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Diversity, abundance, activity period, and factors affecting the appearance of wildlife around the corridors between Khao Yai-Thap Lan National Parks, Thailand by camera trapping

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Abstract. *Sukmasuang R, Charaspet K, Panganta T, Pla-ard M, Khioesree N, Thongbanthum J. 2020. Diversity, abundance, activity period, and factors affecting the appearance of wildlife around the corridors between Khao Yai-Thap Lan National Parks, Thailand by camera trapping. Biodiversitas 21: 2310-2321.* The study on diversity, abundance, activity period, and factors affecting the appearance of wildlife around the wildlife corridors was investigated using camera trap method from September 2017 to November 2018. The corridors located at the royal highway in Ban Bu Phram Subdistrict, Na Di District, Prachinburi Province, Thailand. Based on 21 camera locations, 3,172 trap nights and 6,707 captured pictures totally resulted that a total of 37 species represented by 14 orders and 26 families consisting of 13 species of herbivores, 10 species of carnivores, 10 species of aves and 4 species of reptiles were photographically recorded in the area. Among the wildlife species, 4 species were listed as endangered according to IUCN Red List including Malayan pangolin, large-spotted civet, dhole, Asian forest tortoise, 5 species were listed as vulnerable, there were Sumatran serow, gaur, sambar deer, northern pig-tailed macaque, Asian black bear, and 21 species were listed as least concerned, such as lesser oriental chevrotain, Himalayan porcupine, Asian palm civet, large Indian civet, small Indian civet, hog badger, small Asian mongoose, golden jackal, red jungle fowl, Siamese fireback, coral-billed ground cuckoo and so on. Based on photographic rate of each species, the herbivorous wildlife species represented the relative abundance index of 15.04. The carnivorous wildlife species which had the relative abundance index of 4.70, while the RAI of the aves and reptiles were 1.91 and 0.12. The activity period found that the majority were found at night. This study showed that wildlife corridors have a high influence on the appearance of wildlife, demonstrating the potential of the corridors be used by wildlife for travelling. However, the wildlife corridors should be designed to be suitable for the particular types of animals, especially by increasing the construction of underpasses for mammal at locations with the highest and the number of crossings and also must reduce noise from vehicles, especially at night.

Keywords: Camera trap, Dong Pha Ya Yen-Khao Yai Forest Complex, relative abundance index, wildlife corridor

INTRODUCTION

Deforestation and fragmentation are important causes in the loss of biodiversity (Haddad et al. 2015; Pardini et al. 2017), affecting a larger number of species than biological invasions, overexploitation, or pollution (Collen et al. 2012; Corlett 2016). The causes are leading to habitat degradation, increasing marginal forest land, decreased safe central areas, and increased opportunities for human and environmental disturbances (Didham et al. 2012; Ruffell et al. 2016). These undesirable variations threaten the existence of natural life and increase the opportunities for invasive species to enter the natural area (Pardini et al. 2017). Consequently, this may impact wildlife at the population and genetic level (Matesanz et al. 2017; Schlaepfer et al. 2018(, including mammals and birds (Martin-Albarracin et al. 2015; Hermes et al. 2016) reptiles (Díaz et al. 2000; Griffin 2015) and amphibians (Griffin 2015; Rivera-Ortız 2015). Fragmentation is directly related to the increase in the human population, progressive development, and the construction of basic utilities (Cheptou et al. 2017), which transform natural forests into agricultural areas and habitats. This has been shown to lead to habitat degradation and the disappearance of animal species and populations across the world (Watson et al. 2016).

Road construction for motor vehicle traffic is a major cause of fragmentation, having a significant effect on the disappearance of wildlife populations (Shi et al. 2018). Trombulak and Frissell (2000) stated that roads of all kinds affect terrestrial and aquatic ecosystems in seven general ways: (i) increased mortality from road construction, (ii) increased mortality from collision with vehicles, (iii) modification of animal behavior, (iv) alteration of the physical environment, (v) alteration of the chemical environment, (vi) spread of exotic species, and (vii) increased alteration and use of habitats by humans. da Rosa and Bager (2012) collected neotropical birds killed by car along two federal highways, in southern Brazil. They identified 57 roadkilled species, for a mean roadkill rate of 0.06 ind./km/day. Forman and Alexander (1998) estimated the death of wildlife on the part of a highway route in the Netherlands and reported that 159,000 mammals and 653,000 birds die per year. Heigl et al. (2017) reported in eastern Austria that 180 amphibian and 72 reptile road-kills comprising eight species mainly occurring on agricultural roads. Kernel density estimation analyses revealed a significant clustering of road-killed amphibians and reptiles. Overall, hotspots of amphibian and reptile road-kills were next to the land cover classes' arable land, suburban areas, and vineyards. Conditional probabilities and general linear models identified road-kills especially next to preferred habitats of green toad, common toad, and grass snake, the most often found road-killed species. A citizen science approach appeared to be more cost-efficient than monitoring by professional researchers only when more than 400 km of road are monitored.

The impacts of roads on the well-being, survival, and ultimate population viability of reptiles and amphibians come in two forms: direct effects and indirect effects. Direct effects are the ways in which roads cause mortality or inhibit species movement, such as interactions with vehicles and by creating a barrier to dispersal. Whereas, indirect effects are the resounding impacts that do not immediately threaten species survival; these include habitat fragmentation, inhibiting habitat connectivity, and causing gender skewing and genetic isolation (Griffin 2015). Highways constructed through forests interrupt natural wildlife movement (Shi et al. 2018). According to Fahrig and Rytwinski (2009(, the wildlife that comes into the proximity of cars may have a high level of movement activity, low reproduction rates, and less density due to path disturbances. In contrast, small wildlife was observed to avoid roadside habitats, and therefore were not usually affected by predators hunting on the roadside. Nevertheless, they may be directly affected by highway transportation. Thus the wildlife corridors are an important tool for conservation (Srivastava and Tyagi 2016). The areas have been used as a conservation tool for extensively reviving living populations and natural preservation. Area management through the wildlife corridors has been increasingly used for the separation of discriminating habitats, which is useful for promoting the spread of both plants and animals, and the migration of wildlife from one area to another. This has a positive effect on the conservation of species, populations, and genetic diversity by promoting the establishment of wildlife boundaries in suitable areas (Ament et al. 2014).

