

Abundance and physical factors affecting the appearance of selected terrestrial birds in Khao Yai National Park using camera trapping

PEMIKA KANKA, RONGLARP SUKMASUANG[✉], PRATEEP DUENGKAE,
KITTIWARA SIRIPATTARANUKUL

Department of Forest Biology, Faculty of Forestry, Kasetsart University, 10900 Bangkok, Thailand. Tel.: +66-257-90176, Fax.: +66-294-28107,
[✉]email: mronglar@gmail.com

Manuscript received: 1 November 2022. Revision accepted: 4 January 2023.

Abstract. Kanka P, Sukmasuang R, Duengkae P, Siripattaranukul K. 2023. Abundance and physical factors affecting the appearance of selected terrestrial birds in Khao Yai National Park using camera trapping. *Biodiversitas* 24: 222-232. This study used results from camera traps set for Dhole (*Cuon alpinus*) and their prey during 2017-2020 in Khao Yai National Park to assess the species richness of ground-dwelling birds and identify abundance and also temporal appearance of the species in the area. We selected only the Pheasant species that typically forage on the ground to investigate the physical factors affecting the appearance in Khao Yai National Park. Based on camera trapping data with a total of 4139 trap days, 115 camera locations showed 36 species of birds belonging to 21 families, and 13 orders of ground-dwelling bird species were recorded. Siamese Fireback (*Lophura diardi*), Red Junglefowl (*Gallus gallus*), and Silver Pheasant (*Lophura nycthemera*) were detected with an abundance index of 10.65%, 7.27%, and 1.84%, respectively. The ground-dwelling bird abundance index from the camera traps accounted for 26.85% of the total fauna. Although the Phasianidae were found to be diurnal species, this study also shows a statistically significant difference in the average time between Red Junglefowl and Siamese Fireback. Meanwhile, there was no statistically significant difference between Red Junglefowl and Silver Pheasant during their active time. The water sources showed a significant effect on the presence of the Siamese Fireback in data analysis; however, no physical environmental factors significantly affected the distribution of Red Junglefowl and Silver Pheasant. This study found that surrounding creeks and streams significantly impacted the appearance of the Siamese Fireback. As a result, area management needs to prevent and reduce disturbances along a creek in order to effectively manage the habitat of the Siamese Fireback and other wildlife.

Keywords: Dong Phrayayen Khao Yai Forest Complex, Red Junglefowl, Siamese Fireback, Silver Pheasant, terrestrial bird

INTRODUCTION

Terrestrial birds are the type of birds that are generally found on the ground, not only foraging but also nesting and roosting on the ground. However, most terrestrial birds that do fly generally stay low above the ground or close to cover when flying (Voskamp et al. 2021; Spiller et al. 2022). These birds contribute to energy transmission, seed dispersal, and insect and benthos balance and are the prey of carnivores. Pheasants are also used by people both directly and indirectly, especially for social, recreational, and ecological purposes, including the Siamese Fireback, the national bird of Thailand. In addition, some terrestrial birds, especially pheasants, are used for monitoring environmental and global climate changes (Voskamp et al. 2021; Lu et al. 2022).

The Galliformes (Phasianidae family) are a group of terrestrial birds widely distributed in various habitats. The Phasianidae family, once common in Thailand's forests, is rare and currently only found in a few areas (BirdLife International 2016a, 2016b). The pheasant prefers to inhabit dense forests, including hill evergreen forests, moist evergreen forests, and dry evergreen forests (Dawrueng et al. 2017). It is sometimes found at elevations not exceeding 800 meters above sea level in scant forests such as deciduous dipterocarp and mixed deciduous forests. Due to its small size and dense vegetation, it is currently rare in

nature and difficult to detect (Dawrueng et al. 2017). The fact that the Thai pheasant species are both a protected wildlife species of Thailand under the Wild Animals Preservation of Act BE 2562 and the least concern species according to IUCN (2022) shows how important these wildlife species are. However, the Siamese Fireback population has declined continuously due to natural disasters, forest encroachment, and habitat degradation (McGowan et al. 2012; Dawrueng et al. 2017; IUCN 2022). The total population is suspected to be around 20,000-49,999 individuals based on a conservative estimate of c.2000 individuals in Cambodia and an estimate of c.5,000 individuals in Thailand (BirdLife International 2016a). In the case of the Silver Pheasant, the global population size has not been quantified yet, but the species is reported to be widespread and seemingly common in suitable habitats. The population size in China has been estimated at c.10000-100000 breeding pairs (BirdLife International 2016b). At the same time, Red Junglefowl is reported to be widespread and common to locally common categories (del Hoyo et al. 1994). These findings emphasize the importance of terrestrial birds and their vulnerability, especially species belonging to the Phasianidae family. Round and Gale (2008) observed that the pheasants in Khao Yai National Park preferred to inhabit elevations of more than 800 meters above sea level due to climate change, which has caused the average temperature to

increase approximately 0.6°C over the past 100 years. Tropical Asian deforestation and habitat degradation represent a serious threat to biodiversity globally by decreasing native forests and the habitat for wildlife (Round and Gale 2008; Zou et al. 2019).

Khao Yai National Park (KYNP) is an important source for conserving global wild birds (Bird Conservation Society of Thailand 2021). The results of a survey of wild birds in this area in February 2021 found 171 bird species, including 122 endemic birds and 42 species of migratory birds outside the breeding season. Seven of the bird species, including the Asian Fairy-bluebird (*Irena puella*), the Chestnut-flanked White-eye (*Zosterops erythropleurus*), and the Black-crested Bulbul (*Pycnonotus flaviventris*), have the potential to be both resident and non-breeding migrants. In addition, two species found of hornbills, the Great Hornbill (*Buceros bicornis*) and the Wreathed Hornbill (*Rhyticeros undulatus*), are considered vulnerable (IUCN 2022).

Suwanrat et al. (2014) reported that Siamese Fireback in northeastern Thailand preferred to nest in areas associated with a higher percentage of ground cover, steep slopes, higher basal area of large trees, and low predation pressure significantly. They also reported that the density of the species was higher in the dry evergreen forest than in old forest plantations because dense forest habitats provide more resources and hindering from predation (Suwanrat et al. 2015, 2019).

The Dong Phrayayen Khao Yai forest complex, the largest forest complex in the country's eastern forests, was named a World Natural Heritage site in 2005 (UNESCO 2022), serving as a transitional zone between the ecosystems of the central and northeastern regions. Khao Yai National Park is a part of this forest complex. A large proportion of the area's rainforest comprises dry evergreen forest, while just a small proportion is mixed forest and grassland (UNESCO 2022).

Knowing the physical factors affecting the appearance of the selected terrestrial bird species is important to define important environmental factors to maintain viable populations (Chiatante and Meriggi 2022); however, little investigation on this subject has been performed in the area. The abundance of bird species is largely influenced by the spatiotemporal distribution of some key environmental resources (Girma et al. 2017). Studies on terrestrial birds, particularly those in the pheasant family, are also quite rare in Thailand. Remote cameras activated by a passive infrared sensor, known as camera traps or trail cameras, are used increasingly to study wildlife (Burton et al. 2015; Kolowski and Forrester 2017; Lamelas-Lopez et al. 2020) and ground-dwelling birds in the field (Shi et al. 2017; Romero-Calderón et al. 2021). This study sought to determine the abundance and habitat preferences of ground-dwelling birds in KYNP, particularly those belonging to the Phasianidae family, to support managing the area's biodiversity. Also, to understand the ecosystem conditions, habitat use, and factors affecting the presence of these wildlife species for conservation.

