

SURVEY OF BATS (MAMMALIA: CHIROPTERA) IN THE KHAMMOUAN LIMESTONE NATIONAL BIODIVERSITY CONSERVATION AREA, LAO P.D.R.

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ABSTRACT

This survey recorded the diversity of bats in the Khammouan Limestone National Biodiversity Conservation Area (NBCA), Lao PDR. The baseline data obtained on the species present and their ecological requirements should aid in the formulation of comprehensive and effective management plans.

The NBCA covers a total area of 1,580 km², comprising mainly karst formations, with a dry open xerophytic flora on the limestone and small pockets of mixed deciduous and evergreen forest in the valleys and low-lying areas. The boundary of the NBCA has been drawn primarily around the base of the karst, to the extent that it contains little forest.

Surveys were carried out at 11 sites in the districts of Thakhek, Gnommalat and Hinboun, from 9 January to 2 February 1998, and 13 to 21 January 1999. Forty-one species of bat were recorded. A total of 445 bats of 34 species were caught while they were foraging and commuting. Roost sites of 29 species were discovered as a result of the detailed surveys of 27 caves. Also, this resulted in a collection of skeletal remains of 269 bats of 17 species.

At all of the villages visited bats were said to be hunted. They were shot with guns or catapults, or knocked down with long flexible sticks. In the northern part of the NBCA villagers were able to afford mist-nets, which are far more effective.

Many areas of forest around the NBCA have been either cut down for agriculture or heavily degraded by the removal of timber. There were still some areas of quality forest, although these were being cleared, in some cases quite quickly. Bats that live in and around the karst are heavily dependant on surrounding forested areas for foraging. Unless these areas are protected, many of the more specialised species of bats, as well as many other types of fauna, could soon disappear.

INTRODUCTION

The Khammouan Limestone is one of 18 National Biodiversity Conservation Areas (NBCA), formally declared in October 1993, along with a further 11 recommended areas. The NBCA covers a total area of 1,580 km², comprising mainly karst formations, with a dry open xerophytic flora on the limestone and small pockets of mixed deciduous and evergreen forest in the valleys and low-lying areas. Only 16% of the NBCA is covered by forest, including 11% mixed deciduous and 5% evergreen. Within the region the majority of flat lowland areas have settlements, with the people having cleared land for paddy cultivation and shifting agriculture; however, these areas are excluded from the NBCA

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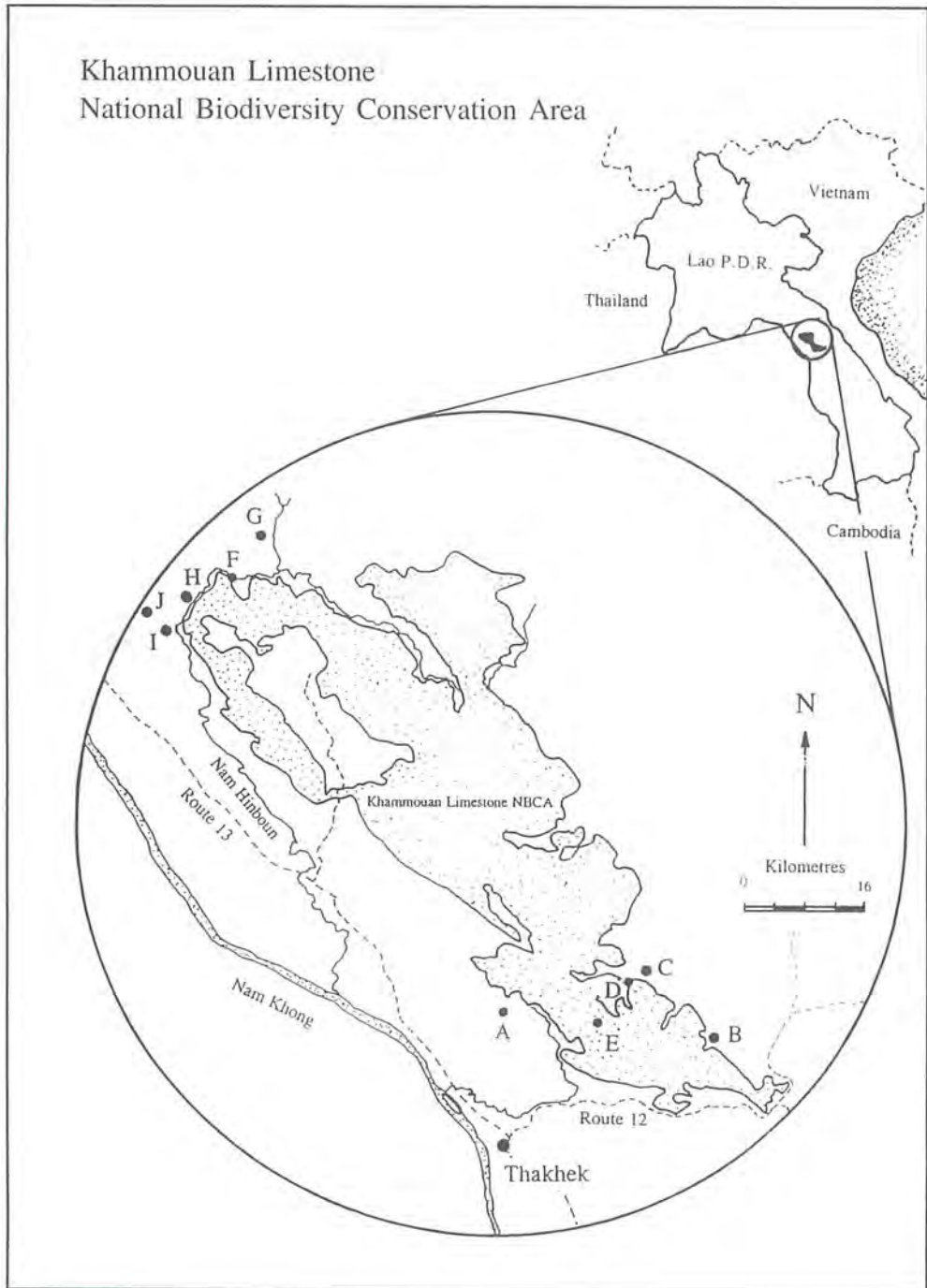


Figure 1. Study areas in Khammouan Limestone National Biodiversity Conservation Area, Lao P.D.R. A. Ban Pontong/Muang; B. Mouangkhai; C. Ban Louang; D. Ban Vieng; E. Tam Dan Jar Camp; F. Ban Kengkhot; G. Tam Thea; H. Nam Hinboun Camp; I. Ban Tonglom; J. Tam Pha Tok Camp.

(BERKMULLER *ET AL.*, 1995). Villagers collect forest products and hunting is widespread. Within the protected area there is little surface water or riverine habitats. The highest elevation is 1,578 m asl, although 95% of the area is 200–500 m asl (BERKMULLER *ET AL.*, 1995).

The present work set out to record the diversity of bats in order to determine areas of importance for the formation of priority management activity. Prior to this study few wildlife surveys had been conducted in the NBCA or the surrounding area (TIMMINS, 1997).

STUDY AREAS

Survey work was conducted in 11 areas in the districts of Thakhek, Gnommalat and Hinboun (Figure 1) in and around the Khammouan Limestone NBCA, Lao PDR, at altitudes of 150–160 m asl., for a total of 33 days, from 9 January to 3 February 1998 and 13 to 21 January 1999. At 7 of the study areas villages were used as a base and in the remaining sites forest camps were used. All of the villages were surrounded by paddy rice and in the villages bananas, kapok, jackfruit and coconuts were grown. Chickens, pigs and cattle, as well as working buffalo, were kept for meat.

Ban Pontong/Mauang, Thakhek District (17°34'40"N, 104°49'30"E/17°33'25"N, 104°49'35"E) on the southwest of the NBCA (Figure 2). The area was approximately 18 km north of the town of Thakhek. The habitat immediately around the base of the karst was heavily degraded mixed deciduous forest, with scrub and bamboo. The low lying areas away from the karst had been cleared for the cultivation of paddy rice (Figure 3). Ten caves were surveyed within this area. Detailed descriptions of some can be obtained from GREGORY *ET AL.* (1996): Tam Pha Deng, 17°33'35"N, 104°49'40"E; Tam Khun Fart (Dirty Bitter Water Cave), 17°34'50"N, 104°49'45"E; Tam Nam Phae, 17°33'35"N, 104°49'45"E; Tam Lort (Underground Tunnel), 17°35'15"N, 104°48'45"E; Tam Lom, 17°35'15"N, 104°48'45"E; Tam Quaie (Buffalo Cave), 17°33'15"N, 104°49'30"E; Tam Jongchott (Crouching Cave), 17°32'55"N, 104°50'10"E; Tam Sompoy (Figure 4), 17°33'05"N, 104°49'50"E; Tam Patchan, 17°34'10"N, 104°51'00"E; Tam Jungvung, 17°33'40"N, 104°50'15"E; Tam Gunhom, 17°33'50"N, 104°50'35"E.

