

SUB-MONTANE HABITAT SELECTION BY A LOWLAND PHEASANT

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ABSTRACT. – The specific habitat and behavioral reasons for elevational range shifts in a variety of species have been poorly documented. Here we investigated the habitat use of a lowland species, Siamese Fireback (*Lophura diardi*), which has expanded its range into sub-montane habitat in Khao Yai National Park in northeastern Thailand where it had not been previously recorded. We found that this Siamese Fireback population tends to use topographically flat areas similar to topography found in lower elevation habitats, with the exception of nest sites, which were placed on steeper slopes, presumably to facilitate predator detection and escape. As reported for other lowland populations, these birds also selected areas with greater under-story cover during the mating season and moved to areas with higher ground vegetation density while rearing young chicks. However, animals in our study area had larger home range sizes than reported for similar lowland *Lophura* species. This difference may be related to a reduced availability of lowland-like habitats in the newly occupied sub-montane areas.

KEY WORDS. – Khao Yai National Park, *Lophura*, Lowland forest species, Siamese Fireback, Thailand.

INTRODUCTION

Changes in distribution of organisms can have several underlying causes such as habitat alteration (Spiegel et al., 2006), including that from climate change (Walther et al., 2002; Hansen et al., 2006; Kannan & James, 2009), food resource degradation (Charmantier et al., 2008; Kimura et al., 2001) or competition from invasive species (Reynolds et al., 2003). Shifts in elevational range should be most obvious in species distributed across an elevational gradient (Hughes, 2000). Species normally restricted to lowland habitats may shift their range to occupy habitats at higher elevations leading to possible detrimental effects for the resident montane species, e.g., greater competition and reduction in their population sizes (Shoo et al., 2005). In addition, lowland species 'moving up' an elevational gradient must adapt to different topographies and micro-habitats (Sekercioglu et al., 2007). Unfortunately, it remains to be seen whether such responses are typical amongst the majority of threatened species across elevational gradients since quantitative data are lacking. The lack of information makes it exceedingly difficult to frame a broad agenda for conservation/habitat management strategies for these environments.

Siamese Fireback (*Lophura diardi*; Bonaparte, 1856) is a distinctive and threatened galliform species restricted to lowland and foothill forest habitat (< 800 m elevation) of South-East Asia. Populations are considered to be in

decline throughout its geographic distribution due to habitat fragmentation and degradation (Round, 1988), with a global population estimated at fewer than 10,000 individuals (McGowan & Garson, 1995; Madge & McGowan, 2002). However, few quantitative data exist regarding its habitat requirements, behavioural ecology and mating systems (Johnsgard, 1999). In the past twenty years the numbers of Siamese Fireback recorded at higher elevations (> 800 m) in Khao Yai National Park, Thailand, has increased significantly (Round & Gale, 2008). They had been largely absent from the site prior to 1983 (P. D. Round, pers. comm.). This lowland species has moved into the sub-montane habitat of the montane Silver Pheasant (*L. nycthemera jonesi*). However, a previous study revealed that in areas of overlap between the Silver Pheasant and the Siamese Fireback, within this national park, there exist small-scale patterns of habitat partitioning by topography, with the Silver Pheasant preferring steeper slopes and the Siamese Fireback flatter areas (Sukumal & Savini, 2009). Whether the shift in elevational range by Siamese Fireback is related to shifts in particular structural features of the montane habitat (such as ground vegetation cover) remains unknown.

The aim of this study is to quantify patterns of habitat selection and breeding behavior of Siamese Fireback which are now inhabiting sub-montane forest. Specifically, we attempt to determine which features of the forest influence patterns of habitat use by females during different periods of

the reproductive cycle. We compare data from microhabitats they use with data from randomly selected areas in sub-montane forest habitat to determine whether such factors can explain the recent elevational range expansion by the species into sub-montane areas.

STUDY AREA

This study was conducted in the Mo Singto area of Khao Yai National Park, Thailand (2,168 km²; 14°26'N 101°22'E; ~130 km NE of Bangkok). The study area of approximately 1 km² is located in hilly terrain, 730–890 m elevation, and is dominated by seasonally wet evergreen forest (Kerby et al., 2000; Kitamura et al., 2004). Average annual precipitation is 2,696 mm (range 2,976 to 2,297 mm) with a dry season from November to April and a wet season from May to October. Average daily temperatures vary between 18.7°C and 28.3°C, and mean humidity ranges from 64.6% during the dry season to 77.1% during the wet season (Savini et al., 2008).

METHODS

Animal capture and marking. – All data were collected between February 2007 and September 2008. Individual pheasants were caught using mist-nets (Keyes & Grue, 1982) and modified traditional leg-snare traps made from bamboo and soft polyester string. Mist nets (3 x 12 m with 15 cm mesh) were set at ground level across pheasant pathways surrounded by leg-snare traps. All pheasants caught were ringed with Thai Royal Forest Department (RFD) metal rings (11A size), and color-ringed with two-color combinations on the left leg and one color-ring and the metal ring on the right leg, so that they could be individually identified in the field. The pheasants were also fitted with a 15 g radio-collar model RI-2B made by Hohil Systems Ltd with a life span of 24 months.

