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**Research Article**

# Species Diversity, Temporal Pattern and Habitat Use of Carnivorous Mammals in the Khao Yai National Park, Thailand

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## Abstract

Large and meso-carnivores play crucial roles in ecosystems. A systematic camera trap study conducted in Khao Yai National Park has confirmed that this area serves as a habitat for at least 18 significant carnivorous wildlife species from 6 families and 14 genera. Most of this wildlife is active during the night. The study identified 2 species as endangered, 6 species as vulnerable, and 2 species as near-threatened according to the IUCN Red List. When considering the conservation status at the national level, there is 1 species in the critically endangered category, 5 species in the endangered category, 6 species in the vulnerable category, and 2 species in the near-threatened category. The study's results have highlighted the close correlation between the distribution of wild animals in the area and human activities. Therefore, it is crucial to enforce strict regulations to avoid disrupting natural behaviors within this ecosystem.

**Keywords:** Activity pattern, Camera trap, Encounter rate, Large and meso-carnivore, Species distribution model

## Introduction

Large and meso-carnivores are vital components of ecosystems, playing a crucial role in shaping them (Ripple et al. 2013; Avrin et al. 2023). They are also essential for conservation efforts, serving as umbrella species to protect biodiversity (Yang et al. 2023). These carnivores influence the ecosystem structure through competition and facilitation, impacting community composition, prey populations, behavior, vegetation, and abiotic processes (Ripple et al. 2014). The carnivore populations typically have low densities and limited reproductive potential due to their extensive spatial requirements and susceptibility to habitat destruction (Rosenblatt et al. 2013). These characteristics make them especially susceptible to catastrophic events or continued population declines, from which they recover slowly (Karssene et al. 2017). The management and conservation of large and meso-carnivores are significantly influenced by human attitudes (Ripple et al. 2014; Piédallu et al. 2016). Almost every species of carnivorous mammal in the world is threatened (Fernández-Sepúlveda et al. 2022). Carnivorous wild animals are generally challenging to observe due to their low population densities (Dib et al. 2020). Most of them are nocturnal, making it difficult to study their behavior (Haswell et al. 2020). Camera trapping is therefore an appropriate method for wildlife and mammal research because it minimally impacts the animals (Dytkowicz et al. 2023). This method can be employed for surveys during both day and night, making it suitable for population studies (Wearn & Paul, 2019). The recorded images captured by camera traps can be used to assess the abundance of carnivorous wild animals and to investigate the relationship between their presence and other environmental factors (Blount et al. 2021). The study of carnivorous mammal communities in an area, especially the diversity of different types, along with temporal appearance as well as the relationship of its appearance with environmental factors in the area will help increase our understanding of interactions in the ecosystem. Accurate and updated species diversity, abundance, and habitat use data are vital for the proper evaluation of the conservation status, as well as for the management and decision-making concerning the key species (Royle et al. 2013; Jiménez et al. 2017; Romairone et al. 2018; Luo et al. 2020; Jayasekara et al. 2021). Furthermore, scientific understanding will be the basis for a positive public attitude towards the conservation of threatened carnivores of all species (Arbieu et al. 2019).

Khao Yai National Park (KYNP) is the most significant protected area located in the central and northeastern regions of Thailand (Khao Yai National Park, 2023). It is a large conservation forest with high biodiversity due to its varied topography and predominantly evergreen forest cover, including dry evergreen forest, moist evergreen forest, and hill evergreen forest (UNESCO, 2023). Consequently, it serves as a suitable habitat for a diverse range of wildlife, including mammals that rely on a carnivorous diet (Charaspet et al. 2020). While there have been past studies on the carnivorous animal diversity in the area (Jenks et al. 2011; 2012; Khoewsree et al. 2020; 2022), ongoing research to monitor population numbers and track changes in these carnivorous species is of the utmost importance for the conservation of both medium and large-sized carnivores that are vulnerable to various threats (Fernández-Sepúlveda et al. 2022). The KYNP has continuously been visited by more than 1 million people throughout the past 10 years (DNP, 2023), and basic infrastructure has been built both within the area and outside the area adjacent to the national park boundary, especially the development of community prosperity, agriculture, tourism, and highways surrounding the park (IUCN, 2017). These are therefore a direct and indirect threat to the area in the long term (IUCN, 2017). It is a picture of the threat these endangered carnivores pose to animals in every part of the world. Understanding the consequences of threats to wildlife is important as well as understanding the valuable habitat that can help improve the attitude of the people to help in conservation, which is the best hope of preserving these valuable natural resources. The objective of this research is to understand the diversity, abundance, temporal activity patterns, and overlap in time of the different carnivore species within the same area of carnivore habitat, as well as to understand the factors affecting the appearance of the species. This information is crucial for promoting public awareness of the value of conservation, restoring and managing ecosystem systems, public engagement, and continuous research efforts.

## Materials and method

### Khao Yai National Park

The KYNP is located between the latitude of N 14° 05' 0.00" to N 14° 35' 0.00" and between the longitude of E 101° 10' 0.00" and E 101° 55' 0.00", covering an area of 2,168 square kilometres. Located in the Phanom Dong Rak mountain range stretching between the central and northeast

regions is the origin of several important watersheds, such as the Nakhon Nayok River and the Mun River. This region was declared part of the World Natural Heritage Area in 2005, since it hosts a collection of many living things. It is home to more than 800 vertebrate species, 112 species of mammals, 392 species of birds, and more than 200 species of reptiles and amphibians (UNESCO, 2023). Most of the forests are dry evergreen forests, moist evergreen forests, or hill evergreen forests. Some of the area is covered by the grasslands formed by shifting cultivation in the past. Temperature and rainfall conditions from the Mo Singto measurement point inside the KYNP showed the average temperature throughout the year is about 21 C, and the highest temperature is between April and May. The highest average temperature is about 27 C, while during December and January, it is the coldest season. Temperatures can drop below 10 C. The air is dry and windy. The average annual rainfall is 2,338.16 millimetres per year, with the heaviest rainfall from May to October. September has the most rainfall with 426.16 mm. The average year-round temperature of the KYNP is 21.28 C, and the highest temperature in April averages 30.33 C while the lowest in January averages 12.25 C. The average relative humidity of Khao Yai National Park was an average of 66 % (Khao Yai National Park, 2021)**.**

**Field data collection**

This study was conducted in the KYNP between November 2017 and March 2020. It involved the installation of 20 automatic camera traps (Trail Camera Model Essential E3, 16MP resolution). The camera traps were placed alternately, with varying numbers in each location, totaling 120 camera locations and a cumulative total of 4,139 trap nights. The study's methodology is as follows: a 1 square kilometer area was marked out on a topographic map at a scale of 1:50,000. One camera trap was installed per grid square, resulting in one camera for each square kilometer. Camera traps were set up in 15 to 20 grid squares at a time, and they remained in each location for 30 days before being moved to a new location. Typically, each camera trap installation location was more than 500 m from the next, ensuring independence in obtaining images within each grid and reducing the probability of capturing the same animal with multiple cameras. The locations of the camera traps and the study area can be seen in Figure 1. Selecting a camera trap location involved considering the suitability of each area, such as animal paths, carnivore traces, and checkpoint routes. Records were made of detailed information about plant communities, roads, surveillance routes, permanent water sources, salt

licks, wells, and forest protection units in the area. Installation of the camera traps was approximately 30-40 cm above the ground, positioned 3-4 m away from the target area, or as deemed appropriate based on the local conditions. The camera was set to capture photos when motion sensors were triggered, taking 3 images spaced 10 seconds apart, continuously throughout the day and night. Camera traps were initially deployed for a 30-day period. After this duration, they were relocated to a new site, using a Global Positioning System (GPS) device to record the precise location where the camera trap was installed. Transfer of the photos from the memory card to a computer and classification of the images used the Camera Trap Manager Program (Zaragozi et al. 2015). Subsequently, data were imported into Microsoft Excel for further analysis.

