Tropical Natural History 11(2): 159-175, October 2011

Bats of the Wind Cave Nature Reserve, Sarawak, Malaysian Borneo

MOHD RIDWAN ABD RAHMAN[1,2*], ROBERTA CHAYA TAWIE TINGGA[1,2], MOHD ISHAM AZHAR[2], NOOR HALIZA HASAN[3] AND MOHD TAJUDDIN ABDULLAH[2]

[1]*Centre for Pre-University Studies, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, MALAYSIA*
[2]*Department of Zoology, Faculty of Resource Science and Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, MALAYSIA*
[3]*Institute for Tropical Biology and Conservation, Universiti Malaysia Sabah, Locked Bag 2073, 88999 Kota Kinabalu, Sabah, MALAYSIA*
* Corresponding author. E-mail: rahmanridwan@gmail.com
Received: 9 January 2011; Accepted: 20 June 2011

ABSTRACT.– A survey of the chiropteran species at the Wind Cave Nature Reserve (WCNR) in the Bau limestone areas (BLA), Sarawak, was conducted from the 10th to 20th January 2008 and the 10th to 20th April 2009. A total of 297 and 367 (net 646) individuals, representing 14 and 11 (net 17) species from four families were captured in 2008 and 2009, respectively, from an effort of 143 each (net 286) sampling nights. This represents eight new recordings for the WCNR and approximately 85%, 45.9% and 17.7% of the total species recorded in the WCNR, BLA and Borneo, respectively. Over both years the most commonly captured species was by far *Penthetor lucasi* followed by *Hipposiderous cervinus*, which were comprised of 63% and 22% of the total (2008 + 2009) captures, respectively. Four and eight species were recorded as the new locality records for Wind Cave (WC) and WCNR, respectively, with *Rhinolopus arcuatus*, H. larvatus*, H. coxi*, H. ridleyi, H. galeritus*, Kerivoula pellucida, Tylonycteris robustula* and *T. pachypus* being new records for WCNR and those marked with an asterix (*) being new records for WC. This documentation is of importance for forest conservation and management in future.

KEY WORDS: Chiropteran, Limestone, Conservation

INTRODUCTION

Classified in the order Chiroptera, bats can be distinguished from other mammals through their capacity of true flight (Payne et al., 1985; Koopman, 1994; Kunz and Pierson, 1994; Francis, 2008). In terms of biodiversity, they are the second largest order in the class Mammalia after rats and squirrels (Rodentia), and are highest in diversity in both the tropical and subtropical regions (Corbet and Hill, 1992; Jones et al., 2002).

As one of the widely distributed taxa, bats takes up many feeding niches, including fruits, leaves, flowers, nectar, pollen, insects, fish, other small vertebrates and blood. They are known to roost in foliage, caves, rock crevices, hollow trees, dead bamboo and have adapted to human-made structures including buildings (Kunz and Pierson, 1994; Francis, 2008). Equally, they play a major role in ecosystem services, including seed dispersal and pollination as well as insect regulation control (Payne et al., 1985; Davidson and Zubaid, 1992; Mickleburgh et al., 1992; Pierson, 1998; Tan et al., 1998).

Caves have been long known to support large colonies of bats (Meredith and Wooldridge, 1992). Thus, caves or limestone areas have often been the main focus for researchers to assess the diversity of bats, especially in Borneo. Among the

well studied caves are the Niah Cave of Niah National Park (NP) (Medway, 1959; Harrison, 1966; Lim et al., 1972; Hall et al., 2002; Nyaun et al., 2004; Mohd Ridwan et al., 2010) and those of the Bau limestone areas (BLA) (Hall et al., 2001; Jub et al., 2003; Karim et al., 2004; Mohd-Azlan et al., 2005; Pathe et al., 2005). Even though there are quite a number of studies carried out on the bat diversity in limestone areas, it is believed that there is still a lot of information to be unveiled due to the unique karst habitat.

The aim of this study was to document the bats species of Wind Cave Nature Reserve (WCNR) and to compare the obtained data with the previous studies at BLA.

MATERIALS AND METHODS

Study Area.– The WCNR (1° 24.915' N and 110° 08.109' E) is situated in the Bau district of Sarawak. The reserve covers 6.16 hectares and includes Wind Cave (WC) itself and the surrounding forest (Sarawak Forest Department, 1992). It is part of the BLA, which is a narrow belt of limestone covering about 150 km^2 in Southwest Sarawak. WC and WCNR are located about 5 km southwest of Bau and 30 km from Kuching.

The WC is situated in a small hill surrounded by alluvium, which stands by the riverbank of Sarawak River. It is surrounding by a remnant forest of medium sized trees and shrubs, including *Excoearia borneensis* (Euphorbiaceae), *Popowia pisocarpa* (Annonaceae), *Eugenia* sp. (Myrtaceae), *Ficus* sp. (Moraceae), *Palaquium* sp. (Sapotaceae) and *Firmiana malayana* (Sterculiaceae) (Khalid, 2008). Surrounding the WCNR, paddy farms (*Oryza sativa*), rubber (*Hevea brasiliensis*), cocoa (*Theobroma cacao*), fruit trees and poultry farm are the intensive agricultural activities in Bau districts.