This study aimed to answer the main hypotheses about the regularity of their presence during the day, the temporal

differences in the presence of the 3 species of pheasants found, and answer questions about spatial factors affecting the distribution of pheasants in the area. Thus, the objectives of this study were to investigate the abundance of ground-dwelling birds, particularly those in the pheasant family. There were also studies on the species' active time, observed differences, and identified the factors affecting the appearance of birds in the pheasant family. The expected results of this study can be used to manage areas for the conservation of wild birds, especially the pheasant family found in the Khao Yai National Park.

MATERIALS AND METHODS

Study area

Khao Yai National Park (KYNP), Thailand is located from latitude N 14°05'0.00" to N 14°35'0.00" and from longitude E 101°10'0.00" to E 101°55'0.00", covering an area of 2168 square kilometers. The study area is located in the Phanom Dong Rak mountain range, between the central and northeastern regions, with important watersheds such as the Nakhon Nayok and Mun rivers. There are more than 800 species of vertebrates, with more than 200 species of reptiles, amphibians, and 112 species of mammals. Among the species present are 19 vulnerable species, 4 endangered species, and 1 critically endangered species listed under the International Union for Conservation of Nature's (IUCN) Red List of Threatened Species (UNESCO 2022). The bird species diversity report from Avibase-The World Bird Database (2022) showed that there were at least 19 globally threatened bird species including Yellow-breasted Bunting (*Schoeniclus aureoles*), Helmeted Hornbill (*Rhinoplax vigil*) and Straw-headed Bulbul (*Pycnonotus zeylanicus*), Green Peafowl (*Pavo muticus*), Masked Finfoot (*Heliopais personatus*) and Silver Oriole (*Oriolus mellianus*), as well as several vulnerable species, for example, Pale-capped Pigeon (*Columba punicea*), Coral-billed Ground-Cuckoo (*Carpococcyx renauldi*), Lesser Adjutant (*Leptoptilos javanicus*), Black-legged Kittiwake (*Rissa tridactyla*), Greater Spotted Eagle (*Clanga clanga*), Eastern Imperial Eagle (*Aquila heliaca*), Great Hornbill (*Buceros bicornis*), Rhinoceros Hornbill (*B. rhinoceros*), Wreathed Hornbill (*Rhytesyros rhinoceros*), Great Slaty Woodpecker (*Mulleripicus pulverulentus*) and Gray-sided Thrush (*Turdus feae*).

The vegetation comprised mostly dry evergreen forests, with some evergreen forests, hill evergreen forests, mixed forests, and grasslands formed by past shifting cultivation (Brockelman et al. 2017). Average temperature and rainfall measurements have been collected at the Mor Singto monitoring station in Khao Yai National Park over the past ten years (2008-2017) (Brockelman et al. 2017). The rainy season occurs from May to October, with an average yearly rainfall of 1897.07 millimeters. September has the highest rainfall, at 353.44 millimeters. KYNP has year-round average temperatures of 21.28°C, with the highest average temperature in April at 30.33°C and the lowest average temperature in January at 12.25°C (Khao Yai National Park

2022). The map of the study area and the location of the camera traps are shown in Figure 1.

Procedures

Camera traps are increasingly used in avian ecology studies to study on bird diversity and abundance (Shi et al. 2017). From October 2017 to March 2020, 20 automatic camera traps (Trail Camera Essential E3, 16MP resolution) were used to conduct surveys within Khao Yai National Park. Survey blocks were set on 1 km × 1 km each (Shi et al. 2017) and were identified on a 1:50,000 topographic map, and a total of 115 blocks were surveyed by placing one camera trap per survey block (Sweitzer and Furnas 2016; Shi et al. 2017; Romero-Calderón et al. 2021). The cameras were deployed in 15-20 blocks at a time for 30 days, 24 hours per day or trap day, and then relocated to a different location, adding up to 4139 total trap days. Each camera trap location was more than 500 meters apart from the other to provide flexibility in image acquisition in each block and to reduce the likelihood of recording the same animal with multiple cameras (Rovero et al. 2010). In addition, all camera trap locations were recorded with Global Positioning System (GPS).

The camera trap placement locations were selected based on the suitability of each area, such as along animal paths (Rovero et al. 2010). The camera traps were positioned approximately 3-4 meters from the target location and 30-40 cm above the ground, attached at about knee height to medium-sized trees (Rovero et al. 2010). That allows the camera to capture smaller mammals, terrestrial birds, and large mammals that may use the site

(Rovero et al. 2010; Meek et al. 2012; Zhang et al. 2018). The cameras were set to take photos when the sensor detects motion, taking 3 consecutive photos at the moment by 10 seconds apart (Rovero et al. 2010).

The photos were uploaded from the memory card to the computer and classified using the Camera Trap Manager program (Zaragozi et al. 2015). The obtained data from the camera trap includes species of animals found, geographic location, and date and time of wildlife encounters. Microsoft Excel will process these data for further analysis.

Data analysis

The common and scientific names suggested by IUCN (2022) were used to identify captured wildlife. Images with more than one wild animal of the same species were counted as one event to obtain independent photographs or events (Fennell et al. 2022). The following criteria are used to determine the independence of animal photographs: (1) consecutive images of different animals of the same or different species; (2) consecutive images of the same animal of the same species with a time interval of more than 30 minutes; (3) images that are not a continuation of the same animal of the same species (Fennell et al. 2022). The average recording time of wildlife using independent images was analyzed to calculate average activity time, and a 95% confidence interval was set using ORIANA version 4.02 (Kovach Computing Services 2022).

The Rayleigh test is a statistical test for the uniformity of a circular distribution of points with $p < 0.05$, the null hypothesis (uniformity) is rejected, indicating the effect of time recorded was used in this study (Moore 1980).

