Journal for Nature Conservation 40 (2017) 113–119

Contents lists available at ScienceDirect

Journal for Nature Conservation

journal homepage: www.elsevier.com/locate/jnc

The conservation value of unlogged and logged forests for native mammals on the East Coast of Peninsular Malaysia

David Magintan[a,b], Shukor Md Nor[b], Tan Poai Ean[a], Alex M. Lechner[c], Badrul Azhar[d,e,*]

[a] Department of Wildlife and National Parks, Km10, Jln Cheras, 56100, Kuala Lumpur, Malaysia
[b] Faculty of Science and Technology, School of Environmental and Natural Resource Sciences, National University of Malaysia, 43600 Bangi, Selangor, Malaysia
[c] School of Environmental and Geographical Sciences, University of Nottingham Malaysia Campus, 43500 Semenyih, Selangor, Malaysia
[d] Biodiversity Unit, Institute of Bioscience, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia
[e] Faculty of Forestry, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia

ARTICLE INFO

Keywords:
Biodiversity
Forest reserve
Logging
Mammals
Species composition

ABSTRACT

Tropical forests across the world provide important habitats for a diverse number of conservation priority species, yet are under threat from a range of anthropogenic impacts including logging. This study aims to quantify mammalian biodiversity in unlogged and logged forests in the adjoining Tembat and Petuang Forest Reserves, Terengganu, on the East Coast of Peninsular Malaysia. Data was collected over a series of surveys using direct and indirect observation methods from 2008 to 2014. A total of 30 medium and large sized mammals species were identified, with 27 of those species found in unlogged forests and 22 species in logged forests. Carnivores encompassed 11 species from 67 observations representing 15% of the total number of observations. The family Felidae had the highest number of species (six species), followed by Hylobatidae, Cercopithecidae and Suidae with three species each. A total of 17 species contributed to more than 90% of the mammal community in the unlogged and logged forests, while six species were uncommon and only observed once during the entire survey. Species abundance in the unlogged forest was significantly greater than the logged forests, but the difference was not significant for species richness. This study provides critical baseline information on the impact of unlogged and logged forests and the identification of threatened species warrant the establishment of conservation measures such as anti-poaching patrol and ranger stations in the study area.

1. Introduction

Tropical rainforests are complex ecosystems that provide shelter and food sources to a vast number of fauna species, supporting more than 80% of terrestrial living organisms (World Bank, 2008), many of which are priorities for conservation (IUCN, 2006; Sodhi, Lian, Brook, & Ng, 2004). Forests also play important roles in the mitigation of the effects of climate change (Walton et al., 2015) primarily through the reduction of CO_2 in the atmosphere (Schlamadinger & Marland, 1996). However, around 13 million hectares of forests continue to be lost globally every year (FAO, 2010a) and about 200 km^2 each day (IUCN, 2015).

Tropical rainforests are threatened by multiple anthropogenic factors including logging, expansion of agricultural land, introduction of invasive species, wildfires, hunting, mining activities and dam construction (De Thoisy, Renoux, & Julliot, 2005; Brook, Sodhi, & Bradshaw, 2008; Olupot, Barigyira, & Chapman, 2009). Deforestation due to human population expansion and economic activities is the primary threat to tropical forest sustainability (Phillips, 1997; DeFries Rudel, Uriarte, & Hansen, 2010; Southworth, Nagendra, & Cassidy, 2012). Globally the rate of forest conversion to other uses or lost through natural causes has decreased from 16 million hectares per year in the 1990s to 13 million hectares a year in the last decade. Nevertheless, the FAO still considers the rate of forest loss alarmingly high (FAO, 2010a). Logging activity for forest production, even when conducted selectively (Martin, Newton, Pfeifer, Khoo, & Bullock, 2015; Burivalova, Sekercioglu, & Koh, 2014; Edwards & Laurance, 2013) and forest conversion into agriculture are the main factors responsible for forest loss and in turn biodiversity loss (Green, Cornell, & Balmford, 2005; Gaveau, Wandono, & Setiabudi, 2007; Fitzherbert et al., 2008). Furthermore, tropical species appear more susceptible to disturbance, thus leading to high levels of extinction in tropical regions (Vamosi & Vamosi, 2008).

The focus of this study is on Malaysia, a high biodiversity region in Southeast Asia (Myers, Mittermeier, Mittermeier, Da Fonseca, & Kent, 2000; Sodhi et al., 2004), found within the Sundaland hotspot, one of

* Corresponding author at: Biodiversity Unit, Institute of Bioscience, Universiti Putra Malaysia, 43400 Serdang, Malaysia.
E-mail address: b_azhar@upm.edu.my (B. Azhar).

http://dx.doi.org/10.1016/j.jnc.2017.10.005
Received 16 June 2017; Received in revised form 6 October 2017; Accepted 24 October 2017

25 global biodiversity hotspots identified by Myers et al. (2000). Like other tropical countries Malaysian forest and biodiversity are also under threat, however, the average annual forest loss from 2005 to 2010 was estimated to be modest, at approximately 0.42% (FAO, 2010a) and this loss is largely attributable to planned land-use changes in line with national development policies. Approximately 45% of Peninsular Malaysia's landscapes are forested land with the production forest covering 116,070 km^2 and protection forest are 46,400 km^2 (FAO, 2010b). Logging of the dominant dipterocarp forests in Peninsular Malaysia is conducted through a Selective Management System (SMS) since 1978 (Appanah & Weiland, 1993); a form of selective felling with diameter limits (Appanah & Weinland, 1993). The harvesting cycle under the SMS is 30 years (Okuda et al., 2003).

Protecting large areas of suitable habitat for mammals is required to avoid further species loss (Francis, 2008) in Peninsular Malaysia (western part of the country), which hosts some 229 species of mammals (Davison & Zubaid, 2007). Of particular concern are threats to medium and large size mammals, which play important ecological roles in tropical ecosystems, especially for seed dispersal (Campos-Arceiz, Traeholt, Jaffar, Santamaria, & Corlett, 2012; O'Farrill, Galetti, & Campos-Arceiz, 2013; Sato, 2014). Even though mammals are one of the most thoroughly studied taxa (Rowe, 1988), attempts at quantifying and conserving mammalian biodiversity are hindered by insufficient data (Jones & Safi, 2011). In Peninsular Malaysia, most protected areas comprise unlogged forests, however, little is known about mammalian biodiversity in forest reserves where logging is being undertaken.

