

## Home range size and microhabitat selection by a tropical partridge species in moist evergreen forest

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**Abstract.** Understanding the diurnal and nocturnal habitat requirements of Galliformes is important for gauging their conservation needs. To examine these requirements, we measured microhabitat usage at daytime foraging and roost sites of the green-legged partridge *Tropicoperdix chloropus* located by radio telemetry at Khao Yai National Park in 2009–2010 and defined which habitat characteristics were influential. During the day, individuals utilised sites that had denser and thicker understory plants and cover than random sites. Binary logistic regression indicated that the density of understory plants and woody climber stems had the largest influence on partridge habitat selection. At night, partridges roost on elevated trees. Adult males roosted alone within their territories during incubation, but during other times, they roosted as a pair or with the family group. After the chicks hatched, the female would take the chicks to roost on the ground within tree buttresses until three weeks of age, when they were able to fly up to roost on trees. The mean roosting tree height was 5.6 m, and the mean perch height was 3.2 m from the ground. The partridges preferred roosting sites with a denser and higher canopy cover to their perch position (>3 m), but a lower density and canopy cover of understory plants under their perch position (<3 m). Binary logistic regression indicated positive associations with percent cover of small trees (3–5 m), but a negative association with percent cover of understory plants. Large trees had the most influence on roost site selection. The use of different forest structures by the partridges during day and night supports the need for maintaining a complex habitat composition for the conservation of this species.

**Key words.** radio telemetry, green-legged partridge, *Tropicoperdix chloropus*, roost-site selection, habitat use

### INTRODUCTION

Habitat composition can influence resource use by birds with respect to foraging, nesting, brood rearing, and roosting (Johnson, 1980). Good quality habitats with high food abundance, camouflaged nest and roost sites, and low human disturbance during the breeding season are important for ensuring optimal reproduction and survival of birds (Cody, 1985; Zheng & Wang, 1998). Therefore, clearly understanding the relationships between habitat preference and structure, on the one hand, and species' ranging behaviour and home range size, on the other, can help predict areas of suitable habitat, gauge their quality, and further improve their conditions for the conservation and management of bird populations (Morris, 2003).

Southeast Asia supports comparatively high levels of biodiversity, but also has a high-level biodiversity threat

(Achard et al., 2002; Schipper et al., 2008; Sodhi et al., 2010). It is expected that a high proportion of vertebrate species will disappear from the region by 2050 (Sodhi et al., 2004) primarily due to deforestation, habitat degradation, and over-hunting (Laurance & Bierregaard, 1997; Watson et al., 2004) as well as a combination of those factors (Symes et al., 2018). Habitat degradation and hunting, mainly using snaring (Gray et al., 2018), are among the most detrimental threat factors for ground birds as their mobility is limited to two dimensions, and most of these terrestrial species exhibit a relatively small ranging capacity.

The green-legged partridge (*Tropicoperdix chloropus*), hereafter GLP, is a small-sized galliform that inhabits predominantly moist-evergreen, semi-evergreen and mixed deciduous forest, secondary growth and bamboo forest (Lekagul & Round, 1991). Its distributional range is relatively large, occurring in Myanmar, Thailand, Cambodia, Laos, and Vietnam (Madge & McGowan, 2002). It is a nationally protected species in Thailand, but globally classified as Least Concern by IUCN (IUCN, 2016). Its ecological requirements continue to be imperfectly understood, although its nesting ecology is known in greater detail (Ong-in et al., 2016). The need for detailed information on habitat requirements and use is recommended as a starting point for initiating conservation action of Southeast Asian partridges (McGowan et al., 1995). Due to accelerating habitat degradation in the entire region, quantitative data on habitat use by such species is becoming

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a key need. Preliminary surveys in southern Thailand, on both side of the Isthmus of Kra, show that general partridge abundance is declining. Thus, studying of day and night-time habitat selection, by using radio telemetry techniques, for the common species can be applied to understand rare and unstudied species in order to make the best possible conservation decisions for Galliformes (Grainger et al., 2017).

