THE DISTRIBUTION OF MEDIUM TO LARGE MAMMALS IN SAMUNSAM WILDLIFE SANCTUARY, SARAWAK IN RELATION TO THE NEWLY CONSTRUCTED PAN-BORNEO HIGHWAY

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Protected Areas in Borneo retain some of the best examples of biodiversity and are the last refuge for wildlife conservation in tropical rainforests. Therefore, understanding the species richness and composition in increasingly fragmented Protected Areas are crucial in wildlife monitoring and management. The recent road construction splitting the oldest wildlife sanctuary in Sarawak has warranted further investigation on the species distribution. Camera trap survey in Samunsam Wildlife Sanctuary (SWS), western Borneo resulted in 20 medium- to large-bodied mammals from 775 independent photos with 2001 camera trap nights from surveys done in 2013–2014 and 2019. SWS records the Endangered *Nasalis larvatus* and *Cynogale bennettii* in the current survey. Under the Sarawak Wild Life Protection Ordinance 1998, *Nasalis larvatus* was the only recorded species considered to be Totally Protected while 12 other species are listed as Protected and the remaining species were not listed. The most frequently recorded species were *Tragulus* spp. (n = 147 in 2013–2014 and n = 166 in 2019) followed by *Macaca fascicularis* in 2013–2014 with n = 109, and *Sus barbatus* (n = 93 in 2019). A similar species richness (n = 13) was recorded both near (< 1000 m) and further away from the road (> 1000 m). However, the mean species richness was higher further away from the road (> 1000 m). *Herpestes brachyurus*, *Hemigalus derbyanus*, and *Echinosorex gymnura* were only recorded near the road while *Cynogale bennettii*, *Hystrix brachyura* and *Nasalis larvatus* were only recorded further away from the road. Through the bipartite network analysis, the majority of the medium- to large-bodied mammals are distributed in the mixed dipterocarp forests. Species that have habitats within proximity to the road have a higher risk of mortality due to roadkill and other anthropogenic pressure. Encroachment is an issue in Samunsam Wildlife Sanctuary and calls for immediate action; stricter enforcement, regular wide-coverage patrols along the river, and on the road to prevent illegal logging, commercial planting, and hunting.

Key words: camera traps, enforcement, fragmentation, Protected Area, road, tropical rainforests

Introduction

Sarawak, belonging to the landmass of Borneo, has one of the most established networks of Protected Areas in Malaysia. It covers some of the most megadiverse mature rainforest in the world (Mohd-Azlan & Lawes, 2011). Among the Protected Areas are a total of five wildlife sanctuaries that have been established in Sarawak since 1978. These five areas total up to 2257.91 km^2 (1.8% of the land area of the entire state) (Forest Department Sarawak, 2020). Despite the sizeable coverage of these Protected Areas, these areas still face fragmentation and isolation due to land conversion, which affects the persistence of species. Wildlife Sanctuaries in Sarawak are entirely off-limits to the public, and entrance only permitted through the permission from the Controller of Wildlife. This is to prevent anthropogenic activities that would bring adverse ecological effects onto the habitat. Wildlife Sanctuaries in Sarawak have been mainly gazetted to protect specific endangered, rare or threatened species (ERTs). Therefore, wildlife sanctuaries Sarawak are considered as category Ib (Strict Nature Reserve) under the IUCN Protected Area category which are important in preserving remnants of high quality ecosystems, species and geodiversity features.

Tropical rainforest in Borneo is experiencing threats from rampant forest conversion, selective logging, hunting for bushmeat, forest fire and wildlife trade (Taylor et al., 1999; Bennett et al., 2002; Kinnaird et al., 2003; Sodhi et al., 2004; Nakagawa et al., 2006; Linkie et al., 2007; Bernard et al., 2009; Gaveau et al., 2014; Brodie et al., 2015a). The proliferation of road construc-

tions and expansion in Sarawak in an unprecedented manner jeopardises forest connectivity, fragmenting forests into patches and catalyses anthropogenic activities within and around these areas (Clements et al., 2014; Alamgir et al., 2020). Forest gaps and fragmentation created by roads in forests would, in turn, induce a negative impact on population density, diversity, disruption to animal movements and their daily activities (Laurance et al., 2009; Tsuyuki et al., 2011; Clements et al., 2014; Mohd-Azlan et al., 2018a). Road ecology and its effect on wildlife population have gained the attention of researchers since the 1990s. Despite its adverse ecological effects, constructions and its expansions are necessary to facilitate population growth, increase accessibility and improve socio-economic development, especially in developing countries, such as Malaysia (Perz et al., 2007; Fahrig & Rytwinski, 2009; Clements et al., 2014; Berg et al., 2015). The Pan-Borneo Highway is an active road construction and expansion project throughout Sarawak which aims to connect the southwest to the northwest with a total length of 1060 km with Phase 1 spanning approximately 765 km and is expected to be completed by 2021 (Phan, 2019; Alamgir et al., 2020). The effects of the Pan-Borneo Highway towards the forest connectivity in Sarawak has estimated a loss of approximately 185 km^2 and 52 km^2 of forest connectivity and core forest areas with 1 km buffer from the road (Alamgir et al., 2020). This includes approximately 11 km of the Pan-Borneo Highway road construction within and near the Samunsam Wildlife Sanctuary (SWS). This has partially split the first gazetted wildlife sanctuary in Sarawak – Samunsam Wildlife Sanctuary – to a certain degree and has caused fragmentation towards its north-eastern border. Therefore, understanding how species respond and where they are distributed within this Protected Area is essential for thwarting potential threats and specifying conservation strategies (Tempa et al., 2011; Bernard et al., 2013; Gandiwa et al., 2014).

