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Home range, habitat use and roost-site selection by lowland female Siamese fireback *Lophura diardi* in northeastern Thailand

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Abstract. Understanding the habitat requirements of threatened species is essential for developing effective conservation and habitat management plans. The Siamese fireback (*Lophura diardi*), a lowland pheasant species found in mainland Southeast Asia, has mostly been studied in its areas of range expansion in submontane forests. However, there is limited information on the species' ranging behaviour and habitat use in their lowland habitat. We investigated the ranging behaviour, patterns of habitat use, and roost site selection using radio telemetry in a small and well-protected lowland forest in northeastern Thailand. The home range size was slightly larger during the non-breeding season (26.4 ± 3.9 SE ha) than during the breeding season (20.8 ± 2.3 SE ha). The birds selected areas with high tree density at 3–5 m height, sparse tree coverage at 0.5–3 m height and high climber density in proximity to water sources. In addition, the Siamese fireback appeared to prefer roost sites on steeper slopes with less canopy cover, presumably to facilitate escape by flushing during attempted predation. Our results provide the first ranging ecology information on lowland *Lophura* species in their typical habitat which can be used as the basis for further research of other cryptic *Lophura* species in Southeast Asia.

Key words. delaunay triangulation, evergreen forest, Galliformes, hotspot analysis, radio tracking

INTRODUCTION

Home range estimation is one of the most widely applied forms of spatial analysis in animal ecology, as it provides the most basic measurement of animal space use patterns (Downs & Horner, 2009). Typically, a home range can be defined as an area habitually traversed by an individual or a group of animals during normal activities over a given period (Burt, 1943; Jewell, 1966). The most intensively used area, often associated with the presence of important resources, is defined as the core area within a home range (Kaufman, 1962). As larger home ranges are often associated with increased risk of predator-prey interaction and other forms of competition (Powell, 2000; Yoder et al., 2004), animals limit themselves to the smallest adequate home range, the size of which is positively correlated with the resources required (Badyaev et al., 1996) and inversely related to resource availability and habitat quality (Whitaker et al., 2007).

The selection of a proper/suitable habitat that offers abundant food resources, barriers against predators and minimal human disturbance, among others, especially during nesting and roosting periods, is critical to the reproductive success and survival of bird species (Block & Brennan, 1993; Riley et al., 1998). Of equal importance are the extent to which these habitat features may vary in use across spatial scales as well as their resulting effect on fitness components and adaptation. For example, food availability during breeding is known to positively influence the clutch size and number of nesting attempts (Buckley et al., 2018), both of which can be used to compensate for losses due to predation. Thus, individuals must integrate various environmental influences on reproductive success and survival into their habitat selection strategies, which may allow alternative strategies to achieve the same net fitness (Chalfoun & Martin, 2007). Understanding the relationship between habitat preferences of threatened birds and the underlying habitat structure is important for assessing habitat quality and suitability, and for implementing adequate conservation and management plans (Morris, 2003). Suitable nocturnal roost sites, which offer conducive microclimates, access to resources required, and facilitate predator evasion, among others, represent a key habitat requirement for many bird species, considering the great amount of time they spend roosting and the associated increased risk of predation (Chamberlain et al., 2000; Woltmann, 2004; Xu et al., 2010). Therefore, roosting behaviour and roost site selection are important determinants of fitness (Cody, 1985; Elmore et al., 2004; Fisher et al., 2004; Li et al., 2010), and identifying microhabitat variables associated with roost site selection will undoubtedly aid in understanding bird-habitat relationships.

The Galliformes are an avian order that has a high proportion of species under the threat of extinction (26% of the 308

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galliform species are listed as threatened on the IUCN Red List, 2019). In Southeast Asia, 66% of the 76 extant species are threatened. Galliformes tend to be cryptic, in some cases not particularly vocal, and prefer dense forest habitats, making most traditional bird survey methods difficult to implement. As a consequence, the order is understudied (IUCN, 2019). Overall, little is known about their distribution, basic life history, and habitat affinities, which are prerequisites for further understanding and management (Conroy & Carroll, 2001). Intensive studies on 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).

In Thailand, the Siamese fireback, *Lophura diardi*, listed as Least Concern (IUCN, 2019), is relatively abundant in some protected areas where it is predominantly found in lowland forests (BirdLife International, 2012). It appears to tolerate considerable habitat degradation and persists in areas with high hunting pressure (BirdLife International, 2012; Suwanrat et al., 2015). In the wild, the species has been reported to be polygynous with the presence of solitary male floaters and multi-male groups (Savini & Sukumal, 2009; Suwanrat et al., 2015), and omnivorous, foraging on all kinds of fruit, leaves, insects, and worms (Johnsgard, 1999). Recently, this lowland species has moved into submontane habitat where it occurs sympatrically with the Silver Pheasant, *L. nycthemera* (Round & Gale, 2008). Previous studies have reported that Siamese fireback shows variation in home range size during different reproductive periods; it prefers flatter and wetter areas with greater understorey cover during the mating season, and then moves to areas with higher ground vegetation density while rearing young chicks (Sukumal & Savini, 2009; Sukumal et al., 2010). However, these studies were based on a very small sample size from a single population and location. Moreover, the general lack of quantitative data has hindered our understanding of the patterns of habitat selection in other forest habitats throughout its range. Pheasants typically roost in trees of varying heights, from mid-storey to canopy (Johnsgard, 1999). Praditsup et al. (2007) observed a single Siamese fireback male at two separate roosting sites surrounded by thick shrub cover, which may be a strategy to reduce the risk of predation.

