THE SARAWAK MUSEUM JOURNAL

Vol. LXIII No. 84 (New Series) Since 1911 ISSN. 0375-3050 December 2007

Bats of Bako National Park, Sarawak, Malaysian Borneo

By

Faisal Ali Anwarali Khan, Siti Nurlydia Sazali, Jayaraj Vijaya Kumaran, Siali Aban, Mohd. Kasyfullah Zaini, Besar Ketol, Jeffrine Rovie Ryan, Ahmad Mashur Julaihi, L.S. Hall and M.T. Abdullah

SARAWAK MUSEUM DEPARTMENT

BATS OF BAKO NATIONAL PARK, SARAWAK, MALAYSIAN BORNEO

by

Faisal Ali Anwarali Khan, Siti Nurlydia Sazali, Jayaraj Vijaya Kumaran, Siali Aban, Mohd. Kasyfullah Zaini, Besar Ketol, Jeffrine Rovie Ryan, Ahmad Mashur Julaihi, L.S. Hall and M.T. Abdullah

ABSTRACT

Two separate assessments on bats diversity were conducted in Bako National Park for 12 trapping-nights. Our first assessment was conducted from 8th to 12th February 2005 followed by the second assessment from 28th August to 3rd September 2005. A total of 295 individuals from 22 species of bats were captured using mist-nets and harp traps during the survey, which accumulated to 226 trapping-nights. *Hipposideros cervinus* was recorded as the most abundance species with 30.85% of total captures. A total of eight new records of bats have been added to this park: *Emballonura monticola*, *Rhinolophus luctus*, *Hipposideros ater*, *Hipposideros bicolor*, *Myotis muricola*, *Myotis ater*, *Pipistrellus vondermanni* and *Kerivoula pellucida*. With these additional records, there are now at least 34 species of bats known to occur in Bako National Park. A complete and long term study covering other areas not included in this study would definitely increase bats diversity found in this park.

Keywords: Bako National Park, bats, new record, diversity.

INTRODUCTION

There are at least 92 species from eight families of bats (Chiroptera) documented in Borneo (Payne *et al.*, 1985). Bats surveys have been conducted by various researchers (Davis, 1958; Medway, nd, 1959, 1977; Lim, 1965; Lim *et al.*, 1972; Start, 1972b, 1975;

Francis, 1989b, 1990, 1994; Hall, 1996; Hall *et al.*, 2004) and they have improved the current knowledge of bats diversity in Sarawak. This was further explored by Nor (1996, 1997), Yasuma and Andau (1999) and Tuen *et al.* (2002a, 2002b) who conducted their studies in Sabah, whereas Abdullah *et al.* (1997b) and Mohd-Azlan *et al.* (2003) conducted studies in the Indonesian-Kalimantan province. Recently, several researchers have actively documented the distribution of bats particularly in Sarawak in order to understand the species richness and their diversity (Abdullah *et al.*, 1997a; Abdullah *et al.*, 2000a; Hall *et al.*, 2002, 2004; Abdullah, 2003b; Abdullah *et al.*, 2003; Gumal *et al.*, 2004; Karim *et al.*, 2004; Tuen *et al.*, 2004; Mohd-Azlan *et al.*, 2005; Abdullah *et al.*, 2005; Jayaraj *et al.*, 2005a; and, Anwarali *et al.*, 2006). These studies were mainly focused on national parks and State forests where the habitats are less disturbed. Subsequently more new locality records were added every year showing better trapping efforts and improved batting techniques. In parallel, this study has also focused on improving our understanding on bat species diversity in protected areas of Sarawak by extensive sampling effort at different habitats and incorporating proper batting techniques (*e.g.*, harp traps and mist nets).

This study was designed to understand the importance of various vegetation types that contributes to bats species diversity and their composition within Bako National Park. Data from previous studies by Start (1972a), France *et al.* (1984), Churchill and Zborowski (1985) and Hall (1992) at Bako National Park were compared to show the species accumulation or reduction during different sampling occasions. We compile our checklist following Payne *et al.* (1985) and Simmons (2005) taxonomic nomenclature.

MATERIALS AND METHOD

STUDY AREA

This study was conducted in Bako National Park which is located at Muara Tebas Peninsula on the north-eastern part of Kuching, about 37 kilometres away from Kuching city. The main

access to the park is by a 20-minute boat ride through Sungai Delima. Bako National Park, the oldest national park of Sarawak, was gazetted as a protected area on 1st May 1957. This park consists of seven different major habitats: heath forest, mangrove forest, mixed dipterocarp forest, riverine forest, beach forest, grassland and cliff vegetation, which provides diverse ecological niches for high species richness and diversity of fauna (Hazebroek and Abang Kashim, 2000). Besides these habitats, seasonal swamp forest are also found around this park, especially as the intermediate between beach and mixed dipterocarp forest during the monsoon season. The main attraction found in this park includes the Bornean endemic proboscis monkey (*Nasalis larvatus*), the endangered flying lemur (*Cynocephalus variegatus*), western tarsier (*Tarsius bancanus*), silvered langur (*Presbytis cristata*) and bearded pig (*Sus barbatus*), which could be observed near the park headquarters area. Such unique fauna is well supported by diverse vegetation found in this park that provides wide varieties of food sources and niches.

Bako National Park (1°42' to 1°44' N, 110°26' to 110°36' E) which covers an area of 2727 hectares (Fig. 1) is the smallest national park in Sarawak (Hazebroek and Abang Kashim, 2000). Survey was carried out using 10 standard mist-nets and three four-bank harp traps during the first trip from 8th to 12th February 2005 that accounted to 65 trapping-nights. During the second trip from 28th August to 3rd September 2005, 20 mist-nests and three four-bank harp traps were used that accounted to 161 trapping-nights. The total trapping-nights effort was calculated based on the number of mist-nets and harp traps used in both sampling occasions. Nets and traps were set up at Ulu Asam Trail, Delima Trail, Tanjung Sapi Trail and Telok Asam area that includes the pathway to the incinerator, representing five different habitats including beach, heath, mangrove, mixed dipterocarp and seasonal swamp forests of Bako National Park. The sampling sites are marked with white stars in Fig. 1.

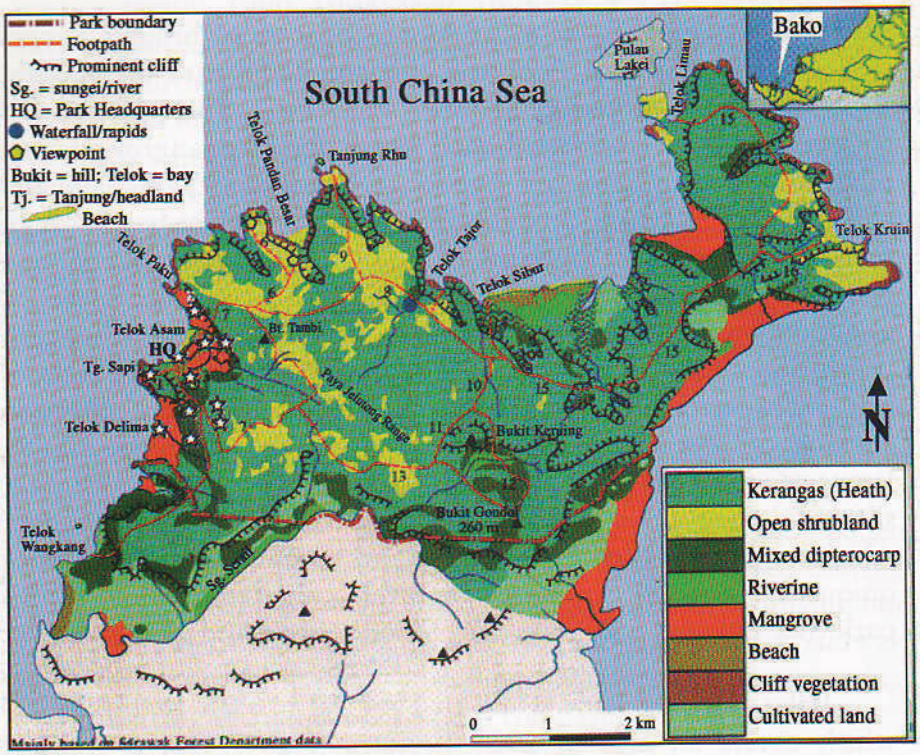

Fig. 1: Topographic map of Bako National Park, Sarawak (adapted and modified from Hazebroek and Abang Kashim, 2000).