Ban Mouangkhai, Gnommalat District (17°31'54"N, 105°04'28"E), on the southeast boundary of the NBCA. The village consisted of 565 people: 123 families and 118 houses. Local people said that the village had been established for c. 200 years. It was surrounded by heavily degraded mixed deciduous and semi-evergreen forest with bamboo. Many of the trees, particularly close to the village, had been removed for either building houses, fuel, or in the low lying areas, to make rice paddies. Four caves were surveyed: Tam Bing (Small Cave) 17°31'50"N, 105°04'45"E; Tam Key Thea (Bat Guano Cave) 17°32'50"N, 105°03'50"E; Tam Nam I (Water Cave) 17°31'23"N, 105°03'55"E; Tam Pra I 17°31'20"N, 105°04'00"E.

Ban Louang, Gnommalat District (17°36'10"N, 104°58'40"E) was on the southeast boundary of the NBCA, 13 km northwest of Ban Mouangkhai. It consisted of 495 people from 100 families. Surveys were along a 500 m stretch of limestone karst 200 m south of the village, in an area of heavily degraded mixed deciduous forest. Many trees, particularly close to the village, had been removed for either building houses, fuel or, in the low lying

areas, to make rice paddies. Two caves were surveyed: Tam Dinhye (Sand Cave) 17°36'05"N, 104°58'40"E; Tam Pra II 17°36'05"N, 104°58'45"E.

Ban Vieng, Gnommalat District (17°35'51"N, 104°57'57"E). The village was 1.5 km west of Ban Louang on the NBCA boundary. It was surrounded by paddy fields in the low lying area, and beyond this by degraded semi-evergreen forest with many larger trees having been removed by locals and commercial timber companies.

Tam Dan Jar Camp, Gnommalat District (17°33'35"N, 104°56'50"E). A valley area of less than 2 km², surrounded by 500–600 m limestone karst was surveyed. The habitat was dense, relatively undisturbed semi-evergreen forest, although some larger trees had been removed and small areas were starting to be cleared. Within the central plain of the valley were two areas of grassland both measuring approximately 900 x 200 m (Figure 5). According to local villagers these areas were cleared by aerial bombing raids by American forces during the Vietnam War, and several bomb craters and shell cases were found. The area has since been maintained as grassland by annual burning and was used for grazing cattle. Much of the valley floor floods during the rainy season. Two caves were surveyed: Tam Houay Si (Figure 6) 17°32'50"N, 104°55'55"E; Tam Dan Jar (Named after Mr Jar who died collecting honey from a bees nest in the entrance to the cave; Tam=Cave, Dan=the type of place bees live in caves), 17°33'35"N, 104°56'50"E.

Ban Kengkhot, Hinboun District (18°04'15"N 104°29'25"E), on the northern edge of the NBCA. The village comprised 324 people from 68 families. The habitat surrounding the village was heavily degraded semi-evergreen forest and rice paddy, with a few areas, 2–4 km south of the village, near the edge of the karst of the NBCA, which was relatively undisturbed forest. Two caves were surveyed: Tam Nong Seng (Light Pond Cave) 18°05'20"N, 104°28'35"E; Tam Kokhair, 18°04'25"N, 104°28'40"E.

Tam Thea (Bat Cave), Hinboun District (18°08'54"N, 104°30'57"E). A large extensive cave system 7 km north of the NBCA boundary. There were three large entrances, each measuring c. 30 x 50 m and several large chambers over 100 m in height. The cave entrances approximately 150 m up a limestone outcrop were accessed via a steep climb up a well worn path. At the base of the karst was bamboo, mixed deciduous trees and scrub for about 100–250 m, with the remaining valley floor, several km², being used for rice cultivation (Figure 7). The cave was 2 km east of the Ban Thamtem, which consisted of 126 people in 23 families.

Nam Hinboun Camp, Hinboun District (18°02'50"N, 104°26'10"E) on the edge of the Hinboun River where it cuts through the limestone karst, forming a steep-sided valley approximately 400 m wide. Nets and traps were put up in semi-evergreen and mixed deciduous forest in the bottom of the valley.

Ban Tonglom, Hinboun District (18°00'35"N, 104°40'50"E) on the northwest edge of the NBCA. The village had 428 people from 77 families. The habitat surrounding the village was mostly rice paddy and heavily degraded semi-evergreen forest and scrub; although, to the east between the village and the karst of the NBCA the forest was less degraded. Two caves were surveyed: Tam En (Swift Cave), 18°01'40"N, 104°25'50"E; Tam Pha Muang, 18°00'30"N, 104°40'50"E.

Tam Pha Tok Camp, Hinboun District, in a valley area of less than 2 km² of dense semi-evergreen forest. Although some of the larger trees had been removed by a commercial logging company the previous year, the forest was relatively undisturbed. The area was surrounded by karst formations reaching heights of 200–300 m. Three caves were surveyed:

Tam Pha Tok, 18°02'N, 104°24'E; Tam Nam II (Water Cave), 18°02'N, 104°24'E; Tam Kok Der Som, 18°02'N, 104°24'E.

Tam Ann, Thakhek district (17°42'30"N, 104°47'50"E). The cave was in the resource area of Ban Nakhu.

METHODS

To catch foraging or commuting bats, mist-nets and harp traps were set in the forest understorey across trails, roads, small tributaries and larger slow-flowing rivers. Harp traps were also used to catch bats as they emerged from roosts at dusk. The mist-nets used ranged in length from 3.6–12.0 m, in depth from 2.1–3.0 m, and were 30 or 50 denier/2 ply. They were placed at various heights from ground level up to the canopy as high as 18 m and were monitored continuously. Two harp traps were used, each with a catch area of 3.3 m². Both traps had four banks of lines as described by FRANCIS (1989).

The species, sex, age and reproductive condition of all animals caught were determined in the field (see ROBINSON, 1998). Body weight was recorded to the nearest 0.5g or 1.0g using 100g and 300g Pesola spring balances, respectively. Measurements of forearm, tail, tibia and ear length were recorded to the nearest 0.1 mm using dial callipers. All bats caught were marked by clipping a small area of fur mid-dorsally, allowing recaptured individuals to be recognised. All bats released were done so at the site of capture within one or two hours.

Bat roosts were located by searching hollow logs and trees, overhangs on river banks, and caves and fissures in rocky outcrops. The species composition of each site was determined by catching bats either within the roost or as they emerged at dusk. The size of bat populations was determined by dusk emergence counts and by visual estimates of numbers of roosting bats. All of the caves visited were surveyed for the remains of dead bats, these being mainly cranial fragments. All dental measurements are across the crowns unless indicated. Measurements were taken using either a pair of dial callipers or a microscope micrometer. The number of individuals measured is given in parentheses. Material collected is stored in The Natural History Museum, London.

RESULTS

Forty-one species of bats were recorded during the survey: 318 bats of 32 species were caught in mist-nets, harp traps and/or in and around caves and 9 additional species were identified from skeletal remains. Roosts of 26 species were discovered. The searching of caves resulted in a collection of cranial and mandible remains of 264 bats of 17 species.

Species Accounts

PTEROPODIDAE

Rousettus leschenaulti (Desmarest, 1820).—A partial ramus (BM(NH)98.681) was collected from a pile of dissociated owl pellets in the entrance to Tam Jungvung. Measurements: $c-m_3$ c.16.2; m_3 1.1 x 1.7.

