

Monitoring the diversity, abundance, activity period and habitat use of wildlife species around the wildlife corridor that connects the natural world heritage site in Thailand

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Abstract. *Pla-Ard M, Khioesree N, Keawdee B, Hungheng W, Chattrakuldee P, Pengthong P, Thongbanthum J, Paansri P, Charaspet K, Panganta T, Chanachai Y, Duengkae P, Marod D, Uthairasmee S, Kaewkrachang T, Bhumpakphan N, Trisurat Y, Suksavate W, Sungkaew S, Pongpattananurak N, Racharak P, Wiwatwittaya D, Taseen W, Sukmasuang R. 2021. Monitoring the diversity, abundance, activity period and habitat use of wildlife species around the wildlife corridor that connects the natural world heritage site in Thailand. Biodiversitas 22: 4983-4996.* The development of roads and highways has a significant impact on biodiversity. Moreover, the highway is developed by dissecting protected areas. Highway 304 in Thailand cuts through Khao Yai National Park (KYNP) and Thap Lan National Park (TLNP), areas assigned as World Natural Heritage Site. This study aimed to monitor the diversity and abundance of wildlife around the wildlife corridor area on the Highway 304 and study the animal period of activity and the factors that affect the distribution of wildlife in the area. The study was conducted during September 2017 and May 2021 using camera traps to monitor the area constantly. A total of 51 wildlife species from 30 families and 14 orders were recorded. The species with the highest abundances were Sambar Deer, Wild Boar, Northern Pig-tailed Macaque, Gaur, Northern Red Muntjac, Siamese Fireback, Malayan Porcupine and Red Junglefowl. The wildlife species recorded included 2 Critically Endangered species, 3 Endangered, 10 Vulnerable and 1 Near Threatened. In this study, we also recorded images of a Fishing Cat, the first photographically recorded in this World Heritage Site. The evenness index indicates that the wildlife community in the area was stable. No significant differences in the diversity and abundance of wildlife before or after the corridor construction were seen. The wildlife in the area was active throughout the day. We also found that the highway was the main factor affecting the presence of wildlife. The study results show the importance of wildlife corridors between the two national parks for maintaining the wildlife community and continuity. Suggestions from the study include the restriction of traffic, noise, vehicle speed and other activities that may attract wildlife closer to the community and cause other impacts.

Keywords: Camera trapping, Dong Phrayayen-Khao Yai Forest Complex, Wildlife corridor

INTRODUCTION

The construction of transportation networks, including roads and highways, has a significant impact on biodiversity (Halfwerk et al. 2011; Laurance and Balmford 2013). The number and extent of roads will expand dramatically this century. Globally, at least 25 million kilometers of new roads are anticipated by 2050 (Laurance et al. 2014). Nine-tenths of all road construction is expected to occur in developing nations, including many regions that sustain exceptional biodiversity and vital ecosystem services. Furthermore, approximately half of all roads occurred in forests, mainly historically exploited forests (Sloan et al. 2018). As a result, roads were penetrating wilderness or frontier areas area major proximate driver of habitat loss and fragmentation, wildfires, overhunting and other environmental

degradation, often with irreversible impacts on ecosystems (Laurance et al. 2014). Unfortunately, much road proliferation is chaotic or poorly planned, and the threat of expansion is so significant that it often overwhelms the capacity of environmental planners and managers (Laurance et al. 2014). In many cases, the development of roads and highways drives deforestation and forest fragmentation, reducing biodiversity and habitat stability and influencing the behavior of wild animals (Fahrig and Rytwinski 2009).

When operational, highways can directly cause the death of wildlife through collision. They also cause injuries to wild animals, reducing the health quality, welfare and long-term survival of such wildlife (Polak et al. 2014). While not causing direct damages, traffic noises from the highways affect various types of wildlife. For example, it hurts the reproduction ability of wild birds (Berthiusen

and Altringham 2012; Northrup et al. 2012) and amphibians that use vocalization during their reproductive activities (Caorsi et al. 2017). Traffic noise also has a detrimental effect on the vigilance of wild mammals (Shannon et al. 2016), whether carnivores or prey species, due to communication problems of the wildlife (Duquette et al. 2021).

Highway 304 in Thailand was developed to be the main route connecting the country's eastern and northeastern regions. This highway cuts through Khao Yai National Park (KYNP) and Thap Lan National Park (TLNP), which are parts of the Dong Phrayayen-Khao Yai Forest Complex World Natural Heritage Site declared by UNESCO in 2005 (UNESCO 2021). There are two non-continuous sections where the highway cuts through the two national parks. The first section is three kilometers long and the second section is approximately 16 kilometers long, adding to approximately 19 kilometers. Wildlife corridors were constructed to connect the two national parks in both sections, following the conditions set by IUCN (2005) to enable wildlife to move freely between the two areas, huge animals of both carnivorous and herbivorous species. The corridors in the first three km long section are divided into two parts, including a 1,200 m underpass and a 430 m overpass. The second 16 km long corridors include one 500 m underpass in the hillside (slope) area and several overpasses and elevated bridges are under construction.

Sawongfu et al. (2011) studied wildlife species along Highway 304 and found 23 mammalian species from 7 orders and 15 families, e.g., Asian Elephant, Gaur, Sambar Deer, Malayan Sun Bear, Asiatic Black Bear, Red Muntjac, Wild Boar, Serow, Pig-tailed Macaque, Golden Jackal, Dhole, etc. In contrast, Sukmasuang et al. (2020a) reported wildlife species along the wildlife corridor in the first 3 km section recorded by camera traps deployed from September 2017 to November 2018, with a total of 3,172 trap nights. The number of species found in the study collated from a total of 6,707 images included 13 herbivorous species, 10 carnivorous species, 10 wild bird species and 4 reptile species, adding up to a total of 37 species from 14 orders and 26 families. Within these species, four are categorized as Endangered by the IUCN (2019), including Dhole, Large Spotted Civet, Sunda Pangolin and Asian Giant Tortoise. In addition, five species are categorized as Vulnerable and 21 are Least Concern species.

Although a study on the wildlife diversity along the forest corridors of Highway 304 has been conducted by Sukmasuang et al. (2020a), this was only performed along the corridors in the first 3 km section, while a similar study in the corridors of 16 km section is lacking. Further studies are needed to reveal the species abundance, the suitability of the habitat area and environmental factors along both sections of the wildlife corridor, and the community areas along the highway, which are approximately 56 km. When analyzing the overall spatial data, it will be helpful to investigate various management aspects along the wildlife corridors connecting the two national parks. Research is required to answer the hypothesis of whether there is a difference in species diversity and abundance across three time periods, i.e., before the opening, at the time of the

opening and after the opening of the wildlife corridor. Also, it would be essential to study factors that affect the presence of wildlife along the highway where the wildlife corridor is constructed.