In this study, we focused on the relatively abundant population of Siamese fireback inhabiting Sakaerat Biosphere Reserve, a fragment of the lowland dry evergreen forest in northeastern Thailand, making it an excellent candidate for quantitative investigation of ranging behaviour, habitat use, and roost site selection. This knowledge is vital for understanding other *Lophura* species, a genus currently lacking in basic empirical knowledge. We estimated home ranges and ranging patterns of eight Siamese fireback individuals in their typical lowland forest habitat and then compared the results to existing data from a submontane population (Sukumal et al., 2010). Sukumal & Savini (2009) observed two female Siamese firebacks occupying a large home range (41.4 ± 7.7 SD ha) within the submontane forest, which was probably due to the slope (>14°) and sub-optimal conditions. Therefore, we hypothesised that the population inhabiting the lowland forest would have a smaller home range than their submontane counterpart, considering the flat topography of the former. We aimed to study the roosting behaviour and determine which habitat variables influence roost site selection and patterns of habitat use during different reproductive cycle periods. We also hypothesised that if the selection of roosting sites is a consequence of predation, then the birds should select areas associated with invisibility and inaccessibility.

MATERIAL & METHODS

Study site. The study was conducted at Sakaerat Environmental Research Station (SERS) (14°30′N and 101°55′E, Fig. 1), a UNESCO Biosphere Reserve since 1967. The reserve covers an area of 78.09 km^2 at an elevation of 280–762 m above sea level. Sakaerat has two major natural forest types: dry evergreen (46.82 km^2) and dry dipterocarp (14.51 km^2), and two large patches of plantation consisting of mature (>20 years) acacia and eucalyptus (14.51 km^2). The remaining area is covered by bamboo (1.12 km^2), grassland (0.93 km^2), and operational buildings (0.25 km^2) (Thailand Institute of Science and Technology, 2012).

The intensive study area within SERS is dominated by dry evergreen forest with tree species such as *Hopea ferrea*, *H. odorata* and *Hydnocarpus ilicifolia*. The study area is located adjacent to the 3–6 km markers of the main paved road entering the protected area, at 350–580 m elevation (Suwanrat et al., 2014). Siamese fireback is quite widespread and is a common sight along the roadsides, forest edges, and nature trails. The station staff irregularly provided the birds with a small quantity of rice in two areas close to the road (Fig. 1) as the station hosts small-scale school-group science camps to teach children about wildlife and forest. During the study period, the average annual precipitation was 1,071 mm, divided into a dry season (November–April, 210 mm average monthly rainfall), and a wet season (May–October, 860 mm average monthly rainfall). The average annual temperature is 26.1°C (ranging from 19.3–32.8°C), and the average relative humidity is 82.2%, with a monthly range of 74–87% (Suwanrat et al., 2014).

Radio tracking. Siamese firebacks were caught using mist nets (Keyes & Grue, 1982) and modified traditional leg snare traps, made from bamboo and soft polyester string in two trapping periods. The first trapping period was from February to April 2010, and the second period was from December 2010 to February 2011. All birds caught were ringed with Thai Royal Forest Department (RFD) metal rings and colour rings to allow individual recognition. In addition, each captured bird was fitted with a 15 g necklace-type radio transmitter (model RI-2B, Holohil System Ltd.) that weighs less than 5% of the animal's weight and has a lifespan of approximately 24 months. Data recording of an individual's location started a few days after capturing and continued as long as the transmitter worked, until the bird died or the radio-tag fell off. We located the birds by homing, meaning that we tracked and approached the radio-collared

