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Original Research Article

Effects of nonlethal tourist activity on the diel activity patterns of mammals in a National Park in Peninsular Malaysia

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ABSTRACT

The activity patterns of mammals are highly variable across species and can be affected by many factors, such as daytime length (i.e., sunrise to sunset), temperature, precipitation, predator–prey or competitive interactions and human activities. However, while several studies have investigated the seasonal and diel activity patterns of mammals using camera traps, information on their diel activity patterns in relation to nonlethal tourist activity is limited. Therefore, here, we conducted video-camera-trap surveys in Endau Rompin National Park in Peninsular Malaysia to examine the detection rates and diel activity patterns of the mammals living there, as well as differences in their diel activity patterns between the open and closed tourist seasons. Barking deer (*Muntiacus muntjak*), bearded pig (*Sus barbatus*), wild boar (*S. scrofa*), greater oriental chevrotain (*Tragulus napu*) and Malayan tapir (*Tapirus indicus*) exhibited significant differences in their diel activities among time periods: Malayan tapir was predominantly nocturnal, the greater oriental chevrotain was predominantly crepuscular and all other species were strongly diurnal. In addition, the data indicated that the Malayan porcupine (*Hystrix brachyura*) was nocturnal and the Asian elephant (*Elephas maximus*) was cathemeral, although the differences between time periods were not significant for these species. The detection frequencies of barking deer, bearded pig, wild boar and Malayan porcupine were higher in the open season. However, these differences were not related to human activity recorded by the cameras, and none of the mammalian species exhibited significant differences in their diel activity patterns between the open and closed seasons, suggesting that nonlethal tourist activity has limited effects on the diel activity patterns of wild mammals in this National Park.

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1. Introduction

The diel activity patterns of mammals can generally be categorised as nocturnal, diurnal, crepuscular (active at twilight) or cathemeral (active throughout the day) (Bennie et al., 2014). However, these are not only highly variable across species (Ikeda et al., 2016; Tan et al., 2018) but also within species, being affected by many factors, such as daytime length (i.e., sunrise to sunset), temperature, precipitation, predator–prey or competitive interactions and human activities (Ross et al., 2013; Bennie et al., 2014; Díaz-Ruiz et al., 2016; Ngoprasert et al., 2017; Gaynor et al., 2018).

Mammalian activity patterns have traditionally been evaluated through direct observation (Koprowski and Corse, 2005). However, this approach requires high survey effort and can disturb animal populations, so there remains a lack of quantitative data on the activity patterns of wild mammals. Recently, camera-trap survey has received increasing attention (Numata et al., 2005; O'Connell et al., 2011; Mohd-Azlan et al., 2018; Jambari et al., 2019) as it allows wildlife to be observed with minimal disturbance, and several studies to date have used this method to investigate the seasonal and diel activity patterns of mammals (Ikeda et al., 2015, 2016; Mohd-Azlan et al., 2018).

Human presence can instil strong fear in wild animals, which may cause them to adjust their activities to avoid contact with humans (Taylor and Knight, 2003; Sibbald et al., 2011). Consequently, human-induced change in diel activity patterns is a growing field of research (Gaynor et al., 2018). It has been shown that tourist activity can affect the diel activity patterns of mammals—for example, leopards (*Panthera pardus*) tend to move more frequently and exhibit more diurnal activity patterns in the absence of tourist activity (Ngoprasert et al., 2017). Additionally, animals avoid using trails on which humans are likely to travel (Griffiths and van Schaik, 1993; Taylor and Knight, 2003; George and Crooks, 2006). However, limited information is available on the effects of nonlethal tourist activity on mammalian activity patterns, particularly diel activity patterns along trails, at the population or community level (Roe et al., 1997; Ngoprasert et al., 2017). Moreover, videos may provide more detailed information than photographs (Swinnen et al., 2014), allowing more accurate identification of mammalian species.

Endau Rompin National Park (ERNP) is the second largest National Park in Peninsular Malaysia and one of the last remaining extensive tracts of largely undisturbed rainforest in southern Peninsular Malaysia. ERNP is open to tourists from March to mid-December and closed through the rest of the year. In the ERNP, tourists are required to follow tour guides along trails during the open season and most field tours operate during the daytime. Thus, we hypothesised that the detection rates and diel activity patterns of the mammals inhabiting the park differed between the open and closed seasons: in particular, ordinarily diurnal mammals exhibited increased nocturnality during open season.