The objective of this study was to quantify and compare mammalian biodiversity in unlogged and logged Malaysian tropical forests. A series of mammal surveys were conducted between 2008 and 2014 in logged and unlogged forest in Reserves in Terengganu. Firstly, we assessed diversity for a number of taxonomic ranks (order, family and species) of medium and large sized mammals in unlogged and logged forests. We then compared species richness and abundance based on feeding guilds. Lastly, we compared survey observations made using animal signs versus direct visual observations. We conclude by discussing the differences in diversity recorded in unlogged versus logged forest, then examine the rare species recorded and finally the implications of our research for the conservation and future research directions for the assessment of medium and large sized mammals in tropical forests in Malaysia.

2. Methods

2.1. Study area

This study was conducted in two adjoining forest reserves, the Tembat Forest Reserve (TFR) and Petuang Forest Reserve (PFR), in Hulu Terengganu, on the east coast of Peninsular Malaysia (Fig. 1). Together these reserves encompass an area of approximately 1722 km^2 and are part of Greater Taman Negara. They are connected to Taman Negara Terengganu (national park) in the south-west, and the Kenyir Lake in the south-east. TFR and PFR include wildlife linkages which contribute to the Central Forest Spine Project, a national wildlife corridor scheme. These linkages are composed of unlogged forests which connect Taman Negara National Parks and the TFR to adjoining forest complexes in Peninsular Malaysia.

The Malaysian government has approved a second dam project within TFR and PFR, which covers 572 km^2, including a 62 km^2 inundation area and 520 km^2 water catchment area. A total of 186 km^2 has been clear felled since 2014 to make way for this project. The areas surrounding the tributaries of the Terengganu river, the Pelagung River and Puah River, were logged in the early 2000s. While other areas in the PFR are protected from logging as they are classified as forests for soil protection due to steep slopes of more than 40° and/or altitudes of more than 1000 m. The forest in the study site are categorised as lowland dipterocarp forest to hill dipterocarp forest, with altitudes that range between 150 m and 420 m.

2.2. Animal sampling

Wildlife surveys were conducted in the study region by the Department of Wildlife and National Parks (DWNP). A total of 28 predetermined transects, 14 in unlogged and 14 in logged forests were surveyed annually from 2008 to 2014. The transect lengths were 15 kilometres and were spaced at 2–5 kilometre intervals apart to avoid intersecting. The survey rate was approximately 2.50–3.75 kilometres per day or 0.42–0.625 kilometres per hour, depending on the topography and forest conditions. In the case of rain, the survey was stopped temporarily until the weather was more favourable for surveying.

The survey teams were deployed at one end of each of the transect simultaneously on the same day, which were accessed mostly via logging roads. Team members were mainly experienced DWNP rangers with at least five years field experience and had been trained to identify mammal species based on animal tracks (Fig. 2). Each team was given four days to complete the transect. Once the survey started, each team followed animal paths, old trails, footpaths and old logging roads while maintaining the general direction of the transect. The survey teams started as early as 8:30 amto increase opportunities to encounter wildlife and stopped for a breaks every 45 min for approximately 15 min until the team reached the desired camp location at approximately 4.30 pm.

The observation methods used during the survey were direct and indirect observations. Direct observations were based on visual identification. However, due to the difficulty of observing animals for long periods of time observers needed to have considerable expertise and only confirmed identifications were recorded. All species identification followed Francis (2008). Indirect observation methods during these surveys were based on the identification and interpretation of field signs. The field signs observed during these surveys include vocalisation, footprints, scrapes and scratches, feeding signs, identification of faeces, carcases and wallows.

2.3. Data analysis

We used similarity percentage (SIMPER) one-way analysis in PRIMER 7 to identify which species contributed most to the differences in species composition in both forest types (i.e. logged and unlogged) (Clarke & Warwick, 2001). We made an assumption that all observations in each transect were independent of each other (i.e. the same individual was not observed twice).

For comparison and correlation between samples the data analyses were carried out in GenStat Release 12.1 software (12nd Edition). A two-sample Poisson Test was used to test the difference between species abundance and richness. We also made a comparison of the number of individuals from different feeding guilds in samples by using the two-sample Poisson Test. Finally, we used the two-sample Poisson Test to assess the importance of observation modes (i.e. direct versus indirect).

3. Results

3.1. Species composition

A total of 449 animal observations were recorded from 2008 to 2014. In total, 30 mammal species were recorded representing 27 genera, 15 families and seven orders of medium and large sized mammals (Table 1). A total of one, seven, and ten species recorded were listed by IUCN (2016) as critically endangered, endangered, and vulnerable respectively (Table 1). Carnivores were observed 67 times or 15% of the total observations, consisting of 11 species from five families, namely, Ursidae, Felidae, Mustelidae, Viverridae and Canidae. Among these families, Ursidae, which was represented by the Malayan

