

# Population characteristics and habitat suitability of Khao Yai National Park, Thailand for Asian elephant and five ungulate species

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**Abstract.** Pla-ard M, Khioesree N, Sungkalak B, Nathalang A, Thomas W, Uthairatsamee S, Paansri P, Chanachai Y, Sukmasuang R. 2021. Population characteristics and habitat suitability of Khao Yai National Park, Thailand for Asian elephant and five ungulate species. *Biodiversitas* 23: 231-243. This study of population characteristics and habitat suitability of Asian elephant (*Elephas maximus* Linnaeus, 1758) and five ungulate species was conducted between October 2017 and July 2020 in Khao Yai National Park (KYNP) using camera traps. One hundred and twenty-two camera trap locations were set up for a total of 4,139 trap nights and 5,461 independent encounters were identified. The target species of Asian elephant, gaur, sambar deer, wild boar, northern red muntjac and lesser oriental chevrotrain were recorded. The results show the occupancy of Asian elephant was 1.21 individuals/km<sup>2</sup> within the study area. The probability occupancy of the Asian elephant was 70% (SE=0.06). In comparison, gaur had a probability occupancy of 57% (SE=0.07), whereas sambar deer was 79% (SE=0.04), followed by wild boar 77% (SE=0.05), northern red muntjac 77% (SE=0.05) and lesser oriental chevrotrain occupancy 63% (SE=0.07). The age structure of Asian elephant between calf, juvenile, sub-adult and adult was 1: 2.1: 1.2: 3.16, and the ratio between adult males and females was 1: 1.72. The results show that roads and salt lick sites were the essential factors affecting the chance of Asian elephants and ungulate species in the area. The habitat suitability for Asian elephant was 331 km<sup>2</sup>, while those for gaur, sambar deer, wild boar, northern red muntjac and lesser oriental chevrotrain were 287.73 km<sup>2</sup>, 249.97 km<sup>2</sup>, 540.40 km<sup>2</sup>, 451.34 km<sup>2</sup> and 434.30 km<sup>2</sup>, respectively. Recommendations for further management involve concentration on the suitable area resulting from this study. Concerning the suitability habitat, it was found that the park boundary was most suited. Therefore, habitat improvements for all large herbivorous mammal species should improve the areas within the national park and especially address the central area, with an emphasis on creating salt lick sites, in addition to grassland and water sources that must be quality and sufficient, the most important habitat factor for these species.

**Keywords:** Camera trapping, Dong Phrayayen-Khao Yai Forest Complex, habitat improvement, herbivorous mammal

## INTRODUCTION

Large herbivorous mammals are significant drivers of the structure and function of terrestrial ecosystems worldwide, however, habitat degradation has caused a significant threat to wildlife, particularly to megafauna, including Asian elephant (*Elephas maximus* Linnaeus, 1758) that has a large home range (Neupane et al. 2020). Moreover, some of these large wildlife interactions with humans beyond the natural ecosystem seem to affect economic and social conditions. The increase in the human population has led to an increased demand for natural resources and human activities in areas that were once inhabited by wildlife, causing conflicts between humans and wildlife (Nyhus 2016). This has become a growing concern around the world, hurting food security, society, the economy, and natural resources in general and degrading the environment (Seoraj-Pillai and Pillay 2017).

The conflict between humans and wildlife species in Asia has mainly been restricted to large mammals, especially Asian elephants, across various countries (Van

de Water and Matteson 2018). Asian elephants are of particular concern because of the relatively high frequency and severity of their adverse interactions with humans (Koirala et al. 2016). The conflict is a major conservation concern in elephant range countries (Shaffer et al. 2019). The evolution of the degraded environment and the encroachment of wildlife habitat, which have led to the constant conflict between humans and wildlife, has appeared in all parts of the world. In Thailand, the conflict between humans and wild elephants has existed for more than 100 years. The Faculty of Forestry (2013) reported violent clashes between humans and wild elephants that occurred in the lowlands of the central part of the country; at that time about 1,000 wild elephants were found living in agricultural areas. To date, human-elephant interactions have been reported around the borders of 42 of the 69 protected areas in Thailand that still contain elephants (Faculty of Forestry 2013).

Dong Phraya Yen-Khao Yai has been declared a World Natural Heritage Site since 2005 (IUCN 2021), making it a globally important area for the long-term conservation of a

wide variety of wildlife habitats and populations for the benefit of the people. However, it is still disturbed because the surrounding area is adjacent to the agricultural area, community locations, highways, and tourist attractions. The management of the central part of the area in Khao Yai National Park (KYNP) as a tourist destination has been going on for a long time, with the development of utilities, accommodation and highways in the area, which has resulted in more than 1,000,000 tourists visiting each year (NPRD 2017). In KYNP alone, there is a population of about 300 wild elephants (Pla-ard et al. 2019), out of a population of 500 wild elephants in the Dong Phrayayen Forest complex (IUCN 2017). Thus, KYNP has an important central area for the wildlife conservation of this natural world heritage site. Nevertheless, it was found that the wild elephants in the KYNP regularly roam outside the national park area to feed on agricultural crops (Pla-ard et al. 2019). Mala (2019) reported that, across the last 10 years, 17 villages had been damaged by marauding elephants, while 13 wild elephants have been killed around KYNP. A tourist was also killed by an elephant in January 2021 (Tangprasert and Wipatayotin 2021). In addition, regular conflicts between locals and Asian elephants have been reported in the KYNP area. Indeed, serious traffic accidents involving Asian elephants occur often on highways surrounding the national park. As a result, the government has worked to mitigate the impact of recreational activities in the park in various ways, including enacting automotive speed limits along the park's 42-kilometer stretch of highway and, in particular, through public relations (NPRD 2017). In the case of a natural accident, Andrew (2019) reported the death of 11 wild elephants after falling from a waterfall in the area in early October 2019. However, problem-solving strategies to guide the problem are still very few and unclear.