The aim of the present study was to gain a better understanding of how nonlethal tourist activity affects the detection rates and activity patterns of mammals in ERNP. To do this, we used video-camera traps to investigate (1) which mammalian species occur on the roads and trails that are used by tourists and park management, (2) the detection rates and diel activity patterns of these mammals, and (3) the differences in detection rates and diel activity patterns of the mammals between the open and closed seasons.

2. Material and methods

2.1. Study site

This study was conducted in ERNP, which is located at the border between the states of Johor and Pahang in Peninsular Malaysia. The northern part of the park is designated as Endau Rompin State Park and managed by the state of Pahang, while the southern part of the park is under the management of the Johor National Parks Corporation (JNPC) and has two tourist areas: the Peta area (195.62 km^2) and the Selai area (293.43 km^2). Our study was conducted at a tourist attraction area (approximately 30 km^2) in the Peta area of Johor (2°31′N, 103°24′E, 40 m above sea level) (Fig. 1).

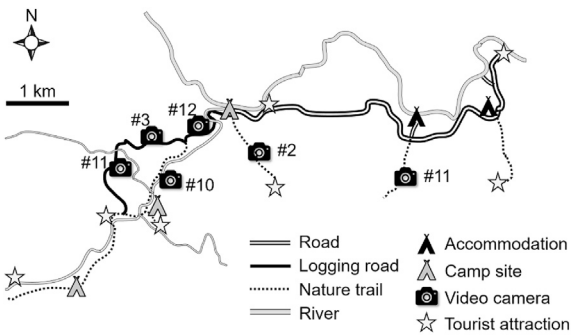

Fig. 1. Map of Endau Rompin National Park and Peta area. Numbers indicate the video-camera IDs.

The forest in the study area comprises mixed dipterocarp forest of the keruing–red meranti (*Dipterocarpus–Shorea* spp.) and kapur (*Dryobalanops* spp.) types (Wong et al., 1987). Annual rainfall in ERNP ranges from 2000 to 3600 mm, while the average annual temperature is 27 °C.

ERNP supports a high diversity and abundance of mammals (Milton, 1963; Davison and Kiew, 1987; Burhanuddin et al., 1995; Aihara et al., 2016; Tan et al., 2018), providing habitat for 149 mammalian species, some of which are endangered (Aihara et al., 2016).

ERNP has been open to the public since September 1993 and provides opportunities for a range of tourist activities, including camping, jungle trekking, night walking, swimming, canoeing, river rafting and nature education. Approximately 3500 people visit the Peta area each year, with jungle trekking from the Kuala Jasin campsite to Upeh Guling waterfall and swimming at Tasik Air Biru (water pond) being particularly popular activities.

2.2. Video-camera-trap survey

To investigate the activity patterns of mammals, especially medium- and large-sized mammals in ERNP, we installed six infrared-triggered video-cameras (Ltl Acorn 6210; LTL Acorn Outdoors, Green Bay, Wisconsin, USA) at a height of ca. 1.0–1.6 m along a logging road that is not currently used for logging but for tourists and park managers, and along nature trails for tourists (Fig. 1). The cameras installed approximately 1–2 km apart from each other (Tobler et al., 2008) to minimise the chances of the same individual mammals being recorded repeatedly (Mohd-Azlan et al., 2018). The settings on all six cameras were standardised to record videos (a recording length of 15 s and a recording interval of 30 s). In addition, the date and time were recorded for all videos.

2.3. Data analysis

We considered an independent wild mammal event to have occurred when one of the following three criteria was met: (1) consecutive recordings of different individuals of the same or different species; (2) consecutive recordings of individuals of the same species taken more than 30 min apart; or (3) nonconsecutive recordings of the same species (O'Brien et al., 2003).

