

# Short Communication: Diel Activity Pattern of Mousedeer in Response to Human Activity at Kinarut Eco Forest Park, Sabah, Malaysia

Andy Russel Mojiol<sup>1,2\*</sup>, Wing Shen Lim<sup>1</sup>, Fiona Evelyn Anthony<sup>3</sup>

<sup>1</sup>Faculty of Tropical Forestry, Universiti Malaysia Sabah, Jalan UMS, 88400 Kota Kinabalu, Sabah, MALAYSIA

<sup>2</sup>Sabah Association for Social Forestry (SASOF), Mailbox 511, 89507 Penampang, Sabah, MALAYSIA

<sup>3</sup>Sabah Forest Development Authority, 1st Floor, Wisma PERKASA, Jalan Gaya, Locked Bag No. 122, 88999 Kota Kinabalu, Sabah, MALAYSIA

\*Corresponding author: andy@ums.edu.my

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## Abstract

The fragmented lowland forest of Kinarut Eco Forest Park, which serves as a habitat for mousedeer (*Tragulus* spp.), is heavily impacted by human activity, though the extent of its impact on this species remains unexplored. This study conducted a camera trap survey at 20 systematically established sampling points along local gravel roads and forest trails to examine the diel activity pattern of mousedeer in response to human activity on these pathways. Over 1,275 nights of camera trapping, 43 independent detections of mousedeer and 302 independent sightings of humans were documented. The present findings validated that mousedeer exhibited a nocturnal behaviour, while humans showed a diurnal behaviour, contributing to a very low similarity in their diel activity patterns along local human pathways ( $\Delta 1 = 0.1086$ ). The observed temporal separation between humans and mousedeer underscores the ability of this terrestrial mammal to adapt to disturbances caused by frequent human visits. This study highlights the significant impact of high levels of human activity, which has prompted a shift in mousedeer behaviour from crepuscular to nocturnal in the fragmented lowland forest ecosystem of this reserve.

**Keywords:** diel activity pattern; human activity; Kinarut Eco Forest Park; mousedeer; temporal partitioning

## 1 Introduction

The lesser mousedeer (*Tragulus kanchil*) and greater mousedeer (*Tragulus napu*), both belonging to the Tragulidae family, are the smallest even-toed ungulates found in Sabah, Malaysia Borneo (Phillipps & Phillipps, 2018). These herbivores, classified as least concern, can be observed across various local lowland forest types and are mainly active during twilight hours (dusk: 5.01 p.m. to 7.00 p.m.; dawn: 5.01 a.m. to 7.00 a.m.) (Mendes et al., 2024; IUCN, 2025). However, these species may adjust their activity patterns to minimize competition and predation risks from other species. Increased habitat degradation, which reduces vegetation cover for concealment, can also lead to noticeable changes in their activity patterns in response to these interactions (Hearn et al., 2018; Khoo et al., 2021). In areas that are frequently accessed by humans, such as pathways, these species tend to be more active during times of low human activity, indicating their attempts to avoid hunting pressures and disturbances caused by human presence (Matsubayashi et al., 2003; Hon & Shibata, 2013; Mendes et al., 2024).

While the mousedeer's general ecology is relatively well documented, a significant knowledge gap exists regarding how fine-scale variations in human disturbance directly influence its diel activity patterns. Previous studies have established that mousedeer are crepuscular, but it remains unclear whether they simply maintain this pattern or actively shift towards more nocturnal behaviour in response to human presence. Understanding this relationship is vital for predicting species resilience and guiding conservation management in increasingly fragmented ecosystems. Various small forest patches,

isolated and surrounded by human settlements and roadways, can be found in the West Coast Division of Sabah, where mousedeer have been observed along local human pathways (Lim et al., 2024; Mojiol et al., 2025). Although human visits to these habitats are common, the impact of these visits on the activity patterns of mousedeer in these areas has not yet been scientifically examined. To address this gap, this research was conducted to evaluate the diel activity pattern of mousedeer in areas along human pathways in response to human activity at Kinarut Eco Forest Park (KEFP). The findings will offer a deeper understanding of how mousedeer behaviourally mitigate human impacts, with important implications for designing wildlife corridors, managing ecotourism, and ensuring the long-term survival of this ecologically important species in human-modified landscapes. Additionally, the research may provide valuable insights into the extent of anthropogenic disturbance on mousedeer activity patterns along human pathways within a fragmented forest ecosystem in Sabah.

