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Camera trapping of terrestrial animals in Tanjung Datu National Park, Sarawak, Borneo

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Abstract. Information on distribution is useful for determining global conservation status of species and for prescribing sound management practices for taxa of conservation importance. Therefore, an attempt to understand the distribution of terrestrial animals using infra-red camera traps in Tanjung Datu National Park, Borneo, was carried out from July 2013 to October 2015 (28 months). A total of 23 camera locations set in various microhabitats and elevations accumulated 2,490 camera days, which resulted in 1,189 independent animal images comprised of 21 mammals, two birds, and one reptile species. The cameras revealed a total of 20 medium to large mammals (excluding treeshrews & small rodents), with the most common species photographed being the pig-tailed macaque (independent images n = 278) and bearded pig (271), while the masked palm civet (1) and Sunda pangolin (1) were only represented by singletons. Most of the common species are listed as Protected (33.64%) in the Sarawak Wild Life Protection Ordinance 1998, while 2.02% species have Totally Protected status. Less than 1% of the species are considered Critically Endangered and Endangered, 3.57% are considered Near Threatened, and 74.3% are considered Vulnerable under the IUCN Red List of Threatened Species. In addition, this survey has provided detailed information on activity patterns of some cryptic species. The absence of larger carnivores suggests that species such as the Sunda clouded leopard and Bornean sun bear may have been extirpated from this small, isolated, and fragmented protected area. We emphasise that regular monitoring of wildlife in National Parks should not be neglected, especially when the surrounding area is experiencing accelerated and unprecedented rates of habitat conversion.

Key words. activity pattern, biodiversity conservation, independent images, protected area, regular monitoring, wildlife survey

INTRODUCTION

Southeast Asia is one of the biodiversity hotspots of the world, representing the rich tropical rainforest. The state of Sarawak, in Malaysian Borneo, has one of the most extensive protected area networks in Malaysia where it now contains remnants of what were once some of the most diverse and continuous mature rainforest in the world (Mohd-Azlan & Lawes, 2012). Currently there are approximately 941,801.4 ha of protected land areas and water bodies in Sarawak, consisting of 37 national parks, 14 nature reserves, and five wildlife sanctuaries. These are the final frontiers in defense to protect Sarawak's biodiversity and prevent extinction. With protected areas being fragmented and isolated, the ability of species to persist is of concern especially when surrounding areas are facing accelerated land conversion to agriculture, agro-forestry, and urban development (Froese et al., 2015; Sawada et al., 2015). In view of this, understanding species occurrence and distribution in protected areas is important for formulating sound management, addressing potential threats, and prescribing conservation strategies (Tempa et al., 2011; Bernard et al., 2013; Gandiwa et al., 2014). Continued monitoring is important and will provide critical information on where native species and threats occur, so that better management and conservation intervention may be implemented to avoid species extinction and changes to ecosystem structure and dynamics (Tempa et al., 2011). However, most cryptic and nocturnal mammals avoid open and disturbed sites and thus are not easily observed through conventional sampling methods. In addition to that, dense tropical rainforest with difficult terrain and remote survey areas may impede continuous monitoring of wildlife activities in Borneo (Mohd-Azlan, 2009; Mathai et al., 2013). Camera trapping is a good alternative to monitor wildlife in tropical rainforests and can be more effective than conventional surveys (e.g., line transects and visual sampling), which can be affected by the level of observer experience (Silveira et al., 2003; Mathai et al., 2013). Camera trapping is an effective and useful tool in monitoring and inventorying elusive, cryptic, and rare animals in the tropics (Mendoza et al.,

