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Observations of occurrence and daily activity patterns of ungulates in the Endau Rompin Landscape, peninsular Malaysia

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Abstract: Camera trap data was used to study occurrence and daily activity patterns in the Endau Rompin Landscape of peninsular Malaysia during 2011, 2013 and 2015 to estimate Malayan Tiger *Panthera tigris jacksoni* population densities. By-catch data were also collected for seven ungulate species: Barking Deer *Muntiacus muntjak*, Bearded Pig *Sus barbatus*, Wild Boar *Sus scrofa*, Greater Mousedeer *Tragulus napu*, Lesser Mousedeer *Tragulus kanchil*, Malayan Tapir *Tapirus indicus* and Sambar Deer *Rusa unicolor*. Of these, Bayesian single-season occupancy analysis suggested that Barking Deer were the most widespread and Mousedeer spp. the least widespread during the study period. Bearded Pig, Malayan Tapir and Wild Boar were recorded in more than half of the camera trap area (Sambar Deer was excluded due to small sample size). Daily activity patterns based on independent captures in 2015 suggest that Barking Deer, Bearded Pig and Wild Boar are mostly diurnal, mousedeer species are crepuscular and Malayan Tapir strongly nocturnal.

Keywords: Bayesian single-season occupancy, by-catch, camera trap, daily activity pattern, Endau Rompin Landscape, occurrence, peninsular Malaysia, ungulate.

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INTRODUCTION

Of the 11 species of ungulates reported from Peninsular Malaysia (Francis 2008), 10 have been reported in the southern Endau Rompin Landscape (ERL). Banteng *Bos javanicus*, Gaur *Bos gaurus* and Sumatran Rhinoceros *Dicerorhinus sumatrensis* were recorded in the past century (Milton 1963; Davison & Kiew 1987; Burhanuddin et al. 1995). The other recently reported ungulate species are Barking Deer *Muntiacus muntjak*, Bearded Pig *Sus barbatus*, Greater Mousedeer *Tragulus napu*, Lesser Mousedeer *Tragulus kanchil*, Malayan Tapir *Tapirus indicus*, Sambar Deer *Rusa unicolor* and Wild Boar *Sus scrofa* (Aihara et al. 2016; WCS - Malaysia Program unpub.). Conservation of wildlife in peninsular Malaysia is regulated by the Wildlife Conservation Act (2010), including harvesting for commercial purposes. Bearded Pig and Malayan Tapir are listed as Totally Protected, and Barking Deer, Greater Mousedeer, Lesser Mousedeer, Sambar Deer and Wild Boar as Protected under the Wildlife Conservation Act (2010). Their status on the IUCN Red List of Threatened Species (IUCN 2017) and Red List of Mammals for Peninsular Malaysia (DWNP 2010) are shown in Table 1.

These ungulates are likely the major prey base for the Critically Endangered Malayan Tiger in peninsular Malaysia (Kawanishi 2002; Goldthorpe & Neo 2011; Kawanishi et al. 2013; Rayan & Linkie 2015). Karanth & Sunquist (1995) found that larger carnivores selectively hunt larger prey when available. A decline in large ungulate prey has been reported to be linked to a decline in a tiger population (Ramakrishnan et al. 1999). Understanding the ecology of large ungulate prey is, therefore, important to predator conservation. Collecting information about these ungulates can be useful to tiger conservation in the ERL.

Camera trapping is an effective non-invasive method to study shy and reclusive wild animals (see O'Connell et al. 2011; Ancrenaz et al. 2012; Sunarto et al. 2013; Trolliet et al. 2014). Detection/non-detection information captured by camera traps can be used to study species occurrence (O'Connell & Bailey 2011; Shannon et al. 2014) and activity pattern (Ridout & Linkie 2009). There are, however, some limitations on the use of these data as indicated by Liang (2015), including the fact that setting cameras at certain heights for large mammals sometimes misses smaller animals that pass by undetected.

In 2011, 2013 and 2015, Wildlife Conservation Society (WCS) - Malaysia Program conducted intensive camera trapping to estimate Malayan Tiger population densities in the ERL. By-catch data exist from the camera trapping from those three years and is used to understand the occurrence and activity patterns of ungulate species. To estimate species occurrence, Bayesian single-season occupancy framework is used.

