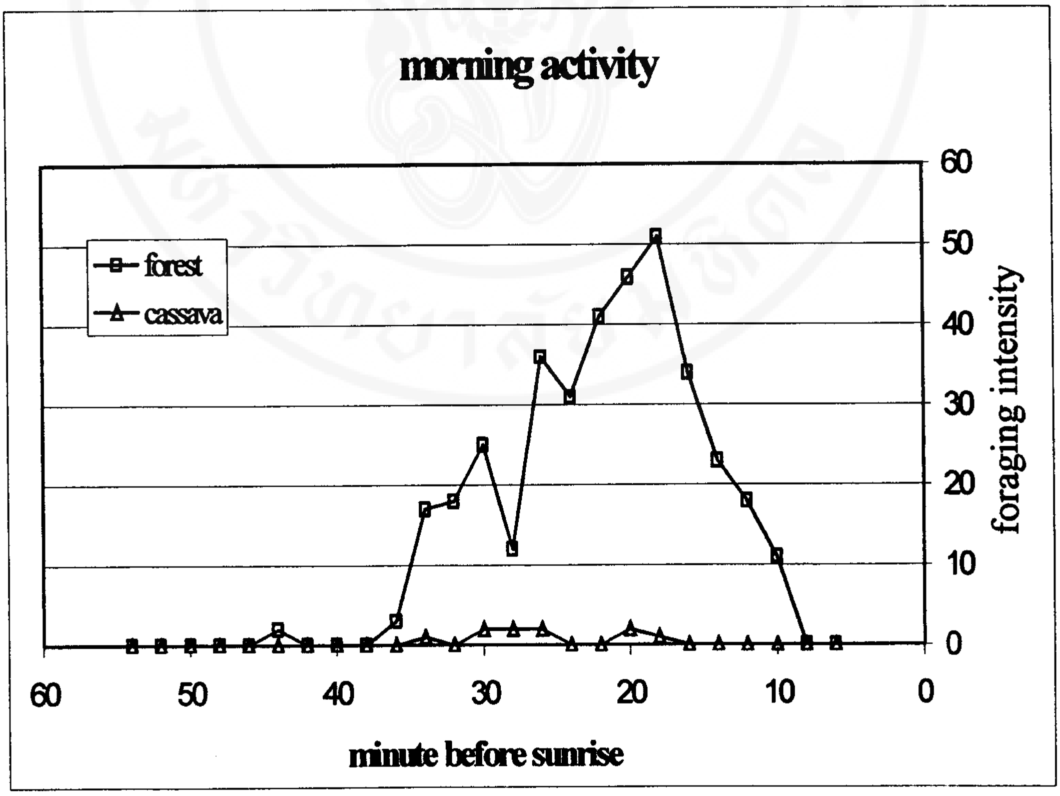


Figure 4.10 Time frequency of foraging activity of *Craseonycteris* at observation points of Step 3, the upper is at dusk and the lower is at dawn. Foraging intensity is the number of interval times when the bat entered the observation points in each two-min period.

Table 4.5 Entering intensity of *Craseonycteris* at all observation points

		No. of bats entered			
		Forest		Cassava	
Pair	Night	Evening	Morning	Evening	Morning
1	28,29 May 99	4	81	4	0
2	27,30 May 99	17	47	10	7
3	5,6 June 99	201	92	0	0
4	7,8 June 99	55	12	5	1
5	18,19 June 99	58	1	5	1
6	20,25 June 99	75	38	0	1
7	7,8 July 99	10	57	1	0
8	9,10 July 99	1	37	0	0
9	11,13 July 99	2	1	0	0
10	12,19,20 July 99	3	2	0	0
total		426	368	25	10

Table 4.6 P-value of Wilcoxon signed ranks test of *Craseonycteris* intensity and dry weight of insects between forest and cassava area both in evening and in morning

Category		Bat	Insect
forest-cassava	evening	0.0092*	0.0831
	morning	0.0092*	1.0000
evening-morning	forest	0.8385	0.0059*
	cassava	0.0747	0.0080*

*Significantly different ($p < 0.01$, two-tailed test)

Table 4.7 Spearman's rho between no. of bats entering and dry weight of insects

	Forest		Cassava	
Size of insects	Evening	Morning	Evening	Morning
A (0-2 mm)	0.5879	-0.3891	0.4087	0.0555
B (2-4 mm)	0.4061	-0.0851	0.3438	-0.0347
C (4-6 mm)	0.4788	-0.2918	0.5255	0.0208
D (6-8 mm)	0.4788	0.0182	0.5968	-0.2913
E (8-10 mm)	0.5394	0.1459	0.2919	0.3826
F (>10 mm)	-0.0303	0.7660*	0.4282	-0.6311
All sizes	0.4424	0.4195	0.4347	-0.3121

*Significantly different
tabular value (0.648), N=10, $\alpha=0.05$, two-tailed test

CHAPTER V

DISCUSSION

To understand the current status and the nature of *Craseonycteris*, information about population and distribution, nature of the bat which limits their adaptability to disturbances, and disturbances as threatening factors both in roost caves and in foraging habitat need to considered. These factors are discussed step by step in this chapter.