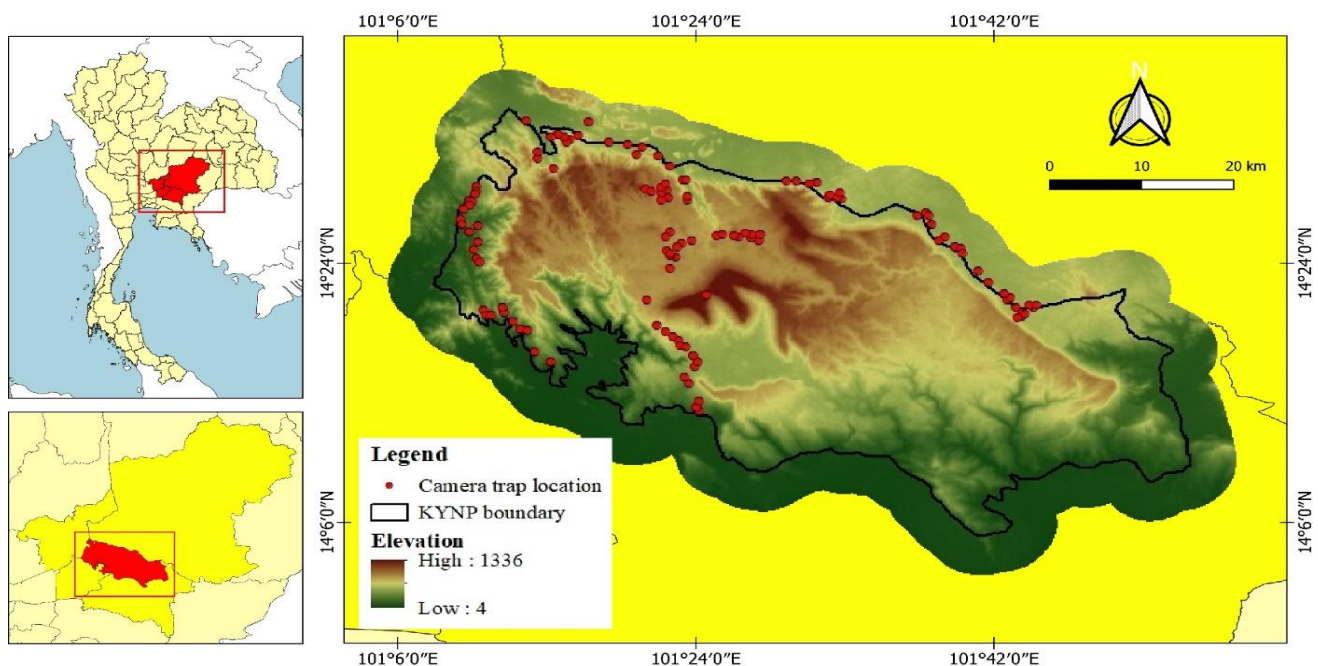


Figure 1. Map of Khao Yai National Park, Thailand and the 115 camera trap positions (red dots), which add to a total of 4139 trap days, placed from October 2017 to March 2020

The Mardia-Watson-Wheeler test (Mardia 1972) was used to calculate the difference in coexistence time. Our main hypothesis was no difference in the average activity time among the species. The results were determined at the significance level of $P < 0.05$. An examination of the covariance associated with the pheasant distribution and physical factors was conducted, including (1) elevation; (2) distance to the nearest village; (3) distance to the nearest road; (4) slope, and (5) distance to the nearest stream using the 'rgdal' package (Bivand 2022) in the RStudio program (Rcore Team 2015) and verified MD5 sums. A single-season dominance model was used, using a model with the lowest ΔAIC value to determine a set of reliable replicas. Based on the study's assumptions, the occupancy model assumes that the camera station has a closed population. We surveyed with a random sampling method each month, a short period compared to the pheasant's life span. This assumption is consistent with the demographic principles of the pheasant species.

RESULTS AND DISCUSSION

The abundance of terrestrial birds

The camera traps were placed in KYNP from October 2017 to March 2020 to study the diversity of ground-dwelling birds, recorded a total of 36 species of ground-dwelling birds, from 13 orders 21 families and 34 genera from 115 camera trap locations, with a total of 4139 trap days. The most common species recorded were Siamese Fireback (n: 441) with an abundance index of 10.65%, Red Junglefowl (n: 301) with an abundance index of 7.27%, and Silver Pheasant with an abundance index of 1.84%. The total recordable bird abundance index was 26.91%, as detailed in Table 1, and out of the 72 wildlife species that could be captured, 73.09% of the mammalian abundance was classified.

Table 1. Ground-dwelling bird species were recorded by camera traps in Khao Yai National Park, Thailand using 115 camera traps, 4139 trap days from October 2017 to March 2020

Common name	Scientific name	No. of independent photographs	No. of locations found	RAI (%)	IUCN 2022
Siamese Fireback	<i>Lophura diardi</i>	441	41	10.65	LC
Red Junglefowl	<i>Gallus gallus</i>	301	45	7.27	LC
Silver Pheasant	<i>Lophura nycthemera</i>	76	4	1.84	LC
Grey-capped Emerald Dove	<i>Chalcophaps indica</i>	43	13	1.04	LC
White-crested Laughingthrush	<i>Garrulax leucolophus</i>	36	10	0.87	LC
Great Myna	<i>Acridotheres grandis</i>	30	3	0.72	LC
Red Turtle-dove	<i>Streptopelia tranquebarica</i>	29	1	0.70	LC
Red-wattled Lapwing	<i>Vanellus indicus</i>	25	4	0.60	LC
Eastern Spotted Dove	<i>Spilopelia chinensis</i>	22	7	0.53	LC
Thick-billed Green-pigeon	<i>Treron curvirostra</i>	18	2	0.43	LC
Coral-billed Ground-cuckoo	<i>Carpococcyx renauldi</i>	17	8	0.41	VU
Green-legged Partridge	<i>Arborophila chloropus</i>	11	5	0.27	LC
Chinese Pond-heron	<i>Ardeola bacchus</i>	9	1	0.22	LC
Green-backed Heron	<i>Butorides striata</i>	7	1	0.17	LC
Malayan Night Heron	<i>Gorsachius melanolophus</i>	7	1	0.17	LC
Green-billed Malkoha	<i>Phaenicophaeus tristis</i>	4	1	0.10	LC
White-breasted Waterhen	<i>Amaurornis phoenicurus</i>	4	1	0.10	LC
Barred Cuckoo-dove	<i>Macropygia unchall</i>	3	2	0.07	LC
Blue Whistling-thrush	<i>Myophonus caeruleus</i>	3	1	0.07	LC
Crested Serpent-eagle	<i>Spilornis cheela</i>	3	2	0.07	LC
Orange-headed Thrush	<i>Geokichla citrina</i>	3	2	0.07	LC
Red-headed Trogon	<i>Harpactes erythrocephalus</i>	3	1	0.07	LC
Black-headed Woodpecker	<i>Picus erythropygius</i>	2	1	0.05	LC
Blue Pitta	<i>Hydrornis cyaneus</i>	2	1	0.05	LC
Common Green Magpie	<i>Cissa chinensis</i>	2	1	0.05	LC
Greater Racquet-tailed Drongo	<i>Dicrurus paradiseus</i>	2	2	0.05	LC
Oriental Pied Hornbill	<i>Anthracoceros albirostris</i>	2	1	0.05	LC
Asian Fairy-bluebird	<i>Irena puella</i>	1	1	0.02	LC
Black-naped Oriole	<i>Oriolus chinensis</i>	1	1	0.02	LC
Collared Falconet	<i>Microhierax caerulescens</i>	1	1	0.02	LC
Common Hill Myna	<i>Gracula religiosa</i>	1	1	0.02	LC
Western Hooded Pitta	<i>Pitta sordida</i>	1	1	0.02	LC
Malay Night-heron	<i>Gorsachius melanolophus</i>	1	1	0.02	LC
Owl	<i>Otus sp.</i>	1	1	0.02	LC
Shikra	<i>Accipiter badius</i>	1	1	0.02	LC
Siberian Blue Robin	<i>Larivora cyane</i>	1	1	0.02	LC
	Total	1114	169	26.91	

The pattern of daily activities

The species determination used were species with more than 10 times of activity-independent photos recorded. According to the research results on daytime activities, Red Junglefowl activity was on average at 10:35 hours, Siamese Fireback was on average at 11:30 hours, and Silver Pheasant was on average at 11:46 hours. On the other hand, the Rayleigh test showed a difference in the appearance of irregular cycles throughout the day except for Thick-billed Green-pigeon (*Treron curvirostra*). Moreover, there were no significant differences in activity periods between the Silver Pheasant and Red Junglefowl on the recording photos of both species. Meanwhile, the Mardia-Watson-Wheeler test showed a significant difference in the relationship between Siamese Fireback and Silver Pheasant

and between Siamese Fireback and Red Junglefowl, as shown in Table 2-3.