The annual rainfall is approximately 4000 mm (Malaysian Meteorological Department, 2008). The district is comprised of limestone and is a rich natural heritage but also is of some economic importance in terms of limestone quarrying, tourism and bird nests (Mohd Azlan et al., 2005).

Field methods, sample identification, processing and preservation.– Field sampling was performed using ground netting, harp trapping and hand netting (Abdullah et al., 1997; Abdullah, 2003; Hall et al., 2002). Eight to 12 mist nets and three harp traps were set in various locations supposed to be in the flyways of bats, such as above streams, narrow pathways in the forest, trails, forest edge and the cave openings (Faisal et al., 2007; Mohd-Azlan et al., 2008). The trapping effort was calculated by the total of the number of nets and traps used multiplied by the total number of sampling days each trap / net was used for.

Bats were identified based on Payne et al. (1985). Selected morphological measurements of the bats were taken using a vernier calliper (Mitutoyo), and bats were weighted using a Pesola spring balance for morphometric studies (Abdullah, 2003). The adult / immature status of each bat was determined following Kunz (1988) by examining the epiphyseal-diaphyseal fusion on the third, fourth and fifth metacarpals. The netted bats were marked with labelled rings. Female bats were also examined for evidence of breeding (carrying pups, lactating or pregnant). Captured bats were held until all the nets were closed

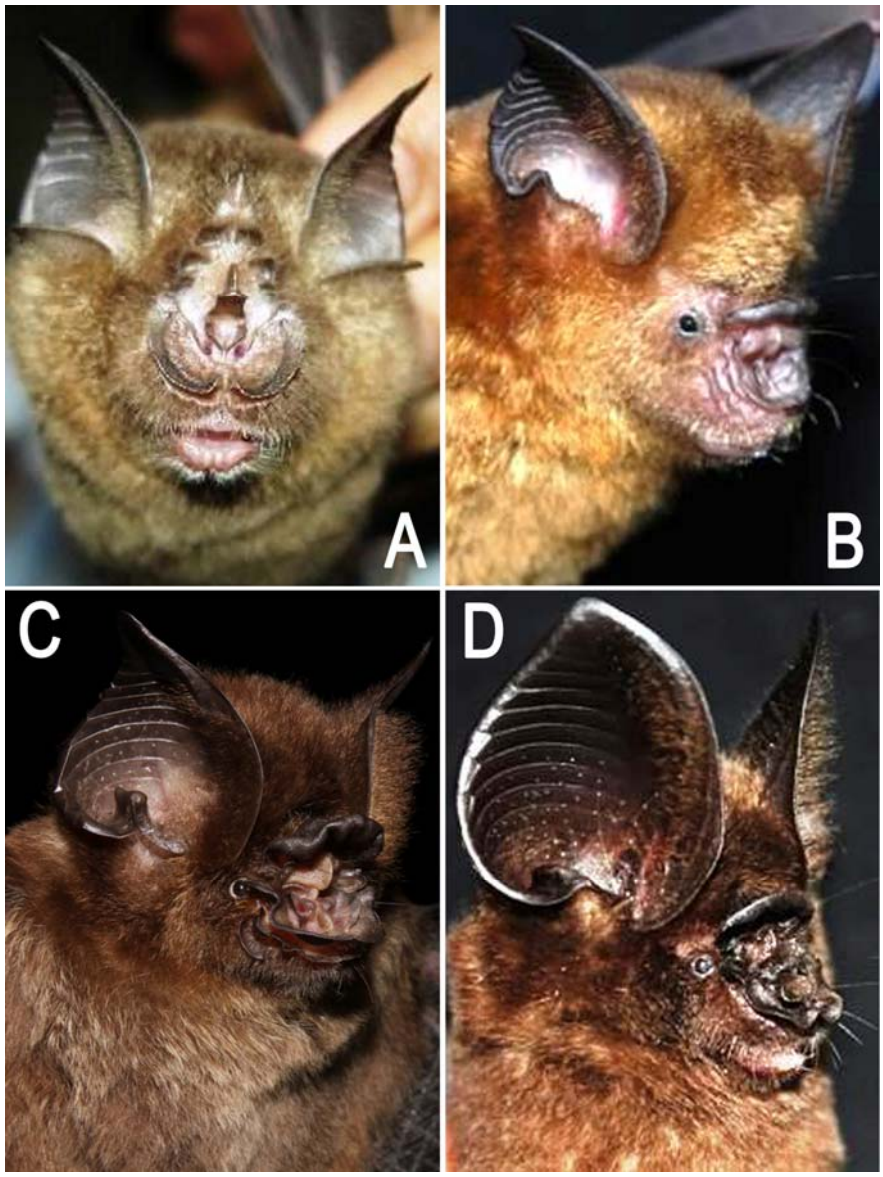

FIGURE 1. A. *Rhinolophus arcuatus* (Photo by Sigit Wiantoro). **B.** *Hipposideros larvatus* (Photo by Faisal Ali Anwarali Khan). **C.** *Hipposideros coxi* (Photo by Mohd Isham Azhar). **D.** *Hipposideros ridleyi* (Photo by Faisal Ali Anwarali Khan).

