Sains Malaysiana 47(7)(2018): 1349–1357
http://dx.doi.org/10.17576/jsm-2018-4707-01

Bats Assemblage and Lunar Phase Effect on Bat Activity at Mixed Dipterocarp Forest, Gunung Gading National Park, Sarawak, Borneo

(Himpunan Kelawar dan Kesan Fasa Cahaya Bulan terhadap Aktiviti Kelawar di Hutan Dipterokarpa Campuran, Taman Negara Gunung Gading, Sarawak, Borneo)

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ABSTRACT

*Bat surveys at Gunung Gading National Park (GGNP) were conducted for 29 non-consecutive nights, which consisted of five separate sampling sessions from November 2011 until November 2015. A total of 378 individuals representing 36 species from six families were captured, from an accumulated effort of 435 trapping nights. This corresponds to approximately 39% (*n*=36) of the total species recorded in Borneo. The most commonly captured species in GGNP for insectivorous bats was* Rhinolophus affinis *(20.1%), whereas for frugivorous bats* Penthetor lucasi *(14.3%) dominated the capture. Species accumulation curve reached asymptote on the 24th sampling night suggesting that sampling saturation has been achieved for the trapping sites studied here. The species diversity (H'= 2.75) showed relatively high diversity of bat species in the park compared to other actively surveyed sites in western Sarawak including Bako National Park (Bako NP), Kubah National Park (Kubah NP) and Mount Penrisen (Mt Penrisen). This was further supported through rarefaction analysis showing that GGNP has largest value of estimated species compared to other actively surveyed sites in western Sarawak. Lunar phase and bat capture rate correlation analysis showed that there is no statistically significant relationship between lunar phase and the bat capture rate at GGNP. This suggests that bat activity reported here were not affected by moonlight. The results from these surveys provided the most comprehensive list of bats for GGNP. Our study highlights the importance of GGNP as an important habitat for bat conservation including the rare bat species found in Borneo,* Phoniscus atrox.

Keywords: Abundance; bats diversity; mixed dipterocarp forest: western Sarawak

ABSTRAK

*Kaji selidik ke atas kelawar di Taman Negara Gunung Gading (GGNP) telah dijalankan selama 29 malam melalui lima sesi persampelan berasingan yang telah dijalankan bermula dari bulan November 2011 hingga November 2015. Sebanyak 378 individu kelawar yang terdiri daripada 36 spesies daripada enam famili telah ditangkap, daripada 435 malam usaha memerangkap. Jumlah spesies yang ditangkap ini bersamaan dengan kira-kira 39% (*n *= 36) daripada jumlah spesies yang pernah direkodkan di Borneo. Spesies yang paling kerap ditangkap di GGNP bagi kelawar pemakan serangga ialah* Rhinolophus affinis *(19.64%), manakala bagi kelawar pemakan buah ialah* Penthetor lucasi *(14.47%). Lekuk akumulasi spesies mencapai asimptot pada malam ke-24 persampelan yang menunjukkan bahawa saturasi persampelan telah dicapai bagi kawasan kajian ini. Jumlah indeks kepelbagaian spesies (H'= 2.75) menunjukkan bahawa taman negara ini mempunyai kepelbagaian spesies kelawar yang lebih tinggi berbanding taman negara lain di bahagian Sarawak barat. Keputusan kajian ini juga disokong oleh analisis perenggangan yang menunjukkan bahawa persampelan di GGNP mempunyai nilai yang lebih besar berbanding taman negara lain di Sarawak barat yang dikaji secara aktif. Analisis hubung kait fasa bulan dan kadar kekerapan kelawar ditangkap menunjukkan bahawa tiada hubungan yang signifikan antara fasa bulan dan kadar kekerapan kelawar ditangkap di GGNP. Keputusan ini sekaligus menunjukkan tiada sebarang hubung kait antara jumlah cahaya bulan dengan kadar aktiviti kelawar. Kajian ini juga telah menghasilkan inventori spesies yang paling komprehensif dan terkini untuk GGNP. Keputusan kajian ini juga menunjukkan kepentingan GGNP untuk beberapa spesies kelawar yang jarang ditemui di Borneo seperti* Phoniscus atrox.