## 2 Materials & Methods

### 2.1 Study area

KEFP covers approximately 411.0 ha of mixed landscapes, including mangrove forests, mixed acacia plantation forests, and secondary lowland dipterocarp forest, with elevations reaching up to 140.0 m above sea level (m.a.s.l.). Managed by the Sabah Forest Development Authority (SAFODA), this reserve was initially established with the long-term goal of conserving a wide range of native tree species and was officially gazetted as a Class IV Amenity Forest Reserve in 2016. The management of KEFP receives financial support from a tree planting program, which involves planting various native tree species to help rehabilitate the local forest habitat (Mojiol et al., 2025). To date, public access to this reserve is restricted, with legal entry granted only to SAFODA staff, researchers, and participants of the tree planting program. Surrounded by human settlements and roadways, the local forest is vulnerable to encroachment from adjacent communities. Furthermore, several gravel roads and forest trails have been established throughout the area, aiming to improve accessibility to varying regions of the reserve for human visitors. As shown in Figure 1, the map provides the location of the KEFP and a visual representation of the research sampling points.

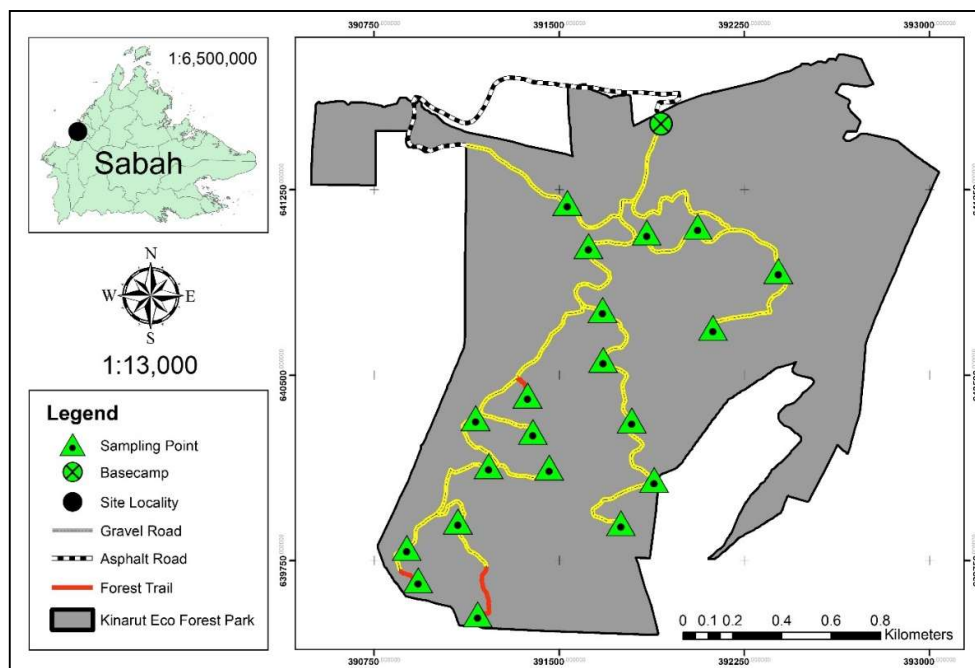


Figure 1: Locations of the 20 sampling points established in Kinarut Eco Forest Park, Sabah.

### 2.2 Camera Trap Survey

A camera trap survey was conducted at KEFP from August 1 to December 5, 2023, to monitor the activities of human and terrestrial mammals along local human pathways. Twenty sampling points were systematically placed along the pathways, each at least 200.0 m apart, and surveyed for 9 to 10 weeks applying Ka Shi H7 camera traps with passive infrared motion sensors (Zhen Shi Jie Ke Ji Co., Ltd.). Each camera trap was mounted on vertical tree stands (0.5 m to 1.5 m above ground level), directed towards the nearest pathways (2.0 m to 5.0 m apart). The cameras were set up to capture three consecutive photographs per trigger event, with a 60-second delay before reactivating (Lim et al., 2024). To ensure the cameras functioned effectively throughout the entire sampling period, objects obstructing their view were removed, and their batteries and memory cards were replaced, every three weeks.

### 2.3 Data Analysis

The captured photographs were used to gather data on the frequency and timing of human and mousedeer sightings at each sampling point. The detection frequency ( $f$ ) was calculated as the number of independent sightings per 100 trapping nights ( $100 \text{ TN}^{-1}$ ). Two successive sightings of the same species at a point were considered independent events if the time gap between them exceeded 30 minutes (Lim et al., 2024). The time of day was divided into three periods: day (7:01 a.m. to 5:00 p.m.), night (7:01 p.m. to 5:00 a.m.), and twilight (Lim et al., 2023). Since the datasets were validated to follow a non-normal distribution (Shapiro-Wilk test:  $p < 0.05$ ), non-parametric tests were employed for data analysis, conducted using RStudio ver. 2024.12.1+562 (R Core Team, 2023) at a 95.0% confidence interval ( $p = 0.05$ ).