(maximum duration of 12 hours) to prevent recapture and to reduce stress.

Selected specimens to serve as museum vouchers were euthanized using chloroform and subjected to skinning procedure and the voucher specimen number and details are given in the species account (below). The liver and muscle were preserved in lysis buffer and 75% (v/v) ethanol. These specimens were then deposited at the Universiti Malaysia Sarawak (UNIMAS) zoological museum. The species richness

was calculated by the total number of species caught, and the relative abundance was estimated by the total number of individuals per species divided by the total number of individuals.

RESULTS

A total of 646 individuals (279 and 367 in 2008 and 2009, respectively) were captured from the 286 trapping nights (143 trapping nights for both 2008 and 2009), over the two years, and these represent four families and 17 species of bats (Table 1). This represents 85%, 45.9% and 17.7% of the chiropteran fauna in the WCNR, BLA and Borneo, respectively. Of the total samples caught in both years, *Penthetor lucasi* was bar far the most abundant species caught in WCNR, followed by *Hipposideros cervinus*, with these two species accounting for 85% of all captures. Of the remaining 15 species, only four had a relative capture abundance of more than 1% (Table 1). Four species of bats were caught as singletons, namely, *H. ridleyi*, *Eonycteris spelaea*, *Kerivoula pellucida* and *Tylonycteris robustula*. Eight species were recorded as new locality records for WCNR (Table 2), namely, *R. arcuatus* (Fig. 1A), *H. larvatus* (Fig. 1B), *H. coxi* (Fig. 1C), *H. ridleyi* (Fig. 1D), *H. galeritus* (Fig. 2A), *K. pellucida* (Fig. 2B), *T. robustula* (Fig. 2C) and *T. pachypus* (Fig. 2D), but all species had been recorded before in Borneo. In addition four species were new locality records for the WC itself (Table 3), comprised of *R. arcuatus*, *H. larvatus*, *H. coxi*, and *H. galeritus* (new records for WCNR as well), which had been recorded within the WCNR before. Five individual of bats from two species namely *P. lucasi* (four individuals) and *H. cervinus* (one individual) were recaptured in 2009.

SPECIES ACCOUNT

Family Pteropodidae

Cynopterus brachyotis (Müller, 1838)

(Lesser short nosed fruit bat)

New Material.– 2♂ (MZU M/02193, 02195); 1♀ (MZU/M/02194).

A total of five individuals were captured at the forest edges outside the cave vicinity. Two forms of *C. brachyotis* have been identified that are distinguished by their forearm (FA) measurement, where the larger (Sunda) and smaller (forest) forms have a FA > 60mm and FA < 60 mm, respectively (Campbell et al., 2004, 2006). All of the individuals captured belong to the larger form. *Cynopterus brachyotis* is a widely distributed species / species complex and is one of the common fruit bats in Southeast Asia. It is the tenant of variety of habitats, including primary forests (small), disturbed forests, orchards, mangrove forests and cultivated areas (large) (Payne et al., 1985; Boon and Corlett, 1989; Francis, 1990; Abdullah, 2003). *Cynopterus brachyotis* habitually roost in small groups on trees, particularly under the fronds of palms. Their diet is not restricted to fruits, but they also feed on leaves, nectars and some insects as well (Boon and Corlett, 1989; Funakoshi et al., 1993, Tan et al., 1998; 1999). According to Mohd-Azlan et al. (2010), this species feeds on up to 18 genera of fruit including 15 families of plant. The current status of *C. brachyotis* is of least concern with unknown population trend (Csorba et al., 2008a).

TABLE 1. Bat species recorded within the WCNR in this survey.

Species	No. of individuals (2008 / 2009)		No. of individuals (2008 + 2009)	
	Adult male	Adult female	Total	% Relative abundance
Peropodidae				
Cynopterus brachyotis	2 /0	2 /1	5	0.77
Penthetor lucasi	111/ 117	95/ 83	406	62.9
Balionycteris maculata	1 / 1	1 / 2	5	0.77
Eonycteris spelaea	1 / 0	0 / 0	1	0.15
Rhinolophidae				
Rhinolophus arcuatus	0 / 3	0/3	6	0.93
Rhinolophus borneensis	2 /1	1/ 1	5	0.77
Rhinolophus affinis	4 / 0	2 /0	6	0.93
Hipposideridae				
Hipposideros diadema	0 /2	0 / 4	6	0.93
Hipposideros larvatus	6/ 7	3 / 5	21	3.25
Hipposideros coxi	4 / 0	2 / 0	6	0.93
Hipposideros ridleyi	0/ 1	0 / 0	1	0.15
Hipposideros galeritus	7 / 2	2 / 3	14	2.16
Hipposideros cervinus	25 / 62	6/ 51	144	22.3
Vespertilionidae				
Kerivoula pellucida	0/ 0	1/ 0	1	0.15
Myotis horsfieldii	1 / 3	0 / 3	7	1.08
Tylonycteris robustula	1 / 0	0 / 0	1	0.15
Tylonycteris pachypus	1 / 0	2 / 8	11	1.70

279 (2008), 367 (2009) and 646 (total) individual bats were caught from 143 (2008), 143 (2009) and 286 (total) net- and trap-nights yielding 1.95 (2008), 2.57 (2009) with an average of 2.26 (total) bats/ (net- and trap- nights).