Kata kunci: Hutan dipterokarpa campuran; kelimpahan spesies; kepelbagaian kelawar; Sarawak barat

INTRODUCTION

Sarawak, Borneo supports one of the richest assemblages of flora and fauna in the Sundaland (Mohd-Azlan & Lawes 2011). However, Bornean forests are highly threatened due to habitat destruction through anthropogenic activities such as monoculture plantations, industrialization, human resettlement, dam construction and timber extraction. As a result, Sarawak is experiencing rapid deforestation and habitat degradation (Mohd-Azlan & Lawes 2011) and this has caused population declines in various bat species

(Altringham 2011), while the remaining population may be confined to isolated protected areas such as national parks.

Bats play important role in maintaining the forest ecology and dynamics as seed dispersers, pollinators and regulating insect population (Boon & Corlett 1989; Mohd-Azlan et al. 2010). Bats are highly diverse group of vertebrates, which represents approximately 33% of the mammalian fauna in Borneo and is dominated by 78 insectivorous species (Payne et al. 1985). The 17 plant-visiting species of the Pteropodidae family are known to visit a variety of plant species where ingested small seeds are carried and discarded further away from the mother tree (Fujita & Tutttle 1991; Marshall 1985, Mohd-Azlan et al. 2010). Due to ecological importance of the bats, various bats studies have been conducted in Sarawak with an emphasis on species distribution and taxonomy based on morphological and genetic data (Jayaraj et al. 2011; Khan et al. 2008).

These studies highlighted that our knowledge of species distribution are incomplete and the actual bat diversity is underestimated in Borneo. Some species that are thought to be confined to specific areas or islands were recorded from multiple new localities around Borneo (*Hipposideros coxi*, Khan et al. 2015; *Kerivoula krauensis*, Struebig et al. 2016). Extensive surveys and collections of new material have also resulted in the description of new bat species in Borneo (Soisook et al. 2015). Findings of new distributional records and new species in Borneo were facilitated by the use of harp traps, sophisticated bat detectors and genetic analyses. These techniques have greatly increased the number of species captured (especially that of the forest-interior bats) and revealed the genetic variation among morphologically cryptic species. Recent reports on new distributional records within previously sampled areas in Sarawak further support the importance of continuous monitoring and the use of multiple capture techniques in properly quantifying species diversity (Bako National Park, Naharuddin et al. 2015; Miri Region, Shazali et al. 2016).

Our study attempts to determine the diversity of bats, to provide baseline data for monitoring, management and conservation within the protected area of Gunung Gading National Park (GGNP). Additionally we also explore the effect of moonlight (through lunar phase) on the activity of bats in GGNP. Surveys such as this will provide valuable data for the design of future protected areas and implementation of species-specific conservation strategies to preserve Sarawak's endangered biodiversity and can be used as a reference to gauge biodiversity loss in similar habitats elsewhere in Borneo (Mohd-Azlan & Engkamat 2013).

MATERIALS AND METHODS

STUDY AREA

The protected area was gazetted in 1983 as the conservation site for *Rafflesia tuan-mudae* (Hazebroek & Kashim 2001). Except for bats, various biodiversity surveys have been conducted in GGNP since then (Patino (2002) for *Rafflesia*; Arif & Mohd-Azlan (2014), Sodhi (2002), Sreedharan (1997) for birds; Das & Haas (2005) for herpetofauna; Mohammed (1998) for insects). GGNP, with an area of approximately 41 km^2, is located at western Sarawak and dominated by mixed dipterocarp forest. This National Park is made up of a complex of mountains with several dominant peaks with the highest point at 965 m (Figure 1).

