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Wildlife-vehicle collisions in Khao Yai National Park, Thailand: Impact on native species for some conservation management

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Abstract. *Rattanawanawong N, Bhumpakphan N, Kutintara U, Sukmasuang R. 2022. Wildlife-vehicle collisions in Khao Yai National Park, Thailand: Impact on native species for some conservation management. Biodiversitas 23: 3050-3061.* Wildlife-vehicle collisions (WVCs) remain a major challenge in wildlife management worldwide, especially in conservation areas with transport routes passing through. This study was operated along a 48 km long highway, which conducted 207 surveys in Khao Yai National Park, a natural world heritage site, from February 2018 to January 2019. A total of 391 wild animal carcasses were found in 90 species. The carcasses found, according to the taxonomic group, were reptiles (67.52%), followed by mammals (14.83%), amphibians (4.35%), birds (3.32%). Reptiles were most affected by road use, especially tortoises in Family Geoemydidae and Family Testudinidae that two critically endangered species were found. This study found that members of Family Colubridae were most affected that 26 species, a total of 144 animal carcasses were found, accounting for 29.15% of the number of all carcasses. The most affected species were forest garden lizard (*Calotes emma*) in the Family Agamidae, where 99 carcasses were found, accounting for 25.31% of the total. In March showed the highest number of the carcasses, followed by April. All of the carcasses found in the evening slightly more than the morning indicated that wild animals died more during the day than at night. The number of vehicles day^{-1} significantly affected wildlife mortality per day. Reducing the number of vehicles per day^{-1} entering and reducing vehicle speed, including the number of tourists, as well as banning travel at night, would mitigate the problem. Further, educational signage about wildlife diversity and the risk of road mortality should be installed at the park to remind visitors about the unique fauna in the national park and emphasize the importance of conservation.

Keywords: Dong Phayayen-Khao Yai Forest Complex, multiple regression analysis, wildlife carcasses

INTRODUCTION

Roads and other linear infrastructure have serious environmental effects on natural habitats worldwide (van der Ree et al. 2015). There has been a significant impact on biodiversity in recent decades (Laurance and Balmford 2013). Globally, at least 25 million kilometers of new roads are anticipated by 2050 (Laurance et al. 2014). Approximately half of all roads pass through forests, mainly historically exploited forests (Sloan et al. 2018). As a result, roads penetrating the wilderness or frontier areas are major proximate drivers of habitat loss and fragmentation, wildfires, overhunting, and other environmental degradation, often with irreversible impacts on ecosystems (Laurance et al. 2014). In addition to environmental degradation, road infrastructure development also affects wildlife survival. Vehicle collisions with animals or wildlife-vehicle collisions continue to be a major challenge (Bartonička et al. 2018), causing invaluable harm to animals and humans worldwide (Pagany 2020). Many documents report on the factors that affect wildlife-vehicle collisions, such as speed and traffic volume (Rincón-Aranguri et al. 2019), road-related factors (Bartonička et al. 2018), driver-related factors (Wilkins et al. 2019) and time factors (Carvalho et al. 2017). Better knowledge of these influencing factors can provide the basis for mitigation measures.

Khao Yai National Park (KYNP) was established in 1962 as one of the five conservation areas in the Dong Phaya Yen-Khao Yai Forest complex, which was declared a Natural World Heritage Site in 2005 (UNESCO 2022). The national park is placed in Saraburi, Nakhon Ratchasima, Prachinburi and Nakhon Nayok Provinces. Highways have been developed between conservation areas within the Dong Phaya Yen-Khao Yai World Heritage Forest Complex. Some highways pass between provinces through the center of the area with a length of about 48 kilometers, resulting in increasing numbers of tourists every year. Between 2014 and 2021, there were between 1.1 and 1.5 million tourists who visited the park per year, with an average of 1.35 million people per year (SE: 60,259.26) (DNP 2022). In the case of the number of vehicles traveling through KYNP during 2014-2021, the figure ranged between 2.89-4.71 hundred thousand cars per year (DNP 2022), at an average of 366,145.75 cars per year (SE: 21,706.92) entering the park for recreation (DNP 2022). The serious impact of the road that cuts through the center of KYNP on wildlife has been ongoing for a long time. However, very few studies have been conducted and little data exists concerning this hidden serious problem.

Thus, there is no clear solution to the problem other than stipulating the speed limit for cars that enter the area. Suwanwaree (2014) reported the number of vertebrates killed by cars on the main road in KYNP from October 2011 to September 2012, with a total survey distance of 52.4 kilometers. It was found that 58 animals were killed. The rate of wildlife killed encounters is 0.012 WVCs $km^{-1}day^{-1}$. Furthermore, the number of vehicles had no relationship with the number of vertebrate fatalities. Nevertheless, a dramatic increase in the number of tourists and the number of vehicles entering the national park per day in the last ten years consequently affects using the main road that cuts through the central area of this national park. Accordingly, wildlife-vehicle collisions are essential to investigate intensively. The study results may be able to be used for management and are needed to ensure ongoing and more detailed studies that are important in terms of both tourism and wildlife conservation. The objectives of this study were to (i) study the species and number of wildlife carcasses obtained from transportation on the main road in KYNP and (ii) to study the relationship between the number of wildlife carcasses and environmental factors, especially the number of tourists and number of vehicles entering KYNP.