To determine which of the four diel activity patterns (i.e., diurnal, nocturnal, crepuscular or cathemeral) was exhibited by each mammalian species, we defined the twilight as ± 1 h from sunrise and sunset (Gerber et al., 2012; Ikeda et al., 2016), and divided the day into three periods [daytime (08:00–18:00 h UTC+08:00), nighttime (20:00–06:00 h UTC+08:00), and twilight (06:00–08:00 h and 18:00–20:00 h UTC+08:00)]. The number of independent events recorded by each of the six video-camera traps was counted separately according to daytime, nighttime and twilight.

We compared the number of independent events recorded among the three periods using generalised linear mixed models (GLMMs) with a Poisson distribution, in which time period was included as a fixed effect, the length of operating hours of the cameras was included as an offset term and each camera-trap was considered a random effect. P values were calculated by Wald chi-square tests using 'car' package (Fox and Weisberg, 2018). Tukey's honestly significant difference (HSD) *post hoc* tests were done using 'multcomp' package (Bretz et al., 2010), when time period was significant in GLMMs.

For species with >10 independent events (Kitamura et al., 2010; Gerber et al., 2012), we defined a mammal as having crepuscular, diurnal and nocturnal behaviour where video events were recorded significantly more during twilight, daytime, and nighttime, respectively. We defined the species as cathemeral when no significant differences were observed in the number of videos among the three times of a day. While this GLMM approach is simple, it can be used as a standard method to evaluate daily activity patterns (Ikeda et al., 2016).

We also compared the number of independent events during the open and closed seasons. We separately counted the number of independent events recorded by each of the six video-camera traps during the open season and by each of the five video-camera traps during the closed season. The effects of season (i.e., open vs. closed) and human activity (i.e., the detection rates of humans) on the number of video records were examined using GLMMs with a Poisson distribution, in which season and human activity were included as fixed effects, number of operating days of the cameras was included as an offset term and camera-trap was considered a random effect. Wald chi-square tests were conducted to calculate P values of the explanatory variables. Tukey's HSD *post hoc* tests were done when season was significant in GLMMs.

To confirm the diel and seasonal human activity patterns in the ERNP, GLMMs with a Poisson distribution, in which time period or season were included as fixed effects, number of operating days of the cameras was included as an offset term and camera-trap was considered a random effect, were used.

We investigated the activity patterns of mammals following the methods of Rowcliffe et al. (2014) using the 'activity' package (Rowcliffe, 2019) in R (R Development Core Team, 2018). The activity patterns of mammals were plotted using a von Mises kernel (Ridout and Linkie, 2009; Rowcliffe et al., 2014). Independent events that were identified using the above-mentioned methods and had a sample size of >10 were used in this analysis. The time of capture was converted to radians prior to fitting a circular kernel density and the 95% confidence interval of the density was estimated from 10,000 bootstrap resamples.

Finally, we investigated differences in the diel activity patterns of mammals between the open and closed seasons by calculating the coefficient of overlap for each species, which ranges from 0 = no overlap to 1 = complete overlap. In this analysis, independent events that were identified using the abovementioned methods were used and the time of capture was converted to radians prior to calculating the overlap. We used Δ-hat 1 to estimate the nonparametric coefficient of overlap

(Schmid and Schmidt, 2006) because this has been shown to perform better than other estimators when the sample size is < 50 (Meredith and Ridout, 2017). The activity patterns of mammals during the open and closed seasons were plotted using a von Mises kernel, and Wald tests were used to demonstrate the differences in activity patterns between seasons.

3. Results

During the study period, we accumulated data for a total of 1323 and 405 trap-days across the video-camera stations in open and closed seasons, respectively (Table 1). The video-camera traps recorded 712 independent events of at least 30 mammalian species, which included four Endangered (EN) species, four Vulnerable (VU) species and three Near-Threatened (NT) species (Table 2). The Asian elephant (*Elephas maximus*), bearded pig (*Sus barbatus*), barking deer (*Muntiacus muntjak*), wild boar (*S. scrofa*), greater oriental chevrotain (*Tragulus napu*), Malayan porcupine (*Hystrix brachyura*) and Malayan tapir (*Tapirus indicus*) were recorded on more than 15 independent occasions. In addition, humans walking and in cars were recorded 361 times during the open season and 24 times during the closed season. The number of detections of human were significantly more during daytime (Wald $\chi^2 = 220.9$, $df = 2$, $P < 0.001$) and the open season (Wald $\chi^2 = 76.1$, $df = 1$, $P < 0.001$) (Table 2).