5.1 Population and Distribution of *Craseonycteris*

5.1.1 Distribution of *Craseonycteris*

In the relatively confined area where *Craseonycteris* is known to exist, the number of bats in most caves is generally low, with only four caves having more than 180 individuals and most *Craseonycteris* are clumped in only a few caves, mainly in the border area between Sai Yok and Erawan National Park. All 'source' caves, or a cave where *Craseonycteris* roosted in at the highest numbers, have small chambers or crevices which are suitable for protecting them from any disturbance by human activity and also from other bats species, since almost all the bats roosted in separate chambers from other bat species.

Although having small populations in many connected caves is favorable to survival since one catastrophic event will not affect them all, but the total population of *Craseonycteris* could easily decrease markedly if any unfavorable catastrophic event threatened groups of the bat in those source caves.

5.1.2 Population movement

Bats are recognized as K-selected organism, the population size is relatively stable and do not fluctuate much (15). In his previous study, Duangkhae (1990) (3) found evidence of seasonal migration of *Craseonycteris*, where the bats in Cave No. 1 abandoned their roost cave in winter and came back in summer. In this study, it is likely that *Craseonycteris* also has partial population movement throughout the year since the number of the bats in some caves varied seasonally and the flight paths from some caves were interconnected with other caves.

Kunz (1982) (27) postulates that most bats established and maintain familiarity with one or more alternate roosts. Relative abundance of roost sites, proximity and stability of food resources, predator pressure, and human disturbance are factors influencing roost fidelity. In addition, it may change seasonally and might be affected by reproductive condition, sex, age, and social organization. At this time, for *Craseonycteris*, it is not possible to understand the mechanism and benefit of this behaviour due to the lack of data about these factors and the complex relationship among them.

The fluctuation of numbers of *Craseonycteris* in each cave, which caused by seasonal migration and population movement, can lead to error and misinterpretation if population monitoring is carried out in different season/time from previous studies. Therefore, to minimize this error, further studies concerning population monitoring should be conducted in the same season/time of year.

5.1.3 Population trend

Although the total population of *Craseonycteris* in this study was found to be higher than the previous study by Duangkhae (1991) (4), with 2,656 bats in 22 caves compared with 2,000 bats in 21 caves, it does not mean that the population of *Craseonycteris* has grown larger than in previous time since some new caves, which the bats lived in at relatively high number, were discovered.

In contrast, the number of *Craseonycteris* in 15 original caves showed a slight decrease in number, from 1,536 to 1,382 individuals. But again, it is not possible to conclude that the population of *Craseonycteris* has actually declined since this slightly lower number might result from the error of estimation or from the different season/time of survey from the previous study, which the fluctuation of the number by partial movement might play a role.

Although it is not possible to conclude that the overall population of *Craseonycteris* has actually increased or declined, however, the numbers of the bat are definitely decreased in some disturbed caves and some activities of humans were found to threaten or likely to threaten the population of the bat, both in roost caves and in the surrounding areas, as will be discussed later.

5.2 Nature of *Craseonycteris*

In this study, nature of *Craseonycteris* refers to some behaviour or lifestyle of the bat that has evolved from selective processes. They are unable to adapt or change themselves much due to their physiological and morphological constraints. This will be discussed under two topics, i.e., the behaviour within roost cave (torpor and response to disturbance) and the behaviour outside the roost cave (foraging behaviour, flight paths, and open area avoidance).

5.2.1 Behaviour within roost cave

5.2.1.1 Lethargic behaviour (torpor)

Altringham (1996) (18) postulates that the very smallest species of bat may be obligate heterotherms some of the time to minimize their energy requirement. For *Craseonycteris*, although its behaviour in the roost cave has never been observed systematically, it is quite believable that *Craseonycteris* inevitably spends almost all time in the cave in a state of torpor, lowering its body temperature and metabolic rate to conserve energy, since the bat is extremely small and spends a relatively short time foraging each day.

Torpor might be the only strategy for *Craseonycteris*, the smallest mammal that eats so little, to maintain its energy balance.