MATERIALS AND METHODS

Study area

Khao Yai National Park (KYNP) is located between the latitude of N 14°05'0.00" to N 14°35'0.00", and between the longitude of E 101°10'0.00" and E 101°55'0.00", covering an area of 2168 km^2. Located in the Phanom Dong Rak mountain range stretching between the central and northeastern regions of Thailand, it is the origin of several important watersheds., KYNP was declared a part of the Natural World Heritage Site in 2005 because it is an important habitat for many living things, especially the outstanding wildlife diversity. It is home to more than 800 vertebrate species, 112 species of mammals, 392 species of birds, and more than 200 species of reptiles and amphibians (UNESCO 2022). Pla-ard et al. (2021a, 2021b, 2022) reported wildlife in the area from camera traps as critically endangered, which include the Sunda pangolin (*Manis javanica*) and the Asian giant tortoise (*Manouria emys*). Three species are categorized as endangered, including the large-spotted civet (*Viverra megaspila*), dhole (*Cuon alpinus*), and the Asian elephant (*Elephas maximus*). Ten species are vulnerable, including the greater hog badger (*Arctonyx collaris*), Asiatic black bear (*Ursus thibetanus*), Malayan 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 leonina*) and coral-billed ground-cuckoo (*Carpococcyx renauldi*), near threatened species such as the Asiatic golden cat (*Catopuma temminckii*) and 32 species that are of least concern include the Javan mongoose (*Herpestes javanicus*), crab-eating mongoose (*Herpestes urva*), and common palm civet (*Paradoxurus hermaphroditus*).

The general geography of KYNP is an area of mountains comprised mainly of limestone and sandstone. The intricate cuttings form the boundary of the Korat Plateau. The highest peak is 1351 meters above sea level. Forest cover conditions in KYNP cover approximately 91.47% of the area. Most of the forests are dry evergreen forests, moist evergreen forests, and hill evergreen forests. Some areas are covered by the grasslands formed by shifting cultivation in the past.

The study area was conducted on the main road in KYNP, starting from checkpoint 1 in Pak Chong District, Nakhon Ratchasima Province (Highway No. 2090, km. 23-40) to checkpoint 2 in Mueang District, Prachin Buri Province (Highway No. 3077 Km. 11-42) (Figure 1).

The entire road has a distance of about 48 kilometers and is about 3.5 meters wide, and the shoulder from the edge of the road to the edge of the drainage ditch is about 3.2 meters wide. The condition of the road from checkpoint 1 to the viewpoint at kilometer 30 is quite steep. On the east side is a very steep hill. There is a drainage ditch to prevent water runoff on the side of the steep hill. But when passing the viewpoint at kilometer 30, there are almost all drainage ditches on both sides, and on the west side is a clear ravine. As for Highway No. 3077, the distance is 31 kilometers. The route is less steep than Highway 2090. The route cuts through a creek and there are many small creeks close to the route on both sides of the road. There are almost all drainage ditches. Between the two routes, there are grasslands and marshes that are exploited by wildlife.

Climate conditions

Temperature and rainfall conditions from the Mo Singto measurement point inside KYNP showed the average temperature throughout the year is about 21°C; the highest temperature is between April and May. The highest average temperature is about 27°C, and from December to January is the coldest part of the season. Temperatures can drop below 10°C. The air is dry and windy. The average annual rainfall is 2338.16 millimeters per year, with the heaviest rainfall from May to October. September has the most rainfall at 426.16 millimeters. The average year-round temperature of KYNP is 21.28°C, the highest temperature in April averages 30.33°C, and the lowest in January averages 12.25°C. The average relative humidity in KYNP was an average of 66% (Khao Yai National Park 2021).

The climate is monsoon with heavy rainfall in the rainy season from May to October and a dry season from November to April. The annual rainfall in the park has sometimes been reported to be as high as 3000 or 4000 mm (Smitinand 1977). However, the record of annual rainfall for 21 years between 1994 and 2014 revealed the mean annual rainfall is approximately 2073 mm, and the overall mean annual temperature for 10 years is 22.4°C (Brockelman et al. 2017).