The number of independent events of barking deer, bearded pig, wild boar, greater oriental chevrotains and Malayan tapir significantly differed among the daytime, nighttime and twilight (Table 2). Barking deer was recorded significantly more in the daytime than at twilight and during the nighttime (Wald $\chi^2 = 77.2$, $df = 2$, $P < 0.001$), with 78.0% and 18.3% of independent events being recorded during the daytime and twilight, respectively (Table 2) (Fig. 2). Bearded pigs (Wald $\chi^2 = 86.7$, $df = 2$, $P < 0.001$) and wild boars (Wald $\chi^2 = 23.1$, $df = 2$, $P < 0.001$) were also recorded significantly more in the daytime than at twilight and during the nighttime (Fig. 2). Malayan tapirs were recorded significantly more in nighttime (Wald $\chi^2 = 7.15$, $df = 2$, $P = 0.028$), with 81.3% of independent events being recorded during the nighttime (Table 2). Greater oriental chevrotains were significantly recorded at twilight (Wald $\chi^2 = 9.13$, $df = 2$, $P = 0.010$), with 42.9% of independent events being recorded at twilight (Table 2). Malayan porcupines were only recorded between 20:00 and 06:00 (Fig. 2), while convergence failure was induced in the GLMM.

There were significantly more detections during the open season than during the closed season for barking deer (Wald $\chi^2 = 4.27$, $df = 1$, $P = 0.039$), bearded pig (Wald $\chi^2 = 7.53$, $df = 1$, $P = 0.006$) and wild boar (Wald $\chi^2 = 5.11$, $df = 1$, $P = 0.238$) (Table 2). On the other hand, human detection rates did not significantly affect mammalian detection rates for any species (Appendix A1). Malayan porcupine was recorded only in the closed season, while convergence failure was induced in the GLMM.

There were no significant differences in the diel activity patterns of bearded pig (Wald value = 1.72, $P = 0.19$) or barking deer (Wald value = 0.04, $P = 0.84$) between the open and closed seasons, with estimated overlap coefficients (Δ-hat 1) of 0.819 for bearded pig and 0.859 for barking deer (Fig. 3).

4. Discussion

This study examined the number of detections and diel activity patterns of mammals in a National Park in Peninsular Malaysia using video-camera traps. At least 30 different species of mammals were recorded by the video-camera traps (Table 2). Aihara et al. (2016) previously reported that ERNP provides habitats for 149 mammalian species, including small, arboreal or flying mammals such as rodents and bats. However, in the present study, the video-camera traps only recorded eight species in the order Rodentia, one species in the order Scandentia and no bats, indicating that the placement of the camera stations at a height of ca. 1.0−1.6 m along a logging road and nature trails was not appropriate for small, arboreal or flying mammals. On the other hand, out of the medium- and large sized terrestrial mammals Aihara et al. (2016) reported, the following 11 species were not recorded in this study: Mabled cat (*Pardofelis marmorata*), flat-headed cat (*Prionailurus planiceps*), short-tailed mongoose (*Herpestes brachyurus*), small Asian mongoose (*H. javanicus*), Asian small-clawed otter (*Aonyx cinerea*), smooth-coated otter (*Lutrogale perspicillata*), Malay weasel (*Mustela nudipes*), large-spotted civet (*Viverra megaspila*), large Indian civet (*V. zibetha*), Malay civet (*V. tangalunga*), and small Indian civet (*Viverricula indica*). The number of detections of barking deer, bearded pig, wild boar, greater oriental chevrotain and Malayan tapir significantly differed among the daytime, nighttime and twilight (Table 2). Less than 5% of the independent events for barking deer, bearded pig and wild boar

Table 1
Location types, operating days during open and closed seasons, and operating hours during daytime, nighttime and twilight of the video-camera traps.