5.2.1.2 Response to disturbance

Craseonycteris responds to disturbance firstly by emitting echolocation sound to determine the situation and usually flies away to temporary roosting site if the disturbance continues. The cost of this behaviour is more expensive for bats than resting. Echolocating bats spend up to ten times more energy than resting bats (reviewed by 18) and energy requirements are far higher in flying bats, which ranges as high as 34 times in some species (28 cited by 23).

Frequently disturbances within roost caves arouse *Craseonycteris* and make it impossible for it to conserve energy through torpor.

5.2.2 Behaviour outside roost cave

5.2.2.1 Foraging behaviour

5.2.2.1.1 Foraging strategy

Resemble to the studies of Duangkhae (1990) (3) and Surlykke et al. (1993) (6), *Craseonycteris* adopted an aerial feeder strategy most of the time in this study, and rarely catch insects from a surface (gleaning). One question rises here is why some previous studies suggested *Craseonycteris* as a foliage gleaner (2, 5, 8).

The plausible explanation is that *Craseonycteris* may have ability to forage in both styles and shift its behaviour depending on the structure of forest and insect community. As described earlier in the first chapter, most bat species are flexible feeders and can forage in wide range of microhabitats or shift the habitat use especially if the area has long term of habitat change. Since all the studies which found *Craseonycteris* adopt aerial feeder strategy conducted later in an open and degraded forest whereas other studies that suggest foliage gleaner strategy conducted in previous time when a forest might not degraded much.

Aerial feeding strategy might suitable for *Craseonycteris* in open and degraded forest habitat but in pristine area where the structure of vegetation and insect community are different, the bat might adopt gleaning strategy more. However, this needs further study before making any conclusion. Anyway, in disturbed habitat, *Craseonycteris* seems to be aerial feeder-opportunistic gleaner.

5.2.2.1.2 Habitat and patch selection

Food abundance is clearly a major factor affecting the movement and distribution of bats (29, 30). From optimal viewpoint, predators should concentrate foraging activity in the most productive patches and the density of them should match the density of prey. Marginal value theorem predicts that forager should remain in a rich patch longer than a poor one (19, 24, 31).

However, these predictions fail to support the result of this study, *Craseonycteris* prefer foraging in the forest but avoid cassava area despite the density of insects is not different. The intensity of the bat exploit patch also not correlate with insect abundance, hence *Craseonycteris* do not select habitat and patch optimally and it must have some factors other than food abundance which strongly influence the habitat and patch selection of *Craseonycteris*. Two questions rise here are why *Craseonycteris* do not forage in open area and which strategy *Craseonycteris* accept for patch selection.

- Why *Craseonycteris* do not forage in open area?

Craseonycteris can forage in many kind of habitats except far from vertical element over large open area and above tree canopy, it is likely that echolocation, which the bat use for navigation and orientation, is the most important constraint factor which limit its ability to forage in large open area and this will discuss in details later (see 5.2.2.3 Open area avoidance).

- Which strategy *Craseonycteris* accept for patch selection?

Craseonycteris forage in a relatively short period and distribute not far much from its flight path and landscape elements, these behaviour constraint the bat for behaving as optimizer since it distribute in confine area and has not enough time to find the most profitable patches.

Instead, *Craseonycteris* might behave as satisficer (24, 31), it search systematically along the flight path and stop over for feeding in some certain points for a certain time before search further, the bat exploit in any familiar patches where the profitability meet its minimal requirement and might leave before the patch is diminished. Specific flight paths of the bat help it reduce the cost of searching for suitable foraging area and yield the foraging more efficiency.

5.2.2.2 Flight path of *Craseonycteris*

Craseonycteris commute along the specific flight paths in all study sites. Flight paths in more natural area of Cave No. 30 are simple and none-branching and do not change for more than ten years whereas flight paths in altered landscape mosaic of Cave Nos. 36 and 54 split more, mostly along linear landscape elements. This means *Craseonycteris* can adapt its flight paths in accord to the change of habitat.

Duangkhae (1990) (3) suggests that the major purpose of flight path of *Craseonycteris* is for minimizing cost of foraging. In this study, some flight paths of the bat in all study sites connect with flight path from other cave and since the bat has partial population movement, then another function of flight path might be the route for movement.

Flight path seems very important for *Craseonycteris,* it serves function as both foraging route and route for movement between the caves. Although it can adapt in accord to the change of habitat, however, none is found in large open area.

5.2.2.3 Open area avoidance

It is obvious that *Craseonycteris* prefers edge and gap habitat but avoids open area both for commuting and foraging, the bat always keep a certain distance from nearby landscape elements, usually not farther than three meters. *Craseonycteris* do not forage over cassava plantation even insects are abundance and commute crossing open area at shortest point.

