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Original Research Article

Quantifying species richness and composition of elusive rainforest mammals in Taman Negara National Park, Peninsular Malaysia

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A B S T R A C T

Rapid urban and agricultural expansions are taking place across Peninsular Malaysia resulting in wide spread forest conversion impacting on important conservation areas. Taman Negara National Park is one of the few protected nature reserves remaining largely intact from such anthropogenic threats. In this study we aimed to quantify species richness, and relative abundance and composition of native mammals in lowland and highland forest in Taman Negara National Park. We deployed cameras at 216 sampling plots in the study areas for 14,776 and 6935 trap nights in lowland and highland forest respectively. Our results show that lowland and highland forest have similar species richness, while highland forest has higher mammal abundance, which is likely to be caused by anthropogenic pressures on lowland forest adversely affecting mammal populations. Both forest types have similar mammal species composition. The mammal community includes most of the rare and endangered species in the region, including Malayan pangolin, Asian elephant, tiger, dhole, large-spotted civet, and Asian tapir. The region of the national park that was less likely to be vulnerable to logging, human settlement, agricultural expansion, and poaching (i.e. the Terengganu's sector), had higher mammal species richness, while the Pahang's sector had lower species richness. Mammal species richness increased with proximity to the park boundary and distance from the nearest river but decreased with the increasing number of intruders. This has important implications for management of the edges of protected nature reserves. In the coming decades, the pristine nature of Taman Negara National Park will become highly threatened if anthropogenic activities inside and outside the park are not monitored. It is vital that the responsible agencies tackle these threats through aggressive enforcement and the creation of a robust framework to monitor any land developments that take place in the vicinity of Taman Negara National Park.

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1. Introduction

Protected nature reserves play a fundamental role in maintaining ecological integrity (Pouzols et al., 2014; Venter et al., 2014; Wegmann et al., 2014), providing habitat, food and raw material for indigenous inhabitants, genetic materials, a barrier against disasters, a stable source of resources, and many ecosystem goods and services (Watson et al., 2014; Burton et al., 2012). There are more than 202,467 protected areas known worldwide, comprising 14.7% of the Earth's land surface, covering almost 20 million square kilometers (IUCN, 2016). As the world's population grows and the demand on natural resources increases, protected nature reserves become both important and threatened by climate change, agricultural expansion, poaching, unsustainable logging, pollution, invasive species, proliferation of road networks, habitat fragmentation and forest degradation (Thomas and Gillingham, 2015; Barber et al., 2014; Johnston et al., 2013).

There is a long history of protected area establishment in Peninsular Malaysia with the first protected nature reserve, the Chior Reserve, gazetted in 1903 (Hezri, 2014). Since then the number of established protected nature reserves have grown substantially, with gazetting and management conducted by both federal and state governments (Suksuwan, 2008). Nevertheless, large areas of the lowland and highland forests predominantly in the coastal areas of Peninsular Malaysia have been converted into oil palm agriculture and urbanized areas (Tee et al., 2018; Adila et al., 2017; Sasidhran et al., 2016; Azhar et al., 2011). The majority of the remaining forests are found within forest complexes along the main central mountain ranges.

Previously known as King George V National Park, Taman Negara National Park (TNNP) is among the oldest and the largest protected nature reserve in the country (UNESCO, 2019). It is widely known for its reputation as one of the world's oldest tropical rainforests, estimated to be more than 130 million year old (Teh and Nik Norma, 2015: Khalid et al., 2013). TNNP is said to host 3000 species of plants, 150 mammals, 480 birds, 30 rodents (UNESCO, 2019) and more than 80 species of bats (Ahmad, 2007), including some rare mammals, such as the gaur, sun bear, and Asian tapir. Peninsular Malaysia is also found within Sundaland, one of 25 global biodiversity hotspots which represent the most biologically richest and endangered terrestrial eco regions globally (Myers, 2000). However, to date, little is known whether these numbers portray reality, as mammals and their habitat are continuously being subjected to exploitation and face enormous threats including habitat degradation and loss, human-wildlife conflicts and poaching (Botani and Powell, 2012).