The objectives of this study are: (i) to study the annual wildlife diversity along the whole Highway 304 that passes through KYNP and TLNP from 2017 – 2021; (ii) to compare the diversity of wildlife between before and after the construction of the wildlife corridors; (iii) to study the animal presence in time and the factors that affect the distribution of wildlife in the area. The expected results of this study allow us to understand the use of wildlife around wildlife corridors based on the diversity and abundance of various wildlife species that can use to determine the pattern of wildlife corridors to suit the species of wildlife in the next phase. Changes in wildlife use before and after the creation of wildlife corridors to confirm the importance of the area and corridor project. Physical and biological factors in the area that affect wildlife presence are used to select management methods that shape human activities to reduce the impact for maintaining the abundance and diversity in the area that can continue to operate in this crucial area.

MATERIALS AND METHODS

Study area

The study was conducted along the sections of Highway 304 that pass through KYNP and TLNP. The forests that the highway passes through on the KYNP side are dry evergreen and moist evergreen forests, whereas on the TLNP side are mountainous terrains with mixed deciduous and bamboo forests, and in some parts of the area, there are deciduous dipterocarp forests interspersed with grasslands, which were formed by settlements in the past. Various plants, especially Indochinese fan palm (*Corypha lecomtei*), are distributed throughout the area.

The general condition of the study area is characterized by hills and mountains with a stream running parallel to the route studied. In general, the forest condition in TLNP is mainly mixed deciduous forest interspersed with dry evergreen forests along the stream, and some parts are secondary forests. While the forest in KYNP is a primarily dry evergreen forest with thick forest canopy coverage, thus, little light can penetrate through to the ground causing high humidity all year round. The characteristics of the first corridor construction section include a 6-meter-high overpass for wildlife to pass under with a total length of 1,200 meters and a 430 meters long car tunnel (Figure 1). IUCN (2005) reported that the plant community in the area between KYNP and TLNP is an alternation of dry evergreen forest, mixed deciduous forest and deciduous dipterocarp forest. Grassland areas are also found in some areas of the two national parks inhabited by large herbivorous species such as Gaur, Banteng, and Sambar Deer. In addition, the park is the only area occupied by tigers in the Northeast of Thailand.

Data were collected along the side of Highway 304 where the wildlife corridors were constructed. The first

section is approximately 3 kilometers, and the second section is approximately 15 kilometers. Camera traps were deployed on both sides of the route along the entire length with the distance from the first position to the last position being approximately 28 kilometers.

Climate

The mean annual temperature is 28.3°C, with the mean highest and the lowest temperature being 33.9°C and 23.8°C, respectively. The highest temperature recorded was 42.9°C on 23 April 1990 in Krabinburi District, Prachinburi and the lowest temperature measured was

8.5°C in Krabinburi District, Prachinburi on 30 December 1975. From the 30-year data record, it is found that the average lowest temperature is in January measuring 18.5°C and the highest is in April, measuring 36.5°C. The annual precipitation is between 1,600-1,900 mm, especially in August and September, with the highest rainfall. The average rainfall per year is 130-140 days. In addition, there may be rainstorms moving through in some years, which increase the amount and distribution of rain. The most significant amount of rainfall measured in 24 hours was 194.9 mm (Meteorological Department 2020).