Several studies have used mammals as models to examine response pattern towards anthropogenic disturbances. According to Dirzo et al. (2014), mammals are amongst the most threatened taxa caused by habitat loss and fragmentation. Mammals are also considered to be reliable indicators of ecosystem quality and are therefore utilised as subjects for many monitoring and assessment programmes throughout the world (Caro, 2010; Ahumada et al., 2011). The studies show that significant effects can be seen on a mammal population within the buffer distance (~ 1–5 km). Thus, the construction of the Pan-Borneo Highway that cuts through sections of SWS will have negative effects on the local mammal population. However, there is no information on the effects of the newly constructed road on medium- to large-bodied terrestrial mammal (> 1 kg) species richness.

As tropical mammals are often cryptic and elusive in nature, camera traps are an efficient and a cost-effective method for monitoring these animals (Mohd-Azlan, 2006; Tobler et al., 2008). In the light of this, we examine the species richness of medium to large mammals in relation to the newly constructed road in SWS using camera trap data, including some data obtained prior to the road construction. The objectives of this study include 1) to identify and describe the distribution of medium- to large-bodied terrestrial mammals in SWS with special reference to endemic/threatened species; 2) to compare the current and previous species richness of medium- to large-bodied terrestrial mammals in SWS; 3) to investigate the distance to road effects on medium- to large-bodied mammals in SWS. We suspect that the newly paved road will influence the distribution of mammals in SWS.

Material and Methods

Study site

Samunsam Wildlife Sanctuary (1.4317 N, 109.4707 E) is located at the western tip of Sarawak. SWS was first gazetted in 1978, with extension in 2000. Samunsam Wildlife Sanctuary covers a total area of approximately 227.98 km^2 giving protection to the endemic *Nasalis larvatus* (Wurmb, 1787), *Rheithrosciurus macrotis (Gray, 1856)* and *Presbytis chrysomelas* (Müller, 1838) (Collins et al., 1990; Alamgir et al., 2020). Previously, SWS was only accessible by boat, roughly a two-hour journey from the jetty in Sematan (Fig. 1). SWS consists of a variety of different forest types: mangrove, nipah (dominanted by *Nypa fruticans* Wurmb), kerangas, riverine and mixed dipterocarp forest (MDF). The mangrove forest lines the lower reaches of the River Samunsam where it forms a broad band near the mouth of the river and gradually tapers out upstream and stops around 6 km upriver. *Avicennia* spp. and *Sonneratia* spp. are located near the river mouth, while *Rhizophora*

spp. extends 1–3 km from the river mouth. After this zonation, *Bruguiera* spp. and *Nypa fruticans* are found further upriver. The nipah forest extends at about 4–6 km from the river mouth. Along the upper and middle reaches of the River Samunsam and its tributaries, belts of riverine forest are formed averaging less than 1 km wide. The riverine forest was dominated by trees from the genera *Hopea*, *Knemam*, *Sterculia*, *Shorea*, and *Syzygium*. The forest features a dense undergrowth and abundant with rattans. The kerangas forest is the most common forest type in Samunsam and is dominated by genera like *Gymnostoma*, *Whiteodendron*, *Tristaniopis*, *Vatica*, and *Shorea*. Rattan and a dense undergrowth are also common in this forest type. Pitcher plants were also observed in the more open areas. MDF is mainly confined to the hills in the north-eastern part of the sanctuary and on patches of elevated, well-drained terrain elsewhere. MDF has a rich flora and tall-broad trees, consisting of trees belonging to the genera *Dipterocarpus*, *Shorea*, *Alstonia*, *Artocarpus*, *Gluta*, and *Xanthophyllum*. The understory has climbing and non-climbing palm genera such as *Licuala*, *Caryota* and *Calamus* (Hazebroek & Abang, 2000).

Data collection

A total of 32 passive infra-red camera traps (Bushnell Trophy Cam HD) were deployed in SWS in July 2013 – September 2014 (six cameras) and August – November 2019 (26 cameras) which accumulated 746 and 1255 total camera trap night respectively (Fig. 1). Camera traps were placed in different habitat types (kerangas, mixed dipterocarp, riverine, mangrove and nipah forests). In 2019, some of the cameras (n = 13) were set along the newly constructed road within and near SWS, over 14.6 km length. Cameras were set up to 1 km away from the road to test for any edge-effects. Standard camera trap operation procedures were used across all sites and adjusted according to Mohd-Azlan et al. (2018b). Cameras were placed approximately 25–30 cm from the ground and GPS locations were marked and recorded. Metal casings and Phyton locks were utilised to prevent theft. To reduce potential moisture damage, the self-regeneration desiccant packet (Humidisorb) was used and the camera was subsequently sealed with silicone. The location of the cameras was chosen based on potential animal pathways or clearings (Ancrenaz et al., 2012; Bernard et al., 2013; Mohamed et al., 2013). Vegetation that would disrupt the passive infra-red trigger of the camera and reduce image quality was removed as well. All the cameras were operational all 24 h daily. No baits or lures were used in both studies. The road proximity was measured using GPS Garmin 64S and Google Earth Pro.