Animal locations. – Each individual pheasant was located by homing several times per day, with at least a two-hour interval between radio fixes for each individual. This time gap was considered sufficient to eliminate any potential disturbance generated from the previous observations (Savini & Sukumal, 2009). Once detected, individuals were followed for 15 min after which the individual and any associated group members were left alone to reduce excessive disturbance, before another collared individual was located. During each 15 min period and for each individual, we recorded their behavior and its proximity to members of the group. We also recorded its location, elevation, and slope at the point each individual was located. Triangulation was used to estimate a bird's position if the individual pheasant could not be seen due to dense ground vegetation.

Reproductive data. – Data for each female caught were divided into four periods according to the chronology of the reproductive cycle: (1) in the group (mating period), (2) incubating, (3) alone with chicks, i.e., the initial period after hatching when females travel alone with their brood

(between one and three months) and, (4) back in her group together with her chicks and the other group members (adult males, adult females and their brood, up to ten individuals in total).

Habitat measurements. – Features of the habitat were recorded using 5-m radius circular plots (Martin et al., 1997). We established plots by centering them on the sites where individual pheasants were first located after homing. In addition, we also established control plots centered on randomly selected locations within the 30 ha Mo Singto Long-term Biodiversity Research Plot (for details on the plot see Brockelman et al., 2002). The Mo Singto plot contains hilly terrain between 730–890 m in elevation, and is covered primarily by seasonally wet evergreen forest. The randomly sampled plots are within and adjacent to use points of studied females for which it is assumed that the plot is representative of the entire area where the focal individuals were found (Fig. 1a). In each plot, habitat features were recorded following Martin et al. (1997). For each plot we counted all understory stems with DBH ≤ 10 cm and trees with DBH >10 cm which were then categorized into three classes based on their height: 0.5–3 m, >3–5 m and >5 m. We also estimated the percentage vegetation cover of each height category.

Home range size analysis. – Home range size was estimated for each period of the reproductive cycle using 95% minimum convex polygons (MCP) as well as kernel home ranges, which are less prone to the effects of outliers (Boitani & Fuller, 2000), based on 50% and 95% probability of use. The analyses were conducted in Arcview GIS version 3.2a with the Animal Movement Extension (Hooge & Eichenlaub, 2000).

Patterns of habitat use analysis. – All statistical analyses were conducted using SPSS version 15.0 (Kinneer & Gray, 2000; Garson, 2009) and R version 2.7 software (Crawley, 2007). Data were examined for normality using Kolmogorov-Smirnov tests. We used non-parametric Kruskal-Wallis tests to compare habitat variables between sites selected by females during four periods of the reproductive cycle and randomly selected areas. Non-parametric Kruskal-Wallis tests were also used to compare topography (slope) between sites selected by females during four periods of the reproductive cycle and randomly selected areas. We used forward stepwise multinomial logistic regression with the presence/absence of females during three reproductive periods (1, 3, and 4, see above) as the dependent variable to identify which habitat features significantly influenced habitat use. There was little movement during the period 2 (incubation), so different tests were conducted (see below). Since stepwise regression procedures involve multiple testing, increasing the risk of type 1 errors (MacNally, 2000; Whittingham et al., 2006), we set our significance level to $\alpha < 0.01$. The order of entry of independent variables into any stepwise regression model and the total number of variables can all effect the final model selection (Whittingham et al., 2006). For the forward selection procedure, we began with a constant-only model and added habitat variables one at a time based upon their relative correlations with the dependent variable until the

Table 1. Home range sizes of two female Siamese Fireback pheasants during different periods of the 12 months reproductive cycle. The duration of each period (months) of the cycle is rounded for clarity.

Months	Year Cycle			
	Period 1 In group Mating	Period 2 Alone Incubating	Period 3 Alone With chicks	Period 4 In group With chicks
	February to April	April to June	May to August	August to February
No. of observations				
Female 1	46	C. ^a	36	64
Female 2	33	C. ^a	107	56
95% MCP (ha)				
Female 1	40.6	Inc. ^b	13.2	36.6
Female 2	42.3	Inc. ^b	7.8	14.8
95% Kernel (ha)				
Female 1	62.4	Inc. ^b	19.8	54.3
Female 2	50.9	Inc. ^b	6.7	22.9
50% Kernel (ha)				
Female 1	8.9	Inc. ^b	3.4	9.5
Female 2	3.4	Inc. ^b	1.3	3.7

^a C. = Data obtained from video cameras (K. Proprasert, unpublished data)

^b Inc. = 87% of time sitting on the nes

step at which all habitat variables not included in the model had a significance of > 0.1 . Goodness of fit was determined using the likelihood ratio test of the overall model (the model chi-square test). Final model selection was determined using Akaike Information Criterion (AIC) whereby the step with the lowest AIC value was judged to be the 'final model'. We then compared the habitat variables identified as having a significant influence on habitat use by females among three periods of the reproductive cycle and the randomly chosen areas using Kruskal-Wallis *H*-tests.