General characteristics of wildlife corridors were recognized, such as Benz et al. (2016) suggesting that the width of the wildlife corridors for large mammal should not be less than 330 feet. Alternatively, Newmark (1993(stated that the size, width, and length of the wildlife corridors should be dependent on the conditions of the area. This includes the topographical conditions and native plants that appear, with the structure and elements of the environment important. For example, in arid areas, the wildlife corridors should be wider than those near waterside areas, due to the variety of species and decreased plant cover. In addition, the wildlife corridors in areas with high conservation importance should be wider because of the importance of preserving the diversity of species, and the abundance of local species, in the core area.

In the case of the highway route between the Pak Thong Chai district and Kabinburi district, the road (Royal Highway No. 304) was completed in 1968, with a total distance of 132 km. The development of transportation led to the separation of the Khao Yai and Thap Lan forests, which were originally connected. This also encouraged settlements along the approach road to both of these designated national parks. The Khao Yai, Thap Lan, Pang Sida, and Ta Phraya National Parks, and the Dong Yai Wildlife Sanctuary, have a continuous territory. The location was registered as a World Natural Heritage Site in 2005 under the name of Dong Phayayen-Khao Yai Forest Complex, covering a total area of approximately 6,155 km^2. The length of the complex covers approximately 230 km and is situated along with the Phanom Dong Rak mountain range, which has territory near Cambodia. However, the World Heritage Committee has expressed concern over the threat to world heritage sites, especially illegal logging, possession of forest areas, construction of reservoirs, and the use of the Pak Thong Chai Highway in Kabin Buri. In 2017, the Dong Phayayen-Khao Yai Forest Complex was a World Heritage Site, which was cited as being under threat (UNESCO 2020). This has led to the government taking various measures to reduce the threatening factors. In the case of the royal highway route 304, the government has created a wildlife corridor between the two national parks at the Ban Bu Phram section in the Nadi district, Prachinburi province. This was in order to reduce the impact of the use of highways on wildlife and encourage the movement of wildlife. The first corridor is located in the Ban Bu Phram area and is approximately 3 km in length.

Thus the aim of this study was to investigate the diversity and abundance of wildlife species around the wildlife corridors, Ban Bu Phram in Bu Phram Subdistrict, Na Di District, Prachinburi Province. This will help effectively manage the area of the wildlife corridors, which appears to include information, study activity patterns, and activity times of wildlife as well as factors affecting the appearance of wildlife at the wildlife corridors.

MATERIALS AND METHODS

Study area

The study site is located at Ban Bu Phram Subdistrict, Na Di District, Prachinburi Province, Thailand. The study was carried out at the royal highway along the wildlife corridors and the surrounding area (Figure 1, 2(. On both sides of the route, the total length is about 3 km, covering about 26 km^2. The general condition of the study area can be classified as mountainous, with a stream flowing parallel to the study path. The forest of Thap Lan National Park is a mixed deciduous forest, which alternates with a dry evergreen forest along the stream, with some parts consisting of restoration forests. In contrast, the forest condition at Khao Yai National Park is mostly a dry evergreen forest with a lot of covers, less sunlight to the ground, and high humidity all year round. The objective of the first construction path is to build an elevation path for wildlife to pass through, at an approximate height of 6 m and length of 1,200 m, and a tunnel with a total length of 430 m.

Climate

The average temperature throughout the year is 28.3°C, with the highest average temperature is 33.9°C and the lowest average temperature is 23.8°C. The highest recorded temperature was measured at 42.9°C in Kabin Buri District, Prachinburi Province on April 23, 1990. The lowest ever temperature was measured at 8.5°C in Kabin Buri district, Prachinburi Province on December 30, 1975. The average data over 30 years showed that the lowest average temperature in January was 18.5°C. The highest average temperature in April was 36.5°C. The total rainfall throughout the year is in the range of 1,600-1,900 mm, especially in August and September, which have the highest amount of rainfall in the year. The average number of rainy days is typically around 130-140 days. In addition, in some years, there may be rainstorms passing through, causing the amount and distribution of rain to increase. The highest rainfall ever detected in 24 hours is 194.9 mm (Thai Meteorological Department 2020(.