Although TNNP is the largest expanse of pristine lowland rainforest in the peninsula, there is a lack of current research assessing the status of biodiversity in the national park and the link between mammal diversity and landscape characteristics and disturbance. This research gap is partly driven by the difficulty of monitoring cryptic, shy and secretive species commonly found in TNNP. Tropical mammals are some of the most threatened species globally, but are also the some of the most poorly researched due to the difficulty of undertaking field studies (Gonthier and Castaneda, 2013; Bhattacharya et al., 2012; Tobler et al., 2008; Linkie et al., 2007). Therefore, there is a critical need for systematic surveys to document tropical wildlife such as through camera trapping (Mugerwa et al., 2012; Karanth and Nichols, 2010). In addition, for conservation planning it is not only important to document wildlife diversity, but also assess the response of forest wildlife to anthropogenic activities.

In this study, we used camera trap data to determine mammalian biodiversity and to identify the key drivers that influence mammal abundance and richness in lowland and highland forest. In Malaysia, highland forests largely remain undeveloped because of the difficult terrain, making it unsuitable for agriculture, timber extraction or human settlements. However, in recent times there has been an increase in disturbance due to hydroelectric dam projects, highways and resorts. The objectives of this study were: 1) to compare mammal species richness and relative abundance between lowland and highland forest; 2) to identify the key drivers that determine mammal species richness in the study areas; and 3) to compare mammal species composition between lowland and highland forest with respect to IUCN species status. We concluded by highlighting the importance of specific drivers of community assemblage and mammal species richness in the context of park management and land use change in peninsula Malaysia.

2. Material and methods

2.1. Study area

This study was conducted within TNNP in north-central Peninsula Malaysia (4°10’ - 4°56′N, 102°00–103°00′E), encompassing an area of approximately 4373 km^2 (Fig. 1). Water covers about 70% of the park area including Lake Kenyir, Tembeling river, Tahan river, Tenur river and Sephia river. Taman Negara is primarily composed of two forest types: lowland to the highland forest. Approximately, 57% (2484 km^2) of its area is 76–305 m above sea level (a.s.l.), 32% (1394 km^2) from 305 to 762 m a.s.l. and another 11% (479 km^2) consists of altitude more than 762 m a.s.l. (Ahmad, 2007). In this study, we divided the sampling plots into lowland and highland forests. Lowland forest was defined as <360 m a.s.l. and highland forest was >360 m a.s.l. (Forestry Department of Peninsular Malaysia, 2019; Grubb et al., 1963). Taman Negara National Park is classified as Environmentally Sensitive Area (ESA) 1 and under the Central Forest Spine (CFS) plan (The Department of Town and Country Planning, 2009). Its boundary stretches 426.34 km and is constantly exposed to ecotourism and logging activities (Ibrahim and Hassan, 2011). The park has three sectors (Fig. 1) represented by the three states which have state-specific park practices such as Kelantan, Pahang and Terengganu.