This study aims to investigate the home-range size and diurnal and nocturnal microhabitat use by the GLP inhabiting undisturbed sub-montane evergreen forest at Khao Yai National Park, Thailand. Firstly, we hypothesise that the understory structure directly affects habitat use for foraging during the day, and we predict that partridges select areas with denser understory vegetation, which directly relates to greater food abundance. Moreover, we predict that partridges select areas with good cover, reducing detection risk from diurnal predators. Secondly, we hypothesise that habitat selection for night roosting serves to increase inaccessibility for potential nocturnal predators, allowing roosting birds an easy overview and escape potential. We predict that partridges select roosting trees with denser surrounding vegetation than those available in general.

## MATERIAL AND METHODS

**Study site.** The study was conducted from March 2009 to October 2010 at the Mo Singto Long-Term Biodiversity Research Plot (hereafter MST; Brockelman et al., 2011), Khao Yai National Park, northeastern Thailand (101°22'E, 14°26'N). The park covers an area of 2,168 km<sup>2</sup> of mainly seasonally wet evergreen forest. The MST plot has an area of 30 ha, where the elevation ranges from 725 to 815 m asl (above sea level) covered by mature evergreen forest, with a small area of 40-year-old secondary forest at its northern edge. The MST plot is part of the Centre for Tropical Forest Science network (CTFS) and has all trees with a diameter at breast height (dbh) greater than 1 cm mapped, permanently tagged, and identified to species level (Brockelman et al., 2011). Average precipitation is 2,697 mm (range 2,967–2,297 mm), with the most rainfall during May–October. The average daily temperature varies annually between 18.7 and 28.3°C, and average humidity ranges from 64.6% during the dry season to 77.1% during the wet season (Savini et al., 2008).

**Bird trapping and tagging.** We used call playback to attract and catch partridges using mist nets (see Ong-in et al., 2016) during the pre-breeding season, which were fitted with radio transmitters (March to May, 2009 and 2010). One day after capture and release, data collection started and continued for as long as the radio transmitter worked or until it became detached from the birds. We located the position of each radio-tagged bird between one to three times per day. The locations of each individual were recorded randomly throughout daylight hours (range 0630–1730 hours) at a minimum of two-hour intervals, using the homing method (Kenward, 2001). Each location was recorded using either the number of the nearest tree tagged following the 30 ha MST plot database (Brockelman et al., 2011) if within the

plot, or by geographic coordinates using a Garmin 60CSx (GPS; < 8 m accuracy) if outside the MST plot.

**Roost location at night.** After sunset, we located roosting birds by homing and recorded their location using the number of the tagged tree within the MST Plot or the GPS location. The vegetation characteristics were measured at the end of the month during which the roost had been located.

**Measurement of microhabitat usage.** Habitat features were recorded within a 5 m-radius circular plot centred on both the foraging points, locations where radio-collared animals were recorded, and random points, locations randomly selected over the study area, which represent the available habitat (Martin et al., 1997). One hundred and twenty points were selected randomly within the MST plot to cover all territories of studied birds and were assumed representative of the whole area.

Microhabitat in the circular plot of foraging and random sites were classified into four categories based on vegetation strata. In each plot, we measured the following habitat variables: the percentage coverage of each vegetation height category (0.5–1 m, 1–3 m, 3–5 m, and >5 m) (Martin et al., 1997; Sukumal et al., 2010), number of tree stems, and slope.

**Roost site characterisation.** Habitat features were recorded using 5 m-radius circular plots centred on sites where the birds were located roosting following Martin et al. (1997) and Sukumal et al. (2010). For each roosting tree location, we measured the following variables: diameter at breast height (DBH), perch height, roosting tree height, and direction of slope.

**Home range analysis.** We estimated the home range and core area using characteristic hull polygons (CHPs), which is a relatively recent non-probabilistic method (Downs & Horner, 2009) that combines all locations within a Delaunay triangulation, following the procedure of José-Domínguez et al. (2015). The rationale of CHPs is that small triangles represent areas of high ranging activity, while large triangles represent the unused or less frequently visited area. In addition, to allow for comparability with other studies, we calculated range sizes of radio-tagged animals using minimum convex polygons (MCP; Mohr, 1947). We defined the home range using 100% and 95% of all locations and the core area using 50% of all locations. Analyses were undertaken using the Home Range Tools (HRT) extension in ArcGIS 9.3 (ESRI, 2009).