BATS IDENTIFICATION, SAMPLE PROCESSING AND PRESERVATION

Bats were identified following Payne *et al.* (1985). External morphological measurements were taken using digital caliper (Mitutoyo) and weight using Pesola spring balance. Adult individuals were determined following Kunz (1988) by observing the epiphyseal-diaphyseal fusion on the third, fourth and fifth metacarpals. Selected specimens were euthanized using chloroform and dissected and preserved in 95% ethanol as voucher specimens. Muscle tissues and blood samples were taken from the specimens. Tissues were preserved in 95% ethanol while 30 μl of blood samples were mixed in 1mM EDTA for further molecular and other medical studies. Voucher specimens were deposited in the UNIMAS Zoological Museum and selected speciments were photographed for further references. Only a

maximum of five individual per species of bats were prepared as voucher specimens. The rest were released after taking their measurements and marking them by ear notching technique.

RESULTS

A total of 295 individuals representing 22 species from seven families: Pteropodidae, Emballonuridae, Megadermatidae, Nycteridae, Rhinolophidae, Hipposideridae and Vespertilionidae were recorded in 226 trapping-nights conducted in Bako National Park (Table 1). Species-accumulation curve (Fig. 2) for the 12 trapping-nights indicates that more species could be recorded given more time since the number of bats species accumulation has not reach a stable stationary phase in the graph. The most abundant species was set by *Hipposideros cervinus* with 91 individuals (30.85%) followed by *H. larvatus* with 57 individuals (19.32%). The least capture, with single individual (0.34%) was recorded for the following eight species: *Emballonura alecto, E. monticola, Saccolaimus saccolaimus, Megaderma spasma, H. diadema, Myotis muricola, Pipistrellus vondermanni* and *Kerivoula pellucida* (Table 2).

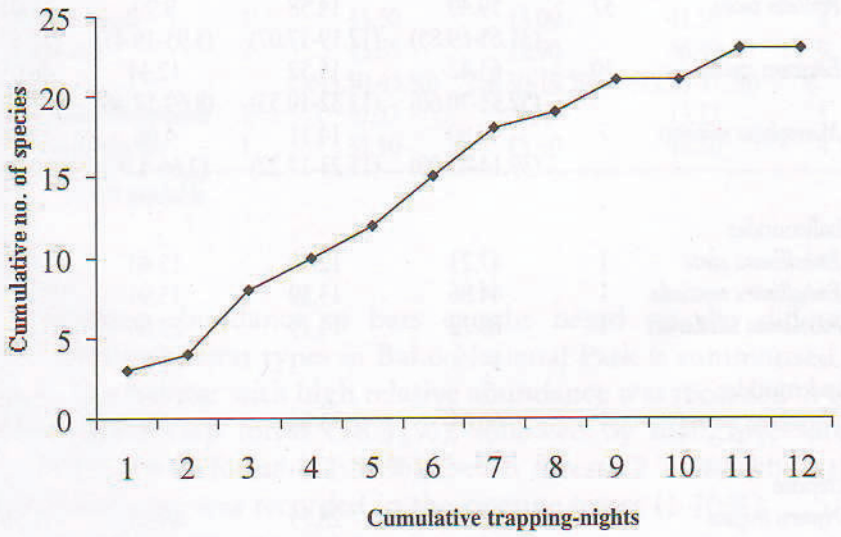

Fig. 2: Cumulative numbers of species against trapping-nights.

Table 1 shows the species list of bats with the mean measurements of external morphological characters for individuals captured in this study. Species identifications were mainly based on forearm length measurement following the field identifications available to us (Payne *et al.*, 1985). Other unique morphological characters (*e.g.*, skin colorations, noseleaf structure, and tail length) were further evaluated to identify morphologically related species. A complete species list with their relative abundance from previous studies is depicted in Table 2.

Table 1: Taxonomic list shows the bats species captured in this study with their average measurements (minimum and maximum ranges). N = number of species with measurements.

Family Species	N	Forearm (mm)	Ear length (mm)	Tail length (mm)	Weight (g)
Pteropodidae					
Cynopterus brachyotis (small form)	4	55.92 (54.76-59.21)	Na	Na	22.50 (19-26)
Cynopterus brachyotis (large form)	17	64.71 (62.99-68.59)	Na	Na	34.72 (23-44)
Penthetor lucasi	37	59.40 (31.65-69.85)	14.58 (12.19-17.07)	9.99 (5.95-18.45)	34.04 (22-47)
Eonycteris spelaea	30	63.42 (52.93-70.60)	15.52 (12.32-19.53)	12.34 (8.69-17.46)	48.05 (22-67)
Macroglossus minimus	7	40.80 (39.14-45.00)	14.11 (11.23-17.22)	4.08 (2.66-4.09)	15.86 (10-25)
Emballonuridae					
Emballonura alecto	1	47.23	12.40	15.40	7
Emballonura monticola	1	44.86	13.39	13.94	8
Saccolaimus saccolaimus	1	68.72	14.19	22.60	41
Megadermatidae					
Megaderma spasma	1	60.64	33.94	Na	22
Nycteridae					
Nycteris tragata	2	50.66 (48.02-53.30)	28.73 (25.48-31.98)	69.98 (64.00-75.96)	11.50 (10-13)

Family Species	N	Forearm (mm)	Ear length (mm)	Tail length (mm)	Weight (g)
Rhinolophidae					
Rhinolophus trifoliatus	4	57.70 (48.10-51.26)	23.46 (16.18-26.65)	28.25 (13.89-37.62)	12.00 (11-13)
Rhinolophus luctus	2	65.21 (63.41-67.00)	30.03 (28.50-31.55)	43.97 (43.25-44.69)	30.50 (27-34)
Hipposideridae					
Hipposideros ater	2	44.54 (44.54-44.87)	15.77 (15.03-16.50)	29.98 (29.58-30.37)	6.5 (6-7)
Hipposideros bicolor	8	45.38 (44.07-46.07)	15.84 (11.88-18.74)	28.30 (22.61-31.80)	7.13 (6-9)
Hipposideros dyacorum	3	40.86 (40.00-41.35)	16.19 (14.06-17.30)	20.08 (17.15-21.80)	5.67 (4-7)
Hipposideros cervinus	91	47.51 (45.60-49.10)	16.81 (15.20-18.20)	22.72 (20.00-25.30)	7.04 (5-9)
Hipposideros galeritus	21	48.67 (42.90-59.46)	12.89 (10.32-18.37)	30.01 (18.43-34.70)	8.40 (6-17)
Hipposideros larvatus	57	58.13 (45.29-65.45)	17.38 (10.06-34.54)	30.62 (18.40-38.91)	17.63 (6-26)
Hipposideros diadema	1	85.10	18.94	47.35	44
Vespertilionidae					
Myotis muricola	1	33.50	13.00	41.50	4
Myotis ater	2	43.65 (43.50-43.80)	18.90 (18.30-19.50)	46.40 (45.50-47.30)	9
Pipistrellus vondermanni	1	32.37	8.90	13.72	5
Kerivoula pellucida	1	31.50	15.30	43.30	4

Na = Data not available

Relative abundance of bats caught based on the different vegetation or habitat types in Bako National Park is summarised in Fig. 3. The habitat with high relative abundance was recorded in the mixed dipterocarp forest (58.31%), followed by mangrove forest (25.76%), heath forest (11.52%), beach forest (2.71%) while the least abundance was recorded in the riverine forest (1.70%).