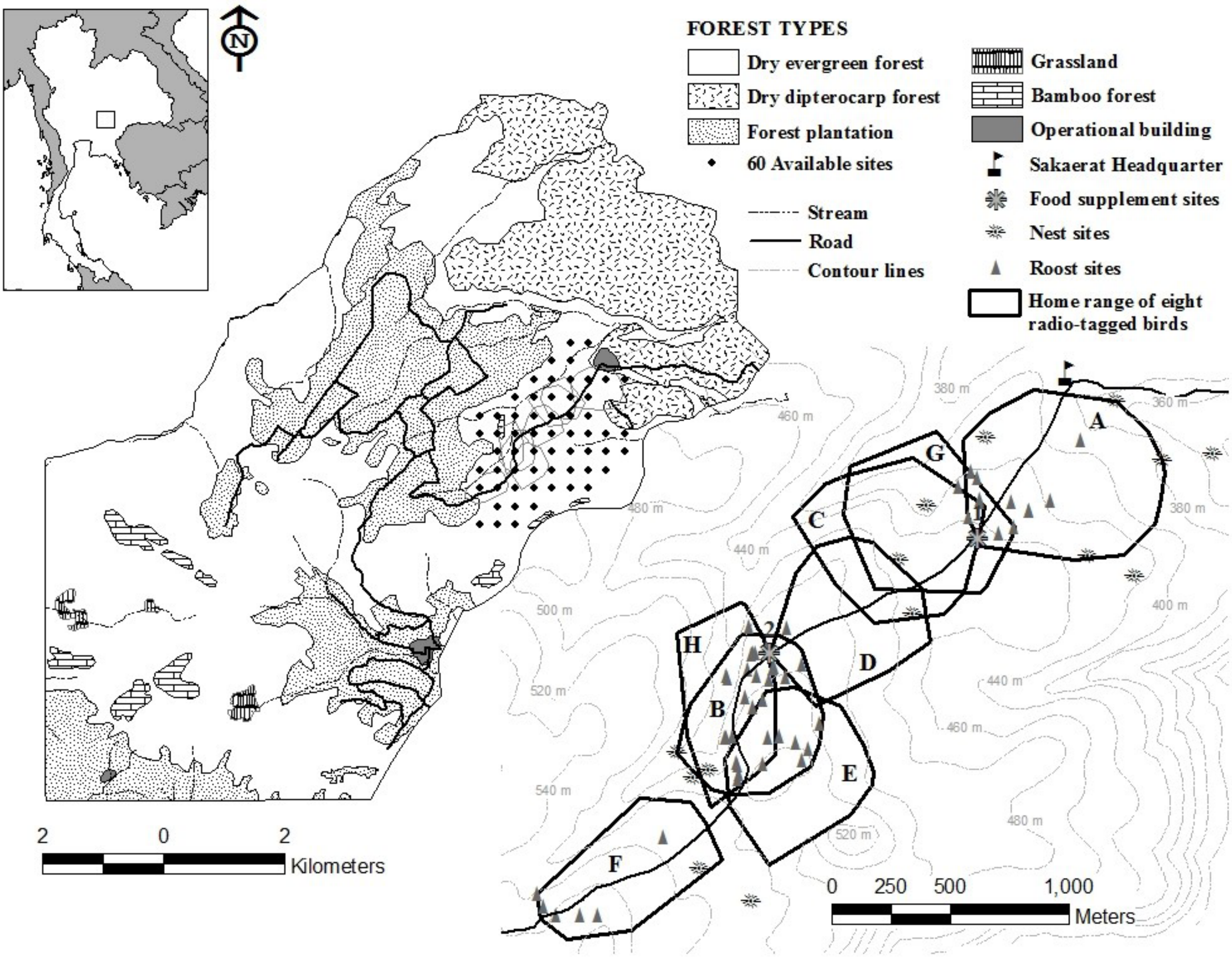

Fig. 1. Location of Sakaerat Environmental Research Station (SERS), northeastern Thailand, including the locations of 60 available sites, two food supplementary sites, 14 nesting sites, and 52 roosting sites. Polygons shown are the home range boundaries of the eight radio-tagged Siamese firebacks (group A–H).

animal using a digital scanning receiver (R410, ATS) with a three-element handheld Yagi antenna at a distance from which it could be directly observed and its exact position recorded. Tracking of each collared animal occurred, on average, every two days to limit the impact of disturbance on the behaviour of individuals. We recorded positions by geographic coordinates using a Garmin 60CSx (GPS; ± 8 m accuracy), as well as group size and composition. Whenever a dead bird or detached transmitter was found, we tried to identify predatory events by analysing the carcass and/or transmitter for bite marks.

We searched for roost sites of Siamese firebacks by tracking birds early in the morning (before 0600 hours) before sunrise. Each roost tree was georeferenced. After the bird left the roost tree, we recorded the tree species, diameter at breast height (DBH), perch height, tree height and distance from the roost point to the tree trunk. In addition, the percentage of vegetation cover above and under the roost point was visually estimated by a single observer (S. Suwanrat), and characteristics of the habitat surrounding the roost tree were recorded using 5 and 10 m radius circular plots centred on the roost tree (see details of habitat measurements below, Fig. 1).

Siamese fireback reproductive cycle. Based on previous studies (Savini & Sukumal, 2009; Sukumal et al., 2010) and our visual observation of the successful hatching of the bird's eggs, we divided the reproductive cycle of breeding females into four periods. Period 1) mating period (February–April), when the dominant male largely monopolises proximity to all females in the group while other males are represented by floaters, solitary males either dispersed from their natal group or secondary disperser forced out after a male take over. Period 2) nesting/incubation (April–June), when females leave their groups to nest and incubate. Period 3) chick rearing (the initial period after hatching, approximately 1–3 months), females travel alone with their chicks. Period 4) non-breeding (July/August–February), females and grown chicks re-associate with the original groups of adults. For non-nesting females or those whose eggs were depredated, we divided the cycle into two periods: 1) breeding period (February–June), corresponding to the above-mentioned Periods 1, 2 and 3, and 2) non-breeding period (July–

February), corresponding to the above-mentioned Period 4 when the last nesting attempt fails and females re-associate with the groups.

Habitat measurements. We employed a used-available design to assess patterns of habitat use by Siamese fireback (Manly et al., 2002; Casazza et al., 2011). We focused on the radiolocations obtained from the five females which were non-nesting females or those whose eggs were depredated during 2011. We ignored the two females whose eggs successfully hatched due to the small sample size and overall small number of locations recorded during the chick rearing period. We randomly selected 30 locations for breeding and non-breeding periods for each of the birds to measure characteristics of the habitat surrounding each location, totalling 150 locations per reproductive period. Features of the habitat were recorded using 5 and 10 m radius circular plots centred on sites where the birds were first located following Martin et al. (1997) and Sukumal et al. (2010). For the 5 m plot, we measured the slope degree using a clinometer. The distance from the centre of the plot to streams that appeared during rainy season was measured using data from a stream polyline dataset provided by the Department of National Parks, Wildlife and Plant Conservation (DNP), and by direct observation. Measurements were made using ArcGIS 9.3 (Environmental Systems Research Institute, Redlands, CA, USA). We counted the number of woody climbing plants (lianas) and all understory stems with DBH ≤10 cm, which were categorised into four classes based on their height: 0.5–1, 1–3, 3–5 and >5 m. The percentage vegetation cover was visually estimated by a single observer (S. Suwanrat) for each height category, including ground covered by vegetation below 0.5 m. For the 10 m plot, we measured the DBH of all trees with DBH >10 cm and estimated their basal area. Habitat measurements were taken at the end of each reproductive cycle period.

To characterise the habitat, 60 available locations, placed 300 m apart (Fig. 1), were systematically selected from the locations generated across the study area using ArcGIS, considering the approximate home range size (30 ha) of Siamese fireback (Sukumal et al., 2010). These were overlaid with the recorded bird locations. We established 5 and 10 m radius circular plots around the available locations and took the same measurements as we did for the bird locations. Although the available locations extended beyond the recorded bird locations, camera-trap photos from our previous study (Suwanrat et al., 2015) confirmed they were within the habitat of Siamese firebacks in that area. Due to the fact that these sites were dry and held no seasonal streams, the vegetation structure and coverage did not vary between seasons. We took habitat measurements for available plots in the ensuing year, in June and August 2012. We then treated those habitat parameters as available year-round to assess patterns of habitat use during different reproductive periods and identify which habitat variables influence roost site selection by birds.