Effective physical factors

Siamese fireback

With an AIC value of 805.56, the Siamese Fireback appearance equation (detection) was significantly shown with all five environmental factors (elevation, slope, distance to villages, streams, and roads). Natural streams were a significant factor in the presence of the Siamese Fireback when all the factors were considered (Table 4). As shown in Figure 2, the five environmental factors are linked to the Siamese Fireback distribution source.

Table 2. Mean time of the ground-dwelling bird species recorded by camera traps in Khao Yai National Park, Thailand using 115 camera traps to deliver 4139 trap days from October 2017 to March 2020 with the Rayleigh test for the uniformity of a circular distribution of points with $p < 0.05$, the null hypothesis (uniformity) is rejected for only the species that had more than 10 of the number of independent photos recorded

Common name	No. of independent photographs	Mean time (hours)	SD (hours)	Rayleigh test	P
Siamese Fireback	441	11:30	4:36	102.15	<0.01
Red Junglefowl	301	10:35	4:04	95.72	<0.01
Silver Pheasant	76	11:46	3:01	40.63	<0.01
Grey-capped Emerald Dove	43	12:15	3:44	16.48	<0.01
White-crested Laughingthrush	36	10:04	3:10	18.07	<0.01
Great Myna	30	14:36	2:38	18.64	<0.01
Red Turtle-dove	29	12:44	3:08	14.73	<0.01
Red-wattled Lapwing	25	19:48	3:34	10.44	<0.01
Eastern Spotted Dove	22	12:34	3:21	10.12	<0.01
Thick-billed Green-pigeon	18	10:58	5:19	2.58	0.07
Coral-billed Ground-cuckoo	17	9:58	3:56	5.85	<0.01
Green-legged Partridge	11	10:16	4:07	3.42	0.02
Total	1049				

Table 3. Comparison of activity time differences of the three Phasianidae recorded by camera traps in Khao Yai National Park, Thailand from 115 camera trap locations to deliver 4139 trap nights from October 2017 to March 2020 using the Mardia-Watson-Wheeler test

Variable	W	P
Red Junglefowl (n: 299) vs Siamese Fireback (n: 438)	9.480	0.009
Red Junglefowl (n: 299) vs Silver Pheasant (n: 38)	4.815	0.090
Siamese Fireback (n: 438) vs Silver Pheasant (n: 38)	10.042	0.007

Table 4. Equation of environmental factors related to the detection of the Siamese Fireback in Khao Yai National Park, Thailand using camera traps

	Estimate	SE	z	P(> z)	Detection			AIC
					Estimate	SE	P(> z)	
(Intercept)	-0.19	0.16	-1.200	0.231	-1.040	0.142	2.23e-13	805.560
Elevation	0.16	0.15	1.100	0.271				
Slope	0.13	0.13	1.020	0.306				
Village	-0.21	0.15	-1.430	0.151				
River	-0.55	0.17	-3.110	0.001				
Road	0.22	0.13	1.660	0.097				

Red Junglefowl

The standardized appearance of five environmental factors (elevation, slope, distance to villages, streams, and roads) was found to be significantly correlated ($P < 0.01$) with the appearance (detection) of wild birds, with an AIC

of 761.00. However, when each factor was considered, there was no significant effect on the appearance of the Red Junglefowl (Table 5). The distribution sources of wild fowls related to the five environmental factors are shown in Figure 3.

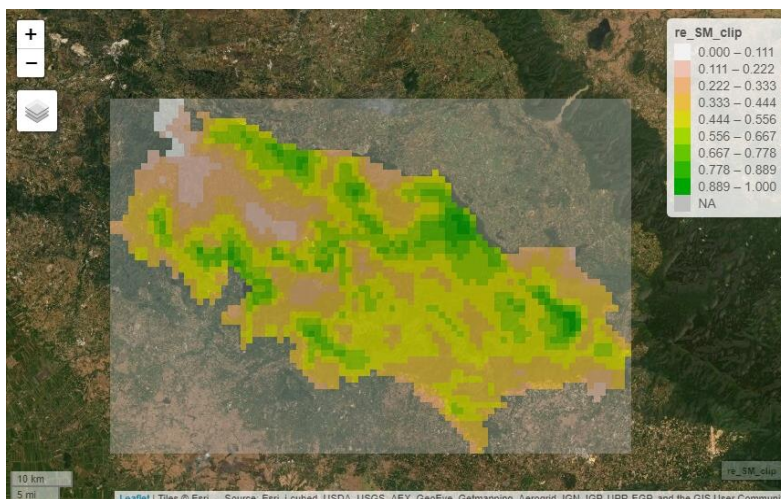


Figure 2. Map showing the probability of detecting Siamese Fireback in Khao Yai National Park, Thailand based on the camera trap data. White represents the lowest probability of detection; green represents the highest probability. Also, 1 means 100% probability of detection, and 0 means the probability of detection is zero

Table 5. Equation of environmental factors related to detecting Red Junglefowl in Khao Yai National Park, Thailand using camera traps

	Estimate	SE	z	P(> z)	Detection			AIC
					Estimate	SE	P(> z)	
(Intercept)	0.09	0.18	0.501	0.617	-1.75	0.169	4.63e-25	761.00
Elevation	0.05	0.15	0.362	0.717				
Slope	-0.07	0.14	-0.537	0.592				
Village	-0.02	0.14	-0.142	0.887				
River	-0.27	0.16	-1.636	0.102				
Road	-0.12	0.16	-0.764	0.445				

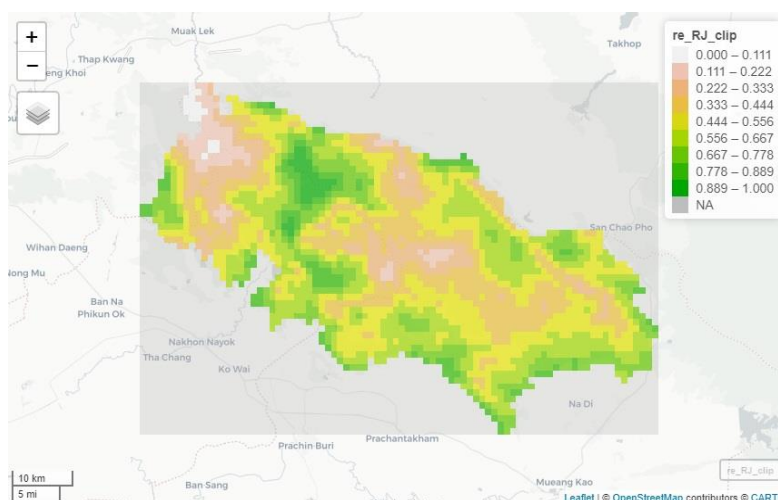


Figure 3. Map showing the probability of detection for Red Junglefowl in Khao Yai National Park, Thailand based on the camera trap data. White represents the lowest probability of detection; green represents the highest probability. Also, 1 means 100% probability of detection, and 0 means the probability of detection is zero

Silver Pheasant

The standardized appearance of five environmental factors (elevation, slope, distance to villages, streams, and roads) were found to be significantly correlated ($P=4.63e-25$) with the appearance (detection) of wild birds, with an AIC of 761.00. However, there was no significant effect on the appearance of the Silver Pheasant (Table 6). The distribution sources of wild fowls related to the five environmental factors are shown in Figure 4.