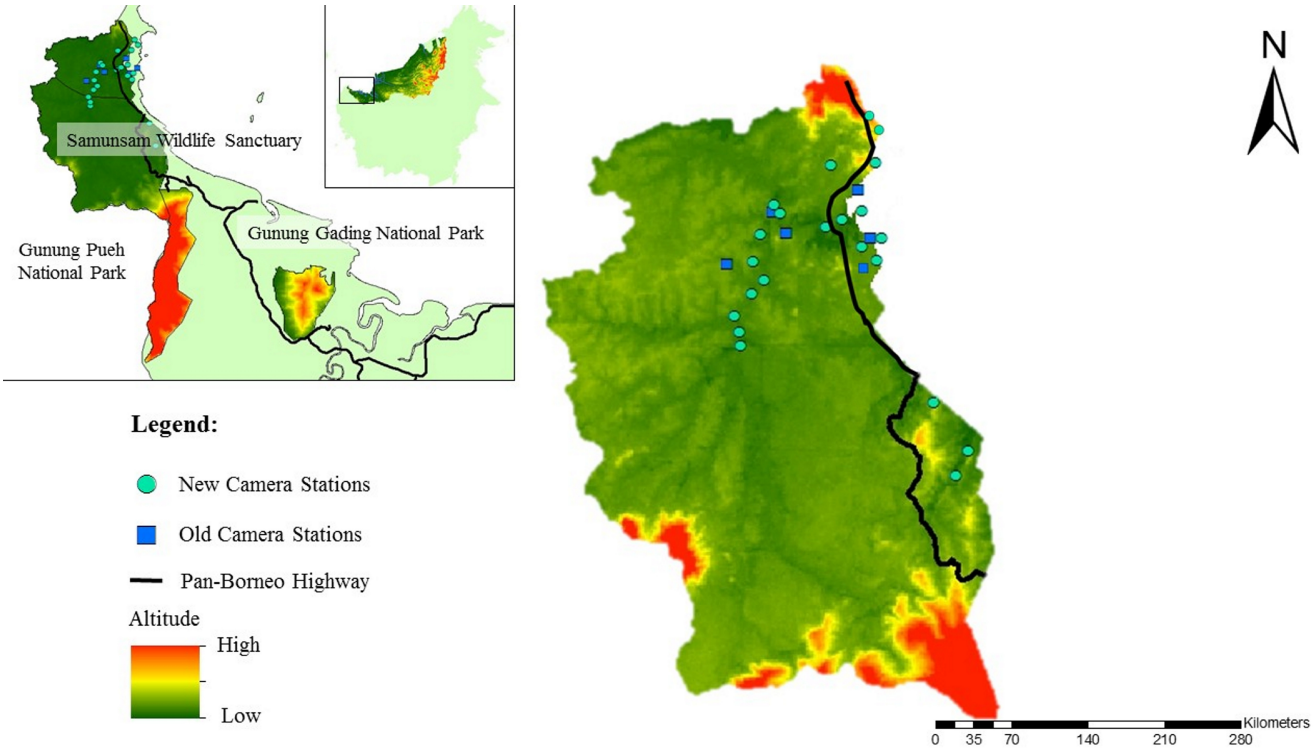

Fig. 1. Map showing the camera trap locations in Samunsam Wildlife Sanctuary (SWS) in Sarawak, Borneo and the nearest Protected Areas. Prior to road construction access to SWS was only by boat from Sematan jetty.

Data analysis

The photos of mammals were identified to species level whenever possible and processed with ReNamer software (Sanderson & Harris, 2013). *Tragulus* spp. were pooled together as they are often difficult to identify to species level using camera trap images. Photos were renamed using ReNamer, converting the photo identifications into date format (yyyy mm dd hh mm ss). Images from each camera were pooled to one-hour intervals to get independent events of different species and the consecutive photographs of individuals of the same species taken within an hour (O'Brien et al., 2003; Kawanishi & Sunquist, 2004; Bernard et al., 2014). Naïve occupancy (ψ) was determined by the proportion of sites that had at a minimum of one detection of the target species as described by MacKenzie et al. (2002). Species richness and completeness ratio was estimated with EstimateS 9.0. The completeness ratio was calculated by dividing the observed species by an estimate (Chao 1 Mean estimator). Habitat types were included in the bipartite network analysis. The bipartite network analysis selected mathematical functions to identify patterns in ecological webs (Blüthgen et al., 2007). Using the package «bipartite» (Dormann et al., 2008) in R (3.6.2), we report three statistics for habitat complexity: i) connectance is one of the measures of interaction pattern which indicates the proportion of the interactions observed to all the possible links (Dunne et al., 2002; Gilbert, 2009); ii) links per species, which is the mean number of links per species of categories of habitat, which is the sum of links divided by the number of species (Dormann et al, 2008); iii) niche overlap, which shows the mean similarity of the interaction patterns between species at the same level, using the Horn's index, whereby a value of 1 indicates a complete niche overlap and 0 indicates no common usage of niches (Horn, 1966). For the niche overlap, we used the Lower Link (LL) referring to the habitats. The mean species richness was calculated into two distance categories from the road (0–1000 m and > 1000 m) to see the effect of the road on medium- to large-bodied mammals with number of species/numbers of camera sites. Photographic records and camera locations coordinates were mapped, visualised and mammalian hotspots were identified through the kernel density function in ArcMap 10.2.