Uddin et al. (2020) reported that a habitat suitability study is crucial to understand changes in animal distribution for landscape conservation planning of the key species, which is an essential step for landscape conservation management. Although Pla-ard et al. (2019) reported a suitable habitat for Asian elephants in the KYNP during 2017 and 2018, it did not include other large herbivores in the same area. Therefore, there is a requirement for an information update related to the population characteristics, habitat suitability, suitable habitat size and factors affecting these species for effective management in this crucial area. The objectives of this study were to study the population abundance, age structure, sex ratio, reproductive rate and recruitment rate of Asian elephants, as well as to study the habitat use of Asian elephants and five other ungulate species including gaur (*Bos gaurus*), sambar deer (*Rusa unicolor*), wild boar (*Sus scrofa*), northern red muntjac (*Muntiacus vaginalis*) and lesser oriental chevrotain (*Tragulus kanchil*) in KYNP. The results gained from this study are expected to provide

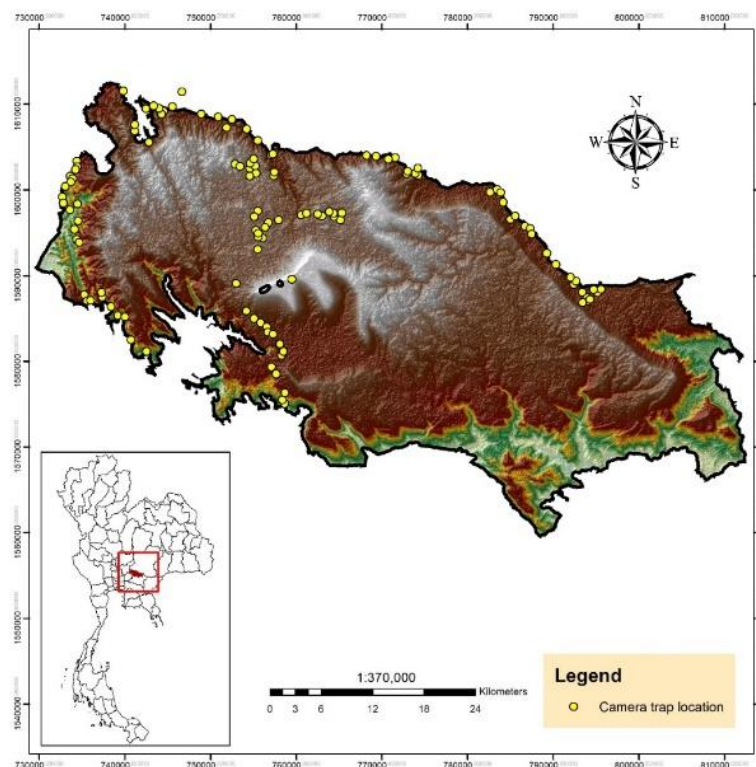
up-to-date information on the species status to enable the long-term conservation management of the area, participate in the conservation of wildlife in the ecosystem, and reduce the conflict between humans and wildlife.

## MATERIALS AND METHODS

### Study area

The KYNP is located in northeastern Thailand, between 14°5'-14°15'N and 101°5'-101°50'E, in the eastern Dongrak mountain range on the Khorat Plateau. It encompasses an area of roughly 2,168 km<sup>2</sup> (Figure 1). The park's elevation spans from 50 to 1,351 m, with most of the terrain falling between 400 and 800 m. The KYNP is an important watershed in the region, regulating water resources to surrounding provinces. Based on 10 years of meteorology data around the head office in the park (2009-2018), the area receives 1,897 mm of annual rainfall with an average temperature of 21°C. The northeastern region of the park falls within a rain shadow area and has a yearly rainfall of 1,300 mm (Brockelman et al. 2011; NPRD 2017). Evergreen forest cover dominates the park's vegetation, but it also features a diverse range of other habitats, including dry mixed deciduous woods, grasslands, and agricultural areas. There are at least 112 mammal species, 392 bird species, and 200 reptile and amphibian species among the fauna species (IUCN 2021). The variety of wildlife found at the KYNP, includes four species of hornbills, Austen's brown hornbill (*Anorrhinus austeni*), oriental pied hornbill (*Anhracoceros albirostris*), great hornbill (*Buceros bicornis*) and wreathed hornbill (*Rhyticeros undulates*); two species of gibbons, white-handed gibbon (*Hylobates lar*) and pileated gibbon (*H. pileatus*); clouded leopard (*Neofelis nebulosa*); golden jackal (*Canis aureus*); marbled cat (*Pardofelis marmorata*); Asian golden cat (*Pardofelis temminckii*); Sunda pangolin (*Manis javanica*); dhole (*Cuon alpinus*); sambar deer (*R. unicolor*); northern red muntjac (*M. vaginalis*); gaur (*B. gaurus*) and Asian elephant (Lynam et al. 2006). Brockelman et al. (2011) reported 36 medium and large mammal species in the forest dynamic plot at Mo Sing To area within the KYNP.

In 1962, the KYNP was established as Thailand's first national park, and in 2005, UNESCO designated it as a natural world heritage site. The world's natural heritage site comprises five nearly contiguous protected areas: Khao Yai National Park, Thap Lan National Park, Pang Sida National Park, Ta Phraya National Park, and Dong Yai Wildlife Sanctuary, which occupy a total area of approximately 6,155 km<sup>2</sup> (IUCN 2021). With an estimated population of around 300 elephants, the area is home to one of the largest and healthiest Asian elephants herds under protection (Pla-ard et al. 2019).



**Figure 1.** Map of Khao Yai National Park, Thailand and the camera trap locations (Department of Land Development 2016)

### Field data collection

The camera traps, Bushnell Trophy Cam Trail Cameras, Essential E3 model were used in this study during October 2017 and March 2020. The abundance of Asian elephants and other chosen mammalian species was studied using camera trap recordings by determining 1x1 square grids on a topographic map at 1:50,000. Each square grid was equal to 1 km<sup>2</sup>. One camera trap was installed in each grid by strapping them on trees approximately 50-70 cm above the ground, that used for multi-species recorded (Meek et al. 2012), along footpaths, forest trails and off-road locations (e.g., near water bodies, natural salt licks, wallows) and aiming the sensors parallel to the ground to maximize the extension of the detection zone (Chaiyarat et al. 2015). In all the study sites, 15-20 cameras were deployed per trip and set to take images in a sequence of 3 images within 10 seconds, with a delay of 30 seconds between consecutive events (Menon 2014). The triggering speed of all the camera models was pretty similar.

The camera traps are activated through a passive infrared beam, shooting a 35 mm analog camera. The sampling sites were at least 500 m away in each 1 km square grid. GPS was used to record the cameras' positions. They were set to operate 24 hours per day and register the date and time for each exposure. At each station, the camera traps were installed for a maximum of 30 days and checked at weekly intervals for photo download and battery replacement. They were then moved to another point to cover more of the study area. A standard form was filled for each camera trap location, containing

information on the date, GPS coordinates, serial number of the camera trap, team members who set up the cameras and habitat description. The times of installation and retrieval of each camera were also recorded and used to calculate the total sampling duration. To calculate the total number of camera trap days at each sampling site, we divided the full time of sampling (in hours) by 24.