Penthetor lucasi Dobson, 1880

(Dusky fruit bat/ Lucas's short-nosed fruit bat)

New Material.– 5♂ (MZU M/02209, 02210, 02214, 02215, 02216); 4♀ (MZU M/02208, 02211, 02212, 02213).

A total of 406 individuals were mist netted around the cave area over the two sampling years, but it is estimated that thousands of *P. lucasi* cling to the ceiling not far from the entrance of cave (Hall et al., 2001). They can form tight clusters of several hundred individuals and can also be seen hanging individually away from the clusters. Barapoi (2004) estimated that there are 70,845 individuals of *P. lucasi* in WCNR using a mark-recapture model estimator. A recent morphological study on the species in Sarawak showed differences in the body and skull sizes (Sri Aman, Kuching and Miri populations). Various ecological factors such as breeding, crowding effect, foraging behaviour, resource availability and selective pressure, are possible causes of these morphological variations among *P. lucasi* populations (Mohd Ridwan and Abdullah, 2010). Elsewhere, *P. lucasi* is widely distributed throughout southern Thailand, peninsular Malaysia, Riau Archipelago and Borneo (Payne et al., 1985; Corbet and Hill, 1992; Abdullah et al., 2007; Francis, 2008) and Sumatra (Maryanto, 2004). This species is listed as of least concern by IUCN (Bates et al., 2008a).

FIGURE 2. A. *Hipposideros galeritus* (Photo by Faisal Ali Anwarali Khan). **B.** *Kerivoula pellucida* (Photo by Faisal Ali Anwarali Khan). **C.** *Tylonycteris robustula* (Photo by Sigit Wiantoro). **D.** *Tylonycteris pachypus* (Photo by Mohd Isham Azhar).

***Balionycteris maculata* (Thomas, 1893)**
(Spotted-winged fruit bat)

Five individuals of *B. maculata* were caught near the cave boundary that is covered mostly by limestone forest. The distinctive pale spot on the wing membranes, finger joints throughout their face and ears allow for easy identification (Francis, 2008). This species is known to occur in primary lowland rainforest up to 1500 m a.s.l and also in mangrove forest areas. They use ferns, rubber trees and excavated termite nests as their roost.

Although their population trend is unknown, *B. maculata* is grouped as of least concern by the IUCN (Bates et al., 2008b).

***Eonycteris spelaea* (Dobson, 1871)**
(Cave nectar bat)

New Material.– 1♂ (MZU M/02192).

Only one single male was netted around blossoming banana trees near the cave entrance. Payne et al. (1985) stated that *E. spelaea* roost in the total darkness of caves. Since it is a strong flyer and capable of covering a large distance to forage, it is not clear if this single, and the previous, records in the WCNR represent forging visitors or residents, and thus if the reported residency at WCNR and within WC (Hall et al., 2001) is still valid. Regardless, being a primary feeder of pollen and nectar, this bat is an important pollinator of the forest trees. *E. spelaea* roost in compact clusters and often cohabits with other bats. They are listed as of least concern by IUCN (Francis et al., 2008a).

Family Rhinolophidae

***Rhinolophus arcuatus* Peters, 1871**
(Arcuate horseshoe bat)

New Material.– 1♂ (MZU M/02204).

Six individuals of *R. arcuatus* were captured using harp traps at the cave openings of WC, which is a new distributional record for WCNR. They were also sighted roosting in the cave. Previous records of this species documented in Borneo have included Padawan, Kubah NP, Fairy Cave NR and the Jambusan Cave of BLA (Jub et al., 2003; Pathe et al., 2005; Mohd-Azlan et al., 2005; Azhar et al., 2009). There are also previous records from east and central Kalimantan (Struebig et al., 2010). *Rhinolophus arcuatus* has a dark brown body, large ears, broad noseleaf which covers the muzzle and lacks lateral lappets. Unlike *R. affinis*, this species is distinguished by having a broad sella which is slightly expanded at the base (Payne et al., 1985). The distribution of *R. arcuatus* is from Sumatra, Flores, Sulawesi, Borneo, Philippines and New Guinea (Payne et al., 1985; Corbett and Hill, 1992). It is listed as of least concern by the IUCN (Rosell-Ambal et al., 2008a).

***Rhinolophus borneensis* Peters, 1861**
(Bornean horseshoe bat)

New Material.– 1♂ (MZU M/02187); 1♀ (MZU M/02219).