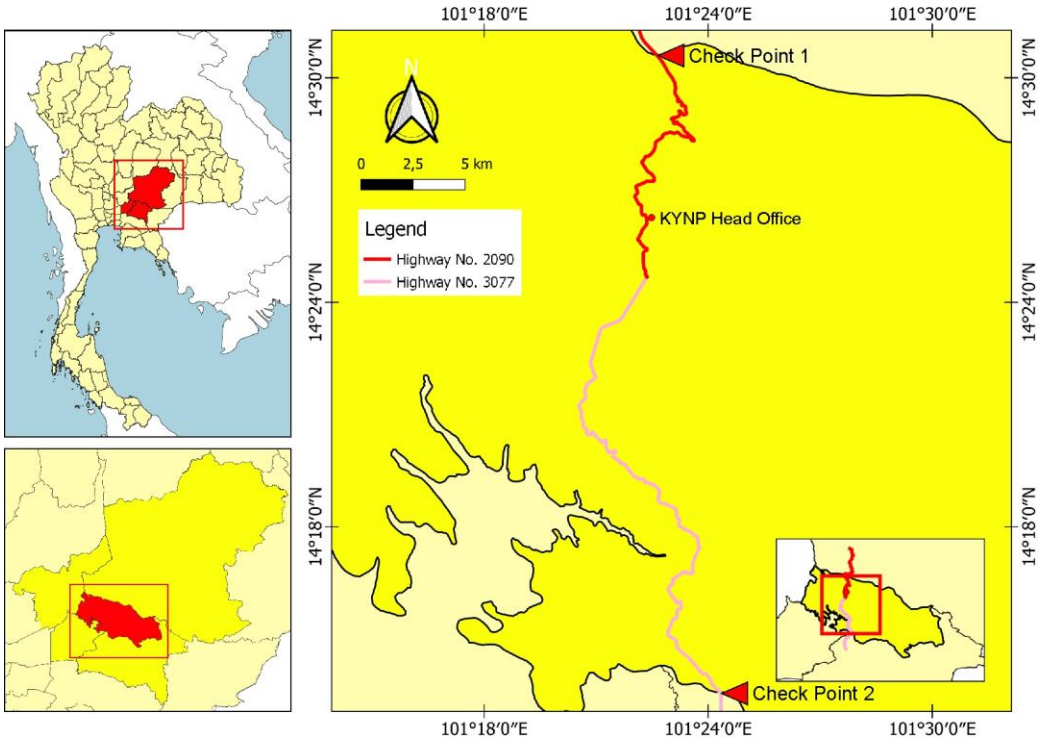

Figure 1. Khao Yai National Park location (1) and the highways No. 2090 and No. 3077 that pass through the center of the national park (2, 3), 48 km length and also showed the check point 1 in Nakhon Ratchasima Province and the check point 2 in Prachinburi Province, Thailand

Data collection

Data collection was conducted on the main road in KYNP, which is divided into two sections of the route, 48 km in total length, starting from checkpoint 1 in Pak Chong District, Nakhon Ratchasima Province (Highway No. 2090 km, a distance of 17 kilometers) to checkpoint 2 in Muang District, Prachinburi Province (Highway No. 3077 km, a distance of 31 kilometers). The study was conducted from February 2018 to January 2019 and covered regularly throughout the year on Saturdays, Mondays, Wednesdays, and Fridays, totaling 207 days of the year. Each day, data collection was divided into 2 periods, once during the morning between 06.00 9:00 a.m. and once during the evening between 3:00 p.m. and 6:00 p.m. by using a motorcycle that drove at a speed of about 30-40 km hour^{-1}. Observation during riding was done carefully, starting from checkpoint 1 to checkpoint 2. When animal carcasses were found, the carcass species were identified. Handbooks by Lekagul and McNeely (1988); Francis (2008) handbooks were used for mammalian carcasses identification. Reptiles and amphibians were identified based on the handbook of Das (2016). Bird carcasses were identified by reference to the handbook of Lekagul and Round (1991). The scientific names of all carcasses were checked with the IUCN red list for threatened data, according to IUCN (2022). The carcasses' locations were recorded using a global positioning system instrument.

We estimated traffic volume for the highway by manually counting vehicles over a sampling schedule that encompassed a 24-hour period. The number of tourists and number of cars that traveled in and out of the area at checkpoint 1 and checkpoint 2 were registered without recounting.

Data analysis

The number of wildlife carcasses found per day were calculated, including all types of wildlife each month. A difference in the number of carcasses found during the day of the survey was conducted. Analysis of Variance (ANOVA) was tested for differences in the number of carcasses found during the days. T-test was used to test the difference in the amount of carcasses day^{-1} during the dry season, from November to April, and the rainy season, from May to October. The significance of the difference was determined at $P<0.05$.

The relationship between the number of tourists' vehicles entering the area and the number of wildlife carcasses found was analyzed by a multiple linear regression model. The significance of the difference was determined at $P<0.05$ with the R program (R Core Team 2021). The difference in the number of wildlife carcasses found during the morning period and evening was also determined.

RESULTS AND DISCUSSION

Species and number of wildlife carcasses

A total of 391 wild animals were found in 95 species, including 58 mammals from 11 species, 11 genera, 10 families, and 6 orders, such as northern pig-tailed macaque (*Macaca leonina*), leopard cat (*Prionailurus bengalensis*),

northern red muntjac (*Muntiacus vaginalis*), lesser oriental chevrotain (*Tragulus kanchil*) Berdmore's squirrel (*Menetes berdmorei*), northern tree shrew (*Tupaia belangeri*). The highest number of dead mammals were house rats (*Rattus rattus*), totaling 19 carcasses, followed by 14 carcasses of Berdmore's squirrel (*Menetes berdmorei*), and 8 carcasses of northern treeshrew (*Tupaia belangeri*). Thirteen carcasses of birds from 19 species, 17 genera, 11 families, and 5 orders were found. The most common bird carcasses were Asian barred owlet (*Glaucidium cuculoides*), black-crested bulbul (*Pycnonotus flaviventris*), and golden-headed cisticola (*Cisticola exilis*), totaling 3 of each species, followed by 2 carcasses of orange-headed thrush (*Zoothera citrina*). Two hundred and sixty-four carcasses of reptiles were also found from 46 species, 29 genera, 11 families, and 2 orders. The most reptile carcasses found were forest crested lizard (*Calotes emma*) with 99 carcasses, followed by Malayan whip snake (*Ahaetulla mycterizans*) with 16 carcasses. Eleven carcasses of long-nosed tree snakes (*Ahaetulla nasuta*) were also found. Seventeen carcasses of amphibians from 8 species, 8 genera, and 5 families were found, including 17 carcasses of common tree frog (*Polypedates leucomystax*), followed by dark-sided frog (*Sylvirana nigrovittata*) with 7 carcasses, and 4 carcasses of Burmese squat frog (*Glyphoglossus guttulatus*). The details are shown in Table 1.

