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Abundance and factors affecting the appearance of Siamese fireback and Red junglefowl in the lowland forest of Thailand

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Abstract. *Sukmasuang R, Chaisomboon P, Paansri P, Trisurat Y, Kanka P, Khiowsree N, Kaewdee B, Siripattanukul K, Chankhao A. 2023. Abundance and factors affecting the appearance of Siamese fireback and Red junglefowl in the lowland forest of Thailand. Biodiversitas 24: 5718-5730.* Pheasants are indeed important species in various ecosystems. Studies of the abundance and factors influencing the presence of pheasant species have been conducted in the lowland areas of the Khao Ang Rue Nai Wildlife Sanctuary, Thailand, using camera trapping and species distribution models. A total of 23 factors, 2 bio-physiological, 2 geophysical, and 19 climate factors, were used to analyze in this study. The study revealed the presence of only two species of pheasants in the surveyed area, namely the Siamese fireback (*Lophura diardi*) and the Red junglefowl (*Gallus gallus*). The encounter rates were calculated as 1.74 photos per 100 trap nights for the Siamese fireback and 2.28 photos per 100 trap nights for the Red junglefowl. The factors influencing the presence of both Siamese fireback and the Red junglefowl were climate factors followed by biophysical and topography factors, respectively. The study's results highlight the importance of climate factors to the appearance of the pheasants, even in lowland areas. The results showed that the both pheasants responded more positively to the secondary forests, the grassland followed by dry dipterocarp forest than to other forest types. Therefore, conservation efforts to protect the areas inside are crucial for conserving the species' population.

Keywords: Dry evergreen forest, Khao Ang Rue Nai (KARN) Wildlife Sanctuary, pheasant species, species distribution model

INTRODUCTION

The pheasant family (Family Phasianidae) comprises a group of ground-dwelling forest birds that primarily forage on the ground (Wang et al. 2020; Kanka et al. 2023). These birds consume a variety of plant matter, especially seeds (Furqan and Ali 2022), as well as small ground-dwelling animals (Hussain and Sultana 2013; Fan et al. 2020), which may include reptiles, rodents (Mason et al. 2020), and insects. This encompasses crawling animals, invertebrate species, and ground-dwelling insects. Thus, these forest-dwelling birds play a crucial role in environmental systems, particularly in the dispersal of plant seeds. They contribute to soil enrichment and fertility by aiding seed distribution (Mason et al. 2020). Furthermore, they serve as prey for various carnivorous forest animals, thus participating in energy transfer within the ecosystem. Pheasants can also act as indicator species that reflect the health of the natural environment (Mekonen 2017), including changes in the ecosystem. Shifts in pheasant populations and behaviors can indicate changes in habitat quality, biodiversity, and environmental conditions (Cao and Shi 2022). Therefore, monitoring pheasant populations can provide essential information about the state of the natural environment and the impact of environmental changes. Indeed, pheasants remain popular game birds and are often cherished for their beauty and aesthetic appeal (Madden 2021). They hold a significant place in art, culture, and traditions across various societies worldwide (Fuller and Garson 2000; Penchart et al. 2012). In general, birds in the pheasant family are known to inhabit a variety of forested habitats, including dry lowland forests, moist lowland forests, and montane forests, with altitudes of up to approximately 1,150 meters above sea level (BirdLife International 2016; DNPWC and DFSC 2018).

The Siamese fireback (*Lophura diardi*) (SFB) is found in several protected forest areas in Thailand (Suwanrat et al. 2014), with an estimated population of around 5,000 individuals based on sightings across all distribution ranges, ranging from 20,000 to 49,999 individuals. In Cambodia, there are reports of approximately 2,000 individuals (BirdLife International 2016). A study conducted by Suwanrat et al. (2019) focused on habitat size for the 8 females Siamese fireback, using radio-tracked from 8 groups throughout 2 to 27 months. The results indicated that the mean annual home range size for the SFB was 31.4 hectares using both 95% minimum convex polygons and characteristic hull polygons based on radio tracking data. During different breeding seasons, the SFB's territory sizes vary, with the largest territory size being outside the breeding season (26.3 hectares), followed by the breeding season (21.7 hectares), and the period when they rear their chicks (9.7 hectares) (Suwanrat et al. 2014). However, Vy et al. (2018) reported that the SFB predominantly utilize flat terrain for their habitat, especially in lowland areas. They avoid nesting in sloped areas (Dwight et al. 2020).

The current climate-based potential geographic distribution of Red junglefowl (*Gallus gallus*) (RJF) revealed that their range was almost entirely restricted to upper southern and central Thailand (Singchat et al. 2022). Highly suitable areas were also located outside protected areas. Future projections for 2050 and 2070 showed the RJF distribution expanding with increased habitat suitability due to the combined effects of future climate, forest canopy, and elevation. The results for both 2050 and 2070 showed a range expansion with high suitability (Singchat et al. 2022). In the area of Khao Ang Rue Nai Wildlife Sanctuary (KARN), located in the crucial lowland region of eastern Thailand, a diverse range of factors can influence the presence of two significant pheasant species: the SFB and the RJF. Understanding their ecological relationships, particularly in a shared ecosystem, is vital for implementing conservation strategies tailored to each species' needs. The distribution of these birds is closely related to climatic changes (Chhetri et al. 2021), highlighting the intricate balance between these species and their environment. The study investigated the natural occurrence concerning environmental factors, encompassing lowland topography, forest types, and climatic conditions. The research employs the Maximum Entropy (MaxEnt) model (Phillips et al. 2017) to facilitate management strategies aimed at conserving the pheasant populations in the area, ensuring their sustained benefits while maintaining the ecological balance indefinitely.

MATERIALS AND METHODS

Study area

The Khao Ang Rue Nai Wildlife Sanctuary (KARN) is situated between the latitude lines 13°00'00" to 13°30'00" North and the longitude lines 101°35'00" to 102°05'00" East. It was established as a protected wildlife area in October 1977. The sanctuary is located primarily within the Chachoengsao Province but spans Chon Buri, Rayong, Chanthaburi, Prachin Buri, and Chachoengsao Provinces, Thailand. Subsequently, there has been an expansion of the sanctuary's area. The total area of the KARN is 1,064 square kilometers (Department of National Parks, Wildlife and Plant Conservation (DNP) 2018) (Figure 1). Most of the upper and central areas are corrugated plains. There is a moderate slope. The area's height above mean sea level ranges from 30-802 meters. The highest peak is in the southeastern part of the area (DNP 2018).

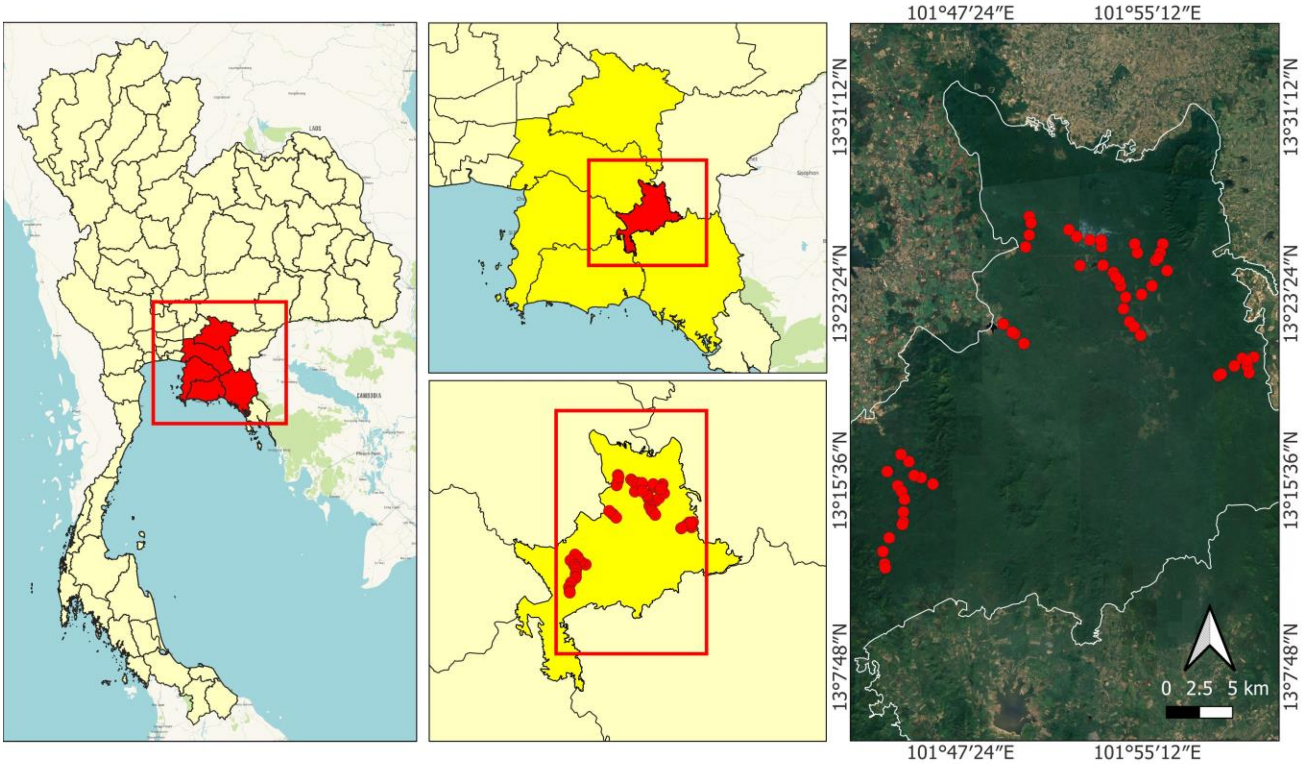


Figure 1. The location and position of the camera traps (red dots) in the lowland area of the KARN, Thailand