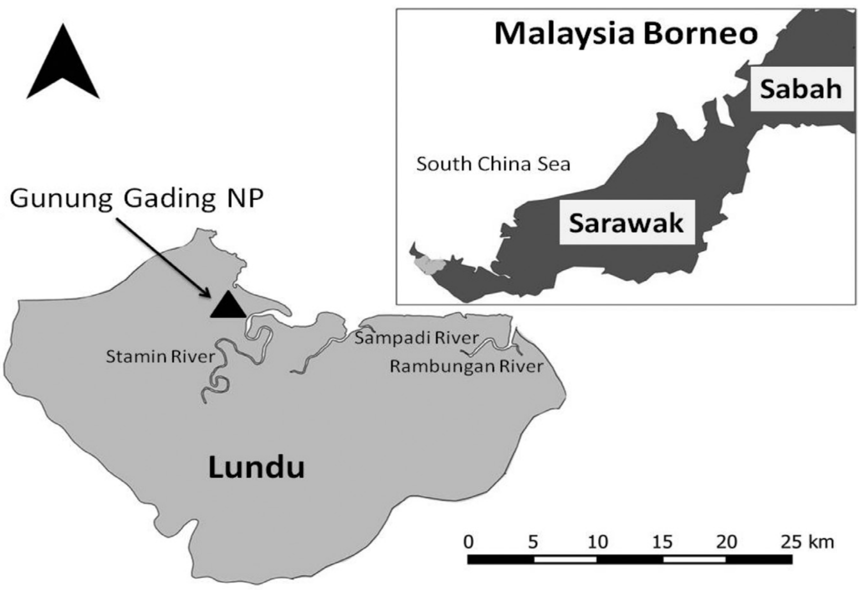

FIGURE 1. Map showing location of Gunung Gading National Park in Lundu District of Sarawak

FIELD SAMPLING TECHNIQUES

Five separate sampling sessions were carried out from 8th to 12th November 2011, 27th January 2012 to 4th February 2012, 12th to 15th April 2012, 25th to 30th August 2015 and 7th to 13th November 2015. The first three sampling sessions were conducted along the Waterfall trail (01º41.380' N, 109º50.718' E - 01º42.127' N, 109º50.180' E) while the fourth and fifth sampling area covered forests near the Park headquarters (1°41'27.6'' N, 109°50'44.3'' E).

Field samplings were done using ground-level mist-nets, harp-traps, hand netting (Francis 1989) and flap-trapping (Francis 2008). An average of ten mist-nets and four harp-traps were set in various locations targeting the flyways of bats such as above streams, narrow pathways in the forest, trails, cleared area in the forest and forest edge (Mohd-Azlan et al. 2008; Mohd-Ridwan et al. 2010). Flap trapping was conducted by walking along the trails and the areas assumed to be bat flyways or foraging areas especially near lights where insects are attracted. The trapping effort was calculated by total number of nets and traps multiplied by total of sampling days. Bats were identified based on Payne et al. (1985). The age, sex, morphological measurements and reproductive state of the captured individuals were recorded. Measurements were taken using Vernier calipers and weight was recorded using Pesola spring balance for morphometric studies. Voucher specimens were euthanized with chloroform, tissue samples (muscles and livers) were collected and preserved in 95% ethanol, full bodies were preserved in 70% alcohol. These specimens were then deposited at the Universiti Malaysia Sarawak (UNIMAS) Zoological Museum.

LUNAR PHASE

Lunar phase for the days and month of sampling was estimated using available online resources at https://www.timeanddate.com/moon/phases/malaysia/seremban. Moonlight intensity was ranked following scale described in Saldana-Vázquez and Munguia-Rosas (2013): (a) New moon (no light, 0% light), (b) Waxing crescent (Obscured gibbous moon, quarter moon and light clouds, very obscured full moon), (c) First quarter moon (obscured full moon), (d) Waxing gibbous moon (full moon light visible with clouds), (e) Full moon (full moon visible with no clouds, 100% light), (f) Waning gibbous moon (full moon light visible with clouds), (g) Last quarter moon (obscured full moon), and (h) Waning crescent (Obscured gibbous moon, quarter moon and light clouds, very obscured full moon). To avoid biased analysis, we removed sampling days in which it rains.

DATA ANALYSIS

The Shannon-Wiener Diversity index (*H'*) was used to estimate species diversity in GGNP, which is sensitive to changes in the abundance of rare species in a community. Student's t-test was conducted to compare the abundance and composition of bats assemblages between mist-nets and harp-traps. The Shannon-Wiener index and diversity *t*-test analysis were calculated using PAST software (Hammer et al. 2001). Rarefaction curve was constructed using *R* (R Development Core Team, 2009) with the vegan package (Oksanen et al. 2011) to compare the species richness with different sampling efforts between other sites actively studied within Western Sarawak including Bako National Park (Bako NP), Kubah National Park (Kubah NP) and Mount Penrisen (Mt Penrisen). The lunar phase and bat capture rate correlation analysis were done to compare the relationship between moonlight and bat activities based on feeding guilds and total individuals recorded. Given that the capture rate between species varies, separate correlation analyses were performed for the two most commonly captured insectivorous species in that park, *H. cervinus* and *R. affinis*.