This paper will provide the first published baseline data of occurrence and activity patterns of ungulates in the ERL. Bayesian statistics offer advantages over the conventional/Frequentist statistics (Dennis 1996; Ellison 1996; Wade 2001; Dorazio 2016), and have been regularly used in wildlife data analysis in recent years (see Royle & Dorazio 2008; Parent & Rivot 2012; Kery & Royle 2015; Dorazio 2016). One of the advantages of Bayesian statistics is incorporating pre-existing data (see Dennis 1996) or prior knowledge into the analysis. The baseline data from this paper can therefore be incorporated into Bayesian analysis in future ungulate occurrence or occupancy studies in the ERL.

MATERIAL AND METHODS

Study area

The ~4,186km^2 forested ERL (Fig. 1) is managed by three main agencies. Endau Rompin State Park Pahang, (approximately 578km^2) and Pahang Permanent Reserved Forests (PRFs; approximately 624km^2) are administered by the State Forestry Department of Pahang, while Johor PRFs (approximately 2,506km^2) are managed by the State Forestry Department of Johor. Endau Rompin Johor National Park (approximately 478km^2) is overseen by the Johor National Parks Corporation. The national park is mainly lowland and hill dipterocarp forest while the PRFs are predominantly lowland dipterocarp forest (Gumal et al. 2014).

The conservation status of the seven species of ungulates for the states of Johor and Pahang are different (Table 1). In the former, due to the Sultan of Johor's decree, there have been no approvals for permits for hunting of protected ungulates since 2010, except in cases where these animals have been shown to harm humans or their property. In such instances, applications still have to be approved by the Department of Wildlife and National Parks (DWNP). In Pahang, permits to hunt are only extended to the Greater Mousedeer, Lesser Mousedeer and Wild Boar.

Data collection

The camera trapping exercise was carried out during the years 2011, 2013 and 2015 in the ERL. For each camera trapping year, camera traps were set up from early June to December and each camera trap station operated for an average of 70 trap nights (Appendix 1). Average spacing