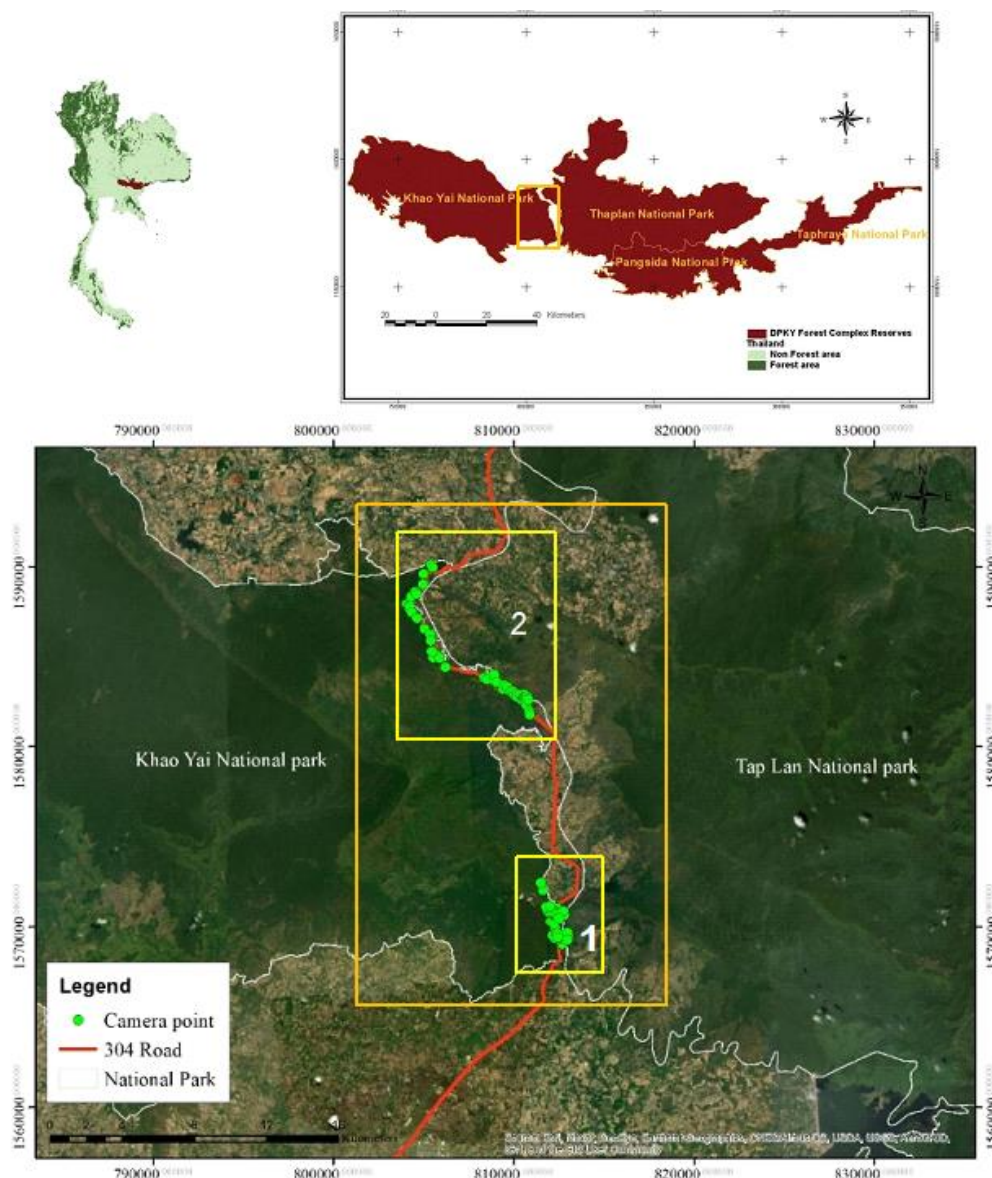


Figure 1. Location of study area and camera traps in Dong Phrayayen-Khao Yai Forest Complex in Thailand and the wildlife corridor areas (yellow rectangles), including areas from kilometer marker 26 to 29 (section 1) and kilometer marker 42 to 59 (section 2), covering the areas of both Khao Yai National Park (KYNP) and Thap Lan National Park (TLNP), Prachinburi Province, Thailand. Sources: Google Earth (2021)

Procedures

Surveys were conducted along the highway. Camera trap locations were chosen according to the area's suitability, for example, along animal trails or areas where animal tracks were seen. The distance of the camera locations on Highway 304 was between 200-1,000 meters. Generally, each camera trap was approximately installed 500 meters apart from others for the independence of the images, reducing the likelihood of capturing images of the same animal by multiple cameras. In each survey trip, 10-15 camera traps were deployed in both National Parks for 1 month in each location and then moved to another suitable location to cover the length of the highway, especially the constructed overpass for the animals to go under, and both sides of the car tunnel for the animals to cross over. The camera traps were placed 30-40 cm above the ground, 3-4 m from the targeted area or as appropriate according to the condition of the area. The cameras were set to take three consecutive images every 10 seconds and set to work 24 hours a day with each 24 hours equaling 1 trap day (TEAM network 2008).

The images captured were transferred into the computer and classified using Camera Trap Manager (Zaragozi et al. 2015) and then imported into Microsoft Excel for further data analysis.

Data analysis

The classification of the wild mammalian species followed Lekagul and McNeely (1988) and for wild bird species observed Lekagul and Round (1991). Only images that could be clearly classified with the date and time shown on the image were identified. The common name, scientific name, taxonomic order and conservation status followed IUCN (2021). This study used the criteria for the independency of animal photographs which include (i) consecutive images of different animals, either the same or different species, (ii) consecutive images of the same animal more than 30 minutes apart and (iii) non-consecutive images of the same animal of the same species (O'Brien and Kinnaird 2011).

The species diversity was calculated using the Shannon-Weiner Index (Krebs 1999) for each wildlife species and the overall wildlife data, based on data on the proportion of images and the number of trap days obtained each year, with the equation presented below:

$$H = - \sum p_i \ln p_i$$

Where:

p_i : S/N ,

S : the number of individuals of one species,

N : the total number of all individuals in the sample,

\ln : the logarithm to the base e .

If $H' \leq 1$, it is classified as low diversity, $1 < H' \leq 3$ as moderate diversity and $H' \geq 3$ as high diversity (Ulfah et al. 2019).

The evenness index is a measure of how similar the abundances of different species are in the community (Pielou 1966; Kvalseth 2015). It is calculated as:

$$\text{Species Evenness} = H / \ln((s-1) / \ln(n))$$

Where:

s : Number of Species Recorded

n : Total Number of Individuals in the Sample

H : Shannon's Diversity Index

Evenness index of $0 < E \leq 0.4$ is classified as a depressed community, $0.4 < E \leq 0.6$ as an unstable community, and if $0.6 < E \leq 1$ as a stable community (Herawati et al. 2019).

The calculation results were used as an index to measure the diversity of the wildlife. The diversity index of the wildlife was then compared between the years 2017 and 2018, which is the period before the opening of the wildlife corridor and 2020 to 2021, which is the period after the wildlife corridors were opened.

The relative abundance index (RAI) of each wildlife species recorded by the camera traps was calculated using the ratio between the presence of the image and the number of the total trap days, which is a method widely used, e.g., Ouboter and Kadosoe (2016), Steinbeiser et al. (2019). The equation is as follows,

$$\text{Relative abundance (\%)} = \frac{\text{trap success} \times 100}{\text{trap nights}}$$

The %RAIs of wildlife species were compared between years 2017 and 2018, which is the period before the wildlife corridor and years 2020 to 2021, which is after the wildlife corridors were opened, using the Mann-Whitney U test at a significance level of $p < 0.05$.

The wildlife activity pattern was studied by dividing the time into 24 hours. The activity time of each species was classified from the number of images, which was divided into 2 periods: daytime, between 06:01-17:59 hrs and nighttime between 18:00-06:00 hrs (Azlan 2009). The percentages of the number of images for both time periods for each species were calculated and the animals were classified into 5 groups following the method of van Schaik and Griffiths (1996). If the number of images during the night was more than 85%, the animals were classified as strongly nocturnal. If the number of images during the night was between 61-84%, the animals were classified as primarily nocturnal. If the number of images during the night was between 40-60%, the animals were classified as cathemeral. If the number of images during the day was between 61-84%, the animals were classified as primarily diurnal, and if the number of images during the day was more than 85%, the animals were classified as strongly daily.

The activity pattern of wildlife from the summary of the activity period from the camera trap images classified by species and the overall data of each animal group were calculated, and with ORIANA version 4.02 (Kovach Computing Services 2019), the Mean Vector (μ) was calculated at 95% Confidence Interval (-/+) for μ and the Circular Variance to compare the time of presence in each period.

The analysis of the suitable habitat of every wildlife species recorded by camera traps was performed using

MaxEnt. MaxEnt only needs the presence data of the interesting species (Phillips and Dudik 2008) based on the relation with environmental factors that affect habitat suitability (Elith et al. 2006; Merow et al. 2013) with methods described below.