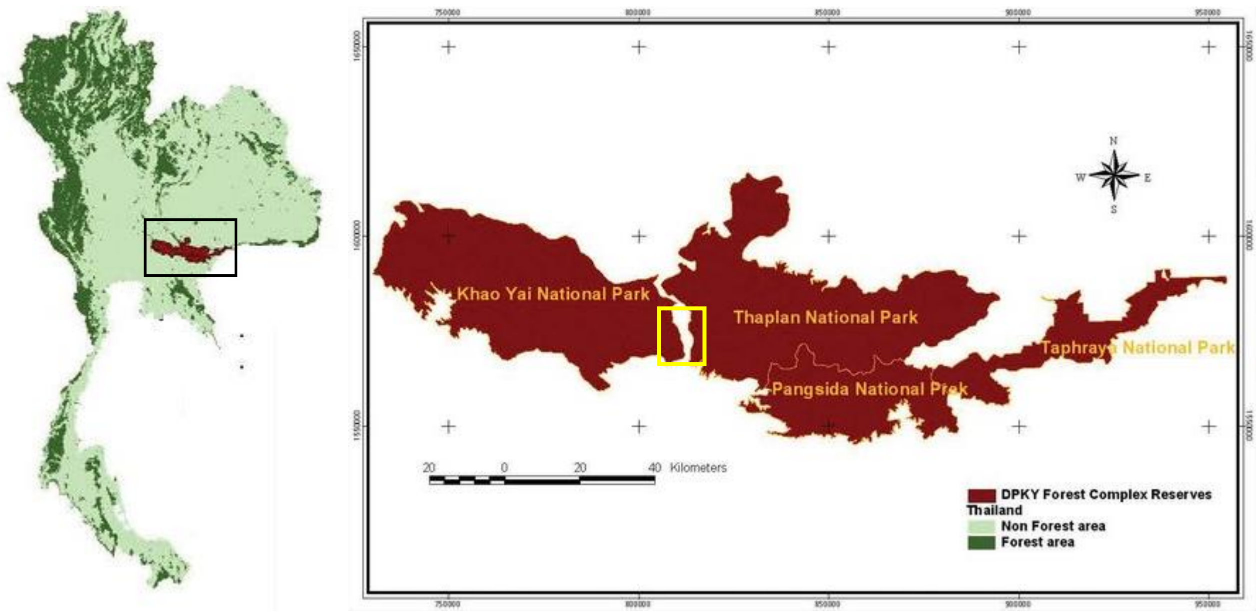

Figure 1. Location of Dong Phayayen-Khao Yai Forest Complex, including the wildlife corridors (Yellow frame) between the 26th km to 29th km area. The study was conducted between September 2017 to November 2018, in both the Khao Yai and Thap Lan National Parks, in the Prachinburi Province, Thailand (Department of Land Development 2016)

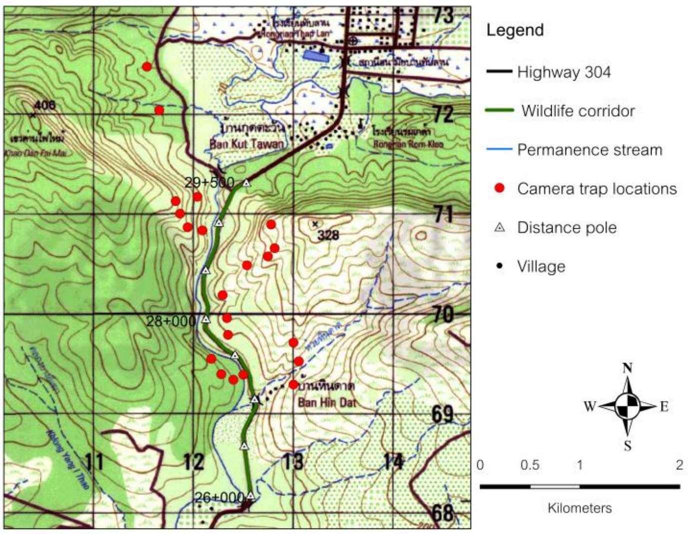

Figure 2. The location of the automatic camera traps around the wildlife corridors and Thap Lan National Park, between September 2017 to November 2018 (Department of Land Development 2016)

Field data procedure

Cameras were installed to capture photos along the highways under construction that connect the two national parks. The cameras were placed to capture photos in 11 areas of Khao Yai National Park and 10 areas of Thap Lan National Park, respectively, during September 2017 to November 2018 (14 months), as follows:

Camera location was defined on a topographic map of 1: 50,000, with each camera far from each other of approximately 200-500 m in a systematic manner (Patrick et al. 2014). The installation proceeded using 1 camera trap set per 1 location. The camera trap was installed in 10 to 15 locations at a time, in each position, the camera was moved to install some new positions as appropriate, in order to cover as much area as possible (Gupta et al. 2009; Jenks et al. 2011, 2012; Siripattaranukul et al. 2015a,b). In particular, the elevated path that was built for wildlife to pass through and the area on both sides that were built as car tunnels to allow wildlife to cross.

The camera location was chosen to capture the picture based on the suitability of each area, including animal crossing routes, areas where signs of wildlife are found, and to provide detailed data recording, including plant communities, roads, and surveillance routes (Lynam et al. 2013; Wongchoo et al. 2013; Siripattaranukul et al. 2015a,b).

The camera trap was installed at approximately 30-40 cm above the ground, and 3-4 m away from the target area (Chutipong et al. 2014), or as appropriate for the area conditions. The camera was specified to take pictures, when the sensor system detected movement, by taking 3 pictures, each 10 seconds apart, over 24 hours a day, which is equivalent to 1 trap night (Team network 2008). The location of the camera trap was recorded using the geocoding machine, where the camera installation was implemented from September 2017 to November 2018.

The photos were obtained from the memory card and transferred to the computer to classify pictures with the Camera Trap Manager, which is an image classification program (Zaragozí et al. 2015). The images were subsequently imported into Microsoft Excel for further data analysis.

Data analysis

All of wildlife species recorded by the cameras were identified, in the case of mammals using the common names and zoological names according to Lekagul and McNeely (1988), in the case of birds according to Lekagul and Round (1991(and in the case of reptiles according to Chan-ard et al. (2015).

Only the pictures that could be clearly classified and with the dates and times shown on the photo were used. A picture capturing more than one carnivorous animal in the same picture was classified as one event (Jenks et al. 2011), and was an independent form or an independent event. The criterion for the independency of the animal photographs was: (i) the sequential pictures of different animals were the same or different species, (ii) sequential pictures of the same animal of the same species, and the pictures were more than 30 minutes apart, and (iii) incoherent pictures of the same animal of the same species (O'Brien et al. 2003).

Biodiversity index of the wildlife species based on photographic recorded (O'Brien et al. 2003) were measured using Simpson's Diversity Index (D), Shannon-Weiner Diversity Index (H´) and the evenness index (Morris et al. 2014) by calculating using Biodiversity Calculator (University of Gothenburg 2019).

Capture frequency the percentage of relative abundance index (RAI) of each species of wildlife were classified according to the carnivorous mammal species, herbivores mammal species, aves, and reptilians. This value was calculated by using RAI = N (100)/A (Carbone et al. 2001; O'Brien et al. 2003; 2011); where N is the number of locations found in that wildlife area multiplied by one hundred divided by A, which is equal to the total number of trap days (total number of trap days = number of camera traps × number of active days).