RESULTS

A total of 378 individuals representing 36 species from six families namely, Emballonuridae, Hipposideridae, Megadermatidae, Pteropodidae, Rhinolophidae and Vespertilionidae were recorded at GGNP (Table 1). Vespertilionidae was the most speciose family (12 species) in this park followed by Pteropodidae (9 species), Hipposideridae (8 species) and Rhinolophidae (5 species), whereas both Emballonuridae and Megadermatidae each with one species. A total of 187 individuals representing 27 species (0.65/net-night) were mist-netted, 171 individuals (23 species) were captured in harp-trap (1.47/trap-night) and 20 individuals (eleven species) were caught using flap-trap (0.69/trap-night). *Rhinolophus affinis* (20.1%) was the most frequently captured species in GGNP followed by *Penthetor lucasi* (14.3%). Five species were recorded as singletons: *Hipposideros ridleyi, Murina rozendaali, M. suilla*, *Phoniscus atrox* and *Rousettus amplexicaudatus*. All species captured in this study are listed as Least Concern or Near Threatened except for *Hipposideros ridleyi* and *Murina rozendaali, which* are listed as Vulnerable in the IUCN Red List (IUCN 2015). Additionally, all species received protected status in Sarawak according to Sarawak Wild Life Protection Ordinance 1998.

COMPARISONS OF TRAPPING METHODS

All three trapping methods were successful in capturing bats (Table 1) although flap-traps were only used in the last two field sampling session. Family Pteropodidae (trapping effort/nights= 0.45) showed the highest overall captured rate using mist-nets, but no pteropodid was trapped using harp-traps during our surveys. Family Hipposideridae (trapping effort/nights= 0.72) recorded with the highest capture rate using harp-traps, followed by family Rhinolophidae (trapping effort/nights= 0.64). As for the flap-trapping the 11 species of insectivorous bats captured using this technique represented five

TABLE 1. List of species caught at Gunung Gading National Park for year 2011, 2012 and 2015 using three different methods including mist-nets, harp-traps and flap-traps (Flap-trap was not used during the 2011 and 2012 trapping session). Species conservation status was assigned to each species according to the IUCN 2016 list

Family Species	♂	♀	Total	Year 2011	Year 2012	Year 2015	Mist Net	Harp Trap	Flap Trap	Relative abundance (%)	IUCN
Emballonuridae											
Saccolaimus saccolaimus	0	2	2			2			2	0.53	LC
Hipposideridae											
Hipposideros ater	6	8	14	1	7	6	4	8	2	3.70	LC
Hipposideros bicolor	6	3	9		7	2	1	8		2.38	LC
Hipposideros cervinus	31	24	55	28	11	16	2	52	1	14.55	LC
Hipposideros dyacorum	3	1	4		1	3	2	2		1.05	LC
Hipposideros diadema	1	2	3			3	1	2		0.79	LC
Hipposideros galeritus	6	1	7	3	2	2		7		1.85	LC
Hipposideros larvatus	2	4	6			6	2	4		1.59	LC
Hipposideros ridleyi	0	1	1			1		1		0.26	VU
Megadermatidae											
Megaderma spasma	0	2	2	1		1	1	1		0.53	LC
Pteropodidae											
Balionycteris maculata	2	9	11	4	3	4	11			2.91	LC
Chironax melanocephalus	0	2	2		2		2			0.53	LC
Cynopterus brachyotis	23	24	47	19	20	8	46		1	12.43	LC
Cynopterus horsfieldii	2	3	5		2	3	4		1	1.32	LC
Dyacopterus spadiceus	2	5	7	6	1		7			1.85	NT
Eonycteris spelaea	1	2	3		3		3			0.79	LC
Macroglossus minimus	0	2	2	1		1	2			0.53	LC
Penthetor lucasii	20	34	54	7	41	6	54			14.28	LC
Rousettus amplexicaudatus	0	1	1		1		1			0.26	LC
Rhinolophidae											
Rhinolophus affinis	35	41	76	12	49	15	18	56	2	20.11	LC
Rhinolophus arcuatus	2	1	3	3				3		0.79	LC
Rhinolophus borneensis	6	5	11	4	1	6	1	9	1	2.91	LC
Rhinolophus luctus	4	3	7	2	2	3	3	4		1.85	LC
Rhinolophus trifoliatus	5	1	6	4	1	1	4	2		1.59	LC
Vespertilionidae											
Glischropus tylopus	3	0	3			3		1	3	0.79	LC
Kerivoula hardwickii	0	3	3		1	2	2	1		0.79	LC
Kerivoula papillosa S. (Small form)	1	1	2			2	1	1		0.53	LC
Kerivoula papillosa L. (Large form)	1	2	3	1		2	2	1		0.79	LC
Kerivoula pellucida	1	1	2			2	1	1		0.53	NT
Murina rozendaali	0	1	1			1		1		0.26	VU
Murina suilla	1	0	1			1				0.26	LC
Myotis muricola	3	2	5			5	3		2	1.32	LC
Myotis ridleyi	2	2	4			4			4	1.05	NT
Phoniscus atrox	1	0	1			1		1		0.26	NT
Tylonycteris pachypus	2	6	8		1	7	5	3		2.11	LC
Tylonycteris robustula	5	2	7	2	4	1	4	2	1	1.85	LC
Number of individuals	177	201	378	98	160	120	187	171	20		
Number of species	28	33	36	16	20	31	27	23	11		
Net and trap-night (Trapping effort)			435	84	168	165	290	116	29		
Bats / Net and trap-night (Capture rate)			0.87	1.17	0.95	0.78	0.65	1.47	0.69		
H' diversity index			2.75	2.24	2.11	3.90	2.38	2.09	2.28		