**Microhabitat modelling.** Our data were not normally distributed, so we used the non-parametric Mann-Whitney *U* test for comparisons of habitat variables between used and random locations. We used logistic regression to model the habitat data, where the probability of the plot being the foraging and roost points (radio-tagged location during daytime foraging and radio-tagged location during roosting: use point) was the response variable (use = 1, random = 0). All variables were standardised for comparison on the same scale before being input into the habitat models. The

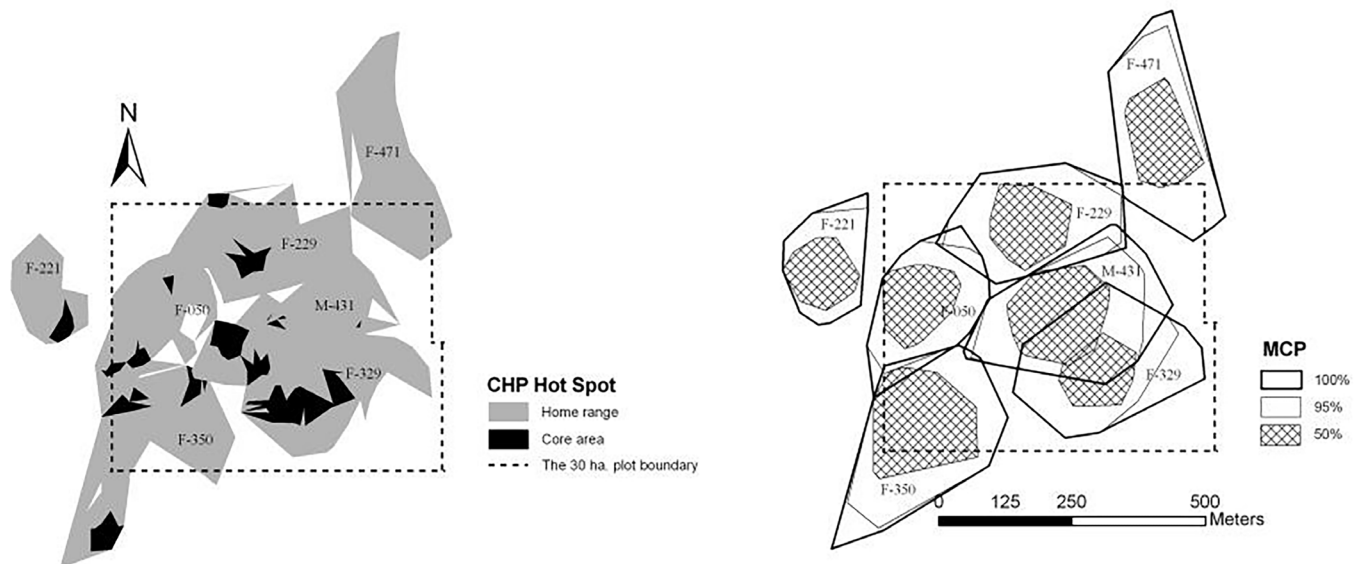


Fig. 1. Analysis of green-legged partridges' group range based on radio locations using the characteristic hull polygon (CHP) and minimum convex polygon (MCP; 100%, 95% and 50%) methods. F refers to females, and M refers to males.

continuous variables (DBH, slope in degrees, number of stems per height class: STM1 [stem height of 0.5–1 m], STM2 [stem height of 1–3 m], STM3 [stem height of 3–5 m], and STM4 [stem height >5 m]) were standardised by dividing the value by twice the standard deviation (Gelman, 2008). The percentage cover of plants in different height classes; cover 0.5–1 m (COV1), cover 1–3 m (COV2), cover 3–5 m (COV3), and cover >5 m (COV4), was standardised by dividing the corresponding value by one hundred and transformed using the arcsine function (Sokal & Rohlf, 1995). Correlation between variables was tested using Spearman's rank correlation. Before entering the variables in a given model, we tested which variables were highly correlated ( $r > 0.5$ ) so they could be excluded from the same model. We used the Akaike's Information Criterion adjusted for small sample sizes ( $AIC_c$ ) to rank models based on their ability to explain the data (Hurvich & Tsai, 1989).