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2011; Mounir & Zuhair, 2012; Mohd-Azlan & Engkamat, 2013). Robust and auxiliary data also may be gained due to the minimal disturbance of this method, which allows the natural behaviour of the animal to be studied (Ramesh et al., 2015). Using similar camera trap methods, various authors have reported different species composition in protected areas across Borneo. This can be partially explained by the total effort expanded, and the ability of the habitat to support these species. For example, Wilting et al. (2010) expended 1,916 trap nights and reported 14 carnivore species, with the highest independent photographic captures recorded for the Malay civet (*Viverra tangalunga*) followed by the common palm civet (*Paradoxurus hermaphroditus*) and Sunda stink-badger (*Mydaus javanensis*). A similar study by Brodie & Giordano (2011) in Maliau Basin Conservation Area, Sabah (2,915 camera trap nights) reported 13 species of small carnivores. Bernard et al. (2013) surveyed Imbak Canyon Conservation Area in central Sabah (1,436 trap nights) and reported 13 carnivore species that includes the endangered Sunda clouded leopard (*Neofelis diardi*) and the vulnerable Bornean sun bear (*Helarctos malayanus*). From all the mentioned surveys, the camera trap method managed to document more than half of the total number of carnivore species in Borneo. Considering some species are elusive and arboreal, documenting a large number of species proves the effectiveness of the usage of camera trapping in species documentation, especially in areas of difficult terrain and accessibility. In order to add data on occurrence of terrestrial animals from another important site in Borneo, we used passive infrared camera traps in Tanjung Datu National Park (TDNP).

MATERIAL AND METHODS

Study site. The study was conducted at Tanjung Datu National Park (TDNP). The TDNP is one of the smallest national park in Sarawak, and is located at the southwestern tip of Borneo on the Datu Peninsula, with a total area of 1,379 ha that consists of mixed dipterocarp forest (MDF) and beach forest. The TDNP is located along the border between Malaysia and Indonesia; half of the peninsula is in Sarawak and the other half in Kalimantan. This protected area is adjacent to secondary forest and agriculture on the Indonesian side, while in Malaysia it borders Telok Melano Village and patches of secondary forest.

Camera settings. We used 10 units of Bushnell, Trophy Camera Brown (Model 119636), USA in this study. The cameras were placed at locations with animal signs (e.g., animal trails and droppings, tracks and vegetation clearings). Cameras were relocated every three to four months; this time period was chosen to balance the acquisition of sufficient detections with satisfying the closure assumption of the occupancy models described below. In total 23 sites were surveyed/monitored from July 2013 to October 2015 (Fig. 1). The cameras were fixed onto trees, approximately 25–30 cm above the ground, and spaced 1–1.5 km to minimise the chances of the same individual animals being recorded repeatedly. Metal casing and python lock were used to secure the camera trap to reduce the risk of it becoming damaged or loss due to human and animal disturbances. All the camera sites were marked by using GPS (Global Positioning System).

Data analysis. DataOrganize and DataAnalyze softwares were used to organise camera trap data and generate occupancy estimates (Sanderson & Harris, 2012). Occupancy is an estimate of species presence in an area, patch, or sample unit that accounts for "false-absences" where species are present but not detected whereas detection (p) is the likelihood of detecting an individual or species during a sampling occasion (Rovero et al., 2014; MacKenzie et al., 2006). The probability of detecting a species at an occupied site is a combination of the probability of the species present at the sampling area and the probability of detecting the species provided that it was present during that time (MacKenzie et al., 2002). Species richness and completeness ratio (i.e., observed / estimated number of species) were estimated using EstimateS (ver. 9.1.0, USA) (Colwell, 2013a, b). The Chao 1 Mean estimator was used for species richness while the completeness ratio was calculated by S(est) / Chao 1 Mean. Projections for accumulation curves, rarefaction curves, and activity patterns were done using RStudio Inc., (ver. 1.1.383, USA) (RStudio Team, 2015). Activity patterns of selected species were analysed in R using the 'overlap' package. Maps of camera trap locations were projected using ESRI Inc., ArcMap (ver. 10.2), USA. We calculated sampling effort as the number of cameras operating at a site (c) and the number of days (d) of operation.

