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SEARCH FOR KITTI'S HOG-NOSED BAT *CRASEONYCTERIS THONGLONGYAI* IN WESTERN THAILAND

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ABSTRACT

Between August, 1983 and April, 1984, a search for Kitti's Hog-nosed Bat *Craseonycteris thonglongyai* was made in three areas in the limestone ranges of western Thailand. Twenty-one roosting caves were discovered out of 51 caves examined, containing a total population of about 2,000 *Craseonycteris*. Discriminant analysis done with 20 variables consisting of various cave characteristics, foraging habitat and presence or absence of other bat species, was performed using 51 caves. Three cave characteristics which related significantly to the presence of *Craseonycteris* were presence of domes, conical ceiling and caves with normal sections. The number of bats per cave varied from 0 to 500 but averaged about 100.

INTRODUCTION

In October 1973, a team led by Kitti Thonglongya collected 19 unidentified bats from two caves near the Sai Yok waterfall. In December 1973, during further exploration along the Khwae Noi River, about 50 caves were checked, but no more caves containing this unidentified species were found. Thirty-three more bats were collected from the two known caves. In 1974, this bat was classified as a new species representing a new family of mammal by Dr. J.E. Hill of the British Museum (HILL, 1974a).

In August 1980, Dr. S.R. Humphrey checked the two caves near Sai Yok Waterfall, and found one more cave on the Huai Bong-Ti River which contained *Craseonycteris* (BAIN & HUMPHREY, 1980). In February 1981, J.D. Pye, searching with an electronic bat detector, found *Craseonycteris* in the same two caves near headquarters and in a third one down the river at Wang Phra. In November 1981, Dr. R. Stebbings and Dr. M.D. Tuttle found that the bats had disappeared from the caves near Sai Yok Park headquarters, and at Wang Pra cave there were about 50 bats instead of 200 estimated by Pye previously. In January 1982, J.A.T. Hall checked with an electronic bat detector but again found no bats in the two caves near headquarters. The 50 bats were confirmed as being *Craseonycteris* at the Wang Pra Cave. Two new groups were discovered, one in a cave outside the eastern boundary of the park, and another in the southern part of the park. In October 1982, I found *Craseonycteris* still in the cave at Huay Bong-Ti River which was visited by Humphrey, and in another cave discovered by Hall, located about 7 km south. In August, 1983, I began a search for Craseonycteris in an area along the Huay Bong-Ti River. Nine new caves were discovered in a 50 km^2 area. After studying a geological map of the area, more caves in this area were checked, and further surveys were done both south and north of the known range, outside the park. I report here on the results of my survey for this