The geolocation data of the presence of every wildlife species obtained from the camera traps were imported to be used to find relationships with other environmental factors. Wildlife was classified as herbivorous mammals or not carnivores, carnivorous mammals, birds and reptiles. The environmental factors were divided into biological environmental factors and physical environmental factors (10), including elevation, water sources both natural and artificial, villages, conditions of utilization of the area, various forest types and agricultural areas, and transportation routes and wildlife crossings. All spatial data were converted into raster data for analysis. There were two data types including continuous data, i.e., elevation layer, permanent river (Lam Phraya Than in Khao Yai National Park that flows smoothly along the constructed wildlife corridor), transportation routes, community sites and constructed wildlife corridors, and category data which is the type of land use that includes plant society and agricultural areas. Models of distribution and likelihood of presence in the habitat were then created according to the environmental factors of each wildlife species by dividing the data set into two data sets with a ratio of 75:25, 75% of the data were used for testing in the MaxEnt program and 25% of the data were used for verification. The equal training sensitivity and specificity were then tested using the criteria of the logistic threshold of animal presence and absence and the percentage contribution for each of the environmental factors obtained from testing the model, which is the result of the analysis of the relationship between the coordinates of the wildlife presence and the primary environment (Phillips and Dudik 2008).

RESULTS AND DISCUSSION

Species diversity

From the deployment of camera traps in 99 locations for 12,945 trap nights, a total of 27,494 images were recorded. A total number of 51 wildlife species from 30 families in 14 orders were recorded including 30 species of mammals from 15 families in 5 orders, 17 bird species from 12 families in 7 orders and 4 species of reptiles from 3 families in 2 orders. The mammalian species in the order Carnivora comprised 4 families including family Mustelidae, there was Greater Hog Badger (*Arctonyx collaris*); family Ursidae with 2 species, Asiatic Black Bear (*Ursus thibetanus*) and Sun Bear (*Helarctos malayanus*); family Herpestidae with 2 species, Javan Mongoose (*Herpestes javanicus*), and Crab-eating Mongoose (*Herpestes urva*); family Viverridae recorded 4 species including Common Palm Civet (*Paradoxurus hermaphroditus*), Small Indian Civet (*Viverricula indica*), Large Indian Civet (*Viverra zibetha*) and Large-spotted Civet (*Viverra megaspila*); family Canidae had 2 species including Dhole (*Cuon alpinus*) and Golden Jackal (*Canis*

aureus); family Felidae recorded 4 species including Leopard Cat (*Prionailurus bengalensis*), Asiatic Golden Cat (*Catopuma temminckii*), Clouded Leopard (*Neofelis nebulosa*) and Fishing Cat (*Prionailurus viverrinus*). Mammals in the order Artiodactyla comprised 4 families including family Bovidae with 2 species, which are Gaur (*Bos gaurus*) and Mainland Serow (*Capricornis sumatraensis*); family Elephantidae including Asian Elephant (*Elephas maximus*); family Cervidae with 3 species including Sambar (*Rusa unicolor*), Northern Red Muntjac (*Muntiacus vaginalis*) and Lesser Oriental Chevrotain (*Tragulus kanchil*); family Suidae with Wild Boar (*Sus scrofa*).

Order Primates comprised family Cercopithecidae with 1 species, the Northern pig-tailed Macaque (*Macaca leonine*). Order Pholidota included 1 species, the Sunda Pangolin (*Manis javanica*) from the family Manidae. Order Rodentia found 3 families including family Hystricidae with the Malayan Porcupine (*Hystrix brachyura*); family Sciuridae found 4 species including Berdmore's Squirrel (*Menetes berdmorei*), Grey-bellied Squirrel (*Callosciurus caniceps*), Variable Squirrel (*Callosciurus finlaysonii*) and Northern Treeshrew (*Tupaia belangeri*), etc. The wild birds recorded were from 8 orders from 12 families. Five families in the order Passeriformes including family Vangidae with 1 species, the Large Woodshrike (*Tephrodornis gularis*) and family Dicruridae with 1 species, which is the Greater Racquet-tailed Drongo (*Dicrurus paradiseus*), family Cettiidae included the Chestnut-crowned Bush Warbler (*Cettia major*), family Muscicapidae included the white-rumped Shama (*Kittacincla malabarica*), family Pittidae included the Blue-winged Pitta (*Pitta moluccensis*), etc. The wild birds in order Pelecaniformes include 2 species from family Ardeidae, which are Chinese Pond-heron (*Ardeola bacchus*) and Malay Night-heron (*Gorsachius melanolophus*).

Order Caprimulgiformes found 2 families including family Caprimulgidae containing 1 species, Large-tailed Nightjar (*Caprimulgus macrurus*) and family Cuculidae including the Coral-billed Ground-cuckoo (*Carpococcyx renauldi*). One family from the order Columbiformes was recorded which family Columbidae was with 4 species including Grey-capped Emerald Dove (*Chalcophaps indica*), Eastern Spotted Dove (*Spilopelia chinensis*), Red Turtle-dove (*Streptopelia tranquebarica*) and Rock Dove (*Columba livia*). Order Galliformes had 1 family, Phasianidae with 2 species, Red Junglefowl (*Gallus gallus*) and Siamese Fireback (*Lophura diardi*), etc.

The camera traps also recorded images of reptiles from 2 orders including order Testudines with the Asian Giant tortoise (*Manouria emys*) from the family Testudinidae and Order Squamata recorded 2 families including family Agamidae containing the Northern Forest Crested Lizard (*Calotes emma*) and family Varanidae with 2 species, the Bengal Monitor (*Varanus bengalensis*) and the Common Water Monitor (*Varanus salvator*). The number of images for each season and the conservation status of the species followed IUCN (2021) as shown in Table 1.