*LC = Least Concern, NT = Near Threatened, VU = Vulnerable families, Emballonuridae (*Saccolaimus saccolaimus*), Hipposideridae (*Hipposideros ater* and *H. cervinus*), Pteropodidae (*Cynopterus brachyotis* and *C. horsfieldii*), Rhinolophidae (*Rhinolophus affinis* & *R. borneensis*) and Vespertilionidae (*Glischropus tylopus*, *Myotis muricola*, *M. ridleyi* & *Tylonycteris robustula*). There was no significant difference in the species and relative abundance of bats captured using mist-nets and harp-traps (t= 1.76, df= 367, p= 0.07).

SPECIES DIVERSITY INDICES

The number of bat species captured in GGNP increased exponentially till the 24th night (Figure 2). Species accumulation curve reached an asymptote beginning 25th night onwards suggesting that sampling saturation was reached for similar sampling techniques. Species diversity index (H'= 2.75) showed relatively high diversity of bat species in GGNP (Table 2) compared to other sites in western Sarawak (Bako NP, Kubah NP, Mount Penrisen; Jayaraj et al. 2011). Similarly, rarefaction analysis comparing species diversity between study sites showed that GGNP supports more bats (83 captured individuals) in western Sarawak (Figure 3).

EFFECT OF LUNAR PHASE ON BAT ACTIVITY

The highest number of species caught was 15 species on the 27th night. The relative abundance of bats was high on the fourth night during full lunar phase (Figure 4). Forty-one individuals from eight species, dominated by *H. cervinus* with 26 individuals followed by *R. affinis* with nine individuals were caught on that night suggesting that insect activity can be high during full lunar phase. Thirteen species of bats dominated by two species *R. affinis* and *H. cervinus* were captured during the waning crescent of lunar phase when moon shifting from a full moon to a new moon phase by decreasing in visibility. Low number of individuals captured during first, seventh, ninth, sixteenth, twenty-sixth and twenty-ninth night due to heavy rain. In general, there were no significant correlation (p>0.05) between lunar phase and the bat activities (Figure 4). Similarly, no significant correlation were observed between the lunar phase and the two most abundant species in the park (*H. cervinus* & *R. affinis*) (p>0.05). Additional sampling may be required to fully understand the complexity of moonlight and the foraging ecology of bats.

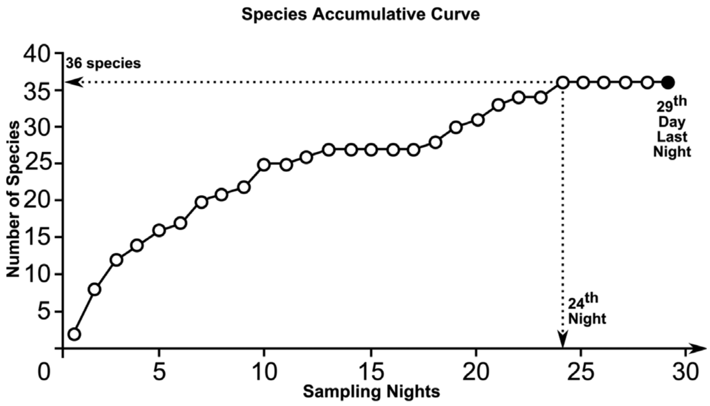

FIGURE 2. Species accumulative curve of bats at Gunung Gading NP for 29 non-consecutive nights with the total accumulative species (36 species) reached on the 24th night

