THE RAFFLES BULLETIN OF ZOOLOGY 2013 **61**(1): 397–405
Date of Publication: 28 Feb.2013

CAMERA TRAPPING AND CONSERVATION IN LANJAK ENTIMAU WILDLIFE SANCTUARY, SARAWAK, BORNEO

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ABSTRACT. — Information on the distribution of species is important in prescribing sound management practices for a protected area. In view of this, we conducted a series of camera trapping surveys in Lanjak Entimau Wildlife Sanctuary, Sarawak, Malaysian Borneo. A total of 20 camera traps was deployed primarily in riverine forests over two sampling periods (2003 and 2006) spanning 10 months altogether. A total of 1945 camera trap days yielded 537 of photographs of at least 21 species of mammals and five species of birds. Of these, four mammalian species are endemic to Borneo and two species are listed as endangered by the IUCN. In addition, our camera trapping survey has provided more detailed information on activity patterns of some cryptic mammal species. Finally, we discuss potential threats to selected mammal species in this area and suggest possible mitigation measures. We emphasize that regular monitoring of wildlife in protected areas should not be neglected, especially when biodiversity in this region is experiencing accelerated and unprecedented rates of extinction.

KEY WORDS. — activity patterns, Borneo, camera trapping, mammals, riverine forest

INTRODUCTION

The need for improved knowledge of the natural history in Sarawak's totally protected areas and what biodiversity they protect is critical, given that ongoing habitat destruction and human encroachment presently threatens most, if not all, protected areas in Sarawak. Additionally habitat alteration, which includes forest clearing for agriculture such as oil palm, has always been a major threat to most mammals in this region (Stevens, 1968; Payne et al., 1985; Mickleburgh et al., 1992; Nowell & Jackson, 1996; Laidlaw, 2000; Fitzherbert et al., 2008)—this has forced many species to seek refuge in increasingly isolated protected areas. The impact of such landscape changes on the carrying capacity of protected areas and species dynamics within them remains poorly understood in Sarawak.

The totally protected forest areas of Sarawak are important habitats for a wide variety of flora and fauna, including many taxa of which are endemic to Borneo. These areas, which consist of nature reserves (<1000 ha), national parks and wildlife sanctuaries, provide legal protection to heavily hunted animals that are not listed in Sarawak's Wild Life Protection Ordinance, 1998 (SWLPO, 1998). These nature reserves and parks, which are governed by National Parks and Nature Reserves Ordinance, 1998 (NPNRO, 1998) normally exhibit significant geomorphic or physiographic features with significant natural habitats for in-situ conservation of biodiversity and serve as key attractions for tourism. Access to wildlife sanctuaries is prohibited except for research purposes; anthropogenic impact should therefore be considered minimal when compared to other totally protected areas such as National Parks and Nature Reserves. As such, wildlife sanctuaries are likely to play a major role in wildlife conservation by providing refugia for many animal species.

Lanjak Entimau Wildlife Sanctuary (LEWS) is the largest of the four wildlife sanctuaries in Sarawak. Previous surveys of LEWS documented the soils and various aspects of its flora, small mammals and primates such as orangutans (Chai, 2000). However, studies on mammals in LEWS, which have emphasized on rodents, shrews, bats and primates, all involved the use of conventional trapping methods such as cage traps, observations and pit-fall traps (Gurmaya et al., 1999; Chai, 2000). In the past decade, the introduction of infrared sensored cameras has elucidated the distribution and behavior of many secretive and cryptic mammals in this

region (Laidlaw, 1999; Kawanishi et al., 2003; Mohd-Azlan, 2006; Mohd-Azlan & Sharma, 2006; Rayan & Mohamad, 2009; Kitamura et al., 2010; Brodie & Giordano, 2011; Cheyne & Macdonald, 2011). Camera-trapping is arguably one of the most cost-effective methods to produce species inventories. In fact, it frequently records more species per sampling site than other sampling methods such as transect-sampling (Siveira et al., 2003; Roberts, 2011) and is more favoured in tropical rainforests (Mohd-Azlan, 2009). In Borneo, the use of camera traps has increased, particularly in species inventories (Matsubayashi et al., 2006; Mohd-Azlan & Lading, 2006; Matsubayashi et al., 2007; Giman et al., 2007; Yasuda et al., 2009) and species specific research (sun bear, Wong et al., 2004; Bornean bay cat, Mohd-Azlan & Sanderson, 2007; Bornean cats, Mohamed et al., 2009; small carnivores, Mathai et al., 2010; orang utan, Matsubayashi et al., 2011).