For the nesting/incubation period (Period 2), we used a forward stepwise binary logistic regression to identify which features of the habitat influenced nest site selection. The presence/absence of females in each reproductive phase was entered as the dependent variable. We used the same criteria for the forward selection procedure as the multinomial stepwise regression model (see above). Similarly, goodness of fit was determined using the model chi-square test and final model selection was determined using AIC. We compared topography (slope angle) between nest sites selected by females and those of randomly selected areas using Mann-Whitney *U*-tests.

RESULTS

Year cycle of females. – Two Siamese Fireback females were fitted with radio collars and observed for 19 months between February 2007 and September 2008 (Female 1) and for eight months between February and September 2008 (Female 2). The female year cycle consists of: (1) associating in a group with other adults during the mating period (mean period \pm SD: 30.3 ± 18.9 days), (2) incubation (mean period \pm SD: 23.5

± 0.71 days), (3) alone with chicks (mean period \pm SD: 69 ± 41.0 days) and (4) associating again in a group of adults along with her chicks (mean period \pm SD: 227 ± 77.8 days).

Home range size patterns. – We compared home range size between the two observed females during each period of the year cycle. The 95% MCP analysis indicated a difference in the home range size during the different phases of the year cycle (Fig. 1a). Home range size decreased when females left the group after the mating season and started to range alone with their young chicks, but increased again when females rejoined the group with their grown chicks (Table 1). Both females showed the same pattern in home range size variation between the different seasonal phases (Fig. 1b). A similar pattern was observed using a 95% kernel for the overall home ranges and a 50% kernel for the core areas (Table 1).

Habitat characteristics between sites selected by females and randomly selected areas. – The forest habitat selected by females during all periods of the reproductive cycle was dominated by tall trees (height > 5 m; mean \pm SD 8 ± 3.1 trees), dense understory trees (height > 3 – 5 m; 13 ± 6.9 stems) and dense understory saplings (height 0.5 – 3 m; 299 ± 170.6 stems). Randomly selected areas were dominated by tall trees (> 5 m; 7 ± 4.1 trees), dense understory trees (> 3 – 5 m tall; 11 ± 6.0 stems) and dense understory saplings (0.5 – 3 m in height; 187 ± 110.5 stems). There was a significant difference between areas selected by females and random areas with areas selected by females having more stems than random plots (tree height > 5 m: Mann-Whitney *U*-test, $z = -2.9$, $df = 1$, $p < 0.05$; understory tree height > 3 – 5 m: Mann-Whitney *U*-test, $z = -2.0$, $df = 1$, $p < 0.05$; tree height 0.5 – 3 m: Mann-Whitney *U*-test, $z = -5.5$, $df = 1$, $p < 0.05$).

Influence of topography on habitat use. – Habitat use by both females for the majority of their reproductive cycle was significantly correlated with topography. Both females selected topographically flatter areas (shallower slopes) during mating (Period 1), when they were alone with chicks (Period 3) and when they were in groups with their chicks (Period 4) than was available in the randomly located areas (Female 1: Kruskal-Wallis H -test, $\chi^2 = 45.3$, $df = 3$, $p < 0.0001$; Female 2: Kruskal-Wallis H -test, $\chi^2 = 44.7$, $df = 3$, $p < 0.0001$), but not during nesting/incubation (Period 2).

Patterns of habitat use during reproductive periods. – There was a noticeable difference in the way understory vegetation

characteristics influenced habitat use by both collared females during different periods of the reproductive cycle (Table 2). During the mating period (Period 1) the habitat used by Female 1 did not appear to be correlated with the understory vegetation, whereas Female 2 used areas with densely spaced trees of 0.5–3 m in height and trees > 5 m in height. There was a difference in which vegetation characteristics were associated with habitat use by both collared females during Periods 3 and 4. When both females were alone with chicks (Period 3), habitat use was significantly correlated with both tree density 0.5–3 m, and tree coverage >3–5 m. In addition, both females selected habitats with a higher tree density in the 0.5–3 m height range. However, our measured