Table 2: Taxonomic list of species, percentage relative abundance and habitat types of bats caught in Bako National Park, Sarawak.

Family Species	Habitat	Current study (2005)	Hall (1992)	Churchill and Zborowski (1985)	Francis *et al.* (1984)	Start (1972)
Pteropodidae						
1 *Pteropus vampyrus*	Na	0	Nr	Sighted only	0	0
2 *Cynopterus brachyotis*	B, H, M and MD	7.12	Nr	0	6.98	11.63
3 *Penthetor lucasi*	H, M and MD	12.54	Nr	0.96	11.63	11.63
4 *Balionycteris maculata*	Na	0	Nr	0	6.98	0
5 *Eonycteris spelaea*	B, H, M and MD	10.17	Nr	0	37.21	6.98
6 *Macroglossus minimus*	H and M	2.37	Nr	3.85	2.32	54.65
Emballonuridae						
7 *Emballonura alecto*	MD	0.34	Recorded	0.96	9.30	0
8 *Emballonura monticola**	MD	0.34	Nr	0	0	0
9 *Saccolaimus saccolaimus*	H	0.34	Nr	1.92	6.98	0
10 *Taphozous melanopogon*	Na	0	Recorded	0	0	0
Megadermatidae						
11 *Megaderma spasma*	H	0.34	Nr	0	0	3.49
Nycteridae						
12 *Nycteris tragata*	MD	0.68	Nr	0	0	3.49

Family Species	Habitat	Current study (2005)	Hall (1992)	Churchill and Zborowski (1985)	Francis *et al.* (1984)	Start (1972)
Rhinolophidae						
13 *Rhinolophus borneensis*	Na	0	Recorded	0	0	0
14 *Rhinolophus philippinensis*	Na	0	Recorded	0	0	0
15 *Rhinolophus trifoliatus*	H and MD	1.36	Nr	2.88	4.65	0
16 *Rhinolophus luctus**	B and H	0.68	Nr	0	0	0
Hipposideridae						
17 *Hipposideros ater**	MD	0.68	Nr	0	0	0
18 *Hipposideros bicolor**	MD	2.71	Nr	0	0	0
19 *Hipposideros dyacorum*	M and R	1.02	Recorded	0.96	0	0
20 *Hipposideros cervinus*	B, H, M, MD and R	30.85	Recorded	50.96	0	0
21 *Hipposideros galeritus*	H and MD	7.12	Recorded	2.88	6.98	3.49
22 *Hipposideros coxi*	Na	0	Recorded	4.81	0	2.33
23 *Hipposideros larvatus*	B, M and MD	19.32	Recorded	20.19	4.65	2.33
24 *Hipposideros diaderma*	MD	0.34	Recorded	0	2.32	0
Vespertilionidae						
25 *Myotis muricola**	R	0.34	Nr	0	0	0
26 *Myotis ater**	M and MD	0.68	Nr	0	0	0
27 *Myotis horsfieldii*	Na	0	Recorded	0	0	0
28 *Myotis hasseltii*	Na	0	Nr	1.92	0	0
29 *Pipistrellus tennuis*	Na	0	Nr	0.96	0	0
30 *Pipistrellus vondermanni**	M	0.34	Nr	0	0	0

Family Species	Habitat	Current study (2005)	Hall (1992)	Churchill and Zborowski (1985)	Francis *et al.* (1984)	Start (1972)
31 *Murina suilla*	Na	0	Nr	1.92	0	0
32 *Kerivoula hardwickii*	Na	0	Nr	4.81	0	0
33 *Kerivoula pellucida**	MD	0.34	Nr	0	0	0
34 *Miniopterus australis*	Na	0	Recorded	0	0	0
Number of families		7	4	5	4	4
Number of species		23	12	15	11	9
Number of individuals		295	Na	101	43	86
Trapping-nights		226	Na	64	39	72
Capture rate (Bats/100 trapping-nights)		131	Na	158	110	119

* New record from this study; Na = data not available, Nr = not recorded in the respective study, B = beach forest, H = heath forest, M = mangrove forest, MD = mixed dipterocarp forest, R = riverine forest. Habitat types in the table only precisely match the species collected in current study.

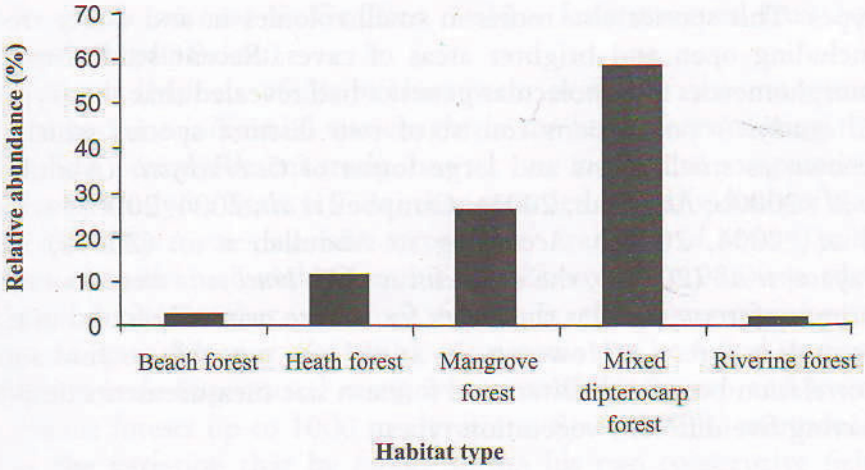

Fig. 3: Relative abundance of bats in the different habitats in Bako National Park.

SPECIES ACCOUNTS

Family: Pteropodidae

Cynopterus brachyotis Müller, 1838 - Malaysian fruit bat (Cecadu Pisang)

A total of 21 individuals of *C. brachyotis* (large and small) were caught using mist-nets. They were mainly captured in mangrove forest, followed by beach and mixed dipterocarp forest. Only one individual was trapped in the heath forest. This species was recorded by both Start (1972a) and Francis *et al.* (1984) in the mangrove area but there was no record by Churchill and Zborowski (1985). Although this is the most common fruit bat that occurs throughout the lowland and highland they depends on the availability of fruits which are important as their main diet (Mohd-Azlan *et al.*, 2003). Payne *et al.* (1985) noted that this species occurs mostly in lower montane, mixed dipterocarp forests, gardens, mangroves and strand vegetation in Borneo.

According to Hall *et al.* (2004), this species is well distributed from lowland to the high altitude montane forests of all habitat

types. This species also roosts in small colonies in and under trees including open and brighter areas of caves. Recent studies using morphometrics and molecular genetics had revealed that the cryptic *C. brachyotis* populations consist of two distinct species which is known as small forms and large forms of *C. brachyotis* (Abdullah *et al.*, 2000b; Abdullah, 2003a; Campbell *et al.*, 2004, 2006; Jayaraj *et al.*, 2004, 2005b). According to Abdullah *et al.* (2000b) and Jayaraj *et al.* (2005b), the small form of *C. brachyotis* were found in primary forests whereas the larger form were primarily found in the secondary forests. However our study was not able to find such correlation between habitats and forearm size measurements despite having five different vegetation types.