The forest vegetation within the area is a plant community that thrives on both flat and lowland terrain, forming the largest expanse of lowland in the eastern part of the Southern Indochina region. The structure of this plant community differs from those in other regions due to environmental factors in the transitional zone between the Sino-Himalayan and Indo-Malayan biogeographic regions. As a result, this area showcases a unique mix of evergreen and deciduous plant communities coexisting, leading to a high level of biodiversity that covers approximately 90% of the total area (DNP 2018). Sukmasuang et al. (2020) and Ruengtik et al. (2019) reported 63 species of mammals from 9 orders, 25 families, and 50 genera; 75 species of reptiles across 3 orders, 17 families, and 50 genera; 36 species of amphibians from 2 orders, 7 families, and 13 genera, and at least 254 documented bird species spanning 16 orders, 54 families, and 165 genera found in the area.

Data collection

In the geographical map with a scale of 1:50,000, each grid cell covers an area of 1 square kilometer. For the deployment of camera traps, one camera trap set was installed per grid cell (Su et al. 2022). The camera trap positions in each grid cell were spaced more than 500 meters apart to ensure independence in capturing images (Selvan et al. 2013). This approach minimizes the likelihood of capturing multiple images of the same individual by multiple cameras.

The selection of camera trap positions was determined based on suitability within each specific habitat. Detailed observations consider plant communities, roads, patrol paths, perennial water bodies, natural depressions, ponds, and forest ranger units. The cameras were mounted at a height of less than 30 centimeters from the ground to ensure efficiency in capturing images of small-sized animals (Williams et al. 2018). They were positioned at a distance of 3-4 meters from the target area where the animals were expected to passing by, following the suitability of the terrain (Game and Wildlife Conservation Trust 2023). The camera traps were set to capture images when triggered by motion detected by the sensor. Each triggering event captures 3 images spaced 10 seconds apart, which continues throughout a 24-hour (Palencia et al. 2021). The camera traps were deployed continuously for 60 days in each location (Kays et al. 2020). After 60 days, the camera traps were relocated to new positions within the same system. The new positions were recorded using a Geographic Positioning System (GPS) device. The installation of camera traps take place between March 2020 and February 2021. The captured images were stored on data cards and transferred to a computer for further analysis. The images were then classified using the image classification software Camera Trap Manager (Zaragozí et al. 2015). Subsequently, the data were imported into Microsoft Excel version 2019 for further data analysis.

Environmental variables

Environmental parameter for the current distribution of the pheasants, used different environmental parameters: climatic parameter (19 climatic variables, assessed by www.worldclim.org), physical parameter (3 variables, assessed by www.modis.gsfc.nasa.gov/), biophysical parameter (2 variables, accessed by www.modis.gsfc.nasa.gov/), and Topography parameter (2 variables, assessed by www.worldclim. org) (Chhetri et al. 2018, 2021).

The 19 climatic variables are Bio-1 (Annual mean temperature), Bio-2 (Mean diurnal range (mean of monthly (max temp-min temp), Bio-3 (Isothermality (P2/P7) (*100)), Bio-4 (Temperature seasonality (standard deviation *100)), Bio-5 (Max temperature of the warmest month), Bio-6 (Min temperature of the coldest month), Bio-7 (Temperature annual range (P5-P6)), Bio-8 (Mean temperature of the wettest quarter), Bio-9 (Mean temperature of the driest quarter), Bio-10 (Mean temperature of the warmest quarter), Bio-11 (Mean temperature of coldest quarter), Bio-12 (Annual precipitation), Bio-13 (Precipitation of wettest month), Bio-14 (Precipitation of driest month), Bio-15 (Precipitation seasonality (coefficient of variation)), Bio-16 (Precipitation of wettest quarter), Bio-17 (Precipitation of driest quarter), Bio-18 (Precipitation of warmest quarter) and Bio-19 (Precipitation of coldest quarter) (O'Donnell and Ignizio 2012; Pearson et al. 2014; Chhetri et al. 2018, 2021) as detailed of the climate variables, codes, and units for each variable as shown in Table 1.

All bioclimatic variables were downloaded from the WorldClim database (www.worldclim.org) at a resolution of 30 sec (~1 km^2) under monthly average conditions for 1970-2000 (Hijmans et al. 2005; Fick et al. 2017). This resolution approximately corresponded with the estimated home range of SFB of approximately 26 ha (Suwanrat et al. 2014). The climate layers were clipped to the study area using QGIS (QGIS Development Team 2020). All layers were converted into ASCII files (Promnun et al. 2020, 2021).

Table 1. Climate variables used for modeling climatic niches

Variable	Code	Unit
Annual mean temperature	bio1	°C
Mean diurnal range (mean of monthly (max temp-min temp))	bio2	°C
Isothermality (bio2/bio7) (X100)	bio3	-
Temperature seasonality (standard deviation X 100)	bio4	C of V
Max temperature of warmest month	bio5	°C
Min temperature of coldest month	bio6	°C
Temperature annual range (bio5-bio6)	bio7	°C
Mean temperature of wettest quarter	bio8	°C
Mean temperature of driest quarter	bio9	°C
Mean temperature of warmest quarter	bio10	°C
Mean temperature of coldest quarter	bio11	°C
Annual precipitation	bio12	mm
Precipitation of wettest month	bio13	mm
Precipitation of driest month	bio14	mm
Precipitation seasonality (coefficient of variation)	bio15	mm
Precipitation of wettest quarter	bio16	mm
Precipitation of driest quarter	bio17	mm
Precipitation of warmest quarter	bio18	mm
Precipitation of coldest quarter	bio19	mm

Data analysis

To classify the species of the bird and pheasant that were captured in photos, based on their common and scientific names according to the International Union for Conservation of Nature (IUCN) (2023). We considered clear photos with identifiable types, accompanied by dates and times on the photos. The independence of the photo's detection was considered (Choo et al. 2020). The independence of the detections was defined as (1) consecutive photographs of different individuals of the same species; (2) consecutive photographs of individuals of the same species when separated by more than 30 min; and (3) non-consecutive photos of individuals of the same species, regardless of the time interval (O'Brien et al. 2003; Blake et al. 2017; Bangthong et al. 2023).

The time information recorded in the photos of the birds obtained from camera traps was used to calculate their active time (Rowcliffe et al. 2014) using the Oriana 4 program (Kovach Computing Services 2023). Mardia-Watson-Wheeler test was used to test the difference between time active of the 2 species (Mardia and Jupp 2000). Watson's U test was used to test a uniform distribution on the circle of the birds and based on time data obtained from camera traps was tested by the Mardia - Watson-Wheeler test (Watson 1962), considering the difference at the significance level of $P<0.05$.

The study involved analyzing the habitat selection of the pheasant species using the MaxEnt program. The goal was to find important factors that affect the species' occurrence and identify suitable habitat areas based on data collected from automatically installed camera traps within the lowland area. This analysis considered the relationships between the pheasant species and various environmental factors that influence habitat selection. Ecological niche modeling was conducted using Maxent v3.4.1 (Phillips et al. 2006; Elith et al. 2011).

The coordinates located within the same grid on environmental layers were considered the same point, and 41 points were obtained. Next, 19 bioclimatic variables layers at present (monthly average conditions for 1970-2000) were downloaded from the WorldClim database (www.worldclim.org) at a resolution of 30 s ~1 km^2 (Hijmans et al. 2005; Fick et al. 2017).

The geographical coordinates of the pheasants, as recorded by the automated camera traps, served as input data. These data were then analyzed in conjunction with various environmental factors, including 19 climatic variables (Table 1). Additionally, biophysical factors such as Forest type and Tree cover, topography factors such as Elevation or Digital Elevation Model (DEM), and Slope are considered, totaling 23 factors. Therefore, to perform the analysis, the data need to be transformed into a raster format for use in the MaxEnt program.

The data consists of two types: continuous data and categorical data. For continuous data, such as slope, numerical forest canopy cover, mean temperature in the coldest quarter, and dry season precipitation, these values can be directly used as they are. Furthermore, it is necessary to convert categorical data, such as plant community types, into numerical categories; each category should be assigned a unique numerical value to represent it in the analysis (Trisurat et al. 2023).

Next, the data was split into training and testing sets with a 75:25 ratio. The training set, accounting for 75% of the data, was used to train the MaxEnt model. Meanwhile, the testing set, constituting 25% of the data, was used to assess the model's performance (Phillips et al. 2017). An equal training sensitivity and specificity criterion was applied, and a logistic threshold was selected to distinguish between the presence and absence of pheasants. Metrics such as percentage contribution and percentage permutation, derived from model testing, were employed to evaluate the importance of each environmental factor (Kalle et al. 2013).