The time period was divided into 24 hours, and the activity duration of the animals was divided from the number of pictures of each species, and divided into two periods: day time between 06:01-17:59 and nighttime between 18:00-06:00 (Azlan and Sharma 2006; Azlan et al. 2009(. The percentage of the number of pictures taken of each animal, over both periods, was calculated and then the animals were classified into five groups, according to the method of van Schaik and Griffiths (1996(. Therefore, if the number of pictures during the night was more than 85%, the animal was classified into a group with activities at night (Strongly nocturnal); if the number of pictures during the night was between 61-84%, the animal was classified as belonging to a group that had most activity at night (mostly nocturnal); and if the number of pictures during the night was between 40-60%, the animal was classified to belong to a group with activities that overlapped between day and night (cathemeral). Furthermore, if the number of pictures during the daytime was between 61-84%, the animal was classified into a group that had the most activity in the daytime (mostly diurnal). Alternatively, if the number of pictures during the daytime was more than 85%, the animal was also classified in a group with activities in the daytime (strongly diurnal).

The summary of the living time information, obtained from the camera traps, were classified by species and included information for each animal group. The ORIANA version 4.02 program (Kovach Computing Services 2019) was used to calculate Mean Vector: μ at 95% Confidence Interval (95%CI) (-/+) and Circular Variance by comparing the time presence across different time periods.

Analysis of the habitat selection of all wildlife captured by camera traps was performed using the MaxEnt program (Phillips and Dudik 2008) (vi). This was to find a suitable area according to the relationship with various environmental factors affecting the habitat selection by using the following methods:

The geographic coordinates where the presence of all wildlife divided by season and data combined were imported and then divided them into herbivores, carnivorous mammals, birds, and reptiles. The data obtained from the installation of automatic photography cameras were used to find relationships with other environmental factors.

The environmental factors were divided into two groups including biological environmental factors, which are the plant society types, and 7 physical environmental factors including elevation, slope, and distance from artificial water sources or natural water sources, agricultural land, transportation routes, community area, and the corridors.

Data analysis was conducted by converting the geographic coordinates and the environmental factors into raster data. There are two types of data: (i) continuous data; including the elevation level, slope, the permanent river (Lam Phraya Than in Khao Yai National Park) that flows smoothly across the crossing of the constructed wildlife, the transportation routes, the community resources, and the corridors, (ii) category data; category of land use that includes the plant community and agricultural areas.

A model of distribution and presence opportunities for habitat use was created according to environmental factors of each wildlife group and each species by dividing the data set into two sets; the 75:25 ratio, 75% of the data were used in the MaxEnt program, and 25% of the data were used for checking.

Equal training sensitivity and specificity were considered. The Logistic Threshold was selected as the division of where animals found or not found, and the percent contribution of the environmental factors obtained from the model testing. It shows the results of the correlation analysis of the coordinates of the wildlife presence and the main environment (Phillips and Dudik 2008).

We evaluated the models using a Receiver Operating Curve (ROC) analysis, using the Area Under the Curve (AUC) as a measure of model fitness, where values higher than 0.5 indicate that the model predictions are better than random. The AUC method has been popularized as an omnipotent statistic in assessing the predictive accuracy of species distribution models and is directly offered by the MaxEnt package (Jiménez-Valverde 2012; Phillips and Dudík 2008). AUC also provides some information on the usefulness of the model, AUC: >0.9 = very good; AUC: 0.7-0.9 = good, AUC: <0.7 = uninformative (Baldwin 2009).

RESULTS AND DISCUSSION

The results of the study around the wildlife corridors were taken from 21 locations with automatic cameras. There were 11 locations in the area of Khao Yai National Park, a total of 1,479 trap nights (average per location = 47.70 trap nights, SE = 3.44, min = 24, max = 100) and ten locations in the area of Thap Lan National Park, a total of 1,693 trap nights (average per location = 45.75 trap night, SE = 3.93, min = 2, max = 137). The time spent capturing wildlife between the two areas was similar (P = 0.98, t = 2.01), including placing the camera traps in the area over 3,172 trap nights. The overall data from the installation of the camera traps, on both areas of the connection path, showed that there were various kinds of wildlife, including 13 species of herbivores, 10 species of carnivores, 10 species of birds, and four species of reptiles. In addition, out of a total of 6,707 captured pictures from 3,172 trap nights, there were humans and also pets, including cats and dogs.

The diversity and conservational status of wildlife

There were 37 species found around the wildlife corridors. In classifying species by Family in this study, six species of Order Artiodactyla were found, which belong to the Cervidae family, including the red muntjac, lesser oriental chevrotain, sambar deer; the Suidae family, including the wild boar, Bovidae family, including the Sumatran serow and gaur. There was also one species of primates, five species of Rodentia, including rat (unknown species), Indochinese ground squirrels, Himalayan porcupines, Finlayson's squirrels, grey-bellied squirrels, and one species of Pholidota, including the Malayan pangolin. The camera traps showed that aves were from nine families, seven orders, and from a total of 10 species and that the reptiles were from three families, two orders, and from a total of four species, as shown in Table 1.

Based on this study (data from Table 1), when analyzed by pooled data showed the Simpson’s Diversity Index was 0.081, whereas Shannon-Weiner Diversity Index was 2.903, and the Evenness Index was 0.804. Bibi and Ali (2013) cleared that the values of Shannon-Weiner Diversity Index usually fall between 1.5 and 3.5, only rarely it surpasses 4.5.

In this study, endangered wildlife species that were found included a total of four species, the dhole, Malayan porcupine, Asian forest tortoise, and large-spotted civet (IUCN 2020). There were five species of wildlife found that are classified as vulnerable species, including the northern pig-tailed macaque, sambar deer, gaur, Sumatran serow, and Asian black bear. There were 21 species of wildlife found in conservation status: least concern, including the Indochinese ground squirrel, Himalayan porcupine, lesser oriental chevrotain, grey-bellied squirrel, Asian palm civet, hog badger, leopard cat, small Indian civet, golden jackal, small Asian mongoose, large Indian civet, red jungle fowl, Siamese fireback, Malayan Night Heron, coral-billed ground cuckoo, common emerald dove, Large-tailed nightjar, Chestnut-crowned bush-warbler, shikra, Bengal monitor, and water monitor (Table 1).