Penthetor lucasi Dobson, 1880 - Dusky fruit bat (Cecadu Hitam Pudar)

A total of 35 individuals were caught in the mangrove forest with another two individuals collected from cliff and mixed dipterocarp forest. This bat species is known to roost at rock crevices near the bridge in the park. According to Payne *et al.* (1985), *P. lucasi* mainly roosts in the rock shelters including caves. Previously, 10 individuals of this species were recorded by Start (1972a) from the edge of mangrove near the forest ridge. Francis *et al.* (1984) recorded this species from mixed dipterocarp and mangrove forests while Churchill and Zborowski (1985) found only one male in the mangrove forest.

Eonycteris spelaea (Dobson, 1871) - Cave fruit bat (Cecadu Gua)

A total of 28 individuals of *E. spelaea* were caught mainly using mist-nets in beach, mangrove and mixed dipterocarp forests with another two individuals captured using harp trap in the heath forest. Start (1972a) previously recorded six females consisting of five sub-adults and one adult during his study in this park followed by Francis *et al.* (1984) who recorded 16 individuals mainly from the mangrove area. This species is also known as the caves dwellers. Moreover, *E. spelaea* also can be differentiated from other species of bats with a distinct odour on them (Payne *et al.*, 1985).

Macroglossus minimus E. Geoffroy, 1810 - Long-tongued fruit bat (Cecadu Madu Bakau)

Six individuals of *M. minimus* were netted in the mangrove forest and one individual was caught in the heath forest during the sampling period. Present study shows a very low record compared to previous study by Start (1972a) that recorded 47 individuals of this species. This species was also recorded by Francis *et al.* (1984) with only one individual while Churchill and Zborowski (1985) recorded four individuals that were all found in the mangrove forest. According to Payne *et al.* (1985), *M. minimus* can be found in most habitats including coastal mangrove, mixed dipterocarp and lower montane forests up to 1000 m elevations. Start (1972a) mentioned that the variation that he found during his two consecutive field trips in different month showed different capture rate for this species. He suggested that, flowering season of mangrove forest contributes toward the high capture of this species. Relating this, we believe the current study might have taken place at a different mangrove flowering time or otherwise the park could have lost some of its mangrove habitat that previously accommodates inidividuals of *M. minimus*.

Family: Emballonuridae

Emballonura alecto Eydoux and Gervais, 1836 - Greater sheath-tailed bat (Kelawar Teng-teng Ceteng Kecil)

Only one representative of *E. alecto* was netted from the mixed dipterocarp forest in this study. This species was not recorded by Start (1972a). Later Francis *et al.* (1984) caught four individuals of this species near the rock crevices in the park. Churchill and Zborowski (1985) recorded one individual whereas Hall (1992) also detected this species at sweep frequency modulated (fm) ranging from 15-70 kHz with the main energy of call at 25 kHz. *E. alecto* usually found roosting in shallow caves or near the deep cave opening, inside the rocks' crevices and near the fallen tree trunks (Payne *et al.*, 1985).

Emballonura monticola Temminck, 1838 - Lesser sheath-tailed bat (Local name not available)

There was only one individual of this species caught using harp trap in the mixed dipterocarp forest during the sampling period which is the first record of *E. monticola* in Bako National Park (Plate X) but a second record of *E. monticola* in Sarawak (Payne *et al.*, 1985; Hall *et al.*, 2004). Payne *et al.* (1985) described that this species always roosts in mixed colonies with *E. alecto* in shallow caves, rocks' crevices and under fallen tree trunks.

Saccolaimus saccolaimus Temminck, 1838 - Pouched tomb bat (Kelawar Dada Putih)

Only one individual of this species was recorded in this study. It was caught using a harp trap in the tropical heath forest. Three individuals of this species were recorded by Francis *et al.* (1984) near the mangrove area, while Churchill and Zborowski (1985) recorded two individuals from the mixed dipterocarp forest. *S. saccolaimus* usually found in colonies roosting from a few to hundreds individuals in hollow trees and rocks' crevices and even in houses (Payne *et al.*, 1985).

Family: Megadermatidae

Megaderma spasma Linnaeus, 1758 - Lesser false vampire (Kelawar Telinga Lebar)

Only one individual of *M. spasma* was caught from the heath forest using harp trap. Start (1972a) previously had recorded this species in the park. Payne *et al.* (1985) noted that *M. spasma* always roost in small colonies in caves, tunnels including hollow trees.

Family: Nycteridae

Nycteris tragata K. Andersen, 1912 - Hollow-faced bat (Kelawar Muka Lekok)

Two individuals of *N. tragata* were netted in the mangrove and mixed dipterocarp forest respectively. Hall *et al.* (2002) had detected this species at the steep fm of 52-135 kHz with the main call at 80 kHz. This species was previously recorded by Start (1972a) but it

was not properly described. Payne *et al.* (1985) treated this species as *N. javanica* which is now known to be confined to Java, Bali and Kangean Island of Indonesia (Corbet and Hill, 1992; Koopman, 1994; Simmons, 2005). Population in Burma, Thailand, Peninsular Malaysia, Sumatra and Borneo is now recognised as *Nycteris tragata*.

Family: Rhinolophidae

Rhinolophus trifoliatus Temminck, 1834 - Trefoil horseshoe bat (Local name not available)

Three individuals of this species were captured using harp traps in the mixed dipterocarp forest whereas another one was caught in the heath vegetation. Churchill and Zborowski (1985) documented three individuals during their study. According to Payne *et al.* (1985), this species often found in the understorey of primary forest where they sometimes roost under large tree leaves.

Rhinolophus luctus Temminck, 1834 - Great woolly horseshoe bat (Kelawar Ladam Terbesar)

Two individuals of this species were netted in the beach and heath vegetation. This was the first record for *R. luctus* in Bako National Park (Plate XI). According to Payne *et al.* (1985), this species can be found in small groups that roost in caves, rocks' crevices and under trees. They are distributed from lowlands up to 1600 m in the mountains and recorded in Sarawak from Lawas to Serabang including upper Sungai Tutoh and the Hose mountains (Payne *et al.*, 1985).

Family: Hipposideridae

Hipposideros ater Templeton, 1848 - Dusky roundleaf bat (Local name not available)

Two individuals of this species were collected and represented as a new record for this Park (Plate XII). They were caught using harp trap in the mixed dipterocarp forest. This is the second record of *H. ater* in Sarawak after Abdullah *et al.* (2003). According to Payne *et al.* (1985), this species usually roosts in caves in large colonies up to a few hundreds individuals. This species looks similar to *H. bicolor*

morphologically whereas *H. ater* usually have smaller forearm compared to the previous. The main key to differentiate between this species is by looking at their internarial septum. *H. bicolor* has straighter internarial septum whereas *H. ater* has an internarial septum which is narrower and slightly swollen on the base (Payne *et al.*, 1985).