Rousettus amplexicaudatus (Geoffroy, 1810).—Remains of 41 (BM(NH)98.640–680) were found in caves: Tam Key Thea (28), Tam Thea (8), Tam Pha Tok (3) and Tam En (2). Measurements: least interorbital width (14) 6.8–8.0; zygomatic width (10) 21.1–24.4; braincase width (10) 14.2–15.3; mastoid width (5) 14.1–15.2; c^1-c^1 (alveoli) (5) 6.7–7.0; m^2-m^2 (1) 11.1; $c-m^2$ (8) 12.1–14.5; $c-m^2$ (alveoli) (5) 12.6–13.5; complete mandible length from condyle (10) 23.3–28.9; ramus length from condyle (14) 24.5–30.2; $c-m_3$ (4) 14.0–15.9; $c-m_3$ (alveoli) (19) 12.5–18.8; m_3 (6) 0.6–1.0 x 1.0–1.4. In addition to the above specimens, remains of 23 attributable to the genus *Rousettus* were recovered from the caves Tam Thea, Tam Key Thea, Tam Kok Der Som and Tam En. Although these specimens could not be identified confidently to species level they were thought to be *R. amplexicaudatus*. These remains included 11 juvenile bats, as indicated by partially erupted teeth.

Cynopterus sphinx (Vahl, 1797).—Caught in four areas: Ban Pontong/Mauang, Ban Kengkhot, Ban Tonglom and Tam Houay Si. At Ban Pontong/Mauang it was caught at three places; feeding on the flowers of kapok and cultivated bananas at a height of 1.5–2.5 m (3 adult males, 2 adult females), 5 m over a dry river bed in mixed deciduous forest (2 adult males, 5 adult females) and one in Tam Sompoy, while roosting in a roof dome at a height of 4 m above the cave floor, in the light zone of the cave. At Ban Kengkhot three adults (2 females) were caught 2 m above the ground along narrow logging tracks in heavily degraded evergreen forest, 2 km east of the village. At Ban Tonglom an adult female was caught 2.5 m above the ground, in heavily degraded semi-evergreen forest 1 km from the village. Seven were caught in the entrance to Tam Houay Si. Forearm (21) 67.7–74.3; tail (20) 9.8–14.5; tibia (21) 25.7–30.0; ear (21) 20.2–24.2; weight (21) 37.0–57.0.

Megaerops niphanae Yenbutra and Felten, 1983.—Four adult females were caught in the entrance to Tam Houay Si. Measurements of 3 individuals: forearm 59.2–62.0; tibia 24.4–26.6; ear 17.5–18.5; weight 29.0–34.0. A damaged skull (BM(NH)98.699) was found on the floor in the entrance to Tam Pha Tok. Measurements: condylocanine length 27.7; least interorbital width 5.0; c^1-c^1 (alveoli) 5.6; m^1-m^1 8.6; $c-m^1$ 8.6.

Eonycteris spelaea (Dobson, 1871).—Six females and 5 males (2 females and 1 male were immature, the rest were adults), were caught in Ban Pontong while feeding from the flowers of kapok and cultivated bananas. Measurements of 11 individuals: forearm 63.9–74.5; tail 10.2–16.3; tibia 27.4–34.2; ear 16.7–20.9; weight 38.0–76.0. A rostrum and 6 rami (BM(NH)98.701–707) were found at Tam Thea, Tam En, Tam Key Thea and Tam Jungvung. Measurements: least interorbital width (1) 6.6; ramus length from condyle (1) 27.2; $c-m_3$ (alveoli) (3) 13.3–14.3.



Figure 2. Ban Mauang, Thakhek District.



Figure 3. View from Tam Jungvung, near Ban Mauang.



Figure 4. Tam Sompoy, located 200 m from Ban Mauang.



Figure 5. An area of grassland, cleared by aerial bombing during the Vietnam War, in a valley comprising semi-evergreen forest surrounded by karst.



Figure 6. Harp trap in the entrance to Tam Houay Si, at Tam Dan Jar Camp.



Figure 7. View from Tam Thea, Hinboun District.



Figure 8. Mist-net site, over the stream, near Ban Mouangkhai, Gnommalat District.

EMBALLONURIDAE

Taphozous theobaldi Dobson, 1872.—Remains of c. 79 (BM(NH)98.714–801 & 98.965) were found on the floor of Tam Thea, 7 were juvenile. Measurements of adults: greatest length of skull (25) 22.4–23.9; condylobasal length (23) 21.9–23.0; least interorbital width (32) 4.9–6.1; zygomatic width (21) 13.9–15.0; braincase width (20) 10.5–11.4; mastoid width (14) 12.4–13.2; c^1-c^1 (alveoli) (47) 4.5–5.2; m^3-m^3 (57) 9.6–10.5; $c-m^3$ (36) 10.4–11.8; ramus length from condyle (26) 18.0–19.3; $c-m_3$ (30) 11.2–12.1.

MEGADERMATIDAE

Megaderma spasma (Linnaeus, 1758).—Sixteen were caught at Ban Pontong/Mauang, Ban Mouangkhai, Ban Vieng and Tam Dan Jar Camp, at heights of 0.5–5 m in deciduous and semi-evergreen forest. At Ban Mouangkhai a roost of 6 was located in the inner light and dark zones of Tam Bing. Measurements of 14 individuals: forearm 61.0–66.0; tibia 34.4–37.5; ear 40.0–47.5; weight 19.0–27.0. The remains of two (BM(NH)98.712 & 98.713) were found, one each at Tam Jungvung and Tam Quaie. Measurements of the specimen from Tam Jungvung: greatest length of skull 25.3; condylobasal length 23.3; least interorbital width 3.5; zygomatic width 14.7; braincase width 10.5; mastoid width 11.6; c^1-c^1 (alveoli) 5.4; m^3-m^3 8.9; $c-m^3$ 10.4; ramus length from condyle 17.3; $c-m_3$ 11.5.

Megaderma lyra Geoffroy, 1810.—Three adult females were caught, one 1.5 m above a river, along the base of a limestone karst, 1.5 km southeast of Mouangkhai Village (Figure 8). Two were caught only 100–250 mm above the ground along a narrow path in degraded semi-evergreen forest 1 km south of Ban Vieng. Measurements: forearm 69.1–71.7; tibia 37.5–39.7; ear 35.1–41.1; weight 40.0–51.0. In addition a roost of c. 50–60 was found in Tam Kok Der Som. The remains of four (BM(NH)98.708–711) were found, two from Tam Thea, one a juvenile, and one each from Tam Jungvung and Tam Pha Tok. Measurements of adults: greatest length of skull (1) 29.6; condylobasal length (2) 26.2, 27.3; least interorbital width (2) 5.2, 5.3; zygomatic width (2) 17.1; braincase width (2) 12.3, 12.5; mastoid width (1) 13.3; c^1-c^1 (alveoli) (3) 5.9–6.2; m^3-m^3 (3) 9.7–10.6; $c-m^3$ (3) 11.7–12.1; complete mandible length from condyle (1) 20.8; ramus length from condyle (1) 21.2; $c-m_3$ (1) 13.1.

RHINOLOPHIDAE

Rhinolophus luctus Temminck, 1834.—Roosts were found at four sites, Tam Lort, Tam Lom, Tam Dinphye and Tam Nong Seng. At Tam Lort two were found hanging in the inner light zone of the cave and an adult female was caught: forearm 72.9; tail 59.4; tibia 38.5; ear 38.8; weight 43.0. One was seen in the dark zone of Tam Lom and another in the light zone at Tam Dinphye. Two were seen at Tam Nong Seng, roosting at the top of a c. 15 m high rift, in the inner light zone of the cave.

Rhinolophus paradoxolophus (Bourret, 1951).—Twenty-one were caught (14 adult males, and 4 adult and 3 immature females) at heights of 0.7–2 m. Eight in semi-evergreen forest: one, 500 m southwest of Tam Dan Jar, three, 2 km east of Ban Kengkhot, three at the Nam Hinboun Camp, and one at the Tam Pha Tok Camp. The remaining 13 bats were caught as they emerged from Tam Houay Si at dusk. A number of individuals, not caught in the trap, were seen to leave the cave after a period of “light sampling”. These were heard on

a bat detector echolocating at c. 25 kHz. It was estimated that the cave contained a roost of at least 50, although the exact location was unknown. Measurements of 17 individuals, except where indicated: forearm 50.9–56.8; tail (16) 25.5–34.8; tibia 21.1–24.8; ear 29.6–38.8; weight 8.5–11.5.

***Rhinolophus macrotis* Blyth, 1844.**—Eleven were caught in the entrance to Tam Houay Si, and one in heavily degraded semi-evergreen forest, 1.5 km east of Ban Tonglom. Ten specimens (5 male, 5 female) were collected (BM(NH)98.129, 130 & 99.56–63).