The abundance of wildlife

The highest relative abundance index (RAI) of herbivorous wildlife was sambar deer followed by wild boar, rat, red muntjac, northern pig-tailed macaque, Indochinese ground squirrel, Himalayan porcupine, grey-bellied squirrel, lesser oriental chevrotain, Finlayson's squirrels, Sumatran serow, gaur and Malayan pangolin respectively, all with a total of relative abundance index of 15.04%. with the highest relative abundance index of carnivorous wildlife was golden jackal, Asian palm civet, small Indian civet, hog badger, Asian black bear, small Asian mongoose, leopard cat, large-spotted civet, large Indian civet, and dhole respectively, all with a total relative abundance index of 4.70%. Whereas, the highest relative abundance index of wild bird that photographically recorded was Siamese fireback, red jungle fowl, Malayan night heron, blue-winged pitta, coral-billed ground cuckoo, white-rumped shama, Shikra, Chestnut-crowned bush-warbler, common emerald dove and Large-tailed nightjar respectively with a total relative abundance index of 1.91%. In regards to the four species of reptiles, all species had the same relative abundance index as there was only one independent picture per species. The total relative abundance index in the reptile group was 0.12%. The total relative abundance index of all wildlife species around the wildlife corridor was 21.77%, as shown in Table 1.

Activity pattern

In examining the wildlife's livelihood period, two species, sambar deer and hog badger, have overlapped activities between day and night (cathemeral: CM), Four species (the Indochinese ground squirrel, Asian black bear, Siamese fireback and Malayan night heron) have most of their activity in the daytime (Mostly diurnal: MD). Fifteen species have intensive activity during the daytime (Strongly diurnal: SD). Four species have activity at night (Mostly nocturnal: MN). Nine wildlife species have intensive activity at night (Strongly nocturnal: SN), In relation to the above-mentioned, it was found that the herbivorous wildlife, or non-carnivorous wildlife, were mostly cathemeral animals. Alternatively, the carnivore mammals were mostly nocturnal animals, the aves strongly diurnal animals, and the reptilians mostly diurnal animals The details were shown in Table 2.

In both areas of Khao Yai National Park and Thap Lan National Park, the nocturnal species of herbivore wildlife were found around the wildlife corridors they were the red muntjac, rat, Himalayan porcupine, gaur, Sumatran serow and Malayan porcupine. Whereas, the diurnal herbivore species were the wild boar, northern pig-tailed macaque, Indochinese ground squirrel, Finlayson's squirrels, lesser oriental chevrotain, and grey-bellied squirrel. The mean activity time of herbivore species was 16.25 (n = 5,410) (SE = 01: 16) 95% CI 13.54-18:56.

Out of the total of 10 carnivorous species, seven species were nocturnal animals. There were three diurnal animals, including the Asiatic black bear, dhole, and small Asian mongoose. The data analysis of the carnivorous wildlife showed that the mean activity time was 00:16 (n = 625) (SE=00:15) 95% CI 23:46-00:45.

In regards to aves, out of a total of 453 pictures, There were ten species of Aves. Of them, nine species were diurnal, so the nocturnal species only one species. The mean activity time of Aves was 10:26 (SE=00:13) 95% CI 13:54-18:56.

There were four recorded species of reptiles from a total of 12 pictures, namely the Asian forest tortoise, northern forest crested lizard, Bengal monitor, and water monitor. All of them were found in the daytime. The mean activity time of reptiles was 11:56 (SE= 01:31) 95% CI 08:57-14:55; as shown in Table 2

The results of the data analysis of all wildlife found around the wildlife corridors in Thap Lan National Park (n = 4,251) showed that the mean activity time was 00:37 (SE = 00: 41), 95% CI between 23:02 and 01:47. The wildlife around the wildlife corridors in Khao Yai National Park (n = 2,456) had a mean activity time of 12:54 (SE = 00: 18), 95% CI 12:17-13:30. There were significant differences (Watson's U^2 Test = 7.787, P <0.001) in the activity time between the two areas, which are on each side of the wildlife corridors. Analysis of the overall data of both areas, obtained from Khao Yai National Park and from Thap Lan National Park (n = 6,707) showed that the meantime of all wildlife activity was 13:31 (SE = 01: 28), 95% CI 10:38-16:25.

Table 1. Species of wildlife by taxonomy, conservation status, number of independent wildlife pictures, number of locations, and relative abundance index that were found around the wildlife corridors between Khao Yai National Park and Thap Lan National Park Prachinburi Province, Thailand

Order/ Family/common name	Scientific name	No. of pictures	No. of locations (%)	RAI	Conservation status [1)]
Herbivores mammal					
Order Artiodactyla					
Family Bovidae					
Sumatran Serow	*Capricornis sumatraensis*	10	4 (19.05%)	0.32	VU
Gaur	*Bos gaurus*	4	4 (19.05%)	0.13	VU
Family Cervidae					
Sambar deer	*Rusa unicolor*	139	10 (47.62%)	4.38	VU
Red muntjac	*Muntiacus muntjak*	45	15 (71.43%)	1.42	
Family Suidae					
Wild boar	*Sus scrofa*	59	15 (71.43%)	1.86	
Family Tragulidae					
Lesser Oriental Chevrotain	*Tragulus kanchil*	16	4 (19.05%)	0.50	LC
Order Primate					
Family Cercopithecidae					
Northern pig-tailed macaque	*Macaca leonina*	44	12 (57.14%)	1.39	VU
Order Rodentia					
Family Muridae					
Rat	*Rattus* spp.	55	9 (42.86%)	1.73	
Indochinese ground squirrel	*Menetes berdmorei*	44	7 (33.33%)	1.39	LC