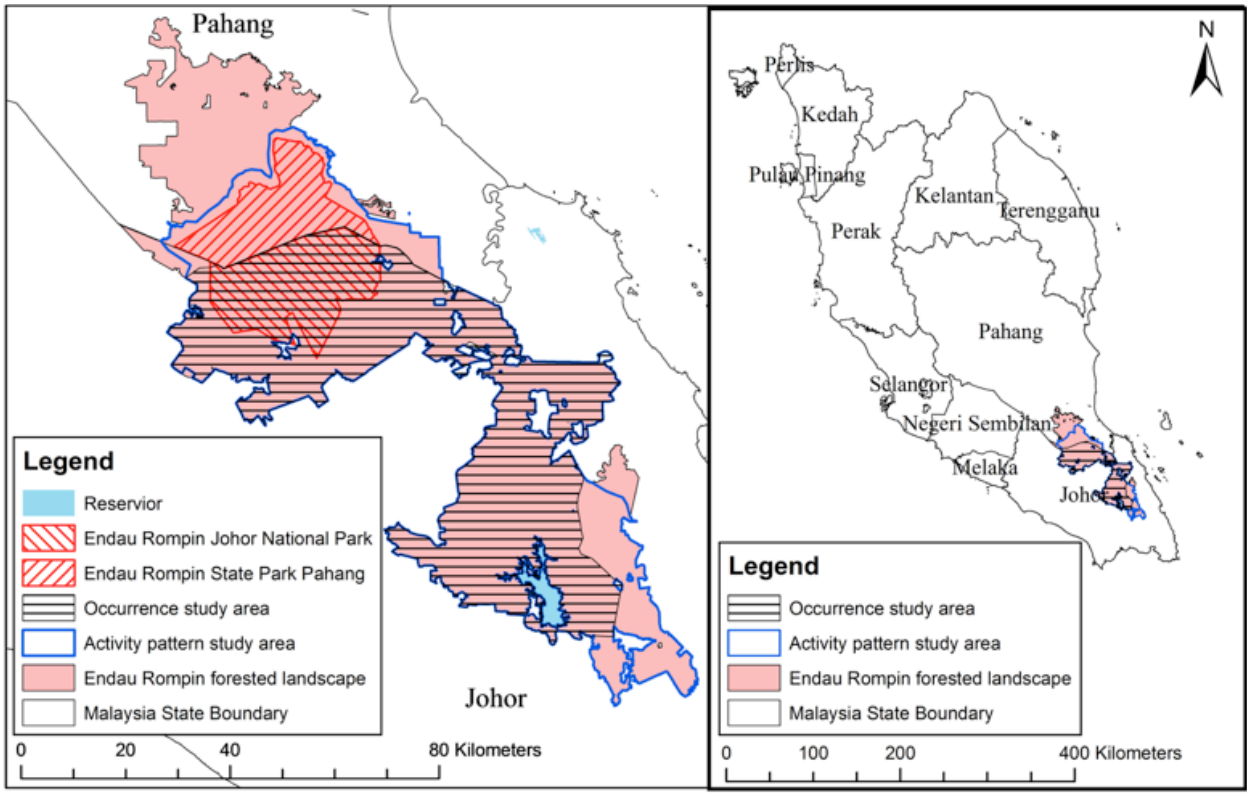

Figure 1. Location of the Endau Rompin forested landscape, occurrence and activity pattern study area in southern peninsular Malaysia.

Table 1. Conservation status of ungulates in the Endau Rompin landscape, Peninsular Malaysia from various sources.

Common name	Scientific name	Protection of Wildlife Conservation Act 2010	Red List of mammals for peninsular Malaysia 2010	IUCN Red List of Threatened Species 2017
Barking Deer	*Muntiacus muntjak*	Protected, but moratorium on hunting them	Near Threatened	Least Concern
Bearded Pig	*Sus barbatus*	Totally Protected	Near Threatened	Vulnerable
Greater Mousedeer	*Tragulus napu*	Protected but can be hunted with a permit in Pahang only	-	Least Concern
Lesser Mousedeer	*Tragulus kanchil*	Protected but can be hunted with a permit in Pahang only	-	Least Concern
Malayan Tapir	*Tapirus indicus*	Totally Protected	Near Threatened	Endangered
Sambar Deer	*Rusa unicolor*	Protected, but moratorium on hunting them	Vulnerable	Vulnerable
Wild Boar	*Sus scrofa*	Protected but can be hunted with a permit in Pahang only	-	Least Concern

between camera trap stations, calculated based on the distance of a camera trap station to the nearest camera trap station, using the R package secr (Efford 2016), was approximately 2–3 km (Appendix 1).

Camera traps were placed on animal trails and logging roads to increase wildlife detection probability (see Karanth et al. 2002; Karanth & Nichols 2002; Sunarto et al. 2013). Two camera traps, positioned about 7m apart, were set up approximately 45cm above ground level at each station (see Karanth et al. 2002; Karanth & Nichols 2002).

The camera traps used were Bushnell Trophy Cam With Viewscreen, Bushnell Trophy Cam Aggressor Brown, Panthera V3, Panthera V4 and Panthera V5. Bushnell camera traps were configured to capture videos, while Panthera camera traps were configured to capture photos. No difference in probability of detection between camera modes was assumed because video footage and still-photography seem to share similar capture success rates (Glen et al. 2013). At the end of deployment, all the images and videos were reviewed and audited or counter-checked by WCS - Malaysia Program researchers.

Wildlife images of uncertain identification, particularly of Bearded Pig and Wild Boar, were sent to Daniel Kong who is experienced in wildlife identification for review. Images that could not be positively identified were excluded from the analyses. Due to difficulty in distinguishing Greater Mousedeer from Lesser Mousedeer from camera trap photos, the two species were grouped as Mousedeer spp.

Occupancy analysis

To estimate species occurrence, detection and non-detection data of ungulates from years 2011, 2013 and 2015 from the ~2,471km^2 occurrence study area (Fig. 1) were analysed for Bayesian single-season occupancy. Camera trap stations set up in the study area increased from 131 camera trap stations in 2011 to 138 camera trap stations in 2013 and to 155 camera trap stations in 2015 (Appendix 1).

A sampling occasion was defined as a 24-hour period (Shannon et al. 2014). A species was recorded as detected (1) or not detected (0) on each occasion for each camera trap station, generating a species-specific detection history. Periods that were less than 24 hours, for example when camera traps were inactive or malfunctioning were recorded as not available (NA). Stolen camera trap stations that yielded no data were excluded.

"BoccSS" function of the R package wiqid (Meredith 2016) was used to estimate the detection and occupancy probabilities (see MacKenzie et al. 2002; 2006) for each species for a season in a Bayesian framework based on species-specific detection histories. Uninformative priors were used because there was no recent published occupancy papers or occupancy study in the landscape to provide such information. To ensure convergence, a total of 45,000 iterations were used after a discarded burn-in of 1,000 iterations.