Discussion

Camera traps deployed in KYNP recorded 36 species of ground-dwelling birds with an overall relative abundance of 26.87%. The top three species found were Siamese Fireback, Red Junglefowl, and Silver Pheasant, respectively. The number of terrestrial bird species recorded in KYNP was more than what was found from the study in Huai Kha Khaeng Wildlife Sanctuary, conducted from November 2017 to March 2019, a total of 1 year and 5 months to deliver 6596 trap days (n: 1314). This study recorded 23 species of ground-dwelling birds from 8 families and 7 orders. The top three recorded were Green Peafowl (*Pavo muticus*) (8.67%), Red Junglefowl (9.07%),

and Red-wattled Lapwing (*Vanellus indicus*) (1.12%), in descending order of relative abundance (Charaspet et al. 2021). The most common species found in Khao Yai National Park from this study were the Siamese Fireback (n: 441), Red Junglefowl (n: 301), and Silver Pheasant, with abundance indices of 10.65%, 7.27%, and 1.84%, respectively. The total wild bird abundance index was 26.85%. On the other hand, from January 2017 to March 2018, a study was conducted in the Khao Ang Rue Nai Wildlife Sanctuary using camera traps in 58 locations, with a total of 4463 trap days and found 2 species of pheasants from 1 family and 1 genus, including Red Junglefowl (n: 1125) and Siamese Fireback (n: 5614). These species had an overall abundance index of 171.17%, 25.21% for Red Junglefowl, and 125.79% for Siamese Fireback (Sukmasuang et al. 2020). Consequently, the conservation areas in the country's east are important for maintaining the Siamese Fireback and Silver Pheasant populations in the wild. However, considering the diversity of species found, KYNP is the most important conservation area for terrestrial birds.

Table 6. Equation of environmental factors related to detecting the Silver Pheasant in Khao Yai National Park, Thailand using camera traps

	Estimate	SE	z	P(> z)	Detection			AIC
					Estimate	SE	P(> z)	
(Intercept)	-55.97	75.75	-0.739	0.460	-2.54	0.349	3.97e-13	98.08
Elevation	28.92	37.19	0.778	0.437				
Slope	-13.85	14.78	-0.937	0.349				
Village	-3.65	3.51	-1.040	0.298				
River	1.93	9.72	0.198	0.843				
Road	6.43	5.95	1.079	0.281				

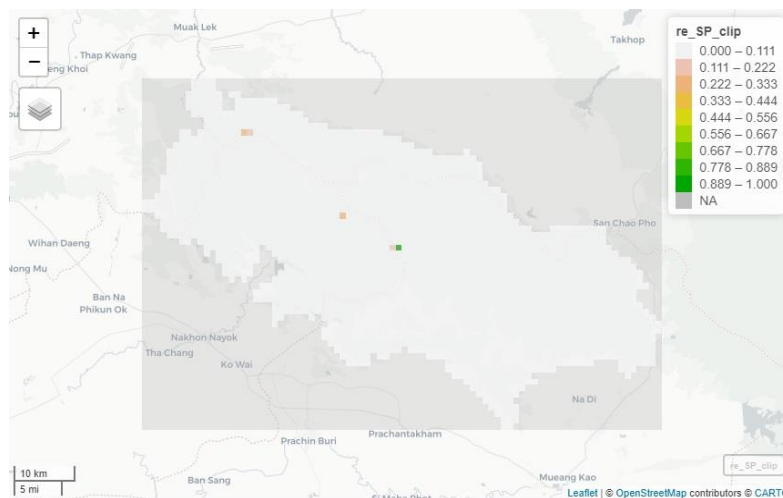


Figure 4. Map showing the probability of detection for Silver Pheasant in Khao Yai National Park, Thailand based on the camera trap data. White represents the lowest probability of detection; green represents the highest probability. Also, 1 means 100% probability of detection, and 0 means the probability of detection is zero

Like most other wild birds, the pheasant family was found to be active during the day when the activity period of terrestrial birds was observed. However, the three species of pheasants were observed to have different foraging patterns because they were large birds that roamed the area, avoiding each other both temporally and spatially. Storch (2013) reported that the disturbance caused by human outdoor recreation and tourism activities is increasingly seen as a threat to wildlife, particularly in areas where threatened wildlife populations overlap with highly frequented tourist locations. Managers of Khao Yai National Park are challenged with reducing the impacts of human disturbance on wildlife, especially for the pheasant family and terrestrial birds (Jameel et al. 2022), which are most active during the day, the same as a human activity. Khoewsree et al. (2022) reported that humans, comprising tourists and some groups of villagers who go into the area illegally, also significantly coexisted temporally and spatially with wildlife in KYNP.

This camera trap study recorded a total of 36 bird species in KYNP from 4139 trap days. In contrast, in the other two conservation areas on the Huai Kha Khaeng Wildlife Sanctuary and Khao Ang Rue Nai Wildlife Sanctuary, 24 species from 6596 trap days and 11 species from 4463 trap days were reported, respectively. Therefore, while compiling all 3 areas, a total of 50 species of terrestrial birds were found living on the forest floors. This data indicates that the abundance of terrestrial birds of Khao Yai National Park from all three areas is the most diverse, as detailed in Table 7.

This study found 36 land-dwelling bird species in KYNP, but only 4 pheasant species were true terrestrial birds. However, we selected only 3 pheasant species because of the large number found for analysis. The results of long-term studies in the other two conservation areas on Huai Kha Khaeng Wildlife Sanctuary, with 6596 trap days, found 24 species of land-dwelling bird species (Charaspet et al. 2021) and Khao Ang Rue Nai Wildlife Sanctuary, with 4463 trap nights, found 11 species of the land-dwelling bird species (Sukmasuang et al. 2020), including 3 areas with 50 land-dwelling bird species living on the forest floor, confirmed to indicate the abundance of land-dwelling bird species of Khao Yai National Park is the most diverse as detailed in table 7. Comparing to the study by Zou et al. (2019), who studied the abundance of ground birds in the Nanling Mountains of the Republic of China, reported a total of 44 bird species and 26 mammal species identified using data from 24 camera traps and 6786 photos. There were three species of pheasants analyzed in this study, including Cabot's Tragopan (*Tragopan caboti*), Silver Pheasant (*Lophura nycthemera*), and White Necklaced Partridge (*Arborophila gingica*). Shi et al. (2017) reported 59 bird species (belonging to 5 orders and 18 families) with a total detection number of 655, including 4 newly recorded species in Wolong National Nature Reserve, Sichuan Province, China. Pheasants (Galliformes) had the highest detection number of all bird groups and accounted for 56.76% of all bird detections in that reserve.