The diel activity pattern of a species was classified as nocturnal (most active at night), crepuscular (most active at twilight), diurnal (most active during the day), or cathemeral (exhibiting no specific active hour throughout the day), based on the time of day it was detected most frequently (Lim et al., 2023). This classification was determined utilizing the Kruskal-Wallis's test, with post-hoc analysis conducted using the Dunn-Bonferroni test. Furthermore, the similarity in diel activity patterns between mousedeer and humans was examined through kernel density plots, utilizing the analysis of overlap, measured by the coefficient of overlapping ( $\Delta$ ) (Hearn et al., 2018). Two equations were used to estimate this coefficient: very high ( $\Delta > 0.75$ ), high ( $0.50 < \Delta < 0.75$ ), low ( $0.25 < \Delta < 0.50$ ), and very low ( $\Delta < 0.25$ ). Formula  $\Delta 1$  was applied for species with sample sizes below 50, while formula  $\Delta 4$  was used for species with sample sizes exceeding 50, as outlined by Ridout and Linkie (2009).

## 3 Results

During a total of 1,275 camera trapping nights across 20 sampling points at KEFP, the mousedeer was observed 43 times ( $f = 3.373 \text{ } 100\text{TN}^{-1}$ ), whereas humans were sighted 302 times ( $f = 23.69 \text{ } 100\text{TN}^{-1}$ ). This result supports the adequacy of a sample size of  $n = 43$  detections, due in part to the synergistic relationship between a rigorous camera trap design and the application of robust non-parametric analyses. Coupled with independent detection events and an analytical approach that prioritizes effect sizes and confidence intervals over mere statistical significance, this sample size provides sufficient power to draw credible ecological inferences, particularly regarding the detection of moderate to strong biological effects with a meaningful degree of precision. Due to the challenge of visually differentiating between the Greater Mousedeer (*Tragulus napu*) and the Lesser Mousedeer (*Tragulus kanchil*) from camera trap footage, both species were grouped and identified simply as 'mousedeer' (genus *Tragulus*) for all subsequent analyses. This conservative approach was adopted to prevent potential misidentification, as key diagnostic characteristics such as size and pelage coloration were often ambiguous or not visible across all recordings, and due to the challenge of differentiating between the two species of mousedeer based on the footage, (Mendes et al., 2024). In addition, nine other species were recorded, though they were not the focus of this study. These species included the Sunda pangolin (*Manis javanica*), Sunda stink-badger (*Mydaus javanensis*), small-toothed palm civet (*Arctogalidia trivirgata*), moonrat (*Echinosorex gymnure*), common palm civet (*Paradoxurus hermaphroditus*), plantain squirrel (*Callosciurus notatus*), leopard cat (*Prionailurus bengalensis*), smooth-coated otter (*Lutrogale perspicillata*), and long-tailed macaque (*Macaca fascicularis*).

The species count of terrestrial mammals recorded in this research was higher than the seven species at Universiti Malaysia Sabah (UMS), but lower than the 12 species at Kawang Forest Reserve (KFR) and the 11 species at Tenghilan Community Forest (TCF), as noted by Lim et al. (2024). This variation is likely due to differences in forest size between these four sites, as larger forests typically support greater mammalian diversity due to their ability to accommodate species with larger home ranges (Phillipps & Phillipps, 2018). Among these sites, TCF has the largest forest area, followed by KFR, KEFP, and UMS, which elucidates the corresponding decline in species count at these sites. In addition, similar species were detected across all four sites, as both Lim et al. (2024) and this research focused on local human pathways and surrounding areas, all located below 700.0 m a.s.l. in the West Coast Division of Sabah. While these areas may serve as routes for terrestrial mammals to navigate and acquire resources, they are also frequented by humans, increasing the risks of close encounters (Hon & Shibata, 2013). Furthermore, disturbance-intolerant species typically avoid these areas to escape predation and disturbance, making disturbance-tolerant species the primary visitors, which in turn results in the sighting of similar species across all four sites (Lim et al., 2023 & 2024).