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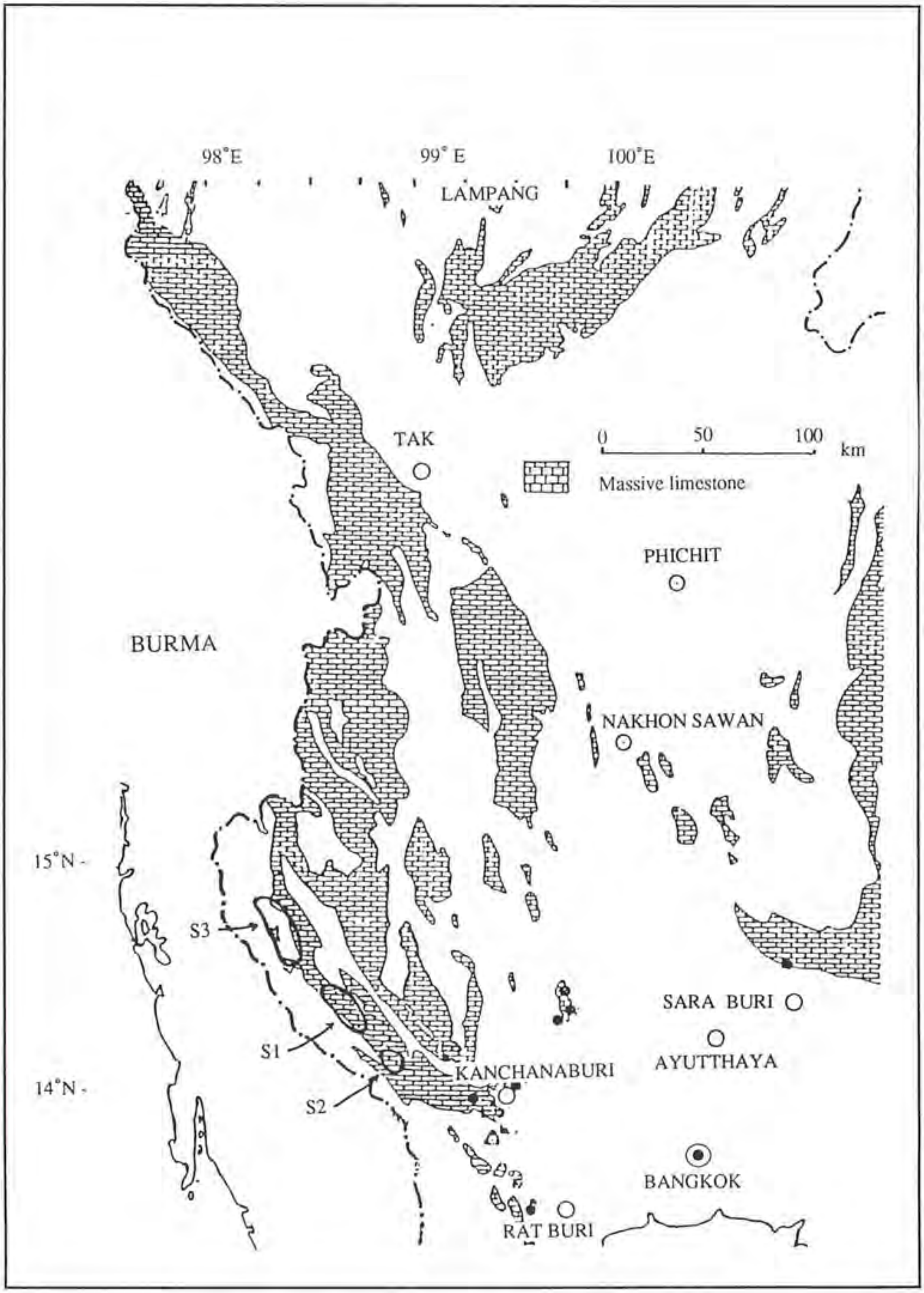

Figure 1. Limestone range in western Thailand. Areas S1 and S2 were found to have with *Craseonycteris*, but none was found in area S3 (from Economic Geology Division Department of Mineral Resource, 1977)