Camera code	Location	Operating days		Operating hours		
		Open season	Closed season	Daytime	Twilight	Nighttime
#2	Nature trail	191	81	2720	1088	2720
#3	Logging road	373	81	4540	1816	4540
#6	Nature trail	363	81	4440	1776	4440
#10	Nature trail	171	81	2520	1008	2520
#11	Logging road	204	81	2850	1140	2850
#12	Logging road	21	0	210	84	210

Table 2
Number of independent events recorded, frequencies of detection during the daytime, twilight and nighttime (n = 6 video-camera traps), and during the open and closed tourist seasons (n = 6 and 5 video-camera traps for the open and closed seasons, respectively) for each mammalian species by the video-camera traps.

Scientific name	Common name	IUCN status[a]	No. of independent events	Mean (±SD) no. of independent events/100 camera-trap days				
				Time period[b]			Season[c]	
				Daytime (n = 6)	Twilight (n = 6)	Nighttime (n = 6)	Open (n = 6)	Closed (n = 5)
Catopuma temminckii	Asiatic golden cat	NT	4	3.99 (±9.25)	0	0	1.68 (±3.85)	0
Panthera pardus	Leopard	NT	4	0.147 (±0.360)	0.441 (±1.08)	0.0881 (±0.216)	0.221 (±0.354)	0
Panthera tigris	Tiger	EN	5	0.552 (±0.660)	0	0	0.177 (±0.274)	0.494 (±0.676)
Prionailurus bengalensis	Leopard cat	LC	13	0	0	1.41 (±2.18)	0.476 (±0.790)	0.988 (±1.61)
Martes flavigula	Yellow-throated marten	LC	2	0.228 (±0.368)	0	0	0.126 (±0.208)	0
Unidentified Felidae	–	–	3	–	–	–	–	–
Helarctos malayanus	Sun bear	VU	3	0	0	0.384 (±0.710)	0.220 (±0.420)	0
Arctictis binturong	Binturong	VU	2	0.0881 (±0.216)	0	0.140 (±0.344)	0.0447 (±0.109)	0.247 (±0.552)
Muntiacus muntjak	Barking deer	LC	218	**16.7 (±18.2) a**	**9.64 (±12.8) b**	**0.844 (±1.00) c**	**9.57 (±1.00)***	7.65 (±6.61)
Rusa unicolor	Sambar deer	VU	5	0.176 (±0.432)	0.220 (±0.540)	0.176 (±0.432)	0.223 (±0.547)	0
Sus barbatus	Bearded pig	VU	237	**22.3 (±20.6) a**	**17.0 (±11.2) b**	**1.45 (±1.35) c**	**14.2 (±10.2)****	7.65 (±8.30)
Sus scrofa	Wild boar	LC	44	**5.96 (±5.16) a**	**0.791 (±1.24) b**	**0.300 (±0.465) b**	**3.16 (±2.39)****	0.741 (±1.10)
Sus spp.	–	–	29	–	–	–	–	–
Tragulus kanchil	Lesser oriental chevrotain	LC	2	0	0.445 (±0.690)	0	0.091 (±0.140)	0
Tragulus napu	Greater oriental chevrotain	LC	21	**0.617 (±1.51) ab**	**1.98 (±4.86) a**	**0.562 (±0.912) b**	0.936 (±2.05)	0.247 (±0.552)
Tragulus spp.	–	–	3	–	–	–	–	–
Tapirus indicus	Malayan tapir	EN	16	**0.147 (±0.360) b**	**0.588 (±0.953) ab**	**1.43 (±1.65) a**	0.838 (±0.896)	0.494 (±0.676)
Manis javanica	Sunda pangolin	EN	1	0	0	0.140 (±0.344)	0	0.247 (±0.552)
Macaca fascicularis	Crab-eating macaque	LC	10	0.952 (±1.90)	0	0	0.313 (±0.766)	0.741 (±1.10)
Macaca nemestrina	Southern pig-tailed macaque	LC	4	0.321 (±0.502)	0	0.147 (±0.360)	0.133 (±0.221)	0.494 (±0.676)
Trachypithecus obscurus	Dusky leaf monkey	NT	1	0.0881 (±0.216)	0	0	0.0447 (±0.109)	0
Presbytis sp.	–	–	1	–	–	–	–	–
Elephas maximus	Asian elephant	EN	22	1.14 (±1.85)	0.220 (±0.540)	1.20 (±1.22)	1.25 (±1.58)	0
Atherurus macrourus	Asiatic brush-tailed porcupine	LC	2	0	0	0.180 (±0.441)	0.0918 (±0.225)	0
Hystrix brachyura	Malayan porcupine	LC	18	0	0	2.09 (±1.79)	1.17 (±1.02)	0
Rattus spp.	–	LC	2	–	–	–	–	–
Callosciurus sp.	–	–	2	–	–	–	–	–
Sundasciurus sp.	–	–	3	–	–	–	–	–
Lariscus insignis	Three-striped ground squirrel	LC	1	0	0.225 (±0.552)	0	0.0459 (±0.112)	0
Sundasciurus tenuis	Slender squirrel	LC	2	0.0901 (±0.221)	0.225 (±0.552)	0	0.0459 (±0.112)	0.247 (±0.552)
Tupaia sp.	–	–	1	–	–	–	–	–
Unidentified	–	–	31	–	–	–	–	–
Total	–	–	712	–	–	–	–	–
Homo sapiens	Human	–	385	**53.5 (±73.0) a**	**5.63 (±5.18) b**	**3.75 (±4.99) b**	**32.9 (±48.1)*****	5.93 (±3.85)