Family Sciuridae					
Grey-bellied squirrel	*Callosciurus caniceps*	18	3 (14.29%)	0.57	LC
Finlayson's squirrels	*Callosciurus finlaysonii*	14	6 (28.57 %)	0.44	
Family Hystricidae					
Himalayan porcupine	*Hystrix brachyura*	26	6 (28.57%)	0.82	LC
Order Pholidota					
Family Manidae					
Malayan pangolin	*Manis javanica*	3	1 (4.76%)	0.09	EN
	Sum	477	Sum	15.04	
Carnivores mammals					
Order Carnivora					
Family Viverridae					
Asian palm civet	*Paradoxurus hermaphroditus*	39	12 (57.14%)	1.23	LC
Large Indian Civet	*Viverra zibetha*	5	3 (14.29%)	0.16	LC
Small Indian Civet	*Viverra indica*	18	5 (23.81%)	0.57	LC
Large-spotted civet	*Viverra megaspila*	6	5 (23.81%)	0.19	EN
FamilyUrsidae					
Asian black bear	*Ursus thibetanus*	7	5 (23.81%)	0.22	VU
Family Mustelidae					
Hog Badger	*Arctonyx collaris*	12	5 (23.81%)	0.38	LC
Small Asian mongoose	*Herpestes javanicus*	7	3 (14.29%)	0.22	LC
Family Felidae					
Leopard cat	*Prionailurus bengalensis*	7	5 (23.81%)	0.22	LC
Family Canidae					
Golden jackal	*Canis aureus*	47	4 (19.05%)	1.48	LC
Dhole	*Cuon alpinus*	1	1 (4.76%)	0.03	EN
	sum	150	sum	4.70	
Aves					
Order Accipitriformes					
FamilyAccipitridae					
Shikra	*Accipiter badius*	1	1 (71.43%)	0.03	LC
Order Galliformes					
Family Phasianidae					
Red jungle fowl	*Gallus gallus*	11	6 (71.43%)	0.35	LC
Siamese fireback	*Lophura diardi*	25	4 (71.43%)	0.79	LC
Order Pelecaniformes					
FamilyArdeidae					
Malayan Night Heron	*Gorsachius melanolophus*	10	2 (71.43%)	0.31	LC
Order Passeriformes					
FamilyMuscicapidae					
White-rumped shama	*Copsychus malabaricus*	2	2 (71.43%)	0.06	
Family Pittidae					
Blue-winged pitta	*Pitta moluccensis*	6	1 (4.76%)	0.19	
Family Cettiidae					
Chestnut-crowned Bush-warbler	*Cettia major*	1	1 (4.76%)	0.03	LC
Order Cuculiformes					
Family Cuculidae					
Coral-billed ground cuckoo	*Carpococcyx renauldi*	3	2 (71.43%)	0.09	LC
Order Columbiformes					
Family Columbidae					
Common Emerald Dove	*Chalcophaps indica*	1	1 (4.76%)	0.03	LC
Order Caprimulgiformes					
Family Caprimulgidae					
Large-tailed Nightjar	*Caprimulgus* macrurus	1	1 (4.76%)	0.03	LC
	Sum	57	sum	1.91	
Reptile					
Order Testudines					
Family Testudinidae					
Asian forest tortoise	*Manouria emys*	1	1 (4.76%)	0.03	EN
Order Squamata					
Family Varanidae					
Bengal monitor	*Varanus bengalensis*	1	1 (4.76%)	0.03	LC
Water Monitor	*Varanus salvator*	1	1 (4.76%)	0.03	LC
FamilyAgamidae					
Northern forest crested lizard	*Calotes emma*	1	1 (4.76%)	0.03	
	Sum	4	sum	0.12	

Note: [1)] IUCN (2020): VU: Vulnerable, EN: Endangered, LC: Least concerned

Table 2. Camera trap data of wildlife species, encounter rate of pictures, mean vector, standard error of mean, 95% confidence interval (CI), and wildlife activity patterns, found around the wildlife corridors between Khao Yai National Park and Thap Lan National Park Prachinburi Province, Thailand (September 2017 to November 2018).

Species	Encounter rate of picture	Mean vector (hour)	Standard Error of mean (hour)	95% Confidence interval (hour)	Type
Non-carnivorous species					
Red muntjak	428	02:45	00:32	01:41-03:50	CM
Wild boar	740	11.05	00:17	10:30-11:39	CM
Northern pig-tailed macaque	563	13:56	00:07	13:43-14:10	SD
Sambar deer	2,566	21:58	00:24	21:11-22:46	CM
Rat	194	00:24	00:13	23:58-00:51	SN
Indochinese ground squirrel	228	08.56	00:29	07:38-10:14	MD
Himalayan porcupine	114	01:07	00:16	00:35-01:39	SN
Finlayson's squirrels	104	13:40	00:35	12:30-14:50	SD
Gaur	68	01:05	00:28	00.10-02:00	MN
Sumatran Serow	228	00:30	00:24	23:42-01:17	MN
Lesser Oriental Chevrotain	87	08:02	00:25	07:11-08:53	SD
Grey-bellied squirrel	81	10:58	00:45	12:42-13:46	SD
Malayan pangolin	9	02.12	00.44	00.44-03.44	SN
Sum	5410	16:25	01:16	13:54-18:56	CM
Carnivorous species					
Asian palm civet	146	22:52	00:13	22:25-23:20	SN
Asiatic black bear	22	17:39	01:07	15:26-19:52	MD
Hog badger	76	04:52	00:58	02:58-06:47	CM
Leopard cat	25	21:59	00:41	20:38-23:20	SN
Small Indian Civet	100	00:35	00:14	00:06-01:03	SN
Large-spotted civet	21	00:32	00:31	23:30-01:33	MN
Golden jackal	173	02:23	00:32	01:19-03:27	MN
Small Asian mongoose	36	13:10	00:36	12:59-14:22	SD
Large Indian Civet	18	23:49	01:26	20:59-02:38	SN
Dhole	8	11:04	00.30	10.03-12.05	SD
Sum	625	00:16	00:15	23:46-00:45	MN
Aves					
Red jungle fowl	56	09:47	00:32	08:44-10:51	SD
Siamese fireback	239	11:22	00:17	10:48-11:57	MD
Malayan Night Heron	96	08:44	00:26	07:51-09:36	MD
White-rumped shama	6	10:37	00:03	10:30-10:44	SD
Coral-billed ground cuckoo	17	08:25	01:32	05:24-11:26	SD
Blue-winged pitta	21	11:04	01:25	08:17-13:51	SD
Common Emerald Dove	9	11:46	00:01	11:42-11:50	SD
Large-tailed Nightjar	3	02.57	-	-	SN
Chestnut-crowned Bush-warbler	3	06:48	-	-	SD
Shikra	3	13:05	-	-	SD
Sum	453	10:26	00:13	13:54-18:56	SD
Reptile					
Asian forest tortoise	3	17:06	-	-	SD
Northern forest crested lizard	3	06:11	-	-	SN
Bengal monitor	3	10:03	-	-	SD
Water Monitor	3	13:55	-	-	SD
Sum	12	11:56	01:31	08:57-14:55	MD