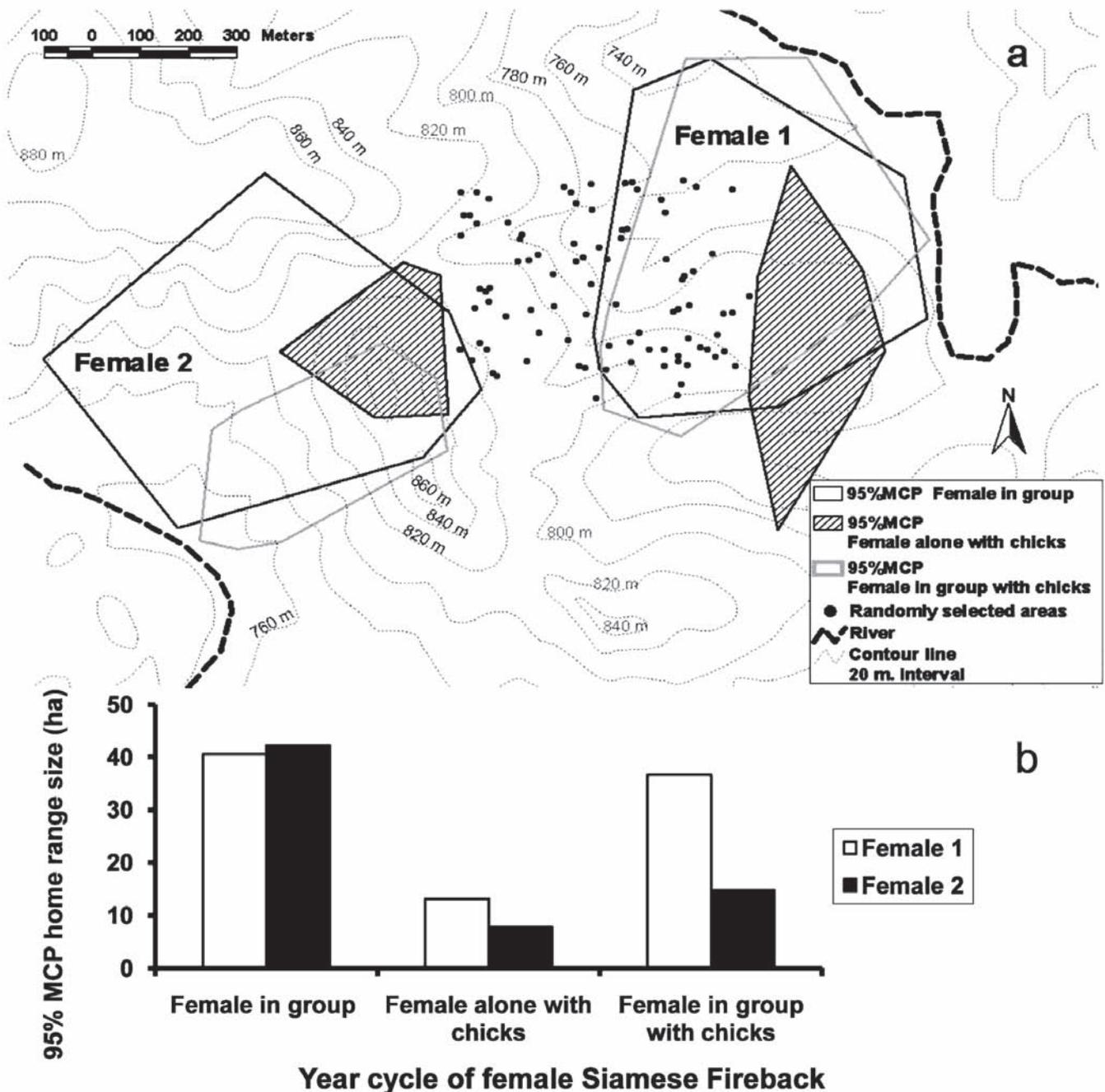


Fig. 1. a, Ranging size during different periods of the year cycle of Siamese Fireback, Female 1 and Female 2, estimated using 95% minimum convex polygons (MCP); b, 95 % MCP home range size compared in different phases of the year cycle between the two female Siamese Firebacks.

Table 2. Results of forward stepwise multinomial logistic regression showing the influence of understory vegetation characteristics on habitat use by female Siamese Fireback during different periods of the reproductive cycle. Significant results ($\alpha < 0.01$) are highlighted in bold.

Variables in three phases of year cycle	Female 1				Female 2			
	Mean	Coefficient	df	p-value	Mean	Coefficient	df	p-value
Female with group (mating) (n = 30)								
Tree density: height 0.5–3 m	135 stems	-0.007	1	0.023	335 stems	0.015	1	<0.0001
Tree density: height > 3–5 m	–	–	–	–	15 stems	0.021	1	0.814
Tree coverage: height > 3–5 m	35.7%	-0.009	1	0.436	55.7%	0.043	1	0.127
Tree coverage: height > 5 m	68.3%	0.023	1	0.04	76.1%	0.059	1	0.002
Female alone with chicks (n = 30)								
Tree density: height 0.5–3 m	508 stems	0.015	1	<0.0001	394 stems	0.02	1	<0.0001
Tree density: height > 3–5 m	–	–	–	–	11 stems	0.495	1	<0.0001
Tree coverage: height > 3–5 m	52.1%	0.047	1	0.007	19.6%	-0.253	1	<0.0001
Tree coverage: height > 5 m	51.5%	-0.037	1	0.027	49.7%	-0.006	1	0.766
Female in group with chicks (n = 30)								
Tree density: height 0.5–3 m	239 stems	0.004	1	0.041	181 stems	<0.0001	1	0.918
Tree density: height > 3–5 m	–	–	–	–	14 stems	0.51	1	0.417
Tree coverage: height > 3–5 m	41.9%	0.007	1	0.548	46.7%	0.009	1	0.649
Tree coverage: height > 5 m	64.1%	0.012	1	0.286	68.7%	0.023	1	0.05
Goodness of fit test			504	0.962			504	1
AIC values				AIC = 357.797				AIC = 282.922