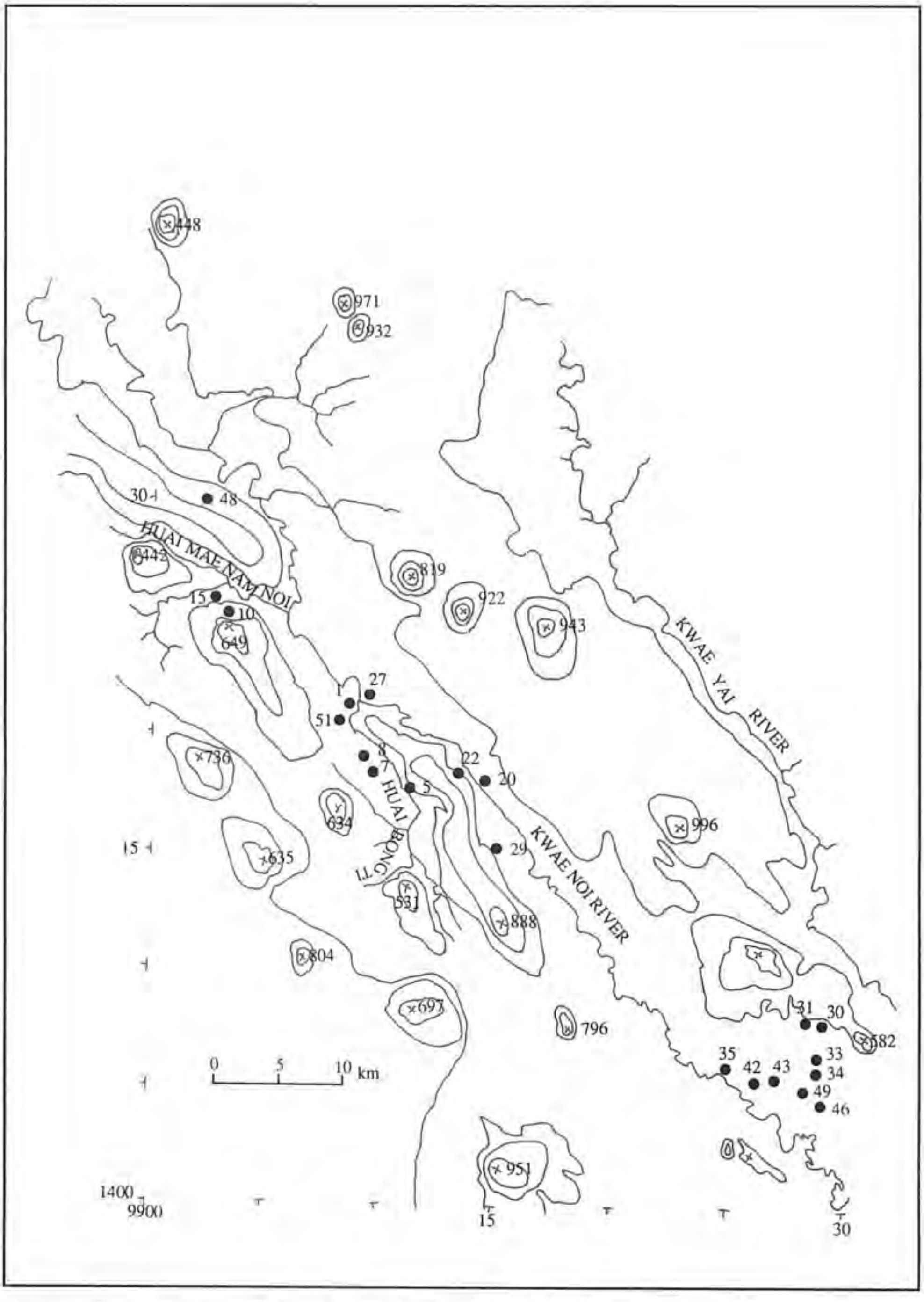

Figure 2. Distribution of caves in areas 1 and 2. Solid dots are caves with *Craseonycteris*.

endangered species. Observations on the behavior and ecology of *Craseonycteris* in two of the cave sites have already been published (DUANGKHAE, 1990).

I recorded several characteristics of caves and the surrounding environment in an attempt to determine which, if any, may be used to help predict the presence or absence of *Craseonycteris.*

Eight structural characteristics of caves, inside and outside temperatures, inside and outside humidity, oxygen level, habitat characteristics such as ground condition and forest type, presence of stalactites and presence of other bat species were recorded.

STUDY AREAS

There are three types of forest in and around the study areas: dry evergreen, deciduous and bamboo forest. The areas in which *Craseonycteris* were checked can be divided into three localities: (1) 98° 45′ – 99° 00′ E, 14° 15′ – 14° 30′ N; (2) 99° 00′ – 99° 15′ E, 14° 00′ – 14° 15′ N; (3) 98° 30′ – 98° 45′ E, 14° 30′ – 14° 45′ N (see map in Fig. 1).

There are many small limestone hills surrounded by some level plains in study area 1. All caves are located near the river. This study area is covered with secondary mixed deciduous forest, bamboo forest and evergreen forest, with some orchards, kapok, corn and shifting rice farms. Most of the area is within the Sai Yok National Park. The caves were found mostly along the Huai Bong-Ti and the Kwae Noi Rivers.

Study area 2 (Figs. 1, 2) is on the slope of the Khwae Noi basin. It has very dry vegetative cover with small bamboo clumps and deciduous dipterocarp forest (Fig. 3). Most of the caves are far from the river. There are cassava farms on the plains, and the only forest present is on the hills. Cave entrances are usually vertically down. The forest is threatened by poor people who earn an income from illegal logging, charcoal production and cassava farming.

Study area 3 is in the valley along the Khwae Noi River. This area was inundated when the dam was completed in June, 1984. There are mixed deciduous and bamboo, forests here. Most of the caves are not far from the river.

MATERIALS AND METHODS

Local villagers were used as guides to indicate the caves they knew. Other possible areas were also checked.