Results

A total of 20 species of medium- to large-bodied mammals (> 1 kg) including *Echinosorex gymnura* (Raffles, 1822) were recorded in SWS throughout 2013–2014 and 2019, representing 42% of Borneo's mammals (excluding marine mammals, and some larger mammals that are absent in Sarawak, i.e. *Elephas maximus* (Linnaeus, 1758) (Table)). The studies recorded 13 and 16 medium- to large-bodied mammals throughout 746 and 1255 efforts, respectively, which naively equalled to 0.017 and 0.013 species recorded per total effort. *Tragulus* spp. had the highest number of records of independent events in both studies (n = 147 and n = 166 in 2013–2014 and 2019, respectively), followed by *Macaca fascicularis* (Raffles, 1821) (n = 109 in 2013–2014) and *Sus barbatus* (Müller, 1838) (n = 93 in 2019) (Table). *Rusa unicolor* (Kerr, 1792) and *Paradoxurus hermaphroditus* (Pallas, 1777) were recorded only once in the 2013–2014 study, while *Herpestes brachyurus* (Gray, 1837) and *Cynogale bennettii* (Gray, 1837) were recorded only once in the 2019 study. In both studies, *Tragulus* spp. (ψ = 0.75 and ψ = 0.95, respectively) had the highest naïve occupancy, followed by *Sus barbatus* (ψ = 0.63 and ψ = 0.70, respectively). Additionally, the study detected 13 species in both distance categories (proximity to the road 0–1000 m and > 1000 m from the road). *Hemigalus derbyanus* (Gray, 1837), *Echinosorex gymnura*, and *Herpestes brachyurus* were only recorded within 1000 m, while *Cynogale bennettii*, *Hystrix brachyura* (Linnaeus, 1758), and *Nasalis larvatus* were recorded beyond 1000 m only (Table).

The detected mammals included four ungulates, nine carnivores, one pholidotan (*Manis javanica* Desmarest, 1822), three primates, two large rodents (porcupines) and one erinaceidaean. Among the recorded mammals, *Nasalis larvatus* is Totally Protected in Sarawak under the WLPO (1998), while 12 other species are Protected. Meanwhile, some of the recorded mammals are listed as species of conservation importance in IUCN (2019), where *Manis javanica* is listed as Critically Endangered (CR), *Nasalis larvatus* and *Cynogale bennettii* as Endangered species (EN), four species listed as Vulnerable (VU) and the rest as Least Concern (LC) (Table).

The mean species richness per site was higher in the first sampling period (2013–2014), whereby the mean value was 5.5 (SE = 1.36), compared to the second sampling period (2019), with a mean value of 4.15 (SE = 0.41) (Fig. 2). The overall sampling saturation appears high for the study in 2013–2014 and 2019 with relatively high completeness ratio = 0.98, suggesting that additional sampling days at the same site would not yield additional species.

Table. The list of medium- to large-bodied mammals photographed in Samunsam Wildlife Sanctuary with its independent events and naïve occupancy according to the sampling year 2013–2014/2019 and the protection and conservation status of each species

Order/Family	Scientific name	Common name	Independent events				Naïve occupancy		Protection and conservation status		
			2013–2014	2019	0–1000 m	> 1000 m	2013–2014	2019	WLPO, 1998	IUCN, 2019	CITES
Artiodactyla											
Tragulidae	*Tragulus* spp.	Mousedeer	147	166	99	67	0.75	0.95	–	LC	–
Suidae	*Sus barbatus*	Bearded pig	39	93	60	33	0.63	0.70	–	VU	–
Cervidae	*Muntiacus muntjak*	Barking deer	3	–	–	–	0.63	–	–	LC	–
Cervidae	*Rusa unicolor*	Sambar deer	1	–	–	–	0.13	–	–	VU	–
Carnivora											
Herpestidae	*Herpestes brachyurus*	Short-tailed mongoose	6	1	1	–	0.25	0.05	P	NT	–
Mustelidae	*Martes flavigula*	Yellow-throated marten	–	3	2	1	–	0.10	–	LC	III
Viverridae	*Arctictis binturong*	Binturong	4	–	–	–	0.38	–	P	VU	–
Viverridae	*Paradoxurus hermaphroditus*	Common palm civet	1	8	6	2	0.13	0.25	–	LC	III
Viverridae	*Hemigalus derbyanus*	Banded palm civet	4	9	9	–	0.25	0.20	P	NT	II
Viverridae	*Viverra tangalunga*	Malay civet	8	7	4	3	0.38	0.20	P	LC	–
Viverridae	*Paguma larvata*	Masked palm civet	–	3	1	2	–	0.10	P	LC	III
Viverridae	*Cynogale bennettii*	Otter civet	–	1	–	1	–	0.05	P	EN	II
Prionodontidae	*Prionodon linsang*	Banded linsang	–	2	1	1	–	0.10	P	LC	II
Pholidota											
Manidae	*Manis javanica*	Pangolin	4	–	–	–	0.25	–	P	CR	I
Primates											
Cercopithecidae	*Macaca nemestrina*	Pig-tailed macaque	42	64	47	17	0.5	0.65	P	VU	II
Cercopithecidae	*Macaca fascicularis*	Long-tailed macaque	109	15	8	7	0.38	0.35	P	LC	II
Cercopithecidae	*Nasalis larvatus*	Proboscis monkey	–	3	–	3	–	0.10	TP	EN	I
Eulipotyphla											
Erinaceidae	*Echinosorex gymnura*	Moonrat	–	2	2	–	–	0.05	–	LC	–
Rodentia											
Hystiricidae	*Hystrix brachyura*	Malayan porcupine	17	8	–	8	0.38	0.15	P	LC	–
Hystiricidae	*Trichys fasciculata*	Long-tailed porcupine	–	5	3	2	–	0.15	P	LC	–
Total number of independent events			385	390	243	147					
Total number of species			13	16	13	13					
Total effort			746	1255							