Table 1. A list of animal carcasses by the taxonomic group found on the 48 km length of the highway passing Khao Yai National Park observed on Monday, Wednesday, Friday, and Saturday during February 2018 - January 2019, with 207 observed days

Order/ Family	Common name	Scientific name	Number of carcasses	IUCN
Order Primates				
Family Cercopithecidae	Northern Pig-tailed Macaque	*Macaca leonina*	2	VU
Order Artiodactyla				
Family Cervidae	Northern Red Muntjac	*Muntiacus vaginalis*	1	LC
Order Carnivora				
Family Felidae	Leopard Cat	*Prionailurus bengalensis*	2	LC
Order Rodentia				
Family Hystricidae	Asiatic Brush-tailed Porcupine	*Atherurus macrourus*	1	LC
Family Muridae	House Rat	*Rattus*	19	LC
Family Sciuridae	Berdmore's Squirrel	*Menetes berdmorei*	14	LC
	Grey-bellied Squirrel	*Callosciurus caniceps*	5	LC
	Variable Squirrel	*Callosciurus finlaysonii*	3	LC
	Southeast Asian Shrew	*Crocidura fuliginosa*	1	LC
Family Tupaiidae	Northern treeshrew	*Tupaia belangeri*	8	LC
Order Chiroptera				
Family Rhinolophidae	-	*Rhinolophus* sp.	1	-
Family Tragulidae	Lesser Oriental Chevrotain	*Tragulus kanchil*	1	LC
		Total	58	
Aves				
Order Cuculiformes				
Family Centropodidae	Greater Coucal	*Centropus sinensis*	1	LC
Order Passeriformes				
Family Cisticolidae	Brown Prinia	*Prinia* sp.	1	LC
	Yellow-bellied Prinia	*Prinia flaviventris*	1	
	Golden-headed Cisticola	*Cisticola exilis*	3	LC
Family Columbidae	Red Turtle-dove	*Streptopelia tranquebarica*	1	LC
	Rock Dove	*Columba livia*	1	LC
Family Corvidae	Hair-crested Drongo	*Dicrurus hottentottus*	1	LC
Family Cuculidae	Chestnut-winged Cuckoo	*Clamator coromandus*	1	LC
Family Halcyonidae	Banded Kingfisher	*Lacedo pulchella*	1	LC
Family Muscicapidae	Sapphire Flycatcher	*Ficedula sapphira*	1	LC
	Orange-headed Thrush	*Zoothera citrina*	2	LC
Family Pittidae	Blue Pitta	*Hydrornis cyaneus*	1	LC
Family Pycnonotidae	Bulbul	*Pycnonotus* sp.	1	LC
	Stripe-throated Bulbul	*Pycnonotus finlaysoni*	1	LC
	Grey-eyed Bulbul	*Iole propinqua*	1	LC
	Black-capped Bulbul	*Rubigula melanictera*	3	LC
Family Cisticolidae	Dark-necked Tailorbird	*Orthotomus atrogularis*	1	LC
	Common Tailorbird	*Orthotomus sutorius*	1	LC
Family Pellorneidae	Abbott's Babbler	*Malacocincla abbotti*	1	LC
Order Strigiformes				
Family Strigidae	Spotted owlet	*Athene brama*	1	LC
	Asian Barred Owlet	*Glaucidium cuculoides*	3	LC
-	Unidentified (sp1)	-	2	-
	Unidentified (sp2	-	1	-
		Total	30	