The caves were marked on a 1:50,000 map. Twenty characteristics were recorded from each cave as follows:

1. *Entrance direction:* compass direction toward which the entrance faced.
2. *Elevation:* elevation of the main entrance in meters.
3. *Entrances:* number of entrances to the cave.
4. *Length:* total length of main chamber was estimated by pacing.
5. *Volume:* total volume of cave in m^3, estimated by multiplying length, width and height.
6. *Chambers:* number of chambers, with each turn in a cave defining a chamber.
7. *Ceiling form:* cross section of the main chamber ceiling. These are divided into three types: dome, umbrella and conical.

8. *Shape of caves:* two variables were recorded; cross section and plan. The plan types were (1) normal, (2) round, (3) many small chambers, (4) long with junction, and (5) short. The five section shapes were (1) normal, (2) declining, (4) vertical entrance, and (5) two floor chambers, with one under the main chamber.
9. *Outside temperature:* temperature at the entrance of the cave.
10. *Inside temperature:* temperature in the main chamber or roosting chamber.
11. *Outside humidity:* humidity at the entrance of the cave.
12. *Inside humidity:* humidity in the main chamber or roost chamber.
13. *Bat species:* the species which could be detected by a QMC Mini Bat Detector. The sound was recorded with a SONY Model WA5000 recorder, and the bat was then caught with a hand net for identification. The ultrasound frequency indicated on the dial was also recorded.
14. *Stalactites:* absence or presence of stalactites in the cave.
15. *Pits:* absence or presence of vertical holes in the cave floor.
16. *Stream*: absence or presence of a stream in the cave.
17. *Oxygen:* low oxygen flame of methane cigaret lighter is about 8 cm long and about 1 cm long with 0.6-cm diameter candle. Normal oxygen flame is about 2 cm long with a methane lighter and about 2 cm long with 0.6-cm diameter candle. These tests were done only in caves where breathing difficulties occurred.
18. *Ground condition outside cave entrance:* four types of ground condition were recorded: (1) sand, (2) clay, (3) rocky, black or clay with limestone, and (4) black with deep humus soil.
19. *Forest type outside cave:* three kinds of forest were recorded.
    (1) Bamboo forest, big *(Bambusa flexuasa* Munro.*)* or small (*Bambusa arundinacea* (Retz.) Willd.) species.
    (2) Deciduous forest. (*Dipterocarpus tuberculatus Roxb.* and *Shorea obtusa* Wall.)
    (3) Evergreen forest.
20. *Plantations:* kinds of crop plants within 1 km from the cave.
    (1) Banana *(Musa sapientum* Linn.*)*; Banana was usually grown around houses or in an area not greater than 2,500 m^2.
    (2) Corn *(Zea mays* Linn.*)*; growing in small areas usually not greater than 2,500 m^2.
    (3) Cassava (*Manihot esculenta* Crantz.); usually huge farms of several km^2.
    (4) Kapok (*Ceiba pentandra* Gaertn.); grow around houses over about 7,500 m^2.
    (5) Orchard; other fruit crops such as jackfruit, mango and lemon.

All the characteristics both inside and outside caves, including the absence or presence of the other 10 bat species, were analysed using SPSS (Statistical Package for the Social Sciences) at the Mahidol University Computing Center. Discriminant analysis was used to determine what characteristics indicated presence or absence of *Craseonycteris*. The discriminating variables were then tested for significance using chi-square tests. Analysis of variance was then done for the caves where *Craseonycteris* was present, to determine how the various cave characteristics were related to population numbers.

RESULTS

Distribution

Of a total of 51 caves searched, 21 caves with *Craseonycteris* colonies were found during the survey. Two caves (Nos. 1 and 30) were selected as sites for the study of ecology and behavior of *Craseonycteris*.

According to the map of mineral resources of Thailand (Economic Geological Division, Department of Mineral Resources, Bangkok, Thailand 1977), the continuous limestone range in western Thailand covers about 60,000 km^2 (Fig. 1). The limestone does not extend all the way west to the Burmese border.

Craseonycteris is confined to the limestone region, and occurred in 41% of all caves searched. The distribution of *Craseonycteris*, however, appears to be confined to a relatively small area. No caves with *Craseonycteris* were found above about latitude 14° 45′ N and below latitude 13° 45′ N.