Note: CITES – Convention on International Trade in Endangered Species of Wild Fauna and Flora; TP – totally protected wildlife species; P – protected wildlife species, «–» – not available/not recorded; LC – Least Concern; NT – Near Threatened; VU – Vulnerable; EN – Endangered; I – species listed under CITES appendix I; II – species listed under CITES appendix II; III – species listed under CITES appendix III.

Forest type preference by medium- to large-bodied mammals in Samunsam Wildlife Sanctuary

The connectance value from bipartite analysis was 0.41. This translates to an average habitat usage of 40% by most of the species, suggesting some species might be specialists and are constrained to certain habitats (e.g. riverine forest and MDF). Links per species (mean number of links) was 1.57 (on average one species uses 25% of the available resources). Niche overlap (LL) was 0.72 suggesting a high overlap in habitat use.

Species richness of medium- to large-bodied mammals along Pan-Borneo Highway

The mean species richness per site was higher in the second category (> 1000 m). The mean species richness for the first category (0–1000 m) was 4 (SE = 0.45) and the second category (>1000 m) 4.3 (SE = 0.75) (Fig. 3). Cameras located in the second category (> 1000 m) had a relatively lower completeness ratio (0.95), where species richness was predicted to be higher than the observed species when compared to the first category (completeness ratio = 0.98). This suggests additional sampling may yield more species further inside the forest.

The heatmap highlights a higher species richness closer to the sea and in areas further inland of the River Samunsam and towards the north-east boundary of the SWS (Fig. 4). A lower species richness was recorded along the south-eastern part of the SWS extension, especially near the fragmented forested areas separated by the road.

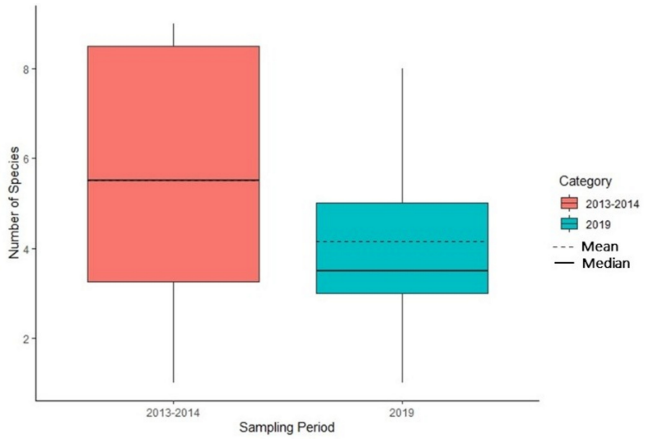

Fig. 2. The boxplot of medium- to large-bodied mammal richness in Samunsam Wildlife Sanctuary throughout the sampling period in 2013–2014 and 2019.

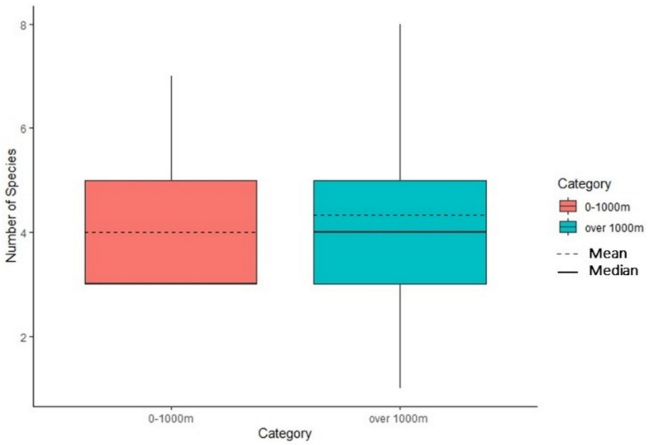

Fig. 3. The boxplot of the mean species richness of medium- to large-bodied mammals per site in each category throughout the sampling period with a buffer distance within 0–1000 m and > 1000 m from the Pan-Borneo Highway.