The mousedeer was validated to be most active at night ( $f = 0.2667 \pm 0.0551 \text{ } 100\text{TN}^{-1}$ ), followed by twilight ( $f = 0.1765 \pm 0.1515 \text{ } 100\text{TN}^{-1}$ ), and was not observed during the day ( $\chi^2 = 16.25$ ;  $p = 0.0003$ ). In contrast, humans were most active during the day ( $f = 2.282 \pm 0.518 \text{ } 100\text{TN}^{-1}$ ), followed by twilight ( $f = 0.1765 \pm 0.1031 \text{ } 100\text{TN}^{-1}$ ), and least active at night ( $f = 0.0157 \pm 0.0157 \text{ } 100\text{TN}^{-1}$ ;  $\chi^2 = 18.38$ ;  $p = 0.0001$ ). Consequently, humans exhibited diurnal behaviour, while the mousedeer displayed nocturnal behaviour when using human pathways at KEFP, as shown in Table 1. The similarity in their diel activity patterns was found to be very low  $\Delta 1 = 0.1086$  (95% CI [0.075, 0.155]), indicating temporal partitioning between humans and mousedeer, as illustrated in Figure 2.

Table 1: Diel activity patterns of humans and mousedeer documented at Kinarut Eco Forest Park

Species	Detection Frequency (100TN <sup>-1</sup> )			Kruskal-Wallis Test		Diel Activity Pattern
	Twilight	Day	Night	$\chi^2$	p	
Human	0.1765 ± 0.1031	2.282 ± 0.518	0.0157 ± 0.0157	18.38	0.0001***	DIU
Mousedeer	0.1765 ± 0.1515	-	0.2667 ± 0.0551	16.25	0.0003***	NOC

Note: 100TN<sup>-1</sup> = Number of independent sightings per 100 trap night;  $\chi^2$  = Chi-square score; p = Significance value (\*\*\* = p < 0.001; 2-tailed); CRE = Crepuscular; DIU = Diurnal; and, NOC = Nocturnal.

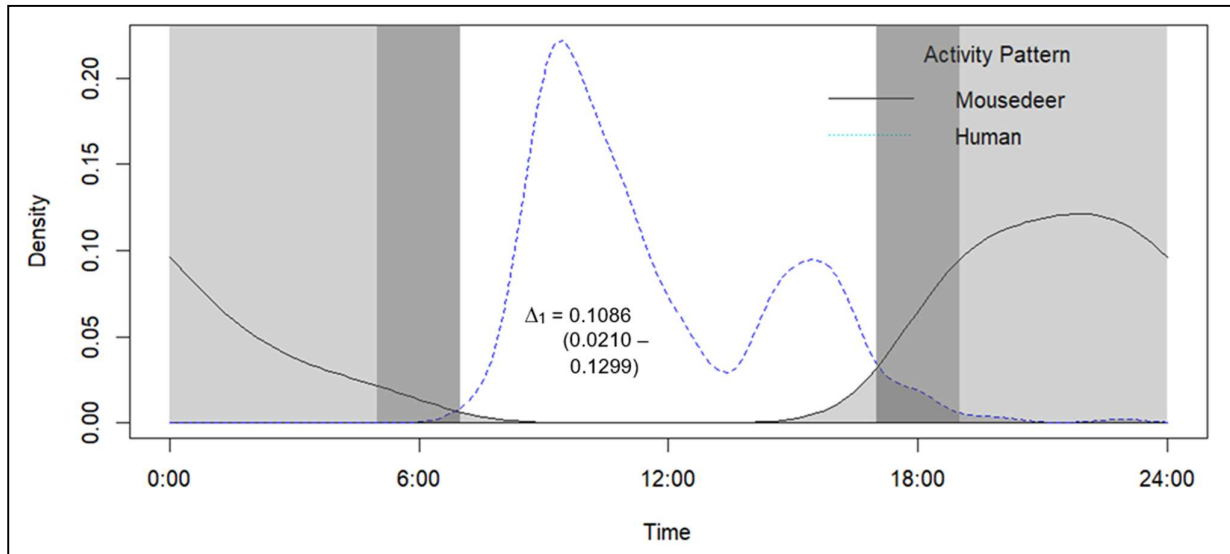


Figure 2: Overlapping diel activity patterns of humans and mousedeer along human pathways at Kinarut Eco Forest Park. The  $\Delta$  value represents the coefficient of overlapping, with the confidence interval range displayed in parentheses.