– = The variable is not selected into the model

vegetation variables did not appear to be associated with habitat use when females returned to their groups with their chicks (Period 4).

Nest site selection. – A total of 11 nests of five different females were observed during the study period. Nine nests were located in the buttresses of large trees (in genera *Aphananthe*, *Ficus*, *Balakata*, *Nephelium*, *Mastisia* and *Cleistocalyx*), one nest was located in a clump of *Rattan* sp. and another nest was located on the ground covered by rattan leaves. The average clutch size was 8 ± 3 (maximum = 14 eggs, minimum = five eggs). All eggs from five of the eleven nests (45%) hatched. Females appeared to prefer to place nests on steeper slopes in the study area although the differences were not statistically significant (Mann-Whitney *U*-test, $z = -1.852$, $p = 0.064$). Forward stepwise binary logistic regression analysis indicated that there were significant differences in under-story vegetational characteristics between nest sites and randomly selected areas, and that females mostly avoided locating their nests in areas with a higher percent coverage of trees >3–5 meters in height (coefficient = -0.094 , Wald chi-square = 5.968, $df = 1$ $p < 0.05$).

DISCUSSION

Female Siamese Firebacks showed a distinct preference for areas that were topographically relatively flat in our sub-montane study area during three periods of their reproductive cycle. Nest-sites, however appear to be on significantly steeper slopes (Fig. 2 and 3). During the mating season (Period 1) females select areas with denser understory coverage (>5 m in height) similar to that observed in a lowland population in Binh Chau-Phuoc Buu Nature reserve in southern Vietnam (Nguyen et al., 1998). Later in the breeding season, when they were alone with young chicks (Period 3), Siamese Fireback females preferred areas with a higher density of understory stems (Table 2 and Fig. 4). Finally, when females re-joined their respective groups together with their grown chicks (Period 4; Table 2) there appeared to be no clear association with any of the vegetation characteristics measured.

This use of dense understory vegetation by females when they are alone with young chicks (Period 3) may be a response to predation risk. Many species, including Galliformes with young chicks, tend to use densely vegetated areas (Lima, 1993; Peh et al., 2005) since the mortality of young chicks for some species is highest in the first few weeks of life, e.g. Ring-neck Pheasant *Phasianus colchicus* (Riley et al., 1998) and Rio Grande Wild Turkey *Meleagris gallopavo intermedia* (Spears et al., 2005). Similar behavior has been observed for female Hume's Pheasant (*Syrnaticus humiae*) in northern Thailand (Iamsiri & Gale, 2008). In addition, predation avoidance could promote the selection of denser habitat, as was the case in at least one of the two females during the mating season (Period 1). During this season Siamese Fireback's tend to utter a loud whistling call, in addition to the typical *Lophura* wing-whirring display (Johnsgard, 1999), which could further increase their risk of being detected by mammalian and avian predators. This was observed by Hale

(2004) where the playbacks of Black-breasted wood-quail (*Odontophorus leucolaemus*) choruses attracted predators. Collectively, similar vegetation characteristics are known to influence patterns of habitat use by male Sichuan Hill Partridge's (*Arborophila rufipectus*) in southern China. During the breeding season, male partridges range mostly in evergreen broadleaf forest habitats which have a dense and tall canopy of vegetation cover, and an open understory (Bo et al., 2009). These patterns of habitat use provide males with greater protective cover from canopy or sub-canopy dwelling predators and probably increase the likelihood of detecting predators if they approach at ground level (Iamsiri & Gale, 2008; Bo et al., 2009). Habitat use by females appeared to be less influenced by vegetation characteristics during Period 4 of the reproductive cycle.

Selection of nesting locations. – During our study, the nesting period for Siamese Fireback occurred between April and June, corresponding exactly to the nesting period for known lowland populations (Baker, 1928; Riley, 1938). The major difference in our study was the mean number of eggs per clutch (mean = 8 ± 3 with a maximum clutch size of 14 eggs), which was noticeably higher than previously reported for this species (mean = 6 ± 2 , Madge & McGowan, 2002). Whether this observed difference is, in part, attributed to the range shift of female Siamese Fireback's to higher sub-montane elevations, or simply an attribute of the scarcity of information on this species throughout its known biogeographic range, remains unknown.