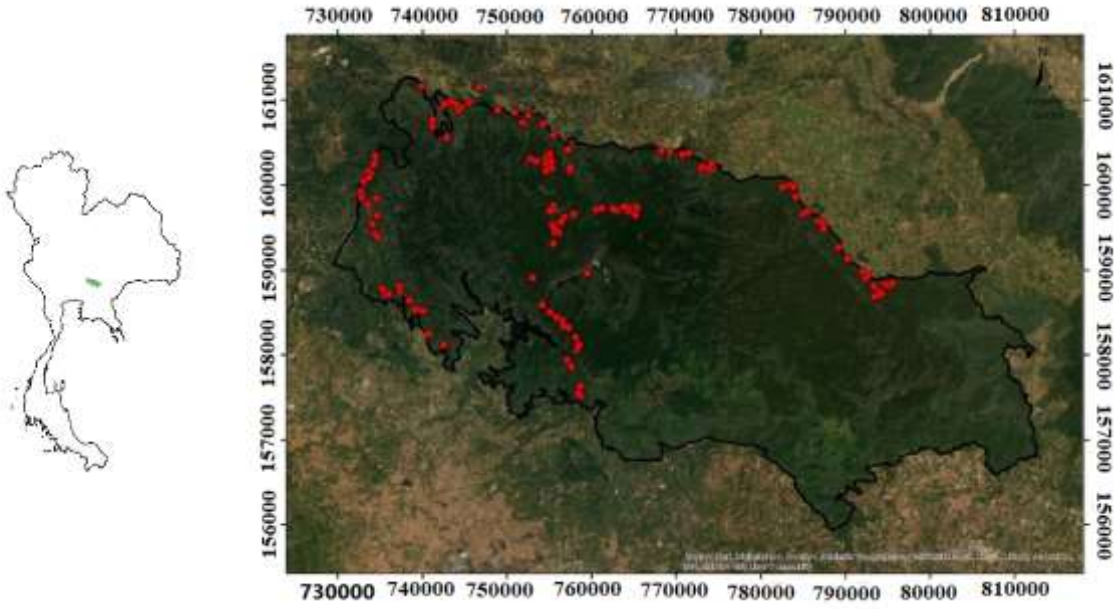



**Figure 1.** Map of the KYNP, the black line is the boundary, and also shows the camera trap locations (red dot), with n=120

## Data analysis

The species of carnivores that can be photographed were identified and recorded. Using common names and zoological names after Lekagul & McNeely (1988) and IUCN (2023), only clearly identifiable images have the date and time shown on the photograph. Pictures with more than one carnivore in the same image were counted as one and would be an independent figure or event.

The criterion for independence of animal photographs is: (1) consecutive images of different animals; that may be of the same species or different species; (2) consecutive images of the same animal of the same species; More than 30 minutes apart (3), discrete images of the same animal of the same species.

Data were summarized by the active period obtained from the camera trap, both by combining the data and classifying by type by dividing the time between 06:01 - 17:59 as the daytime and between 18:00 - 06:00 as the night time. The values are taken to generate the data graph of the carnivores' survival times and other types of wild animals that are prey are studied to classify carnivorous wildlife according to the time shown in the photograph, which were classed differently into 5 groups. If the number of night shots exceeds 85%, the data are categorized as exhibiting a strong nocturnal pattern. Nighttime images representing 61% to 84% fall under the category of the most active pattern. When the number of images taken during both day and night falls between 40% and 60%, it is grouped as displaying a cathemeral overlapped activity pattern (mostly nocturnal and diurnal). Images captured during the daytime within the range of 61% to 84% are associated with predominantly diurnal activity patterns, while more than 85% of daytime images are classified as strongly diurnal activity patterns. Spatial and temporal data are collected using camera trap positions to capture images when wildlife is present (coded as 1) and when it is not present (coded as 0). These data are recorded for each hour of the day. The activity periods were analyzed using R programs (The R Core Team 2020) in conjunction with overlap routines developed by Meredith & Ridout (2021) and circular packages by Agostnelli & Lund (2017). This analysis aimed to compare the activity times of the dhole and potential prey species in the KYNP by calculating the overlap coefficient (Δ) through the Kernel density function.

The degree of temporal overlap was calculated, where a value of 1 indicates complete overlap, and 0 means no overlap. The overlap coefficient is calculated using Δ1 for small amounts of data and Δ4 for larger amounts of data exceeding 50, as outlined in the work of Meredith & Ridout (2021). To assess the validity of the study, a 95% confidence interval was determined through 10,000 bootstrap samples to gauge the extent of overlap in time scales, following the methodology described by Lynam et al. (2013). Additionally, Vitekere et al. (2021) stated that if the coefficient of overlap is ≤0.50, it signifies low overlap, while a range of 0.50–0.75 indicates moderate overlap. A coefficient of overlap ≤0.50, ≥0.75 suggests high overlap.

The MaxEnt program was used to analyze the habitat suitability map and factors affecting the appearance of the species. This methodology, as described in the work of Phillips & Dudik (2006), serves to analyze and quantify the relationship between observed species occurrences and key environmental variables, thereby enhancing our understanding of the factors that influence the presence of wildlife in a given environment. To perform the analysis, the data need to be transformed into a raster format for use in the MaxEnt program. The data consists of two types: continuous data and categorical data. For continuous data, such as Slope, and numerical Forest Canopy Cover, the values can be directly used as they are. For categorical data, such as plant community types, it is necessary to convert them into numerical categories. Each category should be assigned a unique numerical value to represent it in the analysis. Next, the data will be split into two sets: a training set and a testing set, with a 75:25 ratio. The training set (75%) will be used to train the MaxEnt model, while the testing set (25%) will be used to evaluate its performance. The equal training sensitivity and specificity criterion is applied, and a logistic threshold is chosen to distinguish the presence and absence of the pheasants. To assess the importance of each environmental factor, metrics such as percentage contribution and percentage permutation can be used, which are derived from model testing. We selected the predictor variables from the layer of the present time, which were >10% for percent contribution and permutation importance (Khanum et al. 2013). The areas under the curve (AUC) of a receiver operating characteristics (ROC) plot were considered to evaluate the performance of the models. The higher the AUC values appear, the more reliable the models are (Morasca and Lavazza 2020). The contribution of each selected variable was assessed from the percentage contribution and permutation importance. These metrics help indicate the relationship between the presence of the species and the primary environmental variables. Finally, these transformed datasets and analyses can be employed to show the relationships between the presence of the species and the main environmental variables. This analytical process follows the methodology described by Phillips and Dudík (2017).