Images were sorted based on independent animal detections, where images of the same species at the same camera location taken within one hour of each other were deemed non-independent (Mohd-Azlan & Engkamat, 2013). Activity pattern was only analysed for species with more than 18 independent image records. Though the minimum number of detections for activity pattern analysis was recommended to be 20 (Rowcliffe et al., 2014), an exception was made for the greater mouse deer (*Tragulus napu*) with n = 18 so that the activity pattern could be compared to that of the lesser mouse deer (*T. kanchil*). Each image was printed with the date and time the picture was taken. Some photographs do not contain these records due to technical error, and were excluded from the activity pattern analysis. We assumed that the numbers of images taken at different times were correlated to activity intensities of animals (Mohd-Azlan & Sharma, 2006). Time periods were pooled in one-hour intervals and activity levels of a species were measured by the percentage of the total categorised images. Nocturnal animals were classified as those with activity from 1901 to 0500 hours, diurnal species as those active from 0701 to 1700 hours, and cathemeral species as those with no clear pattern or peak in activity (Hon & Shibata, 2013). Activity pattern analysis from the photographic capture was carried out for the long-tailed macaque (*Macaca fascicularis*), pig-tailed macaque (*Macaca nemestrina*), bearded pig (*Sus barbatus*, Müller), sambar (*Rusa unicolor*), greater mouse deer, and lesser mouse deer. Dhat1 is an estimator of overlap that calculates the vectors of densities estimated at T equally-spaced times, t between 0 and 2π (Ridout & Linkie, 2009).