Another interesting result of our study was the use of topographically steeper slopes by nesting females. Selection of these sites was not influenced by any of the recorded vegetation characteristics. One reason therefore could be that nest site selection by females is influenced by a range of factors (operating at multiple scales) that were not recorded during our study. Alternatively, locating nests on steeper slopes can facilitate 'escape-flushing' down-slope in response to an approaching predator – a common phenomenon recorded for several Galliformes (Lima, 1993) including Silver Pheasant (Sukumal & Savini, 2009) and other bird species (Hanners & Patton, 1998).

Home range. – The home range size of both collared females significantly declined whilst they were alone with young chicks (Period 3) but later expanded again when the females and chicks returned to their original group (Period 4). Few quantitative data exist regarding the home range size of this species in their typical lowland forest habitat, but we suspect that the reduction in home range size during Period 3 is related to the reduced mobility of young chicks (Klinger & Riegner, 2008). Davison (1981) estimated a home range of 20 to 25 ha for a closely related lowland species, the Crested Fireback (*L. ignita*) in lowland forest habitat (<150 m), Peninsular Malaysia. If we assume that lowland populations of Siamese Fireback have a similar home range size, we could conclude that the home range size of Siamese Fireback's in sub-montane forests could be potentially double that of lowland populations. Our results also show that Siamese Fireback's tend to cluster in topographically flatter, wetter areas, which

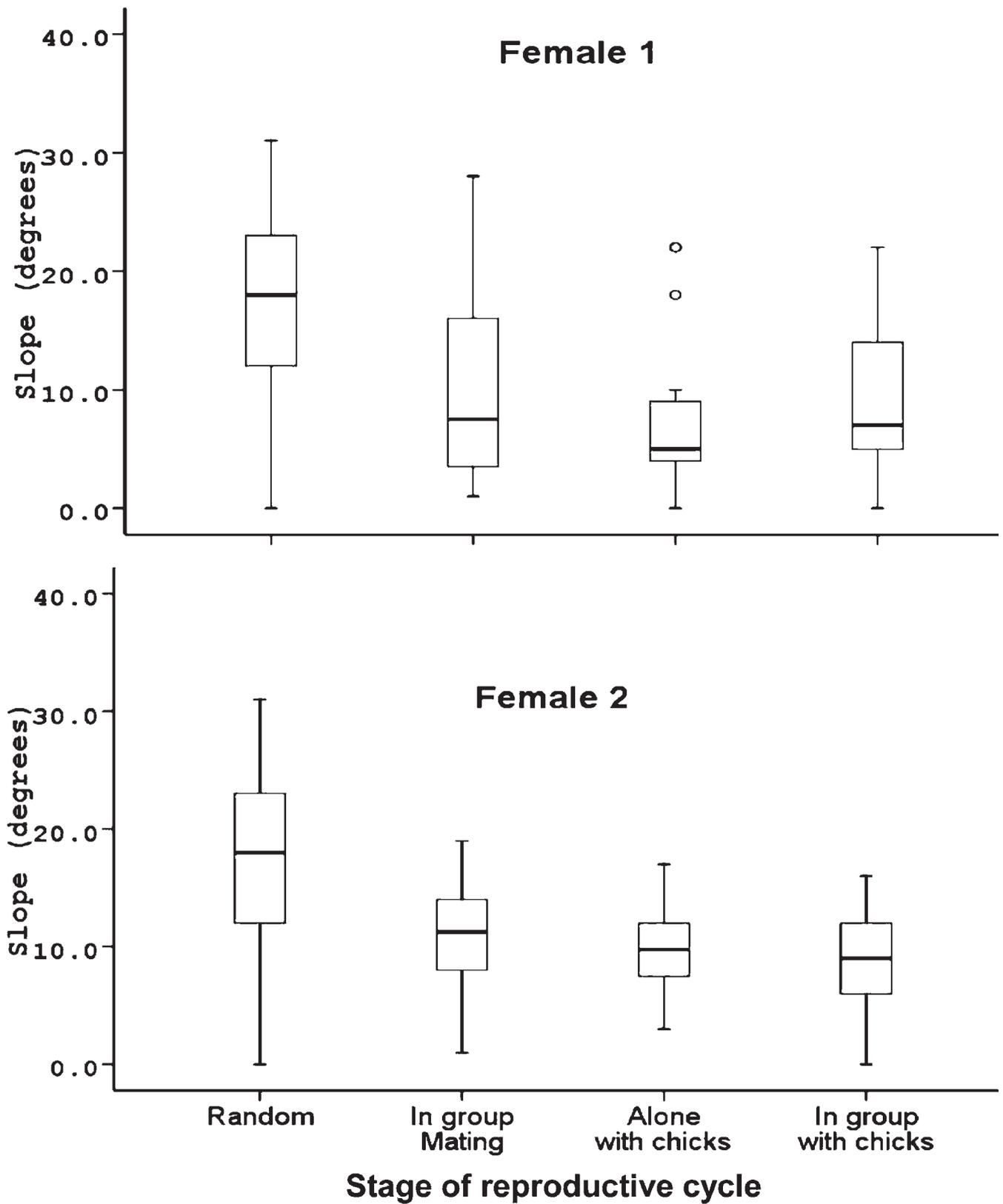


Fig. 2. A comparison of slope in areas used during different periods of the year cycle and randomly chosen areas for Female 1 (a) and Female 2 (b).