[a] Rankings were obtained from the IUCN Red List of Threatened Species (IUCN 2014): LC, Least Concern; NT, Near Threatened; VU, Vulnerable; EN, Endangered.
[b] Values with different letters within a row are significantly different (Tukey's HSD test, $P < 0.05$).
[c] * $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$.

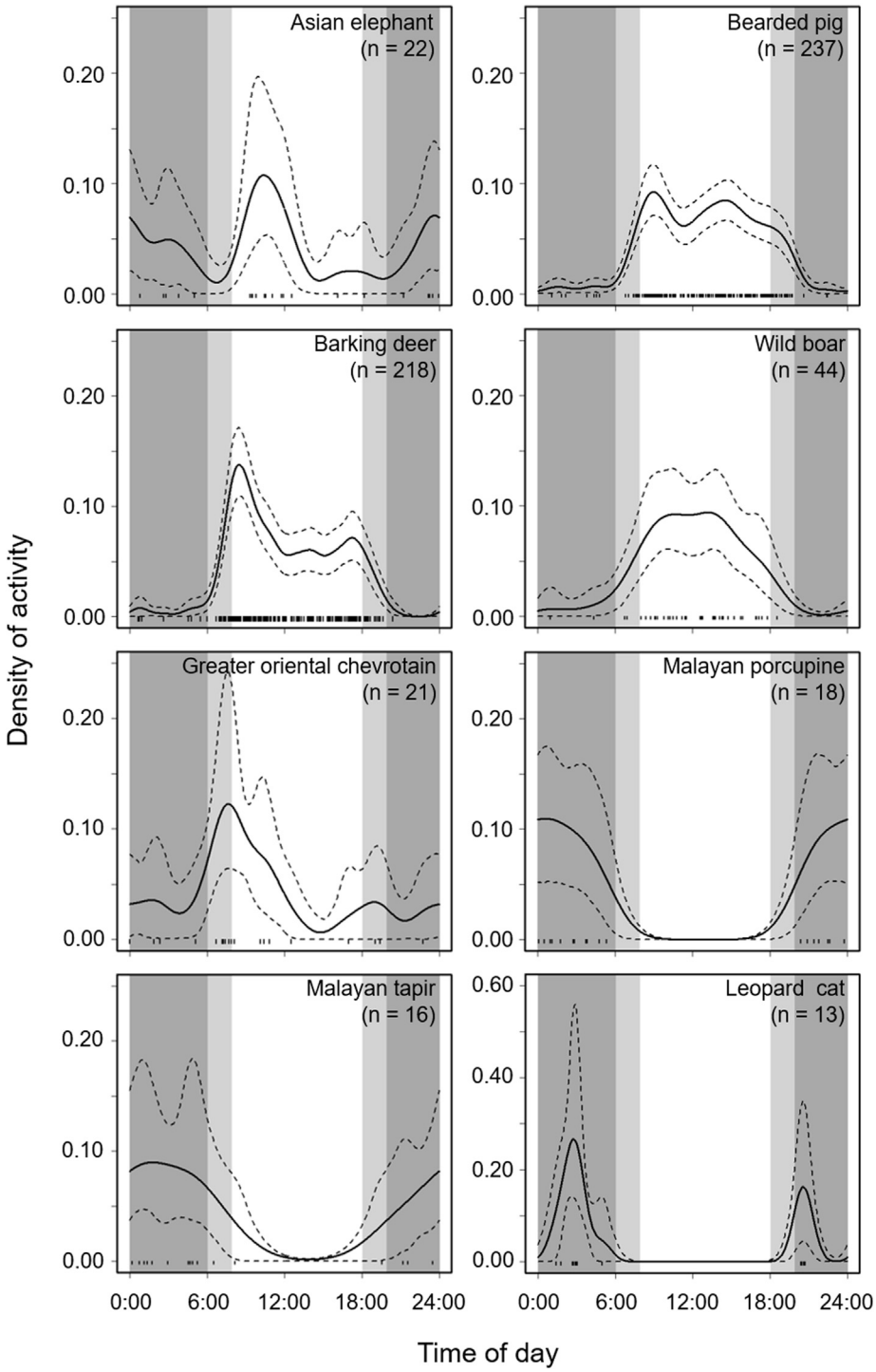

Fig. 2. Density estimates of the daily activity patterns of Asian elephant (*Elephas maximus*), bearded pig (*Sus barbatus*), barking deer (*Muntiacus muntjac*), wild boar (*Sus scrofa*), greater oriental chevrotain (*Tragulus napu*), Malayan porcupine (*Hystrix brachyura*), Malayan tapir (*Tapirus indicus*) and leopard cat (*Prionailurus bengalensis*) in the Endau Rompin National Park of Peninsular Malaysia. The solid lines are kernel-density estimates, while the dashed lines are the 95% confidence intervals of the estimates. The short vertical lines above the *x*-axis indicate the times of the individual videos. The light-grey areas and dark-grey areas indicate twilight and nighttime, respectively.

were captured between 20:00 and 06:00, indicating that these species have strong diurnal activity patterns. Kernel density estimation and the high proportion of videos that were captured during twilight (42.9%) also indicate that the greater oriental