Reptilia				
Order Testudines				
Family Geoemydidae	Giant Asian Pond Turtle	*Heosemys grandis*	2	CR
Family Testudinidae	Elongated Tortoise	*Indotestudo elongata*	2	CR
Order Squamata				
Family Agamidae	Forest Garden Lizard	*Calotes emma*	99	LC
	Greater Spiny Lizard	*Acanthosaura lepidogaster*	1	LC
	Brown pricklenape	*Acanthosaura lepidogaster*	3	LC
	Green-crested Lizard	*Bronchocela smaragdina*	1	LC
Family Colubridae	Keeled Slug-eating Snake	*Pareas carinatus*	3	LC
	Red-Tailed Racer	*Gonyosoma oxycephalum*	1	LC
	Green Cat Snake	*Boiga cyanea*	2	LC
	Long-nosed Tree Snake	*Ahaetulla nasuta*	11	LC
	Ornate Flying Snake	*Chrysopelea ornata*	8	LC
	Gunther's Whip Snake	*Ahaetulla prasina*	16	LC
	Collared Black-headed Snake	*Sibynophis collaris*	6	LC
	Triangled Black-headed Snake	*Sibynophis triangularis*	1	NT
	Striped Kukri Snake	*Oligodon taeniatus*	1	LC
	Yellow-striped Trinket Snake	*Coelognathus flavolineatus*	2	LC
	Copper-headed Racer	*Elaphe radiata*	6	LC
	Laos Wolf Snake	*Lycodon laoensis*	2	LC
	Cantor's Kukri Snake	*Oligodon cyclurus*	8	LC
	Small-banded Kukri Snake	*Oligodon fasciolatus*	7	LC
	Yellow-spotted Keelback Water Snake	*Fowlea flavipunctatus*	5	LC
	Chequered Keelback	*Fowlea piscator*	8	LC
	Black-banded Keelback	*Rhabdophis nigrocinctus*	1	LC
	Red-necked Keelback	*Rhabdophis subminiatus*	2	LC
	Speckle-bellied Keelback	*Rhabdophis chrysargos*	1	LC
	Common Bronzeback	*Dendrelaphis pictus*	9	LC
	Beautiful Bronzeback Tree Snake	*Dendrelaphis formosus*	1	LC
	Javan Rat Snake	*Ptyas korros*	5	NT
	Keeled Rat Snake	*Elaphe carinata*	1	LC
	Oriental Rat Snake	*Ptyas mucosus*	5	LC
	Dog-toothed Cat Snake	*Boiga cynodon*	1	LC
	Gray Cat Snake	*Boiga siamensis*	1	LC
Family Elapidae	King Cobra	*Ophiophagus hannah*	4	VU
	MacClelland's coral snake	*Calliophis macclellandii*	1	LC
	Monocled cobra	*Naja kaouthia*	2	LC
Family Gekkonidae	Tokay gecko	*Gekko gecko*	6	LC
Family Natricidae	Boulenger's Keelback	*Hebius boulengeri*	1	LC
Family Scincidae	Olive Dasia	*Dasia olivacea*	2	LC
	Common Mabuya	*Eutropis multifasciata*	7	LC
	Spotted Forest Skink	*Sphenomorphus maculatus*	2	LC
Family Varanidae	Bengal Monitor Lizard	*Varanus bengalensis*	2	NT
Family Varanidae	Common Water Monitor	*Varanus salvator*	7	LC
Family Viperidae	Vogel's Pit Viper	*Trimeresurus vogeli*	1	LC
	Sumatran Green Pit Viper	*Trimeresurus barati*	1	LC
	Large-eyed Pit Viper	*Trimeresurus macrops*	1	LC
	Pope's Pit Viper	*Trimeresurus popeiorum*	1	LC
	White-lipped Tree Viper	*Trimeresurus albolabris*	1	LC
Family Xenopeltidae	Sunbeam snake	*Xenopeltis unicolor*	1	LC
	Unidentified (sp1)	-	1	
	Unidentified (sp1)	-	1	
		Total	**264**	
Amphibian				
Order Anura				
Family Bufonidae	Asian common toad	*Duttaphrynus melanostictus*	2	LC
Family Dicroglossidae	Gyldenstolpe's Frog	*Limnonectes gyldenstolpei*	3	LC
Family Microhylidae	Beautiful Pygmy Frog	*Microhyla pulchra*	2	LC
	Burmese Squat Frog	*Glyphoglossus guttulatus*	4	LC
	Asian painted frog	*Kaloula pulchra*	2	LC
Family Ranidae	Dark-sided Frog	*Sylvirana nigrovittata*	7	LC
Family Rhacophoridae	common tree frog	*Polypedates leucomystax*	17	LC
	Unidentified (sp1)		2	-
	Unidentified (sp2)		2	-
		Total	**39**	
		Grand total	**391**	

Considering an overview of wildlife carcasses found on the highway, the monthly rate average of 1.89 WVCs day^{-1} for wildlife carcasses of all taxonomic groups was found. The month during which carcasses were found the most was March, which showed 4.28 WVCs day^{-1}, followed by April, with 3.53 WVCs day^{-1}. From daily data collection, it was found that the days on which the animal carcasses were collected were not significantly different (F: 0.59, P: 0.62) when considering the carcasses found during the dry season (November-April) at 2.25 WVCs day^{-1} were similar to those found in the rainy season (May to October) where wild animal carcasses were found at 1.53 WVCs day^{-1}. No significant differences were apparent between seasons (t: 1.21, P: 0.25), although the number of wildlife carcasses found during the dry season was 2.25 WVCs day^{-1}, which was more than during the rainy season (1.53 WVCs day^{-1}), as detailed in Table 2. Some of the wildlife carcasses found are illustrated in Figure 2.

When considering wildlife carcasses by taxonomic group, 58 mammalian carcasses were found, representing a total of 0.27 WVCs day^{-1}, while 29 wild birds' carcasses were found, representing 0.14 WVCs day^{-1}. Two hundred and sixty-three carcasses of reptiles were found, representing 1.27 WVCs day^{-1}, and 36 amphibian carcasses were found, representing 0.17 WVCs day^{-1} (Table 3).

It was found that carcasses were found in each group during the dry season more than during the rainy season for all groups. During the dry season, mammal carcasses amounted to 0.35 WVCs day^{-1}, whereas during the rainy season, it was 0.20 WVCs day^{-1}, which was not a significant difference (t: 1.67, P: 0.12). In the case of birds, 0.22 WVCs day^{-1} were found during the dry season, while 0.07 carcasses/day were found during the rainy season, which was not a significant difference (t: 2.62, P: 0.02) (Table 3).