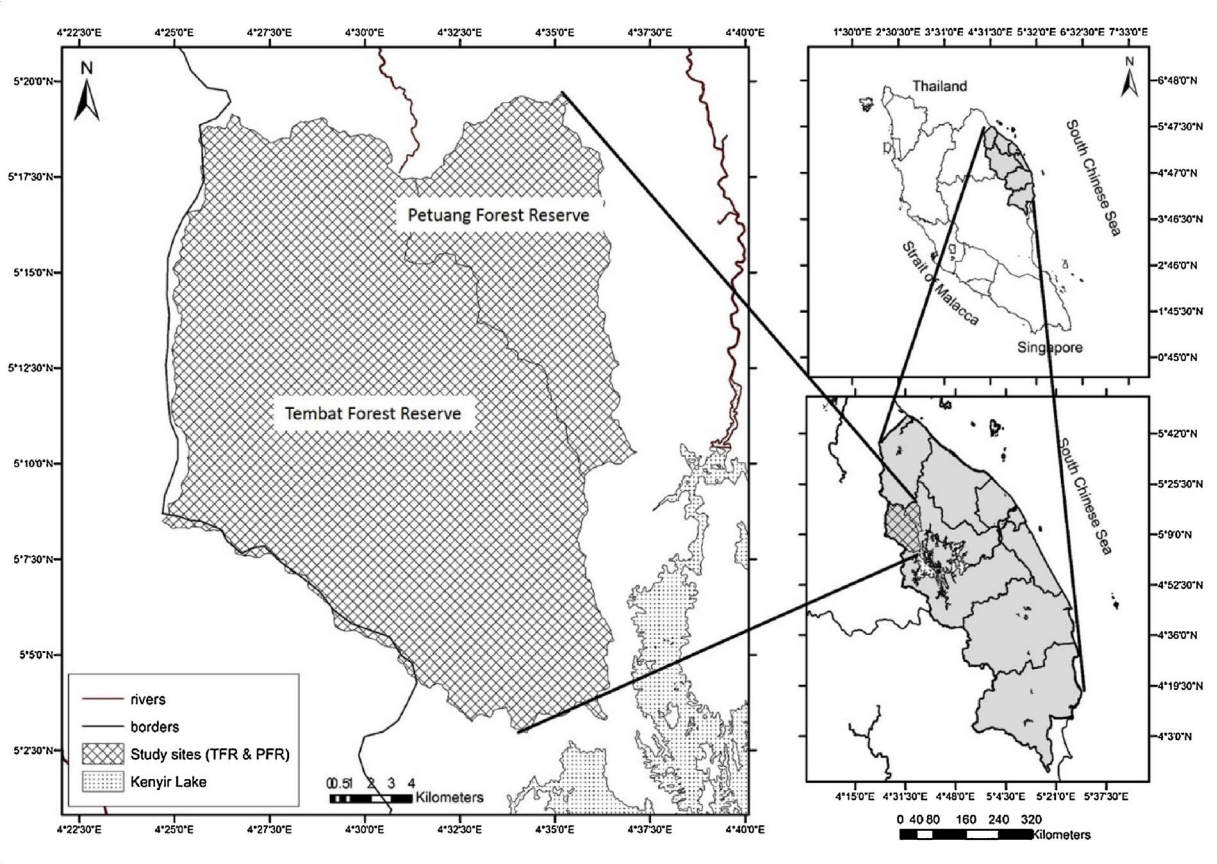

Fig. 1. The study site in Hulu Terengganu, Terengganu, Peninsular Malaysia. The shaded areas indicate Tembat Forest Reserve and Petuang Forest Reserve.

Fig. 2. An animal track left by Malayan sunbear on logging road in the study area.

sun-bear (*Helarctos malayanus*) was observed the most number of times. While the order Carnivora had the highest species richness, the order with the second highest species richness was Artiodactyla, encompassing seven species from 129 observations or 29% of the total observations. The Artiodactyla, wild pig (*Sus scrofa*), accounted for 19% of the total observations. The third richest order was the primates with six species and 97 observations or 22% of the total observations. The white-handed gibbon *Hylobates lar* was the most observed primate species with 13% of the total observations. The remaining orders observed – Proboscidae, Perissodactyla, Rodentia and Pholidota − were represented by one or two families each.

The family observed with the most number of species represented was Felidae with six species from 27 observations, followed by the Hylobatidae (82 observations), Cercopithecidae (15 observations) and Suidae (117 observations) which each were represented by three species. Families with represented by two species were the Mustelidae (13

Table 1
Summary of animals recorded during survey in TFR and PFR, Hulu Terengganu, Terengganu, Peninsular Malaysia.

Order	Family	Common name	Scientific name	Status (IUCN)	Act 716	CITES
Primate	Hylobatidae	White-handed gibbon	*Hylobates lar*	EN	Second Schedule	App. I
1	2	Siamang	*Symphalangus syndactylus*	EN	Second Schedule	App. I
3	4	Dusky leaf monkey	*Trachypithecus obscurus*	NT	First Schedule	App. II
5	Cercopithecidae	White thigh langur	*Presbytis melalophos*	NT	First Schedule	App. II
6	7	Pig tailed macaque	*Macaca nemestrina*	VU	First Schedule	App. II
8	9	Macaca fascicularis	*Macaca fascicularis*	LC	First Schedule	App. II
Carnivore	Ursidae	Malayan sunbear	*Helarctos malayanus*	VU	Second Schedule	App. I
10	Felidae	Malayan tiger	*Panthera tigris*	EN	Second Schedule	App. I
11	12	Black leopard	*Panthera pardus*	NT	Second Schedule	App. I
13	14	Clouded leopard	*Neofelis nebulosa*	VU	Second Schedule	App. I
15	16	Marbled cat	*Pardofelis marmorata*	VU	Second Schedule	App. I
17	18	Leopard cat	*Prionailurus bengalensis*	LC	Second Schedule	App. I
19	20	Asiatic golden cat	*Catopuma temminckii*	NT	Second Schedule	App. I
21	Mustelidae	Smooth otter	*Lutrogale perspicillata*	VU	Second Schedule	App. II
22	23	Asian small-clawed otter	*Aonyx cinerea*	VU	Second Schedule	App. II
24	Viverridae	Binturong	*Arctictis binturong*	VU	Second Schedule	App. III
25	Canidae	Dhole	*Cuon alpinus*	EN	Second Schedule	App. II
Proboscidae	Elephantidae	Asian elephant	*Elephas maximus*	EN	Second Schedule	App. I
Perisodactyla	Tapiridae	Tapir	*Tapirus indicus*	EN	Second Schedule	App. I
26	Rhinocerotidae	Sumatran rhinoceros	*Dicerorhinus sumatrensis*	CR	Second Schedule	App. I
Artiodactyla	Suidae	Wild pig	*Sus scrofa*	LC	First Schedule	n/a
27	28	Barking deer	*Muntiacus muntjak*	LC	First Schedule	n/a
29	30	Sambar deer	*Rusa unicolor*	VU	First Schedule	n/a
31	Bovidae	Serow	*Capricornis sumatraensis*	VU	Second Schedule	App. I
32	33	Gaur	*Bos gaurus*	VU	Second Schedule	App. I
34	Tragulidae	Greater mouse-deer	*Tragulus napu*	LC	First Schedule	n/a
35	36	Lesser mouse-deer	*Tragulus kanchil*	LC	First Schedule	n/a
Rodentia	Hystricidae	Large porcupine	*Hystrix brachyura*	LC	First Schedule	App. III
37	38	Long-tailed porcupine	*Trichys fasciculata*	LC	Second Schedule	n/a
Pholidota	Manidae	Pangolin	*Manis javanica*	EN	Second Schedule	App. I

