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Population Characteristics and Habitat Suitability of Wild Elephant and 5 ungulate species in Khao Yai National Park, Thailand

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ABSTRACT
The study of population characteristics and habitat suitability of wild elephant and 5 ungulate species was conducted between October 2017 and May 2020 in Khao Yai National Park using the camera trap. 122 camera trap locations were set up for a total of 4,139 trap nights and conducting 5461 independence encounters. The target species were wild elephant (Elephas maximus), gaur (Bos gaurus), sambar (Rusa unicolor), wild boar (Sus scrofa), northern red muntjac (Muntiacus vaginalis), and Lesser Oriental Chevrotain (Tragulus kanchil) were recorded. The results showed the occupancy of wild elephants was 1.21 individual/km² within the study area. The probability occupancy of the wild elephant was 70% (SE=0.06) while gaur was probability occupancy of 57% (SE=0.07), whereas the 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 Chevrotain occupancy 63% (SE=0.07). The age structure of wild elephants 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 result showed that roads and ranger station were the important factors affecting the appearance of wild elephants and ungulated species of the area. The habitat suitability for wild elephants is 331 km². While those of the gaur, sambar deer, wild boar, red muntjak and Lesser Oriental Chevrotain were 287.73 km², 249.97 km², 540.40 km², 451.34 km² and 434.30 km² respectively. Recommendations for further management involve concentrated in the suitable area as resulted from this study. In relation to the suitability habitat, it was found that the park boundary was most suitable. 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 licks, the most important habitat factor for the species.
Keywords: *Wild elephant, Camera trap, Age structure, Habitat suitability, Khao Yai National Pak*

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INTRODUCTION

The increased need for natural resources to support the growing human population has caused loss, degradation, and conflict between humans and wildlife [8]. This has become an increasing problem throughout the world, affecting food security, society, the economy, the environment, and overall natural resources [31]. In Asia, the conflict between humans and wildlife species has mainly been restricted to large carnivores e.g., tigers (*Panthera tigris*), leopards (*Panthera pardus*), lions (*Panthera leo*), snow leopards (*Panthera uncia*), and wild elephants (*Elephas maximus*), across a range of countries [3, 37, 39, 43, 22]. Especially elephant are of particular concern because of the relative high frequency and severity of their adverse interactions with human in South Asia [18]. In Thailand, the conflict between humans and elephants has existed for 100 years when more than 1,000 wild elephants came to forage in agricultural land within the Thung Rangsit area [7]. To date, human–elephant interaction has been reported around the borders of 42 of the 69 protected areas in Thailand that still contain elephants [7]. The most important habitat for wild elephants is in the northeast of Thailand at the Khao Yai National Park (KYNP) [33, 7]. Similar to elsewhere, conflict has become a major problem to the endangerment of the elephant species. It has previously been reported that the wild elephant population in the KYNP is approximately between 100 and 200 elephants [6, 33]. It has, therefore, been recommended that the KYNP is the best place to conduct elephant research and undertake technical training [33]. More recent scientific research has been conducted in the KYNP by Lynam *et al.* [20], who used a camera trap method to report a relative abundance of wild elephants of 0.4 ± 0.2 individuals/100 trap nights (n = 121). Moreover, Kitamura et al. [17] studied the role of fruit and seed dispersal by wild elephants in the KYNP by analyzing dung data. It

was fou nd that wild elephants play an important role in the wider distribution and germinating of plants compared with other herbivorous mammal species in the forest; demonstrating the important role of wild elephants in the ecosystem.

The KYNP and other surrounding protected areas were declared natural world heritage sites in 2005 [36]. This likely led to the dramatic increase in tourism, with more than 1,000,000 persons visiting per year since 2013 (National Parks Research and Innovation Development Center (NPRD), 2018) having a direct and indirect impact on the elephant's natural habitat. It was found that the wild elephants in the KYNP regularly roam outside the national park area to feed on agricultural crops. In addition, there have been continuous reports of conflicts between the local people and the wild elephants around the KYNP area. Indeed, there are frequent serious car accidents involving wild elephants, which occur on the roads near the national park. Consequently, the government has attempted to reduce the effect of recreational activities in the park in a number of ways, such as introducing automobile speed limits along the 42 km length of highway within the park, and in particular via public relations. However, there is a requirement for updated information related to the population characteristics of the elephant, to ensure the continued conservation of the species.