Home range analysis. Home ranges were delimited using both 95% Minimum Convex Polygons (MCP) and Characteristic Hull Polygons (CHP) (Downs & Horner, 2009). The 95% MCP was calculated in Arcview GIS 3.2a with the Animal Movement Extension (Hooge & Eichenlaub, 1997), allowing for a comparison with previous studies. We also used a recently developed analytical method (José-Domínguez et al., 2015), which integrates characteristic hull polygons (Downs & Horner, 2009) with spatial statistical criteria (hereafter CHP Hot Spot) to define the boundaries of a home range (HR) and core area (CA). We estimated annual home ranges as well as breeding and non-breeding home ranges for each bird with both the 95% MCP and CHP Hot Spot methods using all radio-locations. The home range size was not estimated during Period 2 due to the minimal movement observed. Also, because of the small number of birds caught in 2010 (n = 2) and radio-tagged birds remaining in 2012 (n = 4), we calculated the mean annual breeding and non-breeding home ranges based on the data obtained from 2011, and also used the home range estimated from 2011 to test the differences between periods and methods. The normality of home range data distribution was examined using the Shapiro-Wilk test. The Bartlett Test was used to determine the homogeneity of variance between different samples. As the home range data met assumptions of normality and the variance was homogeneous, one-way analysis of variance (one-way ANOVA) was used to compare the home range means estimated for the periods by different methods. The non-parametric Mann-Whitney *U*-test was used to compare the mean annual home range size for groups provided with food and those not. The statistical tests were performed using the R program 2.13.0 (R Development Core Team, 2011) and the values given are mean ± SE.

Patterns of habitat use analysis. We fit multinomial logistic regression models with maximum likelihood (Bañuelos et al., 2008; Sukumal et al., 2010; Dinkins et al., 2014) to evaluate female habitat selection during breeding and non-breeding periods. The presence/absence of females in each period was entered as the dependent variable to identify which habitat features significantly influenced the habitat use. A better approach to analyse this type of data is using generalised linear mixed models with female identity as a random factor to account for non-independence of locations collected from the same female in different years. However, the sample size for the roost site analysis was relatively small (five radio-collared birds, 52 roosting sites and 60 random points) and did not allow us to fit the mixed model (Clark & Linzer, 2015). Instead, we used binary logistic regression to identify the variables that influenced roost site selection. Vegetation covers were previously transformed with the arcsine transformation (Sokal & Rohlf, 1995). In order to assess roosting site availability, we used the same data collected from the 60 available plots generated using ArcGIS. The explanatory variables used for building the models were transformed by dividing each numeric variable by twice its standard deviation (Gelman, 2008) to ensure that all variables have the same scale. Highly correlated (r >0.5) variables were selected one at a time and used to fit the regression model. The most parsimonious model, using Akaike's Information Criterion corrected for small sample size (AIC_c; Burnham & Anderson, 2002), was considered the best-fit model. When no single model was overwhelmingly supported by the data, meaning that it shown model uncertainty lower than two ($\Delta AIC_c < 2$), model averaging was used (Burnham & Anderson, 2002). The 85% confidence interval was used to identify variables influencing roost-site selection when model uncertainty occurred, because it renders model selection and parameter evaluation criteria more congruent than the narrower 95% confidence interval (Arnold, 2010). Overlapping with zero and an 85% confidence interval indicates a weak effect or no effect. All analyses were performed with R program 2.13.0 using 'nnet' and 'MASS' (Venables & Ripley, 2002), 'AICcmodavg' (Mazerolle, 2012) and 'PresenceAbsence' (Freeman & Moisen, 2008) packages.

RESULTS

A total of 20 Siamese firebacks (5 males, 15 females) were banded. Of these, 18 birds (3 males, 15 females) were radio-collared. The radio collars of five birds (2 males, 3 females) failed after a few days. Five birds (1 male, 4 females) were depredated. There was no indication that the birds were injured by the snare or mist net, and no bird died as a result of capture stress. Eight females from eight distinct groups (hereafter A, B, C, D, E, F, G, and H; Fig. 1) were tracked for 2 to 27 months, and two of the eight groups (group E and F) were not provided with supplementary food.

Home range size patterns. The mean annual home range size of Siamese fireback in 2011, using 95% MCP, was 31.9 ± 2.1 ha (n = 7), 20.8 ± 2.3 ha (n = 8) during the breeding season and 26.4 ± 3.9 ha (n = 7) during the non-breeding season (Table 1, Fig. 2). Using CHP Hot Spot analysis, the mean annual home range size was 27.7 ± 1.5 ha, 18.3 ± 1.9 ha during the breeding season and 21.7 ± 2.7 ha during the non-breeding season (Table 1, Fig. 2). The mean annual core area, defined using CHP Hot Spot, was 6.6 ± 0.7 ha, with 3.0 ± 0.8 ha during the breeding season and 3.4 ± 0.9 ha during the non-breeding season (Table 1). The estimated home range size for the breeding season was slightly smaller than that for the non-breeding season. However, no significant difference was detected with either the 95% MCP ($F_{1,13} = 1.05$, $p = 0.32$) or CHP Hot Spot ($F_{1,13} = 0.76$, $p = 0.40$).

The mean annual home range sizes of groups provided with food were 33.34 ± 2.54 ha (n = 6) using 95% MCP and 29.04 ± 1.62 ha (n = 6) using CHP Hot Spot methods, whereas the mean annual home range sizes of groups not provided with food were 28.25 ± 3.55 ha (n = 2) using 95% MCP and 24.20 ± 2.60 ha (n = 2) using CHP Hot Spot methods. Groups provided with supplementary food seem to have a larger home range than those not provided with food. However, no significant difference was detected, with either the 95% MCP (Mann-Whitney *U*-test, W = 5.00, p = 0.25) or CHP Hot Spot (Mann-Whitney *U*-test, W = 5.00, p = 0.25).