## 4 Discussion

The present findings highlight that the pronounced temporal partitioning observed between humans and mousedeer reflects a key adaptive response of this ungulate species to regular anthropogenic disturbance along human pathways at KEFP (Hon & Shibata, 2013; Lim et al., 2023). The shift from a naturally crepuscular to a fully nocturnal activity pattern, as documented in this study and others (Mendes et al., 2024), is a clear manifestation of behavioural plasticity. This plasticity shows the ability of an animal to alter its behaviour in response to environmental changes, serving as a crucial mechanism enabling wildlife to persist in human-modified landscapes (Lowry et al., 2013). Through this behavioural adjustment, the mousedeer effectively coexists with humans by avoiding them temporally, rather than spatially. This allows them to continue utilizing human-frequented gravel roads and forest trails within KEFP's fragmented lowland forest ecosystem (Phillipps & Phillipps, 2018; Mendes et al., 2024).

This nocturnal adaptation in mousedeer is part of a broader pattern observed among tropical mammals facing anthropogenic pressure. For instance, similar shifts towards increased nocturnality have been documented in species from jaguars in Belize to sambar deer in Nepal, suggesting a convergent evolutionary response to human disturbance across diverse taxa (Gaynor et al., 2018). In the case of the mousedeer, a small, cryptic ungulate, this strategy minimizes the risk of direct encounters during peak human activity hours, as confirmed by our findings and those of Kobayashi et al. (2024). This further underscores that the intensity of local human activity at KEFP, even if legal and non-lethal, is sufficient to disrupt the natural diel activity patterns of sensitive species (Hon & Shibata, 2013). However, the potential for more severe threats, such as illegal hunting, particularly in accessible areas near the reserve's boundaries, should not be dismissed (Sompud et al., 2023; Lim et al., 2024). It is crucial to distinguish between behavioural adaptations to non-lethal human presence and those driven by predation risk from hunting, as the latter can have more profound demographic consequences and induce different behavioural trade-offs (Cromsigt et al., 2013).

A key limitation of this research is its focus on human pathways, leaving the diel activity pattern of mousedeer in closed canopy areas within KEFP unexplored. The use of closed versus open canopy environments by mousedeer is likely to vary significantly due to differences in microclimate, understory structure, human activity intensity, and the availability of food and concealment cover (Matsubayashi et al., 2003; Kobayashi et al., 2024). It is plausible that in the interior, closed-canopy forests where human presence is minimal, mousedeer may retain their natural crepuscular activity rhythms. Therefore,

future research should address this limitation by employing a stratified sampling design to assess the diel activity patterns of this ungulate species across a gradient of environmental conditions, including canopy cover, distance from human pathways, and varying levels of human activity within the reserve. Such an approach would provide a more holistic understanding of how behavioural plasticity enables the mousedeer to navigate the heterogeneous challenges of a fragmented forest ecosystem.

## 5 Conclusion

This research provides evidence that the nocturnal activity patterns exhibited by the mousedeer along human pathways are shaped by the high intensity of diurnal human activity in these areas. The findings directly support the hypothesis of temporal avoidance as a behavioural strategy, demonstrating that the observed temporal partitioning between mousedeer and humans is an adaptive response. This allows the ungulate to reduce the risk of close encounters with humans while utilizing human pathways for its daily activities. However, it is crucial to continue monitoring its activities throughout the site, extending beyond the local pathways, to acquire a more comprehensive understanding of its diel activity patterns across areas with different environmental conditions. Consequently, the objective of this research has been accomplished.

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### Conflict of interest

The authors declare no conflict of interest.

### Authors' contribution

Corresponding authors are required to acknowledge co-author contributions using the Contributor Roles Taxonomy. The taxonomy includes the following roles: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, and Writing – review and editing.

**ARM:** Conceptualization, Writing- Original draft preparation. **WSL:** Writing -Data curation, Methodology. **FEA:** Visualization, Investigation. **ARM:** Supervision, Writing- Reviewing and Editing,

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Appendix A



Moonrat / **Tikus Ambang Bulan (LC)**  
(*Echinosorex gymnure*)



Mousedeer/ **Pelanduk (LC)**  
(*Tragulus spp.*)

1



Common Palm Civet/ **Musang Pulut (LC)**  
(*Paradoxurus hermaphroditus*)



Sunda Pangolin/**Tenggiling (CR)**  
(*Manis javanica*)

2



Leopard Cat/ **Kucing Batu (LC)**  
(*Prionailurus bengalensis*)



Plantain Squirrel/ **Tupai Pinang (LC)**  
(*Callosciurus notatus*)

3

4



Long-tailed Macaque/ **Kera (EN)**  
(*Macaca fascicularis*)



Sunda Stink-Badger/ **Teledu (LC)**  
(*Mydaus javanensis*)

5  
6  
7