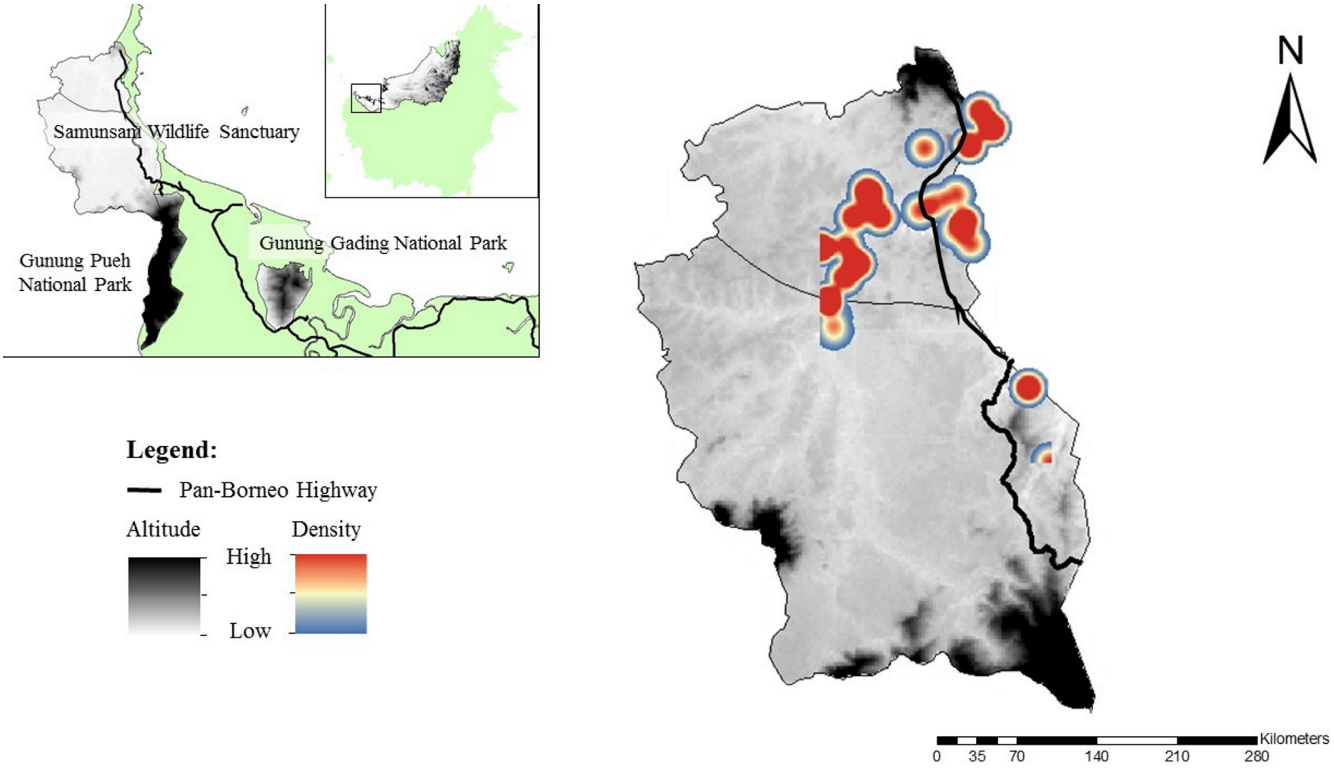

Fig. 4. The distribution of species richness of medium- to large-bodied mammals recorded in Samunsam Wildlife Sanctuary throughout the sampling period.

Discussion

Taking past and current observations into account, the landscape in SWS appears to support a lower species richness compared to other Protected Areas in Sarawak, such as Kubah National Park with 19 species (Mohd-Azlan et al., 2018a), Lanjak-Entimau Wildlife Sanctuary – 21 species (Mohd-Azlan & Engkamat, 2013), Tanjung Datu National Park – 20 species (Mohd-Azlan et al., 2018b) and Baleh National Park – 27 species (Mohd-Azlan et al., 2019a). The species richness of medium- to large-bodied mammals in SWS appeared relatively low compared to nearby Protected Areas as well, including Gunung Pueh National Park (GPNP) neighbouring the Sanctuary and Gunung Gading National Park (GGNP) in the lower east. Both recorded a relatively higher species richness with 22 and 20 species of medium- to large-bodied mammals respectively, despite being four times smaller than SWS (Kaicheen, 2019; Mohd-Azlan et al., 2019b). Nevertheless, SWS which is composed of various types of habitat recorded a relatively higher species richness (n = 16) compared to the Maludam National Park (n = 11) which is a peat swamp forest (Mohd-Azlan, 2004). This

study recorded nine carnivores throughout the study which is relatively low compared to a study in Sebangau peat swamp forest, Indonesia which recorded 12 carnivores included four felids (Cheyne et al., 2010; Cheyne & Macdonald, 2011). The relatively lower species richness in the mangrove and peat swamp forests is probably due to the simplicity of these forests which have a relatively lower habitat heterogeneity compared to the MDF (Yule, 2010; Posa et al., 2011). Habitats with a higher complexity tend to sustain a higher concentration of species richness, where the structures of littoral and alluvial forests are significantly less complex compared to the MDF, therefore supporting fewer species (Mohd-Azlan & Lawes, 2011; Dalling et al., 2016). However, the current survey only lasted 69 days and is not an exhaustive survey to reflect the actual mammal diversity in SWS. These results require further research to confirm the reasons for the absence of felids in SWS.

The increasing need for connectivity to rural areas matched with land clearance for agriculture and deforestation has increased the road networks in Sarawak. Many tropical species are sensitive to forest gaps such as roads where many forest specialists avoid such clearance, edges, while others are susceptible to invasion, colonisation, hunting, roadkill and predation near roads (Laurance et al., 2009). In 2013–2014, only 13 species were recorded in SWS. In the current study, we recorded seven additional species which were not recorded in the previous study: *Nasalis larvatus*, *Martes flavigula* (Boddaert, 1785), *Echinosorex gymnura*, *Trichys fasciculata* (Shaw, 1801), *Paguma larvata* (C.E.H. Smith, 1827), *Prionodon linsang* (Hardwicke, 1821), and *Cynogale bennetti*. *Cynogale bennetti* was not detected in several camera trapping studies in MDF in Sarawak as it is associated with wetlands (Phillipps & Phillipps, 2016). Species like *Arctictis binturong* (Raffles, 1821), *Rusa unicolor*, *Muntiacus muntjak* (Zimmermann, 1780), and *Manis javanica*, were recorded in the previous survey (Mohd-Azlan, unpublished) but were absent during the current one (Table). These species may have been undetected due to the short survey period or these species may be locally extinct or absent in the surveyed areas. These species also may occur in a lower density since the previous survey and that may have reduced the species detection probability.