***Rhinolophus pearsonii* Horsfield, 1851.**—Two adults, a male and female, were caught at a height of 1.5–2 m, in semi-evergreen forest, one, 500 m southwest of Tam Dan Jar and the other 100 m southeast of Tam Houay Si. Also, an adult male and female were caught in the entrance to Tam Houay Si. For 4 individuals: forearm 46.7–51.1; tail 19.8–23.8; tibia 24.9–26.8; ear 26.1–27.3; weight 9.0–13.0.

***Rhinolophus pusillus* Temminck, 1834.**—Roosts were found in Tam Jongchott and Tam Houay Si. Four females were caught at each site, 3 adults and 1 immature at Tam Jongchott, and four adults at Tam Houay Si. Also, an adult male was caught in semi-evergreen forest, 100 m southeast of Tam Houay Si. For 10 individuals: forearm 33.8–37.1; tail 14.0–20.8; tibia 14.0–15.2; ear 14.2–16.6; weight 3.0–4.0. A group of 2–5 were observed foraging together in a small wooden hut, on stilts 4 m long, used to store unchaffed rice. It was totally enclosed with the exception of a gap of c. 300 mm around the eaves and at one gable. The bats were observed flying around the inside of the hut c.1 m from the level of the rice. The hut was monitored intermittently over two successive nights and the bats were present from shortly after dusk for at least five hours.

***Rhinolophus ?subbadius* Blyth, 1844.**—A skull and ramus (BM(NH)98.806) possibly attributable to this species (condylocanine length 12.8; least interorbital width 2.3; zygomatic width 7.1; c^1 – c^1 (alveoli) 3.7; m^3 – m^3 5.3; c – m^3 5.5) was found on the floor of Tam Kok Der Som.

***Rhinolophus malayanus* Bonhote, 1903.**—A total of 18 adults were caught at Ban Pontong, Ban Mouangkhai, Ban Vieng, Tam Dan Jar Camp, Ban Kengkhot and Ban Tonglom. At Ban Pontong in heavily degraded deciduous forest/scrub on the outskirts of the village and around banana plants within the village, whereas at Tam Dan Jar Camp it was caught in relatively undisturbed semi-evergreen forest. Four were caught in the entrance to Tam Houay Si. For 14 individuals: forearm 40.1–43.2; tail 19.3–24.0; tibia 16.3–18.4; ear 17.1–20.3; weight 7.0–8.0. A single bat (BM(NH)98.846) was collected. An adult male was caught foraging with a group of 2–5 *R. pusillus* in a small wooden hut at Ban Pontong, as described above.

***Rhinolophus stheno* Andersen, 1905.**—Five were caught at a height of 1–2 m in semi-evergreen forest, one near Ban Vieng, three 700 m southeast of Tam Houay Si in forest which was undisturbed and one in heavily degraded forest, 1.5 km east of Ban Tonglom. For 4 individuals: forearm 43.9–46.0; tail 16.4–19.9; tibia 20.7–21.8; ear 17.2–20.5; weight 6.0–7.0. One (BM(NH)98.855) was collected.

***Rhinolophus thomasi* Andersen, 1905.**—Found roosting in the dark zone of 6 caves, five at a height of c. 2 m, in a chamber formed by the veins of a large stalactite in Tam Pha

Deng. An adult male was caught while roosting in the dark zone of both Tam Khun Fart and Tam Quaie and 6 were seen hanging in Tam Sompoy, where a single adult male was caught. Also, two adults were caught in Tam Houay Si. At Tam Jongchott several torpid animals were seen hanging on the cave wall.

Seventeen were caught along trails in semi-evergreen forest, 1 km south of Ban Vieng, at Ban Mouangkhai, at Tam Pha Tok Camp and Tam Houay Si. Also, a single bat was caught as it flew down a pathway in scrub at the side of a river at Ban Pontong/Mauang. For 25 individuals: forearm 42.2–44.7; tail 19.5–25.4; tibia 16.4–18.0; ear 17.5–23.7; weight 7.0–9.0. An adult male (BM(NH)98.845) was caught and collected.

HIPPOSIDERIDAE

Hipposideros pomona Andersen, 1918.—Six roosts were found at Tam Nam Phae, Tam Jongchott and Tam Bing where they roosted on the wall in the dark zone of the cave, at Tam Jungvung five hung in a chamber formed by stalactites 1.5 m above the ground, in Tam Pra II one was found roosting in the light zone of a small chamber formed by stalactites, about 10 m above the ground and at Tam Houay Si four were caught at the cave entrance. Sixteen were caught at heights of 0.5–2.0 m in heavily degraded semi-evergreen forest, at Ban Kengkhot, and at Tam Pha Tok Camp and Tam Dan Jar Camp, in undisturbed forest. For 29 individuals: forearm 39.7–43.1; tail 26.4–34.5; tibia 18.1–20.5; ear 20.4–26.0; weight 5.0–8.0.

Hipposideros cineraceus Blyth, 1853.—An adult male (forearm 33.2; tail 23.1; tibia 14.5; ear 15.9; weight 4.0) was caught at a height of 1–2 m along the edge of a river which ran along the base of a limestone karst, adjacent to Tam Nam I. The bat (BM(NH)98.853) was collected.

Hipposideros armiger (Hodgson, 1835).—An adult female (forearm 91.7; tail 59.7; tibia 39.1; ear 31.6; weight 43.0) was caught in Tam Nam II. The bat was hanging from the ceiling in a dark area of the cave approximately 50 m from the entrance. The cave was damp with pools of water in areas and flooded during the rainy season, as indicated by debris on the ceiling. Also, remains of 7 (BM(NH)98.832–836 & 99.54, 99.55) were found, one in each of the following caves; Tam Nong Seng, Tam Quaie, Tam Pra I, Tam En, Tam Kok Der Som and Tam Sompoy. Measurements: greatest skull length 32.4; condylobasal 29.4; condylocanine length (3) 27.2–28.9; least interorbital width (6) 4.0–4.2; zygomatic width (4) 16.9–18.5; braincase width (4) 10.6–11.8; mastoid width (4) 14.1–15.7; c^1-c^1 (alveoli) (4) 8.1–8.6; m^3-m^3 (6) 11.8–12.4; $c-m^3$ (5) 11.8–12.8; complete mandible length from condyle 21.8; ramus length from condyle (4) 21.3, 22.5; $c-m_3$ (3) 13.1–13.6.

Hipposideros larvatus (Horsfield, 1823).—An adult female (forearm 53.6; tail 27.7; tibia 20.0; ear 21.4; weight 9.0) was caught in the entrance to Tam Jongchott. Also, remains were recovered from each of the following caves; Tam Thea, Tam Pha Muang, Tam Kokhair and Tam Jungvung (BM(NH)98.807–810). Measurements: condylocanine length (1) 19.1; least interorbital width (1) 3.3; braincase width (1) 8.6; mastoid width (1) 11.2; c^1-c^1 (alveoli) (2) 5.3, 5.5; m^3-m^3 (1) 8.3; $c-m^3$ (2) 8.3, 9.2; ramus length from condyle (2) 14.5, 14.6; $c-m_3$ (2) 8.8, 8.9.

***Hipposideros diadema* (Geoffroy 1813).**—Cranial remains of 22 (BM(NH)98.811–831) were collected from three caves: Tam En (18), Tam Kokhair (3) and Tam Jungvung (1). Measurements: Condylacanine length (2) 27.0, 27.9; least interorbital width (17) 3.4–4.1; zygomatic width (9) 17.7–19.1; braincase width (2) 11.0, 11.2; mastoid width (2) 14.3, 14.6; c^1-c^1 (alveoli) (5) 7.4–8.2; m^3-m^3 (12) 11.8–12.9; $c-m^3$ (3) 12.1–12.9; complete mandible length from condyle (1) 21.8; ramus length from condyle (1) 22.3; $c-m_3$ (1) 13.6.

***Hipposideros* sp. (A) Gray, 1831.**—A damaged skull (BM(NH)98.838): least interorbital width 2.8; c^1-c^1 (alveoli) 4.8; m^3-m^3 7.5; $c-m^3$ 7.6, was found on the floor of Tam Lom near Ban Pontong. It resembles *H. larvatus*, although it is smaller.

***Hipposideros* sp. (B) Gray, 1831.**—An incomplete skull (BM(NH)98.837): zygomatic width 19.4; least interorbital width 3.1; m^3-m^3 13.0) was recovered from owl pellets found at Tam Jungvung.