TABLE 2. Comparison of the number of captures and species counts of bats for three different trapping technique including mist nets, harp traps and flap trap by bat family

Family	Mist net (10 nets)			Harp trap (4 traps)			Flap trap (1 traps)		
	n	Capture Rate (bats /net-night)	Species counts	*n*	Capture Rate (bats/ trap-night)	Species counts	*n*	Capture Rate (bats/ trap-night)	Species counts
Emballonuridae	0	0	0	0	0	0	2	0.07	1
Hipposideridae	12	0.04	6	84	0.72	8	3	0.10	2
Megadermatidae	1	0	1	1	0	1	0	0	0
Pteropodidae	130	0.45	9	0	0	0	2	0.07	2
Rhinolophidae	26	0.09	4	74	0.64	5	2	0.07	2
Vespertilionidae	18	0.06	7	12	0.10	9	4	0.14	4
H' diversity index		0.92			0.89			1.57	

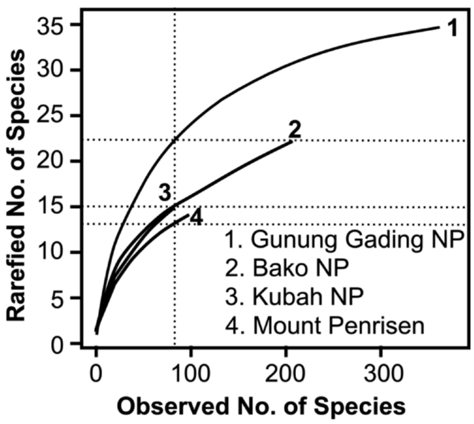

FIGURE 3. Rarefaction curve of Bats in compare to three other sites in Western Sarawak

DISCUSSION

In general, the forest type, resource abundance and suitable roosting sites influence the distribution of bats. According to Tuen et al. (2000), the foraging habitat, diet and feeding strategies are the three main factors, which influenced the bats population. This survey has contributed 36 species representing about 39% of bats in Borneo recorded by Payne et al. (1985). Species composition of chiropterans in GGNP area seems to be relatively higher compared to other studies conducted at lowland mixed dipterocarp forests in Sarawak (Jayaraj et al. 2011; Mohd-Azlan et al. 2008). Bat diversity in GGNP is comparable if not higher than many other studies in Peninsular Malaysia and Borneo (34 species, Wang Kelian State Park, Perlis, Peninsular Malaysia (Jayaraj et al. 2013); 29 species, Lambir Hills National Park (Fukuda et al. 2009; Shazali et al. 2016); 35 species across 6 sites in Peninsular Malaysia (Mohd-Hanif et al. 2015); 35 species, Bako National Park, Sarawak (Jayaraj et al. 2011; Naharuddin et al. 2015); 35 species across 6 sites in Brunei (Struebig et al. 2012); 32 species, Kubah National Park, Sarawak (Jayaraj et al. 2011); 32 species, Mount Penrisen, Sarawak (Jayaraj et al. 2011); but lower in cave ecosystems; 40 species, Niah National Park Sarawak (Mohd-Ridwan et al. 2010; Shazali et al. 2016); 37 species, Bau Limestone Areas, Sarawak (Mohd- Ridwan et al. 2011); 48 species, Mulu National Park, Sarawak (Azhar et al. 2013; McArthur 2012; Shazali et al. 2016).

The insectivorous bats, *R. affinis and H. cervinus* were frequently caught during the study period. The high abundance of these species was possibly due to the availability of food sources and suitable rock crevices roosting sites within the study area. The formation of large rock crevices near the waterfalls at GGNP probably provides suitable roosting sites for these species. These species commonly forage in large group under the forest canopy (Payne et al. 1985). Flying in-group using the same trail when exiting the cave may partly explain why they are caught in large number in the harp-traps. The fruit bats were dominated by *P. lucasi* followed by *C. brachyotis*. These generalist species are known to be able to occupy various types of habitats from lowland to montane forests. They were also reported to be able to adapt to many environmental alterations with the changing of general habitat and ecological requirements (Jayaraj et al. 2011).