Table 1. Wildlife species were recorded along the Highway 304 between Khao Yai National Park and Thap Lan National Park following the taxonomic order, the conservation status and the number of independent wildlife images captured from camera traps from September 2018 to May 2021. The captured images were collated across three periods: before once opened and after the opening of the wildlife corridors from 99 locations, 12,945 trap nights with a total of 27,494 images

Order/Family/common name		Before opening				Year opened		After opening				Combined data		Status
		Year	2017	2018		2019		2020	2021		2017-2021			
		No. of camera locations	17	19		28		31	25		99			
		Number of trap days	1,377	2,364		3,354		3,890	1,960		12,945			
Scientific name		Events	RAI	Events	RAI	Events	RAI	Events	RAI	Events	RAI	Events	RAI	
Mammal														
Order Carnivora														
Family Mustelidae														
Greater hog badger	<i>Arctonyx collaris</i>	14	1.02	100	4.23	171	5.09	65	1.67	29	1.48	379	2.93	VU
Family Ursidae														
Asiatic Black Bear	<i>Ursus thibetanus</i>	0	0	22	0.93	3	0.09	22	0.57	0	0	47	0.36	VU
Sun Bear	<i>Helarctos malayanus</i>	0	0	1	0.04	1	0.03	1	0.02	11	0.05	14	0.11	VU
Family Herpestidae														
Javan Mongoose	<i>Herpestes javanicus</i>	0	0	36	1.52	3	0.09	16	0.41	0	0	55	0.36	LC
Crab-eating mongoose	<i>Herpestes urva</i>	0	0	0	0	13	0	1	0	1	0.05	15	0.12	LC
Family Viverridae														
Common Palm Civet	<i>Paradoxurus hermaphroditus</i>	37	2.68	129	5.46	135	4.02	221	5.68	45	2.30	567	4.38	LC
Small Indian Civet	<i>Viverricula indica</i>	23	1.67	94	3.97	16	0.48	25	0.64	36	0.18	194	1.50	LC
Large Indian Civet	<i>Viverra zibetha</i>	3	0.22	15	0.63	7	0.21	4	0.10	2	0.10	30	0.23	LC
Large-spotted Civet	<i>viverra megaspila</i>	0	0	21	0.88	2	0.06	2	0.05	0	0	25	0.18	EN
Family Canidae														
Dhole	<i>Cuon alpinus</i>	3	0.22	21	0.88	29	0.86	25	0.64	11	0.56	89	0.69	EN
Golden Jackal	<i>Canis aureus</i>	53	3.85	120	5.08	7	0.21	13	0.33	11	0.56	204	1.61	LC
Family Felidae														
Leopard Cat	<i>Prionailurus bengalensis</i>	10	0.73	21	0.89	11	0.33	148	3.80	14	0.71	204	1.58	LC
Asiatic Golden Cat	<i>Catopuma temminckii</i>	0	0	0	0	1	0.03	0	0	4	0.20	5	0.04	NT
Clouded Leopard	<i>Neofelis nebulosa</i>	0	0	0	0	0	0	3	0.08	3	0.15	6	0.05	VU
Fishing cat	<i>Prionailurus viverrinus</i>	0	0	0	0	0	0	0	0	4	0.20	4	0.03	VU
Order Artiodactyla														
Family Bovidae														
Gaur	<i>Bos gaurus</i>	135	9.80	152	6.43	315	9.39	900	23.13	325	16.58	1827	14.11	VU
Mainland Serow	<i>Capricornis sumatraensis</i>	15	1.09	225	9.52	164	4.89	122	3.13	46	2.35	572	0.44	VU
Family Elephantidae														
Asian elephant	<i>Elephas maximus</i>	0	0	0	0	27	0.80	62	1.59	40	2.04	129	1.00	EN
Family Cervidae														
Sambar deer	<i>Rusa unicolor</i>	3167	229.99	2614	11.06	1527	45.53	2829	72.72	1368	69.80	11505	88.87	VU
Northern Red Muntjac	<i>Muntiacus vaginalis</i>	130	5.95	445	18.82	390	11.63	685	17.61	142	7.24	1792	13.84	LC
Lesser Oriental Chevrotain	<i>Tragulus kanchil</i>	0	0	87	3.68	39	1.16	9	0.23	2	0.10	137	1.05	LC

Family Suidae														
Wild boar	<i>Sus scrofa</i>	679	49.31	684	28.93	790	23.55	1120	28.79	631	32.19	3904	30.15	LC
Order Primates														
Family Cercopithecidae														
Northern Pig-tailed Macaque	<i>Macaca leonine</i>	135	9.80	797	33.71	405	12.07	876	22.52	68	3.47	2421	18.70	VU
Order Pholidota														
Family Manidae														
Sunda Pangolin	<i>Manis javanica</i>	3	0.22	0	0	0	0	0	0	3	0.15	6	0.05	CR
Order Rodentia														
Family Hystricidae														
Malayan Porcupine	<i>Hystrix brachyura</i>	31	2.25	97	4.10	196	5.84	140	3.60	36	1.84	500	3.86	LC
Family Sciuridae														
Berdmore's Squirrel	<i>Menetes berdmorei</i>	7	0.51	8	0.33	32	0.95	11	0.28	9	0.45	67	0.52	LC
Grey-bellied Squirrel	<i>Callosciurus caniceps</i>	10	0.72	81	3.42	88	2.62	91	2.33	26	1.33	296	2.29	LC
Variable Squirrel	<i>Callosciurus finlaysonii</i>	7	0.51	101	4.27	10	0.29	6	0.15	12	0.61	136	1.05	LC
Northern treeshrew	<i>Tupaia belangeri</i>	0	0	0	0	0	0	3	0.08	2	0.10	5	0.04	-
Family Muridae														
Rattus spp.	<i>Rattus spp.</i>	12	0.87	189	7.99	133	3.96	140	3.60	15	0.77	489	3.78	-
Aves														
Order Cuculiformes														
Family Cuculidae														
Greater coucal	<i>Centropus sinensis</i>	0	0	0	0	0	0	4	0.10	7	0.36	11	0.08	LC
Order Accipitriformes														
Family Accipitridae														
Shikra	<i>Accipiter badius</i>	3	0.22	0	0	0	0	0	0	0	0	3	0.02	LC
Order Pelecaniformes														
Family Ardeidae														
Chinese pond-heron	<i>Ardeola bacchus</i>	0	0	9	0.38	3	0.09	10	0.26	5	0.26	27	0.21	LC
Malay Night-heron	<i>Gorsachius melanolophus</i>	0	0	96	4.06	0	0	3	0.08	2	0.10	101	0.78	LC
Order Caprimulgiformes														
Family Caprimulgidae														
Large-tailed Nightjar	<i>Caprimulgus macrurus</i>	0	0	3	0.13	0	0	0	0	345	17.60	348	2.69	LC
Family Cuculidae														
Coral-billed Ground-cuckoo	<i>Carpococcyx renauldi</i>	0	0	17	0.72	2	0.06	0	0	3	0.15	22	0.17	VU
Order Galliformes														
Family Phasianidae														
Red Junglefowl	<i>Gallus gallus</i>	55	3.99	94	3.97	131	3.91	153	3.93	59	3.01	492	3.80	LC
Siamese Fire back	<i>Lophura diardi</i>	20	1.45	235	9.94	128	3.82	129	3.32	33	1.68	545	4.21	LC
Order Columbiformes														
Family Columbidae														
Grey-capped Emerald Dove	<i>Chalcophaps indica</i>	0	0	9	0.38	0	0	0	0	2	0.10	11	0.08	LC
Eastern Spotted Dove	<i>Spilopelia chinensis</i>	0	0	0	0	219	6.53	4	0.01	7	0.35	230	1.78	LC
Red Turtle-dove	<i>Streptopelia tranquebarica</i>	0	0	0	0	0	0	0	0	0	0	1	0.01	LC
Rock Dove	<i>Columba livia</i>	0	0	0	0	19	0.57	0	0	0	0	19	0.13	LC