The logistic threshold is utilized to categorize data based on whether its value is greater than or equal to the logistic threshold, indicating presence, or if it is less than or equal to the threshold, indicating absence. Subsequently, the testing of the accuracy of the models derived from the data categorized at different logistic thresholds is performed. This evaluation employs the Area Under

the Curve (AUC) under the graph, which represents the analysis results ranging between 0.00 and 1.00. There are six values, namely minimum training presence, $10^{th}$ percentile training presence, equal training sensitivity plus specificity, maximum training sensitivity plus specificity, equal test sensitivity plus specificity, and maximum test sensitivity plus specificity. These values are used for assessing accuracy and making predictions to identify the suitable model pattern. This approach aims to find a model that best fits the data and its patterns. The values mentioned above are employed to ascertain accuracy and predictive capabilities, following the methodology as outlined by Trisurat et al. (2016). The area under the curve (AUC) under a receiver operating characteristics (ROC) curve indicates the accuracy of a model. When the AUC value approaches 1, it suggests that the model is highly accurate (Fawcett, 2006). The logistic threshold is employed to categorize data as either "present" if it is greater than or equal to the threshold, or "absent" if it is less than or equal to the threshold. The accuracy of models derived from data categorized at different logistic thresholds is then tested using the AUC under the ROC curve, both at significance levels of $P<0.05$ and $P<0.01$. Additionally, the duration of appearance is calculated as a percentage. A map of the probability of the species' presence is generated for each year between 2017 and 2022. Habitat suitability is classified into four levels: (1) unsuitable, (2) low suitability, (3) moderately suitable, and (4) highly suitable.

## Results and discussion

### Species diversity

The results of the study conducted from December 2017 to March 2020 using camera traps at 120 locations, totaling 4,139 trap nights, revealed the presence of large and meso-carnivorous animals from 6 families, 14 genera, and 18 species. The family with the highest number of species detected was Viverridae, with 5 species identified, namely the small Indian civet, large Indian civet, large-spotted civet, Asian palm civet, and binturong (n=139).

The second most abundant family was Canidae, with 2 species detected, the dhole and golden jackal (n=102). In the Felidae family (n=43), 4 species were observed, including the leopard cat, Asiatic golden cat, marbled cat, and clouded leopard. The Mustelidae family had 3 species recorded, namely the yellow-throated marten, hog badger, and smooth-coated otter (n=42). The Herpestidae family had 2 species, the crab-eating mongoose and small Asian mongoose (n=36).

Finally, in the Ursidae family, 2 species were found, the Asiatic black bear and the sun bear (n=25). Please refer to Table 1 and Figure 2 for more details.

**Encounter rate, distribution, and conservation status**

Considering the rate of encounter with carnivorous mammals at the family level, it was found that the family with the highest encounter rate was Viverridae (3.36%), followed by Canidae (2.46%), Felidae (1.04%), Mustelidae (1.01%), Herpestidae (0.87%), and Ursidae (0.60%), in that order. At the species level, the highest encounter rate was observed for the golden jackal (1.69%), followed by the large spotted civet (1.23%), large Indian civet (0.92%), leopard cat (0.92%), dhole (0.77%), greater hog badger (0.70%), common palm civet (0.70%), small Indian civet (0.46%), small Indian mongoose (0.46%), crab-eating mongoose (0.46%), Malayan sun bear (0.36%), Asiatic black bear (0.24%), yellow-throated marten (0.24%), smooth-coated otter (0.07%), binturong (0.05%), clouded leopard (0.05%), marbled cat (0.05%), and Asian golden cat (0.02%), in that order. Regarding the distribution of families, the most abundant was Viverridae, followed by Canidae and Felidae, among others. According to a study on the conservation status of carnivorous mammals conducted by IUCN (2023), there are 2 species with endangered status, 6 species with vulnerable status, and 2 species at near-threatened. When considering the conservation status at the national level, carnivorous mammals in the area are critically endangered with 1 species, in endangered status with 5 species, vulnerable with 6 species, and near-threatened with 2 species. The details are shown in Table 1.

**Daily activity patterns**

When considering the daily activity patterns of carnivorous mammals with a number of photos equal to or more than 10, they can be divided into 5 groups There were groups with activity patterns during the day and night (cathemeral) including Asiatic black bear and Malayan sun bear. The group with the most activity patterns at night (mostly nocturnal) includes the golden jackal, hog badger, and small Indian civet. The group with activity patterns mostly during the day (mostly diurnal) includes the dhole. Finally, the group with strong diurnal activity patterns includes the crab-eating mongoose, small Indian mongoose, and yellow-throated marten, as detailed in Table 2 and Figure 2.

**Temporal overlap**

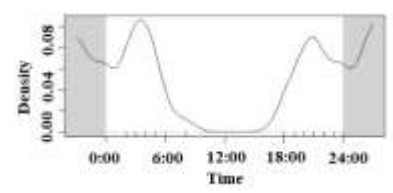
Groups with high temporal overlap values (>75) include the Asiatic black bear and golden jackal, Asiatic black bear and Malayan sun bear, common palm civet and large Indian civet, common palm civet, and large spotted civet, crab-eating mongoose and small Indian mongoose, crab-eating mongoose and yellow-throated marten, dhole and Malayan sun bear, golden jackal and greater hog badger, golden jackal, and large Indian civet, golden jackal and Malayan sun bear, golden jackal and leopard cat, small Indian civet and Malayan sun bear, small Indian mongoose and Malayan sun bear and so on (Fig. 3).