Hipposideros bicolor Temminck, 1834 - Bicolored roundleaf bat (Kelawar Ladam Bulat Biasa)

All eight individuals of *H. bicolor* were caught using mist-nets and harp traps from mixed dipterocarp forest. This species also represents a new record for this park as well as a new record of *H. bicolor* in Sarawak (Plate XIII). This species was detected at the fm of 22 kHz (Hall, 1992). However, several other studies showed that this species echolocate at 131 and 142 kHz in Peninsular Malaysia (Kingston *et al.*, 2001) while 136 kHz in Niah National Park (Hall *et al.*, 2002). Payne *et al.* (1985) noted that this species always roosts in caves or tunnels where they were generally distributed from India to Southern China, Taiwan through Southeast Asia, Sumatra, Java, Borneo, Sulawesi and smaller islands (Payne *et al.*, 1985; Corbet and Hill, 1992).

Hipposideros dyacorum Thomas, 1902 - Dayak roundleaf bat (Local name not available)

Three individuals of *H. dyacorum* were caught using harp traps set up at Delima Trail near the hostel and the mangrove forest. Previous study by Churchill and Zborowski (1985) recorded one female that was caught in the heath forest. Hall (1992) also recorded this species during his study but no description was made. Payne *et al.* (1985) noted that this species can be found in caves, under rocks or hollow trees where they usually forage in the understorey of tall forests.

Hipposideros cervinus (Gould, 1854) - Fawn roundleaf bat (Kelawar Ladam Bulat Gua)

A total of 91 individuals of *H. cervinus* were caught using both mist-nets and harp traps. They are the most abundant species captured in this study. They were collected from various habitat types including beach, heath, mangrove, mixed dipterocarp and also

riverine forests. Churchill and Zborowski (1985) recorded 53 individuals of this species from beach, mangroves, mixed dipterocarp and heath forests while Hall (1992) also recorded this species through his bat detector at the fm of 128 kHz. Hall *et al.* (2002) in his later study detected the same species at the constant frequency (cf) of 127 kHz. *H. cervinus* usually roosts in caves and their population could reach up to 300,000 individuals in a group (Payne *et al.*, 1985).

Hipposideros galeritus Cantor, 1846 - Cantor's roundleaf bat (Kelawar Ladam Bulat Gua)

A total of 21 individuals of *H. galeritus* were recorded in the heath and mixed dipterocarp forests using both mist-nets and harp traps. This species was also recorded by Start (1972a), Francis *et al.* (1984), Churchill and Zborowski (1985) and Hall (1992). It was detected at the cf of 103 kHz (Hall, 1992; Hall *et al.*, 2002). This species also often roosts in small groups in caves with other *H. cervinus* but sometimes in large grouping of several hundreds (Payne *et al.*, 1985). This species also looks similar to *H. cervinus*. They are usually differentiated by their median noseleaf which is much narrower than posterior noseleaf in *H. cervinus* but wider in *H. galeritus* (Payne *et al.*, 1985).

Hipposideros larvatus Horsfield, 1823 - Intermediate roundleaf bat (Kelawar Ladam Bulat Besar)

A total of 57 individuals of *H. larvatus* were caught mainly from the mixed dipterocarp forest with some captured at the beach and in mangrove forest using mist-nets and harp traps. According to Hall (1992), *H. larvatus* can be detected at the cf of 88 kHz. This species was recorded by Start (1972a) and he noted that this species was found commonly outside the mangroves area. Francis *et al.* (1984) recorded two individuals in their study and Churchill and Zborowski (1985) recorded 21 individuals of this species from different habitats including beach forest, mangrove, mixed dipterocarp and also heath forests. According to Payne *et al.* (1985), *H. larvatus* usually found roosting in caves and the main key used to identify this species is by the three lateral leaflets found on their noseleaf. So far this park has been the major habitat for this species in Sarawak. They were rarely found in other localities in Sarawak.

Hipposideros diadema E. Geoffroy, 1813 - Diadem roundleaf bat (Kelawar Bahu Putih)

Only a single specimen of *H. diadema* was caught using harp trap from the mixed dipterocarp forest. Hall (1992) and Hall *et al.* (2002) detected this species at the cf of 66 kHz. However, Start (1972a) and Churchill and Zborowski (1985) did not record any of this species in their studies. Payne *et al.* (1985) noted that *H. diadema* often roosts in large colonies with other bat species in caves and sometimes in hollow trees.

Family: Vespertilionidae

Myotis muricola Gray, 1846 - Whiskered myotis (Kelawar Daun Pisang)

Only one female *M. muricola* was trapped at the rock site near Ulu Asam Trail in the riverine forest. This is a new record for this species in Bako National Park. Hall *et al.* (2002) mentioned that this species echolocate at steep fm of 50-100 kHz with a main call at 62 kHz. This species is widely distributed in Southeast Asia from East of India to New Guinea including Thailand, Peninsular Malaysia, Sumatra, Borneo and Philippines, which can be found in most areas from lowlands up to 1500 m on Gunung Kinabalu (Payne *et al.*, 1985; Corbet and Hill, 1992). According to Payne *et al.* (1985), this species often roosts in the center of folded banana leaves while in Thailand, they are usually found in caves.

Myotis ater Peters, 1866 - Black myotis (Local name not available)

This species is a new record for Bako National Park. Two females were caught using harp traps from the mangrove and mixed dipterocarp forests. So far this species was recorded only in the Kelabit Uplands in Sarawak; Gomantong, Baturong and Gunung Kinabalu in Sabah and distributed in Philippines, Sulawesi and islands through New Guinea. They usually roost individually or in small colonies in caves (Payne *et al.*, 1985; Corbet and Hill, 1992).

Pipistrellus vondermanni - White-winged Pipistrelle (Local name not available)

This single individual record also contributes to a new record of bat species in the park (Plate XIV) that was netted from the mangrove

habitat. This finding also contributes as the third record of *P. vondermanni* in Sarawak after Payne *et al.* (1985) and Abdullah *et al.* (2000a). According to Payne *et al.* (1985), *P. vondermanni* was distributed in Belitung Island of Indonesia but only recorded from Samunsam in Sarawak. The unique feature of this species is that they have a white translucent pair of wings (Payne *et al.*, 1985).

Kerivoula pellucida (Waterhouse 1845) - Clear-winged woolly bat (Kelawar Kepak Jernih)

This species also represents a new record for the park (Plate XV) which was represented by a single male individual that was caught using harp trap in the mixed dipterocarp forest. Hall *et al.* (2002) detected this species with steep and faint fm which was strongest at 70 kHz. According to Payne *et al.* (1985), this species was recorded roosting in a dead curled banana leaves where they usually forage in the understorey of tall forest. They are distributed from Peninsular Malaysia to Sumatra, Java, Borneo and Philippines (Payne *et al.*, 1985; Corbet and Hill, 1992).

CONCLUSION

This study has documented eight new bat records for Bako National Park: *E. monticola, R. luctus, H. ater, H. bicolor, M. muricola, M. ater, P. vondermanni* and *K. pellucida*, 33 years after Start (1972a). From this study, there was another new record of bat *H. bicolor* added to the list of bat species in Sarawak. This species was previously recorded only in Sabah (Payne *et al.*, 1985). The tremendous improvement to this fauna list compared to previous studies is thought to be from the utilisation of different trapping techniques. This study has included harp traps that are known to be much efficient in trapping echolocating bats compared to Start (1972a) and Francis *et al.* (1984) who only used mist-nets during their sampling period in Bako National Park. Studies by Laval and Fitch (1977), Tidemann and Woodside (1978), Francis (1989a) and Mohd-Azlan *et al.* (2000, 2005) have shown that mist-net is less effective in capturing echolocating bats as these bats can actually detect and avoid the nets by their echolocating ability. Eisenberg

(1981), Vaughan (1986) and Abdullah *et al.* (1997b) noted that echolocating bats (mainly insect bats) were also able to escape from the nets by chewing out the nets in just a short time when the nets are left unattended. Study by Mohd-Azlan *et al.* (2005) showed that harp traps were eight times more effective in capturing insect bats than conventional mist-nets.