We selected predictor variables from the current time layer based on their percent contribution and permutation importance, with a threshold of >10% (Khanum et al. 2013). The performance of the models was evaluated using the Areas Under the Curve (AUC) of Receiver Operating Characteristics (ROC) plots, where higher AUC values indicate more reliable models (Lavazza et al. 2023). The contribution of each selected variable was assessed using both percent contribution and permutation importance. These metrics help reveal the relationship between the presence of different pheasant species and the primary environmental variables. Ultimately, these transformed datasets and analyses allowed us to understand the relationships between the presence of each pheasant species and the key environmental variables. This analytical process followed the methodology outlined by Phillips et al. (2017).

RESULTS AND DISCUSSION

Species diversity

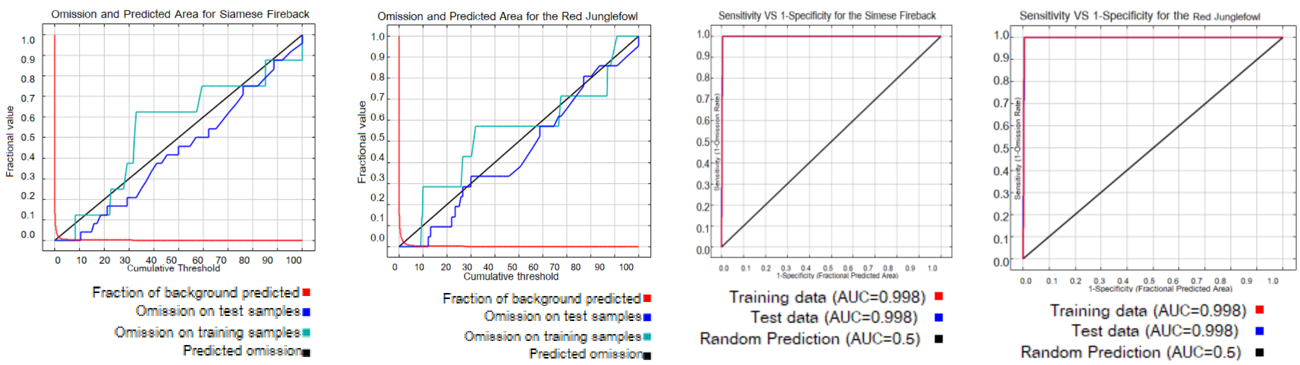
The study revealed the presence of pheasant species within the lowland area of the KARN. There are a total of 2 species of pheasants found in this area. The first was the SFB, and the second was the RJF. In addition to that, 8 other bird species inhabit the area and were captured in the camera trap images. These species are grey-capped emerald dove (*Chalcophaps indica*), red-wattled lapwing (*Vanellus indicus*), Malayan night heron (*Gorsachius melanolophus*), greater coucal (*Centropus sinensis*), coral-billed ground-cuckoo (*Carpococcyx renauldi*), blue pitta (*Hydrornis cyaneus*), pied fantail (*Rhipidura javanica*), and woolly-necked stork (*Ciconia episcopus*). In total, there were 343 independent photographs of these birds. Based on the number of camera trap locations found showed the most distribution of the SFB than other bird species recorded in the area, followed by the RJF. The details are shown in Table 2.

Encounter rate

The study yielded information regarding the photographic rates of two pheasant species in the KARN, 58 camera locations, and 4,463 trap nights. Specifically, for the SFB, a total of 78 independent photographs were captured. This translates to a photographic rate of 1.74 photographs per 100 trap nights. Additionally, 102 independent photographs were recorded for the RJF, resulting in a photographic rate of 2.28 per 100 trap nights. When considering the combined photographic rates of both pheasant species in the area, the rate was 4.05 photographs per 100 trap nights, compared with other bird species recorded was 11.16 photographs per 100 trap nights (Table 2).

Environmental factors affecting appearance

The MaxEnt displayed excellent predictive performance, revealing the strong predictive result of the probability distribution for both the SFB and the RJF models. Illustration of omission curves and Receiver Operating Characteristic (ROC) curve represented the performance of binary classification of MaxEnt models. The ROC curve's Area Under the Curve (AUC) value demonstrates (0.998) for both species. The model performance under the tradeoff between the rate of true-positive and false-positive is shown in Figure S1. The most crucial parameter of the SFB for contribution in the present model was climate (55.3%), followed by biophysical (30.1%) and topography (14.5%). For the RJF, again, the contribution of climate parameters (54.5%) in the model was highest, followed by biophysical (29.8%) and topography (15.6%) (see Table 3). Among the contributions as environmental parameters as predictors showed the top five environmental factors influencing the occurrence of the SFB are Temperature annual range (26.8%), Forest type (26.2%), Slope (12.5%), Precipitation of the driest quarter in a 1 in 4 timeframe (9.9%), and Temperature seasonality (9.6%). In comparison, those influencing the occurrence of the RJF are the Forest type (29.8%), Temperature annual range (23.0%), slope (13.2%), Precipitation of driest quarter (10.6%) and Precipitation of driest month (10.5%) (see Table 3). The study found that the percentage contribution values of the environmental factors affecting the occurrence of both species are not significantly different (t=1.94, P=0.70) analyses (Table 3).



A. Siamese fireback B. Red junglefowl C. Siamese fireback D. Red junglefowl

Figure S1. Illustration of omission curves for the Siamese fireback (A) and the Red junglefowl (B) and Receiver Operating Characteristic (ROC) curve representing performance of binary classification of MaxEnt model for the Siamese fireback (C) and the Red junglefowl (D). The area under curve (AUC) value of the ROC curve demonstrates the model performance under the tradeoff between the rate of true-positive and false-positive

Table 2. Pheasant and other bird species, number of independent photos, rate of capture, % encounter rate, and IUCN conservation status of pheasants and other bird species obtained from camera trapping in the lowland forest of the KARN, 58 camera locations and 4,463 trap nights

Common name	Scientific name	Event	% Encounter rate	No. of location found	IUCN 2023
Siamese fireback (SFB)	*Lophura diardi*	78	1.74	44	LC
Red junglefowl (RJF)	*Gallus gallus*	102	2.28	36	LC
Total of the pheasant species		180	4.05		
Red-wattled lapwing	*Vanellus indicus*	100	2.24	2	LC
Grey-capped emerald dove	*Chalcophaps indica*	24	0.54	8	LC
Coral-billed ground-cuckoo	*Carpococcyx renauldi*	20	0.45	7	VU
Blue pitta	*Hydrornis cyaneus*	9	0.2	1	LC
Malayan night heron	*Gorsachius melanolophus*	4	0.09	1	LC
Woolly-necked stork	*Ciconia episcopus*	4	0.09	4	NT
Greater coucal	*Centropus sinensis*	1	0.02	1	LC
Pied fantail	*Rhipidura javanica*	1	0.02	1	LC
Total of the other birds recorded		343	11.16		

Table 3. Percent contribution according to environmental factors affecting the chances of the appearance of the SFB and the RJF in the low land area of KARN, Thailand

Variable	Code	Contribution		Permutation	
		Siamese fireback	**Red jungle fowl**	**Siamese fireback**	**Red jungle fowl**
Bio-physiological					
Forest type	--	26.2	29.8	0.4	3.2
Tree cover	--	3.9	0.0	0.1	0.0
Subtotal bio-physiological		30.1	29.8	0.5	3.2
Topography					
Slope	--	12.5	13.2	0.1	0.2
DEM or elevation	--	2.0	2.4	33.3	10.7
Subtotal topography		14.5	15.6	33.4	10.9
Climate					
Annual mean temperature	bio1	0.1	0.0	0.0	0.0
Mean diurnal range (mean of monthly (max temp-min temp))	bio2	0.7	0.9	0.0	0.0
Isothermality (bio2/bio7) (X100)	bio3	0.1	0.1	0.2	7.4
Temperature seasonality (standard deviation X 100)	bio4	9.6	3.6	2.9	35.2
Temperature annual range (bio5-bio6)	bio7	26.8	23.0	0.0	0.0
Mean temperature of warmest quarter	bio10	0.1	0.1	1.1	1.5
Subtotal temperature		37.4	27.7	4.2	44.1
Annual precipitation	bio12	5.3	4.0	0.1	0.0
Precipitation of driest month	bio14	1.7	10.5	52.4	22.7
Precipitation seasonality (coefficient of variation)	bio15	0.3	0.5	9.3	19.1
Precipitation of wettest quarter	bio16	0.7	1.2	0.0	0.0
Precipitation of driest quarter	bio17	9.9	10.6	0.1	0.0
Subtotal precipitation		17.9	26.8	61.9	41.8
Total of climate variable		55.3	54.5	66.1	85.9

Considering the results of the analysis of environmental factors combined that affect the presence of the two pheasant species, the SFB and the RJF, both of which have values greater than 0, it is found that, in general, the categorized environmental factors can be divided into three types: biophysical, topography and climatic factors like with Chhetri et al. (2018, 2021), who conducted studies on climate change impacts on distribution of Himalayan pheasants. The study reveals that biophysical factors have an influence on the presence of the SFB (30.1%) and the RJF (29.8%), topography factors have an influence on the presence of the SFB (14.5%) and the RJF (15.6%) and climate factors influence the presence of the SFB (55.3%) and the RJF (54.5%), which have values that are quite similar when determined the combined data.