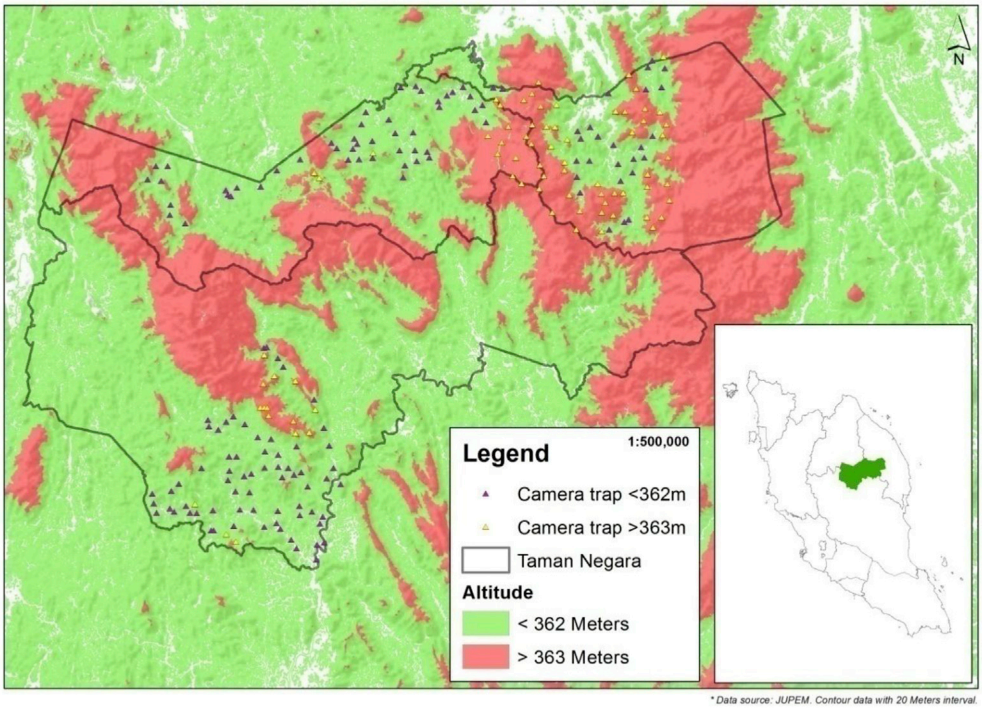

Fig. 1. Camera trap locations in lowland and highland forest of Taman Negara National Park.

2.2. Data acquisition

We used infrared digital camera traps (O'Connell et al., 2011) (Reconyx HC500 Full HD 1080P equipped with 8 GB SD - secure digital card capacity, 12 double AA batteries, casing, and mounted to a tree with a cable lock), triggered automatically by animal movement. Although a single photo was taken for every 5-s interval, species count was limited to those captured within the hour. This was to prevent double count of individual animal (Tobler et al., 2008). A total of 216 sampling plots were set up in the study areas. Each plot covered an area of 2.5 × 2.5 km with two cameras at each plot. One-hundred and forty-four sampling plots were established in lowland forest and 72 sampling plots in highland forest. Cameras were placed in pairs 7–10 m apart (Cheyne and Macdonald, 2011) and 50 cm from the ground (Mugerwa et al., 2012). The camera trap surveys were conducted between March 2014 and November 2014 in Kelantan and Terengganu and from March 2015 to October 2015 in Pahang. The cameras were not deployed in areas designated for ecotourism.

Each camera trap location was georeferenced using a Global Positioning System (GPS) receiver with built-in barometric altimeter (Garmin GPS Map 62cs, Garmin International Inc., Kansas City, USA) and then plotted in a geographical information systems (GIS) using ArcMap 10.2.2 (ESRI Inc., Redlands, CA). The proximity distance to the park edge and rivers was calculated using the GIS. Each animal image was identified using expert knowledge and with the help of “A field Guide to the mammals of South-East Asia” (Francis, 2008).

2.3. Data analysis

We conducted three different statistical tests to identify the key drivers that determine mammal species richness: ANOVA for assessing differences in species richness and relative abundance between lowland and highland forest; a Generalized Linear Model for characterizing the predictors of mammal species richness and SIMPER to characterise community assemblages in the highland and lowland forest.

We standardized species richness and number of animal images by dividing them with the number of trapping nights. A one-way unbalanced design analysis of variance (ANOVA) was used to compare species richness and the number of animal images in lowland ($n = 144$) and highland ($n = 72$) forest habitat. We used the number of animal images to assess relative abundance (Rovero et al., 2010). The normality and homogeneity of variance of both richness and relative abundance were first improved by performing a square-root transformation before the ANOVA (Cuesta et al., 2008; Magura et al., 2005; Gebeyehu and Samways, 2002). In addition, we assessed the number of intruders recorded in the camera traps using the same method as for the animal surveys.