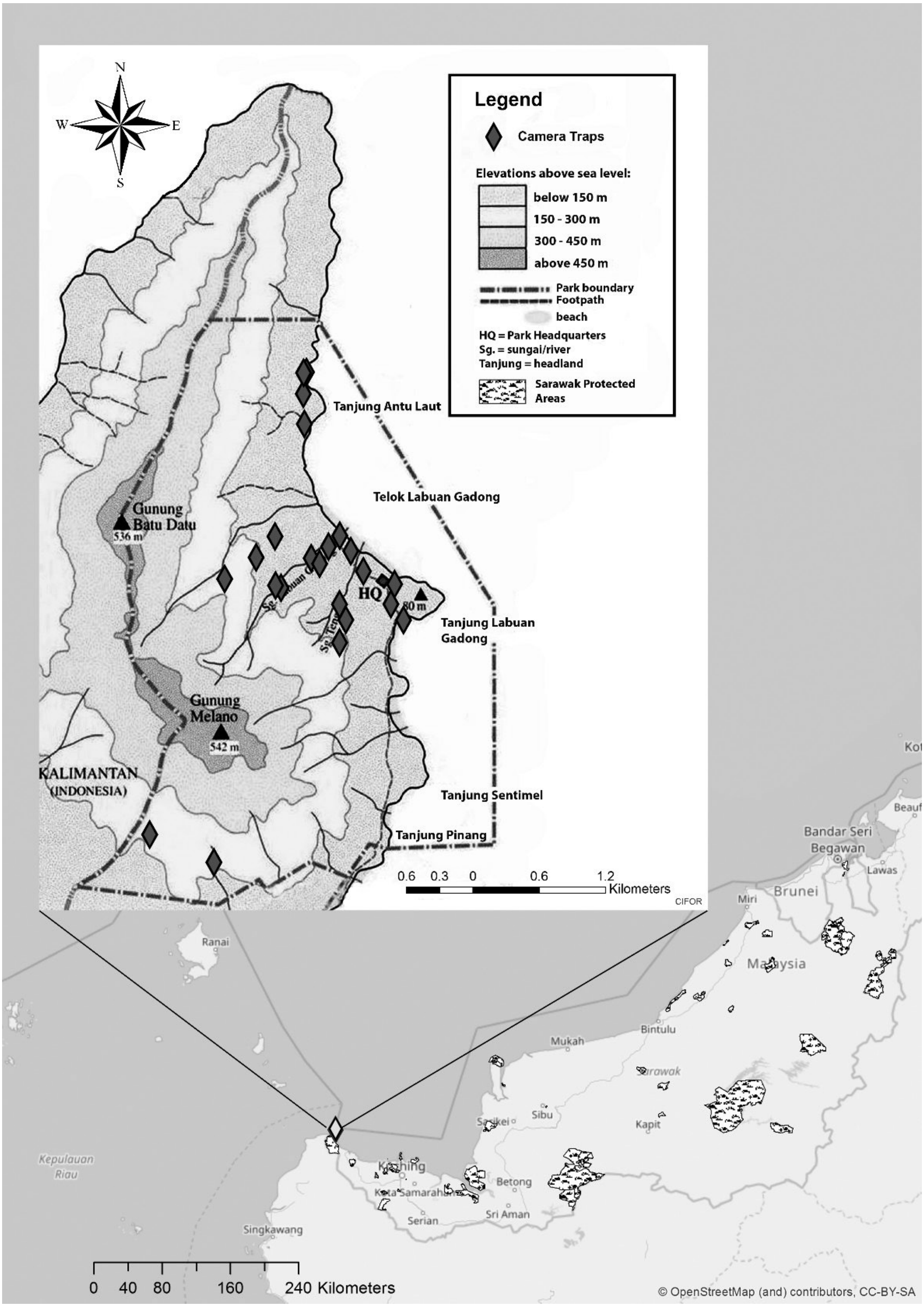

Fig. 1. Tanjung Datu National Park located at the tip of Borneo bordering Kalimantan, Indonesia with camera trap sites. Map of Sarawak indicating locations of Sarawak's protected areas. Tanjung Datu National Park map adapted from Hazebroek & Abang (2000).

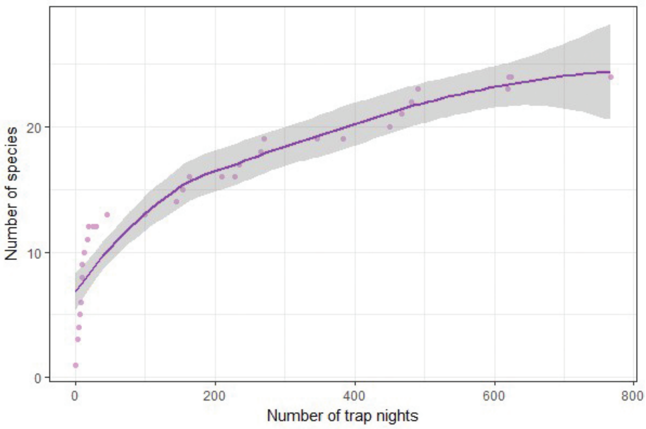

Fig. 2. Species accumulation curve in Tanjung Datu National Park indicates that the sampling saturation is almost reaching an asymptote.

Care was taken in the identification of mouse deer (e.g., throat stripes pattern, greater has 5 white stripes while lesser with 3; sideways lesser with single unbroken white throat line, while greater has a broken line) where if the species was not able to be identified (blurry images & stripes not visible) then it was placed in the unidentified category.