Even though five Bornean felids were found with utilisation on mangrove and/or peat swamp forests in Borneo (Nowak, 2012), they could not be detected in SWS. The non-detection of elusive apex predators (i.e. felids) in both studies – not even the widely distributed wild cat species *Prionailurus bengalensis* (Kerr, 1792) – raises concern. *Prionailurus bengalensis* is known for its high adaptability in a wide range of habitats and a high level of toleration towards anthropogenic disturbance (Mohamed et al., 2009; Cheyne & Macdonald, 2011; Mohamed et al., 2013). The non-detection of *Prionailurus planiceps* (Vigors & Horsfield, 1827) in SWS warrants further exploration as SWS was listed as a potential site for the occurrence of this species due to its strong association with wetlands (Medway, 1983; Nowell & Jackson, 1996; Wilting & Fickel, 2012; Wilting et al., 2016; Mohd-Azlan & Thaqifah, 2020). Some of these species, such as *Pardofelis marmorata* (Martin, 1837), were detected in both GPNP and GGNP, while *Neofelis diardi* (G. Cuvier, 1823) only in GPNP.

Road implications and risks for medium- to large-bodied mammals

The recently built Pan-Borneo Highway, which cuts through the eastern side of SWS, has fragmented and isolated parts of the forest and appears to have adverse effects on the distribution of medium- to large-bodied mammals. A lower species richness was recorded along the south-eastern part of the SWS extension, where the forest was fragmented by the road. This suggests that the thin strip of forest on the east side of the road of the SWS extension is probably unable to support the larger mammal community and prone to localised extinction in the near future. Most of the species recorded in close proximity to the road (< 1000 m) are generalists. They include *Macaca fascicularis*, *Macaca nemestrina* (Linnaeus, 1766), *Sus barbatus*, *Herpestes brachyurus*, *Martes flavigula*, *Tragulus* spp., *Hemigalus derbyanus*, *Paguma larvata*, *Paradoxurus hermaphroditus*, *Viverra tangalunga* (Gray, 1832), *Trichy fasciculata*, and *Echinsorex gymnura* (Table). The proliferation of anthropogenic activities will gradually increase the edge effect which is unfavourable by the ungulates, and carnivores where an avoidance behaviour could be noticed, and ultimately restricts the movement of primates and arboreal animals (Michalski & Peres, 2005; Brodie et al., 2015b; Mohd-Azlan et al., 2018a).

Nasalis larvatus, *Cynogale bennettii* and *Hystrix brachyura* were recorded to have a negative affinity to road proximity suggesting sensitivity to anthropogenic sources (Table). *Nasalis larvatus*, *Hystrix brachyura* and *Cynogale bennettii* were only recorded deeper into the forest core area (2.43 km, 2.61 km and 3.93 km away from the Pan-Borneo Highway, respectively).

Mammals tend to avoid forest frontiers and endemic species can only be spotted within a distance around primary forest unlike widespread species; thus deterioration of population density can be expected within a 5 km buffer zone (Kinnaird et al., 2003; Heaney et al. 2005; Benítez-López et al., 2010; Clements et al., 2014). This might explain the relatively lower capture rates of specialists or even less-adaptable common species near the road. During the study period, groups of *Macaca nemestrina* were observed crossing the Pan-Borneo Highway to access the forest on the western side. Species crossing the road could be a high risk of road mortality (Mohd-Azlan, 2006; Mohd-Azlan & Engkamat, 2006) and are dangerous to drivers along this road. Additionally, this may also increase intrusion and disturbance pressure due to the increased anthropogenic activity such as the collection of non-timber forest products and hunting.

The distance from the sea is considered a proxy for changes in species richness as it affects the flora directly and impacts fauna indirectly through habitat variation. Forest type changes accordingly to the distance from the sea and areas influenced by the tides. The forest structure changes from a structurally simple type, such as the mangrove forest, to the nipah forest type with few plant species and, finally, to forests with more heterogeneity at higher altitudes. In this study, some areas near the coastline recorded higher amounts of species, which could be due to the selection of habitat (mostly in MDF on hills) where the cameras were placed Sampling limitation and spatial and temporal fluctuations in species populations may have caused the lack of statistical significance in the relationship analysis and has prevented the estimation of species occupancy in these habitats. Therefore, additional surveys in relation to the habitat type may provide a comprehensive description of the habitat preference of medium- to large-bodied mammals in SWS.