**Table 1.** Family, common name, scientific name, number of times the image can be independently recorded, encounter rate, number of camera trap stations recorded, and the conservation status of carnivorous mammals in the KYNP with 4,139 camera traps: 120 camera traps were returned between December 2017 and March 2020

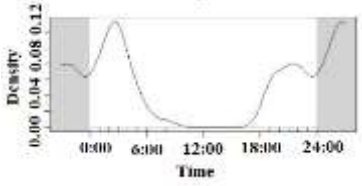
| Common Name | Scientific Name | Number of independent records | % Encounter rate | No. of camera trap stations recorded | IUCN red list | National status |
|---|---|---|---|---|---|---|
| **Family Canidae** | | **102** | **2.46** | **37** | | |
| Dhole | *Cuon alpinus* | 32 | 0.77 | 27 | EN | EN |
| Golden Jackal | *Canis aureus* | 70 | 1.69 | 15 | LC | VU |
| **Family Ursidae** | | **25** | **0.60** | **18** | | |
| Asiatic Black Bear | *Ursus thibetanus* | 10 | 0.24 | 9 | VU | EN |
| Malayan Sun Bear | *Ursus malayanus* | 15 | 0.36 | 10 | VU | EN |
| **Family Mustelidae** | | **42** | **1.01** | **21** | | |
| Greater Hog Badger | *Arctonyx collaris* | 29 | 0.70 | 14 | VU | VU |
| Smooth-coated Otter | *Lutrogale perspicillata* | 3 | 0.07 | 1 | VU | NT |
| Yellow-throated Marten | *Martes flavigula* | 10 | 0.24 | 6 | LC | VU |
| **Family Viverridae** | | **139** | **3.36** | **49** | | |
| Common Palm Civet | *Paradoxurus hermaphroditus* | 29 | 0.70 | 19 | LC | LC |
| Binturong | *Arctictis binturong* | 2 | 0.04 | 1 | VU | VU |
| Large Indian Civet | *Viverra zibetha* | 38 | 0.91 | 23 | LC | NT |
| Large-spotted Civet | *Viverra megaspila* | 51 | 1.23 | 10 | EN | EN |
| Small Indian Civet | *Viverricula indica* | 19 | 0.45 | 9 | LC | DD |
| **Family Herpestidae** | | **36** | **0.87** | **18** | | |
| Crab-eating Mongoose | *Herpestes urva* | 17 | 0.41 | 10 | LC | VU |
| Javan Mongoose | *Herpestes javanicus* | 19 | 0.45 | 9 | LC | LC |
| **Family Felidae** | | **43** | **1.04** | **25** | | |
| Asiatic Golden Cat | *Catopuma temminckii* | 1 | 0.02 | 1 | NT | VU |
| Clouded Leopard | *Neofelis nebulosa* | 2 | 0.04 | 2 | VU | EN |
| Marbled Cat | *Pardofelis marmorata* | 2 | 0.04 | 2 | NT | CR |
| Mainland Leopard Cat | *Prionailurus bengalensis* | 38 | 0.91 | 24 | LC | LC |
| **Anthropological factors** | | | | | | |
| Human (villagers and tourists) | - | 133 | 3.21 | 33 | - | - |
| Domestic dog | - | 328 | 7.92 | 2 | - | - |
| Domestic cattle | - | 46 | 1.11 | 37 | - | - |
| | **Total** | **5456** | | **120** | | |

**Table 2.** Activity patterns of carnivorous mammals in the KYNP, based on camera trap data

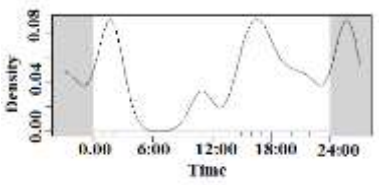
| Species | Total of daytime | % Observation of daytime | Total of night time | % Observation of night time | Activity Pattern |
|---|---|---|---|---|---|
| Asian Palm Civet | 0 | 0 | 29 | 100 | SN |
| Large Indian Civet | 2 | 5.26 | 36 | 94.74 | SN |
| Large-spotted Civet | 2 | 3.92 | 49 | 96.08 | SN |
| Leopard Cat | 5 | 13.16 | 33 | 86.84 | SN |
| Crab-eating Mongoose | 17 | 100 | 0 | 0 | SD |
| Small Asian Mongoose | 10 | 100 | 0 | 0 | SD |
| Yellow-throated Marten | 10 | 100 | 0 | 0 | SD |
| Golden Jackal | 23 | 32.86 | 47 | 67.14 | MN |
| Greater Hog Badger | 6 | 20.69 | 23 | 79.31 | MN |
| Small Indian Civet | 3 | 15.79 | 16 | 84.21 | MN |
| Dhole | 22 | 68.75 | 10 | 31.25 | MD |
| Asiatic Black Bear | 4 | 40 | 6 | 60 | CM |
| Malayan Sun Bear | 7 | 46.67 | 8 | 53.33 | CM |
| Binturong | 1 | 0 | 1 | 0 | - |
| Clouded Leopard | 2 | 0 | 0 | 0 | - |
| Marbled Cat | 2 | 0 | 0 | 0 | - |
| Smooth-coated Otter | 3 | 0 | 0 | 0 | - |
| Asian Golden Cat | 0 | 0 | 1 | 0 | - |