According to the study results, local streams had the greatest effect on the appearance of the Siamese Fireback, following Shah and Shama (2020), who researched species diversity and factors affecting the abundance of birds in Dullu, Nepal, by point count method. Their research found 98 bird species and statistically analyzed factors affecting bird abundance by logistic regression. It was found that as the distance to the nearest water source increased, the likelihood of a bird showing up decreased. Therefore, managing the creek area is important for pheasants and other wildlife species nearest to the water source. While Girma et al. (2017), who studied around Wondo Genet Forest, south-central Ethiopia, reported that slope was a good predictor for bird species abundance in the dry season. In contrast, the wet season accounted for more abundance of the altitude and average vegetation height.

Additionally, this study in KYNP recorded the presence of Coral-billed Ground-Cuckoo, a vulnerable species according to the IUCN red list (BirdLife International 2018). However, analysis of the variables impacting these bird species was not practicable due to the low likelihood of encountering them. Furthermore, in a camera-trap case study of the assemblage structure and dynamics of terrestrial birds in the southwest Amazon by Roncal et al. (2019), where 16 bird species were found. They hypothesized that catching low-volume birds is an obstacle to completing spatial data analysis. Therefore, long-term camera trap studies are beneficial for monitoring the local area's conservation of endangered bird species. This study confirmed that using camera traps focused at ground level can be a useful device in avian conservation efforts because it is an effective technique for measuring bird presence, activity, and behavior in altered habitats (Puffer et al. 2021).

The Rayleigh test for the uniformity of a circular distribution of points showed that the pheasant species had active time during the day. The results showed a difference in the appearance of irregular cycles throughout the day, which means intense interaction with tourist activities in the area. These underscore the need for further appropriate management of creek areas that are important habitats for this wildlife.

This study also used 115 camera trap sites, covering more than all year round, considered suitable for the study (Trolliet et al. 2014; Kays et al. 2020). While Kays et al. (2020) recommended only 25-35 camera sites for precise estimates of species richness, generating abundance indices, and getting quick insight into population size (Tanwar et al. 2022). However, the location used to install the camera traps may affect the study by the influence of environmental factors on the presence of ground-dwelling birds and pheasant species in the area, while it has not yet been distributed to cover the entire area. Moreover, installing camera traps near human activity areas in the national park may also affect the presence of birds on the forest floor (Storch 2013; Sandbrook et al. 2018). Therefore, future studies need to systematically consider the installation location of the camera trap and distribute camera installations to reduce errors.

Table 7. Diversity of bird species that can record images from a camera trap on the ground in Khao Yai National Park (KYNP) compared with Huai Kha Khaeng Wildlife Sanctuary (HKKWS), Uthai Thani Province and Khao Ang Rue Nai Wildlife Sanctuary (KARN), Chachoengsao Province, Thailand

	KYNP ¹ (4139 TD)		HKKWS ² (6596 TD)		KARN ² (4463 TD)	
	No. of independent photographs	RAI	No. of independent photographs	RAI	No. of independent photographs	RAI
Siamese Fireback	441	10.65	1	0.02	5614	125.79
Red Junglefowl	301	7.27	598	9.07	1125	25.21
Silver Pheasant	76	1.84	0	0.00	0	0.00
Grey-capped Emerald Dove	43	1.04	7	0.11	90	2.02
White-crested Laughing thrush	36	0.87	0	0.00	0	0.00
Great Myna	30	0.72	0	0.00	0	0.00
Red Collared Dove	29	0.7	0	0.00	0	0.00
Red-wattled Lapwing	25	0.6	74	1.12	690	15.46
Eastern Spotted Dove	22	0.53	7	0.11	0	0.00
Thick-billed Green Pigeon	18	0.43	0	0.00	0	0.00
Coral-billed Ground-Cuckoo	17	0.41	0	0.00	50	1.12
Scaly-breasted Partridge	11	0.27	0	0.00	0	0.00
Chinese Pond Heron	9	0.22	3	0.05	0	0.00
Green-backed Heron	7	0.17	2	0.03	0	0.00
Malayan Night Heron	7	0.17	0	0.00	12	0.27
Green-billed Malkoha	4	0.1	0	0.00	0	0.00
White-breasted Waterhen	4	0.1	0	0.00	0	0.00
Barred Cuckoo Dove	3	0.07	0	0.00	0	0.00
Blue Whistling Thrush	3	0.07	0	0.00	0	0.00
Crested Serpent Eagle	3	0.07	6	0.09	0	0.00
Orange-headed Thrush	3	0.07	0	0.00	0	0.00
Red-headed Trogon	3	0.07	0	0.00	0	0.00
Black-headed Woodpecker	2	0.05	1	0.02	0	0.00
Blue Pitta	2	0.05	7	0.11	30	0.67
Common Green Magpie	2	0.05	0	0.00	0	0.00
Greater Racket-tailed Drongo	2	0.05	0	0.00	0	0.00
Oriental pied hornbill	2	0.05	10	0.15	0	0.00
Asian Fairy Bluebird	1	0.02	0	0.00	0	0.00
Black-naped Oriole	1	0.02	0	0.00	0	0.00
Collared Falconet	1	0.02	0	0.00	0	0.00
Common Hill Myna	1	0.02	0	0.00	0	0.00
Western Hooded Pitta	1	0.02	0	0.00	0	0.00
Owl	1	0.02	0	0.00	0	0.00
Shikra	1	0.02	0	0.00	0	0.00
Siberian Blue Robin	1	0.02	0	0.00	0	0.00
Siberian Stonechat	1	0.02	0	0.00	0	0.00
Blue Rock-thrush	0	0	1	0.02	0	0.00
Brown Fish Owl	0	0	7	0.11	0	0.00
Green Peafowl	0	0	572	8.67	0	0.00
Greater coucal	0	0	0	0.00	3	0.07
Grey Peacock Pheasant	0	0	1	0.02	0	0.00
Grey-headed Woodpecker	0	0	1	0.02	0	0.00
Indian Roller	0	0	1	0.02	0	0.00
Kalij pheasant	0	0	9	0.14	0	0.00
Oriental Magpie Robin	0	0	1	0.02	0	0.00
Pied Fantail	0	0	0	0.00	5	0.11
Peaceful Dove	0	0	1	0.02	0	0.00
White-throated Bulbul	0	0	1	0.02	0	0.00
White-throated Kingfisher	0	0	1	0.02	0	0.00
White-rumped Shamar	0	0	2	0.03	0	0.00
Woolly-necked Stork	0	0	0	0.00	20	0.45
	1114	26.87	1314	19.99	7639	171.17

Note: 1. This study; 2. Charaspet et al. (2021); 3. Sukmasuang et al. (2020); TD: trap days; RAI: relative abundance index

In conclusion, this camera traps study on Siamese Fireback had an abundance index of 10.65%, Red Junglefowl had an abundance index of 7.27%, and Silver Pheasant had an abundance index of 1.84%. Other results found that the terrestrial bird abundance index accounted for 26.87% of the total fauna. Red Junglefowl was active on average at 10:35 hours, Siamese Fireback was on average at 11:30 hours, and Silver Pheasant was on average at 11:46 hours. However, the Mardia-Watson-Wheeler test showed a significant difference in the relationship between Siamese Fireback and Silver Pheasant and between Siamese Fireback and Red Junglefowl. There were also no significant differences in activity times between the Silver Pheasant and Red Junglefowl.