Note: IUCN Status; IUCN Red List of Threatened Species (2015): LC– Least Concern, VU – Vulnerable, NT – Near Threaten, CR – Critically Endangered; **Protection Status (Wildlife Conservation Act 2010):** First schedule- Protected Wildlife, Second Schedule- Totally Protected Wildlife; **Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES):** App. I- Appendices I, App. II – Appendices II, App. III – Appendices III.

observations), Bovidae (two observations), Tragulidae (10 observations) and Hystricidae (seven observations). Other families namely Ursidae (25 observations), Viverridae (two observations), Canidae (one observation), Elephantidae (64 observations), Tapiridae (79 observations), Rhinocerotidae (one observation) and Manidae (five observations) were only represented by one species each.

The most observed species over the entire period were the wild pig (*Sus scrofa*) (18%) and Malayan Tapir (*Tapirus indicus*) (18%), followed by the Asian elephant, (*Elephas maximus*) (14%) and the White-handed Gibbon (*Hylobates lar*) (12%). All other species were represented by less than 10% of the total observations, including six species which were only observed once. The species that were observed once were *Neofelis nebulosa, Cuon alpinus*, *Dicerorhinus sumatrensis*, *Capricornis sumatraensis*, *Bos gaurus* and *Tragulus napu*.

In unlogged forests, seven species contributed to more than 90% of the total species observed (Table 2). The species which were most observed were *Tapirus indicus* with 26.99% of the total contribution, followed by *Hylobates lar* with 23.91% of species contribution and *Sus scrofa* with 19.11%. The four other species were *Elephas maximus*, *Helarctos malayanus*, *Muntiacus muntjak* and *Sympalangus syndactylus*. While in the logged forest six species contributed more than 90% of the total species recorded (Table 3). These were the *Sus scrofa, Tapirus indicus*, *Elephas maximus*, *Hylobates lar*, *Muntiacus muntjak* and *Lutrogale perspicillata.*

Of all species recorded in both forest types 17 species contributed to 90% of the medium and large size mammals found in the study area (Table 4) and twelve species contributed less than 10% of the total species found in the study area. Three species were only recorded in logged forest, namely, *P. pardus, M. nemestrina* and *C. alpinus.* While eight species were only recorded in unlogged forest, namely, *D. sumatrensis*, *Trichys fasciculata*, *C. sumatraensis*, *N. nebulosa*, *Pardofelis marmorata*, *Tragulus napu*, *Macaca fascicularis* and *Bos gaurus*.

3.2. Species richness and abundance

Of the 30 species recorded, 27 species were found in unlogged

Table 2
Mammal abundance and species composition in unlogged forests. The average similarity in terms of species composition is 33.36%.

Species	Average abundance	Contribution of species (%)	Cumulative contribution (%)
Tapirus indicus	1.55	26.99	26.99
Hylobates lar	1.41	23.91	50.90
Sus scrofa	1.47	19.11	70.01
Elephas maximus	0.98	6.85	76.86
Helarctos malayanus	0.74	5.73	82.59
Muntiacus muntjak	0.60	4.85	87.44
Sympalangus syndactylus	0.54	4.37	91.81

Table 3
Mammal abundance and species composition in logged forests. The average similarity in terms of species composition is 26.18%.

Species	Average abundance	Contribution of species (%)	Cumulative contribution (%)
Sus scrofa	1.35	26.95	26.95
Tapirus indicus	1.20	23.27	50.22
Elephas maximus	1.16	18.90	69.12
Hylobates lar	0.89	14.98	84.10
Muntiacus muntjak	0.51	5.60	89.70
Lutrogale perspicillata	0.27	2.36	92.06

Table 4
Mammal abundance and species composition in both unlogged and logged forests. The average dissimilarity in terms of species composition is 68.41%.

Species	Average abundance		Contribution of species (%)	Cumulative contribution (%)
	Unlogged forest	Logged forest		
Tapirus indicus	1.55	1.2	12.68	12.68
Sus scrofa	1.47	1.35	11.09	23.77
Hylobates lar	1.41	0.89	10.51	34.28
Elephas maximus	0.98	1.16	9.99	44.28
Helarctos malayanus	0.74	0.39	6.16	50.44
Muntiacus muntjak	0.6	0.51	5.41	55.85
Sympalangus syndactylus	0.54	0.14	4.86	60.71
Tracypithecus obscurus	0.48	0.21	4.68	65.38
Lutra perspicillata	0.21	0.27	4.14	69.52
Rusa unicolor	0.34	0.27	3.72	73.25
Panthera tigris	0.27	0.17	3.59	76.84
Presbytis melalophos	0.34	0.21	3.37	80.22
Tragulus kanchil	0.2	0.21	2.42	82.63
Aonyx cinerea	0.1	0.21	2.21	84.85
Catopuma temminckii	0.21	0.17	2.13	86.98
Hystrix brachyura	0.07	0.17	1.93	88.9
Manis javanica	0.2	0.07	1.35	90.25

forests and 22 species in logged forests. The total number of observations in the unlogged forests was 259, while in the logged forests there was 190 observations. The average number of individuals observed in the unlogged forests per transect (mean = 18.50) was greater than in logged forests (mean = 13.57) and statistically significant (Normal Approximation = 3.256, df = 26, p = 0.001, 95% CI [1.962, 7.895]). In contrast, species richness in unlogged and logged forests was not statistically different based on the two-sample Poisson Test.

3.3. Feeding guilds

Our analysis of difference between forest types on feeding guilds shows that only the comparison of number of individual for herbivores between unlogged (mean = 15.57) and logged forest (mean = 11.14) was significantly different (Normal Approximation = 3.206, df = 26, p = 0.001, 95% CI [1.721, 7.136]). The comparison of the number of individuals observed between unlogged and logged forest for carnivores and omnivores were not significantly different based on the two-sample Poisson Test.