The colony size of *Craseonycteris* was small, not greater than 500 bats (Table 1). The average number of *Craseonycteris* per cave was about 100 bats. Other species: *Hipposideros armiger* and *Taphozus melanopogon*) usually had larger colony sizes than *Craseonycteris* (over 1,000 bats per cave).

Behavior within the Cave

Craseonycteris roost mostly in the end of the cave or on the top of the dome chamber. They hide in small holes or in crevices formed by stalactites. Each individual has its own roosting site and maintains a certain distance from other individuals. When disturbed with a strong beam headlight, the bats would take off from the roosting site and fly in circles about the chamber (Fig. 5). Continual disturbance caused the bats to move to temporary roosting sites. Entering the roosting chamber without a light does not affect the bats.

The number of individuals in one roosting chamber varied from 1 to 300, and depended on the availability of roosting sites (Figs. 4 – 6) *Craseonycteris* was never found associating with other species of bat within the cave. During the survey, from August 1983 – May 1984, I did not found any young, but in April 1984 a female *Craseonycteris* with swollen belly was caught. It is possible that this bat was pregnant. *Craseonycteris* have been caught with babies in May (BAIN & HUMPHREY, 1980). The breeding season is possibly in the early part of the rainy season, around May.

Figure 3. The author with bat detector in deciduous dipterocarp forest in area 2.

Figure 4. *Craseonycteris* roosting on flat ceiling in a small side chamber of cave 22.

Figure 5. *Craseonycteris* flying about large conical chamber in cave 7.

Table 1. List of caves with 100-m grid coordinates on 1:50,000 1-RTSD map sheets, and numbers of different species of bats. C.t: *Craseonycteris thonglongyai;* H.a; *Hipposideros armiger:* H.b: *H. bicolor;* R.p: *Rhinolophus pearsoni;* R.m: *R. malayanus;* T.m: *Taphozous melanopogon;* T.l: *T. longimanus;* M.l: *Megaderma lyra;* M.s: *M. spasma;* A.s:*Aselliscus stoliczcanus;* Un: Unknown (not captured for identification).

Cave			Bat species										
No.	Coord.	Map	C.t	H.a	H.b	R.p	R.m	T.m	T.l	M.l	M.s	A.s	Un
1	886869	7437I	130	100	70								
2	871876	"				1							
3	871876	"		120									
4	871876	"		140									
5	930803	"	80	70									
6	925820	"						200					
7	904823	"	300			10							
8	897830	"	500					5			2		
9	931839	"						100					
10	790940	"	68	1200									
11	791940	"											
12	787942	"											
13	788945	"											
14	788954	"		20									
15	783963	"	1	1070									
16	846927	"						500					
17	846927	7437I			50								
18	984806	"		500	300		50						
19	852942	"										400	
20	985814	"	2										
21	983815	"											
22	974818	"	200					200					
23	960824	"			300								
24	963830	"				2							
25	968826	"											
26	865919	"		300		2			8				
27	900878	"	7			2							
28	917874	"							10				
29	997769	"	70		100		205						
30	230630	4837III	5			2							
31	229628	"	50	2						1			
32	224626	"											
33	245599	"	76	20									

Table 1 (continued).

Cave			Bat species										
No.	Coord.	Map	C.t	H.a	H.b	R.p	R.m	T.m	T.l	M.l	M.s	A.s	Un
34	248587	"	38										1
35	183590	"	150					50					
36	245594	"				300							
37	533353	4738IV											
38	497200	4738III											
39	493247	"											
40	457523	4638I		50					1				
41	449559	"		500				500					1
42	195584	4837III	21					5					
43	206580	"	23					2					
44	237565	"	11										1
45	263655	"							900				
46	278558	"	10		100								
47	278588	"				1							
48	773030	4738II	65	1		3							
49	822898	4738I		80	20	4						30	
50				60				53					
51	878860	"	180						170				
	Total		1987	5233	1240	27	255	3415	1071	18	3	430	3

Analysis of Cave Characteristics

Of the 20 Cave characteristics examined, discriminant analysis identified the following as being able to discriminate the presence or absence of *Craseonycteris*. The unstandardized discriminant coefficients obtained are given.