Furthermore, the results showed that streams significantly influenced Siamese Fireback appearance in Khao Yai National Park. Therefore, it is noted that birds that live on the forest floor are active throughout the day, and the flat area along a creek in the forest is an important area for the pheasant to be found. Those preferred locations are considered representatives of wild birds that live on the ground in the area that should be protected and reducing the impact of tourism such as walking tours along the nature trails in the area and follow up for further study. Therefore, managing the area around the streams is important, particularly in preventing and reducing disturbances along streams and creeks to preserve the bird, especially Siamese Fireback and other wildlife. However, Zhang et al. (2018) reported that combined mist netting and camera trapping would be complementary methods in surveying bird diversity on a wide range of body size areas, leading to further study in combining various standard methods available. The results of this study confirmed the diversity of land-dwelling birds in KYNP, which is outstanding compared to HKKWS which is part of Thailand's natural world heritage sites, and KARN, a conservation forest in the eastern part of the country.

ACKNOWLEDGEMENTS

This research is funded by Kasetsart University through the Graduate School Fellowship Program. We would like to thank the Director of the National Parks Wildlife and Plant Conservation Department for permitting research in Khao Yai National Park. We also would like to express our recognition to the Unit for Capital Development for Human Resource Development, Capital for Higher Education Development, Research, and Innovation Creation, Office of National Higher Education Science Research and Innovation Policy Council (NXPO) under the research project on the ecology of important wildlife in Khao Yai National Park. The authors would also like to thank the Forest Biology Department, Faculty of Forestry, Kasetsart University, for supporting this research.

REFERENCES

- Avibase-The World Bird Database. 2022. Khao Yai National Park. www.avibase.bscceoc.org/checklist.jsp?region=TH0004&list=howardmoore.
- Bird Conservation Society of Thailand. 2021. Khao Yai Bird Census Reports. www.bcst.or.th/essential_grid_category/khao-yai/.
- BirdLife International. 2016a. *Lophura diardi*. The IUCN Red List of Threatened Species 2016: e.T22679274A92808547. DOI: 10.2305/IUCN.UK.2016-3.RLTS.T22679274A92808547.en.
- BirdLife International. 2016b. *Lophura nycthemera*. The IUCN Red List of Threatened Species 2016: e. T22679220A92808107 DOI: 10.2305/IUCN.UK.2016-3.RLTS.T22679220A92808107.en.
- BirdLife International. 2018. *Carpococcyx renaldi*. The IUCN Red List of Threatened Species 2018: e.T22684138A132439644. DOI: 10.2305/IUCN.UK.2018-2.RLTS.T22684138A132439644.en.
- Bivand R. 2022. Package 'rgdal', Bindings for the 'Geospatial' Data Abstraction Library. www.rgdal.r-forge.r-project.org.
- Brockelman WY, Nathalang A, Maxwell JF. 2017. Mo Singto Forest Dynamics Plot: Flora and Ecology. National Science and Technology Development Agency, and Department of National Parks, Wildlife and Plant Conservation, Bangkok. www.waa.inter.nstda.or.th/stks/pub/2019/20190722-mo-singto-forest-dynamics-plot.pdf.
- Burton AC, Neilson E, Moreira D, Ladle A, Steenweg R., Fisher JT. 2015. Wildlife camera trapping: A review and recommendations for linking surveys to ecological processes. *J Appl Ecol* 52: 675-685. DOI: 10.1111/1365-2664.12432.
- Charaspet K, Sukmasuang R, Khoewsree N, Pla-Ard M, Paansri P, Keawdee B, Chanachai Y, Bhumpakphan N. 2021. Spatial and temporal overlaps of top predators: Dhole, tiger and leopard, and their potential prey in Huai Kha Khaeng Wildlife Sanctuary, Thailand. *Biodiversitas* 22 (2): 580-592. DOI: 10.13057/biodiv/d220209.
- Chiatante G, Meriggi A. 2022. Habitat selection and density of common pheasant (*Phasianus colchicus*) in Northern Italy: Effects of land use cover and landscape configuration. *Eur J Wildl Res* 68 (26): 1-11. DOI: 10.1007/s10344-022-01575-w.
- Dawruengt T, Ngoprasert D, Gale GA, Browne S, Savini T. 2017. Effect of landscape variables on the long-term decline of Great Argus in the rainforest of Southern Thailand. *Bird Conserv Intl* 27 (2): 282-293. DOI: 10.1017/S0959270916000277.
- del Hoyo J, Elliott A, Sargatal J. 1994. Handbook of the Birds of the World vol. 2: New World Vultures to Guinea-fowl. Lynx Edicions, Barcelona, Spain
- Fennell M, Beirne C, Burton AC. 2022. Use of object detection in camera trap image identification: Assessing a method to rapidly and accurately classify human and animal detections for research and application in recreation ecology. *Glob Ecol Conserv* 35: e02104. DOI: 10.1016/j.gecco.2022.e02104.
- Girma Z, Mamo Y, Mengesha G, Verma A, Asfaw T. 2017. Seasonal abundance and habitat use of bird species in and around Wondo Genet Forest, south-central Ethiopia. *Ecol Evol* 7: 3397-3405. DOI: 10.1002/ece3.2926.
- IUCN. 2022. The IUCN Red List of Threatened Species. Version 2022-2. www.iucnredlist.org.
- Jameel MA, Nadeem MS, Aslam S, Ullah W, Ahmad D, Awan MN, Masroor W, Mahmood T, Ullah R, Anjum MZ. 2022. Impact of human imposed pressure on pheasants of Western Himalayas, Pakistan: Implication for monitoring and conservation. *Diversity* 14 (752): 1-15. DOI: 10.3390/d14090752.
- Kays R, Arbogast BS, Baker-Whallon M, Beirne C, Boone HM, Bowler M, Burneo SF, Cove MV, Ding P, Espinosa S, Gonçalves ALS, Hansen CP, Jansen PA, Kolowski JM, Knowles TW, Lima MGM, Millspaugh J, McShea WJ, Pacifici K, Parsons AW, Pease BS, Rovero F, Santos F, Schuttler SG, Sheil D, Si X, Snider M, Spironello WR. 2020. An empirical evaluation of camera trap study design: How many, how long and when? *Methods Ecol Evol* 11: 700-713. DOI: 10.1111/2041-210X.13370.
- KhaoYai National Park (KYNP). 2022. About Khao Yai National Park. www.khaoyainationalpark.com/en/about/climate.
- Khoewsree N, Pla-ard M, Sukmasuang R, Paansri P, Chanachai Y, Kaewdee B, Phengthong P. 2022. Spatio-temporal analysis of dholes (*Cuon alpinus*) in Khao Yai National Park, Thailand. *Biodiversitas* 23 (5): 2668-2678. DOI: 10.13057/biodiv/d230551.