When examining the percentage of permutation values, it was observed that the climate conditions of SFB were 66.1%, which is lower than the corresponding value for RJF at 85.9%. Additionally, the biophysical factor exhibited a percentage of 0.5% for SFB and 3.2% for RJF. In contrast, the percentage of permutation values for topography factors in SFB (33.4%) was higher than that for RJF (10.9%). These percentage permutation values serve to explain the model's accuracy, particularly when randomization is introduced during the analysis process, as discussed in Altmann et al. (2010) study. Both topographic factors and climate conditions contribute to the variations in model accuracy when predicting the presence of SFB and RJF, as detailed in Table 3.

Furthermore, when we examined the biophysical factors that influenced the presence of the SFB and RJF, we relied on the percentage contribution values for the SFB pheasant. Notably, the factors that had a significant impact were Forest type (26.2%) and Tree cover (3.9%). In particular, when we delved into the forest types that influenced the presence of the SFB (26.2%), Figure S2.GG-HH revealed that the most influential forest types were secondary forest and grassland, followed by dry dipterocarp forest. When we examined the presence of the RJF in response to the forest conditions in the area, it was observed that the RJF exhibited a similar pattern of influence by various forest types as the SFB. However, what distinguished the RJF was that every forest type, including moist evergreen forest, freshwater swamp, rock platform, bamboo forest, mixed deciduous forest, dry dipterocarp forest, forest plantation, mountain forest, and non-forest area, impacted its presence (see Figure S2.GG-HH).

On the other hand, the tree cover (ranging from 0 to 98%) has a positive effect on the presence of both the SFB (3.9%) and the RJF (0.0%). In other words, as the tree cover increases, the likelihood of their presence also increases, even up to 98% (Figure S2.KK-LL). The topography factors affected to SFB occurrence were slope (12.5%) and Digital Elevation Model (DEM) or elevation above sea level (2.0%), in that order.

On the other hand, for the RJF, the bio-physiological factors that affect their presence are Forest type (29.8%), Topography slope (13.2%), and DEM (2.4%), in that order. These values combined in each factor are quite similar when compared between the two species, as shown in Table 3. Considering Figure S2.II-JJ, it is observed that the presence of both the SFB and the RJF is related to slope (ranging from 0 to 22.39%) negatively. As the slope increases, the presence of the SFB and the RJF decreases.

When considering specific climate factors and temperature factors, with percentage contribution falling between > 0% - 1%, it is observed that the factor Annual mean temperature (ranging from 16.92 to 28.64°C) has low relative importance and does not significantly affect the presence of the SFB (0.1%) and the RJF (0.0%) (Figure S2.A-B). On the other hand, the Mean diurnal range (ranging from 6.82 to 12.85°C) has a relative importance of 0.7% for the SFB and 0.9% for the RJF. It shows a negative relationship, indicating that a higher Mean diurnal range leads to a lower likelihood of encountering the SFB and the RJF, as shown in Figure S2.C-D. Considering the percentage contribution values, it is found that the factors that influence the presence of the SFB and the RJF with values falling between >1%-10% include Temperature seasonality (9.6% for the SFB and 3.6% for the RJF), Annual precipitation (5.3% for the SFB and 4.0% for the RJF), Precipitation of driest month (1.7% for the SFB and 10.5% for the RJF), and Precipitation of driest quarter (9.9% for the SFB and 10.6% for the RJF). These values exhibit variability between the two species, the SFB and the RJF. On the other hand, the factors that have an impact on the presence of the SFB and the RJF with values less than 1% include Annual mean temperature, Mean diurnal range, Isothermality, Mean temperature of the warmest quarter, Precipitation seasonality, and precipitation of the wettest quarter. These factors have a relatively lower influence on the presence of the two pheasant species.

When considering the percentage contribution values, it is found that the temperature-related factor, the Temperature annual range, has the most significant influence on the presence of both the SFB (26.8%) and the RJF (23.0%). On the other hand, the precipitation factor, the Driest quarter precipitation, is the most influential in the presence of the SFB (9.9%) and the RJF (10.6%).

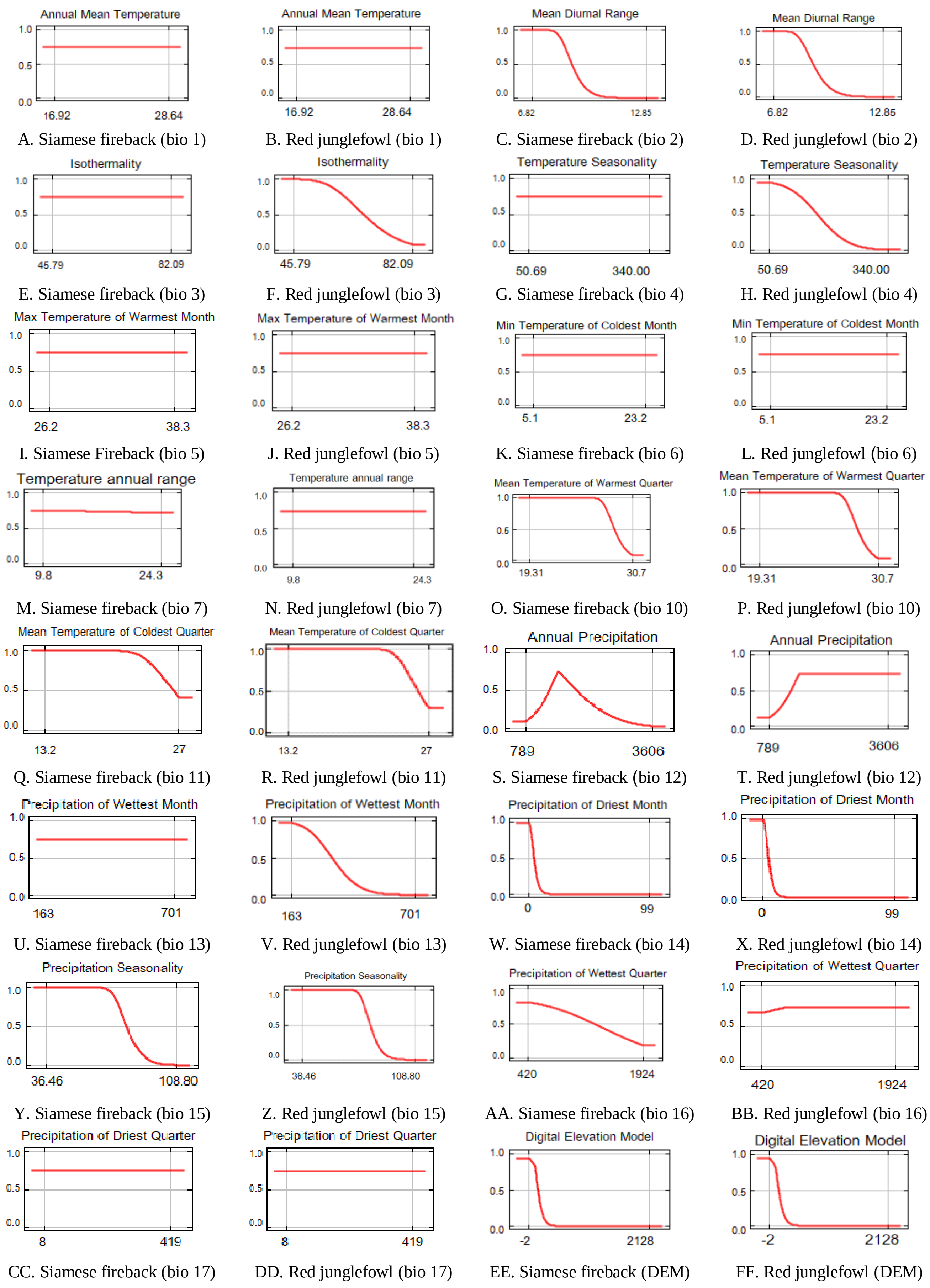
Considering the graph for Isothermality (bio3) (range 45.76-82.09°C), with a relative importance of 0.1 % for both the SFB and the RJF, it is evident that temperature consistency does not influence the presence of SFB. In the case of the RJF, there is a negative correlation with relative importance, suggesting that lower temperature consistency increases the likelihood of encountering the RJF (Figure S2.E-F). For the factor Temperature seasonality (bio4) (range 50.69-340.00°C), which has a relative importance of 9.6% for the SFB and 3.6% for the RJF, the graph (Figure S2.G-H) indicates that this factor affects the presence of the SFB consistently. However, the RJF suggests that as Temperature seasonality increases, the likelihood of encountering them decreases. Additionally, the study finds that higher values of Isothermality and Temperature seasonality have a diminishing effect on the presence of the RJF (Figure S2.F and H). For the case of the RJF, the Temperature annual range (bio7: range 9.8-24.3) factor with a relative importance of 26.8% for the SFB pheasant and 23.0% for the RJF indicates that the Temperature annual range has a consistent influence on the species' presence (Figure S2.M-N). Similarly, Mean temperature of warmest quarter (bio-10: range 19.31-30.7) with a relative importance of 0.1% for both species and a negative relationship suggests that as the average temperature in the Warmest quarter increases, the chances of encountering the SFB and the RJF will decrease (Figure S2.O-P).