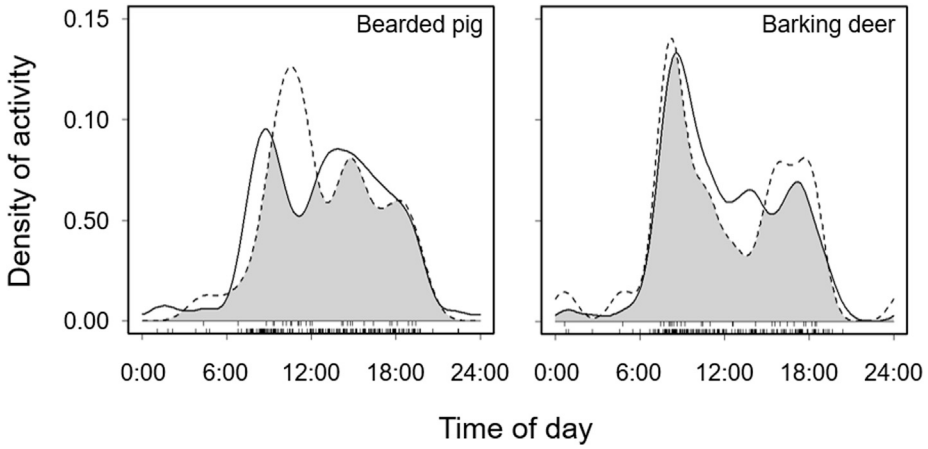

Fig. 3. Density estimates of the daily activity patterns of bearded pig (*Sus barbatus*) and barking deer (*Muntiacus muntjak*) in the Endau Rompin Natonal Park of Peninsular Malaysia during the open and closed tourist seasons. Kernel-density estimates are shown for the open season (dashed lines) and closed season (solid lines). The short vertical lines above the *x*-axis indicate the times of the individual videos in the open season (lower lines) and the closed season (upper lines). The overlap coefficient is the proportion of overlapping area of the two density estimates to the total area, as indicated by the shaded area in each plot.

chevrotain is crepuscular, while the higher proportion of Malayan tapir videos that were captured during the nighttime (81.3%) than during the daytime (6.3%) indicate that this species has a nocturnal activity pattern. By contrast, all of the 18 Malayan porcupine events were captured during the nighttime, indicating that this species has a predominantly nocturnal activity pattern (Appendix A2).