3.4. Observation methods

Our analysis found differences between observations recorded using different methods. We found significant differences between animal signs (mean = 17.143) and visual observation (mean = 1.357) methods in unlogged forests (Normal Approximation = 13.732, df = 26, p = 0.001, 95% CI [13.53, 18.04]) and between animal signs (mean = 12.643) and visual observation (mean = 0.929) in logged forests (Normal Approximation = 11.898, df = 26, p = 0.001, 95% CI [9.785, 13.64]). A comparison between unlogged (mean = 17.14) and logged forests (mean = 12.64) found differences for observations using animal signs (Normal Approximation = 3.085, df = 26, p = 0.002, 95% CI [1.641, 7.359]), however, visual observation methods did not show significant differences based on the two-sample Poisson Test.

4. Discussion

4.1. Impacts of logging on diversity

This study addresses a significant research gap on the impacts of logging on medium and large sized mammals in Peninsula Malaysia. While mammals are commonly found in unlogged forest, little information is available on the range of forest types they use (Francis, 2008). The study is also very relevant for conservation research and planning in Malaysia as the study area was home to a significant proportion of the medium and large mammals, with 13% of the total number of mammals found in Peninsular Malaysia recorded (Davison & Zubaid, 2007), including a number of very rare species such as the critically endangered Sumatran rhinoceros.

The survey found that the species with the highest number of observations in our study area were the Malayan Tapir (*T. indicus*) and wild pig (*S. scrofa*), which is consistent with similar studies in Peninsular Malaysia (Traeholt & Sanusi, 2009; Sasidhran et al., 2016). In our study area *S. scrofa* was most abundant in logged forest, while, *T. indicus* was most abundant in the unlogged forest. Both *S. scrofa* and *T. indicus* are well-distributed mammals in Peninsular Malaysia and found in many different forest types (Kawanishi, Sunquist, & Othman, 2002; Holden, Yanuar, & Martyr, 2003; Novarino, Karimah, Silmi, & Syafri, 2004; Traeholt & Sanusi, 2009). These results suggest that unlogged forest is important for tapir whereas logged forest is favourable for wild boar. The relatively high probability of occurrence of tapirs is probably attributed to the combination of large protected areas that still contain sizeable tracts of unlogged forest (Linkie et al., 2013). In contrast, wild boar is more abundant in logged forest compared to unlogged forest due to the absence of top predator (i.e. tiger) (Ickes, 2001; Sasidhran et al., 2016; Adila et al., 2017).

Primate fauna in Peninsular Malaysia are represented by 11 species from three families (Francis, 2008) and a total of six species of primates were observed in the study area. The primate species observed were *H. lar*, *S. syndactylus*, *T. obscurus*, *P. melalophos*, *M. nemestrina* and *M. fascicularis*. The siamang (*S. syndactylus*), dusky leaf monkey (*T. obscurus*) and white thigh langur (*P. melalophos*) recorded in this study were found mainly in hilly areas in the unlogged forest. These findings are consistent with Mohd-Azlan (2006) study of logged forests of Peninsular Malaysia.

Differences in food resource availability between logged and unlogged forest is likely to be one of the key ecological drivers for differences in diversity found in both forest types. These differences were revealed by the patterns of occurrence of certain groups of mammals such as the primates. For example, higher numbers of the White-handed Gibbon is a reflection of good quality food resources (Asensio, Brockelman, Malaivijitnond, & Reichard, 2014). The high occurrence of Gibbons and leaf monkeys in the unlogged forest in this study may be attributed to the abundance of food sources. However, in certain areas, logging activities were still ongoing during the surveys, thus these activities may also be responsible for lower numbers as primates may avoid these areas. While the comparison of feeding guilds found that herbivores preferred unlogged forests compared to logged forests. Large herbivores such as elephants and Malayan Tapir which are generalists were observed equally in both habitats. Elephants are common in open canopy or logged forests (Sitompul, Griffin, Rayl, & Fuller, 2013) as logged forests are regenerating and provide food in abundance for browsing such as bamboos, rattan and grasses. Alfred, Ahmad, Payne, Williams, and Ambu (2012) showed that elephants in the logged forest occasionally moved to patches of unlogged forest. In contrast the comparison of carnivores and omnivores in both forest types suggest that these groups did not favour either. This may be because they have a preference for habitat edges which are associated with increased numbers of small mammal prey species (Salek, Kreisinger, Sedlacek, & Albrechat, 2010).

Our study is in line with previous research which has shown that

occurrences of mammals in logged forests are not rare and that logged forests can support a wide diversity of medium to large size mammals (Mohd-Azlan, 2006). For example, Mark Rayan and Shariff (2009) found selectively logged forest in Gunung Basor Forest Reserve Peninsular Malaysia accommodates a population of tigers (Mark Rayan & Shariff, 2009) and Kitamura, Thong-Aree, Madsri, and Poonswad (2010) found that the sporadically logged Bala forest on the Thai-Malaysian border has at least 17 species of medium to large sized mammals. While logged forests can support medium and large mammals our study found species richness was lower in logged forests. Such patterns have also been found in other locations such as northern Borneo (Berry et al., 2010) and the Amazon (Parry, Barlow, & Peres, 2007). Commonly species richness declines with increasing habitat modification (Barlow, Overal, Araujo, Gardner, & Peres, 2007) where some taxa, in particular small mammals show a decline in diversity but increase in overall abundance (Bawa & Seidler, 1998).

The small differences in richness and abundance found between logged and unlogged areas are likely to be the property of the relatively good ecosystem conditions (i.e. nature of disturbance) and landscape context as the reserves are relatively unimpacted by the effects of connectivity, intrusion, excision and fragmentation (Mohd-Azlan, 2006). Furthermore, the differences for medium and large mammals may not be representative for all species, as other studies such as Gibson et al. (2011) found that even though biodiversity values were substantially lower in degraded forests, mammals were less sensitive to disturbances.