The initial material for the analysis was the resulting photographs in JPG format. The unloading, storage, sorting and initial processing of images were carried out with the help of the Camera Trap Manager Programme (Zaragozi et al. 2015) and brought into Microsoft Excel for further data analysis. A database of all camera-trap images of elephants and the large ungulate species was created, including the site, date and time of capture (Rovero et al. 2014).

### Data analysis

#### Camera trap

The cleared images of all species obtained from the camera traps were classified based on Lekagul and McNeely (1988). The images were also categorized into independent events, defined as sequences of adjacent images (Sun et al. 2021). The photographs recorded by the camera traps were classified independently following the method of O'Brien et al. (2003), which is (i) consecutive photographs of the same species taken in the same location within 30 minutes will be counted as 1 incidence, (ii) consecutive photographs of a species at the same location within 30 minutes but can be identified as different individuals will be counted as different incidences and (iii)

non-consecutive photographs at different times and locations will be counted as 2 incidences.

The images were arranged by date-month-year, time and camera location. The species, number of animals, sex, and age were then identified, and the accuracy of the information specified for analysis was checked in the next step. Finally, identification of individuals, sex and age structure was performed using the external characteristics (Sun et al. 2021), for which the difference could be seen in the photographs recorded by the camera traps and the details of photographs, especially dates and times, were examined (Varma et al. 2012).

The relative abundance Index (RAI) of the elephants, other ungulate species and all the species recorded was calculated by multiplying the photographic rate by 100 and dividing by the number of trap nights (Debata and Swain 2018) using the following equation:

$$\text{Relative Abundance Index (RAI)} = \frac{\text{Number of each species photographed}}{\text{Trap nights}} \times 100$$

#### *Population structure of elephants*

Classification of the wild elephant population structures, sex and age were performed by considering the size, shape, height and external characteristics from the photographs of the individuals recorded from October 2017 to July 2020, a total of 2 years and 9 months. The identified individuals were classified into 4 age groups, including adult, sub-adult, juvenile and calf (Varma et al. 2012). They described the general characteristics of the Asian elephant in the case of male elephant that adult male elephant notes the depigmentation and folding of the ear, thickness of the tusks and the swelling of the temporal gland as the elephant is in 'musth'. All of which may be characteristics of an adult male elephant. Sub-adult male elephant can note the slight folds and the depigmentation of the ears and size of the tusks. Juvenile male elephant notes the back folding, complete absence of depigmentation of the ear, size of the tusk, and the animal's forehead in question being in line with the middle of the adult's belly. Adult female elephant notes the folding of the ear, depression of the temporal region and the buccalcavity. Sub-adult female elephant with a calf note the slight folds and depigmentation of the ear and the peak of the calf being just above the belly of the sub-adult. The peak of a calf would be under the belly of an adult elephant. Juvenile female elephant notes the back fold and absence of depigmentation of the ear. Also, the peak of the animal in question is in line with the middle of the adult female's belly. In general, the ages of non-adults were estimated by comparing animal heights relative to an adult female where they co-occurred in the same photograph (Varma et al. 2012; Vidya et al. 2014).

The population structure of the Asian Elephant was analyzed from the camera trap photographs as the minimum ratio of calves per animal. The reproductive rate (%) was measured using the number of calves produced per adult female per year (Heard and Zimmerman 2021) and was calculated by multiplying the number of elephant

calves by 100 and dividing by the number of adult female elephants.

$$\text{Reproductive rate} = \frac{\text{Number of elephant calves}}{\text{Number of adult female elephants}} \times 100$$

The recruitment rate was measured as the number of young recruits per adult per year (Bowyer et al. 2014; Louw et al. 2021). The recruitment rate was calculated by adding the number of juvenile elephants and calves and dividing by the number of adult male and adult female elephants times 100 (DeCesare et al. 2012; Menkham et al. 2019).

$$\text{Recruitment rate} = \frac{\text{Number of juvenile elephants} + \text{Number of calves}}{\text{Number of adult males} + \text{Number of adult females}} \times 100$$

The Patch Occupancy was calculated by identifying the information obtained in each 1x1 grid, and conducting an elephant presence-absence history record for each grid, using 1 for presence and 0 for absence (Royle and Nichols 2003; TEAM Network 2008). Then, calculate the occupancy ( $\psi$ ), probability of classification ( $r$ ), the abundance of animals from camera traps within each grid ( $\lambda$ ) for each location with 95% confidence interval, as well as the Akaike's Information Criterion (AIC), and calculate the abundance of the species of interest using the Presence 12.0 program (MacKenzie et al. 2017).

#### *Habitat suitability*

GPS locations of the camera trap that recorded elephant and ungulate species' presence were imported and used to find their relationship with environmental factors. The environmental factors were divided into two groups of physical environmental factors, including distance from salt lick sites, distance from the road, elevation, slope, land use, distance from water sources, distance from the village, and biological, environmental factors including normalized difference vegetation index (NDVI) created from a single image by reducing by a median of the Landsat-8 TM satellite image database (U.S. Department of the Interior 2020) during 2020 was also used to calculate in the species distribution models using MaxEnt program. The data were then converted into raster data for analysis. The species distribution models and probability of occurrence in the habitat relating to the environmental factors of Asian elephants and other herbivorous species were then produced by dividing the data into 2 sets with a 75:25 ratio; 75% of the data were tested with the MaxEnt program and 25% were used for data verification. The equal training sensitivity and specificity used the logistic threshold criteria to divide the data into the presence and absence, and the percentage contribution of each environmental factor from testing the model showed the evaluation of the relationship between the animal presence locations and the main environmental factors (Phillips et al. 2017). The area under the curve (AUC) which ranges from 0.0 to 1.0 indicates the accuracy of a predictor. An AUC of 0.5 and means random guessing. As a rule of thumb, an AUC above 0.85 means high classification accuracy, one

between 0.75 and 0.85 moderate accuracies, and one less than 0.75 low accuracies was determined (Bowers and Zhou 2019).