The rate at which natural habitats are being converted to oil palm plantations is distressing in Southeast Asia (Cooke, 2006; Koh & Wilcove, 2007; Fitzherbert et al., 2008; Koh & Sodhi, 2010; Sodhi et al., 2010) especially around several totally protected areas in Sarawak. The Sarawak Government aimed to bring one million ha under oil palm by 2010, and plans to double the area by 2020. Such imminent threat to natural forests warrants consistent surveys and monitoring programmes to observe trends in species composition and abundance in totally protected areas, especially when different types of surrounding matrices may have strong influence in species richness of a particular area (i.e., birds, Mohd-Azlan & Lawes, 2011). Surveys such as this also provide valuable data for the design of future totally protected areas and implementation of species specific conservation strategies to preserve Sarawak's endangered biodiversity. Moreover, data such as this can be used as a reference to gauge biodiversity loss in similar habitats elsewhere in Borneo. Most of the vertebrate groups that occur in Sarawak have been well-documented in terms of their distribution and occurrence (Payne et al., 1985; Kumaran et al., 2011), but their ecology and dynamics remain poorly studied.

As part of a long term project to monitor terrestrial animals in Sarawak, we report the results of camera-trapping surveys in LEWS. This forest is important as it: 1) is the largest trans-boundary protected area between Malaysia and Indonesia; 2) has high habitat diversity; 3) still consists of a substantial proportion of virgin lowland dipterocarp forest in Sarawak; and 4) has limited access and represents a relatively pristine rainforest.

MATERIAL AND METHODS

Study site. — Lanjak-Entimau Wildlife Sanctuary (LEWS) is considered the largest trans-boundary protected area in Malaysian tropical rain forest (111°53'E to 112°281'E and 1°19'N to 1°51'N; Fig.1). The Indonesian part is the Betung-Kerihun National Park, which stretches for about 200 km along Malaysia-Indonesia border. LEWS, with approximately 1668 km^2 of rugged hilly terrain from about 60–1200 m above sea level, was established in 1983. Lowland dipterocarp forest, hill dipterocarp forest, riverine forest, and old secondary forest (30–130 years old) cover approximately 80% of Lanjak-Entimau area. LEWS receives an average annual rainfall ranging from 2000–4000 mm with much of the rainfall received during the northeast monsoon months of December to March. Sampling was carried out by the authors in Ulu Katibas along Bloh and Joh river areas. The forest has a row of emergent trees of *Dipterocarpus oblongifolius* lining the river fringes in slanting positions with their crowns overhanging the river, while other emergents occurring behind the banks mainly consist of *Koompassia malaccensis*, *Parashorea macrophylla*, *Shorea macrophylla*, *Pometia pinnata*, and *Tristaniopsis whiteana*. The lower story is dominated by *Aporusa* spp., *Baccaurea* spp., *Pternandra* spp., *Vatica umbonata*, *Artocarpus integer*, *Palaquium* spp., and *Shorea* spp. Anthropogenic activities include fishing and agriculture with actively used and abandoned shifting cultivation rice fields bordering LEWS and the Ulu Katibas area. There are several longhouses close to LEWS along the Katibas River, but human disturbance can be considered relatively minimal compared to other protected areas in Sarawak.

Camera trapping. — Surveys were carried out between May–Nov.2003(13 cameras), as well as between Jun–Aug.2006 (7 cameras) using commercially made Cam Trakker® brand camera trap units (n = 15 camera locations; manufactured by Camtrak South, 1050 Industrial Drive, Watkinville, GA 30677. USA) and DeerCam® – DC-100 (n = 5 camera locations; manufactured by Non Typical Inc., 860 Park lane-Park falls, WI 54552). Each unit consists of a plastic