On the other hand, the Annual precipitation (bio-12: range 789-3,606 mm) factor with a relative importance of 5.3% for the SFB and 4.0% for the RJF suggests that the range of 789 to 3,606 millimeters of Annual precipitation affects the presence of the SFB in decreasing trend and increasing and stable trend for the RJF (Figure S2.S-T). The Precipitation of the driest month factor (bio14: range 0-99 mm), with a relative importance of 1.7% for the SFB and 10.5% for the RJF, showed a negative relationship, indicates that as the Precipitation of driest month increases, the likelihood of encountering the SFB decreases (Figure S2.W-X). The Precipitation seasonality factor (bio15: range 36.46-108.80 mm), with a relative importance of 0.3% for the SFB pheasant and 0.5% for the RJF, showed a negative relationship, indicates that as the Precipitation seasonality increases, the likelihood of encountering the SFB decreases (Figure S2.Y-Z). The Precipitation of wettest quarter factor (bio16: range 420-1924 mm), with a relative importance of 0.7% for the SFB and 1.2% for the RJF, showed a negative relationship, indicates that as the Precipitation of wettest quarter factor increases, the likelihood of encountering the SFB decreases whereas in the case of the RJF relationship of this factor somewhat stable with the likelihood of encountering (Figure S2.AA-BB). The Precipitation of the driest quarter factor (bio17: range 8-419 mm), with a relative importance of 9.9 % for the SFB and 10.6% for the RJF, showed the stable trench between the relationship, indicates that the Precipitation of driest quarter factor increases, do not affect to the likelihood of encountering the SFB and the RJF (Figure S2.CC-DD).

When considering the combined climate factors, both temperature and precipitation, based on the percent permutation values, it is found that these factors significantly contribute to the accuracy of the model in explaining the presence of RJF (85.9%) and the SFB (66.1%). Additionally, when looking at the percentage contribution values, it is evident that temperature and precipitation factors have a similar and substantial impact on the presence of both species, the SFB (55.3%) and the RJF (54.5%) (Table 3).

Thus, the study results indicate that temperature factors have a greater impact on the presence of the SFB (37.4%) than the RJF (27.7%) when considering the percent contribution values. On the other hand, when considering precipitation factors as a whole, it is found that they have a more significant impact on the presence of the SFB (17.9%) compared to the RJF (26.8%) (Table 3).

The study showed the relationships between the presence of SFB and the RJF with various environmental factors, including biophysical, topography, and climate conditions considered in the analysis (Figure 3). When considering the results of the analysis of suitable habitat areas of the SFB and the RJF in the area, it was found that the optimal habitat for both pheasant species is located in the middle of the area, which shows the importance of space for keeping both pheasant species (Figure 4).



A. Siamese fireback (bio 1) B. Red junglefowl (bio 1) C. Siamese fireback (bio 2) D. Red junglefowl (bio 2)

E. Siamese fireback (bio 3) F. Red junglefowl (bio 3) G. Siamese fireback (bio 4) H. Red junglefowl (bio 4)

I. Siamese Fireback (bio 5) J. Red junglefowl (bio 5) K. Siamese fireback (bio 6) L. Red junglefowl (bio 6)

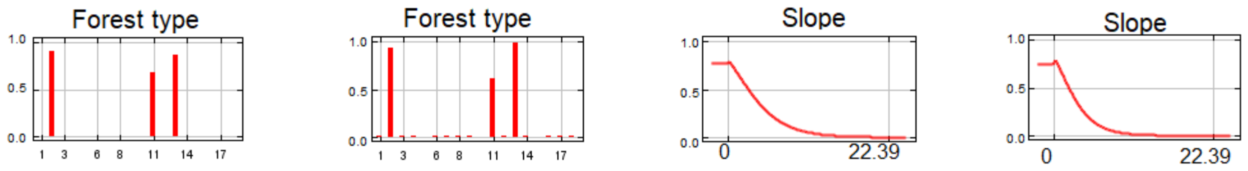
M. Siamese fireback (bio 7) N. Red junglefowl (bio 7) O. Siamese fireback (bio 10) P. Red junglefowl (bio 10)

Q. Siamese fireback (bio 11) R. Red junglefowl (bio 11) S. Siamese fireback (bio 12) T. Red junglefowl (bio 12)

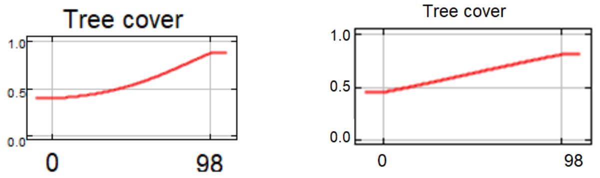
U. Siamese fireback (bio 13) V. Red junglefowl (bio 13) W. Siamese fireback (bio 14) X. Red junglefowl (bio 14)

Y. Siamese fireback (bio 15) Z. Red junglefowl (bio 15) AA. Siamese fireback (bio 16) BB. Red junglefowl (bio 16)

CC. Siamese fireback (bio 17) DD. Red junglefowl (bio 17) EE. Siamese fireback (DEM) FF. Red junglefowl (DEM)

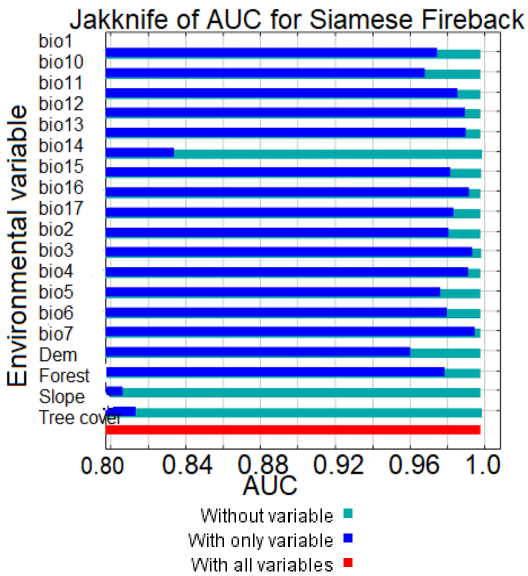


GG. Siamese fireback HH. Red junglefowl II. Siamese fireback JJ. Red junglefowl

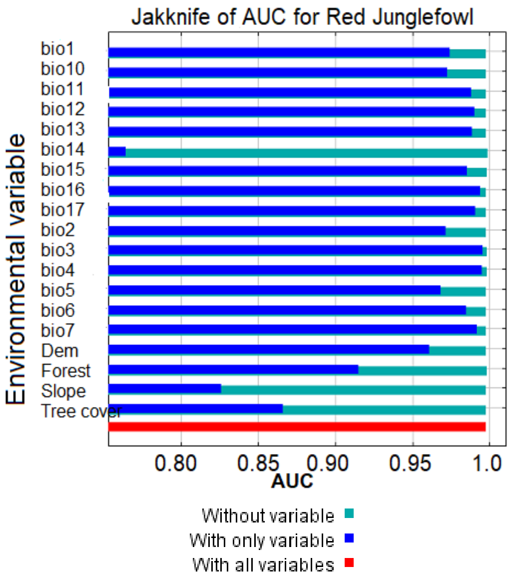


KK. Siamese fireback LL. Red junglefowl

Figure S2. Marginal response curve of the MaxEnt model of the Siamese fireback and the Red junglefowl in relation to each environmental covariate (temperature, precipitation, topography, and bio-physiological conditions) while keeping all others at average sample value

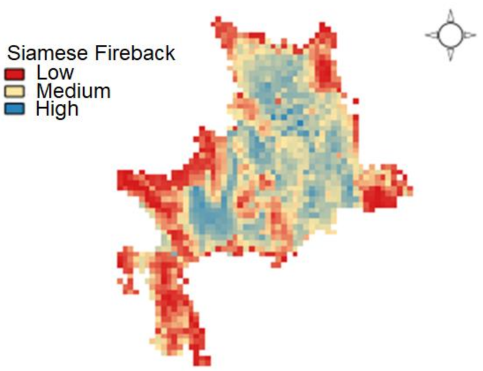


Siamese fireback

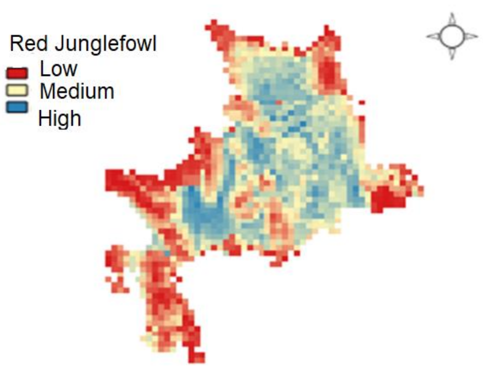


Red junglefowl

Figure 3. Jackknife test results of environmental factors on the presence of the SFB and the RJF for spatial modeling in lowland areas of the KARN, Thailand