## RESULTS AND DISCUSSION

### Number of events and relative abundance index (RAI)

From a total of 122 camera trap locations with 4,139 trap nights, we recorded 2,248 photographs. The photographs of Asian elephants and 5 ungulate species were divided into 355 photographs of Asian elephants, 626 photographs of gaur, 480 photographs of sambar deer, 501 photographs of wild boar, 256 photographs of northern red muntjac and 30 photographs of and lesser oriental chevrotain. The relative abundance index of the Asian elephants was 8.58 %. The RAI of gaur was 15.12 %, sambar deer was 11.59%, wild boar was 12.10%, northern red muntjac was 6.18% and lesser oriental chevrotain was 0.72% (Table 1).

### Patch occupancy

Understanding the changes or differences in the proportion of sites occupied by key area species is essential for conservation management. This study resulted in the patch occupancy of the Asian elephants being 70% (SE=0.06). The gaur had a patch occupancy of 57% (SE=0.07). The sambar deer had a patch occupancy of 79%

(SE=0.04). The wild boar had a patch occupancy of 77% (SE=0.05). The northern red muntjac had a patch occupancy of 77% (SE=0.05). The lesser oriental chevrotain had a patch occupancy of 63% (SE=0.07). The results show the probability of occupancy to occupy the area of large herbivores, including sambar deer, northern red muntjac, wild boar, Asian elephant and lesser oriental chevrotain and gaur, respectively. The details are shown in Table 2.

### Population structure of *Elephas maximus*

The results from 355 photographs of Asian elephants showed the population structure comprised of adult, sub-adult, juvenile, and the calf was 41.95%, 16.70%, 27.97%, and 13.29%, respectively (Table 3).

The calf, juvenile, sub-adult, and adult ratio was 1: 2.10: 1.26: 3.16. The previous study in 2017 with direct observation found the ratio between calves, juvenile, sub-adult and adult was 1: 0.18: 2: 3.4 or most of the population were in the adult class. This was similar to studies at Khao Ang Rue Nai Wildlife Sanctuary, using the same method with a proportion of 1: 1.3: 0.08: 11.3 or most of the population in the adult class. The ratio between the adult male and adult female was 1:1.17, similar to the result from the study in the eastern forest complex by Vinitpornawan et al. (2015). The reproductive rate or the ratio between adult females and calves was 1: 0.5 (Table 4).

**Table 1.** Number of photographs and relative abundance index (RAI) of Asian elephant and five ungulate species in Khao Yai National Park, Thailand

Common name	Scientific name	No. of events	No. locations found	%RAI
Asian elephant	<i>Elephas maximus</i>	355	44	8.58
Gaur	<i>Bos gaurus</i>	626	35	15.12
Sambar deer	<i>Rusa unicolor</i>	480	52	11.59
Wild boar	<i>Sus scrofa</i>	501	51	12.10
Northern red muntjac	<i>Muntiacus vaginalis</i>	256	60	6.18
Lesser oriental chevrotain	<i>Tragulus kanchil</i>	30	11	0.72
Total		2,248		54.29

**Table 2.** Patch occupancy and abundance of Asian elephant and other herbivorous species

Common name	Naïve occupancy <sup>1</sup>	$\psi \pm SE^2$	$\lambda \pm SE^3$	N <sup>4</sup>
Asian elephant	0.37	0.70±0.06	1.21±0.21	38.62±6.67
Gaur	0.25	0.57±0.07	0.85±0.17	27.20±5.60
Sambar deer	0.59	0.79±0.04	1.57±0.24	50.49±7.71
Wild boar	0.50	0.77±0.05	1.49±0.23	47.79±7.57
Northern red muntjac	0.53	0.77±0.00	1.49±0.23	47.93±7.42
Lesser oriental chevrotain	0.28	0.63±0.07	0.99±0.19	31.84±6.08

Note: <sup>1</sup>The number of sites in which a species was detected without cooperating detection probability, <sup>2</sup>Occupancy rate or proportion of sites occupied, <sup>3</sup>The average cell-specific abundance, <sup>4</sup>Estimated abundance

**Table 3.** The population structure of Asian elephant in Khao Yai National Park, Thailand

Age class	Adult	Sub-adult	Juvenile	Calf
No. of individuals	60	24	40	19
Ratio	3.16	1.26	2.10	1
Percentage	41.95	16.70	27.97	13.29

**Table 4.** The ratio between the adult males and adult females, the ratio between adult females and calves, and the recruitment rate of Asian elephant in Khao Yai National Park, Thailand

Age class	Adult male: adult female ratio		Adult female: calf		Recruitment rate (%)
	AM	AF	AF	CL	
No. of individuals	22	38	38	19	31.66
Ratio	1	1.72	1	0.5	

### Habitat suitability

The habitat selection of wild elephant and the other species was analyzed by combining animal appearance data from camera trap photographs along with physical environmental factors including the roads, elevation, slope, salt licks and villages, as well as biological, environmental factors which are normalized difference vegetation index (NDVI), water sources and land use. In the model of the opportunities for the benefit of habitat according to environmental factors, it was found that the factors most influencing Asian elephant and 5 ungulate species were the distance from the road (37.2%), followed by the distance from a salt licks (21.6%), and elevation (17.8%) (Table 5). Furthermore, when considering the data from 122 camera trap locations, the model shows that area under the curve (AUC) indicates an accuracy of 0.95%. Therefore, the model was used to explain the reliability of a 95% Asian elephant and the other species habitat use model (Fawcett 2006). In addition, the threshold value of Maximum training sensitivity plus specificity and p-value for modeling habitat of the species were also reported. The details are shown in Table 5.

#### Asian elephant

The environmental factors affecting the selection of habitat use by Asian elephant are the distance from the road (35.7%), salt lick sites (20.1%), and elevation (20%). The other environmental factors were less effective: slope, the distance from the village, plant community, water source, and land use with percentages equal to 7.9%, 2.4%, 2.8%, 5.6%, and 5.4%, respectively. The distance from the road accounted for 35.7% of the environmental factors that most influenced the appearance of Asian elephant. This can be explained by selecting habitat use near the roads and salt lick sites. In higher elevations and slopes, Asian elephant choose to use the habitat or be present less. Considering the size of habitat suitability, it was found that 331.19 km<sup>2</sup> of the total area could be divided into areas that have a high possibility of Asian elephant presence at approximately 60.51 km<sup>2</sup>, an area with moderate possibility at approximately 73.41 km<sup>2</sup>, and a low possibility at approximately 197.27 km<sup>2</sup>, which is small in comparison with the area of KYNP with a size of 2,168 km<sup>2</sup>. And the distribution of habitat use of Asian elephant is to the north of the park near the village or human activity area and agriculture land (Figure 2). Over the last three years, a study has found that Asian elephant prefers to use the northern part of the park and be close to the village, especially Ban Klong Pla Kang. There is distribution into the KYNP area around the Pak Chong checkpoint because the habitat most used is near the border with crops and fruit

trees that influence Asian elephants to go outside the park, which tends to increase, making confrontation between humans and Asian elephant more violent.