Many researchers postulate four factors concerning the preference of vegetation habitat in open agricultural area by bats, i.e. insect abundance, shelter from wind, shelter from predation, and the use of landscape elements as acoustic landmark. The relative importance of these factors varies depending on situation and bat species (29, 30, 32, 33).

For *Craseonycteris*, insect abundance seems not to be the major factor determining the preference of forest habitat by the bat since it is not different between open (cassava plantation) and forest area. In addition, shelter from wind seems not important much since wind condition in the study area is normally calm and the bat can forage above dry watercourse in cassava area where vegetation are too small for protect it from wind.

The next factor is shelter from predation; pipistrelle bats (*Pipistrellus pipistrellus*) in open agricultural area of Europe commute between the tree lines for avoiding exposure to predatory birds (29, 30). In this study, *Craseonycteris* forage in the time when Collared Scops-Owl and Black-shouldered Kite are active. However, the bat does not avoid expose to these predators, it commutes to forage over dry watercourse and around solitary big tree in cassava area, which seem conspicuously for any predatory bird and hence predation avoidance also should not influence much.

The last factor is *Craseonycteris* might use landscape elements as acoustical landmark as found in many other bat species (29, 30, 34). If so, many researchers suggest that the ability of the bat to use landscape elements as sonar guiding objects is depend on its maximum sonar range (29, 33). *Craseonycteris* emit echolocation sound at high frequency that likely to attenuate rapidly in a short range (6), this orientation constraint might force the bat to follow vertical landscape element and avoid using open area.

Craseonycteris prefer more cluster forest habitat not depending on insect abundance, fly along dirt road to forage in more expose cassava area regardless of predator and wind but usually keep certain distant from nearest landscape objects. These mean the orientation constraint from its perception is the most powerful factor that influences its distribution not to forage and commute in open area.

5.3 Disturbances as Threatening Factor

Disturbances can divided in three types, i.e. Type 1; 'interruption of tranquillity' or the physical presence of intruder, Type 2; 'interference with rights or property' or the change of habitat, and Type 3; 'molestation' or the action that causes direct and damaging contact with animal (25).

For *Craseonycteris*, disturbance occurs both within and outside roost cave and this will discuss separately in terms of disturbance in roost cave and disturbance in foraging habitat.

5.3.1 Disturbance in roost cave

Type 1 is the most common among the three types of disturbance within roost cave, which are found in 23 from 33 caves surveyed. *Craseonycteris* responses to this disturbance by emit the sound, escape to temporary roost site, and might abandon some available roost site or even the cave as found in Cave Nos. 11 and 36. The bat is seemed more sensitive to the disturbance than some other bat species such as *Hipposideros armiger* and *Taphozous melanopogon*, the larger species which can roost in some frequently disturbed caves where no *Craseonycteris* can be found, such as in the Cave Nos. 18, 35, and 68. Although the bat can roost in low level or even in high level disturbed cave if suitable disturb-free chamber available there, number of it tend to decrease with frequency of the disturbance. Hence, population of *Craseonycteris* in those caves might be considered as a sink.

It is not possible to conclude about the impact of disturbance Type 2 to *Craseonycteris* now since the available data is not enough. It seems like the bat can adapt quite well to this type of disturbance, however, number of bat might change rapidly if air ventilation and temperature are change by cave alteration, as found in the case of Indiana bat (*Myotis sodalis*) in Kentucky (reviewed by 25).

Type 3 disturbance occurs in the roost cave not frequently but if it occurs, it is the most harmful to population of *Craseonycteris*. The number of the bat in Cave No. 7 was increased significantly from 300 in the past (4) to 6 individuals in this study, which conducted around 1 month after the villagers catch them for eaten. The overall population of the bat might decrease markedly if this type of disturbance occurs in any source caves, which are clumped in relatively small area.

Within roost cave, disturbance Type 1 is the most common and might cause the population to be a sink. The impact from disturbance Type 2 is still unclear but for Type 3, although occur not frequently, is the most harmful when occurred.

5.3.2 Disturbance in foraging habitat

Outside roost cave, the Type 1 disturbance is clearly causes no impact to *Craseonycteris* since the bat do not fear and can forage very close to human in sometimes.