Studies on the wild elephant and other ungulated species population as well as the distribution and habitat use, the suitable habitat size between wild elephants and other herbivorous species within KYNP, have never been conducted before. The results of this study will provide a better understanding of the interaction between wild elephants and other herbivorous species that are direct resource competitors affecting the carrying capacity of the habitat [6]. Identification of the cause of animals leaving the protected areas is important for dealing with the migration from the protected areas in several ways. Even though there have been studies on the elephant population count in the area, using line-transect with the indirect method [26]. Photographs taken can give accurate results, which can benefit problem management and more effective elephant conservancy programs. The objectives were to study the population abundance, age structure, sex ratio, reproductive rate and recruitment rate of wild Asian elephants, to study habitat use of wild Asian elephants and other ungulated species 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. The size and location of a suitable habitat area for the population management was determined through a key habitat suitability assessment.

MATERIAL AND METHODS

Study area

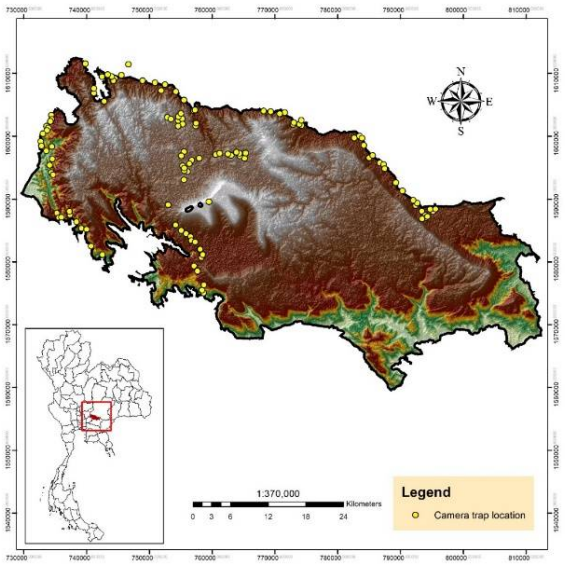


Figure 1 Map of Khao Yai National Park

The KYNP is located in northeastern Thailand between 14°5′–14°15′N and 101°5′–101°50′E and covers an area of approximately 2,168 km^2. The KYNP is an important watershed in the region, regulating water resources to surrounding provinces. The area receives 1,897 mm of annual rainfall with an average temperature of 21°C. The north-eastern region of the park falls within a rain shadow area and has an annual rainfall of 1,300 mm [25]. The park's vegetation is dominated by evergreen forest cover, but it also has a wide range of other habitats, including dry mixed deciduous forests, grasslands, and agricultural

areas. The diversity of the wildlife species is very high, with at least 71 mammal species, 447 bird species, 86 reptile species, and 18 amphibian species [36].

Field Data Collection

Camera trapping

The abundance of wild elephant and other mammalian species studied using camera trap by determining 1 square grid. Each square grid was equal to 1 km^2. One camera trap was installed in every one grid [12, 13, 32, 5]. In all of the study sites, the cameras were set to take photos took a sequence of 3 photos within 10 seconds between consecutive events. The triggering speed of all the camera models was fairly similar. A standard form was filled for each camera trap location, containing information about the date, GPS coordinates, serial number of the camera trap, team members setting up the cameras, habitat and the camera trap locations. The sampling sites were 500 km away from each other at least in each 1 km square grid, and camera traps were set up at 0.4 m above the ground and perpendicular to the trails. The cameras were programmed to remain turned on 24 h a day. Camera traps remained in the field 30 days and were removed to another point to cover more the study area. GPS was used to record the cameras' positions. 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 Camera Trap Manager Programme [42] and brought into Microsoft Excel for further data analysis. The main performance indicators for camera traps are standard for this kind of research [16, 24, 28].

Data Analysis

Camera trap method: The photographs recorded by the camera traps were classified following the method of O'Brien *et al*. [27], which is (1) consecutive photographs of the same species taken in the same location within 30 minutes will be counted as 1 incidence, (2) 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 (3) non-consecutive photographs at different times and locations will be counted as 2 incidences. Identify the species, a number of animals, sex, and age. Then check the accuracy of the information specified for analysis in the next step. Identify individual, sex and age structure using the external characteristics and classification into 4 classes including an adult, subadult, juvenile, and calve [1, 39, 40].