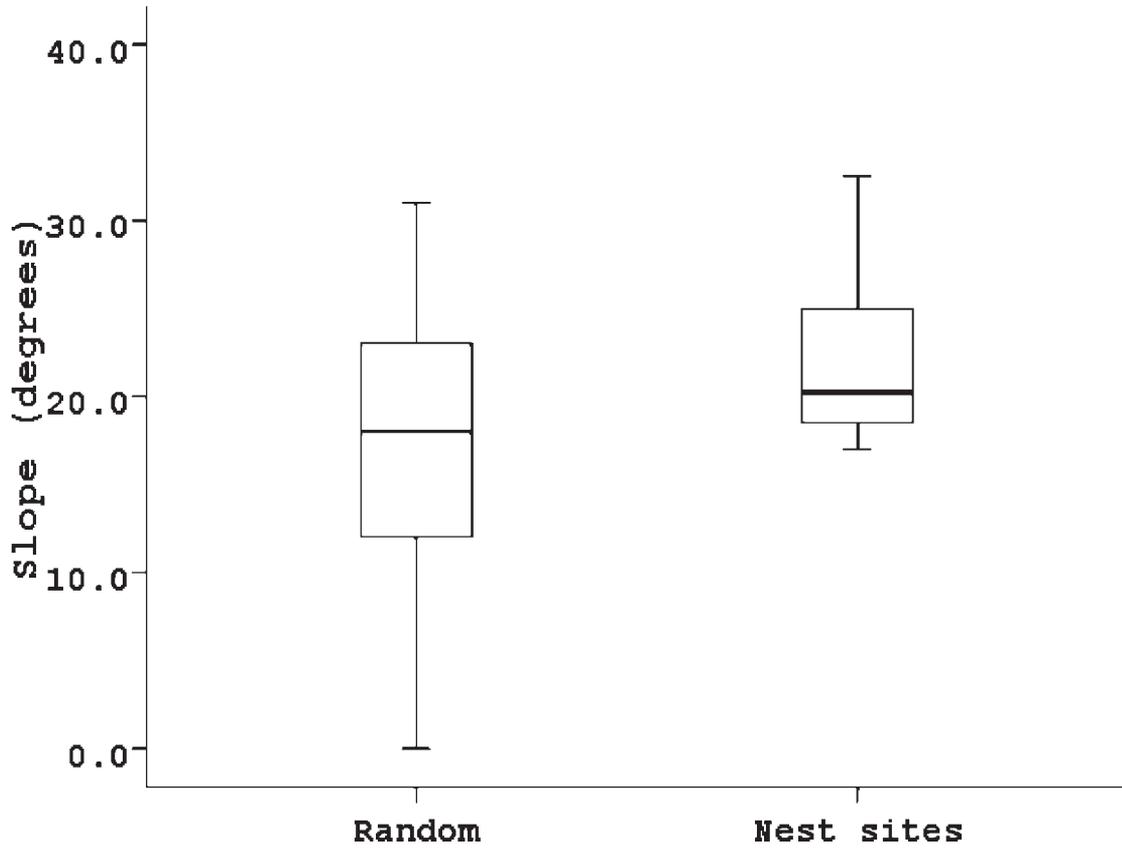


Fig. 3. A comparison of slope between nest site locations (n=10) and random areas (n=90).