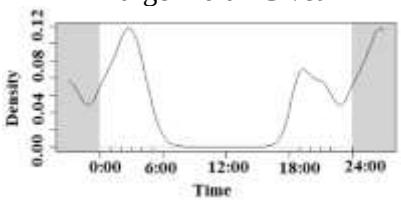

Large Indian Civet



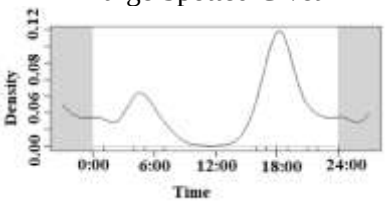

Large Spotted Civet



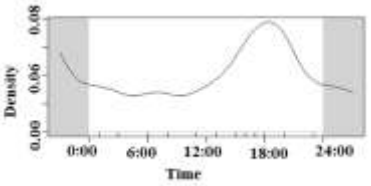

Asiatic Black Bear



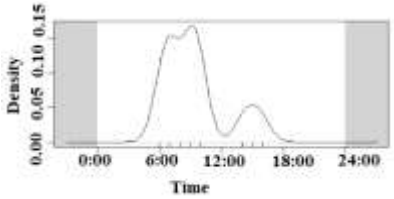

Common Palm Civet



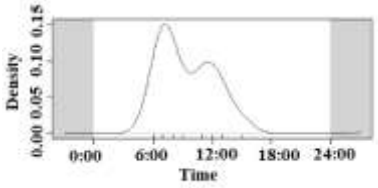

Small Indian Civet



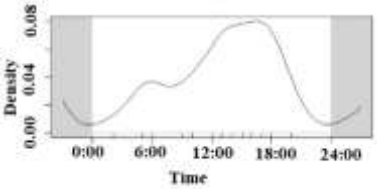

Malayan Sun Bear



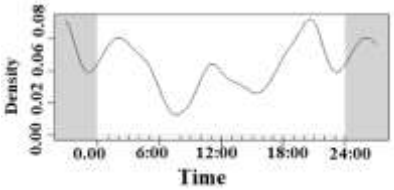

Crab-eating Mongoose



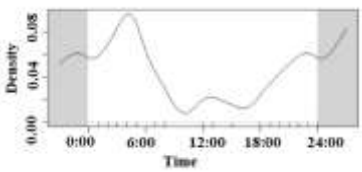

Small Indian Mongoose



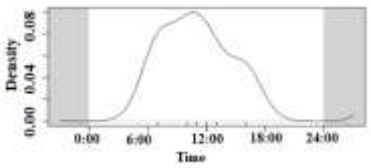

Dhole




Golden Jackal




Greater Hog Badger




Yellow-throated Marten

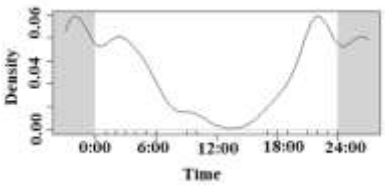
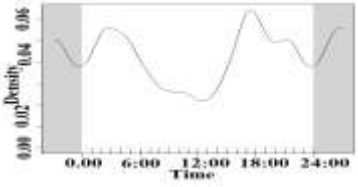
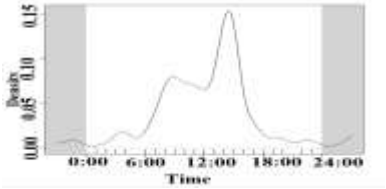
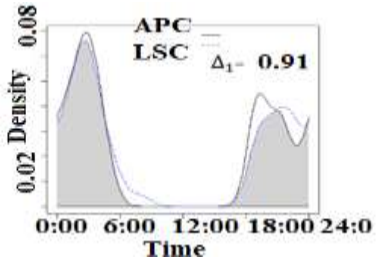
| Species | Total of daytime | % Observation of daytime | Total of night time | % Observation of night time | Activity Pattern |
|---|---|---|---|---|---|
|  | |  | |  | |
| Leopard cat | | All of the carnivorous mammals | | Human | |

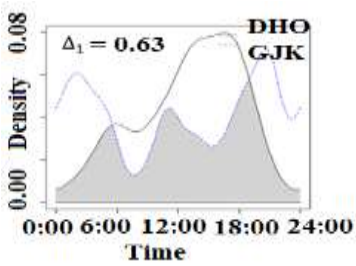
**Figure 2.** An example of wildlife carnivorous activity captured on a camera trap in the KYNP

Groups with moderate overlap (>50–75) such as Asiatic black bear and common palm civet, Asiatic black bear and dhole, Asiatic black bear and hog badger, Asiatic black bear and large spotted civet, Asiatic black bear and leopard cat, Asiatic black bear and small Indian mongoose, common palm civet and golden jackal, common palm civet and hog badger, common palm civet and small Indian civet, common palm civet and Malayan sun bear, dhole and golden jackal, dhole and leopard cat, dhole and small Indian mongoose, dhole and small Indian civet, dhole and yellow-throated marten, golden jackal and large spotted civet, golden jackal and small Indian civet, golden jackal and yellow-throated marten and so on

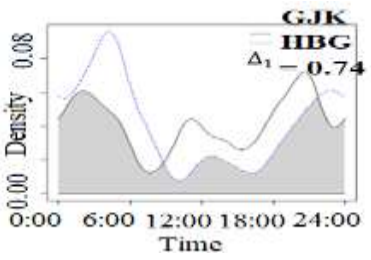
Groups with little overlap (<50), such as between Asiatic black bear and crab-eating mongoose, Asiatic black bear and small Indian mongoose, Asiatic black bear and yellow-throated marten, common palm civet and crab-eating mongoose, common palm civet and dhole, common palm civet and small Indian mongoose, common palm civet and yellow-throated marten, dhole and large spotted civet, golden jackal and small Indian mongoose, hog badger and small Indian mongoose, hog badger and yellow-throated marten and so on as detailed in the analysis results in Table 2 and Figure 3.



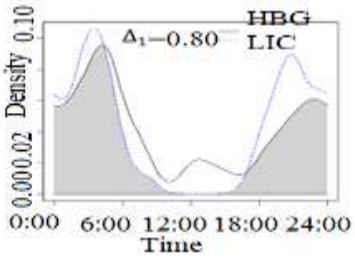

Asian Palm Civet & Large-spotted Civet



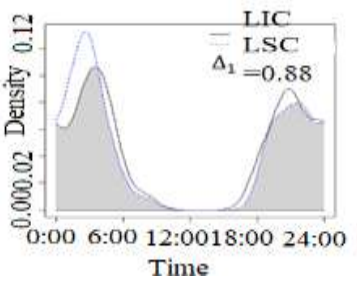

Dhole & Golden Jackal



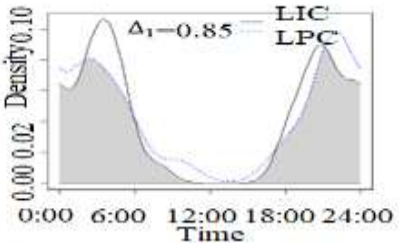

Golden Jackal & Greater Hog Badger



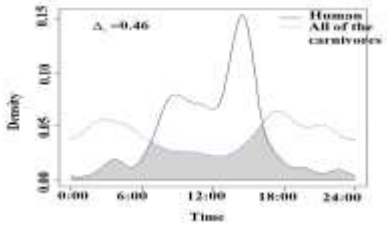

Hog Badger & Large Indian Civet



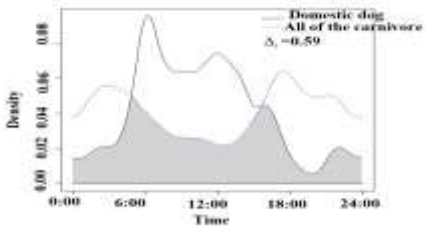

Large Indian Civet & Large-spotted Civet



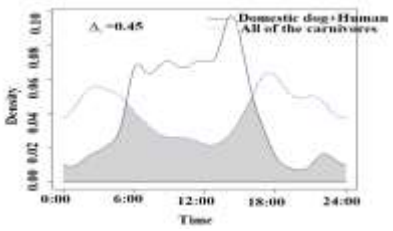

Leopard Cat & Large Indian Civet




Human and all of the carnivores




Domestic dog and all of the carnivores




Human plus domestic dog and all of the carnivores

**Figure 3.** Example of Kernel density estimation on circular data from camera-trapping records of activity patterns of the estimate of daily activity pattern and temporal overlap of carnivores. The overlap coefficient is the grey area between diel activity patterns.

## Distribution and environmental factors

When considering the analysis results from a sufficiently large amount of data, it was found that the AUC values were between 9 0 - 9 5 % , indicating high accuracy. It was found that when considering the picture including the percentage contribution value and the permutation % value, consistent results were found. National Park Protection Units, which number 33 units around the area, have the greatest effect on the appearance of carnivorous wild animals. This was followed by forest roads, elevation, forest type or land use, in addition to slope, which indicates the difficulty of accessing the area, as well as the denseness of the treetop covering which affects the appearance of wild carnivorous mammals. The details of the analysis results are shown in Table

4. The suitable habitat for carnivorous wild animals in the area is still in the middle of the area. At present there is a highway for tourism. The sources of tourism activities and accommodations as well as the office of the national park are located as shown in Figure 4.