For Type 2 disturbance, although *Craseonycteris* seems quite adaptive to the change of habitat since it can adapt its flight paths and can forage in suburban area and many kinds of plantation, however, this does not mean that the bat prefer these altered habitats or these degraded habitat cause no adverse impact to the bat. Fenton (1997) (35) suggests that the degradation and loss of habitat can affect bats without reducing their diversity. This means population of bats in degraded habitat might be a sink. In this study, *Craseonycteris* avoid using open area both for commuting and foraging and this reduce the available foraging habitat for the bat. In addition, since flight paths of *Craseonycteris* serve one function as migration route, then some open area such as cassava plantation and highway might form the barrier for the migrating bat.

Although it has no data about disturbance Type 3 to *Craseonycteris* outside roost cave, however, it is uncommon behaviour for human except bat biologist to try catching or killing the bat outside roost cave, especially for local villagers. Then the impact from this type of disturbance to *Craseonycteris* should not be significant.

Outside roost cave, disturbance Type 2 by large open agricultural area seems to be the most important factor threaten to *Craseonycteris* since it reduces available foraging area and possibly forms a barrier for migrating bat while Types 1 and 3 disturbances seem less important.

CHAPTER VI

CONCLUSION

Due to the discovery of some new caves, the total population of *Craseonycteris* was found to be higher than the previous study of Duangkhae (1991), at 2,656 compared with 2,000 individuals

However, the population of *Craseonycteris* in original caves had changed slightly from the past from 1,536 to 1,382 individuals but it is not possible to conclude that the population of the endangered bat has actually declined since the lower number might result from the error of estimation or from different season/time of survey from the previous study, and partial movement might play a role

The numbers of *Craseonycteris* in most caves was generally low with the median at 66 and most of the bats up to 71% were clumped in only a few caves in a very confined area. The total population of the bats could decrease markedly if any unfavorable catastrophe occurs in those source caves.

Craseonycteris commute along the specific flight path, which serves function as both foraging route and route for movement between the caves. The bats can adapt their flight paths in accord to the change of landscape since flight paths in altered landscape mosaic are split more and many are located along man made landscape elements.

Although *Craseonycteris* seems adaptive quite well to the change of habitat since it can forage in suburban and many kinds of plantation area, however, the bat preferred to use edge and gap habitat but avoided using large open area of cassava plantation even insects were similarly abundant. It is likely that the limitation of echolocation range of *Craseonycteris* themselves is the most powerful factor constraints them to keep certain distant from nearest landscape objects.

In most area, cave disturbances and the alteration of landscape are seemed to be the important factors threaten to the population of the endemic and endangered *Craseonycteris*.

In roost cave, torpor is likely to be an essential behaviour for *Craseonycteris* but frequently disturbances arouse the bats from conserving energy. In addition, percent of *Craseonycteris* present and numbers of the bats in each cave tend to decrease with increased disturbance level. This might lead the population to be a sink since the bats may abandon their roost cave or potential roost site.

The alteration of habitat to an open cassava plantation or highway reduced available foraging area for *Craseonycteris* and might form a barrier for migrating bat, in addition.

CHAPTER VII

CONSERVATION RECOMMENDATION

Although hunting is an important factor affecting the presence of *Craseonycteris* but cave disturbances and habitat conversion to open agricultural area are also important as well. As *Craseonycteris* distribute in a relatively confined area, if the disturbances continued degree it might lead the endemic bat to extirpate or finally extinct.

To prevent this, some recommendations are made for future study and for future management.

1. Tourism and activities of monk should be prohibited in a cave where *Craseonycteris* roost or as even they look like a suitable cave for the bat. If it is not possible, these activities can be allowed only in a non-breeding season in some cave where no bat is found. In addition, tourist and monk should be informed how to use the cave without causing any impact to the bat.
2. Anybody who is interested in *Craseonycteris* can watch the bat near cave entrance when they are emerging from roost cave or at foraging site since the presence of the bat are quite predictable both in time and space and they do not fear people when they are foraging.
3. Network of hedges and tree lines should be planted in open agricultural area in order to supply foraging habitat and migrating route for *Craseonycteris*. In addition, the mixed agriculture of tree or shrub such as kapok, tamarind, mango, and custard apple should be planted instead of cassava.

4. Since roost caves and foraging sites of *Craseonycteris* are located both in and outside protected area where there are many stakeholders involving. An integrated management by all stakeholders should be set up.
5. The intensive study on an impact of cave disturbance to *Craseonycteris* should be conducted especially in breeding season and dry season.
6. *Craseonycteris* can forage in many kind of plantation and might be affected by insecticide, then the further study should be focused on this impact.
7. Any future study on population monitoring should be conducted at the same season and time of the year to prevent the error from intra-population movement.
8. Future study to understand the cost and benefit and the factor affecting seasonal movement and intra-population movement of *Craseonycteris* should be set up.

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