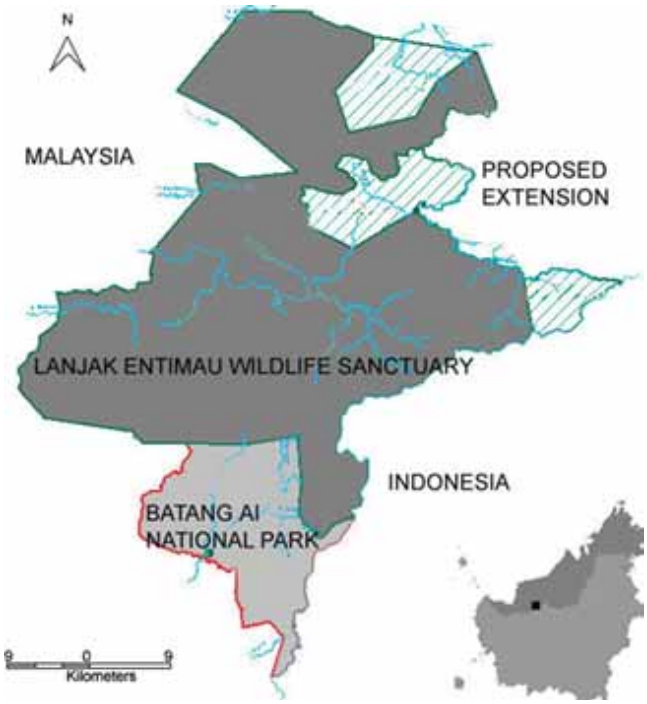

Fig. 1. Lanjak Entimau Wildlife Sanctuary in southern Sarawak bordering Batang Ai National Park. Striped areas show proposed extension on the northwest of the sanctuary.

casing, camera with built in flash, sensors with selectors and a viewing window. These cameras combine a fully automatic 35 mm camera with a passive infrared heat-in-motion detector. The heat-in-motion sensor operates on a horizontal plane, thus it is important that it is aimed parallel to the ground. Cameras were set from 30–40 cm above the ground in order to increase the probability of detecting small- to medium-sized mammals. When something moves and gives off heat, a silent electronic switch engages the camera, which takes a photograph. Both Cam Trakker and DeerCam were clustered with moderate sensitivity scores with percentage of detection of 78% and 60% respectively (Swann et al., 2004). For obtaining clear photographs in the dense tropical rainforest, 400 ASA colour print were used. These units are equipped with a delay selector mechanism that precludes the camera from taking a photograph for a set period of time. The time delay between photographs on Cam Trakker® was set to a minimum of three minutes, while DeerCam® was set at an interval of two minutes, which eliminates wastage of film on a single situation. All cameras were operational 24 hours a day with no break in monitoring except in instances of malfunction. Time and date were also recorded for each exposure except during camera malfunction or excessive moisture on the film due to high humidity and condensation. The cameras were checked every 30 days to reload new film rolls. However, there were several instances where the films had been fully consumed before checking, so there could be gaps in our records. The same camera locations were maintained throughout the duration of each sampling session. Cameras were only removed or relocated to accommodate undesirable local conditions such as tree falls, dense undergrowth, malfunction, or inundation by rainwater. Cameras were rotated occasionally, due to temporary malfunction (i.e., unable to rewind film). Due to these factors, the trapping effort in each camera trap location was not similar. However, only the active camera days were included in order to calculate the total number of camera days:

$$\text{Total camera days (TCD)} = \Sigma\ cd_{\ i} \qquad (1)$$

where c is the active camera operating within a site and d is the number of days. Cameras were deployed at 20 locations in two different forest types (riverine forest and mixed dipterocarp forest) with unequal sampling effort (226 Σcd for riverine forest and 1719 Σcd for mixed dipterocarp forest). Cameras were set near animal trails at least 500 m apart along major rivers and hill ridges. The survey targeted at medium and large terrestrial animals or arboreal mammals, which spend substantial time on the ground. No cameras were deployed very close to streams (i.e., 10–50 m) to prevent camera malfunction from flooding. Unequal sampling effort limited our ability to further compare species richness among habitat types. The trapping success for all the identified animal species was calculated based on the number of independent photographs per 100 trap-nights for each habitat type. We defined an independent event as consecutive photographs of different species and consecutive photographs of individuals of the same species taken one hour apart (O'Brien et al., 2003; Kawanishi & Sunquist, 2004). Photo trap rate index (PTRI) was calculated using the formula below:

$$\text{Photo trap rate index (PTRI)} = N_i \times 100 / \sum cd \qquad (2)$$

where N is the number of independent photos for species$_i$ and ∑cd is the total trap days. The two species of mouse deer, *Tragulus* spp., three species of mongoose, *Hespestes* spp., and two species of muntjac, *Muntiacus* spp., that were known to occur in Borneo were pooled respectively, for the purposes of discussion and because they are often indistinguishable on photographs.