***Hipposideros* sp. (C) Gray, 1831.**—The remains of 15 (BM(NH)98.947–98.961) were recovered from Tam Thea, Tam Dan Jar, Tam Pha Muang and Tam Jungvung. The taxonomy of this species is currently being investigated.

***Aselliscus stoliczkanus* (Dobson, 1871).**—Tam Jongchott and Tam Houay Si, were used as roost sites. At Tam Jongchott several were seen roosting on the cave wall 50–100 m from the entrance. Most appeared torpid. Two torpid immature females were caught. During the evening emergence 28 were caught. In the entrance to Tam Houay Si 28 were caught. Each cave was thought to contain a roost of at least 100 individuals.

Seventeen were caught at Ban Mouangkhai, Ban Vieng, Tam Dan Jar Camp, Ban Kengkhot, Nam Hinboun Camp, Ban Tonglom and Tam Pha Tok Camp, at heights of 0.5–1.5 m above the ground in mixed deciduous and semi-evergreen forest, both degraded and relatively undisturbed. For 58 individuals: forearm 40.4–45.4; tail 31.6–40.4; tibia 17.9–20.6; ear 9.4–13.4; weight 3.5–6.0. Remains of four (BM(NH)98.839–842) were found at Tam Kok Der Som (3) and Tam Jungvung (1). Measurements: condylacanine length (3) 12.3–13.3; least interorbital width (4) 1.7–1.9; zygomatic width (4) 7.3–7.4; braincase width (3) 6.0; mastoid width (1) 7.0; c^1-c^1 (alveoli) (3) 3.2–3.3; m^3-m^3 (2) 5.1–5.2; $c-m^3$ (2) 5.1–5.2; ramus length from condyle (1) 9.3; $c-m_3$ (1) 5.4.

VESPERTILIONIDAE

***Myotis siligorensis* (Horsfield, 1855).**—Roosts were found in five caves: Tam Nam I, Tam Kokhair, Tam Houay Si, Tam Quaie and Tam En. At Tam Nam I five bats, three separate and a pair, were found roosting in crevices/shafts formed in stalactites, in the inner light zone of the cave. The roost entrances measured c. 30 x 25 mm and had depths of up to 300 mm. The bats roosted at various depths within these cavities from the deepest point to having noses level with the entrance. All of the roosts were stained with oils from the bats' fur suggesting long term usage. The roost entrances were at heights of 1–2 m above the cave floor, which was wet and muddy. In Tam Kokhair an adult male was found roosting in a crevice, 3 m from the floor of the cave in the inner light zone. The cave was on the banks of the Nam Hinboun. A single bat was found roosting in a crevice in the side of the cave wall in Tam En. The roost was 3.5 m above the cave floor in the dark zone of the cave. An adult female was found roosting in the veins of a stalactite in the entrance

to Tam Quaie, 4.5 m above the ground. Also, 18 were caught as they emerged from Tam Houay Si and 56 as they flew over slow-flowing water adjacent to the entrance of Tam Nam and Tam Pong (17°34'N, 104°50'E), at Tam Dan Jar Camp and over a small stream which led from a large pool, known as "Pellangwa", at the base of the limestone karst, 3 km south of Ban Kengkhot. Measurements of 39 individuals (excluding voucher specimens): forearm 30.5–34.7; tail 31.0–36.9; tibia 12.7–15.7; ear 9.7–14.2; weight 3.0–6.0. Four specimens (BM(NH)98.123 & 98.962–964) were collected. Measurements: forearm 32.5–35.3; tail 32.2–35.6; tibia 41.1–15.3; ear 10.8–12.8; greatest skull length 12.6–13.1; condylobasal length 11.3–11.9; condylocanine length 10.6–11.4; least interorbital width 2.9–3.2; zygomatic width 7.4–7.6; braincase width 6.2–6.8; mastoid width 6.6–6.9; c^1-c^1 (alveoli) 3.0–3.3; m^3-m^3 4.8–5.1; $c-m^3$ 4.4–5.0; $c-m_3$ 4.9–5.2.

***Myotis ricketti* (Peters, 1869).**—Thirteen were caught, an adult male and female over a slow flowing pool along the base of a limestone karst, 1.5 km southeast of Mouangkhai Village (Figure 8), an adult male over a small slow flowing stream at Tam Dan Jar Camp and a further 9 as they emerged from Tam Houay Si and flew over a small 10 m diameter pool in the entrance. Weights and measurements of 7 individuals (except where indicated): forearm 51.5–55.4; tail 47.6–51.0; tibia 19.8–21.7; ear 16.5–22.3; foot length, excluding claws (3) 17.5–20.0; weight 17.0–20.5. Cranial measurements of two voucher specimens (BM(NH)98.849 & 98.850): greatest skull length 20.1, 19.6; condylobasal length 18.8, 18.5; condylocanine length 18.2, 17.6; least interorbital width 5.0, 4.8; zygomatic width 13.2, 12.4; braincase width 9.9, 9.5; mastoid width 10.2, 9.9; c^1-c^1 (alveoli) 5.6, 5.5; m^3-m^3 8.4, 8.3; $c-m^3$ 8.5, 8.0; $c-m_3$ 8.8, 8.4.

Five droppings were collected from two bats caught near Mouangkhai Village, which were put in clean cotton bags for a period of c.1 hour, shortly after capture. Observations on the droppings using a x 10 and x 30 power binocular microscope showed that they contained c. 97% fish scales, with small amounts of insect chitin.

***Ia io* Thomas, 1902.**—Roosts were found in Tam Houay Si and Tam Pha Tok. In Tam Houay Si an adult male was caught, c. 1 km from the cave entrance. It was torpid, roosting at a height of 5 m, on a flat c. 60 m high, slightly overhanging cave wall. Also, a group of three was seen on a similar wall, although at heights of 12–15 m. The bats were 1.5 and 7 m apart from each other, and c.1.5 km from the cave entrance. At Tam Pha Tok an adult female was found roosting in a small pocket in the ceiling of the cave entrance. The hole was c. 150 mm deep with an entrance of c.50 mm diameter. This was at a height of 4 m in the light zone of the cave. Measurements of the 6 individuals caught: forearm 75.6–79.8; tail 66.0–71.6; tibia 33.6–36.5; ear 23.6–27.7; weight 46.0–57.0. Rostrums of two (BM(NH)98.843 & 98.844) were found, one each from Tam En and Tam Houay Si. Measurements of a single specimen: c^1-c^1 (alveoli) 8.5; m^3-m^3 11.6.

***Tylonycteris robustula* Thomas, 1915.**—Three females (2 adults and 1 immature) were caught c. 1.5 m above a river, along the base of a limestone karst, 1.5 km southeast of Mouangkhai Village. Measurements: forearm 25.5–27.2; tail 27.8–31.1; tibia 10.1–12.0; ear 10.2–11.2; weight 3.5–4.5. The largest and the smallest (BM(NH)98.851 & 98.852) were collected. Cranial measurements: greatest skull length 12.4, 12.4; condylobasal length 11.6, 11.5; condylocanine length 11.5, 11.3; least interorbital width 3.8, 3.7; width across supraorbital tubercles 6.2, 5.9; zygomatic width 9.1, 8.9; braincase width 6.8, 6.6; mastoid

width 7.5, 7.4; c^1-c^1 (alveoli) 3.7, 4.1; m^3-m^3 5.5, 5.5; $c-m^3$ 4.1, 4.1; $c-m_3$ 4.5, 4.5.

***Pipistrellus pulveratus* (Peters, 1871).**—Three were found roosting in crevices formed by the veins of a stalactite, 3.5 and 4 m off the floor in the entrances to Tam Sompoy and Tam Pha Tok, respectively, and at a height of 2 m above the wet and muddy floor at Tam Nam I. Six were caught while they flew over water near Ban Pontong, and three as they emerged from Tam Houay Si. For 10 individuals (except where indicated): forearm 32.5–36.4; tail (9) 32.7–40.5; tibia 12.8–15.0; ear 11.2–14.3; weight 4.0–5.5. Cranial measurements of three voucher specimens (BM(NH) 98.124–126): greatest skull length 13.1–14.1; condylobasal length 12.6–13.3; condylocanine length 12.1–12.7; least interorbital width 3.4–3.8; zygomatic width 8.0–8.7; braincase width 6.4–6.6; mastoid width 7.0–7.2; c^1-c^1 (alveoli) 4.2–4.4; m^3-m^3 5.3–5.7; $c-m^3$ 4.5–4.9; complete mandible length from condyle 8.5–9.2; ramus length from condyle 9.1–9.5; $c-m_3$ 4.8–5.1.