We followed the procedures of Suwanrat et al. (2014) to evaluate the model classification accuracy using the area under the receiver operating characteristic curve (AUC; Hosmer & Lemeshow, 2000). We chose an optimal threshold cut-off value for classification based on the AUC using the minimised difference between the proportions of uses correctly predicted (sensitivity) and the proportion of non-uses correctly predicted (specificity) (Fielding & Bell, 1997). We estimated the coefficients of parameters using model averaging when no single model had strong support ( $\Delta AIC_c < 2$ ; Richards et al., 2010). We used an 85% confidence interval to identify variables with significant influence on habitat selection; this interval renders model selection and parameter evaluation criteria more congruent with the AIC results as compared to 95% confidence intervals (Arnold, 2010). Statistical analyses were performed using R version 3.4.3 (R Core Team, 2017), with the MASS (Venables & Ripley, 2002), AICcmodavg (Mazerolle, 2012), and PresenceAbsence packages (Freeman & Moisen, 2008).

## RESULTS

Seven partridges, belonging to seven different breeding pairs, were radio-tagged, followed, and their home range size measured (Fig. 1). However, data from only six groups were analysed for roosting behaviour and roost site selection, as no roost site was recorded for one radio-collared animal tagged during preliminary work.

**Home range size.** Between 34 and 126 locations were collected across the seven groups. The mean  $\pm$  standard error (SE) home range (HR) size using the CHPs estimator was  $4.01 \pm 0.4$  ha, and the size of the core area (CA) was  $0.45 \pm 0.15$  ha. Using the MCPs estimator, the mean home range size  $\pm$  SE was  $5.69 \pm 0.59$  ha (100% MCP) and  $5.11 \pm 0.51$  ha (95% MCP), while the core area was  $2.02 \pm 0.26$  ha (50% MCP) (Table 1).

**Habitat characteristics (used vs. random).** GLPs were observed using forest with predominantly dense understory saplings (STM1 and STM2). Other habitat variables did not vary significantly between foraging and random locations (Table 2). A set of nine regression models was generated to explain the probability of the presence of foraging partridges (Table 3). The best model, based on  $\Delta AIC_c$  and  $AIC_c$  weight ( $w_i$ ) (Table 3), includes the density of trees at height 1–3 m (STM2), number of woody climbers (CLB), and percent coverage of trees at height 0.5–1 m (COV1), which correctly predicted habitat use in 76.4% of cases. Model averaging was estimated for the coefficients (Table 4) based on the accumulated 95% model weight. Estimated coefficients for tree density at height 1–3 m (STM2) and the number of woody climbers had a significantly positive influence on habitat use of green-legged partridge (Table 4).

**Roosting behaviour.** Six different groups were monitored during roosting over 161 nights, from May 2009 to October 2010. The partridges used 75 different individual trees. Partridges roosted alone on 73% of the recorded occasions,

Table 1. Sizes (ha) of the home range (HR) and core area (CA) of green-legged partridge using different ranging estimators. F is female, and M is male.

No	Group identifier	No. of radio-locations	CHP Hot Spot		MCP			No. of roosting trees	No. of night observations
			HR	CA	100%	95%	50%		
1	F-221	34	1.74	0.17	2.86	2.71	1.35	n/a	n/a
2	M-431	126	5.42	0.56	7.19	6.16	2.71	18	51
3	F-471	69	4.76	0.00	5.79	5.32	1.95	15	32
4	F-329	76	3.36	1.18	6.62	5.58	1.43	9	22
5	F-350	61	4.70	0.72	7.11	6.57	3.21	12	22
6	F-050	78	3.55	0.20	4.53	3.93	1.68	13	21
7	F-229	60	4.56	0.34	5.74	5.50	1.82	8	13

CHP Hot Spot: characteristic hull polygons with hot-spot analyses; MCP: minimum convex polygon.