To examine the relationship between mammal species richness and predictor variables, a Generalized Linear Model (GLM) was used. The predictor variables were altitude, distance to park boundary, distance to the nearest river, number of intruders (i.e. poachers), number of trapping nights, and state-specific park management (i.e. Kelantan, Pahang or Terengganu). Intruders were identified in the camera trap images by their appearance. The altitude range was used to categorize the habitat types into highland or lowland forest (Linkie et al., 2007). Due to identification difficulties (i.e. low picture quality and weather conditions), we were not able to identify the species of chevrotains and civets and thus were recorded as merely chevrotain or civet, respectively.

Prior to regression modeling, a correlation test was performed to detect multicollinearity among all the predictor variables. We tested for strongly correlated variables using a Wald test with a threshold of $|r|<0.7$ to avoid bias in model estimation (Dormann et al., 2013). However, no predictors were dropped as multicollinearity between predictor variables was weak. For the GLM the estimated slope value was reported for each significant predictor variable. We used a Poisson distribution, log-link function to estimate the relationship between species richness and the predictor variables. The value of R^2 criterion was used to determine how close the data are to the fitted regression line. These analyses were performed via Genstat version 15 (VSNI Hermel, Hempstead, UK) a statistical package for windows (Payne, 2009).

Finally, we assessed similarity percentages (SIMPER) to determine species contribution into community assemblages in highland and lowland forest. The SIMPER tests were conducted using multivariate statistical analysis via Primer-e Version 6 (Primer-e Ltd., Lvybridge, United Kingdom) a statistical package for windows (Clarke, 1993). Analyses of similarity (ANOSIM) were used to examine the differences in mammal species composition between highland and lowland forest. We ran permutation tests 999 times to obtain the inferential result. We used the Bray-Curtis measure of similarity, comparing in turn, each species in lowland with each species in highland habitat.

3. Results

3.1. Species richness and relative abundance of lowland and highland forest

We recorded 8556 and 5837 images from 14,776 to 6935 trap nights in lowland and highland forest, respectively. The species identified with the camera traps constituted 15 families, 31 genera and 34 species (Table 1). The most frequently photographed species was southern red muntjac (*Muntiacus muntjac*) with 2923 (20.31%) images from 160 sampling plots. This was followed by sun bear (*Helarctos malayanus*) with 2017 (14.01%) images from 144 sampling plots and wild boar (*Sus scrofa*) with 1758 (12.21%) images from 134 sampling plots. Camera traps from both habitat types only captured four (0.03%) images of gaur (*Bos gaurus*), three (0.02%) images of long-tailed macaque (*Macaca fascicularis*) and two (0.01%) images of Asian small-clawed otter (*Aonyx cinereus*) (Table 2). The macaque is mostly arboreal and the otter highly aquatic.

Mammal species richness in highland forest (mean $\pm$ SE $= 0.09 \pm 0.02$ species per trap night) did not differ significantly ($df = 1$; $F = 0.14$; $p = 0.711$) from lowland forest (mean $\pm$ SE $= 0.08 \pm 0.01$ species per trap night). However, the number of mammal images in highland forest (mean $\pm$ SE $= 0.91 \pm 0.10$ images per trap night) was significantly higher ($df = 1$; $F = 5.31$; $p = 0.022$) than lowland forest (mean $\pm$ SE $= 0.62 \pm 0.07$ images per trap night).

3.2. Environmental factors that underpin mammal species richness

Our results indicated that five predictor variables significantly determined species richness ($R^2 = 18.77\%$). As suspected, mammal species richness increased with larger number of total trap nights and with increasing distance from nearest river (Table 3). We also found that mammal species richness was negatively influenced by distance to nearest park boundaries and the presence of intruders (Table 3). Mammal species richness was influenced by state-specific park management (Table 3). Terengganu had the highest slope in species richness, but Pahang had the lowest. Altitude had no significant effect ($p > 0.05$) on mammal species richness.