***Pipistrellus tenuis* (Temminck, 1840).**—Two were caught as they emerged from Tam Houay Si, and were collected (BM(NH)98.127 & 98.128). Measurements: forearm 30.7, 33.4; tail 30.0, 31.8; tibia 12.5, 13.3; ear 11.2, 11.2; weight 4.0, 4.5; greatest skull length 11.6, 12.1; condylobasal length 11.1, 11.7; condylocanine length 10.8, 11.3; least interorbital width 3.5, 3.7; zygomatic width 7.8, 8.2; braincase width 6.1, 6.3; mastoid width 6.6, 6.9; c^1-c^1 (alveoli) 3.8, 4.0; m^3-m^3 5.3, 5.4; $c-m^3$ 4.1, 4.2; ramus length from condyle 8.5, 8.6; $c-m_3$ 4.2, 4.2.

***Hesperoptenus blanfordi* (Dobson, 1877).**—Four adults were caught, one at Ban Pontong at a height of c. 5 m above the ground, in relatively undisturbed mixed deciduous forest and three in the entrance to Tam Houay Si. Weights and measurements: forearm 28.2–29.0; tail 25.7–30.2; tibia 11.4–12.0; ear 9.3, 12.5; weight 6.0, 7.0.

***Miniopterus schreibersii* (Kuhl, 1819).**—Caught in the entrance to Tam Houay Si, and collected (BM(NH)98.856). Measurements: forearm 42.1; tail 45.7; tibia 16.0; ear 12.5; weight 8.5; greatest skull length 15.4; condylobasal length 15.0; condylocanine length 14.0; least interorbital width 3.6; zygomatic width 8.3; braincase width 7.7; mastoid width 8.3; c^1-c^1 (alveoli) 4.5; m^3-m^3 6.3; $c-m^3$ 6.1; $c-m_3$ 6.5.

***Miniopterus magnater* Sanborn, 1931.**—Caught at a height of c. 0.5 m above a slow flowing river near Ban Pontong. The bat (BM(NH)98.848) was collected. Measurements: forearm 49.4; tail 57.5; tibia 20.5; ear 14.7; greatest skull length 16.6; condylobasal length 16.2; condylocanine length 15.4; least interorbital width 4.2; zygomatic width 9.7; braincase width 8.4; mastoid width 9.1; c^1-c^1 (alveoli) 5.0; m^3-m^3 7.4; $c-m^3$ 6.8; $c-m_3$ 7.0.

***Murina cyclotis* Dobson, 1872.**—Five adults were caught in semi-evergreen forest, one at Ban Vieng where the forest was degraded and three in the entrance to Tam Houay Si. Measurements: forearm 30.0–32.9; tail 35.1–39.7; tibia 17.1–18.5; ear 12.6–16.0; weight 5.0–5.5.

Cranial measurements of two voucher specimens (BM(NH)98.854 & 99.51): greatest skull length 15.8, 16.8; condylobasal length 14.7, 15.6; condylocanine length 14.3, 15.0; least interorbital width 4.1, 4.3; zygomatic width 9.1, 10.3; braincase width 7.6, 7.6; mastoid width 7.8, 8.4; c^1-c^1 (alveoli) 3.8, 4.5; m^3-m^3 5.3, 5.9; $c-m^3$ 5.5, 5.8; $c-m_3$ 5.9, 6.1.

***Murina* sp. Gray 1842.**—An adult female (BM(NH)99.50) was caught in the entrance to Tam Houay Si and collected. Measurements: forearm 34.5; tail 37.5; tibia 15.7; ear 15.2; weight 5.5; greatest skull length 16.0; condylobasal length 14.9; condylocanine length 14.3; least interorbital width 4.3; zygomatic width 9.4; braincase width 7.5; mastoid width 8.1; c^1-c^1 (alveoli) 4.0; m^3-m^3 5.7; $c-m^3$ 6.0; $c-m_3$ 6.5.

***Harpiocephalus harpia* (Temminck, 1840).**—Two adults were caught in the entrance to Tam Houay Si. One was collected (BM(NH)98.858). The cave was in an area of relatively undisturbed semi-evergreen forest. Measurements: forearm 46.8, 52.5; tail 48.7, 55.7; tibia 21.5, 23.5; ear 17.9, 19.2; weight 16.0, 22.5. Cranial measurements of voucher specimen: greatest skull length 21.4; condylobasal length 19.7; condylocanine length 19.0; least interorbital width 5.5; zygomatic width 13.3; braincase width 9.6; mastoid width 11.4; c^1-c^1 6.4; c^1-c^1 (alveoli) 6.3; m^3-m^3 6.3; $c-m^3$ 6.9; $c-m_3$ 7.6.

***Kerivoula hardwickii* (Horsfield, 1824).**—Nine adults and an immature were caught at heights of 0.5–1.5 m, at three localities. At Ban Pontong five were caught in degraded mixed deciduous forest and two each in degraded semi-evergreen forest at Ban Tonglom and in relatively undisturbed semi-evergreen forest at Tam Dan Jar Camp. Also, one was caught in the entrance to Tam Houay Si. Measurements of 9 bats: forearm 30.5–33.4; tail 37.2–46.5; tibia 16.2–18.4; ear 12.0–15.3; weight 3.0–4.5. Cranial measurements of a single adult female (BM(NH)98.847) collected: greatest skull length 13.4; condylobasal length 12.4; condylocanine length 12.4; least interorbital width 3.0; zygomatic width 7.9; braincase width 7.2; mastoid width 7.1; c^1-c^1 (alveoli) 3.3; m^3-m^3 4.9; $c-m^3$ 5.5; $c-m_3$ 5.7.

***Phoniscus jagorii* (Peters, 1866).**—Two adults (BM(NH)99.49 & 52) were caught in the entrance to Tam Houay Si and collected. Measurements: forearm 37.0, 37.7; tail 39.4, 42.9; tibia 19.0, 20.3; ear 13.8, 15.5; weight 8.0, 7.5; greatest skull length 15.9, 16.1; condylobasal length 14.7, 15.0; condylocanine length 14.7, 14.9; least interorbital width 4.0, 4.0; zygomatic width 10.0, 9.9; braincase width 7.6, 7.7; mastoid width 8.3, 8.2; c^1-c^1 (alveoli) 3.6, 3.7; m^3-m^3 6.0, 5.9; $c-m^3$ 6.9, 7.0; $c-m_3$ 7.3, 7.2.

***Tadarida ?plicata* (Buchanan, 1800).**—The remains a single animal (BM(NH)99.53) were found on the floor of Tam Ann. Measurements: forearm (dry) 48.1; greatest skull length 20.5; condylobasal length 18.9; condylocanine length 18.0; least interorbital width 4.4; zygomatic width 12.7; braincase width 10.7; mastoid width 11.6; c^1-c^1 (alveoli) 5.2; m^3-m^3 9.2; $c-m^3$ 7.6; $c-m_3$ 8.1; complete mandible length from condyle 13.1; ramus length from condyle 13.7.

Guano Collection

Guano was collected for fertiliser at only two sites, Tam En (Swift Cave) and Tam Key Thea (Bat Dung Cave). At Tam En, villagers collected it for themselves and to sell at about 100 baht/50-kg sack. This was mainly from a large roost of swifts. At Tam Key Thea the guano collected was old and evidence of historically a much more substantial collection of bats having used the cave. At the time of the visit there were bats present, but not enough to make guano collection profitable.

Hunting

People from the villages thought that bats tasted delicious and they hunted them when possible. At Ban Pontong, because villagers could not afford to buy mist-nets, they would shoot bats with shotguns. At the entrance to several caves, Tam En, Tam Kok Der Som, Tam Key Thea and Tam Thea, villagers placed long flexible sticks with branches, often with thorns, tied to the ends. These were used to knock down flying bats as they emerged from the cave or flew around inside. At Tam En, villagers acting as guides, used catapults to shoot stones at a cluster of 1000–2000 fruit bats about 70 m up in the roof of a large chamber, causing them to scatter about the cave. Also in the cave were several lengths of bamboo tied together to make long mist-net poles.