Table 2. Comparison of habitat variables between ranging habitat, roosting habitat and random sites.

Habitat variables	Daytime foraging sites						Roosting sites							
	Foraging (n=408)			Random (n=120)			P-value	Roost (n=75)			Random (n=104)			P-value
	Mean	±	SE	Mean	±	SE		Mean	±	SE	Mean	±	SE	
Slope (degree)	17.3	±	0.4	18.3	±	0.7	0.38	16.8	±	1.9	16.9	±	1.8	0.99
Tree density: height 0.5–1 m (stems)	48.8	±	1.2	42.8	±	1.9	0.003	43.0	±	4.6	65.9	±	4.3	< 0.001
Tree density: height 1–3 m (stems)	70.1	±	1.6	46.5	±	1.8	< 0.001	61.2	±	4.3	80.9	±	4.6	< 0.001
Tree density: height 3–5 m (stems)	12.8	±	0.3	12.5	±	0.5	0.92	21.9	±	3.9	8.8	±	1.8	< 0.001
Tree density: height >5 m (stems)	12.7	±	0.3	13.0	±	0.4	0.29	11.6	±	1.9	13.7	±	1.5	0.0055
Tree coverage: height 0.5–1 m (%)	30.5	±	0.8	24.9	±	1.1	< 0.001	26.7	±	2.8	42.3	±	2.9	< 0.001
Tree coverage: height 1–3 m (%)	54.6	±	0.9	43.1	±	1.4	< 0.001	51.7	±	2.2	56.4	±	2.9	0.41
Tree coverage: height 3–5 m (%)	33.2	±	0.7	31.0	±	1.0	0.35	49.8	±	2.8	25.1	±	3.5	< 0.001
Tree coverage: height >5 m (%)	74.9	±	0.8	76.9	±	1.6	0.07	66.5	±	2.3	77.2	±	1.9	< 0.001
Number of woody climber (stems)	13.3	±	0.7	11.9	±	1.1	0.28	16.2	±	5.8	13.1	±	3.7	0.13
Roost tree height (metre)								5.6	±	0.8	7.6	±	1.9	0.06
Perch height (metre)								3.2	±	0.4	4.0	±	1.4	0.90
Roost tree DBH								5.7	±	1.3	8.1	±	3.6	0.73

Note: DBH: diameter at breast height; SE: standard error

Table 3. Binary logistic regression models explaining the probability of habitat use by green-legged partridges in Khao Yai National Park, Thailand, based on the variables included in models. STM1 is density of trees at height 0.5–1 m, STM2 is density of trees at height 1–3 m, STM3 is density of trees at height 3–5 m, STM4 is density of trees at height >5 m, COV1 is percent coverage of trees at height 0.5–1 m, COV2 is percent coverage of trees at height 1–3 m, COV3 is percent coverage of trees at height 3–5 m, COV4 is percent coverage of trees at height higher than 5 m, and CLB is number of woody climbers. The null model was excluded from the table because of a lack of support relative to the tested top models.

Model	LL	K	$\Delta AIC_c$	$w_i$	AUC
<b>Foraging site (9 models tested)</b>					
STM2 + CLB	-241.87	3	0.00	0.58	76.48
STM2 + COV1	-241.75	4	1.80	0.24	76.41
STM2 + STM1 + STM3 + STM4 + CLB	-240.91	6	4.19	0.07	77.01
STM2	-244.99	2	4.23	0.07	75.64
<b>Roosting site (11 models tested)</b>					
STM3 + COV1 + COV3 + COV4	-59.20	5	0.00	0.80	93.05
COV1+ COV2 + COV3 + COV4	-60.77	5	3.15	0.17	92.84

LL is log-likelihood; K is the number of parameters in the model;  $\Delta AIC_c$  is difference in  $AIC_c$  values; model with  $\Delta AIC_c$  value 0 has highest support, values between 0 and 2 have substantial support, values greater than 2 have less support;  $w_i$  = Akaike model weight; AUC = area under the receiver operating characteristic curve.