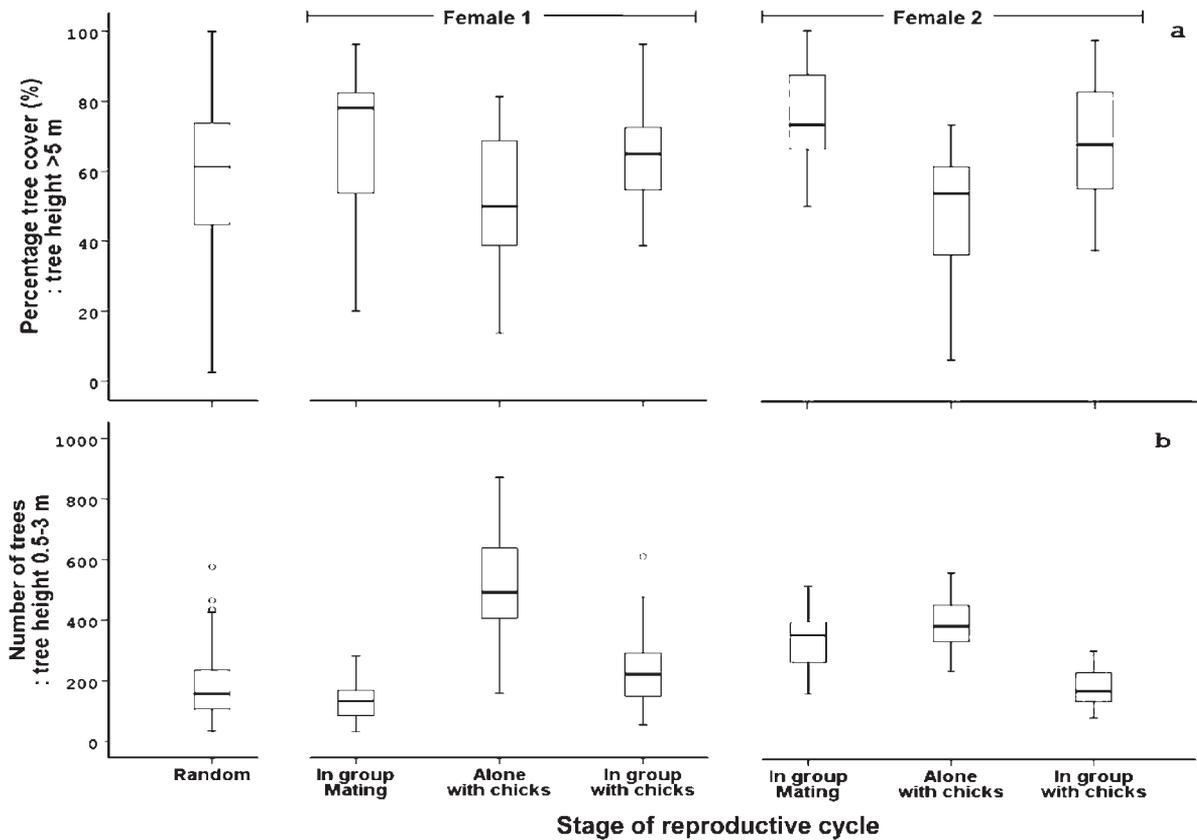


Fig. 4. The comparison of percentage tree cover (height >5 meters) between used areas during the three periods of the year cycle and random areas for Female 1 and Female 2 (a), and the comparison of tree density (height 0.5-3 meters) between used areas during the three periods and random areas for Female 1 and Female 2 (b).

might force them to increase their range size because these areas are patchily distributed at sub-montane elevations in the Mo Singto area (N. Sukumal, pers. obs.).

We are unsure as to how representative our results are for the species as a whole across its known biogeographic range since our conclusions are based on a very small sample (only two females) from one location. The low sample size was mainly a consequence of the difficulty in catching (and subsequently collaring) birds in hilly terrain where vegetation was particularly dense. Increasing the sample size could eventually be achieved by increasing the mist netting effort during the breeding season when the birds appear less attentive to their surroundings. To date, no quantitative data exist regarding patterns of habitat selection by females in other forest habitats throughout its range, and consequently, no comparisons can be made. The selection for flatter, wetter areas by both females could be a consequence of trying to occupy habitat with characteristics of typical lowland understory vegetation (Johnsgard, 1999). Alternatively, these patterns could be a constraint influenced by interspecific competition with the sympatric Silver Pheasant, which tends to occupy drier, steeper slopes (Sukumal & Savini, 2009). Further detailed research is needed on lowland populations of Siamese Fireback to (a) investigate their habitat use and the size of their home range, (b) nest-site selection and (c) their social structure.

CONCLUSIONS

Although suggestions have been made (Round and Gale, 2008), it still remains largely unclear what is the driving force for Siamese Fireback in Khao Yai National Park to expand their range into higher elevation forests. Independently from the cause generating the observed shift, our study examined habitat use by a lowland forest bird species which is now found ranging into sub-montane forest. Across habitat and elevational gradients some bird species appear physiologically highly tolerant to both micro-climate and micro-habitat changes (Martin, 2001). If populations of Siamese Fireback at Mo Singto are tolerant of similar abiotic and biotic factors across an elevational gradient, then there may be two main/principal reasons as to why this lowland species is expanding 'upward' either: (1) as a direct response to lowland habitat degradation, or (2) the 'amount' of available optimal habitat at higher sub-montane elevations has significantly increased providing the species with an alternative to lowland habitat saturation. However, few long-term data exist regarding the relative abundance of the lowland Siamese Fireback populations or changes in forest micro-habitat structure (e.g. over the past 20 yr) to test either hypothesis. We conclude that the Siamese Fireback population within the Khao Yai National Park is a suitable candidate for such long-term research. If the factors that provide the driving force behind the elevational range expansion of Siamese Fireback across temporal scales can be identified, then this could enable ecologists to predict with greater accuracy the responses of other lowland species to changes in habitat, including those caused by climate change.

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