3.3. Species composition in lowland and highland forest

In lowland habitat, the mammal community was dominated by southern red muntjac (21.30%), followed by wild boar (17.04%), Malayan porcupine (14.51%), sun bear (12.12%), Asian tapir (9.28%), mouse deer (6.30%), pig-tailed macaque (4.67%), leopard (3.57%), and Asian elephant (3.31%). In highland forest, ten species constituted more than 90% of the mammal community (Table 4): southern red muntjac (23.90%), sun bear (20.78%), Asian tapir (7.49%), wild boar (7.05%), leopard cat (6.30%), Malayan porcupine (6.23%), golden cat (5.82%), clouded leopard (5.78%), civet (3.62%), and leopard (3.17%) (Table 4). No significant difference in species composition was detected between lowland and highland forest (ANOSIM, number of permutations = 999; Global $R = 0.028$; $p = 0.15$).

4. Discussion

Taman Negara National Park and other protected nature reserves are efficient and effective *in-situ* conservation means to address biodiversity loss in Southeast Asia. These nature reserves must be protected from deforestation and poaching. Our findings demonstrate that TNNP plays a crucial role as regional biodiversity hotspot as the national park supports the majority

Table 1
Checklist of species and the IUCN red list of threatened species in lowland and highland forests of Taman Negara National Park.

Family	Species	IUCN status
Bovidae	**Gaur**	Vulnerable
	Bos gaurus	
	Sumatran serow	Vulnerable
	Capricornis sumatraensis	
Cervidae	**Sambar deer**	Vulnerable
	Rusa unicolor	
	Southern red muntjac	Least concern
	Muntiacus muntjak	
Suidae	**Wildboar**	Least concern
	Sus scrofa	
Tragulidae	**Chevrotain**	Least concern
	Tragulus kanchil	Least concern
	Tragulus napu	
Canidae	**Dhole**	Endangered
	Cuon alpinus	
Felidae	**Golden cat**	Near threatened
	Catopuma temminckii	
	Clouded leopard	Vulnerable
	Neofelis nebolusa	
	Leopard	Vulnerable
	Panthera pardus	
	Tiger	Endangered
	Panthera tigris	
	Marbled cat	Near threatened
	Pardofelis marmorata	
	Leopard cat	Least concern
	Prionailurus bengalensis	
Herpestidae	**Short-tailed mongoose**	Near threatened
	Herpestes brachyurus	
Mustelidae	**Asian small-clawed otter**	Vulnerable
	Aonyx cinereus	
	Yellow-throated marten	Least concern
	Martes flavigula	
	Malayan weasel	Least concern
	Mustela nudipes	
Ursidae	**Sun bear**	Vulnerable
	Helarctos malayanus	
Viverridae	**Binturong**	Vulnerable
	Arctictis binturong	
	Civet	Least concern
	Arctogalidia trivirgata	Least concern
	Paguma larvata	Least concern
	Paradoxurus hermaphroditus	Least concern
	Prionodon linsang	Least concern
	Viverra tangalunga	Endangered
	Viverra megaspila	Least concern
	Viverra zibetha	
Tapiridae	**Asian tapir**	Endangered
	Tapirus indicus	
Manidae	**Sunda pangolin**	Critically endangered
	Manis javanica	
Cercopithecidae	**Long-tailed macaque**	Least concern
	Macaca fascicularis	
	Pig-tailed macaque	Vulnerable
	Macaca nemestrina	
	White-thighed langur	Near threatened
	Presbytis siamensis	
Elephantidae	**Asian elephant**	Endangered
	Elephas maximus	
Hystricidae	**Malayan porcupine**	Least concern
	Hystrix brachyura	

Note: Global protection status under International Union for Conservation of Nature Red List of Threatened Species (IUCN) 2019-1.

Table 2
Number of species mammal recorded and number of images for each species recorded.

Species	Total # images	
	Lowland	Highland
Southern red muntjac	1925	998
Sun bear	759	1258
Wild boar	1373	385
Asian elephant	943	303
Asian tapir	804	307
Malayan porcupine	646	223
Pig-tailed macaque	569	193
Golden cat	193	409
Yellow-throated marten	48	446
Chevrotain	386	23
Leopard	220	149
Clouded leopard	64	244
Leopard cat	46	251
Marbled cat	15	262
Civet	131	109
Sambar deer	208	0
Tiger	71	91
White-thighed langur	113	25
Short-tailed mongoose	3	49
Sumatran serow	4	45
Malayan weasel	4	28
Dhole	9	20
Binturong	11	13
Sunda pangolin	3	5
Gaur	4	0
Long-tailed macaque	3	0
Asian small-clawed otter	1	1

Table 3
Key landscape drivers for mammal species richness.