Eggs of females A and C hatched successfully in 2011, and both females showed a similar variation in home range size during different reproductive periods (Table 1, Fig. 2). The 95% MCP indicated that home range size decreased when females left the group after the mating season and started to range alone with their chicks (Period 3, 9.5 ± 0.7 ha, n = 2). It increased again when females re-joined the group with their grown chicks (Period 4, Fig. 2). Similar results were obtained with CHP Hot Spot for the overall home range (Table 1). Overall, higher annual home range estimates were obtained using the 95% MCP method in comparison with the CHP Hot Spot (Table 1), although these were not significantly different ($F_{1,10} = 1.42$, $p = 0.26$).

Patterns of habitat use. A total of 18 regression models were fitted to explain habitat use of Siamese fireback during different seasons. Model selection indicated that the best fit model with the highest support ($AIC_{weight} = 0.97$, Table 2, Fig. 3) included tree coverage at 1–3 m height, tree density at 3–5 m height, number of climbers, and distance to streams. The estimated beta coefficient for tree coverage at 1–3 m height and distance to streams was negative, suggesting that females preferred areas with less tree coverage at 1–3 m height, closer to streams. However, the beta coefficient for tree density at 3–5 m height and number of climbers was positive, suggesting that females preferred areas with higher densities of understorey stems at 3–5 m height and climbers (Table 3).

Roosting behaviour. After 66 tracking days, a total of 52 different roosting sites (49 trees and 3 climbers) were used by five radio-tagged birds from four different groups, and 10.3% of these were used more than once (Table 1). Twenty-five roosting sites (48.1% of total) were located in core areas, 12 of which were used during the breeding periods and 13 during non-breeding periods.

Characteristics of roosting trees and roost site selection. The mean tree height was 8.2 ± 0.3 m with an average DBH of 9.1 ± 0.7 cm. The mean perch height was 5.6 ± 0.2 m, and the mean distance from a roost point to the nearest tree trunk was 2.7 ± 0.2 m. The mean vegetation cover above and under the roost point were 77.32 ± 1.49% and 23.85 ± 1.79%, respectively.

A candidate set of 16 regression models were fitted to explain roost site selection. Model selection indicated that the best model had the highest support while the second best model had reasonable support ($\Delta AIC_c = 0.96$; Table 2). Model averaging was estimated for the coefficients of the variables in the confidence set. The estimated coefficient for [degree of] slope had a significantly positive influence on roost site selection, whereas those for tree coverage at >5 m height and basal area of large trees had a significantly negative influence (Table 3).

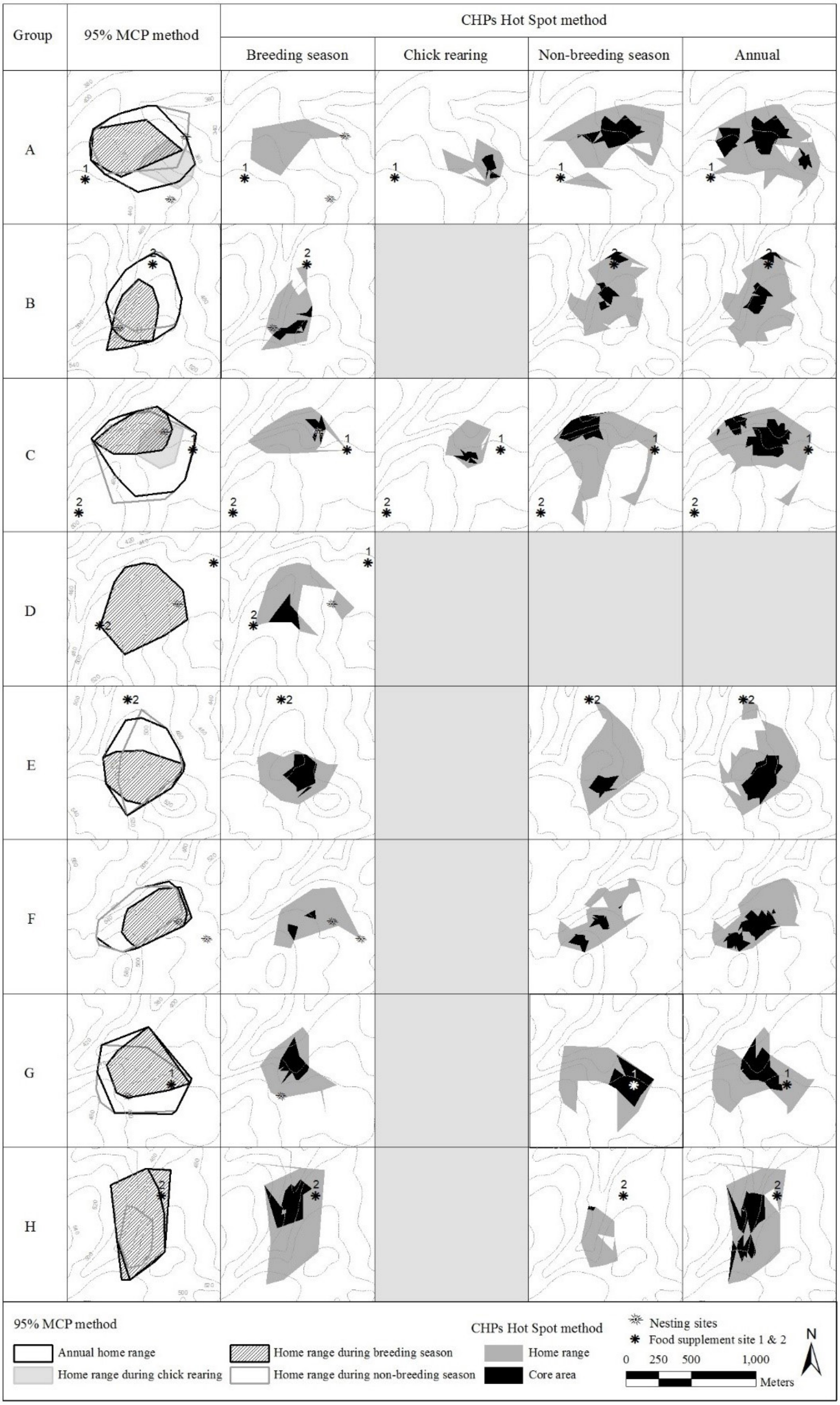

Fig. 2. The variation in home ranges and core areas of the eight female Siamese fireback in 2011 during different reproductive periods, estimated using 95% MCP and CHP Hot Spot methods. Locations shown were the food supplement sites (1 and 2) and nesting sites during the breeding season.