Activity patterns were only investigated for the two sympatric porcupines (common porcupine, *Hystrix brachyura*, and thick-spined porcupine, *Thecurus crassispinus*), bearded pig, *Sus barbatus*, and Malay civet, *Viverra tangalunga*, because they had the most detections based on the filtered data. Each photograph was printed with the date and time the picture was taken. Some photographs do not contain these records due to technical error. Such photographs were excluded from the activity pattern analysis. Repetitive shots of the same species at the same location within one hour were also excluded (Kawanishi & Sunquist, 2004). We assumed that the numbers of photographs taken at various times were correlated to activity levels of mammals (Mohd-Azlan & Sharma, 2006; Kitamura et al., 2010). Time periods were pooled in one-hour intervals and activity levels of a species were measured by the percentage of the total qualified photographs. In order to obtain the percentage of nocturnal and diurnal activity levels we divided two time zones, daytime (0600–1759 hours) and nighttime (1800–0559 hours), based on sunrise and sunset times derived from averaged GPS data. Nocturnal activity classes are defined as having >90% of detections occurring during the night, with diurnal activity classes having <10% of detections occurring during the night (van Schaik & Griffiths, 1996). Animals not falling within these categories were classified as arrhythmic. To assess the sampling completeness at LEWS, we calculated the completeness ratio (i.e., observed/estimated number of species: Soberon et al., 2000; Clements et al., 2006). Species accumulation curves and estimators for mammal species were computed using EstimateS Version 8.2.0 (Colwell, 2009).

RESULTS

The total number of camera days amounted to 1945 over a period of 10 months of non-consecutive sampling (226 camera days in mixed dipterocarp forest and 1719 in riverine forest). A total of 537 of photographs were exposed, equivalent to 26.85 shots per camera deployed. Approximately 3.72% of the total photographs could not be utilised due to technical error and poor angle of animal shots which the species could not be determined. Most of the unidentified animals consist of small mammals which could not be identified even to genera level due to poor image quality. The remaining 517 photographs (96.28%) showed images of mammals (79.7%), birds (19.5%), reptile and man (hunters) both with two

photographs (0.4% each). Mouse deer, *Tragulus* sp. was the most commonly photographed animal (25.51%) followed by great argus, *Argusianus argus* (13.22%). In contrast, six species of mammals were photographed only once during this study. We only recorded 20 genera and at least 21 species of wild mammals, excluding unidentified species of squirrels, rodents and civets recorded via camera trapping in the study area (Table 1). This study also reports four species of birds which spend substantial amount of time on the ground, namely the argus pheasant, blue-headed pitta, *Pitta baudii*, crested and crestless firebacks, *Lophura* spp., and emerald dove, *Chalcophaps indica*. Total animal captures over total trap days is equivalent to 0.28; this indicates low animal activity in the study area. Most animals were photographed alone or in pairs, except for the bearded pig, *Sus barbatus* (up to four individuals) and pig-tailed macaque, *Macaca nemestrina* (up to three individuals). Only a single exposure resulted in two species recorded in a single frame, a bat and common porcupine, *Hystrix brachyura*. The expected species richness of medium-large mammals is 26.43 while the sampling saturation was relatively high (completeness ratio = 0.79; Fig. 2). Of the 27 animal species recorded, two are endangered while nine are listed as vulnerable in the IUCN red list 2011 (IUCN, 2011), whereas five species including the Bornean sun bear (*Helarctos malayanus euryspilus*) are endemic to Borneo. Five species receives Totally Protection status, moreover approximately 22% of the species (n = 6) are not listed under SWLPO 1998. Approximately 70% of the species (n = 19) recorded in this survey are not listed in CITES (Convention on International Trade in Endangered Species of Wild Fauna and Flora), while six species from this category are not listed in any Schedule of the SWLPO 1998 and therefore do not receive any protection outside this reserve if it were to be hunted for self-consumption by the local community.

Both the porcupines are strictly nocturnal and show at least two peaks in their daily activity level (Fig. 3). During the second half of the night (0000–0600 hours) there is significant difference in their activity pattern (paired t-test; t = 5.84, P = 0.00) when compared to the first half of the night (1800–0000 hours; paired t-test; t = –1.43, P = 0.21) between these species. The Malay civet is predominantly nocturnal, with activity peaking at dawn and dusk. The bearded pig records higher activity during the night, but shows no clear activity pattern, suggesting that its activity patterns are arrhythmic.