Figure 2. Examples of species killed on the highway in KYNP, Thailand during February 2018 - January 2019, with 207 observed days. A. Asiatic Brush-tailed Porcupine (*Atherurus macrourus*); B. Grey-bellied Squirrel (*Callosciurus caniceps*); C. Lesser Oriental Chevrotain (*Tragulus kanchil*); D. Blue Pitta (*Hydrornis cyaneus*); E. Golden-headed Cisticola (*Cisticola exilis*) F. Banded Kingfisher (*Lacedo pulchella*); G. Giant Asian Pond Turtle (*Heosemys grandis*); H. Elongated Tortoise (*Indotestudo elongata*); I. King Cobra (*Ophiophagus hannah*); J. Green-crested Lizard (*Bronchocela smaragdina*); K. Olive Dasia (*Dasia olivacea*); L. Dark-sided Frog (*Sylvirana nigrovittata*). Photograph by N. Rattanawanawong

Table 2. The number of carcasses for all types of wildlife found by month and date of the survey and comparison between the dry season and the rainy season in KYNP observed on Monday, Wednesday, Friday, and Saturday during February 2018 - January 2019, with 207 observed days

Season	Month	Number of wildlife carcasses by date of collection					Number of days collected	WVCs day^{-1}	Average WVCs season^{-1}
		Monday	Wednesday	Friday	Saturday	Total			
The dry	November	4	7	6	5	22	16	1.38	2.25
	December	4	6	5	3	18	18	1.00	
	January	4	5	4	4	17	17	1.00	
	February	10	13	5	8	36	16	2.25	
	March	11	20	24	22	77	18	4.28	
	April	17	14	24	5	60	17	3.53	
The wet	May	4	16	7	4	31	17	1.82	1.53
	June	5	3	12	16	36	18	2.00	
	July	8	3	4	10	25	17	1.47	
	August	3	12	5	5	25	18	1.39	
	September	6	6	2	5	19	17	1.12	
	October	4	10	8	3	25	18	1.39	
Total		80	115	106	90	391	207	1.89	
Ratio		1.00	1.44	1.32	1.12				

Table 3. The number of mammal, bird, reptile and amphibian carcasses per day found by month in KYNP observed on Monday, Wednesday, Friday, and Saturday during February 2018 - January 2019, with 207 observed days.

Season	Month	The number of carcasses of each type of wildlife											
		Mammal	WVCs day^{-1}	Average WVCs day^{-1}	Bird	WVCs day^{-1}	Average WVCs day^{-1}	Reptile	WVCs day^{-1}	Average WVCs day^{-1}	Amphibian	WVCs day^{-1}	Average WVCs day^{-1}
The dry	November	6	0.38	0.35	4	0.25	0.22	9	0.56	1.39	2	0.12	0.24
	December	3	0.17		1	0.06		12	0.67		0	0	
	January	8	0.47		2	0.12		5	0.29		0	0	
	February	11	0.68		6	0.37		24	1.5		0	0	
	March	7	0.39		6	0.33		55	3.05		4	0.22	
	April	1	0.06		3	0.17		37	2.18		19	1.12	
The wet	May	3	0.17	0.20	3	0.17	0.07	23	1.35	1.15	2	0.12	0.10
	June	5	0.28		1	0.06		28	1.56		2	0.11	
	July	5	0.29		1	0.06		15	0.88		4	0.23	
	August	2	0.11		0	0		21	1.17		2	0.11	
	September	3	0.18		2	0.12		14	0.82		0	0	
	October	3	0.17		0	0		20	1.11		1	0.06	
Total		57	0.27		29	0.14		263	1.27		36	0.17	
Ratio			1.00			0.52			4.70			0.63	

Table 4. The number of tourists and number of vehicles traveling in KYNP observed on Monday, Wednesday, Friday, and Saturday during February 2018 - January 2019, with 207 observed day

Season	Month	Number of tourists						Number of vehicles					
		Monday	**Wednesday**	**Frida**	**Saturda**	**Tourists day^{-1}**	**Average tourists day^{-1}**	**Monday**	**Wednesday**	**Friday**	**Saturday**	**Vehicles day^{-1}**	**Average vehicles day^{-1}**
The dry	November	10,708	8,732	13,378	50,41	5,201.81	4,650.87	3,365	2,658	3,819	12,125	1,372.93	1,216.51
	December	54,260	12,996	23,540	88,95	9,986.22		12,724	3,342	6,596	21,026	2,427.11	
	January	9,397	16,874	13,655	38,95	4,640.00		2,956	4,780	3,941	8,683	1,197.64	
	February	7,169	5,363	10,133	26,62	3,080.75		2,390	1,405	3,161	8,405	960.06	
	March	6,736	5,668	9,198	22,53	2,452.17		2,099	1,507	2,850	5,811	681.50	
	April	11,942	7,336	13,524	10,45	2,544.29		3,055	2,108	3,456	2,598	659.82	
The wet	May	9,009	7,197	6,173	16,73	2,300.88	3,084.32	2,602	2,057	1,860	4,476	646.76	838.01
	June	5,631	4,458	8,102	16,73	2,394.89		1,982	1,479	2,474	6,521	692.00	
	July	11,277	4,544	18,877	16,27	2,998.29		3,350	1,463	5,326	3,931	827.64	
	August	11,535	7,369	6,880	20,37	2,564.44		3,151	2,254	2,145	5,566	728.83	
	September	5,561	4,714	7,315	26,63	2,601.29		1,975	1,584	2,112	7,390	768.29	
	October	23,884	12,794	15,792	49,16	5,646.11		5,936	3,030	3,908	11,688	1,364.56	
	Total	167,108	98,045	146,567	392,03	3,882.86	Total	45,585	27,667	41,648	98,220	1,029.56	
	Ratio	1.00	0.59	0.88	2.3		Ratio	1.00	0.61	0.91	2.15		