Siamese Fireback



Red junglefowl

Figure 4. Distribution map of the SFB and the RJF according to appropriate factors in lowland areas in the KARN, Thailand

Table 4. The number of picture records, the median of active time, standard error, and the results of testing the uniform activity times in the daily cycle of the pheasants and the wild birds that can be recorded from camera traps in the KARN, Thailand

Species	Number of pictures recorded	Median (hour)	SE (hour)	Watson's U Test Uniform	Watson's U Test (P)
Siamese fireback	4910	08:41	00:05	65.67	<0.005
Red junglefowl	1036	10:11	00:08	17.61	<0.005
Red-wattled lapwing	488	11:50	00:10	9.98	<0.005
Grey-capped emerald dove	72	10:44	00:11	3.85	<0.005
Coral-billed ground-cuckoo	47	09:07	00:51	0.69	<0.005
Blue pitta	30	07:10	00:33	1.04	<0.005
Woolly-necked stork	20	06:50	00:39	0.75	<0.005
Malayan night heron	12	09:44	01:49	0.24	<0.025
Pied fantail	5	17:02	00:00	--	--
Greater coucal	3	07:19	00:00	--	--
Total	6623	09:19	00:04	88.46	<0.005

Active time

The analysis reveals that, on average, ground-dwelling birds were captured on camera at around 09:19 AM (SE = 0.04) for all recorded species. Specifically, the SFB was captured at 08:41 AM (SE = 0.05), while the RJF was captured at 10:11 AM (SE = 0.08). Notably, there was a significant difference in the image-capturing times between the SFB and the RJF, as indicated by the Mardia-Watson-Wheeler test (value = 226.92, $p<0.01$). Additionally, according to Watson's U Test for Uniformity, it was found that pheasants and other bird species displayed distinct activity times, and this difference was statistically significant ($p<0.005$). The detailed results are presented in Table 4.

Discussion

Bird surveys conducted using camera traps primarily focus on ground-dwelling bird species, as documented in studies by Kuhnen et al. (2013), Mohd-Azlan and Engkamat (2013), and Murphy et al. (2017). In the case of ground-dwelling bird species photographed in the study area, 10 such species were observed, including 2 pheasant species. This number is lower than the diversity of ground-dwelling bird species recorded using camera traps in Khao Yai National Park (KYNP) and Huai Kha Khaeng Wildlife Sanctuary (HKKWS), as reported by Kanka et al. (2023) and Charaspet et al. (2021), respectively. Specifically, in KYNP, 36 ground-dwelling species, including 4 pheasant species, were recorded, while HKKWS documented 23 ground-dwelling species, including 5 pheasant species. Laneng et al. (2021) also reported 3 pheasant species in Sabah, Malaysian Borneo, based on year-round camera trap data. Nonetheless, when we considered the photographic rates of all the SFB photos recorded in the study area, they were found to have been the highest among the areas, HKKWS and KYNP, highlighting their significance for conserving the SFB. Moreover, based on the camera trap data obtained from this study, it was also revealed that the lowland area is home to 6 families of carnivorous wild mammals, totaling 14 species in addition to pheasants and other terrestrial birds. The most abundant carnivorous mammal species is the Asian palm civet (*Paradoxurus hermaphroditus*), followed by the large-spotted civet (*Viverra megaspila*), golden jackal (*Canis aureus*), leopard cat (*Prionailurus bengalensis*), dhole (*Cuon alpinus*), small Indian civet (*Viverricula indica*), large Indian civet (*Viverra zibetha*), hog badger (*Arctonyx collaris*), crab-eating mongoose (*Herpestes urva*), yellow-throated marten (*Martes flavigula*), Javan mongoose (*Herpestes javanicus*), Malayan sun bear (*Helarctos malayanus*), Asiatic black bear (*Ursus thibetanus*), and clouded leopard (*Neofelis nebulosa*), respectively.

According to Su et al. (2022), all of the carnivorous species mentioned have the potential to prey on ground-dwelling birds, including pheasants. Khoewsree et al. (2022) reported a significant spatial and temporal overlap between the RJF and SFB with Dhole in Khao Yai National Park. Similarly, Charaspet et al. (2021) found that the presence of RJF corresponds to the niche overlap index of carnivorous mammals when considering spatial and temporal overlap coefficients in Huai Kha Khaeng Wildlife Sanctuary (HKKWS). Additionally, snakes such as the reticulated python (*Malayopython reticulatus*) (Sukumal 2009) are known to prey on pheasants. Birds of prey like the crested serpent-eagle (*Spilornis cheela*) may also be potential predators of pheasants, although there is limited reporting on this aspect (Sukumal 2009). Rodents, reptiles, and coucals are identified as the primary nest predators of RJF and other ground-nesting pheasants, as Rao et al. (2023) reported.

This study's results indicate that climate factors primarily influence the presence of pheasants in the area; in contrast, Round and Gale (2007) suggested that elevation is a significant factor affecting the presence of pheasant family birds. This conclusion is further supported by Receiver Operating Characteristic (ROC) analysis, demonstrating the model's accuracy with an Area Under the Curve (AUC) value of 0.998 for both the SFB and the RJF (Figure S1). This high AUC value signifies the model's reliability in examining the relationship between the primary environmental factors affecting the presence of SFB and RJF.

The study shows that the most significant parameter influencing the presence of the SFB and the RJF in the current model is climate factors, followed by biophysical and topographic factors. These findings underscore the importance of climate-related variables in determining the occurrence of these pheasants, even in the lowland areas of Thailand, where there is less variability in weather conditions throughout the year, as compared to higher-altitude regions around the world (Pires et al. 2019; Pepin et al. 2022).

Interestingly, this study's results align with those of Chhetri et al. (2021), who concluded that the most critical parameter affecting the occurrence of three Himalayan pheasant species was climate, followed by physical or topographic and biophysical factors respectively. The study also found that the type of forest influencing the occurrence of both species is the dry evergreen forest, which is consistent with research conducted on pheasants in the KYNP area (Kanka et al. 2023). Chhetri et al. (2018, 2021) also noted that temperature is crucial in the Himalayas, and as a result, many species may experience changes in their range, expansion, or contraction. Proper habitat management through protecting intact dry-evergreen forests as a continuous unit is vital for controlling environmental conditions, particularly regarding climate.

Climate change is expected to have a negative impact on biodiversity (Yousefi et al. 2019). Tropical forests, including those in Southeast Asia, are vulnerable to climate change, with increased temperatures and alterations in rainfall patterns (Trisurat et al. 2023). These global climate changes may affect temperature, precipitation, soil moisture, and other environmental factors in these forests, ultimately impacting terrestrial birds and mammal species, particularly in lowland habitats (Upadhyay 2020). However, for trees with limited seed dispersal, terrestrial birds may provide a mechanism to help trees adapt their distribution quickly enough to respond to changing environmental conditions (Hernandez et al. 2023). Protecting unique species like pheasants and other terrestrial birds is crucial for biodiversity conservation because of their diverse diets, which place them in a complex and interconnected role within the ecosystems they inhabit (Simcharoen et al. 2020).

The analysis indicates that ground-dwelling birds are typically captured on camera at around 08:41 AM (SE = 0.05) for the SFB and 10:11 AM (SE = 0.08) for the RJF. These findings align with the observations made by Selven et al. (2013), who conducted studies in the Eastern Himalayan lowland tropical forest of Arunachal Pradesh, India. Selvan et al. (2013) reported activity patterns of the grey peacock-pheasant (*Polyplectron bicalcaratum*), Red junglefowl, and Kalij pheasant (*Lophura leucomelanos*), with mean activity times of 6.30 hrs±3.37 hrs, 7.49 hrs±0.14 hrs, and 8.29 hrs±0.18 hrs, respectively. That suggests the pheasants, as per Selvan et al. (2013), are active in the morning, consistent with the findings of this study.

In addition to human activities that may disrupt their habitat, such as illegal hunting, logging, collecting forest products and the introduction of domestic animals into protected areas, it's crucial to focus on maintaining large contiguous patches of intact forest. During studies, it has been observed that forest fires impact the nesting sites of pheasants, especially during the dry season, potentially causing them to abandon their nests. Recommendations include ongoing monitoring of population dynamics, demographic characteristics, distribution, and habitat use of pheasants concerning climate. Preserving the secondary forest, grassland and the dry dipterocarp forest in lowland areas is important for conservation, as these forests are affected by climate change and have experienced significant human activities over extended periods. Ground-nesting pheasants are highly alert species (Bu et al. 2019); therefore, protecting their habitat and reducing human disturbance will positively contribute to their population growth.