1.	Number of entrances	0.49826
2.	Length	– 0.01929
3.	Number of chambers	0.18378
4.	Ceiling form 1	1.23960
5.	Ceiling from 3	1.39879
6.	Plan shape 3	– 1.53661
7.	Plan shape 4	– 1.17193
8.	Section shape 1	– 1.58228
9.	Cassava	2.54042
10.	Stalactites	1.30448
	(Constant)	– 3.74723

The distribution of discriminant scores is shown in Fig. 6. A discriminant score of >1.0 always contained *Craseonycteris* while caves with a discriminant score of <– 0.6 never had any *Craseonycteris*. Within the range – 0.6 to 1.0, some had bats present and some had no bats.

Table 2 summarizes the numbers of caves correctly and incorrectly classified by the variables, and Table 3 summarizes the characteristics of caves with and without *Craseonycteris*.

Three cave characteristics which related significantly to the presence of *Craseonycteris* were dome $x^2 = 8.516$, $p < 0.005$) and conical ($x^2 = 5.426$, $P < 0.025$) ceiling form and caves with normal sections ($x^2 = 5.426$, $p < 0.025$) (Table 3). There was no relation between the number of *Craseonycteris* and cave characteristics in those caves where *Craseonycteris* was present.

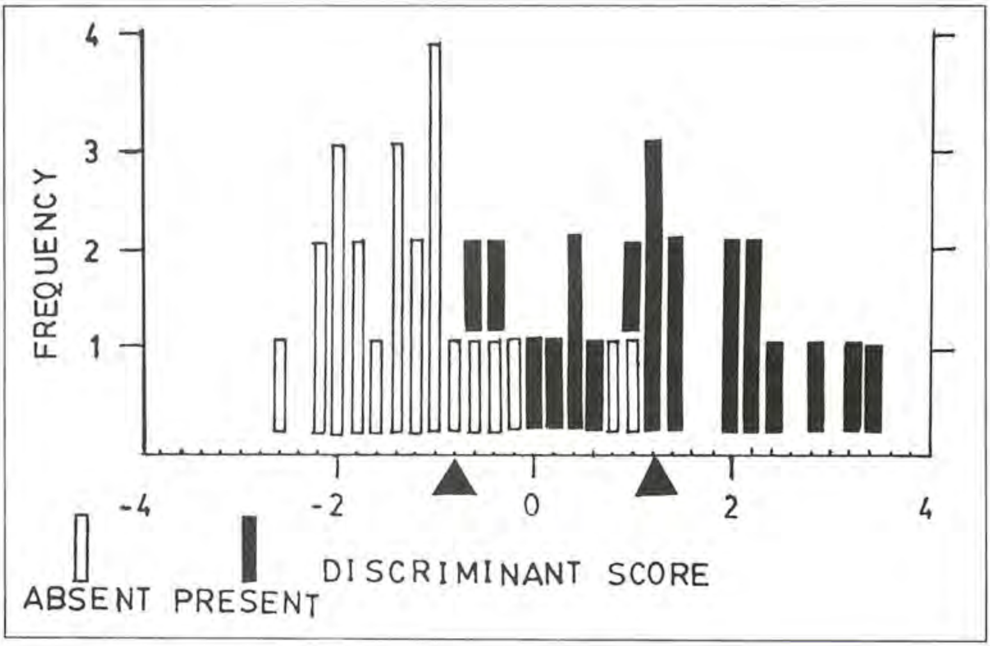

Figure 6. Distribution of discriminant scores of 45 caves, 21 of which contained *Craseonycteris* .

Table 2. Number of caves with and without *Craseonycteris,* and predicted number based on discriminant analysis of cave characteristics. Percent of caves correctly classified by discriminant analysis: 89.

	Actual number	Predicted number	
		without	with
Caves without	24	22 (91.7%)	2 (8.3%)
Caves with	21	3 (14.3%)	18 (85.7%)

Table 3. Chi-square tests on the important cave characteristics. Variable: Presence of *Craseonycteris;* M/L: More than expected (+) and less than expected (-); Sig: Significance.
Null hypothesis: Presence of cave characteristics has no value in predicting presence of *Craseonycteris.*

Characteristic	Variable	M/L	Chi^2	P	Sig
Number of entrances	1 entr	-	2.488	<0.5	
Number of Chambers	1 cham	-	2.897	<0.1	
Ceiling form					
Dome	Presence	+	8.516	<0.005	*
Conical	„	+	3.999	<0.05	*
Plan type					
Many small chambers	„	+	1.869	<0.5	
Long with junctions	„	+	0.89	<0.5	
Section type					
Normal	„	-	5.426	<0.025	*
Stalactites	„	+	3.494	<0.1	