- Kolowski JM, Forrester TD. 2017. Camera trap placement and the potential for bias due to trails and other features. *Plos One* 12: e0186679. DOI: 10.1371/journal.pone.0186679.
- Kovach Computing Services. 2022. ORIANA. www.kovcomp.co.uk/oriana/oribroc.html.
- Lamelas-Lopez L, Pardavila X, Amorim IR, Borges PAV. 2020. Wildlife inventory from camera-trapping surveys in the Azores (Pico and Terceira islands). *Biodivers Data J* 8: e47865. DOI: 10.3897/BDJ.8.e47865.
- Lu S, Liu Z, Tian S, Song K, Hu Q, Li J, Xu J. 2022. Sex-specific movement responses of Reeves's pheasant to human disturbance: Importance of body characteristics and reproductive behavior. *Animals* 12: 1619. DOI: 10.3390/ani12131619.
- Mardia KV. 1972. A multi-sample uniform scores test on a circle and its parametric competitor. *J R Stat Soc B: Stat Methodol* 34: 102-113. DOI: 10.1111/j.2517-6161.1972.tb00891.x.
- McGowan P, Owens L, Grainger M. 2012. Galliformes science and species extinctions: What we know and what we need to know. *Anim Biodivers Conserv* 35 (2): 321-331. DOI: 10.32800/abc.2012.35.0321.
- Meek PD, Ballard G, Fleming P. 2012. An Introduction to Camera Trapping for Wildlife Surveys in Australia. PestSmart Toolkit publication, Invasive Animals Cooperative Research Centre, Canberra, Australia. www.invasives.com.au/.
- Moore BR. 1980. A modification of the Rayleigh test for vector data. *Biometrika* 67 (1): 175-180. DOI: 10.2307/2335330.
- Puffer SR, Tennant LA, Lovich JE, Agha M, Smith AL, Delaney DK, Arundel TR, Leo J, Fleckenstein LJ, Briggs J, Walde AD, Ennen JR. 2021. Birds not in flight: using camera traps to observe ground use of birds at a wind-energy facility. *Wildl Res* 49 (3): 283-294. DOI: 10.1071/WR21071.
- Rcore Team. 2015. RStudio: Integrated Development Environment for R, Boston, MA. www.rstudio.com/.
- Romero-Calderón AG, Botello F, Sánchez-Hernández J, López-Villegas G, Vázquez-Camacho C, Sánchez-Cordero V. 2021. Species diversity of mammals and birds using camera-traps in a cloud forest in a Mexican Hotspot. *Southwest Nat* 65 (1): 28-33. DOI: 10.1894/0038-4909-65.1.4.
- Roncal CM, Middendorf E, Forsyth A, Cáceres A, Blake JG, Zambrano AMA, Broadbent EN. 2019. Assemblage structure and dynamics of terrestrial birds in the southwest Amazon: a camera-trap case study. *J Field Ornithol* 90 (3): 1-12. DOI: 10.1111/jof.12299.
- Round PD, Gale GA. 2008. Changes in the status of *Lophura* pheasants in Khao Yai National Park, Thailand: A response to warming climate? *Biotropica* 40 (2): 225-230. DOI: 10.1111/j.1744-7429.2007.00363.x.
- Rovero F, Tobler M, Sanderson J. 2010. Camera trapping for inventorying terrestrial vertebrates. In: Eymann J, Christoph H, Carlos MJ, Yves S, Didier (eds). *Manual on Field Recording Techniques and Protocols for All Taxa Biodiversity Inventories*. The Belgian National Focal Point to the Global Taxonomy Initiative. www.researchgate.net/publication/229057405.
- Sandbrook C, Luque-Lora R, Adams WM. 2018. Human bycatch: Conservation surveillance and the social implications of camera traps. *Conserv Soc* 16 (4): 493-504.
- Shah SB, Shama HP. 2020. Bird diversity and factors affecting bird abundance at Dullu Municipality, Dailekh, Nepal. *Biodiversitas* 23 (3): 1535-1545. DOI: 10.13057/biodiv/d230343.
- Shi X, Hu Q, Li J, Tang Z, Yang J, Li W, Shen X, Li S. 2017. Camera-trapping surveys of the mammal and bird diversity in Wolong National Nature Reserve, Sichuan Province. *Biodivers Sci* 25 (10): 1131-1136. DOI: 10.17520/biods.2017193.
- Spiller KJ, King DI, Bolsinger J. 2022. Foraging and roosting habitat of Eastern Whip-poor-wills in the northeastern United States. *J Field Ornithol* 93 (1): 6. DOI: 10.5751/JFO-00057-930106.
- Storch I. 2013. Human disturbance of grouse-why and when?. *Wildl Biol* 19: 390-403. DOI: 10.2981/13-006.
- Sukmasuang R, Charaspet K, Reontik J, Pla-ard M. 2020. Temporal overlap of carnivorous mammal community and their prey in Khao Ang Rue Nai Wildlife sanctuary, Chachoengsao Province, Thailand. *Biodiversitas* 21 (3): 922-932. DOI: 10.13057/biodiv/d210310.
- Suwanrat S, Ngoprasert D, Sukumal N, Suwanwaree P. 2014. Reproductive ecology and nest-site selection of Siamese Fireback in lowland forest. *Raffles Bull Zool* 62: 581-590.
- Suwanrat S, Ngoprasert D, Sukumal N, Suwanwaree P. 2019. Home range, habitat use and roost-site selection by lowland female Siamese fireback *Lophura diardi* in northeastern Thailand. *Raffles Bull Zool* 67: 498-509. DOI: 10.26107/RBZ-2019-0039.
- Suwanrat S, Ngoprasert D, Sutherland C, Suwanwaree P, Savini T. 2015. Estimating density of secretive terrestrial birds (Siamese Fireback) in pristine and degraded forest using camera traps and distance sampling. *Glob Ecol Conserv* 3: 596-606. DOI: 10.1016/j.gecco.2015.01.010.
- Sweitzer RA, Furnas BJ. 2016. Data from camera surveys identifying co-occurrence and occupancy linkages between fishers (*Pekania pennanti*), rodent prey, mesocarnivores, and larger predators in mixed-conifer forests. *Data Brief* 6: 783-792. DOI: 10.1016/j.dib.2016.01.032.
- Tanwar KS, Sadhu A, Jhala YV. 2021. Camera trap placement for evaluating species richness, abundance, and activity Scientific Reports 11: 23050. DOI: 10.1038/s41598-021-02459-w.
- Trolliet F, Huynen MC, Vermeulen C, Hambuckers A. 2014. Use of camera traps for wildlife studies. A review. *Biotechnol Agron Soc Environ* 18 (3): 446-454.
- UNESCO. 2022. Dong Phrayayen-Khao Yai Forest Complex. www.whc.unesco.org/en/list/590/.
- Voskamp A, Butchart SHM, Baker DJ, Wilsey CB, Willis SG. 2021. Site-based conservation of terrestrial bird species in the Caribbean and Central and South America under climate change. *Front Ecol Evol* 9: 1-13. DOI: 10.3389/fevo.2021.625432.
- Zaragozi B, Belda A, Giménez P, Navarro JT, Bonet A. 2015. Advances in camera trap data management tools: Towards collaborative development and integration with GIS. *Ecol Inform* 30: 6-11. DOI: 10.1016/j.ecoinf.2015.08.001.
- Zhang Q, Gong Y, Song X, Wang X, Yang C, Shu Z, Zou F. 2018. Comparing the effectiveness of camera trapping to traditional methods for biodiversity surveys of forest birds. *Biodivers Sci* 26 (3): 229-237. DOI: 10.17520/biods.2017275.
- Zou F, Zhang Q, Zhang M, Lee M, Wang X, Gong Y, Yang C. 2019. Temporal patterns of three sympatric pheasant species in the Nanling Mountains: N-mixture modeling applied to detect abundance. *Avian Res* 10 (42): 1-10. DOI: 10.1186/s40657-019-0181-6.