The Relative Abundance Index (RAI) of the elephant and other ungulate species was calculated by multiplying the Photographic Rate by 100 and dividing by the number of trap nights [2] .

Analyze the population structure of the wild Asian elephants from the camera traps, the reproductive rate, and the recruitment rate. The Reproductive rate was calculated by multiplying the number of elephant calves by 100 and dividing by the number of adult female elephants [4] and 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 [4].

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 [38, 30]. Calculate the occupancy (ψ), probability of classification (r), the abundance of animals from camera traps within each grid (λ) 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 [21].

Habitat suitability : The GPS locations of the camera trap that recorded elephant and ungulate species presence were imported and used to find the relation with environmental factors. The environmental factors including elevation, slope, distance from the road, ranger station, village, the plant society type, river, and land use type. A model of the distribution and probability of occurrence in the habitat relating to the environment factor was produced by the MaxEnt program.

RESULT AND DISCUSSION

A total of 122 camera traps locations, a total of 4139 of trap night have recorded a total of 5461 photographs. Which photographs of wild elephant and 5 ungulate species were divided into 355 photographs of wild elephant, 626 photographs of gaur, 480 photographs of sambar, 501 photographs of wild boar, 256 photographs of northern red muntjac and 30 photographs of lesser oriental chevrotain. The relative abidance index (RAI) of the wild elephant was 8.58 %. The RAI of gaur was 15.12 %, sambar was 11.59%, wild boar was 12.10%, Northern Red Muntjac was 6.18% and Lesser Oriental Chevrotain was 0.72%.

Patch occupancy: It was found patch occupancy of the wild elephant had 70% (SE=0.06) with an abundance of 1.2 individual/ km^2. For the other species, the gaur had a patch occupancy of 57% (SE=0.07) and an abundance of 0.85 individual/ km^2. The Sambar had a patch occupancy of 79% (SE=0.04) and an abundance of 1.57 individuals/ km^2. The wild boar had a patch occupancy of 77% (SE=0.05) and an

abundance of 1.49 individuals/ km^2. The northern red muntjac had a patch occupancy of 77% (SE=0.05) and an abundance of 1.49 individuals/ km^2. And the Lesser Oriental Chevrotain had a patch occupancy of 63% (SE=0.07), an abundance of 0.99 individual/ km^2

Population structure of wild elephant: The population structure that comprised of adult, sub-adult, juvenile, and calf was 41.95%, 16.70%, 27.97%, and 13.29% respectively.

The ratio : The ratio between calf, juvenile, sub-adult, and adult was 1: 2.1: 1.2: 3.16. Comparing to the previous study in 2017 with direct observes that 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 As with this study and studies at Khao Ang Ruanai Wildlife Sanctuary, the same method was studied with the proportion of 1: 1.3: 0.08: 11.3 or most populations in the adult class.

The ratio between the adult male and adult female was 1:1.172. Which similar to the result from the studied in the eastern forest complex [32].

The reproductive rate or the ratio between an adult female and calve was 1: 0.5 (Table 4). Compared with Menkham *et al* [23] and Chaiyarat *et al,* [5] who studied wild elephant population using the camera traps method like this study, found that the reproductive rate or the ratio between an adult female and calve at 1: 0.3 seemed this study which Menkham *et al* [23] were described as if there are 10 adult female elephant then there will be 3 calves.

The proportion of the adult sex ratio was very similar and showed very little variation in gender, with a normal population structure ratio identified. Based on the study of Pla-ard *et al*. [26], 300 individuals of wild elephant in the area was reported. Thus, the population growth rate was calculated as 118 adult wild elephants, with 62 adult female elephants based on the ratio adult male to adult female elephants. Therefore, considering the ratio of adult female elephants to calves found in the population was 1: 0.50, there were also new born wild elephants in the population of 56 individuals. However, as female wild elephants have a gestation period of 22 months [20] and raising new born requires approximately 3–4 years, the length of pregnancy and breast-feeding of female elephants requires 5–6 years [11]. Therefore, the number of new born elephants relates to the number of wild elephants in the past 5–6 years. Thus, each year, approximately 9–11 wild elephants emerge, excluding deaths in the population. Kumara *et al*. [19] reported a sex ratio of adult male: adult female of 1:4.1 and a ratio of adult female: immature elephant ratio of 1:0.35. These findings reflected 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 [10, 34, 35]. In this study, the sex ratio between adult male and adult female 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 [41] and Ruhuna National Park in Sri Lanka [15], respectively. Poaching of adult male Asian elephant (*E. maximus*) has significantly altered their sex ratio in the Western Ghats [1, 34, 35]. 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**.**

Table 1: Percentage contribution of the environmental factors on elephant presence over the year shows the elephant presence was influenced by environmental factors.