#### Gaur

From the data from 35 locations where gaur occurred, the analysis showed AUC indicates the model was highly reliable with 91.6% accuracy. The area suitable to use was 287.73 km<sup>2</sup>. When considering the environmental factors affecting appearance, the distance from salt lick sites was found to have the most effect at 48.9%, meaning the chance of the occurrence of gaur is high when close to salt lick sites and decreases when far from salt lick sites, followed by the elevation, from 0 m there is a chance of the appearance of gaur and it rises to the level of 400 m. Types of land use had a 10.6% effect with gaur using dry evergreen forest more than other types. The slope of the areas affects at 10%; when the slope increases the probability of appearance decreases. The distance from the road impacts the chance of appearing at 6.6%. Gaur appears more near the road and less when the distance is far from the road and the distance from the village, which affects at 2.3%. The distance from water source had an effect of 0.5% and the vegetation index has the least impact on the appearance at 0.4%.

#### Sambar deer

The data on locations where sambar deer appear on the camera trap showed 52 locations; the analysis showed that the model's accuracy was 95.4%. The habitat suitable was 249.97 km<sup>2</sup>. When considering the environmental factors affecting the probability of sambar deer appearance, it was found that the distance from salt lick sites affects the chance of appearing as high as 63.6%; the further the distance from salt lick sites, the lower chance for a sambar deer appearance. The elevation of an area affects the appearance of 13.9%, with approximately 400 m high having the highest probability of appearance. The land-use type influences the chance of occurrence at 10.1%, and sambar deer select dry evergreen forest more than other types of land use. The distance from the road affected 7.3%; the sambar deer appeared near the road and decreased as the distance was further away. The environmental factors which affect the chance at a low level consisted of vegetation index affecting the probability of occurrence at 2.4%, water source (1.9%), slope (0.7%) and the distance from a village (0.1%).

#### Wild boar

Wild boar appeared in camera trap images at 51 locations and analysis showed that the model's accuracy



was 91.1 %. The suitable habitat covered 540.40 km<sup>2</sup>. When considering the environmental factors affecting the probability of wild boar appearance, we found the distance from salt lick sites is an environmental factor that affects the chance of occurrence at 51%, followed by 18% for the distance from the road. The further the distance from the road and salt lick sites, the lower the chance of their appearance. From an elevation of 0 m above sea level, the chance of appearance will rise to an elevation of 400 m. The elevation affects the chance of appearance at 15.5%, which is the wild boar appears more often as the elevation rises to less than 500 m and begins to decrease as the elevation increases above that. The land-use type affects the chance of occurrence at 7.8%; wild boar uses the dry evergreen forest the most and chooses to use the secondary forest. The other environmental factors that affect chance of appearance include the distance from water source at 3.1%; the further the distance, the less chance of seeing a wild boar. The area's slope affects at 2.9%; the higher slope affects the lower the chance of a wild boar's appearance. The distance from the village was 0.8%, with wild boar having a higher chance of appearing not far from the village and begins to decrease as the distance goes further. The vegetation index had the lowest effect on the occurrence chance of 0.3%.

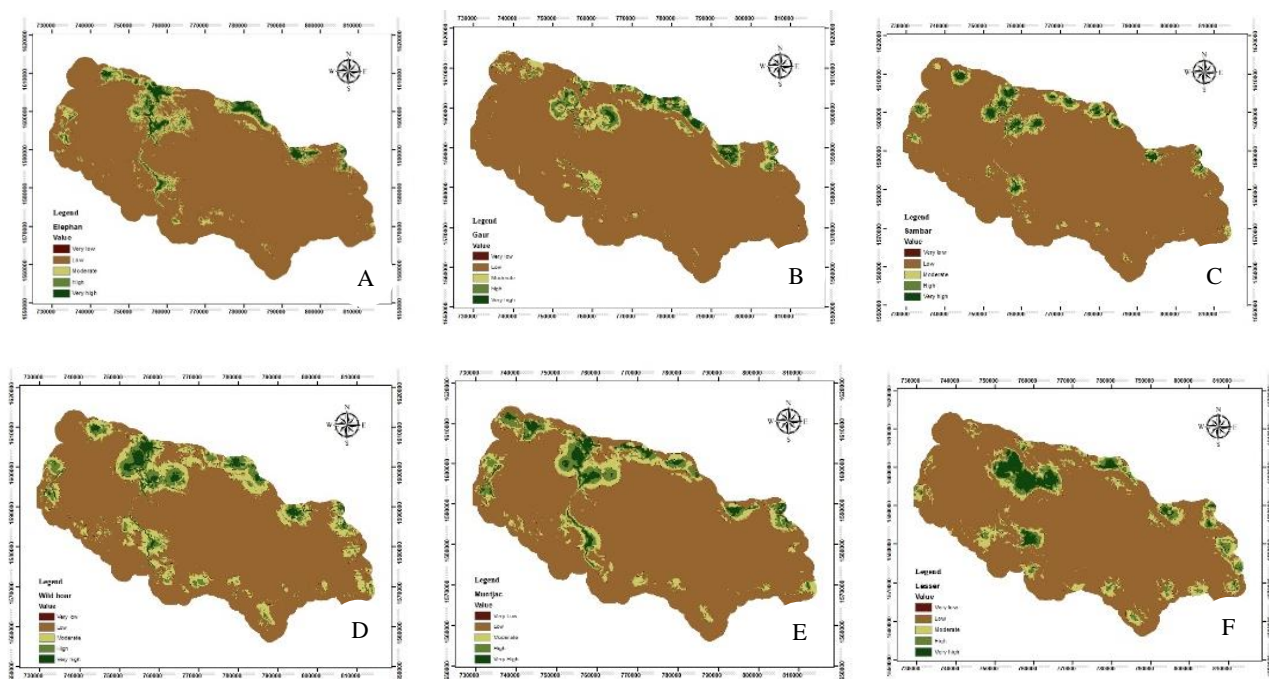
#### *Northern red muntjac*

Northern red muntjac appeared on the camera trap at 60 locations, and the analysis showed that the model's accuracy was 92.8%. The suitable habitat was 451.34 km<sup>2</sup>. When considering the environmental factors affecting the probability of northern red muntjac appearance, we found that environmental factors that had the most effect were as