## Discussion

The number of camera traps installed was 120 camera locations, totaling 4,139 trap nights, with 5,456 images obtained totally. A total of 86 wildlife species were recorded, including 39 mammals, 19 carnivorous wild animals, and 5 pets, including 328 images of domestic dogs and 1 domestic ca, 1 image of an invasive bird, the Indian peacock, 46 images of domestic cows and buffalo combined, and 133 images of humans obtained from the camera. They were 71 villagers, 5 monks, 2 hunters, 2 illegal loggers, and 60 tourists. Thus, 507 images of pets and humans, or 12.24% of the encounter rate. The study found 6 families, 11 genera, and 18 carnivorous mammal species. This study found that there is a high level of interaction between wild animals and human activities in the area. In the case of the carnivorous species, the results showed very high diversity when compared with various areas in the eastern, northeastern, and western regions of the country. A total of 25 carnivorous mammal species were found. In the study area, the KYNP, a total of 19 species including the fishing cat photographically recorded. The existence of the fishing cat in the area remains a mystery. The succession, evolution, and distribution in Thailand require further study (Tantiphisanu et al. 2014; Eva et al. 2022). The number of carnivorous wildlife species found in the study area reached 19 species, which is very high when compared to those found in other areas of Thailand (Table 5). The results of the temporal appearance study found that most of the species (7 in total) were active at night. Only 4 species, namely the crab-eating mongoose, small Asian mongoose, yellow-throated marten, and dhole, were found to be active during the day. The Asiatic black bear and Malayan sun bear were active during the overlapping period between day and night, a behavior known as cathemeral. Gaynor et al. (2018) reported that human activity has led to carnivorous wild animals shifting their activity patterns to be more nocturnal, which is consistent with Sukmasuang et al. (2020a), who found that dholes in the KYNP showed high activity in the early morning based on satellite data. When considering the factors influencing the presence of these carnivorous wildlife species, it was found that forest protection units, highways, elevation, land use, slopes, and NDVI (Normalized Difference Vegetation Index) values all play an important role. These factors collectively determine suitable habitat areas for carnivorous wildlife. However, the suitable habitat area is relatively small compared to the total area size, and it often overlaps with areas of

human activity of both villagers and tourists. Comparing these findings with studies in other areas, such as the study by Jayasekara et al. (2021) in Maduru Oya National Park, Sri Lanka, using camera traps, a total of 3,402 camera trapping days resulted in the capture of 69 different animal taxa, including 12 meso- carnivore mammal species. Kalle et al. (2013) reported that factors influencing the appearance of carnivorous mammal species in camera traps, such as the jungle cat (*F. chaus*), common palm civet, (*Paradoxurus hermaphroditus*), small Indian civet (*Viverricula indica*), and three species of mongooses (Indian grey mongoose (*Herpestes edwardsii*), stripe-necked mongoose (*H. vitticollis*), and ruddy mongoose (*H. smithii*), included distance from villages, rainfall, and seasonally warmer temperatures. The results of the study when considering both the number of species and their distribution found that the most suitable areas for conservation are also in humans' activities areas, along the highway that cuts through and along the boundary of the KYNP. Thus, management of these important areas depends on a public understanding of the presence of this important carnivorous wildlife. There should therefore be restrictions on the use of the route, especially during the night time when carnivorous wildlife is most active. Entry to the area and the release of pets should be strictly illegal and this measure should be implemented urgently. Rattanawanawong et al. (2022) reported that many wild animals have died as a result of using highway routes during one year in the KYNP. Ninety wildlife species were affected, with 391 carcasses belonging to carnivorous animals, including 2 leopard cats. Sukmasuang et al. (2020a) reported finding a female dhole that was killed in a vehicle collision at dusk in the KYNP while her pack was hunting prey along the highway in February 2017, confirming the direct impact of the highway on wild animals. In general, carnivorous wild animals play a significant role as top consumers in the food chains and food webs within ecosystems. Each species requires a unique habitat, and their presence indicates the good quality of the ecosystem. This should foster a positive conservation attitude grounded in science, and specific measures for management should be implemented.

## Conclusion

This study identified a high number of wild mammals in the area, surpassing other key protected forest areas in western, eastern, and northeastern Thailand. Most of the activity was observed during the night. The study results revealed that the distribution of wild animals in the area is closely correlated with human activities. Therefore, it is essential to impose strict regulations, particularly concerning nighttime travel, to avoid disrupting natural behaviors within this ecosystem. Additionally, measures should address issues such as the disposal of food waste,

garbage, and cooking food, which can attract wild animals, both carnivorous and herbivorous, as well as rodents that are prey for carnivorous wild animals (Chanachai et al. 2022). Taking into account the suitable habitat areas for carnivorous wild animals from the study results, it was observed that human and pet presence in the conservation area accounted for up to 9.29% of the total number of photos obtained. This signifies various levels of disturbance in the area, including concerns about disease outbreaks from pets to wild animals or pets venturing into the surrounding human society with wild ticks as carriers (Takhampunya et al. 2021). Furthermore, the study found that the presence of the national park protection unit has an impact on the appearance of these important wildlife species. Therefore, patrolling and conservation efforts in these crucial areas are essential to preserve these species and other wildlife in the area.

**Acknowledgements**

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**Table 3.** The calculated temporal overlaps coefficient (Δ) using Kernel density functions of carnivorous mammal species activity sampled via camera trapping from Dec. 2017 to March 2020, in the KYNP, (1=identical activity), with approximate 95% bootstrap confidence intervals (BCI)