Table 4. Results of logistic regression showing the influence of variables on habitat use by green-legged partridge. The estimates of coefficients were derived from model averaging and unconditional standard error (Uncond. SE) and its 85% confidence interval (CI).

Variables	Coefficient	Uncond. SE	Lower 85% CI	Upper 85% CI
<b>Foraging site</b>				
Tree density: height 1–3 m (STM2)	2.86	0.41	2.27	3.45
Number of woody climber (CLB)	0.55	0.23	0.22	0.88
Tree density: height 0.5–1 m (STM1)	-0.19 <sup>a</sup>	0.27	-0.57	0.20
Tree density: height 3–5 m (STM3)	-0.18 <sup>a</sup>	0.24	-0.53	0.16
Tree density: height >5 m (STM4)	-0.14 <sup>a</sup>	0.23	-0.47	0.19
Tree coverage: height 0.5–1 m (COV1)	0.36 <sup>a</sup>	0.75	-0.72	1.44
<b>Roosting site</b>				
Tree density: height 3–5 m (STM3)	1.61	0.9	0.32	2.91
Tree coverage: height 0.5–1 m (COV1)	-6.67	1.58	-9.94	-5.39
Tree coverage: height 1–3 m (COV2)	-0.92 <sup>a</sup>	1.23	-2.68	0.85
Tree coverage: height 3–5 m (COV3)	7.49	1.72	5.01	9.97
Tree coverage: height >5 m (COV4)	-4.03	1.26	-5.84	-2.22

<sup>a</sup>Estimates coefficients of variables used by green-legged partridge. Overlap of confidence intervals with zero indicates a weak or no effect of defining habitat use.

and in pairs or with their grown chicks for the remainder. During incubation, the male roosted alone, but within the territory and within 60.0±3.9 m (range = 55.6–83.1 m, n = 7-night observations) of the female. Females with young chicks were accompanied by the male during the day, but at night, the female brooded the chicks (during the first two weeks) on the ground within tree buttresses (n = 1-night observation). Once the chicks were about three weeks of age (n = 3-night observations across two groups) they roosted under the female’s wings on elevated perches until they reached about two months, after which they roosted alone, but near their parents.

**Roost site characteristics.** A total of 75 roosting trees were used for this analysis during a total of 161 observed nights.

During this study, 41 trees (55%) were used only once for roosting, while 34 trees (45%) were used more than once. The partridges chose thirty-two plant species (including two species of vines) for roosting during the study period. The trees used had a mean height (± SE) of 5.6±0.8 m (range = 3.0–10.5 m) and mean DBH of 5.7±1.3 cm (range = 1.9–18.5 cm). The mean perch height was 3.2±0.4 m (range = 1.8–6.3 m). There is a significant difference in a range of characteristics between roosting and random sites. Selected sites had a higher density of small trees (STM3) and percentage cover of small trees (COV3), but a lower density of understory saplings at heights of 0.5–1 m (STM1), 1–3 m (STM2), and >5 m (STM4), and lower percent coverage of understory saplings at heights of 0.5–1 m (COV1) and >5 m (COV4) (Table 2).

Microhabitat at roosting sites had a lower density of trees at height 0.5–1 m (STM1), 1–3 m (STM2), >5 m, and tree coverage at height >5 m, but had greater tree density at height 3–5 m (STM3), and tree coverage at height 0.5–1 m (COV1) and 3–5 m (COV3) than random sites. Other habitat variables did not vary significantly between roost locations and random locations (Table 2). A set of eleven regression models was generated to explain the probability of roost sites of GLP, and the null model was excluded from the table (Table 3). The best model includes the density of trees at height 3–5 m (STM3), percent coverage of trees at height 0.5–1 m (COV1), 3–5 m (COV3), and >5 m (COV4), which correctly predicted habitat use in 93% of cases. Model averaging was estimated for the coefficients (Table 4) based on the accumulated 95% model weight. Estimated coefficients for tree density and coverage at height 3–5 m (STM3 and COV3) had a significantly positive influence on roosting sites. Conversely, tree density at height 0.5–1 m and coverage at height >5 m had a significantly negative influence on roosting sites of green-legged partridges (Table 4).