Each camera trap station represented a sampling point (Efford & Dawson 2012) instead of a fixed-size plot, allowing estimation of the true "proportion of area used/occupied" by a species (MacKenzie & Royle 2005; Efford & Dawson 2012). The conventional occupancy definition is not applicable in this paper because the animals do not remain in front of the camera traps all the time as opposed to the Efford & Dawson (2012) definition that the animal uses or is always found in the occupied area. Therefore, instead of occupancy, the authors opted to use the term occurrence to represent the probability of a camera trap station used by at least one individual. Due to the by-catch nature of the data, however, modelling with site-specific variables is not explored in this paper. This is because the original study is not designed to investigate how site-specific variables will affect occurrence. The authors do not wish to mislead readers to biased estimates.

Daily activity pattern analysis

A total of 238 camera trap stations in the ~3,454km^2 study area (Fig. 1) in 2015 produced a total of 18,254 trap nights. Each camera trap station operated for an average of 76.7 trap nights. Camera trap data from the year 2015 was used for this analysis because of potential variation in activity patterns from one year to another (McDonough & Loughry 1997; Blake et al. 2012). Activity patterns of terrestrial animals may change in response to food availability (Schnurr et al. 2004), hunting (Kitchen et al. 2000; Gray & Phan 2011), habitat conversion (Presley et al. 2009) and habitat fragmentation (Norris et al. 2010).

To ensure independence, detections of a species that were captured within 30 minutes of previous triggers of the same species at the same location were excluded (Ridout & Linkie 2009; Linkie & Ridout 2011). After conversion of capture times into radians, density Plot function of the R package overlap (Meredith & Ridout 2016) was used to fit a kernel density function to the radian data (see Fernández-Durán 2004) and plot a probability density distribution of a photo or video being captured within any particular interval of the day, also known as daily activity pattern (Linkie & Ridout 2011). In the ERL, from July to December 2015, sunrise and sunset times were approximately 07:00 and 19:00 hours respectively (Time and Date AS 2015). From this analysis, camera-trapped species are classed as diurnal (active during daytime), nocturnal (active during night), crepuscular (active during twilight and dawn) and cathemeral (irregular active hours).

RESULTS

Occupancy

With an average occurrence of 85% (Table 2), Barking Deer appeared to be the most widespread ungulate in the camera trap area. Bearded Pig, Malayan Tapir and Wild Boar, on the other hand, with an average occurrence of 59%, 67% and 67% (Table 2) respectively, were found in more than half of the study area. Mousedeer spp., with an average occurrence of 67% (Table 2), was the least widespread ungulate in the camera trap area.

Activity pattern

This study provided insights into the daily activity pattern of ungulates on old logging roads and animal trails (Images 1–6). Barking Deer (81.7% of observations between 07:00 and 19:00 hours), Bearded Pig (69.6% of observations between 07:00 and 19:00 hours) and

Table 2. Bayesian single-season occupancy estimates of each ungulate species for each camera trapping year, with 95% highest density intervals in parentheses. Number of camera trap stations (n) for each year was also included. Sambar Deer was excluded because of small sample size.

Species	2011 (n = 131)	2013 (n = 138)	2015 (n = 155)	Mean occurrence
Barking Deer	0.83 (0.76–0.90)	0.82 (0.75–0.88)	0.89 (0.84–0.93)	0.85
Bearded Pig	0.56 (0.46–0.66)	0.65 (0.56–0.72)	0.57 (0.50–0.63)	0.59
Malayan Tapir	0.73 (0.63–0.83)	0.71 (0.62–0.80)	0.57 (0.49–0.64)	0.67
Mousedeer spp.	0.45 (0.36–0.54)	0.41 (0.33–0.49)	0.28 (0.23–0.34)	0.38
Wild Boar	0.69 (0.61–0.78)	0.75 (0.67–0.83)	0.50 (0.42–0.59)	0.67

Wild Boar (78.7% of observations between 07:00 and 19:00 hours) were mostly diurnal (Table 3). Malayan Tapir (15.9% of observations between 0700 and 1900 hours) was strongly nocturnal (Table 3). Mousedeer spp. (51.0% of observations between 07:00 and 19:00 hours) appeared to be crepuscular (Fig. 2) and Sambar Deer (58.1% of observations between 07:00 and 19:00 hours) appeared to be cathemeral (Fig. 2). Through simulations, Rowcliffe et al. (2014) found that with a sample size of 20, the kernel model described by Ridout & Linkie (2009) consistently produced <20% median bias. Due to the small sample size of Sambar Deer (n = 15), we made no conclusion about its activity pattern.