Table 5. The number of wildlife carcasses by the taxonomic group of wildlife found in the morning between 6:00 AM - 9:00 AM and the evening between 3:00 PM - 6:00 PM on the highway passing in KYNP observed on Monday, Wednesday, Friday, and Saturday during February 2018 - January 2019, with 207 observed days

	During 06.00-09.00 AM	During 15.00-18.00 PM	Total
Birds	12	17	29
Mammals	28	29	57
Reptile	126	137	263
Amphibian	20	16	36
Total	186	199	385

Table 6. Multiple Linear Regression equation between the numbers of wildlife carcasses/day encountered with the number of tourists and the number of vehicles who entered KYNP between February 2018 and January 2019 during a total data collection of 207 days.

Variables	Estimate	SE	Z	P
All carcasses model	**Ln (Y) = 1.71 - 3.8e-02 Sqrt (X_2)**			
Intercept	1.71	5.40e-01	3.18	0.01
X_2	-3.8e-02	1.68e-02	-2.25	0.04
Mammal carcasses model	**Y = -8.76e-02 - 6.04e-04 (X_1) + 2.63e-03 (X_2)**			
Intercept	-8.76e-02	1.48e-01	-5.91e-01	0.57
X_1	-6.04e-04	1.95e-04	-3.09	0.01
X_2	2.63e-03	8.52e-04	3.08	0.01
Reptile carcasses model	**Y = 8.68 - 1.08 Ln (X_2)**			
Intercept	8.68	3.29	2.63	0.02
X_2	-1.08	4.80e-01	-2.25	0.04

Notes: Y: number of carcass/days; X_1: number of tourists; X_2: number of vehicles; Ln: natural logarithms; Sqrt: Square root

In the case of reptiles, 1.39 carcasses/day were found during the dry season and 1.15 WVCs day^{-1} were found during the rainy season, which did not differ significantly (t: 0.49, P: 0.62), and 0.24 WVCs day^{-1} of amphibians were found during the dry season, while 0.10 carcasses/day of amphibians were found in the rainy season, meaning it did not differ significantly (t: 0.76, P: 0.46) (Table 3).

Number of tourists and vehicles

For the number of tourists who visited KYNP, it was found that there was an average of 3882.86 people day^{-1}, with a total of 392,031 people during the 207 days of the study period, while the average number of vehicles was 1029.56 vehicles day^{-1}, with a total of 98,220 vehicles during the 207 days study period. This study found that there were more tourists with 4650.87 tourists/day during the dry season or the tourist season, while there were 3084.32 people day^{-1} during the rainy season, as detailed in Table 4. It was found that the number of tourists per day did not differ significantly between the dry season and rainy season (t: 0.53, P: 0.59).

The number of cars per day during the dry season was 1216.51 vehicles day^{-1}, while there were 838.01 vehicles day^{-1} during the rainy season, meaning there was no significant difference (t: 0.59, P: 0.56) (Table 4).

The numbers of wildlife carcasses found in the morning and evening hours were found to be similar. There were 186 remains found during the morning and 199 in the evening (Table 5).

The results found that wildlife mortality was significantly correlated with both the number of tourists and the number of vehicles entering the national park's highways, which showed with the model of Ln (Y) = 1.71 - 3.8e-02 Sqrt (number of vehicles) when Y was the number of wildlife carcasses/day found.

In the case of mammalian carcasses found that there was a relationship with the number of tourists and a significant number of cars entering the national park it showed the equation of Y = -8.76e-02 - 6.04e-04 (number of tourist) + 2.63e-03 (number of cars) while reptile carcasses found to be significant with number of cars entering the area with the model was Y = 8.68 - 1.08 Ln (number of vehicles) as detailed in Table 6. In the case of the bird and amphibian models, it was found that there was no significance. Thus, there were no indications in this study.

Discussion

KYNP is a part of a natural world heritage site. The area contains unique biological phenomena and outstandingly high levels of diversity and endemism (Khoewsree et al. 2022; UNESCO 2022). Based on IUCN red list data (IUCN 2022), it was found that 2 species of carcasses were critically endangered (CR), while 2 species of carcasses were vulnerable (VU), 3 were near threatened (NT), and 79 were least concerned (LC) status (IUCN 2022). This represented the ongoing loss of wildlife biodiversity for more than half a century in the area or even in other national parks and wildlife sanctuaries. The direct

loss of wildlife resources from WVCs is high and was not considered to be improved; this impact cannot be eliminated even if certain measures were taken.