Five individuals of *R. borneensis* were captured during the survey. This species is quite common and has been recorded from previous studies around BLA outcrops including WCNR (Hall et al., 2001; Karim et al., 2004; Mohd-Azlan et al., 2005). This bat is known to roost in colonies of several hundred individuals and is abundant in the cave systems in Sabah (Payne et al., 1985). They are also reported to use hollow bamboos and trees, young leaves of banana and rock crevices as their roost. They are listed as of least concern by IUCN (Hutson et al, 2008).

***Rhinolophus affinis* Horsfield, 1823**
(Intermediate horseshoe bat)

Six individuals of *R. affinis* were captured in WCNR. There have been previous reports of *R. affinis* at WCNR (Hall et al., 2001) and at Jambusan Cave (Pathe et al., 2005), plus it has also been

TABLE 2. Taxonomic list of bat species in the WCNR from this survey and comparison with that from previous surveys within the Bau limestone areas (BLA).

#	Species	This survey	Mohd-Azlan et al. (2005)	Pathe et al. (2005)	Karim et al. (2004)	Jub et al. (2003)	Hall et al. (2001)
	Pteropodidae						
1	*Cynopterus brachyotis*	+		+	+	+	+
2	*Cynopterus horsfieldii*		+		+	+	
3	*Penthetor lucasi*	+	+	+	+	+	+
4	*Rousettus amplexicaudatus*		+			+	
5	*Balionycteris maculata*	+	+	+	+	+	+
6	*Eonycteris spelaea*	+	+		+	+	+
7	*Macroglossus minimus*		+	+	+		
	Mollosidae						
8	*Cheiromeles torquatus*					+	
	Emballonuridae						
9	*Emballonura alecto*				+		+
	Rhinolophidae						
10	*Rhinolophus arcuatus**	+	+	+		+	
11	*Rhinolophus borneensis*	+	+		+		+
12	*Rhinolophus affinis*	+		+			+
13	*Rhinolophus luctus*		+	+	+		
14	*Rhinolophus sedulus*		+	+		+	
	Nycteridae						
15	*Nycteris tragata*				+		
	Megadermatidae						
16	*Megaderma spasma*				+		+
	Hipposideridae						
17	*Hipposideros diadema*	+	+	+		+	+
18	*Hipposideros larvatus**	+	+	+		+	
19	*Hipposideros dyacorum*		+	+		+	
20	*Hipposideros ater*		+	+		+	
21	*Hipposideros cineraceus*		+	+		+	
22	*Hipposideros bicolor*		+	+		+	
23	*Hipposideros coxi**	+	+				
24	*Hipposideros ridleyi**	+					
25	*Hipposideros galeritus**	+	+	+		+	
26	*Hipposideros cervinus*	+	+	+		+	+
	Vespertilionidae						
27	*Kerivoula intermedia*		+	+		+	
28	*Kerivoula pellucida**	+	+			+	
29	*Myotis muricola*		+	+		+	
30	*Myotis ater*					+	
31	*Myotis ridleyi*		+	+			
32	*Myotis hasselti*		+			+	
33	*Myotis horsfieldii*	+		+		+	+
34	*Pipistrellus tenuis*			+			
35	*Tylonycteris robustula**	+					
36	*Tylonycteris pachypus**	+					
37	*Glischropus tylopus*				+		+
	Total number of species	**17**	**23**	**21**	**12**	**23**	**12**
	Total number of families	**4**	**4**	**4**	**6**	**5**	**6**

*New record for WCNR

recorded in Kubah NP, Mount Penrissen, Samunsam and Kuching, Sarawak (Payne et al., 1985; Mohd-Azlan et al., 2008; Jayaraj, 2008). This bat is habitually found roosting in caves, often associated with other horseshoe bats, such as *R. borneensis*. It forages in the dense understorey of forests (Payne et al., 1985) and has been found roosting in large numbers in limestone caves and also netted in the forest at the canopy level in Peninsular Malaysia (Kingston et al., 2006). *Rhinolophus affinis* is listed as of least concern by the IUCN (Waltson et al., 2008).

Family Hipposideridae

***Hipposideros diadema* (Geoffrey, 1813)**
(Diadem leaf-nose / Horseshoe bat)

New Material.– 1♀ (MZU M/02231).

Six individuals of *H. diadema* were caught using harp traps, set at the cave openings. This species is quite common and has been recorded in previous surveys within the BLA (Hall et al., 2001; Jub et al., 2003; Pathe et al., 2005; Mohd-Azlan et al., 2005). Payne et al. (1985) stated that this species is known to roost in large colonies with other species of bats and outlandishly in tree hollows. *Hipposideros diadema* is listed as of least concern by IUCN (Csorba et al., 2008b).

***Hipposideros larvatus* (Horsfield, 1823)**
(Intermediate leaf-nose / Horseshoe bat)

New Material.– 4♂ (MZU M/02183, 02184, 02185, 02186); 1♀ (MZU M/02188).