Variable	Slope	SE	Wald statistic	p
Distance to nearest boundary	−0.000003601	0.00000074	23.7	<0.001
Distance to nearest river	0.00002692	0.00000196	189.3	<0.001
Intruders	−0.001461	0.000474	9.5	0.002
Total trap nights	0.0029167	0.0000989	870.6	<0.001
State (reference level: Kelantan)			1402.8	<0.001
Pahang	−0.1362	0.0113		
Terengganu	0.2594	0.0100		

of flagship rainforest mammal community including 19 conservation priority species (Table 1). Most forest mammal species in lowland forest in Peninsular Malaysia, particularly large-size animals have been extirpated due to commercial logging, agricultural expansion, habitat fragmentation and urbanization (Adila et al., 2017; Jamhuri et al., 2018; Sasidhran et al., 2016; Tee et al., 2018).

4.1. Species richness and relative abundance between lowland and highland forest

We found that mammal species richness in highland forest were similar to lowland forest. In terms of mammal abundance, highland forest appeared to have more individuals compared to lowland forest. Mammal abundance is likely to be lower in lowland forest due to increased anthropogenic disturbances such as tourism, poaching and upstream fishing forest (Ahumada et al., 2013; Wong and Linkie, 2013; Wilting et al., 2010). This is supported by our finding that the number of intruders caught by camera traps caused a significant decline in mammal species richness. This result is also in accordance with a study in Kerinci Seblat National Park which showed that habitat use by sun bears changed with lowland forest loss (Wong and Linkie, 2013).

4.2. Influence of landscape variables on mammal species richness

We found that mammal species richness decreased significantly with distances to protected nature reserve boundaries. Park boundaries are likely to be more disturbed and have a different structure to the interior (Laurance et al., 2011; Oluput and

Table 4
Species composition of forest mammals in the study areas.

Habitat/species	Average abundance	Species contribution (%)	Cumulative contribution (%)
Lowland forest			
Southern red muntjac	2.38	21.30	21.30
Wild boar	1.94	17.04	38.34
Malayan porcupine	1.40	14.51	52.85
Sun bear	1.45	12.12	64.97
Asian tapir	1.43	9.28	74.26
Chevrotain	0.95	6.30	80.56
Pig-tailed macaque	0.96	4.67	85.23
Leopard	0.66	3.57	88.80
Asian elephant	1.11	3.31	92.11
Highland forest			
Southern red muntjac	3.04	23.90	23.90
Sun bear	3.11	20.78	44.68
Asian tapir	1.40	7.49	52.17
Wild boar	1.53	7.05	59.22
Leopard cat	1.28	6.30	65.52
Malayan porcupine	1.20	6.23	71.75
Golden cat	1.53	5.82	77.57
Clouded leopard	1.24	5.78	83.35
Civet	0.80	3.62	86.97
Leopard	0.83	3.17	90.14

Sheil, 2010). Forest-edge habitats with strong vertical layering share characteristics that are a mixture of two or more plant communities or succession stages providing a greater selection of food and cover necessary to meet species requirements. For example, small ungulates such as chevrotain and muntjac are more common roaming edge areas (Barker, 2018; Brodie et al., 2014; Salek et al., 2010) consuming the abundant fruits, seeds and soft leaves (Farida et al., 2006; Matsubayashi and Sukor, 2005) mostly from fast-growing pioneer colonist rather than closed forest species. The presence of such kind of those herbivores in high densities further will attract adaptable and versatile carnivores' species such as civets (Brodie and Giordano, 2011), leopard cat (Azlan and Sharma, 2006), clouded leopards and leopards (Brodie et al., 2014; Athreya et al., 2013; Stein and Hayssen, 2013) to these areas.