Species	**Environment Factor (Percentage Contribution)**							
	Distance from Road	**Distance from Ranger Station**	**Distance from Water Sources**	**Distance from Village**	**Land Use**	**Normalized Vegetation Index**	**Ele-vation**	**Slope**
All Species	37.2	21.6	1.4	0.7	15.4	3.3	17.8	2.7
Asian Elephant	35.7	20	5.6	2.4	5.4	2.8	20.1	7.9
Gaur	6.6	48.9	0.5	2.3	10.6	0.4	20.6	10
Sambar	7.3	63.6	1.9	0.1	10.1	2.4	13.9	0.7
Wild Boar	18.6	51	3.1	0.8	7.8	0.3	15.5	29
Northern Red Muntjac	26.2	41.6	0	1.2	13.4	0.3	14.6	2.6
Lesser Oriental Chevrotain	0.3	58.3	4	0	6.3	0	6.3	24.4

Habitat Suitability: The habitat selection of wild elephant and the other species was found that the most factors influencing to the wild elephant and 5 ungulate species were the distance from the road (37.2%), followed by the distance from ranger station (21.6%), and elevation (17.8%).When considering the data

from 122 camera trap locations, the model showed that the AUC indicates an accuracy of 0.95%. The model was to explain the reliability of a 95% wild elephant and the other species habitat use model [9].

Wild elephant: The distance from the road were 35.7% of the environmental factors that the most influenced the appearance. This can explain that the selection of habitat use nears the roads and ranger station. The higher elevation and slope, wild elephants choose to use the habitat or their presence was less. Considering the size of habitat suitability, it was found that only 331.19 km^2. Which is small in comparison with the area of Khao Yai National Park with a size of 2,168.75 km^2. And the distribution of habitat use of wild elephant is to the north of the park which near the village or human activity area and agriculture land. A study over the last three years has found that the wild elephant prefers to use the northern part of the park and close to the village especially Ban Klong Pla Kang. And distribute into KYNP area around the Pak Chong checkpoint because the most of habitat use is near the border with crop and fruit trees that influenced to wild elephant go outside the park and tends to be increasing. And the confrontation between humans and wild elephant more violent.

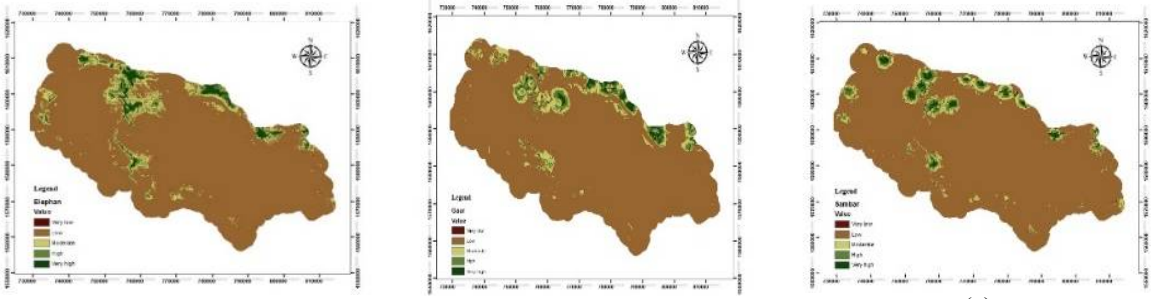
Gaur: The habitat suitability was 287.73 km^2. The environmental factors affecting the appearance, the distance from the ranger stations was found the most effect of 48.9% meaning the opportunity of the occurrence of gaur are high when close to the ranger station followed by the elevation, from 0 meter there is a chance of the appearance of the gaur it is rise to the level of 400 meters. Types of land use were 10.6% with the gaur using in the dry evergreen forest than other types.