Most generalist species (i.e. *Macaca nemestrina*, *Macaca fascicularis*, *Hystrix brachyuran*, *Viverra tangalunga*, *Herpestes brachyurus*, *Paradoxurus hermaphroditus*, *Sus barbatus*, *Trichys fasciculata*, and *Tragulus* spp.) were recorded in more than two habitat types while some species were only detected in a single habitat (i.e. *Nasalis larvatus*, *Cynogale bennettii*, *Martes flavigula*, *Paguma larvata*, and *Prionodon linsang*). *Hemigalus derbyanus*, *Prionodon linsang*, *Martes flavigula*, and *Paguma larvata* are uncommon to peat swamp forest but frequently recorded in MDF, which is consistent with Phillipps & Phillipps (2016). On the other hand, *Nasalis larvatus* was recorded in the MDF opportunistically while travelling on the ground, therefore may not be indicative of this habitat preference but suggest that this species is also dependent on MDF.

Regular and extensive patrolling in Samunsam Wildlife Sanctuary and its extension are needed. Boat patrols are to go further up the River Samunsam (> 6 km from the headquarters), River Bedaun and River Belinsah, and road patrols on the Pan-Borneo Highway should also be carried out regularly. Establishing the Spatial Monitoring And Reporting Tool (SMART) intrusion system to highlight the high-risk areas where regular patrolling should be encouraged. The forest edges near the road should be enriched to increase cover that will also contribute to reducing erosion and soil stability. Informative signboards with relevant contact numbers can also be included for the public to report accidents or road-kills. Road-kills should be documented and mapped whenever possible to improve conservation strategies. Community engagement with the locals should be implemented to bring about awareness and to create a shared responsibility of the sanctuary and its wildlife.

Conclusions

A total of 20 species of medium- to large-bodied mammals from 11 families were recorded throughout the surveys (13 species in 2013–2014 and 16 species in 2019). An elusive and wetland-associated species such as *Cynogale bennettii* was recorded further inland and far away from the influence of roads suggesting that it is a highly sensitive species. However, species such as *Tragulus* spp. and *Sus barbatus* were considered more resilient and adaptable species, appearing on almost all the sites and in all forest types surveyed. A high species concentration was identified in the north-eastern fragment of SWS,

adjacent to the road, suggesting conservation efforts should focus on these areas. The analysis has also shown that a more considerable amount of species was associated with MDF compared to all other forest types surveyed, further highlighting their conservational importance. Even though our sample size is relatively small, such information is useful for monitoring purpose in the future, especially by relevant authorities and shall be interpreted carefully. Further studies are needed for a better understanding of the extent of the disturbance caused by the road in relation to the functional diversity and species of conservation importance distributed along the road distance gradient.

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РАСПРОСТРАНЕНИЕ СРЕДНИХ И КРУПНЫХ МЛЕКОПИТАЮЩИХ В ЗАКАЗНИКЕ ДИКОЙ ПРИРОДЫ САМУНСАМ (САРАВАК) В СВЯЗИ С НЕДАВНО СОЗДАННЫМ ШОССЕ ПАН-БОРНЕО

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Особо охраняемые природные территории (ООПТ) в Борнео являются одними из лучших примеров биоразнообразия и являются последним убежищем для сохранения дикой природы в тропических лесах. Поэтому понимание видового богатства и состава во все более фрагментированных ООПТ имеет решающее значение для мониторинга и управления дикой природой. Недавнее строительство дороги, разделяющей самый старый заказник дикой природы в Сараваке, потребовало дальнейшего изучения распространения видов. В результате исследования с использованием фотоловушек в заказнике дикой природы Самунсам на западе Борнео было зафиксировано 20 видов средних и крупных млекопитающих на основании 775 независимых фотографий, полученных за 2001 фотоловушко-сутки в 2013–2014 гг. и 2019 г. В настоящем исследовании были зарегистрированы исчезающие (Endangered) виды *Nasalis larvatus* и *Cynogale bennettii* в заказнике дикой природы Самунсам. В соответствии с Постановлением о защите дикой природы Саравака от 1998 г., *Nasalis larvatus* был единственным зарегистрированным видом, который считался полностью охраняемым. В то же время 12 других видов занесены в список охраняемых таксонов, а остальные виды не были перечислены в Постановлении. Наиболее часто регистрируемым видом был *Tragulus* spp. (n = 147 в 2013–2014 гг. и n = 166 в 2019 г.), затем следуют *Macaca fascicularis* (n = 109 в 2013–2014 гг.) и *Sus barbatus* (n = 93 в 2019 г.). Сходное видовое богатство (n = 13) было отмечено как вблизи (< 1000 м), так и на удалении от дороги (> 1000 м). Однако среднее видовое богатство становилось выше при удалении от дороги (> 1000 м). *Herpestes brachyurus*, *Hemigalus derbyanus* и *Echinosorex gymnura* были зарегистрированы только у дороги, в то время как *Cynogale bennettii*, *Hystrix brachyura* и *Nasalis larvatus* были зарегистрированы только на удалении от дороги. Согласно результатам двухстороннего сетевого анализа, большинство средних и крупных млекопитающих распространено в смешанных диптерокарповых лесах. Виды, обитающие в непосредственной близости от дороги, имеют более высокий риск гибели в результате дорожно-транспортных происшествий и других антропогенных факторов. Нарушение среды является проблемой в заказнике дикой природы Самунсам и требует немедленных действий, а именно, более строгого соблюдения, регулярного широкого патрулирования реки и дороги для предотвращения незаконных рубок, коммерческих посевов и охоты.

Ключевые слова: дорога, обеспечение исполнения, особо охраняемая природная территория, тропические леса, фотоловушки, фрагментация