Data presented here needs to be interpreted with caution as sampling at GGNP was dominated by ground level mist-netting and harp-trapping which methods are biased toward bats species that are commuting and/or foraging under the canopy. However, we managed to catch a near threatened supra-canopy forager, *D. spadiceus*. The species were rarely caught in the understorey traps except when they came down to drink or to feed on lower fruit trees. At Padawan, several individuals of *D. spadiceus* were found flying under the canopy to feed on cacao trees (Mohd-Ridwan per comm. 2009) and at the hilly forest edge (Mohd-Ridwan et al. 2010). As *D. spadiceus* was captured only in low numbers through its distribution range, it was considered to be a rare species.

Forest specialists from the genus *Kerivoula*, namely *K. hardwickii, K. papillosa* and *K. pellucida* are foraging mainly in dense vegetation. Hasan and Abdullah (2011) indicated that *K. papillosa* may be a species complex with two distinct forms, *K. papillosa* S. (small form) and *K. papillosa* L. (large form). The phylogenetic analysis recovered two clades congruent with the two morphological forms. In GGNP, both morphotypes were found in sympatry suggesting that GGNP provides suitable habitats for both of them.

Family Pteropodidae represented the highest number of individuals captured by mist-netting. These mist-nets were set up across trails and nearby areas with food sources, suggesting that these frugivores were foraging on the vegetation below or in the canopy level. Placement of mist-nets in different habitats can also provide insight into the relative habitat use among species (Kunz & Fenton 2003). *Rhinolophus affinis* and *H. cervinus* was the most abundant species caught in the harp-traps, both of this species are known to commute in large groups which resulted in high number of captured individuals. Throughout these sampling activities, a rare species of bat, *Phoniscus atrox* was caught in a harp-trap that was set up on a trail. This is the first record of *P. atrox* in GGNP and also in Sarawak. In Borneo, previous record of this species was from Lumerau, Madai and Sepilok in Sabah (Hill & Francis 1984) and Tg Putting of Kalimantan (Struebig et al. 2006).

'Lunar phobia' is the term used for the reduced activity in bright moonlight (during full moon) to avoid predators (Lang 2006). Our results from GGNP showed that in general no significant correlation (p>0.05) exists between lunar phase and bat activity. In line with the findings of Saldana-Vázquez and Munguia-Rosas (2013), we assume that this might be mainly due to the canopy cover, which hinders the moonlight to be perceptible in the understory. As most of our sampling efforts using mist-nets and harp-traps targeted species that fly below the canopy, we assume that predation risk was minimal at our sampling sites. Similar observation