RESULTS

Camera trapping of 2,490 trap days recorded 1,898 images with 1,189 independent detections. Substantial numbers of images (5.13%) could not be identified due to poor animal angle or over exposure. We recorded 24 species from eight orders and 15 families with 13.71% unidentified species. 7.82% of the mouse deer images could not be identified until species level resulted with 2.69% and 1.51% of independent images for the lesser mouse deer and greater mouse deer respectively. The expected species richness of medium to large mammals is 20.33 while the sampling saturation was relatively high (completeness ratio = 0.92) (Fig. 2). In Sarawak, according to the Wild Life Protection Ordinance (1998), only three species are listed as Totally Protected while 15 other species were given Protected status. Only seven species are listed in CITES Appendix II and four in CITES Appendix III. The Sunda pangolin (*Manis javanica*) and the Bornean banded langur (*Presbytis chrysomelas*) were classified as Critically Endangered by The IUCN Red List of Threatened Species. Five species are listed as Vulnerable (sambar; bearded pig; binturong (*Arctictis binturong*); pig-tailed macaque and tufted ground squirrel (*Rheithrosciurus macrotis*) while thirteen others are listed as Least Concern. The highest naive occupancy estimates were 0.87 for the bearded pig, followed by 0.70 for the pig-tailed macaque and 0.52 for the long-tailed macaque, showing large spatial distributions for these species in TDNP (Table 1), possibly due to tolerance for a wide range of microhabitats and elevations. The lowest naïve occupancy estimates were for the common water monitor, crested fireback, short-tailed mongoose, masked palm civet, Sunda pangolin, Bornean banded langur, long-tailed porcupine and painted treeshrew. The low naïve occupancy for some of these species assumes that these species can be absent from other locations, even when there is a distinct chance that they can go undetected on some of the camera sites. This may be further explained by the detection probability (p) as in Table 1.

Two habitat types were compared for detection probability, mixed dipterocarp forest and beach forest. The highest detection of species in both MDF and beach forest were of the pig-tailed macaque and followed by the bearded pig. Most species recorded had higher detection rates in MDF than in beach forest except for the bearded pig, greater mouse deer, pangolin, pig-tailed macaque and Bornean banded langur. Meijaard & Sheil (2008) suggested that the lesser mouse deer are ecologically more adaptable than the greater mouse deer; however, based on this present study, this may not be the case, since the detection estimates were higher for the greater mouse deer than the lesser mouse deer.

The long-tailed macaque (Number of independent images, n = 46) and pig-tailed macaque (n = 278) are strictly diurnal and the species showed similar activity patterns (Fig. 3). However, these species are partly arboreal while the camera trap records only provide information on terrestrial activities, therefore the overall activities can be underrepresented using this technique. Very limited activity was recorded during the night for both species. In contrast, species such as the lesser mouse deer and greater mouse deer showed higher activity during night. They are predominantly nocturnal with activity peaking during dawn and dusk particularly at 0600 hours. The bearded pig showed arrhythmic activity pattern that is higher recorded during night with its activity peaking at 2000 hours and lower activity recorded during the day starting from 0900 until 1800 hours. This may be due to higher visitor activities during the day or avoidance of midday heat. The sambar showed bimodal peak activity during dawn (0600 hours) and dusk (1900 hours) with constant fluctuations throughout the hours suggesting arrhythmic activity pattern. Overlap estimates between these species showed that the long-tailed macaque and pig-tailed macaque have high activity overlap with 0.899. However, though the bearded pig and sambar seems to occur almost at all time during both day and night, their overlap estimates were only around 0.669.

DISCUSSION

Camera trapping is useful for studying wildlife occurrence, especially for cryptic species. Our study recorded at least 24 species in TDNP, consisting of 16 species of medium to large mammals (excluding treeshrews and small rodents). Sampling saturation was relatively high, with an extensive sampling period of over two years given the fact that this is a small national park, suggesting that increasing the survey effort may not have resulted in additional species being detected. Sampling saturation is a conceptual tool for qualitative study used to identify and establish the final sample size (Gotelli & Colwell, 2011). Even though the image frequency may not represent abundance, it may illustrate rarity or trends through image capture rates (Mohd-Azlan & Engkamat, 2013). Animals that were recorded in single detections may occur naturally at low abundance (e.g., apex predators) in TDNP or may be predominantly

Table 1. List of species, status, total independent events and occupancy estimates. N = naïve occupancy estimates, p = detection probabilities, MDF = mixed dipterocarp forest, B = beach forest, WLPO 1998 = Wild Life Protection Ordinance 1998, WCA 2010 = Wildlife Conservation Act 2010, CITES = Convention on International Trade in Endangered Species of Wild Fauna and Flora, IUCN = The IUCN Red List of Threatened Species, TP = totally protected wildlife species, P = protected wildlife species, NL = not listed, N/A = not available, * = insufficient data, I = species listed under CITES appendix I, II = species listed under CITES appendix II, LC = least concern, NT = near threatened, VU = vulnerable, EN = endangered, CR = critically endangered. Zero indicates values calculated being too small to be represented in three decimal digits.