4.2. Rare species

Six species were observed only once during the study period, with five of these found only in unlogged forests. These single observations in most cases represent species which are rare in the area except for the greater mouse-deer (*T. napu*) which are well-distributed in Peninsular Malaysia (Francis, 2008) and only one observation was made. Greater mouse-deer's are currently not at risk and one of the reasons for the single observation of this species was the difficulty in detecting footprints due to their small size (Francis, 2008). However, Heydon and Bulloh (1997) found that mouse-deer appeared to be more adversely affected by selective logging than other ungulates or primates. Matsubayashi and Jum-Rafiah (2005) found that greater mouse-deer were found in less disturbed in forests, while lesser mouse-deer (*T. kanchil*) preferred immature logged forests. In this study, of the nine observations made for lesser mouse-deer, four were recorded in unlogged forests and five in logged forests.

Interestingly, we found tracks of the Sumatran rhinoceros (*S. rhinoceros*) during the survey in 2008, a critically endangered species (DWNP, 2010; IUCN, 2015). Even though the study area are known to be rhinoceros habitat (Abdul-Kadir, 2006), no signs were observed in the consecutive years, 2013 and 2014. The last documented indirect observation of the Sumatran rhinoceros in Peninsular Malaysia was in 2010 (Magintan, Rufino, Cosmas, & Dennis, 2010) in the unlogged forest of Temenggor, the northern part of Peninsular Malaysia. Despite a huge effort by the DWNP and other agencies in carrying out surveys and camera trapping, the occurrence of Sumatran rhinoceros is uncertain.

There were also single observations of other species, namely *C. sumatraensis*, *N. nebulosa*, *C. alpinus,* and *B. gaurus*, suggesting that these species rarely occur in the study area or only at low densities. All of the species recorded with single observations, except for the greater mouse deer are critically endangered and protected under Second Schedule of the wildlife conservation Act 2010. Similar to other surveys in Malaysia, those species were seldom observed, most likely due to their low density, even though the habitat is suitable in our study area. For example, Wild gaur (*B. gaurus*) is found mostly in the lowland forests of Peninsular Malaysia such as Taman Negara National Parks and Temenggor-Belum forest complexes (Dennis, 2006; Dennis 2008). Wild gaur also prefers forest edges and logged forests with abundant food resources (Ebil, 1982). While, *C. alpinus* occurs across Peninsular Malaysia (Francis, 2008) and has been recorded in the northern parts of Endau-Rompin (Gumal et al., 2014), Taman Negara (Kawanishi & Sunquist, 2004) and Jerangau Forest Reserve in Terengganu (Mohd-Azlan & Sharma, 2006). Finally, *C. sumatraensis* has been reported to occur in unlogged rainforests of Peninsular Malaysia in Taman Negara Pahang, Terengganu and Kelantan (Kawanishi & Sunquist, 2004) and in the highly fragmented forest of Bala, southern Thailand (Kitamura et al., 2010).

4.3. Limitations and future research

There are three main limitations of this study, some of which are also common to many field survey studies and may be addressed in future research. Firstly, the surveys were only limited to medium and large mammals. Secondly, the number of researchers undertaking each survey was not of equal number and the time interval spent by researchers or the effort was not always equal. Finally, direct and indirect methods had differing effectiveness between forest types and species. While the first two are difficult to account for due to practical issues associated with variability in weather, staffing, terrain, cost of equipment for such a large area (e.g. camera trapping) etc we specifically addressed differences in survey methods in this study.

Overall we found visual observations were not as effective as indirect observations. Evidence for indirect observations was obtained mostly on the bare ground along the routes or trails used by animals. Footprints of larger mammals such as elephants, tapirs and sambar were identified easily compared to medium sized mammals such as the felids, and mouse-deer. Thus visual observation were likely to be more accurate the larger the mammal. Animal footprints in logged forests compared to unlogged forests were prone to be removed by heavy rain because of less canopy cover. However, for certain mammal groups such as the primates which are active during the day (Francis, 2008) they require visual observation technique.

While our research findings provide baseline information on the occurrence of wildlife in the study area, more ecological research, population studies, especially on species with low-density species can be conducted using advanced methods such as camera trapping. To obtain a complete inventory of mammals in TFR and PFR, all possible methods of study need to be included in the future research.

5. Conclusions

The results of this study have highlighted the importance of both unlogged and logged forests for a high number of species and the significance of these forest reserves. Larger mammals such as elephants especially benefited from logging activities where sprouting and regeneration of new plants in logged forests supply a variety of food sources. However, while some mammals benefit, other smaller organisms were affected. Furthermore, there is a possibility of poachers encroaching the area due to the presence of many trails (e.g. logging road) enabling access. Conservation in these logged forested areas must account for differences in impacts of logging between medium and large mammals. Additionally, the presence of a number of threatened and listed species in low numbers indicate the need for increased patrolling by the authorities to combat poaching.

Acknowledgements

We thank the Department of Wildlife and National Parks, Peninsular Malaysia, particularly the Director of Biodiversity Conservation Division for organising the surveys, and state directors for providing staffs and logistics during the surveys. We are indebted to wildlife rangers of the department who performed the surveys and data collection. We thank the Forestry Department Peninsular Malaysia for

providing logistic support and their consent to do research in the study area.

References

Abdul-Kadir, A. H. (2006). The distribution of the Sumatran Rhinoceros (Dicerorhinus sumatrensis) and threats to their population in Peninsular Malaysia. In O. Sahir, Y. Siti Hawa, S. Elagupillay, M. N. Shukor, A. Norhayati, & M. S. Shahrul Anuar (Eds.). *In Management and status of resources in protected areas of Peninsular Malaysia* (pp. 11–124). Kuala Lumpur, Peninsular Malaysia: Department of Wildlife and National Parks.

Adila, N., Sasidhran, S., Kamarudin, N., Puan, C. L., Azhar, B., & Lindenmayer, D. B. (2017). Effects of peat swamp logging and agricultural expansion on species richness of native mammals in Peninsular Malaysia. *Basic and Applied Ecology, 22*, 1–10.

Alfred, R., Ahmad, A. H., Payne, J., Williams, C., & Ambu, L. N. (2012). Home range and ranging behavior of Bornean Elephant (Elephas maximus borneensis) females. *PUBLIC LIBRARY OF SCIENCE, 7*, e31400. http://dx.doi.org/10.1371/journal.pone.0031400.

Appanah, S., & Weiland, G. (1993). Will the management system for hill dipterocarp forests, stand up? *Journal of Tropical for Sciences, 3*, 140–158.