| species | APC | CEM | DHO | GJK | HBG | LIC | LSC | LCT | SAM | SIC | SBE | YTM |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **ABB** | 0.58 (0.27-0.75) | 0.24 (0.03-0.48) | 0.64 (0.53-0.95) | 0.74 (0.57-1.01) | 0.59 (0.36-0.72) | 0.56 (0.35-0.75) | 0.57 (0.36-0.72) | 0.59 (0.40-0.78) | 0.20 (0.03-0.32) | 0.62 (0.51-0.87) | 0.77 (0.58-0.94) | 0.35 (0.15-0.45) |
| **APC** | | 0.05 (-0.05-0.16) | 0.30 (0.18-0.33) | 0.66 (0.52-0.86) | 0.68 (0.52-0.71) | 0.83 (0.69-0.89) | 0.91 (0.76-1.09) | 0.75 (0.58-0.94) | 0.06 (0.01-0.14) | 0.59 (0.40-0.78) | 0.52 (0.26-0.67) | 0.10 (0.01-0.18) |
| **CEM** | | | 0.44 (0.19-0.61) | 0.31 (0.18-0.33) | 0.29 (0.21-0.37) | 0.13 (0.08-0.19) | 0.10 (-0.05-0.16) | 0.19 (-0.02-0.21) | 0.77 (0.62-0.82) | 0.21 (0.04-0.25) | 0.37 (0.15-0.45) | 0.70 (0.57-1.01) |
| **DHO** | | | | 0.63 (0.51-0.87) | 0.47 (0.19-0.61) | 0.36 (0.19-0.61) | 0.32 (0.15-0.45) | 0.40 (0.40-0.77) | 0.50 (0.21-0.65) | 0.56 (0.35-0.75) | 0.76 (0.65-0.99) | 0.67 (0.52-0.71) |
| **GJK** | | | | | 0.74 (0.65-0.90) | 0.72 (0.50-0.79) | 0.68 (0.52-0.71) | 0.73 (0.62-0.82) | 0.35 (0.19-0.46) | 0.66 (0.52-0.86) | 0.79 (0.69-0.89) | 0.43 (0.40-0.77) |
| **HGB** | | | | | | 0.80 (0.72-0.96) | 0.74 (0.62-0.82) | 0.80 (0.58-0.94) | 0.31 (0.18-0.33) | 0.62 (0.52-0.71) | 0.62 (0.40-0.78) | 0.35 (0.21-0.39) |
| **LIC** | | | | | | | 0.89 (0.79-0.96) | 0.86 (0.71-0.93) | 0.13 (-0.05-0.16) | 0.64 (0.44-0.84) | 0.56 (0.35-0.75) | 0.18 (0.01-0.23) |
| **LSC** | | | | | | | | 0.83 (0.75-0.90) | 0.10 (-0.05-0.17) | 0.58 (0.40-0.78) | 0.57 (0.35-0.75) | 0.14 (-0.01-0.19) |
| **LPC** | | | | | | | | | 0.19 (-0.02-0.23) | 0.61 (0.36-0.72) | 0.52 (0.26-0.67) | 0.24 (0.19-0.33) |
| **SAM** | | | | | | | | | | 0.19 (0.04-0.25) | 0.35 (0.19-0.39) | 0.81 (0.72-0.91) |
| **SIC** | | | | | | | | | | | 0.74 (0.65-0.99) | 0.29 (0.03-0.45) |
| **MSB** | | | | | | | | | | | | 0.50 (0.26-0.67) |

**Notes:** APC: Asian Palm Civet, CEM: Crab-eating Mongoose, DHO: Dhole, GJK: Golden Jackal, HBG: Hog Badger, LIC: Large Indian Civet, LSC: Large-spotted Civet, LCT: Leopard Cat, SAM: Small Asian Mongoose, SIC: Small Indian Civet, SBE: Sun Bear, YTM: Yellow-throated Marten, ABB: Asiatic Black Bear, APC: Asian Palm Civet, CEM: Crab-eating Mongoose, DHO: Dhole, GJK: Golden Jackal, GHB: Greater Hog Badger, LIC: Large Indian Civet, LSC: Large-spotted Civet, LPC: Leopard Cat, SAM: Small Asian Mongoose, SIC: Small Indian Civet, MSB: Malayan Sun Bear

**Table 4.** The percentage contribution and percentage permutation values that show the relationship between the presence of carnivorous wild animals and the physical environment in the KYNP

| Variables | | Ranger | road | dem | Land use | Villages | Slope | Water | NDVI |
|---|---|---|---|---|---|---|---|---|---|
| Percent contribution | DHO | 38.1 | 28.7 | 17.9 | 10.1 | 3 | 1.3 | 0.8 | 0.0 |
| | GJK | 48.2 | 0.0 | 9.8 | 27.7 | 13.0 | 1.3 | 0.0 | 0.0 |
| | GHB | 11.8 | 26.3 | 0.0 | 56.9 | 0.0 | 3.2 | 1.9 | 0.0 |
| | CPC | 16.3 | 41.8 | 18.0 | 18.7 | 2.8 | 0.8 | 1.2 | 0.5 |
| | LIC | 37.1 | 18.0 | 30.1 | 12.8 | 0.0 | 0.8 | 1.2 | 0.0 |
| | LSC | 0.1 | 0.0 | 0.6 | 90.4 | 6.8 | 2.1 | 0.0 | 0.0 |
| | LPC | 25.6 | 26.5 | 38.2 | 1.3 | 0.8 | 7.2 | 0.4 | 0.1 |
| | AOS | 40.7 | 21.6 | 16.4 | 13.9 | 0.2 | 2.5 | 1.2 | 3.6 |
| Percent permutation | DHO | 23.1 | 35 | 22.9 | 9.2 | 2.0 | 6.8 | 1.0 | 0.0 |
| | GJK | 69.5 | 0.0 | 8.4 | 1.9 | 20.2 | 0.0 | 0.0 | 0.0 |
| | GHB | 28.4 | 31.9 | 0.0 | 28.4 | 0.0 | 6.6 | 4.6 | 0.0 |
| | CPC | 20.7 | 25 | 41.8 | 5.8 | 2.5 | 0 | 0 | 4.2 |
| | LIC | 22.8 | 34.1 | 31.9 | 10.6 | 0.1 | 0.5 | 0.0 | 0.0 |
| | LSC | 0.0 | 0.0 | 21.5 | 50.1 | 17.2 | 11.2 | 0.0 | 0.0 |
| | LPC | 5.7 | 40.6 | 35.4 | 0.1 | 0.2 | 17.6 | 0.3 | 0.2 |
| | AOS | 45.2 | 14.3 | 25.2 | 6.5 | 0.1 | 4.2 | 1.1 | 3.5 |

**Notes:** DHO: Dhole, GJK: Golden Jackal, GHB: Greater Hog Badger, CPC: Common Palm Civet, LIC: Large Indian Civet, LSC: Large-Spotted Civet, LPC: Leopard Cat, AOS: All of the carnivorous mammals combined