					Estimates	Protection Status				
Order/Family	**Scientific Name**	**Common Nam**	**No of Independent Images**	**N**	**p (MDF)**	**p (B)**	**WLPO 1998**	**WCA 2010**	**CITES**	**IUCN**
Squamata										
Varanidae	*Varanus salvator*	Common water monitor	1	0.043	0.012	0.000	P	P	II	LC
Galliformes										
Phasianidae	*Argusianus argus*	Great argus	12	0.217	0.357	0.003	TP	TP	II	NT
	Lophura ignita	Crested fireback	1	0.043	0.012	0.000	P	TP	III	NT
Artiodactyla										
Cervidae	*Rusa unicolor*	Sambar	25	0.304	0.527	0.141	NL	P	NL	VU
	Muntiacus muntjak	Bornean red muntjac	5	0.130	0.150	0.002	NL	*	NL	LC
Suidae	*Sus barbatus*	Bearded pig	271	0.870	0.650	0.714	NL	TP	NL	VU
Tragulidae	*Tragulus napu*	Greater mouse deer	18	0.261	0.342	0.660	NL	P	NL	LC
	Tragulus kanchil	Lesser mouse deer	32	0.348	0.558	0.002	NL	P	NL	LC
Carnivora										
Felidae	*Prionailurus bengalensis*	Leopard cat	2	0.087	0.157	0.001	P	TP	II	LC
Herpestidae	*Herpestes brachyurus*	Short-tailed moongose	4	0.043	0.012	0.000	P	TP	NL	NT
Mustelidae	*Martes flavigula*	Yellow-throated marten	3	0.130	0.037	0.000	NL	TP	III	LC
Viverridae	*Arctictis binturong*	Binturong	5	0.348	0.158	0.141	P	TP	III	VU
	Hemigalus derbyanus	Banded palm civet	11	0.304	0.251	0.003	P	TP	II	NT
	Viverra tangalunga	Malay civet	14	0.348	0.157	0.141	P	*	NL	LC
	Paguma larvata	Masked palm civet	1	0.043	0.012	0.000	P	TP	III	LC
Pholidota										
Manidae	*Manis javanica*	Sunda pangolin	1	0.043	0.000	0.141	P	P	I	CR
Primates										
Cercopithecidae	*Macaca nemestrina*	Pig-tailed macaque	278	0.696	0.783	0.799	P	P	II	VU
	Macaca fascicularis	Long-tailed macaque	46	0.522	0.368	0.286	P	P	II	LC
	Presbytis chrysomelas	Bornean banded langur	8	0.043	0.000	0.386	TP	*	NL	EN

Order/Family	Scientific Name	Common Nam	No of Independent Images	Estimates		Protection Status				
				N	p (MDF)	p (B)	WLPO 1998	WCA 2010	CITES	IUCN
Rodentia										
Hystricidae	*Hystrix brachyura*	Malayan porcupine	13	0.304	0.216	0.002	P	P	NL	LC
	Hystrix crassispinis	Thick-spined porcupine	19	0.130	0.544	0.002	P	*	NL	LC
	Trichys fasciculata	Long-tailed porcupine	2	0.043	0.360	0.000	P	TP	NL	LC
Sciuridae	*Rheithrosciurus macrotis*	Tufted ground squirrel	4	0.130	0.037	0.000	TP	*	NL	VU
Muridae	N/A	Rat	5	0.087	0.452	0.002	*	*	*	*
Scandentia										
Tupaiidae	*Tupaia picta*	Painted treeshrew	3	0.043	0.360	0.000	P	*	*	LC
Total independent images			784							
Total Species		24								