Order Passeriformes															
Family Vangidae															
Large woodshrike	<i>Tephrodornis gularis</i>	0	0	0	0	1	0.03	0	0	1	0.05	2	0.01	LC	
Family Cettiidae															
Chestnut-crowned bush warbler	<i>Cettia major</i>	0	0	3	0	0	0	0	0	0	0	3	0.02	LC	
Family Muscicapidae															
White-rumped Shama	<i>Kittacincla malabarica</i>	3	0.22	3	0.13	0	0	0	0	0	0	6	0.04	LC	
Family Pittidae															
Blue-winged pitta	<i>Pitta moluccensis</i>	0	0	21	0.09	0	0	0	0	0	0	21	0.16	LC	
Family Dicruridae															
Greater Racquet-tailed Drongo	<i>Dicrurus paradiseus</i>	0	0	0	0	0	0	0	0	1	0.05	1	0.01	LC	
Reptile															
Order Testudines															
Family Testudinidae															
Asian forest tortoise	<i>Manouria emys</i>	3	0.22	0	0	0	0	0	0	0	0	3	0.02	CR	
Order Squamata															
Family Agamidae															
Northern forest crested lizard	<i>Calotes emma</i>	0	0	3	0.13	0	0	0	0	0	0	3	0.02	-	
Family Varanidae															
Bengal monitor	<i>Varanus bengalensis</i>	0	0	3	0.13	0	0	0	0	0	0	3	0.02	LC	
Common water Monitor	<i>Varanus salvator</i>	0	0	3	0.13	15	0.44	0	0	0	0	18	0.13	LC	
	Total	4,558		6,559		5,033		78,43		3,361		27,494			

Regarding the diversity index across the observed periods, it was found that in 2017 the diversity index of both mammals and birds and the overall species was the lowest. It then increased from 2018 to 2021, similar to the evenness index of wild mammals and birds that was between 0-1. Lower values mean low distribution in the area, whereas the high values mean a large distribution. From Table 2, the combined data showed that the overall wildlife evenness index was similar during 2018-2021, while in 2017 the value was low. This was caused by the installation of camera traps in the early stages of the study that did not cover the whole area, while in 2018 the deployment of the camera traps covered more of the area. The evenness of the species shows the distribution of the abundance between species within the community. The high evenness index means that the abundance of the wildlife in the community is similar (Zhang et al. 2012).

Regarding the conservation status of the wildlife according to the IUCN Red List, we found 2 species that are categorized as Critically Endangered (IUCN 2021), which are the Sunda Pangolin (*Manis javanica*) and the Asian Giant Tortoise (*Manouria emys*). Three species are categorized as Endangered including Large-spotted Civet (*Viverra zibetha*), Dhole (*Cuon alpinus*) and Asian Elephant (*Elephas maximus*). Ten species are Vulnerable including Greater Hog Badger (*Arctonyx collaris*), Asiatic Black Bear (*Ursus thibetanus*), Sun Bear (*Helarctos malayanus*), Clouded Leopard (*Neofelis nebulosa*), Fishing Cat (*Prionailurus viverrinus*), Gaur (*Bos gaurus*), Mainland Serow (*Capricornis sumatraensis*), Sambar Deer (*Rusa unicolor*), Northern Pig-tailed macaque (*Macaca leonine*) and Coral-billed Ground-cuckoo (*Carpococcyx renauldi*). One Near-Threatened species is the Asiatic Golden Cat (*Catopuma temminckii*) and 32 species that are Least Concern for example the Javan Mongoose (*Herpestes javanicus*), Crab-eating Mongoose (*Herpestes urva*), Common Palm Civet (*Paradoxurus hermaphroditus*), Small Indian Civet (*Viverricula indica*), Large Indian Civet (*Viverra zibetha*), Golden Jackal (*Canis aureus*), Leopard Cat (*Prionailurus bengalensis*), Northern Red Muntjac (*Muntiacus vaginalis*), Lesser Oriental Chevrotain (*Tragulidus kanchil*), Wild Boar (*Sus scrofa*), Malayan Porcupine (*Hystrix brachyura*), etc. Details are shown in Table 1.

Regarding the abundance of the herbivorous wildlife, the predominant species in the study area was the Sambar Deer with 88.87%, followed by Wild Boar (30.15%), Northern Pig-tailed Macaque (18.7%), Gaur (14.11%), Northern Red Muntjac (13.84%), Malayan Porcupine (3.86%), etc. In the carnivorous group, the species with the highest abundance was the Common Palm Civet at 4.38%, followed by Greater Hog Badger (2.93%), Golden Jackal (1.61%), Leopard Cat (1.58%), Small Indian Civet (1.50%), Dhole (0.69%), etc. For ground foraging birds, the Siamese fireback had the highest abundance at 4.21%, followed by the Red Junglefowl (3.8%), Large-tailed Nightjar (2.69%), Eastern Spotted Dove (1.78%), Malay Night-heron (0.78%), Chinese Pond-heron (0.21%), etc. (Table 1).

Results from the test on the difference in the abundance of wildlife before and after the opening of the wildlife corridors indicate no difference in the abundance of wildlife (Mann-Whitney U-test = -0.07709, P = 0.94). Furthermore, it was found that there was no difference in the average abundance of wildlife in the study area before the use of the wildlife corridors in 2017-2018 and during the opening in 2019 (Z= 0.77301; P=0.4413). There was no difference in the average abundance after opening the wildlife corridors in 2020-2021 and when they first opened in 2019 (Z = 0.64585, P=0.5157). Furthermore, the Shannon-Weiner index of all the wildlife recorded during the total length of the study was 1.98 and the evenness index was 0.88. Therefore, there was little difference in the values between the years, as shown in Table 2.