In conclusion, this study on environmental factors and habitat use of pheasants in the lowland area, utilizing camera trapping, identified two species of pheasants within the sanctuary, both belonging to the same family and two different genera: the RJF and the SFB. The study found that the most influential factors affecting the presence of the RJF and SFB were climate-related, followed by biophysical and topographic factors. The likelihood of encountering these pheasants increases in the secondary forest and grassland, followed by dry dipterocarp forest. Therefore, conservation efforts targeting the protection of the forests and open clearing areas are crucial for preserving the pheasants’ population.

REFERENCES

Altmann A, Toloși L, Sander O, Lengauer T. 2010. Permutation importance: A corrected feature importance measure. Bioinformatics 26 (10): 1340-1347. DOI: 10.1093/bioinformatics/btq134.

Bangthong P, Sukmasuang R, Khoewsree N, Plaard M, Paansri P, Kaewdee B, Chairat R, Duengkae P, Siripattaranugul K. 2023. Species diversity, temporal pattern and habitat use of carnivorous mammals in the Khao Yai National Park, Thailand. J Wildl Biodivers 7 (Supplementary issue): 128-151. DOI: 10.5281/zenodo.10023306.

BirdLife International. 2016. *Lophura diardi*. The IUCN Red List of Threatened Species 2016: e.T22679274A92808547. DOI: 10.2305/IUCN.UK.2016-3.RLTS.T22679274A92808547.en.

Blake JG, Mosquera D, Loiselle BA, Swing K, Romo D. 2017. Long-term variation in abundance of terrestrial mammals and birds in eastern Ecuador as measured by photographic rates and occupancy estimates. J Mammal 98 (4): 1168-1178. DOI: 10.1093/jmammal/gyx046.

Bu H, Shen X, Li S. 2019. Predation patterns on artificial nests of ground nesting pheasants in the montane forest, Southwest China. Acta Ornithol 54 (1): 35-43. DOI: 10.3161/00016454AO2019.54.1.003.

Cao A, Shi X. 2022. The effects of climate change on habitat connectivity: A case study of the Brown-eared pheasant in China. Land 11 (6): 806. DOI: 10.3390/land11060806.

Charaspet K, Sukmasuang R, Khioewsree 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.

Chhetri B, Badola HK, Barat S. 2021. Modelling climate change impacts on distribution of Himalayan pheasants. Ecol Indic 123: 107368. DOI: 10.1016/j.ecolind.2021.107368.

Chhetri B, Badolaa HK, Barat S. 2018. Predicting climate-driven habitat shifting of the near threatened Satyr Tragopan (*Tragopan satyra*; Galliformes) in the Himalayas. Avian Biol Res 11 (4): 221-230. DOI: 10.3184/175815618X15316676114070.

Choo YR, Kudavidanage EP, Amarasinghe TR, Nimalrathna T, Chua MAH, Webb EL. 2020. Best practices for reporting individual identification using camera trap photographs. Glob Ecol Conserv 24: e01294. DOI: 10.1016/j.gecco. 2020.e01294.

Department of National Parks, Wildlife and Plant Conservation (DNP). 2018. Khao Ang Rue Nai Wildlife Sanctuary. www.dnp.go.th/wildlifenew/animConserveDep.aspx.

DNPWC and DFSC. 2018. Pheasant Conservation Action Plan for Nepal (2019-2023). Department of National Parks and Wildlife Conservation and Department of Forests and Soil Conservation. Kathmandu, Nepal. www. nepalindata.com/resource/PHEASANT-CONSERVATION-ACTION-PLAN-FOR-NEPAL-2019-2023/

Dwight IA, Vogt JH, Coates PS, Fleskes JP, Connelly DP, Gardner SC. 2020. Linking nest microhabitat selection to nest survival within declining pheasant populations in the Central Valley of California. Wildl Res 47 (5): 391-403. DOI: 10.1071/WR18199.

Elith J, Phillips SJ, Hastie T, Dudík M, Chee YE, Yates CJ. 2011. A statistical explanation of MaxEnt for ecologists. Divers Distrib 17 (1): 43-57. DOI: 10.1111/j.1472-4642.2010.00725.x.

Fan F, Bu H, McShea WJ, Shen X, Li BV, Li S. 2020. Seasonal habitat uses and activity patterns of blood pheasant *Ithaginis cruentusbe* in the presence of free-ranging livestock. Glob Ecol Conserv 23: e01155. DOI: 10.1016/j.gecco. 2020.e01155.

Fick SE, Hijmans RJ. 2017. WorldClim 2: New 1-km spatial resolution climate surfaces for global land areas. Intl J Climatol 37 (12): 4302-4315. DOI: 10.1002/joc.5086.

Fuller RA, Garson PJ. 2000. Pheasants. Status Survey and Conservation Action Plan 2000-2004. WPA/BirdLife/SSC Pheasant Specialist Group. IUCN, Gland. Switzerland and Cambridge, UK and the World Pheasant Associatiion, Reading, UK. www.portals.iucn.org/library/node/7813.

Furqan M, Ali Z. 2022. Feeding ecology, threats and conservation management of Kalij pheasant (*Lophura leucomelanos*) in Azad Jammu and Kashmir, Pakistan. Pak J Zool 54 (6): 2543-2551. DOI: 10.17582/journal.pjz/20200816170856.

Game and Wildlife Conservation Trust. 2023. Camera Traps for Game Management. Charity registered in England and Wales, 1112023, in Scotland SC038868. www.gwct.org.uk/advisory/guides/camera-traps-for-game-management/.

Hernandez JO, Naeem M, Zaman W. 2023. How does changing environment influence plant seed movements as populations of dispersal vectors decline? Plants 12 (7): 1462. DOI: 10.3390/plants1207146.

Hijmans RJ, Cameron SE, Parra JL, Jones PG, Javis A. 2005. Very high-resolution interpolated climate surfaces for global land areas. Intl J Climatol 25 (15): 1965-1978. DOI: 10.1002/joc.1276.

Hussain MS, Sultana A. 2013. Diet of threatened pheasant species in Himalayas, India-A faecal analysis approach. Ecol Balk 5 (1): 57-68. www.eb.bio.uni-plovdiv.bg.

IUCN. 2023. The IUCN Red List of Threatened Species. Version 2022-2. www.iucnredlist.org.

Kalle R, Ramesh T, Qureshi Q, Sankar K. 2013. Predicting the distribution pattern of small carnivores in response to environmental factors in the Western Ghats. PLoS One 8 (11): e79295. DOI: 10.1371/journal.pone.0079295.

Kanka P, Sukmasuang R, Duengkae P, Siripattaranugul K. 2023. Abundance and physical factors affecting the appearance of selected terrestrial birds in Khao Yai National Park using camera trapping. Biodiversitas 24 (1): 222-232. DOI: 10.13057/biodiv/d240127.

Kays R, Arbogast BS, Baker-Whatton M et al. 2020. An empirical evaluation of camera trap study design: How many, how long, and when? Methods Ecol Evol 11 (6): 700-713. DOI: 10.1111/2 041-210X.13370.

Khanum R, Mumtaz AS, Kumar S. 2013. Predicting impacts of climate change on medicinal asclepiads of Pakistan using Maxent modeling. Acta Oecol 49: 23-31. DOI: 10.1016/j.actao.2013.02.007.

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.

Kovach Computing Services. 2023. Oriana. www.kovcomp.co.uk/

Kuhnen VV, De Lima REM, Santos JF, Machado Filho LCP. 2013. Habitat use and circadian pattern of Solitary Tinamou *Tinamus solitarius* in a southern Brazilian Atlantic rainforest. Bird Conserv Intl 23 (1): 78-82. DOI: 10.1017/S0959270912000147.

Laneng LA, Nakamura F, Tachiki Y, Vairappan CS. 2021. Camera-trapping assessment of terrestrial mammals and birds in rehabilitated forest in Inikea Project Area, Sabah, Malaysian Borneo. Landsc Ecol Eng 17: 135-146. DOI: 10.1007/s11355-020-00442-7.

Lavazza L, Morasca S, Rotoloni G. 2023. On the reliability of the area under the ROC curve in empirical software engineering. In: Eldh S (eds). Proceedings of the International Conference on Evaluation and Assessment in Software Engineering (EASE ’23), Oulu, 14-16 June 2023. [Finland]. DOI: 10.1145/3593434.3593456.

Madden JR. 2021. How many gamebirds are released in the UK each year? Eur J Wildl Res 67: 72. DOI: 10.1007/s10344-021-01508-z.

Mardia KV, Jupp PE. 2000. Directional Statistics. John Wiley & Sons, London. DOI: 10.1002/9780470316979. www.wiley.com/en-us/Directional+Statistics-p-9780471953333.

Mason LR, Bicknell JE, Smart J, Peach WJ. 2020. The impacts of non-native gamebird release in the UK: An updated evidence review. RSPB Research Report No. 66. RSPB Centre for Conservation Science, Sandy, UK. www.rspb.org.uk/globalassets/mason-et-al-2020-rspb-gamebird-review-1-compressed.pdf

Mekonen S. 2017. Birds as biodiversity and environmental indicator. J Nat Sci 7 (21): 28-34. www.core.ac.uk/reader/234657570.