Note: SN: Strongly nocturnal, CM: Cathemeral, SD: Strongly diurnal, MN: Mostly nocturnal, MD: Mostly diurnal

Factors affecting the appearance of wildlife around the wildlife corridors

To analysis the factors affecting the appearance of wildlife around the wildlife corridors, we used the environmental factors within a radius of 3 km from the wildlife corridors. The wildlife corridors had an elevated path for wildlife to pass (length: 570 m) and a car tunnel to allow wildlife to walk on the roofs of the tunnel (length of 430 m).Therefore, a total length of 1,000 m has been provided for wildlife to walk through and walk across, with both parts separated by approximately 1 km. The total length of the wildlife corridor system is approximately 3 km, in order to accommodate the volume of cars that use the route. There are approximately 36,000 vehicles per day, via analyzing within a radius of 3 km from the wildlife corridors, which covers an area of 26 km^2.

The environmental factors that were examined to determine their influence on wildlife appearing in the wildlife corridors included the roads that were outside of the wildlife links, both the natural water source and the water source that had been created, the village area, land use (includes various types of forests and agricultural areas), and the elevation of the area.

The average %Area under Curve (AUC) in each group of herbivorous wildlife indicated the accuracy of the model. The average %AUC of herbivores, carnivores, Aves, and reptiles were between 85 and 89%, 83 and 86%, 82 and 95%, and 71%, respectively.

Twelve species of herbivores, were analyzed in this study. The wildlife corridors had the most influence on the appearance of herbivores (%AUC, 53.34% to 75.84%), followed by the village area (%AUC 8.45% to 30.50%), while other factors, such as water resources, the area elevation, land use, and roads had little effect on wildlife appearance.

The %AUC of carnivorous wildlife were ranged between 83-86%, demonstrating the high accuracy of the model. It was found that the wildlife corridors had the most influence on the appearance of carnivorous wildlife, with the wildlife corridors affecting the appearance of carnivorous wildlife by 33.92% during the dry season and up to 82.50% during the rainy season. The overall data showed that the wildlife corridors had an effect on the appearance of the carnivorous wildlife by 64.58%, followed by the village area (39.72%), the dry season (3.16%), and the rainy season (10.40%), respectively. The other factors, including water sources, elevation of the area, land use, and road, had little effect on the appearance of the carnivorous wildlife.

Suitable living space was analyzed on the Aves captured by the camera trap, and nine factors influencing appearance were identified. The average of aves appearance was 82% during the rainy season, and 87% during the dry season. The overall data analysis of 95% demonstrated the high accuracy of the model. The analysis of the results showed that the wildlife corridors had the most influence on the appearance of aves, with 50.00% during the dry season, up to 62.99% during the rainy season. The overall data, showed that the wildlife corridors influenced the presence of aves by 31%.

In reptiles captured with the camera traps, the suitable living space was analyzed and three factors influencing appearance were identified. The reptiles' appearance was on average 82% during the rainy season, and 87% during the dry season. The overall data analysis of 95% demonstrated the high accuracy of the model. The analysis of the results showed that the wildlife corridors had the most influence on the appearance of reptiles, with 50.00% during the dry season, and up to 62.99% during the rainy season. The overall data showed that wildlife corridors influenced the presence of 31% of the reptiles.

Discussion

There were 37 species of wildlife observed consisting of 13 herbivore species, ten carnivore species, ten aves species, and four reptile species. This species diversity compares favorably against the results of the 18 species that Sawongfu et al. (2011) previously reported. However, this study did not find tigers. This study operated around a small area between the 26th km and 27th km of the royal highway route 304. However, despite the disturbance, there was a high species richness of wildlife, consisting of an abundance of wildlife, except for Finlayson's squirrels, gray-bellied squirrels, ground squirrels, and rat, which were found on camera traps. Similar to the studies from Lynam et al. (2003(and Jenks et al. (2011), which were conducted in Khao Yai National Park, we also observed small Indian civets in the area of the wildlife corridors. However, we did not observe tigers, binturong, yellow-throated martens, Malayan sun bears, clouded leopards, Asiatic golden cats, or Asian elephant, compared to the results of the study conducted in the inner part of Khao Yai National Park (as shown in Table 3). In the present study, the overall relative abundance index (RAI) suggested that there were fewer species compared to observations in past studies (Lynam et al. 2003; Jenks et al. 2011). Nevertheless, a higher relative abundance index (RAI) was found compared to a study conducted by Jenks et al. 2011, therefore demonstrating the diversity and abundance of wildlife around the wildlife corridors.

The number of wildlife species around the wildlife corridors is similar to the study of Ghazali et al. (2019). They studied the construction area to create wildlife corridors through the Labis Timur Ecological Corridor Forest in Johor, Malaysia. A total of 24 species of land-dwelling mammals from 8 orders, and 14 families, were found, and 11 species of carnivore, and 13 species of herbivorous or non-carnivorous wildlife reported. Aryall et al. (2012) studied the landscape of Terai Arc, in Nepal by observing the footprints of mammals and the traces, faces, and footprints of the wildlife. The study found five wildlife species i.e., gaur, sambar deer, Indian smooth-coated otter (*Lutrogale perspicillata*), and sloth bear (*Melursus ursinus*) classified as vulnerable by the IUCN present in the area of the corridor. In addition, there was evidence of Leopards and large Indian civets classified as threatened and Indian rhinoceros and Bengal tigers that are about to become extinct. The study also found 96 species of aves by direct observation, particularly three species of vultures. These confirmed the importance of the area management for wildlife around the corridors.