## DISCUSSION

The mean home range size of the GLP was 4.0 ha using the CHPs Hot Spot method, which excludes areas not used within the outlines of the home range (Duckham et al., 2008; Downs & Horner, 2009), and 5.7 ha using MCP, extensively used in other studies, but including areas that are less frequently used (Powell, 2000). The binary logistic regression revealed that GLPs predominantly used forest structure with dense understory saplings (vegetation height level lower than 3 m), whereas other variables were not significant for model selection. At night, radio-tagged partridges roosted alone in 73% of occasions and in pairs, or with their grown chicks, for the remainder. The partridges seem to reuse the same tree for night roosting, where mean height of the roosting tree was 5.6 m. The model selection for night roosting showed a higher percent cover of tree height 3–5 m, whereas the percent cover of tree height 0.5–1 m was lower than random locations.

**Home range size and population density.** Little is known about the home range size of tropical Southeast Asian partridges. The home range we report on is smaller compared to the one measured for the Sichuan hill-partridge (*Arborophila rufipectus*), the only regional partridge for which extensive ecological data are available, with an estimate using MCP ranging between 9.5 to 13 ha (Dai et al., 2009). The higher latitude where the latter species is found likely accounts for the lower density of resources. The GLPs' home ranges were predominantly non-overlapping (Fig. 1), which is a common finding in studies of group-territorial birds. This was the case for all but two groups. The increase in range size after their young had fledged in July was most likely in response to increased foraging requirements during chick-rearing. However, the core area of the CHPs did not overlap for any group.

The estimated density of GLPs was 16.7 males/km<sup>2</sup>. Akin to home range size, this estimate was higher than that of the Sichuan hill-partridge (weight 350–470 g), which inhabits primary (2.75 males/km<sup>2</sup>; Xu et al., 1994; Dai et al., 2009) and secondary subtropical forest (0.75 males/km<sup>2</sup>; Xu et al., 1994). The density difference between these two regions may have resulted from both natural (i.e., forest structure, topography) and anthropogenic factors (fragmentation, hunting pressure). In our study area, the forest structure was more even, the climatic conditions more stable, and the topography flatter.

**Habitat use in relation to vegetation structure.** Identifying factors that influence habitat selection at multiple spatial scales is of considerable importance in ecology. Both food availability (foraging habitat) and predation risk are likely to influence distribution patterns (Cody, 1985). In general, predators should attempt to match the distribution of their prey and to avoid areas of high predation risk (Lima, 1993). The use of dense understory vegetation recorded in this study may be a response to predation risk. Many terrestrial species, including Galliformes, tend to use densely vegetated areas (Lima, 1993), which provide good shelter and abundant food.

Some Galliformes studies suggest that predation risk is an important factor affecting habitat selection (Walsberg, 1983; Whitaker et al., 2006). Liao et al. (2008) reported that thick understory coverage, related to shrub density, was positively correlated with the habitat selection by Sichuan hill-partridge. Some species tend to use denser vegetation areas to rear their young due to their high mortality during this stage: for example, the ring-necked pheasant *Phasianus colchicus* (see Riley et al., 1998) and the Rio Grande wild turkey *Meleagris gallopavo intermedia* (see Spears et al., 2005). At our site, increased use of areas with a denser understory cover by Siamese fireback *Lophura diardi* to minimise predation risk during the chick-rearing period has been reported (Sukumal et al., 2010).

It is often assumed that dense vegetation can provide a good habitat by decreasing detection by predators. Buner et al. (2005) reported that released grey partridges *Perdix perdix* prefer areas with a high density of wild-flower strips and hedges (enhanced areas) within an intensively cultivated agricultural landscape, taking advantage of the higher food quality and concealment. In terms of movement, partridges inhabiting high-quality areas spend less time searching for food, resulting in smaller home ranges.