Mohd-Azlan J, Engkamat L. 2013. Camera trapping and conservation in Lanjak Entimau wildlife sanctuary, Sarawak. Borneo. Raffles Bull Zool 61 (1): 397-405. www.zoobank.org/References/ED367842-7592-4305-AE18-32BBDCA4ECCC.

Murphy AJ, Farris ZJ, Karpanty S, Kelly MJ, Miles KA, Ratelolahy F, Rahariniaina RP, Golden CD. 2017. Using camera traps to examine distribution and occupancy trends of ground-dwelling rainforest birds in northeastern Madagascar. Bird Conserv Intl 28 (4): 567-580. DOI: 10.1017/S0959270917000107.

O’Brien TG, Kinnaird MF, Wibisono HT. 2003. Crouching tigers, hidden prey: Sumatran tiger and prey populations in a tropical forest landscape. Anim Conserv 6 (2): 131-139. DOI: 10.1017/S1367943003003172.

O'Donnell MS, Ignizio DA. 2012. Bioclimatic predictors for supporting ecological applications in the conterminous. United States: US Geological Survey Data Series 691. DOI: 10.3133/ds691.

Palencia P, Rowcliffe JM, Vicente J, Acevedo P. 2021. Assessing the camera trap methodologies used to estimate density of unmarked populations. J Appl Ecol 58: 1583-1592. DOI: 10.1111/1365-2664.13913.

Pearson RG, Stanton JC, Shoemaker KT, Aiello-Lammens ME, Ersts PJ, Horning N, Fordham DA, Raxworthy CJ, Ryu HY, McNees J, Akçakaya HR. 2014. Life history and spatial traits predict extinction risk due to climate change. Nat Clim Change 4: 217-221. DOI: 10.1038/nclimate2113.

Penchart K, Sukmasuang R, Wajjawalku W. 2012. Genetic diversity of selected pheasant species in captive conditions. Eur J Sci Res 83 (2): 190-199. www.europeanjournalofscientificresearch.com.

Pepin NC, Arnone E, Gobiet A, Haslinger K, Kotlarski S, Notarnicola C, Palazzi E, Seibert P, Serafin S, Schöner W, Terzago S, Thornton JM, Vuille M, Adler C. 2022. Climate changes and their elevational patterns in the mountains of the world. Rev Geophys 60 (1): e2020RG000730. DOI: 10.1029/2020RG000730.

Phillips SJ, Anderson RP, Dudík M, Schapire RE, Blair ME. 2017. Opening the black box: An open-source release of Maxent. Ecography 40 (7): 887-893. DOI: 10.1111/ecog.03049.

Phillips SJ, Anderson RP, Schapire RE. 2006. Maximum entropy modeling of species geographic distributions. Ecol Model 190 (3-4): 231-259. DOI: 10.1016/j.ecolmodel.2005.03.026.

Pires JPA, Marino NAC, Silva AG, Rodrigues PJFP, Freitas L. 2018. Tree community phenodynamics and its relationship with climatic conditions in a lowland tropical rainforest. Forests 9 (3): 114. DOI: 10.3390/f9030114.

Promnun P, Kongrit C, Tandavanitj N, Techachoochert S, Khudamrongsawat J. 2020. Predicting potential distribution of an endemic Butterfly Lizard, *Leiolepis ocellata* (Squamata: Agamidae). Trop Nat Hist 20 (1): 60-71. www.li01.tci-thaijo.org/index.php/tnh/article/view/198819.

Promnun P, Tandavanitj N, Kongrit C, Kongsatree K, Kongpraphan P, Dongkumfu W, Kumsuan D, Khudamrongsawat J. 2021. Phylogeography and ecological niche modeling reveal evolutionary history of *Leiolepis ocellata* (Squamata, Leiolepidae). Ecol Evol 11 (5): 2221-2233. DOI: 10.1002/ece3.7186.

QGIS Development Team Q. 2020. QGIS Geographic Information System. Open-Source Geospatial Foundation. www.qgis.org/en/site/.

Rao X, Li J, He B, Wang H, Wu G, Teng T, Ling Q. 2023. Nesting success and potential nest predators of the red Junglefowl (*Gallus gallus jabouillei*) based on camera traps and artificial nest experiments. Front Ecol Evol 11: 1127139. DOI: 10.3389/fevo.2023.1127139.

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.

Rowcliffe JM, Kays R, Kranstauber B, Carbone C, Jansen PA. 2014. Quantifying levels of animal activity using camera trap data. Methods Ecol Evol 5 (11): 1170-1179. DOI: 10.1111/2041-210X.12278.

Ruengtik J, Sukmasuang R, Charaspet K, Pla-Ard M, Panganta T, Duengkae P, Bhumpakphan N. 2019. Diversity and abundance of carnivorous mammals in Khao Ang Rue Nai Wildlife Sanctuary, Chachoengsao Province. Thai J For 38 (2): 1-15. www.li01.tci-thaijo.org/index.php/tjf/article/view/245836/168064. [Thailand]

Selvan KM, Lyngdoh S, Veeraswami GG, Habib B. 2013. An assessment of abundance, habitat use and activity patterns of three sympatric pheasants in an eastern Himalayan lowland tropical forest of Arunachal Pradesh, India. Asian J Conserv Biol 2 (1): 52-60. www.ajcb.in/journals/full_papers_july_2013/6_AJCB-Vol2-No1-Muthamizh-Selvan%20et%20al.pdf.

Simcharoen S, Simcharoen A, Hasin S, Cuthbert F, Smith JLD. 2020. Diet of the Large Indian Civet (*Viverra zibetha* L., 1758) in West-Central Thailand. Malay Nat J 72 (3): 287-293. www.eds.s.ebscohost.com/eds/pdfviewer/pdfviewer?vid=0&sid=9ca695fe-217b-4f77-81dd-9feaee96d472%40redis.

Singchat W, Chaiyes A, Wongloet W, Ariyaraphong N, Jaisamut K, Panthum T, Ahmad SF, Chaleekarn W, Suksavate W, Inpota M, Chaisongkram C, Kaewsalubnil N, Muangmai N, Chamchumroon W, Matsuda Y, Duengkae P, Srikulnath K. 2022. Red Junglefowl resource management guide: Bioresource reintroduction for sustainable food security in Thailand. Sustainability 14: 7895. DOI: 10.3390/su14137895.

Su T, Li Q, Wang X, Cui G, Man Z, Li W, Zhao M. 2022. The ecological roles of medium and small carnivores in the terrestrial animal community in Liancheng National Nature Reserve, China. Animals 12 (24): 3518. DOI: 10.3390/ani12243518.

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.

Sukumal N. 2009. Habitat Use and Home Range Analysis of Siamese Fireback (*Luphula diardi*) and Silver Pheasant (*L. nycthemera*) in Sub-montane Forest, Khao Yai National Park, Thailand. [Dissertation]. King Mongkut's Institute of Technology Thonburi, Thailand. [Thailand]

Suwanrat J, Ngoprasert D, Sukumal N, Savini T. 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. www.zoobank.org/References/7F3427CE-84DC-483A-84FD-AD950FE264DF.

Suwanrat J, Ngoprasert D, Sukumal N, Suwanwaree P, Savini T. 2014. Reproductive ecology and nest-site selection of Siamese Fireback in lowland forest. Raffles Bull Zool 62: 581-590. www.zoobank.org/References/7C014AD9-D4D3-43E1-9093-B11C79DFDB75.

Trisurat Y, Sutummawong N, Roehrdanz PR, Chitechote A. 2023. Climate change impacts on species composition and floristic regions in Thailand. Diversity 15 (10): 1087. DOI: 10.3390/d15101087.

Upadhyay RK. 2020. Markers for global climate change and its impact on social, biological and ecological systems: A review. Am J Clim Change 9 (3): 159-203. DOI: 10.4236/ajcc.2020.93012.

Vy NT, Ngoprasert D, Browne S, Savini T. 2018. Status and range decline of two galliform species in Southeast Asia. Bird Conserv Intl 28 (3): 423-438. DOI: 10.1017/S0959270917000168.

Wang B, Xu Y, Price M, Yang N, Liu W, Zhu B, Zhong X, Ran J. 2020. Niche partitioning among three montane ground-dwelling pheasant species along multiple ecological dimensions. Ibis 163 (1): 171-182. DOI: 10.1111/ibi.12842.

Watson GS. 1962. Goodness-of-fit tests on a circle. II. Biometrika 49 (1/2): 57-63. DOI: 10.2307/2333467.

Williams ST, Maree N, Taylor P, Belmain SR, Keith M, Swanepoel LH. 2018. Camera trap and questionnaire dataset on ecosystem services provided by small carnivores in agro-ecosystems in South Africa. Data Brief 18: 753-759. DOI: 10.1016/j.dib.2018.03.071.

Yousefi M, Ahmadi M, Nourani E, Rezaei A, Kafash A, Khani A, Sehhatisabet ME, Adibi MA, Goudarzi F, Kaboli M. 2017. Habitat suitability and impacts of climate change on the distribution of wintering population of Asian Houbara Bustard *Chlamydotis macqueenii* in Iran. Bird Conserv Intl 27 (2): 294-304. DOI: 10.1017/S0959270916000381.

Zaragozí 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.