A total of 21 individuals were caught at cave openings of WC, and there were sightings of this bat roosting inside the cave. This is the first record of *H. larvatus* in WCNR (and WC), but they are considered as common and have been recorded in previous surveys within the BLA (Jub et al., 2003; Pathe et al., 2005; Mohd-Azlan et al., 2005). This species is usually found using rock crevices, mines and caves as their roost. According to Francis (2008), the cave colonies may be tremendously large. *H. larvatus* is listed as of least concern by IUCN (Bates et al., 2008c).

***Hipposideros coxi* Shelford, 1901**
(Cox's leaf-nose / Horseshoe bat)

New Material.– 1♂ (MZU M/02198).

A total of six individuals of *H. coxi* were trapped at the cave openings of WC, and these are the first record of *H. coxi* in WCNR and WC. However, the same species was recorded by Jub et al. (2003) and Mohd-Azlan et al. (2005) at Fairy Cave, and it is endemic to Borneo, southern Sarawak and Central Kalimantan (Payne et al., 1985; Struebig et al., 2010). This species is listed as data deficient by IUCN (Francis et al., 2008b).

Hipposideros ridleyi
Robinson and Kloss, 1911
(Ridley's leaf-nose / Horseshoe bat)

New Material.– 1♂ (MZU M/02232).

A single male was trapped in a harp trap near bamboo trees at WCNR and is a new locality record for *H. ridleyi* in WCNR. However, this species has been recorded in Kubah NP, Lambir NP and Similajau NP (Mohd-Azlan et al., 2008; Jayaraj, 2008). In Peninsular Malaysia, *H. ridleyi* is known to breed twice a year (Payne et al, 1985; Kingstons et al., 2006). It appears to be a

TABLE 3. List of species of bats extant to Wind Cave.

No.	Species	Status in Wind Cave
1	*Eonycteris spelaea*	Roost at main entrance cave (Hall et al., 2001)
2	*Penthetor lucasi*	Large colonies roost at main entrance cave (Hall et al., 2001)
3	*Emballonura alecto*	Roost at main entrance (Hall et al., 2001)
4	*Megaderma spasma*	Roost in cave (Hall et al., 2001)
5	*Hipposideros cervinus*	Numerous roost in cave (Hall et al., 2001)
6	*Hipposideros coxi**	Recorded leaving the cave
7	*Hipposideros diadema*	Scattered roost in cave (Hall et al., 2001)
8	*Hipposideros dyacorum*	Roost in cave (Hall et al., 2001)
9	*Hipposideros galeritus**	Numerous roost in cave
10	*Hipposideros larvatus**	Numerous roost in cave
11	*Rhinolophus affinis*	Scattered roost in cave (Hall et al., 2001)
12	*Rhinolophus arcuatus**	Recorded leaving the cave
13	*Rhinolophus borneensis*	Scattered roost in cave (Hall et al., 2001)
14	*Myotis horsfieldii*	Cluster roost inside bell hole of cave (Hall et al., 2001)

*New extant record for the cave

lowland forest species and has been found in kerangas. There are high chances that it is a cave dwelling species, but most records have noted that the individuals were found roosting in culverts and drainpipes. Noted for its decrease in population levels, *H. ridleyi* is listed as vulnerable by IUCN (Francis et al., 2008c).

Hipposideros galeritus Cantor, 1846
(Cantor's leaf-nose / Horseshoe bat)

New Material.– 1♂ (MZU M/02179); 1♀ (MZU M/02203).

A total of 14 individuals were captured using a harp trap at the cave openings of WC. This species is well distributed and relatively common in the BLA (Jub et al., 2003; Pathe et al., 2005; Mohd-Azlan et al., 2005). *Hipposideros galeritus* often roosts in small groups in caves with *H. cervinus* (Payne et al., 1985). This species is listed as of least concern by IUCN (Francis et al., 2008d).

Hipposideros cervinus (Gould, 1854)
(Fawn round-leaf bat)

A total of 144 individuals were caught at WCNR using harp traps. This is a common species (second highest relative capture abundance in this survey), which has often been captured in previous surveys around BLA outcrops (Hall et al., 2001; Jub et al., 2003; Pathe et al., 2005; Mohd-Azlan et al., 2005). Known as a cave dwelling species, *H. cervinus* can reach up to 300,000 individuals in a group and usually forage in forest understories (Payne et al., 1985). *H. cervinus* is classified as of least concern by IUCN (Csorba et al., 2008c).

Family Vespertilionidae

Kerivoula pellucida (Waterhouse, 1845)
(Clear-winged woolly bat)

A single pregnant female was caught in a harp trap placed near bamboo trees in the vicinity of the rubber plantation, next to the WCNR headquarters, and is a first record of *K. pellucida* in WCNR. However, this species has been recorded in Fairy Cave (Mohd-Azlan et al., 2005). Payne et al.

TABLE 4. The number and proportion of reproducing female bats (pregnant, lactating or carrying pups) caught at WCNR.