Asensio, N., Brockelman, W. Y., Malaivijitnond, S., & Reichard, U. H. (2014). White-handed Gibbon (Hylobates lar) core area use over a short-time scale. *Biotropica, 46*, 461–469.

Barlow, T., Overal, W. L., Araujo, I. S., Gardner, T. A., & Peres, C. A. (2007). The value of primary, secondary and plantation forests for fruit-feeding butterflies in the Brazilian Amazon. *Journal of Applied Ecology, 44*, 1001–1012.

Bawa, K. S., & Seidler, R. (1998). Natural forest management, and conservation of biodiversity in tropical forests. *Conservation Biology, 12*, 46–55.

Berry, N. J., Phillips, O. L., Lewis, S. L., Hill, K. J., Edwards, D. P., Tawatao, N. B., ... Keith, C. H. (2010). The high value of logged tropical forests: lessons from northern Borneo. *Biodivers. Conserv. 19*, 985–997.

Brook, B. W., Sodhi, N. S., & Bradshaw, C. J. A. (2008). Synergies among extinction drivers under global change. *Trends in Ecology & Evolution, 23*, 453–460.

Burivalova, Z., Sekercioglu, C. H., & Koh, L. P. (2014). Thresholds of logging intensity to maintain tropical forest biodiversity. *Current Biology, 24*, 1–6.

Campos-Arceiz, A., Traeholt, C., Jaffar, R., Santamaria, L., & Corlett, R. T. (2012). Asian Tapir are no elephants when it comes to seed dispersal. *Biotropica, 44*, 220–227.

Clarke, K. R., & Warwick, R. M. (2001). *Change in marine communities: an approach to statistical analysis and interpretation.* Plymouth, UK: PRIMER-E Ltd.

DWNP (2010). *Department of wildlife and national parks. Red list of mammals for peninsular Malaysia*. Kuala Lumpur, Malaysia: Department of Wildife and National Parks Peninsular Malaysia.

Davison, G. W. H., & Zubaid, A. (2007). The status of mammalian biodiversity in malaysia. In status of biological diversity in malaysia and threat assessment of plant species in Malaysia. In L. S. L. Chua, L. G. Kirton, & L. G. Saw (Eds.). *Proceedings of the seminar and workshop, 28–30 june 2005. forest research institute Malaysia* (pp. 3–27).

De Thoisy, B., Renoux, F., & Julliot, C. (2005). Hunting in northern French Guiana and its impact on primate communities. *Oryx, 39*, 149–157.

DeFries, R. S., Rudel, T., Uriarte, M., & Hansen, M. (2010). Deforestation driven by urban population growth and agricultural trade in the twenty-first century. *Nature Geoscience, 3*, 178–181.

Dennis, T. C. Y. (2006). Distribution of gaur in taman negara. *Journal of Wildlife and Parks, 23*, 1–9.

Dennis, T. C. Y. (2008). The distribution of gaur in titiwangsa main range −Temenggor forest reserve and its surrounding areas. In S. Elagupillay, Y. Siti-Hawa, A. H. Abdul-Kadir, H. Hasdi, B. L. Lim, H. Rosli, A. Noorlidah, M. N. Shukor, & I. Rahmah (Eds.). *In Biodiversity resources and conservation status in Peninsular Malaysia* (pp. 13–18). Kuala Lumpur, Peninsular Malaysia: Department of Wildlife and National Parks.

Ebil, Y. (1982). Habitat requirements for the Malayan Gaur (Bos gaurus hubbacki). *Journal of Wildlife and Parks, 1*, 7–15.

Edwards, D. P., & Laurance, W. F. (2013). Biodiversity despite selective logging. *Science, 339*, 646–647.

FAO (2010a). *Food and agriculture organization, global forest resources assessment 200–Main report*Rome, Italy: FAO Forestry Paper 140. Food and Agriculture Organization of the United Nations.

FAO (2010b). *Food and agriculture organization of the united nation global forest resources assessment 2010: country Malaysia, FRA2010/123.* Rome, Italy: Food and Agriculture Organization of the United Nations.

Fitzherbert, E. B., Struebig, M. J., Morel, A., Danielsen, F., Brühl, C. A., Donald, P. F., & Phalan, B. (2008). How will oil palm expansion affect biodiversity? *Trends in Ecology & Evolution, 23*, 538–545.

Francis, C. M. (2008). *A field guide to the mammals of South-East Asia.* UK.P: New Holland PublishersLondon392.

Gaveau, D. L. A., Wandono, H., & Setiabudi, F. (2007). Three decades of deforestation in southwest Sumatra: have protected areas halted forest loss and logging, and promoted re-growth? *Biological Conservation, 134*, 495–504.

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., ... Sodhi, N. S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature, 478*, 378–383.

Green, R. E., Cornell, S. J., & Balmford, A. (2005). Farming and the fate of wild nature. *Science, 307*, 550–555.

Gumal, M., Abu Bakar, M., Mohd Nawayai, Y., Liang, S. H., Lee, B., Low, C. P., ... Ng, S. (2014). *Small-medium wild cats of endau rompin landscape in johor.* Peninsular Malaysia: CATnews 01/201410–18 [8(Spring)].

Heydon, M. J., & Bulloh, P. (1997). Mousedeer densities in a tropical rainforest: the impact of selective logging. *Journal of Applied Ecology, 34*, 484–496.

Holden, J., Yanuar, A., & Martyr, D. J. (2003). The asian tapir in kerinci seblat national park, sumatra: evidence collected through photo-trapping. *Oryx, 37*, 34–40.

IUCN (2006). *Guidelines for the conservation and sustainable use of biodiversity in tropical timber production forest.* Gland, Switzerland: IUCN.

IUCN (2015). *IUCN red list of threatened species.* Gland, Switzerland: IUCN. Http://www.iucnredlist.org/[accessed 11 November 2015].

Ickes, K. (2001). Hyper-abundance of native wild pigs (Sus scrofa) in lowland dipterocarp rain forest of Peninsular Malaysia. *Biotropica, 33*, 682–690.

Jones, K. E., & Safi, K. (2011). Introduction Ecology and evolution of mammalian biodiversity. *Philosophical Transactions of the Royal Society B, 366*, 2451–2461.