Table 1. Summary of the number of radio locations, nest attempts, roost sites, and home range size (ha) of eight radio-tagged Siamese firebacks estimated during the reproductive periods between 2010–2012, excluding period 2 (nesting), using 95% MCP and CHP Hot Spot methods. Period 1: mating period (February–April) or breeding season for non-nesting females or females with depredated nests (February–June), Period 2: Nesting (usually nesting start in April and end in June), Period 3: chick rearing (the initial period after hatching, 1–3 months), Period 4: non-breeding (July/August–February).

Group	Year	No. of radio-locations					No. of nest attempted/status		No. of roost sites	95% MCP method (ha)				CHPs Hot Spot method (ha)							
		Period 1	Period 2	Period 3	Period 4	Total				Period 1	Period 3	Period 4	Annual	Period 1		Period 3		Period 4		Annual	
		Mating	Nesting	Chick rearing	Non-breeding		Failed	Success		Mating	Chick rearing	Non-breeding		Mating		Chick rearing		Non-breeding			
														HR[a]	CA[b]	HR	CA	HR	CA	HR	CA
A	2010	35	Inc.(f)	–	56	91	1	0	13	19.4	–	39	44	23	1.8	–	–	34.3	7.1	35	7.3
	2011	39	Inc.(s)	31	92	162	2	1	–	19.8	10.2	31.8	38.3	16	0	8.5	1.2	29	6.1	35	9.2
	2012	72	Inc.(p)	–	–	–	3	0	–	28.8	–	–	–	19	4	–	–	–	–	–	–
B	2010	108*	–	–	–	–	–	–	21	33.6	–	–		36	6	–	–	–	–	–	–
	2011	44	Inc.(f)	–	110	154	1	0	–	14.6	–	25.2	29.2	14	2.1	–	–	22.6	2.4	26	3.1
	2012	49	Inc.(f)	–	64	113	1	0	6	11.9	–	20.1	23.7	9.9	0.8	–	–	15.8	2.6	21	3.4
C	2011	33	Inc.(s)	36	77	146	1	1	–	14.7	8.8	42.5	38.5	16	1.3	8.4	0.9	28.1	4.6	28	8.3
D	2011	35	Inc.(p)	–	–	–	1	0	–	31.9	–	–	–	18	2.7	–	–	–	–	–	–
E	2011	50	–	–	71	121	–	–	–	18.5	–	24.4	31.8	18	4.8	–	–	22.9	2	27	6.5
	2012	78	–	–	45	123	–	–	6	18.4	–	18.2	22.1	18	2.6	–	–	18.6	2	22	4.2
F	2011	44	Inc.(f)	–	104	148	2	0	–	16	–	21.4	24.7	17	0.9	–	–	15.7	2	22	5.6
	2012	67	Inc.(f)	–	45	112	1	0	6	15	–	25.1	27.8	12	2.6	–	–	26.2	1.9	25	4.6
G	2011	47	Inc.(f)	–	37	84	1	0	–	20.7	–	30.2	25.7	17	5.9	–	–	24.2	6.4	26	6.1
H	2011	51	–	–	30	81	–	–	–	29.8	–	9	35	31	6.4	–	–	9.1	0.1	30	7.6

Note HR[a] = Home range estimated, CA[b] = Core area estimated, Inc. = Incubating (f: nest failure, s: nest success, p: nest and/or bird was depredated), *data obtained from collared male before the radio tag fell off and then the female in group was caught the following year.