DISCUSSION

The survey during August, 1983, to April, 1984 showed that *Craseonycteris* does not occur in caves in the limestone range above 14° 30′N (Fig. 1, S3). HALL (1982) reported no *Craseonycteris* in his survey during 1982 in caves south of the S2 area and extending to the limestone range in Ratburi Province. My recent survey in October, 1986 with J.D. Pettigrew of caves in Yala and Pattani Provinces in South Thailand near the Malaysian border found no *Craseonycteris*. It may not occur in the continuous limestone ranges extending to northern Thailand or southern Thailand. However, a survey of the limestone ranges east of the known *Craseonycteris* sites would probably offer the best chance of finding *Craseonycteris*, because the area is located at the same latitude as the known range and has similar forest habitat.

Craseonycteris prefer roosting in complex caves with many chambers. The reason for this could be energetic. If they roost in simple chambers, any disturbance from animals such as bears, tigers, porcupines, snakes, other bats and man could make them lose energy rapidly, as they are very small. MCNAB (1982) has shown that small bats have to spend more energy in proportion to their mass than larger bats to maintain body temperature. Keeping a certain individual distance in the roost may also minimize disturbance between individuals.

Insectivorous bats such as *Craseonycteris*, with a weight of about 2 g, should have a lower body temperature than other bats, according to MCNAB (1982). This could be the answer to why *Craseonycteris* prefer to roost at the top of the dome and in conical chambers. The top of the dome and conical chambers trap hotter air (TUTTLE & DIANE 1977). According to MCNAB (1969) increased ambient air temperature decreases the metabolic rate. Roosting at the top of conical and dome chambers possibly enables *Craseonycteris* to expend less energy.

Most of the caves located near the river contained more *Craseonycteris* than those farther away. In study area 1 (Fig. 1), which is covered with dry evergreen forest, most of the caves found near the river had much higher populations that those of study area 2, where only cave number 35 is near the riverside, all others being in deciduous forest. However, dry evergreen forest may provide better foraging than deciduous forest.

During the hot and dry weather conditions in summer (April), small numbers of bats were found in the hunting areas, and hunting behavior changed from flying in circles in the hunting area to a straight flight pattern over cassava and other clear areas. Insect prey may be in short supply in summer. Only some *Craseonycteris* still hunt, perhaps pregnant females who need food to grow their fetus.

There was no correlation between actual numbers of bats per cave and cave characteristics. The numbers of *Craseonycteris* in the caves may be an implication of regional distribution, as the highest numbers were found in study area 1. In study area 3, at latitude 14° 45′ – 15° 00′ N, there were no *Craseonycteris*. Both north and south of study area 1, *Craseonycteris* populations are lower, and distribution may be linked to dispersal from a central site. However, no definite conclusion can be reached without more field work.

Cassava was determined by discriminant analysis to be an important characteristic, but because most cassava fields may be relatively recent, it is unclear if cassava or some other correlated environmental variable is responsible for the correlation. Cassava is usually grown on relatively good soil in level areas. Comparing field observations in cassava plantations with kapok plantations (with a much smaller area than cassava), the kapok areas had a greater density of hunting bats. In cassava plantations I seldom detected the bats. This may indicate that there are more insects for *Craseonycteris* in kapok than in cassava areas.

Craseonycteris and water

Seven caves in study area 2 are very far from the river, with the closest one being about 4 km away (Fig. 2, cave 42), and the farthest being about 7 km away (caves 30 and 31). It is very hot and dry during the day in summer (April). I waited with my Mini Bat Detector many times at the river bank (Fig. 2, T1) about 7 km from a cave on the river bank (cave 35), but never found any *Craseonycteris* along the river. Drinking water may not be necessary for *Craseonycteris,* although the caves near the river show a greater number of *Craseonycteris.*

Craseonycteris and oxygen in ambient air at roost site

Five caves in study area 1 have low-oxygen air (caves 8, 12,13,15 23). One of them (cave 8) was checked. About 500 *Craseonycteris* were found. Low-oxygen caves therefore can be used for roosting. According to MCNAB (1969), small insectivorous bats regulate body temperature to reduce metabolic rate. Metabolic rate will decrease at higher ambient air temperatures up to a certain point. It is possible that the low-oxygen cave had a certain temperature level that enabled *Craseonycteris* to minimize metabolic rate. At this temperature *Craseonycteris* requires the smallest amount of oxygen for respiration. Less disturbance and better protection from some predators may also be possible by roosting in low-oxygen caves.