follows. The distance from the salt lick sites affects 41.6% of the chance of appearing, the chance for appearance is high when near saltlick sites and decreases as the distance is further. This is the same for the distance to the road (26.2%). The elevation affects the chance of appearance at 14.6%; the probability of appearance increases from an altitude of 12 m to approximately 400 m and when the height increases to more than 400 m the chance of northern red muntjac appearing begins to decrease. The land-use pattern was 13.4%, with the largest selection of habitats in the dry evergreen forest. The area's slope affects the appearance of the northern red muntjac at 2.6%; when the slope increases, there is a lower chance of appearance. The distance from the village affects the appearance at 1.2%; northern red muntjac has an appearance distance of about 100 m, but the further the distance, the less likely they are to appear. The vegetation index was 0.3%. The thicker the vegetation cover, the lower the chance of the appearance of northern red muntjac. The distance from water source affects the chance of appearance by 0%; the chance of appearing is constant whether near or far from the water source.

#### *Lesser oriental chevrotain*

Lesser oriental chevrotain appeared on the camera traps at 11 locations; the analysis showed that the model's accuracy was 95.7%. The suitable habitat area was 434.30 km<sup>2</sup>. When considering the environmental factors affecting the probability of lesser oriental chevrotain appearance, we found that the distance from salt lick sites affected the chance of appearing of 58.3%, meaning that at a distance far from saltlick sites the chance of appearance was less.



**Figure 2.** Habitat suitability maps of Asian elephant (A), gaur (B), sambar deer (C), wild boar (D), northern red muntjac (E), lesser oriental chevrotain, (F) based on camera trap data

**Table 5.** Percentage contribution of the environmental factors on Asian elephant and other large herbivore species presence over the year, the environmental factors influencing the species presence.

Species	Environment factor (percentage contribution)								Test AUC	Maximum training sensitivity plus specificity	
	Distance from Saltlick site	Distance from road	Elevation	Slope	Land use	Distance from water sources	Normalized difference vegetation index	Distance from village		Cloglog threshold value	P-value
Asian elephant	20	35.7	20.1	7.9	5.4	5.6	2.8	2.4	0.949	0.382	6.996E-7
Gaur	48.9	6.6	20.6	10	10.6	0.5	0.4	2.3	0.955	0.164	4.036E-4
Sambar deer	63.6	7.3	13.9	0.7	10.1	1.9	2.4	0.1	0.939	0.120	2.721E-5
Wild boar	51	18.6	15.5	29	7.8	3.1	0.3	0.8	0.900	0.362	9.044E-4
Northern red muntjac	41.6	26.2	14.6	2.6	13.4	0	0.3	1.2	0.950	0.176	1.757E-7
Lesser oriental chevrotain	58.3	0.3	6.3	24.4	6.3	4	0	0	0.680	0.506	1.354E-1
All species	21.6	37.2	17.8	2.7	15.4	1.4	3.3	0.7	0.887	0.326	1.253E-7
	305	131.9	108.8	77.3	69	16.5	9.5	7.5			



The slope of areas affected at 24.4%, so the chance of appearance is reduced when the slope increases. The elevation has an effect at 6.3%; when the elevation increases the chance of the lesser oriental chevrotain appearance decreases. The land-use type affects 6.3%, with the highest occurrence in secondary forest, followed by dry evergreen forest. Far from a water source, the probability of appearance will be decreased. The vegetation index and the distance from the villages had 0% influence, meaning the chance of appearance was equal everywhere. The habitat suitability maps are shown in Figure 2. The habitat suitability analysis showed that roads and salt lick sites were the essential factors affecting Asian elephant and ungulate species in the area.

## Discussion

Large herbivores act as both keystone species and umbrella species in ecosystems and should be managed for the maintenance and restoration of biodiversity (Found 2016). The results of this study based on camera trap data revealed that, from the 6 large herbivorous species studied, the highest abundance of large herbivorous species in the KYNP were gaur, followed by wild boar, sambar deer, Asian elephant, northern red muntjac and lesser oriental chevrotain, in order. In addition to being prey for carnivores, especially dhole (Charaspet et al. 2020; Khoewsree et al. 2020), which are the main predators of the area, these wildlife species also contribute to the conditioning of the ecosystems by taking part in conditioning the plant society and soil conditions in the area (Scott et al. 2018).

Considering the results from the analysis of the probability in the site occupancy, it was found that sambar deer had the highest probability of site occupancy ( $\psi = \text{Pr}(\text{the species occupy site})$ ) with a value of ( $\psi \pm \text{SE}$ )  $0.79 \pm 0.04$ , followed by wild boar with a value of  $0.77 \pm 0.05$ , northern red muntjac with  $0.77 \pm 0.05$ , Asian elephant with  $0.70 \pm 0.06$ , lesser oriental chevrotain with  $0.63 \pm 0.07$  and the lowest was the gaur with a value of  $0.57 \pm 0.07$ . When comparing with the results of the study on the probability of site occupancy of the ungulates studied using the same camera trap method from Central and East Kalimantan in Indonesia by Bersacola et al. (2019), it was found that the probability of site occupancy of the wild boar was  $0.59 \pm 0.27$ , northern red muntjac was  $0.59 \pm 0.19$ , sambar deer was  $0.57 \pm 0.09$  and the lesser oriental chevrotain was  $0.27 \pm 0.08$ , which are less than the results of this study. Jathanna et al. (2015) reported the probability of site occupancy of the Asian elephant at the Western Ghats of Karnataka, India, to have a total value of  $0.637 \pm 0.04$ , which is similar to the results found in the KYNP. The calculated area size occupied by Asian elephant in the study area was 13,483 km<sup>2</sup> from the total area of 21,167 km<sup>2</sup> or approximately 64%. From the results of the probability of site occupancy that was calculated, when considering the total area of the KYNP that covers an area of 2,168 km<sup>2</sup>, the size of the area occupied by Asian elephant in the KYNP is 1,515 km<sup>2</sup>, the gaur is 1,235.57 km<sup>2</sup>, sambar deer is 1,712.72 km<sup>2</sup>, northern red muntjac and wild boar are 1,669.36 km<sup>2</sup> and lesser oriental