Table 3. Number of independent captures, and percentage of captures from sunrise (07:00 hours) to sunset (19:00 hours), for each ungulate species.

Species	Number of independent captures	Percentage of captures from 07:00–19:00 hours (%)
Barking Deer	1393	81.7
Bearded Pig	714	69.6
Malayan Tapir	361	15.9
Mousedeer spp.	387	51.0
Sambar Deer	15	58.1
Wild Boar	222	78.7

DISCUSSION

Occupancy

Proxy of vegetation cover using normalized difference vegetation index, measure of terrain ruggedness using digital elevation models, distance to closest roads as a proxy of human disturbance and habitat classification based on high-resolution satellite images are a few of the site-specific variables which can be incorporated into the occupancy analysis. Modelling with site-specific variables, however, is not encouraged due to the by-catch nature of the data. A different sampling strategy and greater sampling efforts to include data on variables will be required to study the correlation between site-specific variables and occurrence.

Bearded Pig and Wild Boar are known to forage in oil palm plantations that lie adjacent to forests (Hone 1995; Maddox et al. 2007; Luskin et al. 2013). Considered as agricultural pests, they can be eradicated (with permits) under the Wildlife Conservation Act 2010. The effect of hunting pressure along forest-plantation edge habitats on the occurrence of bearded pig and wild boar is unknown. This is because data is not easily available for firearms and frequency of hunting incidents, and terrain and food availability, which in turn affect Bearded Pig and Wild Boar occurrence along forest-plantation edge habitats. And it is difficult to analyse this problem via an occupancy design or camera trap by-catch data.

A second reason for the difficulty to analyse is the three management systems in the landscape, i.e. protection and law enforcement effort is different between the national parks and PRFs. Johor National Parks Corporation maintains a 24-hour presence at the national park entrances of Peta and Selai. Patrols are conducted in the national park sporadically. The state forestry department of Johor mainly maintains daytime monitoring of PRFs where there is ongoing logging activity. Logging road gates are placed at most of the PRF entrances to deny unauthorized vehicle access but not intruders on foot or by motorbikes. Finally, the DWNP is supposed to be patrolling both areas as they have jurisdiction. It is not clear how these odd differences in protection and enforcement effort can affect ungulate occupancy in the landscape as the study area is a contiguous forested habitat that allows unimpeded wildlife movement.

Activity pattern

Mostly diurnal, the Barking Deer, Bearded Pig and Wild Boar exhibited two activity peaks, in the morning