At Ban Thamtem, villagers said that they used mist-nets to regularly harvest bats from caves in the rainy season, particularly Tam Thea. The nets were purchased from Thailand for 5,000 kip. In this cave several old and tangled, discarded nets were found on the floor. In 1995 Mouangkhai villagers took several people from Thakhek to Tam Key Thea, where, using mist-nets, they caught enough bats to fill two 50-kg rice sacks. Villagers did not eat bats during our stay at any of the villages. They were hunted mainly in the rainy season when they were more abundant.

DISCUSSION

Species Distribution and Status

Forty-one bat species were recorded, 5 Megachiroptera (fruit bats) and 36 Microchiroptera. The Megachiroptera: *Rousettus leschenaulti*, *R. amplexicaudatus*, *Cynopterus sphinx*, *Megaerops niphanae* and *Eonycteris spelaea*, have all been previously recorded in Lao PDR (PHILLIPS, 1967; DEUVE, 1972; CORBET & HILL, 1992; FRANCIS *ET AL.*, 1996; ROBINSON, 1998), and are probably widespread in the country, perhaps with the exception of *R. amplexicaudatus*, which may not occur in the extreme north.

Taphozous theobaldi was found in a large cave complex, Tam Thea, in Hinboun District. This was only the second record and roost site, known for this species in Lao PDR, the first being from Xe Piame NBCA, close to the Cambodian border (ROBINSON, 1998). Although the species has been recorded in northeast Thailand and southern Vietnam (CORBET & HILL, 1992) this record extends the northerly range of this species in Southeast Asia.

There are two species of *Megaderma* which occur across Southeast Asia, including Lao PDR (CORBET & HILL, 1992). Both species, *spasma* and *lyra*, were found in the present study.

Nine species of *Rhinolophus* were recorded, 8 of which: *Rhinolophus luctus*, *R. paradoxolophus*, *R. macrotis*, *R. pearsonii*, *R. pusillus*, *R. malayanus*, *R. thomasi* and *R. stheno*, were previously known from Lao PDR (PHILLIPS, 1967; FRANCIS *ET AL.*, 1996; FRANCIS *ET AL.*, 1997a; ROBINSON, 1998; FRANCIS *ET AL.*, 1999). *Rhinolophus paradoxolophus* is listed as "Threatened: vulnerable" and *R. thomasi* as "Lower risk: near threatened" by IUCN (1996). A skull possibly attributable to *Rhinolophus subbadius* was found in a cave in the north of the NBCA. This is a species not previously recorded from

Lao PDR, although it was known, from a few records, in northeast India, Myanmar and northern Vietnam (CORBET & HILL, 1992). The species is listed as "Data deficient" by IUCN (1996). The current record represents a slight southern extension of the species' range.

From the family Hipposideridae, 9 species were recorded, 5 of which: *Hipposideros pomona*, *H. cineraceus*, *H. armiger*, *H. larvatus* and *A. stoliczkanus*, are known to be widespread across much of Southeast Asia (CORBET & HILL, 1992, FRANCIS *ET AL.*, 1997a). *Hipposideros pomona* is listed as "Data deficient" by IUCN (1996). *Hipposideros diadema* was recorded only from cranial remains at three sites on the northern edge of the NBCA, including two skulls recovered from recent owl pellets. These records extend the range of this species northwards; until recently, it had not been found any further north than southern Lao PDR. There are three, clearly distinct species of *Hipposideros*, labelled A, B & C which have as yet been identified only to genus.

Thirteen species of the family Vespertilionidae were recorded. What is currently recognised as *Myotis siligorensis* (CORBET & HILL, 1992) was caught at several sites in both the north and south of the NBCA. This bat is believed to be that recorded by FRANCIS *ET AL.* (1998) in a survey of the Khammouan Limestone NBCA. *Myotis alticraniatus* is a synonym of *M. siligorensis* (CORBET & HILL, 1992). However, recent evidence suggests that *M. alticraniatus* may be a distinct species, to which the Lao specimens may be attributable (Francis, pers. comm.).

Thirteen *M. ricketti*, listed as "Near-threatened" by IUCN (1996), were caught flying at 0.3–0.5 m at two sites over slow-flowing open water and at a third over a 10 m diameter pool in a cave entrance. At one site they were observed flying low over the water, occasionally dipping their feet into it. *M. ricketti* is a species recorded from south, east and northeast China and Hong Kong (CORBET & HILL, 1992), and more recently Lao PDR (FRANCIS *ET AL.*, 1996). It has been speculated that it eats fish (ALLEN, 1938, FRANCIS *ET AL.*, 1996), as do some other large-footed bats such as *Noctilio leporinus*, *M. vivesi* (ALTENBACH, 1989) and *M. adversus* (ROBSON, 1984); however, until now this had not been proven. Droppings collected during the present study contained large amounts of fish scales (ROBINSON & WEBBER (1998), indicating that fish could be an important constituent of its diet.

Ia io is a species with few records, ranging from India, through Thailand to North Vietnam and China (TOPAL, 1970; ROBINSON *ET AL.*, 1995). There was only one previous record of the species from Lao PDR, from Tran-Ninh in the northwest, recorded by BOURRET (1942), although originally misidentified (TOPAL, 1970). In the present study the species was recorded from three localities both in the south and north of the NBCA. The species is listed as "Lower risk: near threatened" by IUCN (1996).

Hesperoptenus blandfordi was caught in the south of the NBCA. The species is known from few localities in Lao P.D.R (FRANCIS *ET AL.*, 1999; ROBINSON, 1997).

Harpiocephalus harpia was caught in a cave entrance in the south of the NBCA. There are few records of this species, which had only been recorded once in Lao PDR prior to this study (FRANCIS, 1995).

Two species of *Pipistrellus*, *P. tenuis* and *P. pulveratus* were caught. *Pipistrellus tenuis* is known from both north and south Laos (CORBET & HILL, 1992; ROBINSON, 1998). *Pipistrellus pulveratus* has been caught previously only in central (CORBET & HILL, 1992) and western (ROBINSON *ET AL.*, 1995) Thailand, northern Vietnam (BATES *ET AL.*,

1997) and southern China (CORBET & HILL, 1992); hence this is the first record for Lao PDR. The species is listed as “Lower risk: near threatened” by IUCN (1996).

An unidentified species of *Murina* was collected in the entrance to Tam Houay Si. This bat is cranially very similar to *M. tubinaris*, although it differs in several respects, the most noticeable being its pelage. The bat is thought to represent an undescribed species close to *M. tubinaris* (Francis, pers. comm.).

Phoniscus jagorii was collected in the entrance to Tam Houay Si. The specimens agree with the description given by HILL (1965), although slightly smaller. These animals are believed to be similar to those previously recorded by FRANCIS *ET AL.* (1998). This species has until recently been known only from the Philippines and Kalimantan, Java, Bali, Lombok and Sulawesi in Indonesia.

The remains of a *Tadarida* sp. were found in Tam Ann. The skull of this animal resembles those of *T. plicata* previously collected from Laos (BM(NH)94.204) and Cambodia (BM(NH)70.1044); however, these specimens are larger in all respects than those from Thailand and Myanmar in the Natural History Museum. The taxonomy of this species is currently being investigated.

Of the remaining species of Vespertilionidae recorded, *Tylonycteris robustula*, *M. schreibersii*, *M. magnater*, *Kerivoula hardwickii* and *Murina cyclotis* are all widespread species found across much of Southeast Asia (CORBET & HILL, 1992), although there are no specific records for *M. schreibersii* in Lao PDR. This species is listed as “Lower risk: near threatened” by IUCN (1996).

Seasonal Activity of Bats

FRANCIS *ET AL.* (1998) comment on the small number of bats caught during a survey in January/February 1998 of the Khammouan Limestone NBCA using mist-nets and harp traps, and in particular the absence of any large *Hipposideros* species. A similar situation was found in the present survey and many of the cave sites visited had few bats present. However, local people from all the villages visited said that caves were occupied by larger numbers of bats during the rainy season, a period when they were caught for food.

In a cave survey conducted between 19 March and 11 April 1996, a few weeks prior to the start of the rainy season, GREGORY *ET AL.*, (1996) reported that several cave systems around the villages of Ban Pontong and Muang contained bats. At Tam Quaie, only 250 m from Ban Muang, GREGORY *ET AL.* (1996) reported large numbers of “long-eared” bats. However, during this survey, from 9 to 16 January (in the “dry season”), few bats were found in these systems. Tam Quaie in particular contained only 3–4 bats, although droppings and cranial remains from a large insectivorous bat were found.