Activity pattern and period

Study results showed that in the study area along the Highway 304 in part between the 2 National Parks, wild animals were found engaged in activities throughout the day, alternating between species. When considering only the wildlife that had more than 30 images recorded, it was found that 8 species of wildlife had activity patterns that were strongly nocturnal including Common Palm Civet, Malayan Porcupine, Greater Hog Badger, Leopard Cat, Small Indian Civet, Large Indian Civet, Large-spotted Civet, Large-tailed Nightjar as well as rat species that were recorded as *Rattus* sp.

Table 2. Biodiversity and evenness index of mammals and wild birds that were recorded by camera traps along the Highway 304 between Khao Yai National Park and Thap Lan National Park during 2017-2021 and combined data analysis

Year	Before opening		Year opened	After opening		Combined data
	2017	2018	2019	2020	2021	
Terrestrial Mammal						
Shannon-Weiner index	0.3037	2.251	1.991	1.861	1.935	1.753
Evenness index	0.1843	0.1705	1.1197	1.0909	1.0983	1.0277
Terrestrial Bird						
Shannon-Weiner index	0.4988	1.309	0.2496	0.9706	1.553	1.713
Evenness index	0.2267	0.7797	0.1405	0.4714	0.9586	0.9534
Combined data						
Shannon-Weiner index	0.8157	2.501	2.167	1.924	2.238	1.98
Evenness index	0.3784	1.1027	0.9418	0.8577	0.983	0.8852

Eight species were strongly diurnal including Grey-bellied Squirrel, Dhole, Berdmore's Squirrel, Siamese Fireback, Red Junglefowl, Eastern Spotted Dove, Malay night-heron and Javan Mongoose. There were 4 species that were mostly nocturnal including Sambar Deer, Gaur, Mainland Serow and Golden Jackal. Four species mainly were diurnal including Northern Pig-tailed Macaque,

Lesser Oriental Chevrotain, Variable Squirrel and Asian Elephant, and 3 species that were cathemeral including Wild Boar, Northern Red Muntjac and Asiatic Black Bear. The activity period and the confidence interval of the activity period of the recorded wildlife species are shown in Table 3.

Table 3. Time and activity pattern of wildlife found in the study area along the Highway 304 between Khao Yai National Park and Thap Larn National Park during 2017 to 2021

Common name	Encounter rate of pictures	Mean vector (hour)	Circular variance (hour)	% of day time	Type
Common palm civet	576	23:39	00:09	0.69	SN
Malayan porcupine	500	01:29	00:11	4.8	SN
Rattus spp.	485	00:53	00:09	2.47	SN
Greater hog badger	377	01:32	05:08	22.28	SN
Large-tailed nightjar	348	23:46	00:13	1.72	SN
Leopard cat	204	03:22	00:20	13.72	SN
Small indian civet	194	00:22	00:18	11.34	SN
Large indian civet	30	23:07	00:44	0	SN
Large-spotted civet	25	00:58	00:42	12	SN
Siamese fireback	544	10:11	00:10	100	SD
Red junglefowl	492	11:08	00:09	100	SD
Grey-bellied squirrel	264	12:23	00:13	92.04	SD
Dhole	49	11:23	00:30	91.83	SD
Eastern spotted dove	221	12:10	00:31	100	SD
Malay night-heron	101	08:58	00:30	82.18	SD
Berdmore's squirrel	67	10:26	00:29	91.04	SD
Javan mongoose	55	12:59	00:24	94.54	SD
Sambar deer	11,500	22:38	00:06	28.69	MN
Gaur	1,826	22:48	00:16	35.6	MN
Mainland serow	572	00:22	00:19	21.5	MN
Golden jackal	209	02:18	00:29	33.97	MN
Northern pig-tailed macaque	2418	12:19	00:05	84.78	MD
Lesser oriental chevrotain	137	08:25	00:20	81.02	MD
Variable squirrel	136	13:44	00:42	83.82	MD
Asian elephant	129	08:09	00:24	82.95	MD
Wild boar	3903	00:29	00:25	42.35	CM
Northern red muntjac	1785	11:35	00:20	57.03	CM
Asiatic black bear	47	20:02	01:06	46.8	CM
Chinese pond-heron	27	13:01	00:14	100	Not classified
Coral-billed ground-cuckoo	22	10:05	02:10	100	Not classified
Blue-winged pitta	21	11:04	01:25	100	Not classified
Rock dove	19	09:58	00:11	100	Not classified
Common water monitor	18	13:42	00:24	100	Not classified
Crab-eating mongoose	15	10:21	00:53	100	Not classified
Sun bear	14	23:07	01:12	21.42	Not classified
Greater coucal	11	11:2	00:38	100	Not classified
Grey-capped emerald dove	11	12:05	00:14	100	Not classified
Sunda pangolin	6	05:19	00:00	0	Not classified
White-rumped shama	6	10:37	00:03	100	Not classified
Clouded leopard	6	04:34	00:42	0	Not classified
Northern treeshrew	5	09:20	00:14	100	Not classified
Asiatic golden cat	5	06:42	00:00	20	Not classified
Fishing cat	5	07:00	00:00	100	Not classified
Shikra	3	13:05	00:00	100	Not classified
Chestnut-crowned bush warbler	3	06:48	00:00	100	Not classified
Asian giant tortoise	3	--	--	100	Not classified
Northern forest crested lizard	3	06:11	00:00	100	Not classified
Bengal monitor	3	10:03	--	100	Not classified
Large woodshrike	2	09:36	00:09	100	Not classified
Red collared dove	1	07:25	--	100	Not classified
Greater racquet-tailed drongo	1	08:21	-	100	Not classified

The factors affecting the distribution of wildlife and suitable habitats

This study revealed that the formula used to analyze the average home range could analyze 13 wildlife species and reported the average area under the curve (AUC) value of 90.49%. When considering the values used to measure the importance of the environmental variables that affect the presence of wildlife in the study area from the average % contribution, it showed that the factor that had the highest effect on the presence of wildlife was the highway with the % contribution of 54.66%, followed by land use (12.33%), community location (8.81%) and the normalized difference vegetation index (NDVI) in the study area (8.16%). Similarly, when considering the permutation importance, we found that the most important factor was the highway which was 51.67%, followed by ranger station location (13.79%), community location (13.65%) and the normalized difference vegetation index (NDVI) (8.64%) in the study area. Details are shown in Table 4.