chevrotain is 1,365.84 km<sup>2</sup>. However, when considering the results of occupancy calculations without taking into account the probability of classification (naïve occupancy), it was found that the size of the area occupied by Asian elephant and large ungulates in the KYNP were about one times less, with values of 802.16 km<sup>2</sup> for Asian elephant, 542 km<sup>2</sup> for gaur, 1,279.12 km<sup>2</sup> for sambar deer, 1,084 km<sup>2</sup> for wild boar, 1,149.04 km<sup>2</sup> for northern red muntjac and 607.04 km<sup>2</sup> for lesser oriental chevrotain. This indicates that the size of the area is quite limited for living in, which is by the results of the analysis of the optimum area size that showed that by analyzing the overall data, the optimal habitat size for Asian elephant was approximately 331 km<sup>2</sup>. In comparison, that for the gaur was 287.73 km<sup>2</sup>, sambar deer was 249.97 km<sup>2</sup>, wild boar was 540.40 km<sup>2</sup>, northern red muntjac was 451.34 km<sup>2</sup>, and lesser oriental chevrotain was 434.30 km<sup>2</sup>. When considering the presence of those wild animals in the area, it was found that they appeared in the same areas with human activities, both along the highway that cuts through the national park and the boundaries of the national park.

For factors affecting the presence of large herbivores, when considering all types of data from the study, it was found that roads and salt licks have the highest proportions of importance, respectively. In the case of large herbivores such as gaur, sambar deer, wild boar, northern red muntjac and lesser oriental chevrotain, the salt licks had the highest importance for their presence, followed by the area around the highway.

When considering the AUC value that indicates the reliability of the study results from the program found that the value is higher than 0.90 in all species, which means that all equations are reliable in gaur, northern red muntjac, Asian elephant, sambar deer and wild boar respectively except for lesser oriental chevrotain, which was found to have the AUC value of 0.680, that showed low accuracy (Bowers and Zhou 2019) probably due to the small number of the positions recorded. In addition, the installation of camera trap in the area at the high as Asian elephant of the operation may be less than the reality. Thus lowering the AUC value of lesser oriental chevrotain was performed.

Gray (2018) used camera trap, between 30 and 50 cm above and perpendicular to the ground, to study the abundance of ungulate species, including lesser oriental chevrotain, northern red muntjac, sambar deer, wild boar and serow (*Capricornis milneedwardsii*) while this study used between 50 and 70 cm above and perpendicular to the ground. Therefore, the small size of mammals may not be recorded or is less than it should be. Further investigation on lesser oriental chevrotain and northern red muntjac is needed. In general, placing camera traps high in trees significantly compromised detection of our target fauna and other species compared to a typical lower deployment strategy (Meek et al. 2016).

However, Gray and Phan (2011) used camera trap sets mounted on a tree at 25-100 cm high above the ground to study the diversity and habitat use of wildlife in Cambodia's northern and eastern plains. They reported 23 species of mammals, including Asian elephants, banteng (*B. javanicus*), gaur, sambar deer, wild boar, leopard

(*Panthera pardus*), dhole, Siamese hare (*Lepus peguensis*) and so on. That can calculate the abundance and habitat use of each species. While Suzuki et al. (2017) used camera trap sets mounted on a tree at 30-50 cm high above the ground to study wildlife diversity and habitat use in Chhep Wildlife Sanctuary located in northern Preah Vihear Province and borders Thailand and Laos. They reported 30 mammalian species in the area.

The results of the camera trap study from this study found 35 species of mammals, 34 species of terrestrial birds and 2 species of reptiles, 71 wildlife species totally confirming the results of the study based on classification images gained by mounted at the high of 50-70 cm on trees above the ground are said to be accurate in recording small to large wildlife. This indicates that the method and the high of camera trap on trees above the ground during this study had less effect on recording wildlife at the high of 50-70 cm above the ground than less than the study of Gray and Phan (2011) when determined small body size of animals such as bird and reptile species recorded. The small size of northern red muntjac and lesser oriental chevrotain that resulted in this study may be less due to the small population size in the area. Long-term investigation should be a procedure.

For Asian elephant, it was found that highways (roads) and salt licks were the most significant for their appearance, in order. When considering the study results of Sharma et al. (2020) that reported the area along the roads as the most important factor affecting the presence of wild elephants in the Western Terai of Nepal, they had the same results. When considering the factors affecting the presence of Asian elephant in the arid areas of Africa, from the study of Williams et al. (2017) in Kasigau wildlife corridor, SE Kenya, it was found that water source was the factor that affected the appearance of Asian elephant the most, due to arid terrain and water sources being important factors in the survival of Asian elephant. In Thailand, in natural areas without highways cutting through, it was found that the main factors affecting the presence of Asian elephant, from the study of Htet et al. (2021), were the forest condition, saltlick and activity areas of park rangers. And when considering the study of factors affecting the presence of wild elephants in the Khao Ang Rue Nai Wildlife Sanctuary, from the study by Menkhem et al. 2019, it was found that the salt licks and man-made water sources were the factors with the highest influence affecting the appearance of Asian elephant. This is the same as Pla-ard et al. (2019), who found that saltlick sites are an essential factor for the appearance of Asian elephant in the KYNP, by using the location data of the Asian elephant obtained from patrols.

The results of this study reveal that, when considering the overall data, the factors affecting the appearance of gaur, sambar deer, wild boar, northern red muntjac and lesser oriental chevrotain, the highest were salt lick, elevation above sea level, areas along roads, slope, type of land use, water source, distance from village or agricultural area and the plant society coverage. The salt lick sites in the KYNP are areas where grassland is managed by burning every year, have a water source to attract wildlife

and are areas with tourist activities almost all year round. The wildlife in the national park is used to humans and sometimes causes damage to human property or even endangers life. In the border areas, Asian elephants feed on agricultural crops grown in the community's living areas. Based on the results of this study, recommendations for the necessary management of Asian elephant and other large herbivores include creating salt licks, as well as grassland sites and water sources, placed away from human activity areas and away from the boundaries of the national park, coming deeper into the park area. There are open areas in the central part of the park that need to be managed to attract wildlife. In addition, strict management of solid waste, sewage and odor caused by cooking should be acted on to avoid attracting wildlife and increase caution about speed and noise while traveling on the highway, both within the national park and the surrounding areas adjacent to the park.