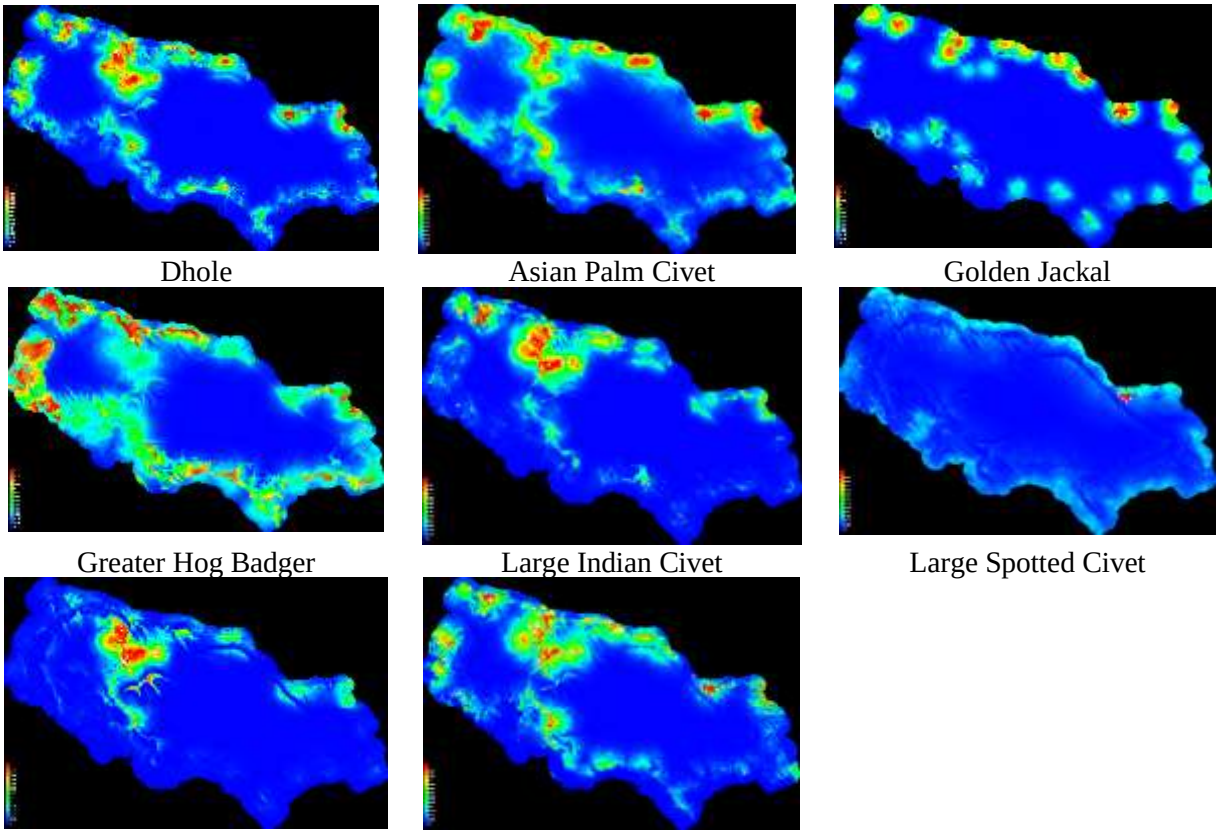


**Figure 4.** Results of analysis of suitable habitat areas for carnivorous mammals using the MaxEnt program in the hot spot area of the KYNP, the red area represents the most suitable and blue means least appropriate

**Table 5.** Carnivorous mammal species found in the KYNP compared with other protected areas with installed camera traps

| No. | Common name | KYNP* 4139 TN | | KARN* 4463 TN | | HKKWS* 6,596 TN | | SLPWS * 3600 TN | | KY-TL NPS* 12,945 TN | | PKWS* 16,245 TN | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | NIR | %ER | NIR | %ER | NIR | %ER | NIR | %ER | NIR | %ER | NIR | %ER |
| 1 | Golden Jackal | 70 | 1.69 | 81 | 1.81 | 784 | 11.89 | 375 | 10.42 | 153 | 1.18 | 17 | 0.10 |
| 2 | Dhole | 32 | 0.77 | 88 | 1.97 | 83 | 1.25 | 225 | 6.26 | 69 | 0.53 | 45 | 0.28 |
| 3 | Asiatic Black Bear | 10 | 0.24 | 2 | 0.04 | 32 | 0.49 | 33 | 0.91 | 40 | 0.31 | 57 | 0.35 |
| 4 | Malayan Sun Bear | 15 | 0.36 | 2 | 0.04 | 19 | 0.29 | 0 | 0 | 32 | 0.25 | 44 | 0.27 |
| 5 | Yellow-throated Marten | 10 | 0.24 | 12 | 0.27 | 13 | 0.20 | 3 | 0.08 | 0 | 0.00 | 5 | 0.03 |
| 6 | Greater Hog Badger | 29 | 0.70 | 13 | 0.29 | 7 | 0.11 | 152 | 4.22 | 68 | 0.53 | 33 | 0.20 |
| 7 | Small Indian Civet | 19 | 0.46 | 30 | 0.67 | 23 | 0.35 | 0 | 0 | 42 | 0.32 | 6 | 0.04 |
| 8 | Large Indian Civet | 38 | 0.92 | 14 | 0.31 | 862 | 13.07 | 37 | 1.03 | 10 | 0.08 | 51 | 0.31 |
| 9 | Large-spotted Civet | 51 | 1.23 | 143 | 3.20 | 8 | 0.12 | 33 | 0.92 | 23 | 0.18 | 0 | 0.00 |
| 10 | Asian Palm Civet | 29 | 0.70 | 153 | 3.43 | 526 | 7.97 | 21 | 0.58 | 510 | 3.94 | 6 | 0.04 |
| 11 | Small Asian Mongoose | 19 | 0.46 | 5 | 0.11 | 1 | 0.02 | 0 | 0 | 15 | 0.12 | 0 | 0.00 |
| 12 | Crab-eating Mongoose | 17 | 0.41 | 13 | 0.29 | 78 | 1.18 | 3 | 0.08 | 11 | 0.08 | 26 | 0.16 |
| 13 | Leopard Cat | 38 | 0.92 | 108 | 2.42 | 207 | 3.14 | 67 | 1.86 | 154 | 1.19 | 29 | 0.18 |
| 14 | Clouded Leopard | 2 | 0.05 | 2 | 0.04 | 2 | 0.03 | 12 | 0.33 | 5 | 0.04 | 11 | 0.07 |
| 15 | Marbled Cat | 2 | 0.05 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.01 |
| 16 | Banded linsang | 0 | 0 | 0 | 0 | 2 | 0.03 | 0 | 0 | 0 | 0 | 0 | 0 |
| 17 | Smooth-coated otter | 3 | 0.07 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 18 | Golden cat | 1 | 0.02 | 0 | 0 | 2 | 0.03 | 5 | 0 | 0 | 0 | 3 | 0.02 |
| 19 | Masked palm civet | 0 | 0 | 0 | 0 | 23 | 0.35 | 0 | 0 | 0 | 0 | 0 | 0 |
| 20 | Binturong | 0 | 0 | 0 | 0 | 1 | 0.02 | 0 | 0 | 0 | 0 | 4 | 0.02 |
| 21 | Fishing cat | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 7 | 0.05 | 0 | 0 |
| 22 | Leopard | 0 | 0 | 0 | 0 | 637 | 0 | 9 | 0 | 0 | 0 | 0 | 0 |
| 23 | Tiger | 0 | 0 | 0 | 0 | 242 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 24 | Spotted linsang | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 0.02 |
| 25 | Ferret badger | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0.01 |
| | **Total** | **385** | **9.29** | **666** | **14.89** | **3552** | **27.40** | **975** | **26.69** | **1139** | **8.80** | **342** | **2.11** |

**Notes: ***

KYNP: Khao Yai National Park (This study), KARN: Khao Ang Rue Nai Wildlife Sanctuary (Sukmasuang et al. 2020b), HKKWS: Huai Kha Khaeng Wildlife Sanctuary (Charaspet et al. 2020), SLPWS: Salak Pra Wildlife Sanctuary (Charaspet et al. 2020), KY-TL NPS: the area between Khao Yai and Thap Lan National Parks (Pla-ard et al. 2021), PKWS: Phukhieo Wildlife Sanctuary (Rattanawat Chairat 2023 personal communication)

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