The results showed that a total of 391 wild animal carcasses were found. It was found that the overall carcass rate in KYNP (0.04 WVCs km^{-1}) was lower than that in the Mudumalai Tiger Reserve, southern India as reported by Baskaran and Boominathan (2010) on the forest path over a total distance of 248 km, where 180 wildlife carcasses were found, representing 0.72 WVCs km^{-1}. Amphibians were the most affected taxa (53%) of road kills, followed by reptiles (22%), mammals (18%); including a leopard (*Panthera pardus*), and birds (7%) (Baskaran and Boominathan 2010), compared to other studies. For example, Jeganathan et al. (2018) surveyed the Anamalai Hills in Western Ghats, India, and reported an equivalent of 635 km. They documented 1854 vertebrate carcasses during surveys or about 2.9 WVCs km^{-1}. In Thailand, Srisuwor et al. (2020) reported the impact of traffic on Highway No. 304 that pass through KYNP and Thap Lan National Park on the wildlife between December 2018 and August 2019 with a total accumulative distance of 1062 km found 41 wildlife carcass species, with 176 individuals were killed that showed 0.17 WVCs km^{-1}. Kummoo et al. (2020) reported the WVCs on the highway that cuts through Nam Nao National Park, Thailand. Based on a 1496 km survey, they reported 1389 carcasses of 578 amphibians, 540 reptiles, 190 mammals, and 81 birds, which accounted for 1389 carcasses or 0.93 WVCs km^{-1}. Sur et al. (2022) reported the WVCs in Kaziranga National Park, Assam India on a 64 km long highway that passed through it from October 2016 to September 2017. A total of 6036 individual cases of roadkill were registered, belonging to 53 species, 23 other taxa, and 30 families of vertebrates. Pagany (2020) analyzed wildlife mortality from cars of 82.1 million WVCs in 43 countries, which comprised a data collection period of 1125 years and a road network of 29.3 million kilometers in total. The WVCs density concerning the road network was below 20 WVCs km^{-1} in 90% of the studies was a median of 1.6 WVCs km^{-1} and an average of 24 WVCs km^{-1}. Thus, the WVC density that occurred in KYNP was lower than the median and average reported by Pagany (2020). In the case of traffic volume and the number of tourists showed a very high volume when compared with Healey et al. (2020), who reported that motorized vehicles that traveled on the road totaled approximately 229 vehicles d^{-1} (SE±53.4) vehicles d^{-1}, range 74-527 vehicles d^{-1}.

Multiple regression models showed a significant relationship between the number of wildlife carcasses and the volume of vehicles day^{-1}. If limiting the number of tourists and the number of vehicles less than the average effect on the reduction of wildlife mortality in KYNP, the number of vehicles directly affects the death of wildlife. During the period when there is a large number of vehicles entering the area in February, which is the peak tourist season of the year, it then dropped in March, and wild animal deaths were found to increase in April until the highest in May, after which it dropped again in June and July. This may be due to wild animals avoiding the high number of cars that come in during the high season. They then came back to the area near the highway and tourist attractions. Thus, many wild animals die by car after the tourist season. In addition, the results of the daily mortality test with monthly mean temperature showed that the daily mortality of wildlife correlated significantly with an average monthly temperature. It means that there is a strong direct relationship between the average temperature and the number of wildlife carcasses found per day. In the case of amphibians, in general, almost amphibian species appear during the rainy season. Due to a smaller number of cars entering KYNP during the rainy season than that of the dry season, however, this result showed a smaller number of amphibian carcasses were found during the rainy season. When determining the relationship equation for wildlife carcass encounters per day with the number of vehicles and the number of tourists entering the area, it was found that the volume of vehicles day^{-1} affected wildlife mortality per day when considering all wildlife species. Meanwhile, the daily mortality of mammals was associated with both the number of tourists and the number of vehicles entering the area. This can be used to determine the number of vehicles and the number of tourists to set the rate of wildlife deaths per day to be at the desired level**.**

It could be said that mortality due to collisions with vehicles has been identified as a major conservation issue in KYNP. The authors recommend reducing the current posted speed limit to less than 50 km h^{-1}. Wildlife mortality hotspots on the highway should be identified for management concentration. A reduction in speed would increase the probability of drivers avoiding collisions with wildlife. Further, wildlife crossing signs should be erected along the highway, just before each hotspot, as such signs have been shown to change drivers' behaviors (Collinson et al. 2019). Other recommendations to mitigate the impact of vehicle use on the highway passing through KYNP were reducing the number of vehicles entering the route, including the number of tourists, as well as banning travel at night. Educational signage about wildlife diversity and the risk of road mortality should be installed at the park entrances to remind visitors about the unique fauna in this national park and emphasize the importance of conservation (Healey et al. 2020).

In conclusion, a total of 391 wild animal carcasses were found in 90 species. The carcasses found according to the taxonomic group were reptiles (67.52%), followed by mammals (14.83%), amphibians (4.35%) and birds (3.32%). Reptiles were most affected by road use, especially tortoises in Family Geoemydidae and Family Testudinidae that two critically endangered species were found. This study found that members of Family Colubridae were most affected that 26 species, a total of 144 animal carcasses were found, accounting for 29.15% of the number of all carcasses. The most affected species were forest garden lizard (*Calotes emma*) in the Family Agamidae, where 99 carcasses were found, accounting for 25.31% of the total. In March showed the highest number of the carcasses, followed by April. All of the carcasses found in the evening slightly more than the morning indicated that wild animals died more during the day than

at night. Multiple regression models showed a significant relationship between the number of WVCs day^{-1}, the volume of vehicles day^{-1}, and the number of tourists. Thus, reducing the number of vehicles and the vehicle speed must be done. Educational signage about wildlife diversity and the risk of road mortality should be installed at the park entrances and other appropriate areas in the park to remind visitors about the unique fauna in this national park and emphasize the importance of conservation.

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