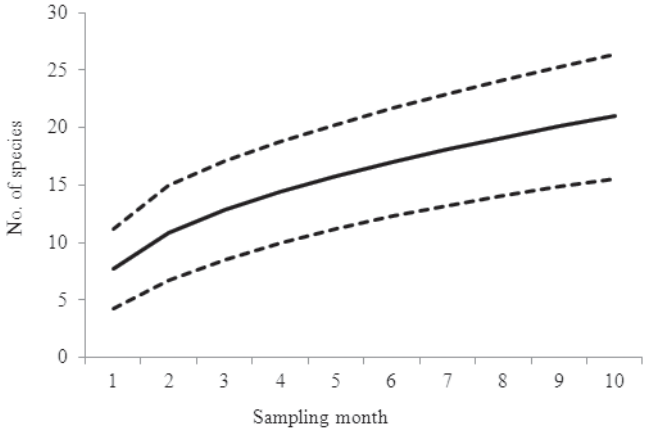

Fig. 2. Expected species accumulation curve (—) and 95% CI (– –) for mammalian species in Lanjak Entimau Wildlife Sanctuary. Relatively high sampling saturation was achieved based on a sampling completeness ratio of 0.79 (observed/expected no. of species).

DISCUSSION

Our study discovered that at least species 27 species of animals including 21 species of mammals (medium to large >1.5 kg) occur in LEWS. Medium to large mammal species richness filtered similarly (excluding squirrels, bats, birds, and rodents) in this study is higher, if not comparable, with similar studies in Borneo (Maludam National Park, 11 species, Mohd-Azlan, 2004; Loagan Bunut National Park, 10 species, Mohd-Azlan et al., 2006; Lambir Hills National Park, 13 species, Mohd-Azlan & Lading, 2006; Kubah National Park, 8 species, Mohd-Azlan et al., 2007; acacia plantation, Sarawak, 16 species, Giman et al., 2007; Deramakot production forest, Sabah, 23 species, Matsubayashi et al., 2011). However, the species richness of the medium to large mammals in this study is lower when compared to similar surveys in Peninsular

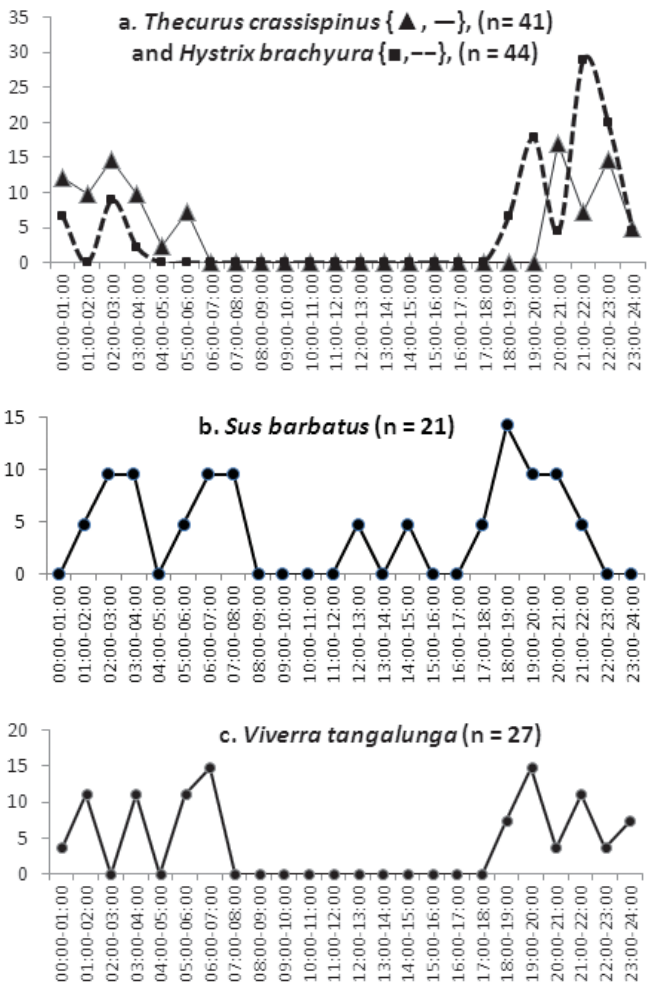

Fig. 3. Activity levels (%) of (a) porcupines, (b) bearded pig, and (c) Malay civet based on pooled camera trapping records in LEWS a period of 10 sampling months. Note the different scalings of the vertical axis.