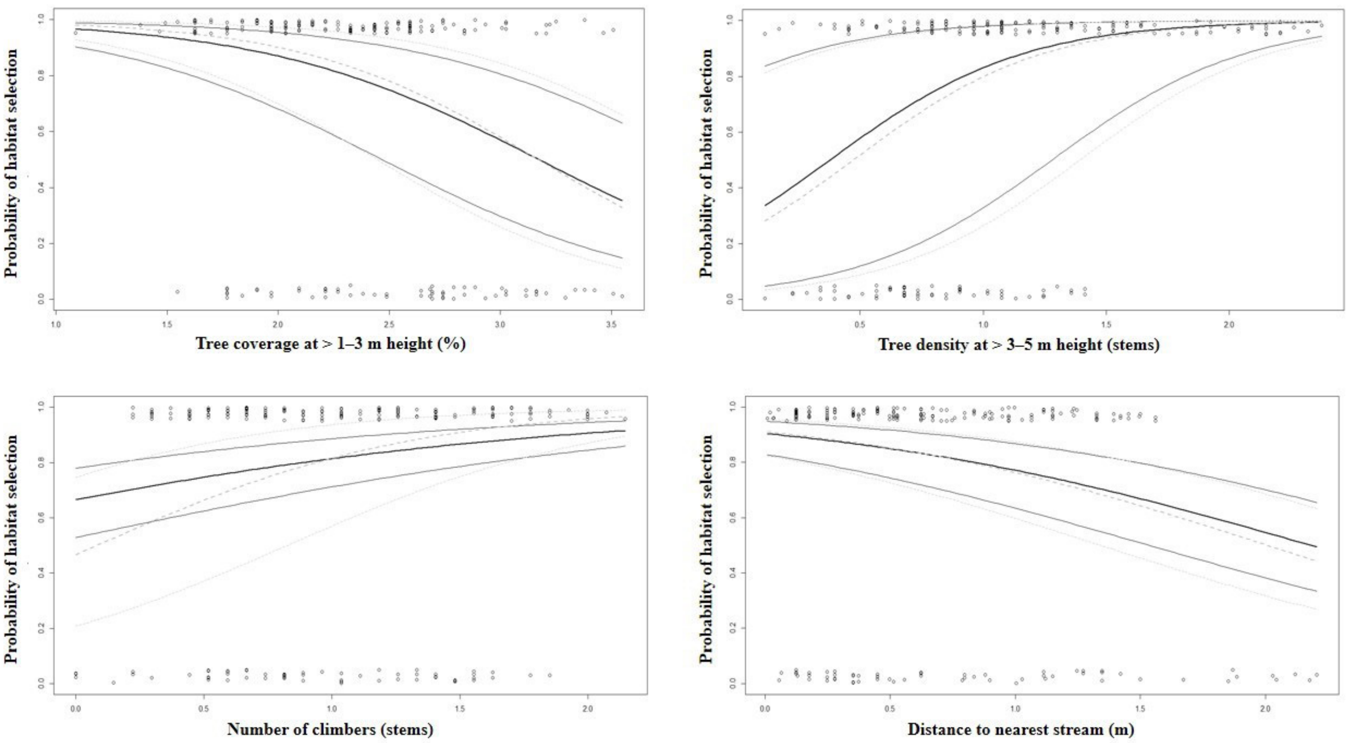

Fig. 3. The occurrence probability of Siamese fireback in relation to habitat variables. Shown are predicted values and 95% confidence limits for breeding (black solid lines) and non-breeding (gray dashed lines) periods.

DISCUSSION

Understanding the ranging behaviour and habitat use of pheasants is fundamental to effective habitat management practice. Our findings are the first step towards a more detailed knowledge of the responses of Siamese fireback to habitat conditions in lowland dry evergreen forests. However, caution must be taken when interpreting our results given the small sample size. We also had to limit our results to females, as there is little information available on males in these habitats.

Home range variation. Our study on lowland Siamese fireback shows that their home range size varied and was larger during the non-breeding period compared to the breeding period. The smaller breeding home ranges may result from a trade-off between food requirements and cover needed to avoid predation. We suggest that females limit their movement within optimal habitat during the breeding season, particularly during nesting, resulting in smaller home ranges. Similar patterns have been observed for green peafowl *Pavo muticus* (Sukumal et al., 2017) and great argus *Argusianus Argus* (Winarni et al., 2009). However, various other factors could impact the size of the home range, such as body size (Jenkins & Benn, 1998), habitat quality and food abundance (Elchuk & Wiebe, 2003), and human disturbances (Koehler & Pierce, 2003). The home range sizes of two observed females with successful nests significantly declined during Period 3 and then expanded again in Period 4, as also observed for a submontane population of Siamese fireback (Sukumal et al., 2010). The reduction in home range size during Period 3 was related to the limited mobility of young chicks (Klinger & Riegner, 2008).

Siamese fireback in SERS exhibited a smaller (30%) annual home range (31.9 ± 2.1 ha, n = 7) than previously reported for the submontane population in Khao Yai National Park, northeastern Thailand (41.4 ± 7.7 ha, n = 2, Sukumal et al., 2010), although the sample size in that study was smaller. The home range size difference between these two sites may have resulted from both natural and anthropogenic factors. The submontane population in the Mo Singto area, Khao Yai National Park, generally preferred flatter and wetter areas and likely expanded their home ranges as these preferred areas were patchily distributed at submontane elevations (Sukumal et al., 2010). On the other hand the lowland forest found in SERS, considered the suitable habitat for the species as it is flatter and a more homogenous topography allowing for reduced home range sizes. No direct effect of the supplementary feeding on the ranging behaviour of targeted groups was recorded. Two non-mutually exclusive reasons can be advanced: (1) the station provided Siamese fireback with rice irregularly, depending on when student groups visited, which normally happened twice per week during the study period, and (2) the station provided an insufficient quantity of rice for it to make a significant impact.

Mean annual home range estimated using 95% MCP was slightly larger than the one estimated using CHP Hot Spot. Although 95% MCP allows for comparison with previous studies, this method tends to overestimate sizes by including areas never truly used and does not provide information about space use within the polygon (Powell, 2000; José-Domínguez et al., 2015). In our study, areas in the MCP home range that were excluded by the CHP Hot Spot method had special characteristics, i.e., they were open patches of dry dipterocarp forest, dams and a helipad, which the birds tend to avoid. This study highlights the usefulness of the CHP

Table 2. The set of logistic regression models with accumulated Akaike weights sum of ≥0.95 explaining patterns of habitat use and roost site selection by female Siamese fireback. Habitat variables: Cover 2 and Cover 4, respectively, denote tree coverage at height 1–3 m and >5 m, Stem 3 denotes tree density at height 3–5 m, BA denotes basal area of trees with DBH >10 cm, Climber denotes number of woody climbers, Stream denotes distance to the nearest stream, and Slope is degree of slope area.

Model	**K**	**ΔAIC**	w_i
Pattern of habitat use during different periods[a]			
Cover 2 + Stem 3 + Climber + Stream	10	0.00	0.97
Cover 2 + Stem 3 + Climber + BA	10	8.01	0.02
Cover 2 + Stem 3 + Climber	8	8.61	0.01
Null model	2	73.87	0.00
Roost-site selection[b]			
Slope + Cover 4 + BA	4	0.00	0.62
Slope + Cover 4	3	0.96	0.38
Null model	1	43.38	0.00

[a]Multinomial logistic regression
[b]Binary logistic regression

Table 3. Results of logistic regression showing the influence of variables on habitat use by female Siamese fireback during different periods. For roost site selection, estimates of coefficients were derived from model averaging and unconditional SE and its 85% confidence interval.