There was no significant difference in the number of independent events of Asian elephant among time periods (Table 2), despite being captured more than 15 times. Almost equal numbers of independent events of the Asian elephants were captured during the daytime and nighttime (50.0% and 45.5%, respectively), indicating a cathemeral activity pattern.

The diel activity patterns of the mammalian species that were recorded in the present study were similar to those found in previous studies using camera-trapping techniques in tropical forest in Thailand (Kitamura et al., 2010), Peninsular Malaysia (Kawanishi and Sunquist, 2004; Mohd-Azlan, 2006; Tan et al., 2018), Sumatra (van Schaik and Griffiths, 1996; Linkie and Ridout, 2011), Java (van Schaik and Griffiths, 1996) and Borneo (Bernard et al., 2013).

The diel activity patterns of barking deer and bearded pig did not significantly differ between the open and closed tourist seasons (Fig. 3). Few studies have demonstrated that tourist activity has negative effects on wild mammal activity; for example, leopards tend to move more frequently, have 70% higher detection rates and exhibit more diurnal activity in the absence of tourist activity (Ngoprasert et al., 2017). In addition, sun bear and wild pig change their period of activity toward a more nocturnal life style in order to avoid human traffic in Sumatran rain forest (Griffiths and van Schaik, 1996). Since ERNP is a protected area, lethal human activities (e.g. hunting) are strictly prohibited and tourists are required to follow guides to enter the park. The findings of the present study suggest that these protection methods are effective in preventing tourists from having any significant negative effects on the diel activity patterns of the mammals that inhabit ERNP.

Conversely, the number of detections of barking deer, bearded pig and wild boar were significantly different between the open and closed seasons (Table 2). However, these were not affected by human activity. Aside from differences in tourist numbers, the open and closed seasons also differ in rainfall levels, with less rainfall occurring during the open season. Therefore, it is possible that these species are (1) more active, (2) move in larger areas or (3) have higher population densities during the open season than during the closed season due to climatic differences. Larger home ranges increase the number of records per trap effort (Sollmann et al., 2013). The population densities of mammals have been shown to vary among seasons and years (Hancock et al., 2005) as a result of changes in factors such as food resources, rainfall and temperature. Therefore, further studies on the population density dynamics and/or activity levels of these species among years are required to better understand the observed pattern.

5. Conclusion

The present study demonstrated the detection rates and diel activity patterns of the mammals in ERNP. Barking deer, bearded pig and wild boar were diurnal, greater oriental chevrotain was crepuscular, and Malayan tapir and Malayan porcupine were nocturnal, while Asian elephant was cathemeral. These diel activity patterns of the mammalian species were similar to those reported in Thailand, Sumatra, Java, Borneo as well as Peninsular Malaysia. The present study also highlighted that the mammalian diel activity patterns did not differ between open and closed seasons. Kronfeld-Schor and Dayan (2003) and Gerber et al. (2012) stated that actual changes of activity patterns were rare, and suggested that activity patterns had become fixed and were no longer amenable to manipulation, and that they could adjust their behaviour in another niche dimension (e.g., diet or space). The present study supported the previous studies. Gaynor et al. (2018), however, stated that

the nocturnality among wild-life in human dominated areas has increased. The present study suggests that the current protection methods in ERNP are effective in preventing tourists from having any significant negative effects on the diel activity patterns of the mammals. In the present study, however, changes of the diel activity patterns were tested for only barking deer and wild boar. The current protection methods must be continued, and trends in activity patterns and abundance of the mammals in ERNP need to be monitored.

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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.e00772.

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