CONCLUSIONS

The presence or absence of *Craseonycteris* can be predicted from relatively few cave characteristics with about 88% certainty. The most important characteristics are dome and conical ceiling form and normal section type of cave. The small size of this bat and the difficulty it presumably has in maintaining its energy balance may have an important influence on such behavioral factors as location of roosting sites, response to oxygen level, and foraging behavior.

Craseonycteris seems to be the most widespread in the limestone region, and occurred in 41% of all caves searched. The second most frequent bat *(H. armiger),* occurred in only 31% of all caves (Table 1). However, the colony sizes of *Craseonycteris* were small, not greater than 500 bats. Several other species *(H. armiger, T. melanopogon)* had larger total abundances than *Craseonycteris.* Its short foraging distance may limit colony size. Only more available caves can support a larger population due to small numbers of *Craseonycteris* in each cave. These caves must also be near suitable foraging habitat.

The map of Mineral Resources of Thailand (Economic Geological Division, Department of Mineral Resources, Bangkok, Thailand, 1977) shows that the continuous limestone range in western Thailand covers about 60,000 km^2 (Fig. 1). There are about 20 km^2 per cave containing *Craseonycteris*, by rough estimate. Therefore there could be about 3,000 available caves throughout this range. The average population of *Craseonycteris* in each colony is about 100 bats. The total population could be as high as 300,000 bats, but more survey work needs to be done to establish the range of the species within the limestone areas.

RECOMMENDATIONS

1. The caves near park headquarters which formerly had *Craseonycteris* should be better protected from disturbance by people and foraging habitat near them should be protected or improved. Growing kapok and other trees near caves with small colonies, and near the caves without *Craseonycteris*, should be tried to create more foraging area.

2. Details of food resources and food habits should be further studied.

3. Further surveys should be made throughout the entire limestone range to establish more exactly the range of the species. A study of population changes should be made to find out if they can increase in the improved habitat, decrease in disturbed habitat and are stable in remote habitats.

4. Poor people around the forest should have improved living standards. About 90% of people around and inside the forest are poor shifting cultivators. Slash-and-burning farming occurs every dry season in summer (March and April) for rice planting in the rainy season (May-November). They borrow money from tycoons for supporting their families while waiting for the harvest. Then the tycoons require then to do illegal logging, hand-sawing lumber and cutting bamboo in the forest to work off their debts. When roads connect to the villages and transportation becomes available, every piece of wood will be gathered to make charcoal. There will not even be small trees left. The cleared land will then be planted in cassava. Most of the land will be bought by the tycoon later, and the farmers will become wanderers again.

To solve this problem, the farmers should be organized into cooperatives, I think if there were sufficient land for agriculture, equipment, and extension helps, the farmers would work for the cooperatives, and receive a better salary to support their families and education for their children, cheap food, clothes, free medical service, etc. By providing some income from visitors, the bat caves could be an asset to the community and therefore the people might protect them.

5. The caves located near villages outside the park area should be protected by law. The Forestry Department could employ local villagers to look after the caves and improve foraging habitat.

6. The bat foraging area can serve as a viewing area for visitors to see the world's smallest bat. It is not necessary for visitors to enter the cave to see it. Bungalows could be constructed near the foraging area. Tourists could easily see the bats hunting every morning and evening. Bringing tourists to see the world's smallest bat could provide extra income for villagers. Part of money could go to Royal Forestry Department to support protection or further research on *Craseonycteris*.

7. Fences should be constructed around the cave entrance about 100 m away. Entering *Craseonycteris* caves should be strictly prohibited.

8. Collecting the bat should not be allowed for any reason until we know more about population sizes and changes.

9. Locations of caves in the remote areas should be kept secret.

10. An educational display about *Craseonycteris* should be established at the Sai Yok National Park. A model of a roosting site and cave with *Craseonycteris* should be made. Good pictures and slides with explanations about *Craseonyceris* should be shown to tourists and students.

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