Jenks et al. (2012) suggested that rangers should increase patrolling efforts of border areas and should increase wildlife patrolling in inaccessible areas with mobile range units may be more effective than establishing more ranger stations along park boundaries. Later international and inter-agency collaboration to suppress illegal wildlife poaching reveals that the much-increased patrolling and monitoring effort has a steady coinciding reduction in offenses (IUCN 2021). The population of elephants is large compared to other areas in the forest complex (IUCN 2017). However, the number of wildlife protected from poaching and has good area management should increase every year. Therefore, the population dynamics of this wildlife should be monitored and the relationship with local carnivores and the health of wildlife populations.

In the case of the proportion of the adult sex ratio, it was very similar and showed very little variation, having 1:1.72 adult males to adult females. This is similar to the report of Nofinska et al. (2019) in Bukit Barisan Selatan National Park, Indonesia. Based on DNA analysis, they found that the ratio between adult males and adult females was 1:1.70. They also reported that the samples were dominated by 30.8 % of sub-adult males, 21.2 % sub-adult females, 13.5 % adult females, 9.6 % adult males and 5.8 % juvenile males. The adult sex ratio of the elephants in the area is still not different from the previous study of Pla-ard et al. (2019), which showed the ratio of adult male to adult female elephants to be 1:1.10. However, the previous result was based on a different method, confirming unbiased study results. In this study, the ratio between adult males and adult females was classified as normal when compared with the normal ratio of 1:1.87 and 1:1.85 reported in the Rajaji National Park in India (Williams et al. 2007) and Ruhuna National Park in Sri Lanka (Katugaha et al. 1999), respectively. De and Spillet (1966) suggested that a greater or less than 1:1 sex ratio may usually be found in an area free from selective shooting or predation. The poaching of adult male Asian Elephants has significantly altered their sex ratio in the Western Ghats (Arivazhagan and Sukumar 2008). Therefore, because of the normal sex ratio found in this study, it may be speculated that there has not been any

significant elephant poaching within the KYNP for a considerable time. Kumara et al. (2012) reported a ratio of adult males: adult females of 1:4.1 and a ratio of adult females: immature elephants of 1:0.35 in Biligiri Rangaswamy Temple Tiger Reserve, India. Those findings reflect the past severe poaching of male elephants, with poaching likely lowering the calf-to-adult female ratio. This would affect birth rates and disturb the demographic structure, inhibiting the long-term survival of elephants (Foley et al. 2001). The ratio between adult females and calves, or the reproductive rate of the elephant, was 1: 0.50. The reproductive rate of wild female African elephants was 0.186 births per female per year (Lee et al. 2016), lower than that of this study. Based on Pla-ard et al. (2019) study, 300 wild elephants were reported in the area. Thus, the population growth rate was calculated as 127 adult wild elephants, with 80 adult female elephants, based on the ratio of adult male to adult female elephants of 1:1.72. Therefore, considering the ratio of adult female elephants to calves found in the population was 1: 0.50; there were also 40 newborn wild elephants. Menkham et al. (2019) and Chaiyarat et al. (2015) studied the wild elephant population using the camera trap method as in this study and found that the reproductive rate or the ratio between adult females and calves was 1: 0.3. From the Menkham et al. (2019) study, if there are 10 adult female elephants, there will be 3 calves. However, as female wild elephants have a gestation period of 22 months (Lueders et al. 2012) and raising newborns requires approximately 3-4 years, the length of pregnancy and breast-feeding of female elephants requires 5-6 years (Fowler and Mikota 2006). Therefore, the number of newborn elephants relates to the number of Asian elephant in the past 5-6 years. Thus, approximately 7-8 wild elephants emerge each year, excluding deaths in the population. Consider the recruitment rate in the wild elephant population that was found to be 31.66 in Table 4. Similarly, the recruitment rate, if calculated in the period 5-6 years for the same reason above, the annual recruitment rate in the wild elephant population will be between 5.28 and 6.33 per year, excluding the mortality rate, which shows reasonable results. Considering the results of Dobias (1985), who reported an average population of 150 wild elephants in the KYNP, our findings' sex ratio and the age structure suggest that the population has increased by approximately 150 individuals in the past 36 years.

Temporal analysis with Oriana Program (Kovach Computing Services 2019) showed appearance of the 6 large herbivore species based on photographically recorded to increase understand the temporal interaction among the wild animals found that 3 species had mostly recorded at night including Asian elephant (n=355) with the average time recorded of 20:46 (311.507°), gaur (n=626) with the average time recorded of 22: 15 (333.83°), sambar deer (n=480) with the average time recorded of 23:53 (358.358°). At the same time, it was found that there were 3 species with an average time during day. There were wild boar (n=501) with an average time recorded of 13:02 (195.624°) northern red muntjac (n=256) with an average time recorded of 07:44 (116.166°) and lesser oriental chevrotain (n=30) with an average time recorded of 11:13

(168.303°). Therefore, it can be concluded that individuals are detected 24 hours a day, but they vary according to the natural characteristics of each species.

The relative abundance index of the Asian elephant based on camera trap record was 8.58%. The patch occupancy was 70% (SE=0.06) and the abundance was 1.21 individuals/km<sup>2</sup>. The ratios between adults, sub-adults, juveniles and calves were 3.16: 1.2: 2.1: 1. The ratio between male and female was 1: 1.172, while the ratio between females and calves was 1:0.5. Asian elephant mostly use dry evergreen forest and select to use the habitat on the north part of KYNP near the border between the park and human activity land. The habitat suitable for Asian elephant covers 331 km<sup>2</sup>. The suitable areas for gaur, sambar deer, wild boar, northern red muntjac and lesser oriental chevrotain were 287.73 km<sup>2</sup>, 249.97 km<sup>2</sup>, 540.40 km<sup>2</sup>, 451.34 km<sup>2</sup> and 434.30 km<sup>2</sup>, respectively. The results also showed that salt lick sites and roads were the important factors affecting the appearance of Asian elephant and ungulate species in the area. Recommendations for further management involve concentrating on the suitable area identified from this study. Concerning the suitable habitat, it was found that the park boundary was most suited. Therefore, habitat manipulation, grassland habitats and water sources improvement for all large herbivorous mammal species should improve the areas within the national park and especially address the central area, with an emphasis on creating salt licks, the most important habitat factor for the species in addition to managed water and grassland sources. Moreover, the wildlife corridor area should be implemented so that the wild elephant population can travel between the national parks within the Dong Phrayayen Khao Yai forest complex. Collaboration with the surrounding agencies and communities to reduce the attraction of going out to roam in agricultural areas around the park to mitigate the conflict between humans and wild elephants should be intensively done.

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