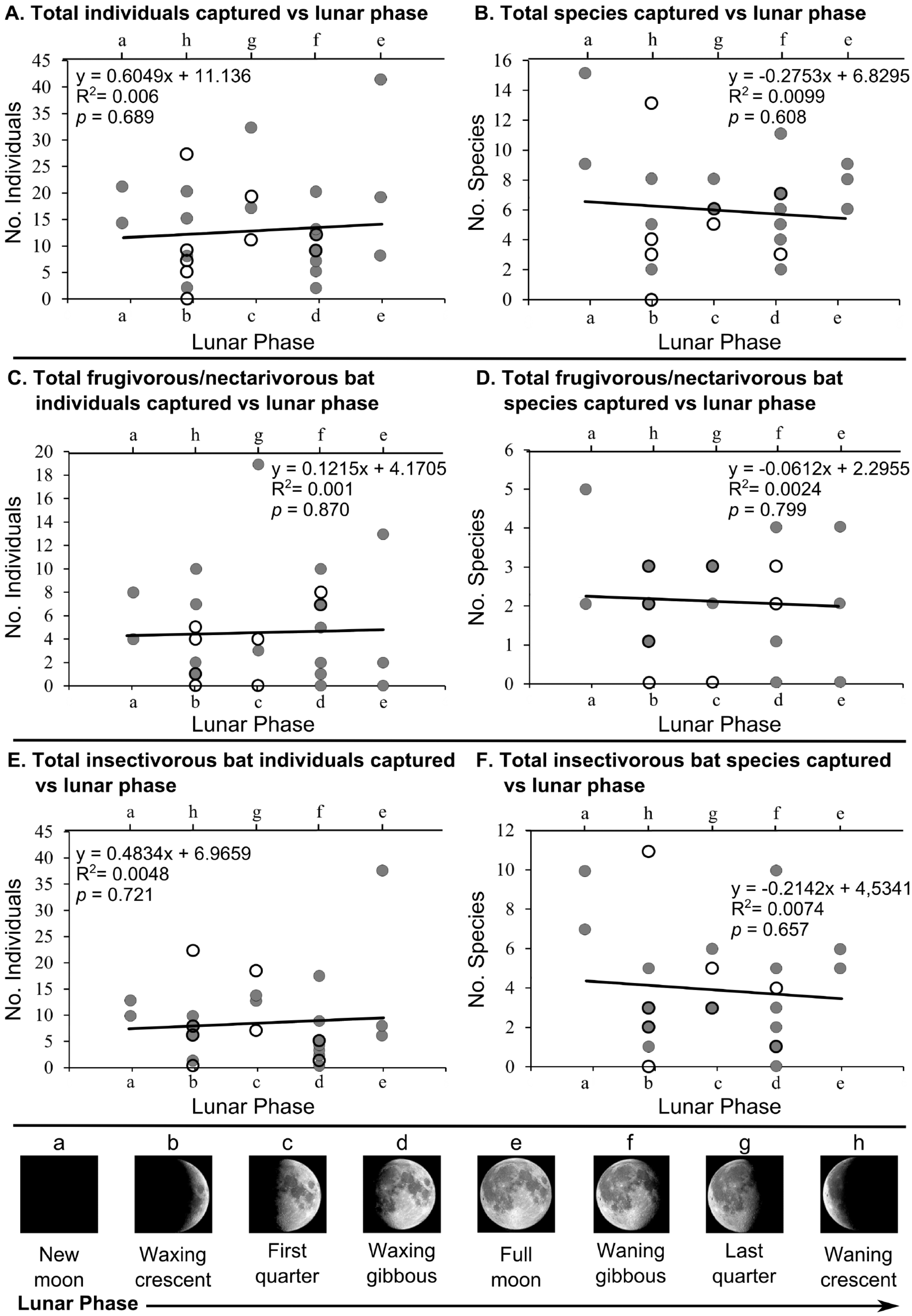

FIGURE 4. Linear regression analysis of bat activities and the corresponding lunar phase as determined from the moon calendar. Linear regression of bat activity A) Total individuals captured, B) Total species captured, C) Total frugivorous/nectarivorous bat individuals captured, D) Total frugivorous/nectarivorous bat species captured, E) Total insectivorous bat individuals captured, and F) Total insectivorous bat species captured, were plotted based on different lunar phase (shown at the bottom of the figure; a – h) The bottom x-axis for lunar phase for each plot represent lunar phase (a – e) identified by grey dot and the top x-axis for lunar phase for each plot represent lunar phase (f – h) identified by open circle

was also made previously, where cloud cover was thought to minimize moonlight penetration thus increasing foraging activity of African insectivorous bats (Fenton et al. 1977).

CONCLUSION

This study provides up-to-date information on the bat species diversity at GGNP. GGNP records the highest bat species diversity in western Sarawak. Furthermore, this survey also highlights the importance of GGNP for protecting rare bat species found in Borneo. The complex vegetation along different latitudinal gradient surrounded by orchards at the edges of the park may have contributed to the high diversity of bats in this national park. Future samplings of sites not covered in our study may add more species to the list provided herewith. Although our study does not provide support for lunar phobia, we recommend the hypothesis to be further tested as our sampling may be biased as all the traps were positioned within the forest and under the canopy where moonlight penetration is minimal. The GGNP in western Sarawak appears to be a species diverse area and therefore should be considered as a priority area for conservation efforts.

ACKNOWLEDGEMENTS

The funding for this study came from four grants, namely MOE, NRGS/1088/2013 (02), RAGS/STWN109(2)/1043/2013(10) and RACE/g(2)/1107/2013 (15). We also would like to express our greatest gratitude to UNIMAS for awarding the Zamalah Award 2014 to NFDAT. We also acknowledge the Sarawak Forestry Department for granting research permits. Our gratitude goes to the Park Wardens, Park Managers and staff members of GGNP and the Department of Zoology, Faculty of Resource Science and Technology, UNIMAS for their kind assistance. The research of GC and TG received support from the Hungarian Scientific Research Fund (OTKA) K112440.

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Received: 9 May 2016
Accepted: 3 November 2016