Nets and traps placement would also influence the bats species sampled. Mist-nets and harp traps were placed in the understorey, thus the sampling effort is biased towards understorey bats. According to Francis (1994) and Mohd-Azlan *et al.* (2000), fruit bats would utilise the upperstorey of the rainforest as the understorey fruits are scarce. Heidemen and Heaney (1989) observed that large fruit bats such as *Pteropus* often utilised the canopy stratum and this pose a problem when sampling using ground based mist-nets. *P. vampyrus* was normally observed foraging at the canopy and flies long distances to feed. They were previously sighted in Bako National Park but were not caught in this survey signifying the limits of bats species that can be sampled at the understorey stratum. Several species of large fruit bats, for example, *Rousettus* spp., *Dyacopterus* spp. and bats weighing more than 30 g are rarely netted using ground based mist-nets (Abdullah and Hall, 1997; Hall *et al.*, 2004). This is possible due to the rarity of the species or the bats mostly utilised the subcanopy and canopy stratum for their foraging purposes.

The usage of various kinds of methods to sample bat community would also provide a broader view of the bats species in Bako National Park. Using methods such as mist-nets, harp traps and other indirect sampling methods including bat detectors also provide better idea of the bats species, especially the insect bats within the area. A group of *Saccolaimus* species were observed to be free flying in Pulau Lakei with only one individual of *S. saccolaimus* successfully caught throughout the study. This indicates that limit of mist-nets to capture more representatives of this species and the species might be under-represented in term of number of individuals or even species. Despite the limits, mist-nets and harp traps have produced several new distributional records of bats for Bako National Park as well as in Sarawak.

Species richness and composition could be related to the different habitat found in Bako National Park. There are at least seven major vegetation types in this park (Hazebroek and Abang Kashim, 2000). In this study, only five different vegetation types were studied. In Bako National Park, the most highly utilised habitat was the mixed dipterocarp forest with 15 species, heath with nine species, mangrove with eight species, beach with five and riverine with three species. Food availability is the major factor that determine animal feeding and reproductive behavior (Mackinnon *et al.*, 1996). The mixed dipterocarp forest is the richest forest in Borneo in terms of flora that are predominantly covered by tall and emergent dipterocarps and many other species such as figs, which in-turn could sustain a large community of bats.

Low diversity of bats found utilising heath forest can be associated with the scarcity of flowering plant in this forest as a number of bats depended on fruit and nectars (Mackinnon *et al.*, 1996; Hazebroek and Abang Kashim, 2000). Consequently such vegetation also attracts less insect, hence, the lesser occurrence of insect bat around this habitat type. It might be that, most of the species recorded in this area is just due to chance when the bats try to cross this area to enter other forest in search of food as heath forest often interdigitates with other forest formations (Mackinnon *et al.*, 1996). The seasonal availability of mangrove flowers also affects the community of fruit and nectar bats in the mangrove areas especially *M. minimus* (Start, 1974; Hall *et al.*, 2004). The availability of insects around the mangrove areas also determined the utilisation of insect bats in this forest. Fireflies are the common insects that can be found in this area besides ants and mosquitoes (Mackinnon *et al.*, 1996).

Hall *et al.* (2004) noted that 20 net-nights is the minimum effort necessary to adequately record local fruit bats community. Although the present sampling effort exceeded the minimum effort suggested by Hall *et al.* (2004), the cumulative species graph (Fig. 2) showed that the trapping-nights was not adequate to represent the overall bats community in Bako National Park or for the five different vegetation studied here. This is very important especially for insect bats as the number of insect bats recorded in the

park were still increasing on the last sampling night. The efforts of 226 trapping-nights was only able to record a total of 22 bats species from overall of 34 known bat species in Bako National Park. Therefore more sampling effort is needed to document the bat species in Bako National Park.

Hall (1996) noted that there are 27 species of bats in Gunung Mulu National Park based on direct, indirect field observations and literature. This is slightly lower than overall checklist in Bako National Park. Salleh *et al.* (1999) only recorded five species of bats and the low diversity observed during their survey primarily caused by the use of only mist-nets for capturing bats. Jayaraj *et al* (2006) recorded 15 species of bats in Mount Penrissen and Anwarali *et al.* (2006) recorded 14 species of bats during their survey at Mount Murud. Although most of the species recorded at both of these localities includes submontane species but it is still low (by half) compare to the present study. In Kayan Mentarang National Park, only 11 species were recorded (Mohd-Alan *et al.*, 2003) which was relatively low compared to the other protected areas noted in this study. In the limestone formations of Bau, a total of 23 species of bats were recorded. This is mainly due to large extensive network of limestone caves that are present in the area that holds more cave roosting species there. Bako National Park also precedes Niah National Park, as only 31 species were recorded in Niah National Park despite the cave/limestone habitat found in Niah National Park (Hall *et al.*, 2002). Among all the sites compared, the highest diversity of bats was recorded in Crocker Range National Park with 41 species (Tuen *at al.*, 2002b).

CONCLUSION AND RECOMMENDATION

This study has documented the increase in the number of bat species from 26 to 34 species for this park. Since the survey was only conducted for 12 trapping-nights at five different habitats, we were restricted to cover a small area near the park headquarters. Besides that, the sampling efforts of this survey was also based at the

understorey level of the forests. This might be biased towards the sub-canopy and canopy levels, including the exception of other habitat types, namely the cliff vegetation and the shrubland areas that might not represent the overall species in this park yet. Hence, lengthening the duration of the survey and including other different sites will certainly influence the accuracy of the sampling results. Furthermore, the results can be more reliable if the sampling methods are varied such as the use of bats detector in line transects surveys to record any presence of echolocating bats in the study area. Fieldwork also can be carried out at different time of the year, in particular during both dry and monsoon seasons to ensure that there is no bias towards any seasons. Thus, all these factors are to be considered for upcoming studies in Bako National Park so that the bats species diversity record can be updated and monitored. This study has provided a new inventory checklist and records of bats for future monitoring, management and conservation in Bako National Park.

ACKNOWLEDGEMENTS

We would like to thank the Sarawak Forestry Department for approving our research permit no. 04608 to conduct fieldwork in national parks in Sarawak, Universiti Malaysia Sarawak for providing us with the administrative and logistic supports during this study and the Sarawak Forestry Corporation, in particular Bako National Park for allowing us to use their facilities. We would also like to thank the Bako National Park staff, Mr. Charlie Laman, second year and final year students of Animal Resource Science and Management programme for helping in the field. Special thanks to Mr. Mohd. Azlan Jayasilan (UNIMAS) for his constructive comments on this paper, Ms. Chong Yee Ling (UNIMAS), Dr. Norhayati A. (UNIMAS) and Dr. Robert J. Baker (Texas Tech University) for sharing their photographs. Research funding provided by the Ministry of Science, Technology and Innovation (MOSTI) under IRPA Grant 09-02-09-1022-AE001 awarded to MTA.

REFERENCES

Abdullah, M.T.

2003a Biogeography and Variation of *Cynopterus brachyotis* in Southeast Asia. PhD thesis. The University of Queensland, St. Lucia, Australia.

2003b Short notes on a colony of thick-thumbed pipistrelle near Mulu National Park. *The Sarawak Museum Journal*, LVIII (79): 268-269.

Abdullah, M.T. and Hall, L.S.