Sambar deer: The habitat suitability was 249.97 km^2. The environmental factors affecting the probability of the sambar appearance, it's found the distance from ranger station was an effect on the opportunity appearing as high 63.6%, the further of the distance from the ranger station, the opportunity of the sambar appearance decrease. The elevation of areas influences the appearance of 13.9%, with the approximately 400 meters of the high has the highest opportunity of appearance. Sambar select dry evergreen forest more than other type of land use.

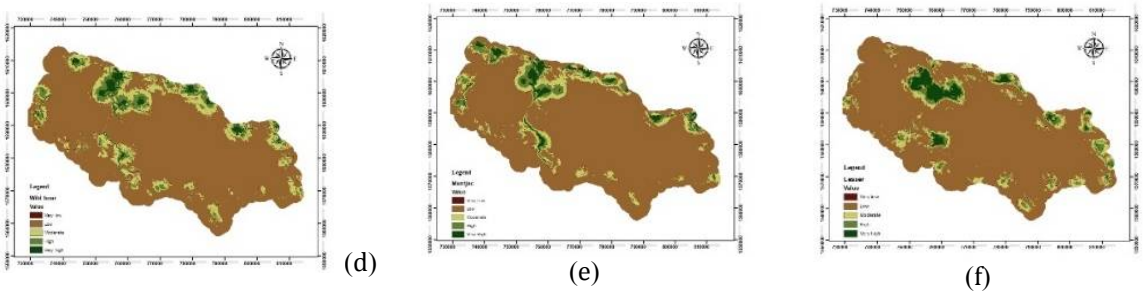
Wild boar: The habitat suitability was 540.40 km^2. The environmental factors affecting of wild boar appearance, we found the distance from ranger station is an environmental factor that affects the opportunity of occurrence of 51%, followed by 18% of the distance from the road. the further the distance from the road and forest ranger, the chance of their appearance decrease. Elevation of 0 meter above sea level, the chance of appearance will rise to elevation of 400 meters. The elevation affects 15.5% of the appearance chance, that is the appearance of wild boar has higher as the elevation rise to less than 500 meters and begins to decrease as the elevation increase. Wild boar used the dry evergreen forest the most and choose to use the secondary forest.

Northern Red Muntjac: The habitat suitability was 451.34 km^2. When considering the environmental factors affecting the probability of northern red muntjac appearance, we found the Environmental factors that most affect their appearance are: The distance from the ranger station affects 41.6% of the chance of appearing, the opportunity of appearance is high when near the ranger station. This is the same as the distance to the road (26.2%). The land use pattern was 13.4% with the largest selection of habitats in the dry evergreen forest.

Lesser Oriental Chevrotain: The habitat suitability was 434.30 km^2. When considering the environmental factors affecting the probability of Lesser Oriental Chevrotain appearance. We found the environmental factors that the distance from ranger station influenced the chance of appearing was 58.3%, meaning the distance far from ranger station which the opportunity of the appearance was less. The slope of areas affects 24.4%, when the slope increased, the chance of the appearance is reduced. Lesser Oriental highest occurrence in secondary forest and followed by dry evergreen forest.



(a) (b) (c)



(d) (e) (f)

Figure 2 Habitat suitability maps of wild elephant (a), Gaur (b), Sambar deer (c), Wild boar (d), Northern Red Muntjac (e), Lesser Oriental Chevrotain (f) based on camera trap data.

CONCLUSION

The relative abundance index of the wild elephant was 8.58%. The patch occupancy was 70% (SE=0.06) and the abundance was 1.21 individual/km^2. The ratio between adult, sub-adult, Juvenile, and calve 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 The wild elephant the most using in dry evergreen forest and select to use the habitat on the north part of KYNP that near the border between park and human activity land. The habitat suitability for wild elephants is 331 km^2. While those of the gaur, sambar deer, wild boar, northern red muntjac and Lesser Oriental Chevrotain were 287.73 km^2, 249.97 km^2, 540.40 km^2, 451.34 km^2 and 434.30 km^2 respectively. The result also showed that roads and ranger station were the important factors affecting the appearance of wild elephants and ungulated species in the area. Recommendations for further management involve concentrated in the suitable area as resulted from this study. In relation to the suitability habitat, it was found that the park boundary was most suitable. 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 licks, the most important habitat factor for the species.

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