Variables	**Coefficient**	**SE**	**Lower 95% CI**	**Upper 95% CI**
Pattern of habitat use during different period[a]				
Breeding period				
Tree coverage: height 1–3 m	–1.62	0.36	–2.33	–0.91
Tree density: height 3–5 m	2.56	0.46	1.66	3.47
Number of climber stems	0.79	0.37	0.06	1.53
Distance to the nearest stream	–1.03	0.33	–1.68	–0.37
Non-breeding period				
Tree coverage: height 1–3 m	–1.89	0.37	–2.62	–1.16
Tree density: height 3–5 m	2.61	0.47	1.7	3.53
Number of climber stems	1.62	0.38	0.87	2.38
Distance to the nearest stream	–1.16	0.34	–1.83	–0.48
	Coefficient	**Uncond. SE**	**Lower 85% CI**	**Upper 85% CI**
Roost site selection[b]				
Model averaging				
Slope	2	0.58	1.17	2.83
Tree coverage: height >5 m	–2.69	0.69	–3.68	–1.69
Basal area	–0.93	0.55	–1.71	–0.14

[a]Multinomial logistic regression, [b]Binary logistic regression

Hot Spot method in determining the home range and core area. However, the effect of sample size on the accuracy of CHP Hot Spot method needs to be investigated.

Patterns of habitat use. Our results suggest that patterns of habitat use by Siamese fireback may be strongly influenced by vegetation characteristics during different seasons. The birds showed a distinct preference for secondary forest patches with dense tree stems at 3–5 m height, sparse tree coverage at 0.5–3 m height, and high climber density. Within known home ranges, those characteristics were provided by patches of *Streblus ilicifolius,* a thick spiny tree which is about 3–5 m tall. Patterns of habitat use also indicated that the birds not only selected habitats that provided the best food resources, but also those with sufficient vegetation cover, which was most likely to reduce predation risk. We suggest that using patches of *S. ilicifolius* offers shelter from canopy-dwelling raptors and increases the likelihood of detecting predators approaching from the ground. This habitat structure is similar to that used by the endangered Sichuan partridge *Arborophila rufipectus* (Liao et al., 2008; Bo et al., 2009). Siamese fireback selected areas during the breeding season to ensure maximum reproduction and survival probability, whereas in the non-breeding season, birds selected areas suitable for foraging and predation avoidance (Jones, 2001). Furthermore, Siamese fireback preferred areas in close proximity to water sources, particularly during the non-breeding period. This can be associated with lower precipitation and higher proportion of bare ground during the dry season. Water represents a physiological need as the primary foraging behaviour of Siamese fireback involves searching for food in damp leaf litter and digging up plant roots, similar to many other Galliformes (Mackinnon et al., 2000; Lu & Zheng, 2003; Wu et al., 2008). Thus, Siamese fireback appears to avoid drier and harder ground farther from stream beds and areas with lower precipitation.

Roost site selection. Siamese firebacks mostly roost in understorey trees which may allow them to detect potential threats during periods of poor visibility. Higher perches and those farther from tree trunks greatly reduce the chance of attacks by nocturnal predators (i.e., *Paradoxurus hermaphroditus*, *Viverra zibetha*, *V. megaspila*, *Prionailurus bengalensis*, Suwanrat et al., 2014).

The preference of steeper slopes for roosting is considered a common characteristic for avian roosting (Cody, 1985). The steeper the slope, the higher chances birds have to escape by gliding when predators attack. It is therefore not surprising that Siamese firebacks always roost facing downslope, and often glide in a downslope direction when suddenly disturbed, as observed among other Galliformes (Cong & Zheng, 2008; Li et al., 2010; Xu et al., 2010; Ong-in, 2011). Although we have no clear data to support why the birds select the area associated with less tree coverage at >5 m height for roosting, we present two possible hypotheses based on our observations. First, when attacked by predators, Siamese firebacks have two avoidance strategies: gliding downslope or flushing through the open canopy. Selecting open canopy habitat can facilitate escape by flushing. Second, using areas with less canopy cover may not be a consequence of roost site selection but is rather related to the bird activity before entering the roosting site, in the late afternoon, or after leaving the roosting site, in the early morning. Longer periods of light penetration to the forest floor may help birds maximise foraging opportunities (Smith & Dallman, 1996). Roosting in areas with low canopy cover allows the birds to receive the last evening light or the earliest morning light in comparison to adjacent areas, providing a vantage point for predator detection prior to entering or leaving the roost. This stands in contrast to previous studies on Galliformes which indicated that forest-dwelling species usually roost in large-diameter trees, in areas with high tree density (e.g., Thompson, 2003; Ai-Wu et al., 2006), high canopy cover (e.g., Rumble, 1992; Lu & Zheng, 2002; Thompson, 2003; Jia et al., 2005; Sweringin, 2007), and where large-diameter trees are abundant (e.g., Rumble, 1992; Thompson, 2003; Sweringin, 2007). We suggest that roost site selection of Siamese fireback is not random; they prefer a place that can enhance predation avoidance while maximising foraging success.

Conclusions. Our results suggest that Siamese fireback shows seasonality both in home range size and habitat selection, both of which were correlated with environmental conditions, reproductive behaviour, and energy requirements. The species in Sakaerat Biosphere Reserve primarily selected habitats that provided access to food and water resources and shelter. Birds selected areas on steep slopes with less canopy cover for roosting, presumably to facilitate escape-flushing in response to danger. Our results provide the first information on lowland *Lophura* species in their original microhabitat and can form the basis for further research of other cryptic *Lophura* species in Southeast Asia.

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