1997 Abundance and distribution of fruit bats and other mammals in the tropical forest canopy in Borneo. *The Sarawak Museum Journal*, LI (72): 63-74.

Abdullah, M.T., Rahman, M.A. and Hall, L.S.

1997a New records for bats in Sarawak, Malaysia. *Malayan Nature Journal*, 50: 365-367.

Abdullah, M.T., Jub, N. and Jalaweh, N.

2003 First record of *Hipposideros ater* in Sarawak, Malaysian Borneo. *The Sarawak Museum Journal*, LVIII (79): 271-274.

Abdullah, M.T., Abang, A.A.A. and Tuen, A.A.

2005 Biodiversity and conservation of chiroptera in the Gunung Berumput-Pueh mountainous complex, Sarawak. In: Tuen, A.A. (ed.), *Diversity and Conservation of Biological Resources in Western Sarawak*. Universiti Malaysia Sarawak. Unpublished report.

Abdullah, M.T., Moritz, C., Grigg, G.G. and Hall, L.S.

2000b Evidence of cryptic species within *Cynopterus brachyotis* by using mtDNA sequence. In: Yaacob, Z., S. Moo-Tan & S. Yorath (eds.), *Proceedings of the International Conference on In-Situ and Ex-Situ Biodiversity Conservation in the New Millenium*. Yayasan Sabah, Kota Kinabalu.

Abdullah, M.T., Siswanto, H., Widiyanto, A., Setiabudi, A. and Firmansyah

1997b Abundance, diversity and distributional records of bats in disturbed habitats in Kalimantan Barat, Indonesia. *The Sarawak Museum Journal,* LI (72): 75-84.

Abdullah, M.T., Hall, L.S., Rahman, M.A., Ketol, B., Marni, W. and Sait, I.

2000a A note on the rare *Pipistrellus vondermanni* in Sarawak, Malaysian Borneo. *Malayan Nature Journal*, 54 (4): 375-376.

Anwarali, F.A., Ketol, B., Marni, W., Tuen, A.A., Abang, F., Fong, P.H. and Abdullah, M.T.

2006 Small mammals diversity of Mount Murud. *Conference on Natural Resources in the Tropics: Development and Commercialization of Tropical Natural Resources, 6-8 June 2006.*

Campbell, P., Schneider, C.J., Adnan, A.M., Zubaid, A. and Kunz, T.H.

2004 Phylogeny and phylogeography of Old World fruit bats in the *Cynopterus brachyotis* complex. *Molecular Phylogenetics and Evolution* 33(3): 764-781.

2006 Comparative population structure of *Cynopterus* fruit bats in Peninsular Malaysia and southern Thailand. *Molecular Ecology* 15: 29-47.

Churchill, S. and Zborowski, P.

1987 Bat survey of Bako National Park, Sarawak. *The Sarawak Museum Journal*, XXXVII, (58): 171-179.

Corbet, G.B. and Hill, J.E.

1992 *The Mammals of the Indomalayan Region: A Systematic Review.* Oxford University Press, New York. 488 pp.

Davis, D.D.
1958 Mammals of the Kelabit Plateau north Sarawak. *Fieldiana Zoology*, 39 (15): 119-147.

Eisenberg, J.F.
1981 *The Mammalian Radiations: An Analysis of Trends in Evolution, Adaptation and Behavior.* The University of Chicago Press, United States of America. 610 pp.

Francis, C.M.
1989a A comparison of mist nets and two designs of harp trap for capturing bats. *Journal of Mammalogy*, 70 (4): 865-870.

1989b Notes on fruit bats (Chiroptera, Pteropodidae) from Malaysia and Brunei, with the description of a new subspecies *Megaerops wetmorei* Taylor, 1934. *Canadian Journal of Zoology*, 67: 2878-2882.

1990 Trophic structure of bat communities in the understorey of lowland dipterocarp rain forest in Malaysia. *Journal of Tropical Ecology*, 6: 421-431.

1994 Vertical stratification of fruit bats (Pteropodidae) in the lowland dipterocarp rainforest in Malaysia. *Journal of Tropical Ecology*, 10: 523-530.

Francis, C.M., Melville, D.S. and Wong, P.L.
1984 Notes on some bats in Bako National Park and Samunsam Wildlife Sanctuary, Sarawak. *The Sarawak Museum Journal*, XXXIII (54): 171-176.

Gumal, M., Sompud, J. and Kong, D.
2004 *Wildlife Survey of the Proposed Extension to Maludam National Park Betong Division Sarawak.* Forest Department Sarawak, Malaysia. 34 pp.

Hall, L.S.
1992 Bako field notes. Unpublished.

1996 Observation on bats in Gua Payau (Deer Cave), Gunung Mulu National Park, Sarawak. *The Sarawak Museum Journal*, L (71): 111-124.

Hall, L.S., Richards, G. and Abdullah, M.T.
2002 The bats of Niah National Park, Sarawak. *The Sarawak Museum Journal*, LVII (78): 255-282.

Hall, L.S., Grigg, G.G., Moritz, C., Ketol, B., Sait, I., Marni, W. and Abdullah, M.T.
2004 Biogeography of fruit bats in Southeast Asia. *The Sarawak Museum Journal*, LX (81): 191-284.

Hazebroek, H.P. and Abang Kashim, A.M.
2000 *National Parks of Sarawak.* Natural History Publications (Borneo), Kota Kinabalu. 502 pp.

Heaney, L.R.
1986 Biogeography of mammals in southeast Asia: estimate of rates of colonisation, extinction and speciation. *Biological Journal of the Linnean Society*, 28: 127-165.

1991a A synopsis of climatic and vegetational change in southeast Asia. *Climatic Change*, 19: 53-62.

1991b An analysis of patterns of distribution and species richness among Philippine fruit bats (Pteropodidae). *Bulletin of American Museum of Natural History*, 206: 145-167.

Heidemen, P.D. and Heaney, L.R.
1989 Population biology and estimates of abundance of fruit bats (Pteropodidae) in Philippines submontane rainforest. *Journal of Zoology London*, 218: 565-586.

Jayaraj, V.K., Laman, C.J. and Abdullah, M.T.
2004 Morphological variation in the genus *Cynopterus* of Peninsular Malaysia and Borneo. *Proceedings of the Regional Conference on Ecological and Enviromental Modelling (ECOMOD 2004)*.

2005b Application of multivariate techniques in determining morphological variation in the genus *Cynopterus* of Peninsular Malaysia and Borneo. *International Conference on Biogeography and Biodiversity: Wallace in Sarawak – 150 years later.*

Jayaraj, V.K., Faisal, A.A.K. and Abdullah, M.T.
2005a Bats of Mount Penrissen, Padawan, Sarawak. *The Sarawak Museum Journal*, LXI (82): 263-274.

Jayaraj, V.K., Faisal, A.A.K., Ketol, B., Hall, L.S. and Abdullah, M.T.
2006 Additional notes on the bats of Mount Penrissen with special reference to *Kerivoula minuta* and *Kerivoula intermedia*. *Journal of Biological Science*, 6(4): 711-716.

Karim, C., Tuen, A.A. and Abdullah, M.T.
2004 Mammals. *The Sarawak Museum Journal*, LIX (80): 221-234.

Kingston, T., Lara, M.C., Jones, G., Akbar, Z., Schneider, C.J. and Kunz, T.H.
2001 Acoustic divergence in two cryptic *Hipposideros* species: a role for social selection? *Proceedings of the Royal Society of London Bulletin*. 268:1381-1386.

Koopman, K.F.
1994 *Handbuch der Zoologie*. Walter de Gruyter and Co., Berlin. 217 pp.