Family	Species	Reproducing females Number / proportion (%)		
		2008	2009	Total (%)
Peropodidae	*Cynopterus brachyotis*	0	0	0
	Penthetor lucasi	11/95	0	11.6
	Balionycteris maculata	0	0	0
	Eonycteris spelaea	0	0	0
Rhinolophidae	*Rhinolophus arcuatus*	0	0	0
	Rhinolophus borneensis	0	0	0
	Rhinolophus affinis	0	0	0
Hipposideridae	*Hipposideros diadema*	0	0	0
	Hipposideros larvatus	0	0	0
	Hipposideros coxi	0	0	0
	Hipposideros ridleyi	0	0	0
	Hipposideros galeritus	0	0	0
	Hipposideros cervinus	0	0	0
Vespertilionidae	*Kerivoula pellucida*	1/1	0	100
	Myotis horsfieldii	0	0	0
	Tylonycteris robustula	0	0	0
	Tylonycteris pachypus	0	5/8	62.5

Details of the trapping intensity are as per table 1.

(1985) stated that this species forages in the understories of tall forests and is dependent upon the primary forest. Thus, its declining population levels along with the declining amount of primary forests warrants the status as near threatened (Francis et al., 2008e).

Myotis horsfieldii (Temminck, 1840)
(Horsfield's myotis / Horsfield's bat)

New Material.– 3♂ (MZU M/02182, 02220, 02221); 1♀ (MZU M/02222).

Seven individuals of *M. horsfieldii* were caught during this survey, but small colonies consisting of four to six individuals were seen roosting inside the bell holes of the cave. This species has been suggested to be a species complex and that a taxon revision is needed (Rosell-Ambal et al., 2008b). Familiar to tunnels, caves, bridges, palm fonds and crevices of old buildings, this species often roost in single or small groups with only few individuals. There are also records of this species from lowland forests and agricultural areas (Rosell-Ambal et al., 2008b) in Borneo.

Tylonycteris robustula Thomas, 1915
(Greater bamboo bat)

New Material.– 1♂ (MZU M/02196).

A single individual was trapped within the vicinity of the rubber plantation next to the WCNR using a harp trap, and is a new locality record for the WCNR. It has a dark brown to dark greyish brown upperparts with slightly paler underparts. The fur is smooth and sleek with the presence of large dark brown, flattened disk-like pads at the base of the thumb and sole of the foot. Often associated with bamboo internodes as their roost, this species can be found in Southern China, southeast Asia mainland, Philippines, Sumatra, Java, Sulawesi and Borneo (Payne et al., 1985; Francis, 2008).

This species is listed as of least concern by IUCN (Bates et al., 2008d).

***Tylonycteris pachypus* (Temminck, 1840)**
(Lesser bamboo bat)

New Material.– 1♂ (MZU M/02200); 4♀ (MZU M/02190, 02202, 02205, 02206).

A total of 11 individuals were caught using a harp trap placed at the rubber plantation, and like its counterpart, *T. pachypus,* this is a new locality record for the WCNR. Five pregnant females were recorded in April 2009. This species has brown to reddish upperparts, slightly paler underparts with strongly tinged orange. The fur is rather short and fluffy with an extremely flattened skull and they have enlarged disk-shaped pads on the thumb and feet. This species can be found in central and northern India, China, Southeast Asia, Philippines, Sumatra, Java, Lombok and Borneo (Payne et al., 1985). *Tylornycteris pachypus* is listed as of least concern by IUCN (Bates et al., 2008e).

DISCUSSION

Including the new locality records of this report, there are 20 species of bats recorded at WCNR, which represents just over half (54%) of the total number of species (37) of bats recorded within the BLA. A comparison between this bat survey at the WCNR and those others within the BLA, namely, Hall et al. (2001), Jub et al. (2003), Karim et al. (2004), Pathe et al. (2005) and Mohd-Azlan et al. (2005) is summarized in Table 2. In these studies, Hall et al. (2001) recorded 12 species of bats at WCNR, of which three were not found in this study, giving a total of 20 species for the WCNR, assuming those species recorded in 2001 by Hall et al. and not found in this survey are still present but just stochastically missed in the sampling traps. The 17 species recorded for WCNR in this survey compare reasonably well with other surveys in the BLA, being in between the 23 and 21 species from Fairy Cave (Jub et al., 2003; Mohd-Azlan et al., 2005) and Jambusan Cave (Pathe et al., 2005), respectively, and the 12 species from 16 hills of BLA (Karim et al., 2004).

There are various factors that could explain the discrete species diversity in each study asides an actual allopatric species distribution. Among them are the trapping techniques, forest structures and phenology of the study site, sampling effort and the habitat of the chosen study site (Hall et al., 2004; Mohd-Azlan et al., 2005). According to Mohd-Azlan et al. (2005), the settings of traps in a highly disperse manner within the trapping site, combined with the usage of more effective traps in the likes of four-banks harp trap, affects the total capture rate and this certainly varies between the current and previous surveys. The potency of the harp traps compared to mist nets in capturing insectivorous bats was validated, where the ability to echolocate among insectivorous bats maximise their manoeuvrability and awareness during flight to avoid mist nets due to their early detection of the net (Abdullah et al., 1997; Mohd-Azlan et al., 2005). This does not mean that it is impossible to capture insectivorous bats with mist nets. Frequent checking of the nets can increase the odds of capturing them as they often chew their way out in a short time (minutes) if the nets are left unattended (Abdullah et al., 1997).