Discussion

The results from continuous monitoring of the wildlife diversity along the Highway 304 between Khao Yai National Park and Thap Lan National Park revealed 51 species, consisting of 30 species of mammals (including 15 species of carnivorous mammals and 15 species of non-carnivorous mammals), 17 species of wild birds and 4 species of reptiles. This study recorded more species than previous studies in Thailand, for example, the camera trap study by Kolasartsanee (2021), who recorded 15 species of mammals in Khao Soi Dao Wildlife Sanctuary, Chanthaburi Province and the mammal diversity study of Jenks et al. (2011) in KYNP who recorded 14 species of carnivorous and 12 species of non-carnivorous mammals (with a total of 26 species). Sukmasuang et al. (2020b) reported 14 species of carnivorous mammals in Khao Ang Rue Nai Wildlife Sanctuary from a camera trap survey. In contrast, Khoewsree et al. (2020) reported 19 species of carnivorous mammals and 14 species of non-carnivorous mammals adding to a total of 33 species. The species found in this study, but not in Khoewsree et al. (2020), include the Fishing Cat. In this study, we did not record Marbled Cat, Crab-eating Macaque, Smooth-coated Otter, Yellow-throated Marten and Asiatic Brush-tailed Porcupine. This study shows that we recorded more species than in Huai Kha Khaeng Wildlife Sanctuary, which also used a camera trap survey and recorded 16 species of carnivorous mammals and 13 species of herbivorous mammals adding to a total of 29 species (Charaspet et al. 2019). This study contributes to more valid and accurate data on the wildlife diversity in Khao Yai National Park, Dong Phrayayen-Khao Yai Forest Complex, the world's natural heritage site that has an outstanding diversity of wildlife. In particular, the record of a Fishing Cat is the first photographic sighting within the area. Finding habitat sites at the side of the

highway at high risk of threat is a concern for protecting this species and various other threatened wildlife species that were found along the highway.

The evenness index of the species shows the distribution of the abundance between species in the community, which if high means the abundance of wildlife in the community is similar. The biodiversity index of wildlife (H) in the studied area was 1.98, which is in the moderate diversity level, while the evenness was 0.88, showing a stable wildlife community in the study area. The results were at a good level each year and had a steady trend. The diversity index and the evenness index of the species in this study are higher than the study by Herawati et al. (2019), who reported the diversity and evenness index of freshwater fish in Cipanas River, West Java, Indonesia to be 1.20 to 2.08 and 0.27 to 0.47, respectively.

The important wildlife species found along the underpass corridor include Gaur, Serow, Sambar Deer, Northern Red Muntjac, Wild Boar, Leopard Cat, Golden Jackal, Dhole, Malayan Porcupine, Hog Badger and Civets. However, the Clouded Leopard, Asiatic Black Bear, Leopard Cat, Gaur, Sambar Deer and Serow used the overpass. Furthermore, camera trap surveys showed that Serow, Hog Badger, Malayan Porcupine and Water Monitor used the tunnels under the road connecting the two national parks, the safest from disturbance. Wild elephants have not been shown to cross the road or use any corridors.

The results of this study showed the richness of the study area and indicated that there should be preventive measures, as well as reduction of the impact of human activities on wildlife in the area, especially the transportation on this highway and other activities occurring in the surrounding area including agriculture and waste disposal which may attract wildlife to consume. A total of 16 species in the area were listed under the IUCN Red List with species 2 being Critically Endangered, 3 Endangered, 10 Vulnerable, 1 Near Threatened and 32 Least concerned. If there is no action other than the sole declaration of a national park without any additional protection measures, it will lead to the disappearance of these wild species.

In this study, we had the first camera trap record of a Fishing Cat in the area. Giridhar (2016) reported the distribution of Fishing Cats in Asia, which does not include forest areas in the mainland that are not connected to the sea of Southeast Asia. However, Appel (2016), Duckworth (2016) and Willcox (2016) reported that the distribution of Fishing Cats remains unclear. The continuous camera trap monitoring in this study confirms the range of Fishing Cats in the corridor connecting the two national parks, indicating the importance of the habitat. The results of studying the wildlife activities from species with more than 20 images recorded, most of them (13 species) were nocturnal, while 12 species were diurnal, and 3 species were cathemeral.

Table 4. Factors that affect the presence of some wildlife species analyzed using MaxEnt and the camera traps data recorded in the study area along the Highway 304 during 2017-2021 and environmental data

[illegible]

In this study, Sambar Deer had the highest abundance, followed by Wild Boar, Northern Pig-tailed Macaque, Gaur, Northern Red Muntjac, Malayan Porcupine and Red Junglefowl. In the carnivorous group, the species with the highest abundance was the Common Palm Civet followed by Greater Hog Badger, Golden Jackal, Leopard Cat, Small Indian Civet and Dhole. The ground foraging bird species with the highest abundance was the Siamese Fireback, followed by the Red Junglefowl, Large-tailed Nightjar, Eastern Spotted Dove, Malay Night-heron and Chinese Pond-heron.

There was no difference in the abundance and diversity of the wildlife before and after the construction of the wildlife corridors. In addition, wildlife activities were seen around the corridor area throughout the day which confirms the constant use of wildlife. Therefore, human activities in the area should be taken with extreme caution due to the presence of wildlife considering the species, abundance and timing of exercise throughout the day.

It was also found that the highway is the factor that affects the wildlife presence the most, that showed the significance of the highway including the wildlife corridors affects the appearance of wildlife which shows the importance of various activities, especially on highway traffic that should be controlled significantly reducing the speed of the car, noise, lighting, because it hurts wildlife. The factors that affected wildlife presence included land use, villages, canopy coverage and water source but it happens in both positive and negative directions. This refers to other environmental factors that appear in areas other than highways that must be managed in parallel, such as reducing crops and prohibiting reduced water bodies developments near highways to reduce wildlife attraction. Results of the relative species and number, suitable habitat distribution, and time show the area's importance through which the highway passes. The construction of the wildlife corridors connecting the two national parks is significant for maintaining the continuity of the species population.

Suggestions inferred from the study results include the management of human activities in the area, including transportation, sound use, following the speed limit and maintaining the continuity of the tree canopy. In addition, according to the study, activities of humans living in the area, farming and waste disposal may attract wildlife closer to communities. This may affect wildlife management in the long run. The results show that the habitats of various types of wildlife are also suitable habitats for a wide range of species. However, currently this area, especially in the National Forest outside of TLNP, is occupied by people for farming, habitation and conducting activities outside of the main transportation route. Therefore, the constructed corridor between the two national parks must also address land issues that impede wildlife movement between the two national parks.

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