Had the present study relied only on mist-nets and harp traps then no large *Hipposideros* would have been found. However, as a result of cave surveys, four species of large *Hipposideros* were recorded, from recent cranial remains and one live specimen. Also, the remains of several other species not caught in nets or traps were found. This suggests that more/different species occur in the area at other times of the year, highlighting the importance of surveying roost sites to complement the netting and trapping of bats.

In several caves where few bats were found, there was evidence of substantial recent use. For instance, at Tam Pha Mauang only two small bats were seen, but droppings up to 200 mm deep were found on rocks below previously used roost sites. At Tam Thea, the

remains of 137 dead bats of six species (*R. amplexicaudatus*, *E. spelaea*, *M. lyra*, *T. theobaldi*, *H. larvatus* and *H. sp. C*) were found on the floor, 79 were *T. theobaldi*, whereas a visual search revealed only a small group of fruit bats. Some of these remains (*T. theobaldi* and *M. lyra*) were clearly of juveniles, as shown by the degree of tooth eruption and the unfused epiphyses of the metacarpal-phalangeal joints, suggesting the cave was used during the breeding season, which occurs in the rainy season. Dead juvenile bats, *Rousettus* sp., were found in Tam Key Thea, another site that contained few live bats at the time of survey.

The activity of bats in the region appears to be seasonally variable, as indicated by local people, previous surveys (GREGORY *ET AL.*, 1996) and clear signs of use by bats at some time during the year, in particular during the breeding season. However, this begs the question of where the bats were during the dry season, when the present survey took place. Clearly there have been substantial changes in the habitat in and around the NBCA, with land having been cleared for cultivation or timber. Also, many of the caves are heavily disturbed by hunters. Although both of these factors have impacts on bat populations, they will occur over the long term, and hence cannot account for the relatively short term seasonal changes recorded in this study. Bats may form large and conspicuous clusters during the breeding season, but outside this period they may exist in much smaller groups and as individuals. In a region such as the Khammouan Limestone, with extensive karst formation, it is doubtful that roosts would be a limited resource. Also, the activity of individuals may be reduced during a period when food may be limited. Several species of tropical insectivorous bats, such as *H. armiger*, *R. thomasi*, *R. malayanus*, *R. pearsonii* and *R. stheno*, are known to go into torpor (ROBINSON *ET AL.*, 1995), a strategy for saving energy (ERKERT, 1982). During the present survey, *R. thomasi*, *A. stoliczkanus* and *I. io* were found torpid, allowing them to be lifted off the wall by hand. They felt cold to the touch and it took them several minutes to warm up enough to be able to fly away. Many of the caves surveyed were several kilometres long with many passages and chambers, maintaining a cool stable temperature and providing vulnerable torpid bats protection from predators. Torpid *I. io* were observed roosting about 1.5 km from the entrance of Tam Houay Si.

During the dry season bats may migrate to areas with better foraging/climate. However, there is no evidence for this, and it is unlikely that they would fly as far as the several 100 kms, from the NBCA needed to areas with better foraging /climate.

Hunting

Hunting of wildlife is widespread across much of Lao PDR (MARTIN, 1992; SRIKOSAMATARA *ET AL.*, 1992; ROBINSON, 1994; BERGMANS, 1995; ROBINSON, 1997; DUCKWORTH *ET AL.*, 1994) and was a common practice among villagers surrounding the NBCA. At all of the villages visited, people reported eating bats which were shot with guns or catapults, or knocked down with long flexible sticks, although by far the most effective technique was the use of mist-nets. However, only in the north of the NBCA could villagers afford to buy mist-nets.

The hunting of animals with low reproductive rates such as bats can have a serious impact on population levels, particularly if combined with forest clearance. Also, bats are particularly vulnerable due to their habit of roosting in clusters, often of several thousand

animals. Villagers stated that bats are hunted mainly during the rainy seasons when they are in larger, more conspicuous clusters, making capture easier. This period is probably the breeding season for most bats, so the effect of hunting may be compounded by the death and abandonment of young.

Habitat

As its name suggests, the Khammouan Limestone NBCA contains large amounts of karst formation, most of which is covered in a dry xerophytic vegetation. Small pockets of mixed deciduous and semi-evergreen forest occur only in the valleys and plains. The boundary of the NBCA has been drawn primarily around the base of the karst, so that it contains little forest, approximately 16 percent of the total area (BERKMULLER *ET AL.*, 1995). Many areas of forest around the NBCA have been either cut down for agriculture or heavily degraded by the removal of timber. There are still some pockets of quality forest, although this was being cleared, in some cases quite quickly. Species of bats and other animals that live in and around the karst will be heavily dependant on nearby forested areas for foraging. Unless these areas around the NBCA are protected, much of the karst fauna could soon disappear.

The NBCA contains few perennial river systems. However, those that are present will be important to the fauna of the area, providing a vital source of drinking water and, for bats, foraging areas. In a region with an extended dry season, the distribution of species such as *M. ricketti*, which feeds on fish, may be governed by the presence of these rivers, streams and pools. Also, a requirement of "fishing" or "trawling" bats is the need for still or undisturbed slow-flowing water (JONES & RAYNER, 1991) and consequently this could reduce the number of foraging areas further. Near Ban Pontong, a perennial river was being dammed, drainage channels dug and a pump employed to irrigate the land. Clearly, increasing developments of this nature, unless controlled, could have serious implications for bat conservation.

CONSERVATION RECOMMENDATIONS

Below are a number of recommendations to prevent the deterioration of the fauna and flora of the Khammouan Limestone NBCA. However, the introduction of such measures would be useless unless backed up by a large scale education program. Indeed, some measures may already be in force, but it is likely that they will have little effect without an education program targeted at all levels of the community, from young school children to the elders of the villages.

- 1. Expand boundaries to encompass forested areas around base of limestone.** The Khammouan Limestone NBCA currently has within its boundary only small areas of quality forest. Much of the fauna living in and around the NBCA will be dependent upon the maintenance of forest beyond the protected area. The extensive cave system "Tam Houay Si" (more than 2 km long) is used by at least 22 species of bat. This cave is obviously a valuable resource to the local bat population and should be protected. The cave is located just within the boundary of the Khammouan Limestone NBCA and is surrounded by good quality evergreen forest, although much of this may be

considered to be outside the NBCA. Recently a Vietnamese logging company was given logging concessions in an area adjacent to this, near Ban Vieng, in Gnommalat District. Although caves are valuable resources to bats, protecting them is not enough to maintain populations. Quality habitat also needs to be maintained in these areas.

Serious consideration should be given to the extension of the NBCAs' boundaries to include areas of quality, undisturbed habitat. These areas should not be chosen in isolation, but selected to provide a cohesive network of habitat, so preventing the fragmentation and isolation of all populations, not only bats.

2. **Ensure adequate protection of forests within and around NBCA.** Ideally the removal of any timber by commercial companies should be prohibited, and the clearance, by local people, of forest areas for agriculture and large trees for timber should be controlled.
3. **Protect waterways.** The NBCA has few perennial river systems, the presence of which are likely to be important to the fauna and people of the area, providing a vital source of drinking water, foraging areas and, for animals such as fish and amphibians, a habitat in which to survive the dry season. In a region with an extended dry season, the distribution of species such as *M. ricketti*, a bat found in the Khammouan Limestone which feeds on fish, may be governed by the presence of these rivers, streams and pools.

There is evidence that waterways are beginning to be developed for land irrigation. It is vital that such development is strictly controlled if the supply and quality of these systems are to be maintained. In a limestone region pollution can travel quickly over large distances in the ground water (WATSON *ET AL.*, 1997). Therefore, any deterioration of water quality is likely to have a significant impact, not only on the wildlife, but also local villagers, affecting drinking water and impacting on fish stocks.

4. **Protect animals, especially bats, from non-sustainable hunting.** The combination of modern hunting practices, such as the use of mist-nets and guns, and land clearance is putting the fauna of the area under increasing pressure. Ideally there needs to be some control both within the protected area and its periphery. It would not be realistic to prevent hunting altogether within the protected area, as hunting is a way of life for many of the villagers and probably provides an important source of protein for their diet. However, the use of modern techniques such as mist-nets and guns should be prohibited. These allow wildlife to be caught in abundance, with surplus being sold to markets for food. Any wildlife caught in the protected area should be for local consumption, with its sale being prohibited.

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