Mammal species richness was determined by the state-specific park management where different sectors of TNNP are located. Terengganu's TNNP had higher mammal species richness than other sectors, most likely because logging and human settlement did not occur in neighboring forest reserves, along the national park's boundaries (Hedges et al., 2013). In contrast, Pahang's TNNP had had lower mammal species richness. Moreover, poaching is a more serious issue in Pahang compared to Kelantan and Terengganu. From 2013 to 2015, as many 39 poachers were apprehended in Pahang's TNNP, followed by 30 poachers in Kelantan's TNNP and 15 poachers in Terengganu's TNNP (Department of Wildlife and National Parks, 2015, 2014, 2013). The Pahang's and Kelantan's sectors also shared much of their borders with industrial oil palm plantations. Poaching can reduce wild animal populations that cross into adjacent plantations from the national park (Azhar et al., 2014, 2013).

Prior studies have noted the importance of water as a habitat requirement (Simpson, 2011; Yarrow, 2009). However, in this study, proximity to the nearest river was found to decrease mammal species richness. Rivers are important resources for many animals and are often home to a diverse assemblage of species.

Another important finding was the presence of intruders in the study area. The detection of 340 (2.36%) images of intruders shows that poaching remains a real threat and negatively influences the distribution, abundance and mammal species richness. The extensive presence of intruders is likely to cause a general decline in diversity due to poaching for bush meat or for the pet trade such as deer and gibbon (Jambari et al., 2015). Our results further support this previous research, which links species richness to the existence of poachers (Ratnayeke et al., 2018; Magintan et al., 2017; Azhar et al., 2014).

Finally, we found that total trap nights influence the number of animal images recorded. Longer total trap nights provide higher rates of detecting mammal species. It is possible that greater trapping effort is required to increase the probability of sampling all mammal species in the area.

Our analysis indicated that community assemblages in the study area were not influenced by altitude. Topography is an important factor that influences communities in a range of ways in which species select and utilize sites such as the provisioning of great Argus dancing grounds (Dinata et al., 2008), sambar deer home range (Yen et al., 2013), elephant's requirement for food (Jothish, 2013) and clouded leopard prey availability (Chiang et al., 2015). However, whether the patterns we found reflect real habitat selection or are due to the effects of human activities such as habitat fragmentation and poaching remain unclear.

Our results could be biased since the analysis was not rectified for imperfect detection of mammals (Royle and Nichols, 2003). Detection probabilities can give more satisfactory estimates of animal populations and ignoring detection probabilities may lead to overconfidence. Nevertheless, Welsh et al. (2013) indicated that the computation of detection probabilities can also result in bias from ignoring non-detection.

4.3. Mammal species composition in lowland and highland forests

Species composition did not differ significantly between lowland and highland forest. However, gaur, long-tailed macaque and sambar deer were recorded in highland forest and were not sampled in lowland forest. Surprisingly, the southern red muntjac was found to be the most abundant species in both areas. This result may be explained by the fact that southern red muntjac has the ability to adapt to a wide variety of forest types including primary, secondary, dry forest, hill forest, hill and grasslands habitats up to 3000 m a.s.l., likely due to its omnivorous diet (Francis, 2008). A previous study by Laidlaw (2000) on mammals in forest reserves in Peninsula Malaysia showed that the existence of mineral licks, and an abundance of food at the forest-edges in lowland forest are important factor increasing mammal species richness.

5. Conclusions

This study highlighted the importance of state-specific park management, distance to river, distance to the park boundary and intruder abundance as predictor variables in determining community assemblage and mammal species richness. This information can be used to tackle conflicts arising from and to plan for future land-use. Through habitat protection and enforcement measures protected nature reserves such as TNNP can be managed effectively to protect wildlife populations which include many rare species such as the gaur and tiger. We suggest that the landscape factors identified in this study are considered and integrated into conservation planning within the national park and other forest areas where natural habitat is preserved. Patrolling the park and its boundary should be done regularly to ensure the survival of conservation priority species. Finally, limiting human activities around park boundaries would greatly mitigate human wildlife conflict.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gecco.2019.e00607.

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