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Roosting behaviour of the endangered Sichuan Hill-partridge *Arborophila rufipectus* during the breeding season

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Summary

Roosting behaviour in diurnal ground-dwelling birds is important to their conservation as they are particularly vulnerable to predation when on their roosts. In 2005, we studied the roosting behaviour of the globally 'Endangered' Sichuan Hill-partridge (*Arborophila rufipectus*) in Laojunshan Nature Reserve, southwest China, a site dominated by evergreen broadleaf forest. Our study showed that the birds roosted on elevated perches and roosting behaviour was associated with social organization. Breeding males roosted alone within their territories before mating or during the female's involvement in incubation, but at other times they roosted with the female bird. After hatching of the brood, the adult males roosted on the ground close to the brooding female for about two weeks. After this time the male left the female and chicks to roost elsewhere in the territory. High vegetation cover around the perch site was a key predictor of roosting sites for the partridges. Only six out of 84 tree and shrub species were typically used by the roosting birds, although individual roosting plants varied from night to night. The median height of roosting plants was 6.9 (3.8–10.5) m, which was significantly lower than many shrubs within the breeding territory. Perches were 1.7–6.4 (median = 2.7) m from the ground and independent of roost tree height, suggesting an optimum roosting height. The partridges preferred roosting sites with denser shrub vegetation. In terms of the species' conservation, our results highlight the importance of protecting primary forest that contains suitable roosting trees and shrubs.

Keywords: *Arborophila rufipectus*, Conservation, Roosting habitat, Sichuan Hill-partridge

Introduction

The Sichuan Hill-partridge (*Arborophila rufipectus*) is one of the characteristic species of the Chinese Subtropical Forests Endemic Bird Area (Stattersfield *et al*. 1998). It is a nationally protected animal in China and classified as 'Endangered' in the IUCN Red List (IUCN 2005), because of its largely restricted range (1,800 km^2), very small population (< 2,000 birds) and severely fragmented habitat (Dowell *et al*. 1997, Dai *et al*. 1998, Li *et al*. 2003, Liao 2006). Conservation action for the partridges, including studies on their habitat use and breeding biology, has been proposed (McGowan *et al*. 1995, Fuller *et al*. 2000) and is now under way.

From earlier field surveys on the species, we know that the Sichuan Hill-partridge is a typical montane forest resident. They are confined to subtropical broadleaf evergreen vegetation and appear to prefer primary forest habitat (Li and Zhang 1974, King and Li 1988, Xu *et al*. 1994, Dai *et al*. 1998, Li *et al*. 2003), although they will also occupy secondary and replanted broadleaf forest over 20 years old where it is found adjacent to primary forest (Dai *et al*. 1998, Dowell &

Dai 2000). These surveys focused on diurnal habitat requirements of the species and, apart from one observation of birds roosting in shrubs by Li and Zhang (1974), they did not consider the roosting requirements of the species. In fact, roosting behaviour of all 18 *Arborophila* species remains enigmatic. Considering this lack of biological information and the fact that roosting habitats are important to species survival (Cody 1985), we investigated roosting behaviour and habitat selection of the Sichuan Hill-partridge in Laojunshan Nature Reserve in Sichuan province, China, from April to October 2005.

Study area

Fieldwork was carried out at Laojunshan Nature Reserve, Pingshan County, Sichuan Province, China, from early April to October 2005. The reserve, which covers an area of 35 km^2, is situated in the Xiao Liang mountains (28°45′N, 103°56′E) at an altitude of 1,000 to 2,010m. Annual average temperature is 12.5°C and annual total precipitation is 1,500 mm. Vegetation covering the reserve is characterized by evergreen broadleaf forest including *Castanopsis delavayi*, *C. omeiensis*, *Davidia involucrata*, and *Cylobabanopsis myrsinaefolia*. The shrub layers are well developed and are dominated by *Eurya loquiana*, *Alangium chinense*, *Rhododendron hunnewelliana* and *Camellia oleifera*. There is also a thick understorey of bamboos, especially *Chimonobambusa quadrangularis* (Sichuan Academy of Forestry 2004). There is a healthy population of Sichuan Hill-partridge in the reserve.