Kawanishi, K., & Sunquist, M. E. (2004). Conservation status of tigers in a primary rainforest of Peninsular Malaysia. *Biological Conservation, 120*, 329–344.

Kawanishi, K., Sunquist, M., & Othman, S. (2002). Malayan tapir (Tapirus indicus): far from extinction in a malaysian rainforest. *Tapir Conservation, 11*, 23–27.

Kitamura, S., Thong-Aree, S., Madsri, S., & Poonswad, P. (2010). Mammal diversity and conservation in a small isolated forest of Southern Thailad. *The Raffles Bulletin of Zoology, 58*, 145–156.

Linkie, M., Guillera-Arroita, G., Smith, J., Ario, A., Bertagnolio, G., Cheong, F., ... Gumal, M. T. (2013). Cryptic mammals caught on camera: assessing the utility of range wide camera trap data for conserving the endangered Asian tapir. *Biological Conservation, 162*, 107–115.

Magintan, D., Rufino, M. B. M., Cosmas, N., & Dennis, T. C. Y. (2010). Some evidences of sumatran rhinoceros presence in temenggor forest reserve. *Perak. Journal of Wildlife and Parks, 26*, 5–10.

Mark Rayan, D., & Shariff, W. M. (2009). The importance of selectively logged forests for tiger conservation: a population density estimate of tigers Panthera tigris in Peninsular Malaysia. *Oryx, 43*, 48–51.

Martin, P. A., Newton, A. C., Pfeifer, M., Khoo, M., & Bullock, J. M. (2015). Impacts of tropical selective logging on carbon storage and tree species richness: a meta-analysis. *Forest Ecology and Management*. http://dx.doi.org/10.1016/j.foreco.2015.07.010.

Matsubayashi, H., & Jum-Rafiah, A. S. (2005). Activity and habitat use of two sympatric mouse-deer species Tragulus javanicus and Tragulus napu, in Sabah, Malaysia Borneo. *Malayan Nature Journal, 57*(2), 235–241.

Mohd-Azlan, J., & Sharma, D. S. K. (2006). The diversity and activity patterns of wild felids in a secondary forest in Peninsular Malaysia. *Oryx, 40*, 36–41.

Mohd-Azlan, J. (2006). Mammal diversity and conservation in a secondary forest in peninsular Malaysia. *Biodiversity and Conservation, 15*, 1013–1025.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature, 403*, 853–858.

Novarino, W., Karimah, S. N., Silmi, M., & Syafri, M. (2004). Habitat use by malay tapir (Tapirus indicus) in west sumatra, Indonesia. *T Apir Conservation, 13*(2), 14–18.

O'Farrill, G., Galetti, M., & Campos-Arceiz, A. (2013). Frugivory and seed dispersal by tapir: an insight on their ecological role. *Integrative Zoology, 8*, 4–17.

Okuda, T., Suzuki, M., Adachi, N., Quah, E. S., Hussein, N. A., & Manokaran, N. (2003). Effect of selective logging on canopy and stand structure and tree species composition in a lowland dipterocarp forest in peninsular Malaysia. *Forest Ecology and Management, 175*, 297–320.

Olupot, W., Barigyira, R., & Chapman, C. A. (2009). The status of anthropogenic threat at the people-park interface of Bwindi Impenetrable National Park, Uganda. *Environmental Conservation, 36*, 41–50.

Parry, L., Barlow, J., & Peres, C. A. (2007). Large-vetebrate assemblages of primary and secondary forests in the Brazillian Amazon. *Journal of Tropical Ecology, 23*, 653–662.

Phillips, O. L. (1997). The changing ecology of tropical forests. *Biodiversity and Conservation, 6*, 291–311.

Rowe, T. (1988). Definition, diagnosis, and origin of Mammalia. *Journal of Vertebrate Palentology, 8*, 241–264.

Salek, M., Kreisinger, J., Sedlacek, F., & Albrechat, T. (2010). Do prey densities determine preferences of mammalian predators for habitat edges in an agricultural landscape? *Landscape and Urban Planning, 98*, 86–91.

Sasidhran, S., Adila, N., Hamdan, M. S., Samantha, L. D., Aziz, N., Kamarudin, N., ... Azhar, B. (2016). Habitat occupancy patterns and activity rate of native mammals in tropical fragmented peat swamp reserves in Peninsular Malaysia. *Forest Ecology and Management, 363*, 140–148.

Sato, H. (2014). The roles of primates as seed dispersers. *Primate Research, 30*, 53–78.

Schlamadinger, B., & Marland, G. (1996). The role of forest and bioenergy strategies in the global carbon cycle. *Biomass Bioenergy, 10*, 275–300.

Sitompul, A. F., Griffin, C. R., Rayl, N. D., & Fuller, T. T. (2013). Spatial and temporal habitat use of an Asian Elephant in Sumatra. *Animal, 3*, 670–679.

Sodhi, N. S., Lian, P. K., Brook, B. W., & Ng, P. K. L. (2004). Southeast Asia biodiversity: an impending disaster. *TRENDS in Ecology and Evolution, 19*, 654–660.

Southworth, J., Nagendra, H., & Cassidy, L. (2012). Forest transition pathways in asia –studies from Nepal, India, Thailand, and Cambodia. *Journal of Land Use Science, 7*, 51–65.

Traeholt, C., & Sanusi, M. (2009). Population estimates of malay tapir, tapirus indicus, by camera trapping in krau wildlife reserve, Malaysia. *T Apir Conservation, 18*, 18–26.

Vamosi, J. C., & Vamosi, S. M. (2008). Extinction risk escalates in the tropics. *PloS One, 3*(12), e3886. http://dx.doi.org/10.1371/journal.pone.0003886.

Walton, Z. L., Poudyal, N. C., Hepinstall-Cymerman, J., Gaither, C., & Boley, B. B. (2015). Exploring the role of forest resources in reducing community vulnerability to the heat effects of climate change. *Forest Policy and Economics*. http://dx.doi.org/10.1016/j.forpol.2015.09.001.

World Bank (2008). *Forests sourcebook: practical guidance for sustaining forests in development cooperation.* Washignton, DC USA: World Bank.