Table 1. Photo trap rate index (PTRI) of animals recorded via camera traps and associated standard errors for each site in LEWS for a period of 10 months. Bornean endemic species are indicated in bold text. Site abbreviations: MDF, mix dipterocarp forest; RF, riverine forest. IUCN, International Union for Conservation of Nature, 2011; LC, least concern; Vu, vulnerable; NT, near threatened; En, Endangered; NL, not listed; SWLPO, Sarawak Wildlife Protection Ordinance, 1998; CITES, Convention on International Trade in Endangered Species of Wild Flora and Fauna. Σcd, total camera days.

Order/ Family	Species	Common name	MDF	RF	Total photos	IUCN	SWPO	CITES
Mammalia								
Artiodactyla								
Cervidae	*Rusa unicolor*	sambar deer	0.44	0.41	8	Vu	NL	NL
	Muntiacus sp.	muntjac	3.54	2.04	43	LC	NL	NL
Suidae	*Sus barbatus*	bearded pig	1.33	1.05	21	Vu	NL	NL
Tragulidae	*Tragulus* sp.	mouse deer	6.19	6.86	132	LC	NL	NL
Carnivora								
Felidae	***Pardofelis badia***	**Bornean bay cat**	0	0.06	1	En	I	II
	Pardofelis marmorata	marbled cat	0	0.12	2	Vu	I	I
	Prionailurus bengalensis	leopard cat	0	0.06	1	LC	II	II
Herpestidae	*Herpestes* sp.	mongoose	0.44	0.12	3	LC	II	NL
Mustelidae	*Martes flavigula*	yellow-throated marten	0.44	0.12	3	LC	NL	NL
Ursidae	***Helarctos malayanus euryspilus***	**Bornean sun bear**	0	0.06	1	Vu	II	I
Viverridae	*Arctictis binturong*	binturong	0.44	0	1	Vu	II	NL
	Paguma larvata	masked palm civet	0	0.06	1	LC	II	NL
	Prionodon linsang	banded linsang	0	0.06	1	LC	II	II
	Viverra tangalunga	Malay civet	0	1.86	32	LC	II	NL
Primate								
Cercopithecidae	*Macaca fascicularis*	long-tailed macaque	0	0.70	12	LC	II	NL
	Macaca nemestrina	pig-tailed macaque	1.77	2.21	42	Vu	II	NL
Rodentia								
Hystricidae	*Hystrix brachyura*	common porcupine	0.88	2.62	47	LC	II	NL
	Thrichys fasciculata	long-tailed porcupine	0	0.35	6	NL	II	NL
	Thecurus crassispinus	**thick-spined porcupine**	2.21	2.56	49	NL	II	NL
Sciuridae	***Rheithrosciurus macrotis***	**tufted ground squirrel**	0	0.17	3	Vu	II	NL
Pholidota								
Manidae	*Manis javanica*	pangolin	0.44	0.12	3	En	II	II
Reptilia								
Varinidae	*Varanus salvator*	monitor lizard	0	0.12	2	LC	II	II
Aves								
Phasianidae	*Argusianus argus*	great argus	12.39	2.50	71	NT	I	II
	Lophura ignita	crested fireback	0.88	0.93	18	NT	II	NL
	Lophura erythrophthalma	crestless fireback	0	0.12	2	Vu	II	NL
Columbidae	*Chalcophaps indica*	emerald dove	0	0.35	6	LC	NL	NL
Pittidae	***Pitta baudii***	**blue headed pitta**	0	0.23	4	Vu	I	NL
Std. Error			0.51	0.29				
Richness			7	16	27			
Unidentified			3	17	20			
Human			0	2	2			
TOTAL			74	463	537			
Effort/Σcd			226	1719	1945			

Malaysia (secondary forest in Terengganu, 27 species, Mohd-Azlan, 2006; Taman Negara, Pahang, 27 species, Kawanishi, 2002), but comparable to what that has been reported by Kitamura et al. (2010) in southern Thailand (21 species). In general, these comparisons suggest that higher species richness may not necessarily indicate higher habitat quality as suggested by Kitamura et al. (2010). Additionally, when a species is not recorded by camera trap it does not necessarily indicate that the species is absent (Mohd-Azlan, 2009). For example, the local community around the study area reports clouded leopard, *Neofelis diardi*, but the camera trapping survey did not detect this species. Similarly, Kitamura et al. (2010) also reported species that were observed during field surveys, but not in camera trap surveys. The difference in trapping effort may also contribute to the total species richness in a survey. Furthermore, our surveys may not have detected cryptic species that are predominantly arboreal (e.g., clouded leopard, primate species) and those which are closely associated with aquatic habitats (e.g., otters, flat-headed cat, *Prionailurus planiceps*). As sampling saturation was relatively high for medium-large mammals at our camera locations, our cameras need to be relocated to other habitat types with higher trapping effort in the future in order to maximise the probability of detecting all of LEWS's medium to large mammal species.