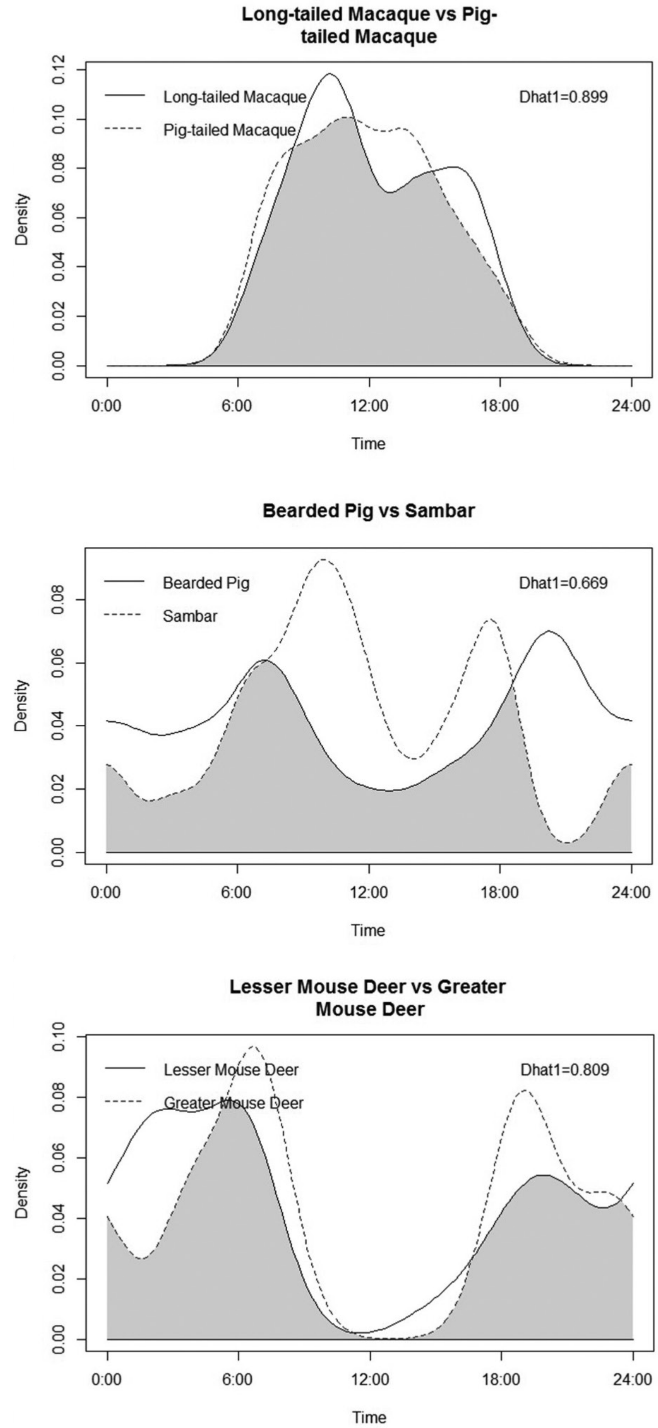

Fig. 3. Activity pattern for selected species in Tanjung Datu National Park showing Dhat1 as an estimator of overlap (shaded area). Dhat1 compares curves at n.grid (number of points to estimate density for species comparison) and best for small samples. Dhat1 coefficient estimator ranges from 0–1.

arboreal (e.g., Binturong). Other undetected species (e.g., Sunda clouded leopard, marbled cat, Bornean sun bear) may be locally extinct in this national park, though this warrants further study. However, small fragmented protected areas may not be able to support long-term survival, especially for certain species of conservation importance.Medium to large mammal species richness in this area is higher than or comparable to similar studies using camera trapping in other parts of Sarawak (Maludam National Park, 11 species, Rahman, 2004; Loagan Bunut National Park, 10 species, Mohd-Azlan et al., 2006; Lambir Hills National Park, 13 species, Mohd-Azlan & Engkamat, 2006; Kubah National Park, 8 species, Mohd-Azlan et al., 2007). However, the medium to large mammal species richness was lower than in Lanjak Entimau Wildlife Sanctuary, Sarawak (21 species; Mohd-Azlan & Engkamat, 2013). However, a species not being detected on a camera trap survey may not necessarily be absent from the area. Therefore, more rigorous statistical analysis would be needed to show that this area has more or fewer species than other areas.