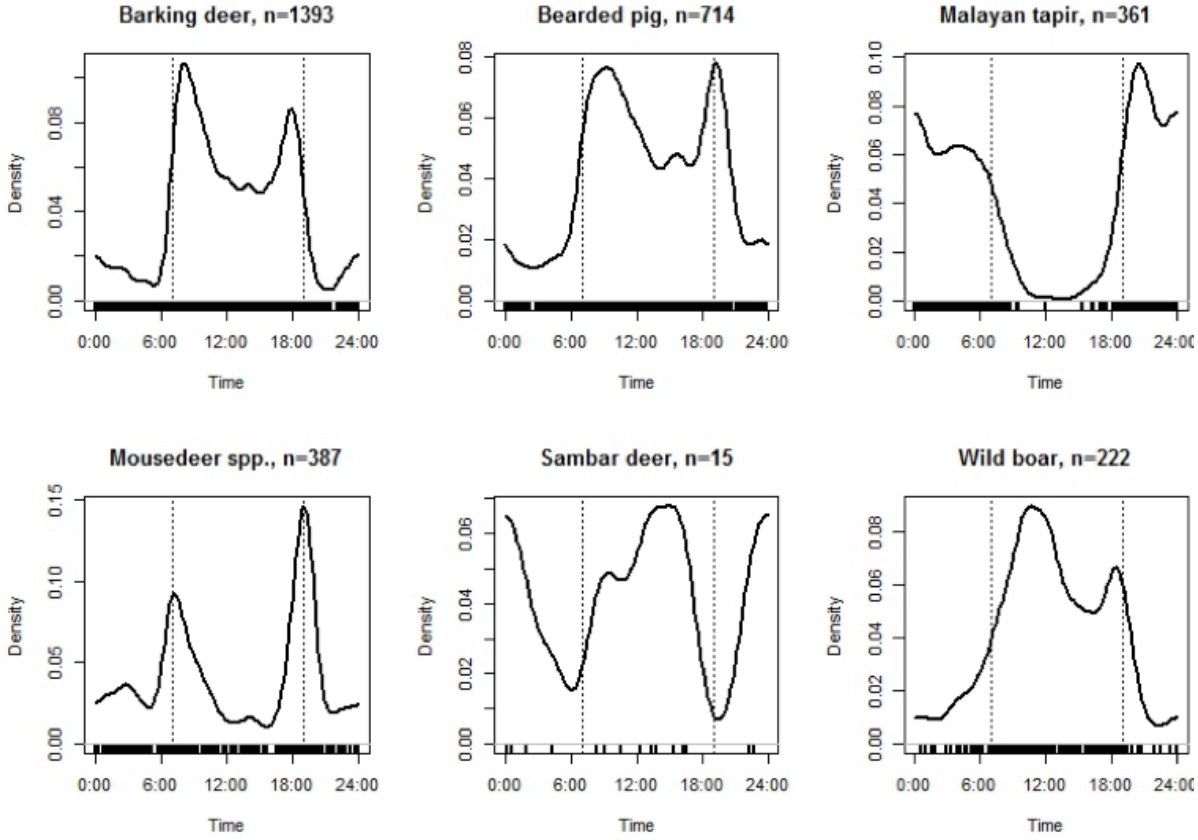

Figure 2. Density estimates of the daily activity patterns of each ungulate species. Number of independent captures (n) for each species was also included. The kernel-density estimates are indicated by the solid lines, times of individual photographs are indicated by the short vertical lines above the X-axis and approximate time of sunrise and sunset are represented by the grey dashed vertical lines.

after sunrise and in the late afternoon around sunset (Fig. 2). There appears to be a reduction in activity in the afternoon. In the tropical rainforest, primates and flying foxes have long been observed with twin activity peaks (Chivers 1980; Bennett & Caldecott 1989; Gumal 2004) when they were observed using scan sampling. The lull in activity tended to be around mid-day when the sun was strongest. During these periods, these guilds of animals were often seen resting and in the case of flying foxes, fanning to cool their dark bodies (Gumal 2004). The lull for the ungulates could be driven by a similar biological requirement to cool their bodies during the hottest part of the day, thus resting in shade or reducing their foraging activity. The lull could also be exaggerated as the camera traps tended to be set up at old logging roads and animal trails where shade was limited. Harsh sunlight in the afternoon could have deterred ungulates from using the roads or trails. In conjunction with activity pattern analysis, a forest canopy cover study (see Korhonen et al. 2006) should reveal if ungulate avoidance of logging roads and animal trails depends on the amount of sunlight in the afternoon.

Daily activity pattern can also be potentially used as a proxy to monitor the status of ungulates in the ERL. Activity patterns of mammals were affected by human disturbance and hunting (Gray & Phan 2011). In the Kaeng Krachan National Park, Ngoprasert et al. (2017) found that leopards became more diurnal in the absence of tourist activity. Several studies further noted that poached species became more nocturnal in response to high hunting pressure (Di Bitetti et al. 2008; Ohashi et al. 2013; van Doormaal et al. 2015). A change in daily activity pattern, particularly an increase in nocturnal activity, therefore, can serve as a potential indicator of human disturbance and hunting. If such a change is observed in conservation area, we recommend that immediate studies be undertaken to investigate the cause.

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Image 1. Vulnerable adult female Bearded Pig with young in the ERL, peninsular Malaysia.

Image 2. Least Concern male Barking Deer in the ERL, peninsular Malaysia.

Image 3. Endangered adult Malayan Tapir in the ERL, peninsular Malaysia.

Image 4. A pair of Least Concern Mousedeer sp. in the ERL, peninsular Malaysia.

Image 6. Least Concern Wild Boar in the ERL, peninsular Malaysia.

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Appendix 1. Camera trapping details and efforts.

Year	Average spacing between camera trap stations (km)	Total camera trap stations for occupancy analysis	Total trap nights	Average trap nights per camera trap
2011	3.2	131	9401	71.8
2013	3.2	138	10160	73.6
2015	2.5	155	11399	73.5

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