Animals that appear with single records are the banded linsang, *Prionodon linsang*, binturong, *Arctictis binturong*, Bornean bay cat, *Pardofelis badia*, masked palm civet, *Paguma larvata*, sun bear, *Helarctos malayanus*, and leopard cat, *Prionailurus bengalensis*; this could be due to the fact that these species naturally occur in low abundance within LEWS, are arboreal or may have low preference towards riverine forest. The Bornean bay cat, which is one of the rarest cats in the world (Mohd-Azlan & Sanderson, 2007) and is a Bornean endemic, was recorded in this study (Mohd-Azlan et al., 2003) even though it was once thought to be extinct in Sarawak (Hazebroek & Morshidi, 2001). Among the porcupines, the long-tailed porcupine, *Thrichys fasciculata*, which is rarely studied and poorly represented in museum collections (van Weers, 1993), had fewer photo detections compared to other sympatric porcupine species. Nevertheless, we believe that this species is still relatively more common than previously believed as it was recorded in most camera trapping surveys in Malaysia (e.g., Mohd-Azlan & Lading, 2006; Giman et al., 2007; Mohd-Azlan et al., 2007; Matsubayashi et al., 2011).

Our study adds to a growing literature documenting activity patterns of elusive tropical rainforest animals using auxiliary information derived from camera trap surveys (Mohd-Azlan & Sharma, 2003; Kawanishi & Sunquist, 2004; Wong et al., 2004; Maffei et al., 2005; Grassman et al., 2006; Mohd-Azlan, 2006; Tobler et al., 2009; Kitamura et al., 2010; Matsubayashi et al., 2011). Two sympatric porcupines, the endemic thick-spined porcupine *Thecurus crassispinus* and the more widely distributed common porcupine, *Hystrix brachyura*, showed a high degree of overlap in their daily activity patterns. However, during the first half of the night, *H. brachyura* showed higher activity level compared to *T. crassipinus*, while during second half of the night the later species showed higher activity level. This suggests that these species could be reducing inter-specific competition by adopting different temporal foraging strategies. The higher nocturnal activity pattern of the bearded pig in this study is inconsistent with its sympatric species, the common wild pig, *S. scrofa* in southern Thailand (Kitamura et al., 2010) and in Taman Negara National Park, Peninsular Malaysia (Kawanishi & Sunquist, 2004). Additionally, this result is also incongruent with what has been reported by Mohd-Azlan (2004) in Maludam National Park, where this species had higher diurnal activity (>70%). The difference in the activity pattern could be attributed to hunting levels, different type of human activities in these areas (Griffiths & van Shaik, 1993) and prey-predator relationships. The activity level of the Malay civet in this study (85% nocturnal) corroborates with other studies in Lambir Hills National Park (84% nocturnal; Mohd-Azlan & Lading, 2006) and Jerangau Forest Reserve, a secondary forest in Peninsular Malaysia (85% nocturnal; Mohd-Azlan, 2006).

Threats to wildlife in LEWS. — Despite the fact that ungulates are under heavy hunting pressure over generations in many parts of the world, including Sarawak (Milner-Gulland et al., 2003; Piper & Rabett, 2009) where the local community is allowed to hunt for personal consumption outside protected areas, they are relatively well-represented in this forest. The mouse deer is the most frequently photographed (132 photos) ungulate followed by barking deer (43 photos), pigs (23 photos), and deer (8 photos). These photo frequencies are higher when compared to those of Lambir Hills National Park, where there have been reports of hunting (Mohd-Azlan & Lading, 2006). Even though photo frequencies do not represent abundance, they may illustrate rarity or show trends via photo capture rates. Two photos of hunters were noted during the day near Satap River. Even though the local communities are allowed to hunt along the buffer zones, they may sometimes unintentionally wander inside the sanctuary's boundary. Apart from this, there were unconfirmed reports indicating encroachment from foreign hunters. However, the level of hunting and fishing in this area is considered relatively minimal when compared to other Totally Protected Areas in Sarawak (i.e., Mohd-Azlan, 2004; Mohd-Azlan & Lading, 2006; Mohd-Azlan et al., 2007). Despite the importance of surrounding matrix habitat for maintaining species diversity, forests adjacent to LEWS is either being logged and/or being converted to oil palm.