There are signs of encroachment in this protected area, especially near the international border. Five photographic captures of humans outside the main trails have been documented, and one camera that was stolen during the study suggest intrusion. However, under the Sarawak Wildlife Protection Ordinance, 1998, local communities are allowed to hunt species that are not protected (i.e., bearded pig, sambar, mouse deer, muntjac) for personal consumption outside a protected area such as national parks or wildlife sanctuaries. Therefore, the existence of these ungulates in this area suggests that TDNP may act as a refugium for some of these hunted species from local communities near the national park.

This study adds to a growing literature documenting activity patterns of elusive tropical rainforest animals. The activity patterns of the two sympatric macaques exhibit some similarities, where both are active diurnally, but showed slightly different daily activity patterns suggesting that these species are ecological similar with comparable temporal and spatial patterns (Mohd-Azlan et al., 2017). This strategy may reduce competition and conflict for resources. The activity pattern of pig-tailed macaques is consistent with similar studies in other protected areas such as the Lambir Hills National Park (Mohd-Azlan & Engkamat, 2006). The bearded pig's arrhythmic activity pattern is consistent with that reported in Lanjak Entimau Wildlife Sanctuary (Mohd-Azlan & Engkamat, 2013).

Approximately 83% of the wildlife recorded in this study had higher detection probabilities in MDF than in beach forest. This could be simply due to differences in habitat structure in the two forest types that render animals more easy to detect in the taller MDF (which often has a more open understory). But these differences in detectability could also be related to underlying differences in relative abundance – indeed, detectability and abundance are known to often be positively correlated (Royle & Nichols, 2003; Royle, 2004). The beach forests here are characterised by sandy soils with creeping plants and lower vegetation diversity than in MDF, possibly making beach forest less favorable habitat for many species. The distribution of the bearded pig in the beach forest is consistent with that reported by Navennec et al. (2016). However, the bearded pig utilises this habitat to forage, for example by predating turtle nests and invertebrates. Seasonal movements of bearded pigs, especially when dipterocarp seeds are scarce in the MDF, may have contribute to enhanced use of beach forest by this species than by other species. Indeed, bearded pigs in Borneo are known to be an ecologically opportunistic species that can exploit a wide variety of habitats and resources (Navennec et al., 2016).

This study has documented some cryptic species in a previously unsurveyed protected area, providing a baseline against which to measure future community and population dynamics. The non-detection of several species of conservation importance also warrants further study to understand the nature of possible localised extinction. These data are essential for understanding basic mammal ecology in tropical rainforests, so as to facilitate the effective management of protected areas. Therefore, regular monitoring of wildlife in protected areas is critical for assessing threats and conservation needs in order to ensure long-term viability, especially for species of conservation importance.It has been long recognised that the existing protected areas of Sarawak need to be connected to enhance their conservation value and to maintain long term metapopulation viability (Mohd-Azlan & Lawes, 2011; Brodie et al., 2016). Monocultures, such as rubber and oil palm, near protected area boundaries should be controlled as this may also create easy access that may increase illegal excision of natural resources from protected areas. In view of this, there is a need to restore the degraded habitat outside protected areas to increase connectivity between TDNP and the nearby Samunsam Wildlife Sanctuary, which may allow movement of wildlife to sustain viable populations. Additionally, the completion of the Pan Borneo Highway will connect major roadway to Telok Melano, bordering the national park, which is expected to spike ecotourism activities in this hidden forest of Sarawak.

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