**Roosting behaviour.** GLPs forage on the ground during the day and roost in trees at night, akin to related species, e.g., Sichuan hill-partridge (Liao et al., 2008), white-collared hill-partridge (*A. gingica*) in Southeast China, and common hill-partridge (*A. torqueola*) in South Sichuan (Liao et al., 2007). This study showed that denser vegetation is one key factor influencing roosting habitat selection by the GLP.

The partridges mostly roosted singly or huddled together as a pair or family group on the same branch. Similar behaviour has been observed for the Sichuan hill-partridge (Liao et

al., 2008), blood pheasant *Ithaginis cruentus* (see Jia et al., 1999), Tibetan eared pheasant *Crossoptilon harmani* (see Lu & Zheng, 2002) and may be beneficial for thermoregulation, protection from predation, and foraging efficiency (Eiserer, 1984). When female GLPs were incubating, the male roosted within 60 m of the nest. This distance is slightly farther in the other Galliformes, e.g., ~300 m for blood pheasant (Jia et al., 1999), and >200 m for Tibetan eared pheasant (Lu & Zheng, 2002) and Sichuan hill-partridge (Liao et al., 2008).

**Roost site selection.** GLPs showed a strong preference for a thick cover of small trees (percent cover >3–5 m), but a lower understory cover (percent cover of understory plant height <3 m) when selecting roost sites (see Table 2 for roost-site characteristics). In addition, roosting model selection indicates that a higher percent cover of small trees, but lower percent cover of understory saplings was a key factor. These selections are likely to reduce predation by potential arboreal predators. The selection of roosting sites with lower understory coverage may make it easier for the partridges to detect ground predators. This preference for small trees with a thicker canopy cover while roosting has been observed in other birds. Sichuan hill-partridges roost on trees surrounded by a thicker shrub cover as a strategy to reduce the chance of predation, but avoid dense bamboo as it limits movement (Liao et al., 2008).

Few studies have documented whether the selection or reuse of roosting trees affects individual survival. Reuse of trees and even branches was observed in this study, but not for more than three days consecutively, which may be a strategy to avoid olfactory predators by preventing the build-up of droppings under the roosting tree.

**Implications for conservation.** Our study area encompasses primary forest with dense understory plants consisting of a complex forest structure that provides shelter for ground birds including partridges. While primary forest is likely to provide good shelter (concealment) for tropical hill-partridges, more degraded patches might be limited in providing such suitable structure due to increased edge effects or simply because of forest floor drying, which leads to a reduction of suitable understory thickets. This has been suggested as a possible cause in the dramatic reduction and possible extinction of Edward's pheasant in the lowlands of central Vietnam (Grainger et al., 2017).

Ultimately, the GLP is most likely affected by severe dispersal limitation between small forest patches over its range. Their preferred microhabitat appears incompatible with the agricultural landscape often surrounding forest patches. This will have a negative impact on the long-term survival of the species. With limited dispersal potential, shifts of suitable habitat due to climate change will impact the species distribution, as has been observed in Sichuan hill-partridges (Liao et al., 2008). Particularly important for the conservation of the species is the introduction of measures that protect, maintain, and enhance large patches of suitable habitat to maintain viable populations.

## CONCLUSIONS

Here we report details on the home range size, habitat use, roosting behaviour and roost site selection of a relatively common, but ecologically unknown *Tropicoperdix* partridge. In light of a proposed taxonomic reclassification, green-legged partridge was considered distantly related to *Arborophila* (hill-partridges), from which it was split (Chen et al., 2015), but our results show ecological similarities (Vy et al., 2018; Chhin et al., 2019). Unfortunately, a more detailed generalisation for the genus cannot be made yet as no data on similar ecological aspects are currently available for other tropical *Tropicoperdix* species and very few are for *Arborophila* species. We therefore call for the collection of similar data, expanding our ecological knowledge on *Tropicoperdix* and *Arborophila* species in general, especially where the two genera are sympatric, and on *T. chloropus* in particular.

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