Conservation recommendations for LEWS. — Wildlife legislation can be improved to better protect wildlife in LEWS. The endangered Bornean bay cat has erroneously been listed in CITES appendix II, which makes export of this species much easier—this should be urgently amended. Animals listed in Appendices I and II of CITES are automatically included in Schedule 2 of SWLPO 1998 thus receive additional protection in Sarawak (excluding those already listed in Schedule 1 and 2 of SWLPO 1998). Therefore, animals listed in CITES provides protection to a non-listed (SWLPO 1998) species in Sarawak. However, animals which are not listed in any of these (CITES &

SWLPO 1998) can be considered as not protected outside a totally protected area (i.e. yellow-throated marten, *Martes flavigula*) which can be hunted for personal consumption. In order to keep up with the current wildlife conservation status locally and globally, Sarawak need to review the Wildlife Protection Ordinance immediately to cover loop holes and provide additional protection to Sarawak's wildlife especially the globally threatened species.

The State government should be proactive and encourage timber concessionaires to be part of UN-REDD-plus Programme (The United Nations Collaborative Programme on Reducing Emissions from Deforestation and Forest Degradation in Developing Countries) to commit on low-carbon and climate resilient development from logging and forest-clearing activities. However, in order to embark on REDD-plus programmes, Sarawak would require technical assistance, capacity building and financial support for a number of enabling activities. Such programmes and incentives can be used to promote sustainable land use around protected areas such as LEWS. Monocultures such as oil palm plantation near boundaries should be avoided. Besides contributing to adverse ecological process (Fitzherbert et al., 2008), plantations such as oil palm will also create easy illegal access which makes monitoring and enforcement process difficult. Park (i.e., Batang Ai National Park; Fig. 1) and sanctuary extensions should be encouraged as this can reduce effects of fragmentation and encroachment.

Enforcement of wildlife laws is the greatest challenge in wildlife management in many Southeast Asian countries, mainly due to lack of political will and capacity to enforce these laws (Bennet, 2011; Harrison, 2011). Increasing human pressures and socioeconomic development also make forest protection more challenging (Tang et al., 2010). Nevertheless, enforcement activities should be stepped up to control hunting in this totally protected area, especially in areas bordering Kalimantan, Indonesia. Hunting activities and wildlife trade outside the sanctuary need to be closely monitored. Even though bush meat is an alternate source of protein for local communities, any species being consumed or sold must be closely monitored to prevent local extinctions. Construction of additional ranger stations near the border and strategic entry points to the sanctuary, as well as increasing the number of staff to conduct regular patrols should be implemented to curb illegal hunting. The Special Wild Life Committee (SWC), which consists of a Warden, rangers, and local people (Honorary Wildlife Ranger), need to be seriously and consistently involved in the management decisions and enforcement within the sanctuary to deter excisions and intrusion with full support from local authorities. Sanctuary boundaries need to be clearly marked and sign posted with warning signs to avoid any accidental entry. Strong local political will, with a concomitant increase in awareness campaigns and involvement of local communities in ongoing research projects and management of the area, would further enhance the status of LEWS as an effective totally protected area in Sarawak.

Given the importance of transboundary ecosystem services, strategies for managing shared services between totally protected areas and surrounding human-dominated landscapes are urgently needed. Malaysia (Sarawak and Sabah), Brunei, and Indonesia (Kalimantan) need to expedite the implementation of activities stated in the Heart of Borneo Initiative (HoB), which seeks to connect 22 parks and reserves into a continuous 24 million ha trans-boundary conservation area (WWF, 2005). Pervasive negative anthropogenic impacts and pressing climate change issues warrant documentation and monitoring of what is left in natural habitats including protected areas, if we are to ensure that sustainable development can proceed alongside wildlife conservation.

ACKNOWLEDGEMENTS

We thank Sarawak Forestry Department; (NCCD.907.4.4(Jld. VI)-207); (No. 02866), Sarawak Forestry Corporation, Universiti Malaysia Sarawak (1/50/330/2002(67); (1/125/514/2005(13); (01(S81)/817/2011), Jim Sanderson and Cat Action Treasury for their support. We are indebted to Lanjak Entimau Wildlife Sanctuary personnel for their help in the field. We also thank Munau Jawa for organising and help in the field. The earlier draft of this manuscript was improved substantially by comments from Reuben Clements and two anonymous reviewers.

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