The problems associated with the highway route and wildlife corridors include the obvious impact of transportation on the wildlife between Khao Yai and Thap Lan National Parks. The sounds, car speeds, and pollution caused by cars and accidents can leak down the edge of the road. Therefore, the important ways to decrease the impact on wildlife in the area may include creating wildlife overpasses and green bridges for the Sumatran serow, creating culverts to allow carnivorous or small wildlife to walk through, creation of an underpass for large wildlife, such as sambar deer, gaur, wild boar or wild elephant, and creation of tunnels range from 1-3 ft (0.35-1 m) in diameter for reptiles and amphibians (Clevenger and Huijser 2011(.

Table 3. Species and diversity of key wildlife that was found around the wildlife corridors between Khao Yai National Park and Thap Lan National Park compared with the results of the study conducted in the inner part of Khao Yai National Park studied by Jenks et al. (2011) and Lynam et al. (2003).

Common name	Scientific name	This study (2020)	Jenks et al. (2011)	Lynum et al. (2003)
Sambar Deer	*Rusa unicolor*	4.38	1.85	2.43
Eurasian Wild Pig	*Sus scrofa*	1.86	0.78	1.28
Golden jackal	*Canis aureus*	1.48	0.12	0.00
Barking Deer or red muntjak	*Muntiacus muntjak*	1.42	1.11	5.47
Pig-Tailed Macaque	*Macaca nemestrina*	1.39	0.58	2.50
Asian Palm Civet	*Paradoxurus hermaphroditus*	1.23	0.08	0.20
Malayan Porcupine	*Hystrix brachyura*	0.82	0.75	1.69
Small Indian Civet	*Viverricula indica*	0.57	0.00	0.00
Lesser Mouse-Deer	*Tragulus javanicus*	0.50	0.08	0.56
Hog Badger	*Arctonyx collaris*	0.38	0.10	0.71
Serow	*Capricornis milneedwardsii*	0.32	0.06	0.00
Leopard cat	*Prionailurus bengalensis*	0.22	0.12	0.80
Asiatic Black Bear	*Ursus thibetanus*	0.22	0.14	0.00
Small Asian mongoose	*Herpestes javanicus*	0.22	0.37	0.27
Large-spotted Civet	*Viverra megaspila*	0.19	0.10	0.00
Large Indian civet	*Viverra zibetha*	0.16	1.40	1.23
Gaur	*Bos gaurus*	0.13	0.34	1.06
Sunda Pangolin	*Manis javanica*	0.09	0.12	0.00
Dhole	*Cuon alpinus*	0.03	0.02	0.45
Tiger	*Panthera tigris*	0.00	0.00	0.13
Binturong	*Arctictis binturong*	0.00	0.15	0.07
Yellow-throated marten	*Martes flavigula*	0.00	0.00	0.54
Malayan Sun Bear	*Helarctos malayanus*	0.00	0.27	0.73
Clouded leopard	*Neofelis nebulosa*	0.00	0.06	0.48
Asiatic Golden Cat	*Pardofelis temminckii*	0.00	0.00	0.07
Asian Elephant	*Elephas maximus*	0.00	0.42	0.25
		15.61	9.02	20.92

Caldwell et al. (2019) analyzed camera data from three underpasses in Hallelujah Junction Wildlife Area, Sierra County, California, USA, from June 2017 to December 2018, based on 3,589 detections, which were predominately mule deer (*Odocoileus hemionus*), rodents, lagomorphs, California quail (*Callipepla californica*), bobcats *(Lynx rufus*), mountain lions (*Puma concolor*), and coyotes (*Canis latrans*). They also used occupancy modeling and daily activity estimates to analyze species' spatial and temporal activity within the underpasses. Predator- prey interactions and human disturbances were among the most important factors that influenced wildlife travel through the underpasses. Mule deer avoided underpasses highly used by mountain lions, and mountain lions followed mule deer daily temporal activity patterns and seasonal activity patterns. These results indicate that predator- prey interactions influenced deer and mountain lion use of the underpasses. Coyotes favored underpasses and seasons with higher rodent and lagomorph presence, suggesting that the presence of prey was also important to coyote the use of the underpasses. Coyotes, mountain lions, and bobcats all exhibited either temporal or spatial avoidance of human activity within the underpasses.

In areas where there are no crossings for wildlife, it is sometimes reported that wildlife crosses the road, especially in areas that still remain as forests near the highway. The direct mortality of animals due to vehicle collisions is a primary and obvious effect that reduces animal populations (Schwartz et al. 2020). Therefore, the crossing must be constructed in an area that still looks natural, whether overpasses, underpasses (Beckmann and Hilty 2010; Ament et al. 2014), so that wildlife can travel across the forest as appropriate. The results of installing camera traps in the underpass that was 2 meters wide and 2 meters high, showed that Sumatran serow, hog badger and water monitor would regularly travel in an underpass if present (Sukmasuang R 2020, personal. communication).

This study was undertaken to examine the diversity, abundance, activity period, and habitat suitability of wildlife around the corridors. In addition to the area of Khao Yai National Park, it was found that the area still has a diverse and abundance of wildlife. We observed the large wildlife around the wildlife corridors to be active at night, including the Sambar deer, gaur, Sumatran serow. Concerning to the habitat suitability, the wildlife corridors under construction, whether it's overpasses or underpasses, can have a profound effect on the appearance of wildlife around the wildlife corridors. Therefore, it is recommended that the building of wildlife corridors should continue on the highway 304 route that passes through the forest areas. The corridors should proceed appropriately by taking into account the species and the number of wildlife in the area. In order to have cross-traveling between the two national parks, each wildlife groups should be continually monitored and studied.

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