Kunz, T.H. (ed.)
1988 *Ecological and Behavioural Methods for the Study of Bats*. Smithsonian Institute Press, Washington, DC. 533 pp.

Laval, R.K. and Fitch, H.S.
1977 Structure, movements and reproduction in three Costa Rican bat communities. *Natural History*, University of Kansas, 69: 1-28.

Lim, B.L.
1965 Food and weight of small animals from First Division, Sarawak. *The Sarawak Museum Journal*, XII (25/26): 360-372.

Lim, B.L., Chai, K.S. and Muul, I.
1972 Notes on the food habit of bats from the Fourth Division, Sarawak with special reference to a new record of Bornean Bat. *The Sarawak Museum Journal*, XX (40/41): 351-357.

MacKinnon, K., Hatta, G., Halim, H. and Mangalik, A.
1996 *The Ecology of Kalimantan*. Oxford University Press, London. 802 pp.

Mayr, E.
1944 Wallace's line in the light of recent zoological studies. *Quarterly Review of Biology*, 19: 1-14.

Medway, L.
nd The living creatures of Niah Cave. Unpublished.

1958 300,000 bats. *The Sarawak Museum Journal*, VIII (12): 667-679.

1971 The quaternary mammals of Malesia: a review. In: Ashton, P. & M. Ashton (eds.), *Quaternary Era in Malaysia*. Miscellaneous series, 3. Department of Geography, University of Hall. Pp. 63-83.

1977 *Mammals of Borneo: Field Keys and An Annotated Checklist*. Monographs of the Malayan Branch of the Royal Asiatic Society No. 7, Kuala Lumpur. 172 pp.

Mohd-Azlan, J., Sharma, R.S.K. and Zakaria, M.
2000 Species diversity and relative abundance of understorey bats at Air Hitam Forest Reserve, Selangor, Malaysia. *Malayan Nature Journal*, 54 (1): 69-75.

Mohd-Azlan, J., Maryanto, I., Kartono, A.P. and Abdullah, M.T.
2003 Diversity, relative abundance and conservation of chiropterans in Kayan Mentarang National Park, East Kalimantan, Indonesia. *The Sarawak Museum Journal*, LVIII (79): 251-265.

Mohd-Azlan, J., Neuchlos, J. and Abdullah, M.T.
2005 Diversity of chiropterans in limestone forest area, Bau, Sarawak. *Malaysian Applied Biology*, 34 (1): 59-64.

Morley, R.J. and Flenley, J.R.
1987 Late Cainozoic vegetational and environmental changes in the Malay archipelago. In: Whitmore, T. C. (ed.), *Biogeographical Evolution of the Malay Archipelago*. Clarendon Press, Oxford. Pp. 50-59.

Nor, S.M.
1996 The mammalian fauna on the islands at the northern tip of Sabah, Borneo. *Fieldiana Zoology*, 83: 1-51.

1997 *An Elevation Transect Study of Small Mammal on Mount Kinabalu, Sabah, Malaysia.* PhD thesis. University of Illinois, Chicago.

Payne, J., Francis, C.M. and Phillipps, K.
1985 *A Field Guide to the Mammals of Borneo.* The Sabah Society and World Wildlife Fund Malaysia, Kota Kinabalu. 332 pp.

Salleh, M.A., Sim, E.U.H., Rahman, M.A. and Abdullah, M.T.
1999 Isolation of genomic DNA from fruit bats of Kelabit Highlands for DNA archiving and determination of genetic variation. *ASEAN Review of Biodiversity and Environmental Conservation (ARBEC)* September-October 1999.

Simmons, N.B.
2005 Order Chiroptera. In: *Mammal Species of the World. 3rd Edition*. Wilson, D.E. and Reeder, D.M. (eds.), Johns Hopkins University Press, Washington. Pp. 312-525.

Start, A.N.
1972a Some bats of Bako National Park, Sarawak. *The Sarawak Museum Journal*, XX (40-41): 371-376.

1972b Notes on *Dyacopterus spadiceus* from Sarawak. *The Sarawak Museum Journal*, XX (40-41): 367-370.

1974 *The Feeding Biology in Relation to Food Sources of Nectarivorous Bats (Chiroptera: Macroglossinae) in Malaysia.* PhD thesis. University of Aberdeen.

1975 Another specimen of *Dyacopterus spadiceus* from Sarawak. *The Sarawak Museum Journal*, XXIII (44): 267.

Tidemann, C.R. and Woodside, D.P.
1978 A collapsible bat trap and a comparison of results obtained with the trap and with mist nets. *Australia Wildlife Research*, 5: 355-361.

Tuen, A.A., Abdullah, M.T., Laman, C.J., Rahman, M.A., Sim, E.U.H., Ketol, B., Sait, I. and Marni, W.
2002a Mammals of Balambangan Island, Sabah. *Journal of Wildlife and Parks*, 20: 75-82.

Tuen, A.A., Lakim, M.B. and Hall, L.S.
2002b Preliminary survey of bats of the Crocker Range National Park Sabah, Malaysia. *ASEAN Review of Biodiversity and Environmental Conservation (ARBEC)* July-September 2002.

Tuen, A.A., Sait, I., Ketol, B. and Abdullah, M.T.
2004 Mammals of Gunung Murud. Universiti Malaysia Sarawak. Unpublished.

Vaughan, T.A.
1986 *Mammalogy. 3rd Edition.* Saunders College Publishing, Philadelphia. 576 pp.

Yasuma, S. and Andau, M.
1999 *Mammals of Sabah, field guide and identification.* Japan International Cooperation Agency (JICA) and Sabah Wildlife Department. Kota Kinabalu.

Plate X: *Emballonura monticola* Temminck, 1838 – Lesser sheath-tailed bat. (Photo: Chong Yee Ling)

Plate XI: *Rhinolophus luctus* Temminck, 1834 – Great woolly horseshoe bat. (Photo: Dr. Norhayati A.)

Plate XII: *Hipposideros ater* Templeton, 1848 – Dusky roundleaf bat. (Photo: Robert J. Baker)

Plate XIII: *Hipposideros bicolor* Templeton, 1834 – Bicoloured roundleaf bat. (Photo: Robert J. Baker)

Plate XIV: *Pipistrellus vondermanni* – White-winged Pipistrelle. (Photo: Chong Yee Ling)

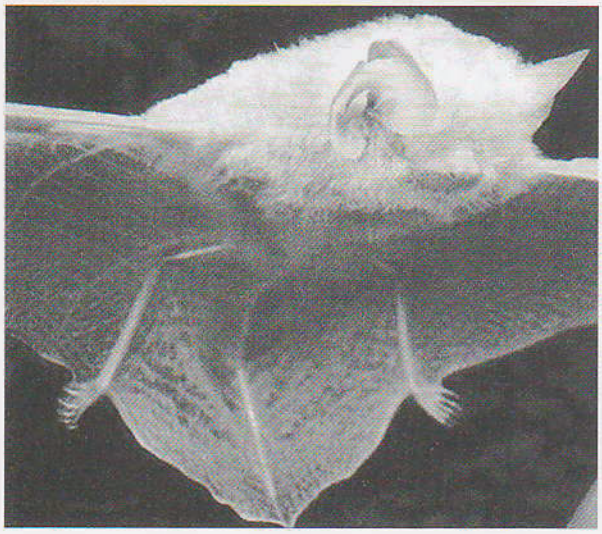

Plate XV: *Kerivoula pellucida* (Waterhouse, 1845) – Clear-winged woolly bat. (Photo: Chong Yee Ling)