Combining the previous survey results with those of this one yields 14 species of bats as being recorded as using WC as their roost (Table 3), derived from nine species

recorded by Hall et al. (2001) and five additional species recorded here which were caught using harp traps erected at the cave entrance. However, there are three species of bats listed in the previous survey in 2001 that are not recorded in the current study, namely, *M. spasma*, *E. alecto* and *G. tylopus*. If this is not stochastic sampling and these three species are no longer resident in WC, then their absence could represent recent environmental disturbance around the limestone area, such as forest fragmentation, guano mining, quarrying and ecotourism, which may have caused undue stress and affected the survival of the bats.

Consistent with the surveys of Jub et al (2003), Mohd-Azlan et al. (2005), Azhar et al. (2009), Jenang et al. (2009) and Mahusin (2009), the high abundance of *P. lucasi* and *H. cervinus* could be due to differences in the intensity of disturbance, food availability, breeding season, stress management and the surrounding vegetation. Mohd-Azlan et al. (2005) also mentioned that the high abundance of these species could be due to the suitability of the roosting site. Cave roosts are essential shelters that can act as a hedge from harsh environmental conditions and potential predators, a secure mating place and a place to rear young and to interact with other individuals (Kunz, 1982).

The availability of food (fruits) throughout the year is presumably a key influential factor in sustaining populations of frugivorous bats in the tropics (Fleming, 1988). In contrast, figs (*Ficus* sp.) are the primary food for chiropterans and avians in Southeast Asia (Lambert and Marshall, 1991), and individual *Ficus* sp. were spotted growing around the WCNR. Besides figs, plants such as *Melastoma* sp., *Calamus* sp. and bamboo trees, which can be an important roost to certain species of bats, are also be found within the study area.

In total, 17 individuals of bats from four species were observed at various reproduction stages, in particular, pregnant females and females carrying pups (Table 4). Numerically, the highest number of pregnant or lactating females caught was from *P. lucasi* (11 individuals) between January and February 2008, followed by *T. pachypus* with five individuals in April 2009. Kofron (2007) carried out a study on the reproduction of *P. lucasi* in Brunei, noted that the reproduction of the species correlates with the flowering and fruiting of specific plant species. Parallel with this, *P. lucasi* is also known to practice synchronised birth within October. Similarly in Peninsular Malaysia, six individuals of pregnant *T. pachypus* were also recorded during April (Kingston et al., 2006). The *Tylonycteris* spp. were reported as highly seasonal breeder species which are mating in October-November and giving birth in mid-April each year (Marshall, 1971).

The major threats to the bats in Borneo at present are habitat loss, cave disturbance and hunting activities (Struebig et al., 2009, 2010). Bats in the tropics depend most of all on the forest for food and shelter. The conversion of land from a forest habitat into agricultural sites inevitably reduces the foraging activities and availability of roosting sites. The declining bat population can be deduced to be likely, at least in part, as a result of the conversion of forested areas into *Acacia*, oil palm, cocoa and rubber plantations (Amit, 2009).

The numbers of oil palm and cocoa plantations are substantially increasing around the limestone areas in Sabah and Sarawak (Hobbs, 2004). A sizable amount of land surrounding the Niah NP has been

cleared for oil palm plantations, which has then reduced the food availability for the micro-bats (Hall et al., 2002). According to Mohd-Azlan et al. (2005), the cause of declining bats in BLA might be due to the local community practice of shifting cultivations where most of the cleared lands were confined to the limestone forest. This notion is also supported by Suyanto and Struebig (2007), who reported that the foraging abilities of both frugivorous and insectivorous bats was affected by the scarcity of fruiting and flowering trees and the deteriorating insect diversity, due to the diminished forest cover.

Ergo, it is crucial to maintain the natural forested areas from being converted to monoculture areas, potentially leading to a sharp decline in species richness and abundance of bats. Continuous and uncontrolled encroachment of caves in Borneo such as ungovernable guano mining, ecotourism and swift nest collecting would threaten the long term survival of cave bats.

ACKNOWLEDGEMENTS

This study was supported by the Zamalah MOSTI awarded to MRAR and grant MoHE-FRGS /06(08)/660/2007(25) awarded to MTA. We are most grateful to Muhamad Ikhwan Idris and Dhana Jay Rajagopal for valuable suggestions to improve the manuscript. Thanks to the Sarawak Forestry Corporation (SFC) and Sarawak Forestry Department (SFD) for research permits (NPW.907.4.2 (III)-01), the staff of WCNR and especially to Saip Sulong and Mr. Razak. Many thanks to our colleagues at the Zoology Department for their undying support and gracious assistance during the fieldworks. We are also thankful for the photographic contribution by Faisal Ali A.K., Sigit Wiantoro and Mohd Isham Azhar. Last but not least, thank to Faculty of Resource Science and Technology, Universiti Malaysia Sarawak (UNIMAS) for transportation and administration.

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