Methods

Males called loudly in the morning and afternoon/evening from late March until hatching (mid-May to mid-July) and again in late summer until the end of October. The unique male calls allowed us to locate calling males near to dusk. Once located by call, we tracked the male to his roosting perch. Through direct observation, we then described his roosting behaviour (calling and movement pattern), identified the species of tree/shrub which held the roosting perch and estimated perch height. The following morning, we returned to the roost site prior to the bird's departure. A 10 × 10-m habitat quadrat was placed directly underneath the roost site with the position of the bird at its centre and the following parameters were measured: altitude, slope direction, slope angle, distance to stream, overall vegetation cover, number, height and diameter at breast height of all individual trees and shrubs. Within the quadrat, four 4 × 4-m sub-samples were set to estimate height, cover and number of bamboo plants. Measurements of individual plants for each quadrat were averaged. To quantitatively assess the availability of roosting habitats, a site was chosen randomly within the territory and the same measurements were taken as those at the roost. Roosting sites for a total of 24 territorial males were recorded, 16 (including two pairs) between April and June, and eight between August and October. In addition, we observed one focal male for five and another for seven successive nights within their breeding territories to investigate night-to-night variation in roosting plants (but only one 10 × 10-m habitat quadrat was sampled for each individual). Also four brood roosting sites were located through closely following partridge families.

Because of the strong male territoriality throughout the study, and the even vegetation profile at the site, we pooled the data from roosting sites used by males or pairs (but not brood roosting sites) observed from early April to early October. Chi-square tests were used to examine the preference for roosting plants. Because the habitat variables did not fit with normal distribution even though they were natural log-transformed (One-Sample Kolmogorov-Smirnov test, all $P < 0.05$), Mann-Whitney *U* tests were run to compare the difference between roosting and random sites, and Spearman's correlation coefficients were calculated to examine the relationship between perch height and roosting plant height, and between two vegetation variables in the study area. All statistical tests are two- tailed and results are shown as medians, inter-quartile ranges (IQR) and range in some cases.

Results

Roosting pattern in relation to social organization

From late March or early April, male Sichuan Hill-partridges began to establish territories. During this period, we found seven roosts that were all in elevated perches used by solitary males (Table 1). Once a pair formed, the male remained in close proximity with his mate during day time (based on observations of three pairs). During the night, both members of the pair roosted within the male's territory on elevated perches but in different individual plants which were 2.5–3.5 m apart (observations on two pairs during April). Between May and June, seven other single-male roosts were located above ground level. During this period, we located no nest sites around 17 different single-male roosting sites, suggesting that the males did not guard the incubating females.

After hatching, the brood was joined by the male. During the night, the female brooded the young under dense undergrowth on the ground. The male stayed near the brooding female (0.5–1.4 m, $n = 4$ night observations for different families) and roosted on the ground. However, when the chicks reached about 9–13 days old ($n = 5$ broods), the males separated from the brood during day and night and roosted alone on elevated perches ($n = 8$ males).

Roosting behaviour

Territorial male partridges called throughout the day. However, for all 34 roosting observations, males were silent for about one hour before arriving at their roost site. Once the birds were ready to get up onto their roosting perch they uttered calls again. After alighting on their perches, several calls were heard. The birds first jumped onto a lower branch and moved then moved from one branch to another to reach their favoured perch. When the lowest branches of the selected plant were relatively high (4.7–5.7 m, $n = 2$), they used the lower branches extending from neighbouring plants as a starting point. In the morning, the birds dropped to the ground directly in most cases (18 of 24 observations) but in the other six cases they moved down between branches. The median time of evening arrival at final perches was 17.5 minutes (range = 5–25, IQR = 8) after sunset and morning departure was 25.5 minutes (range 4–33, IQR = 17) before sunrise.

Roosting habitat selection

All Sichuan Hill-partridge territories and thus roosting sites we studied were confined to evergreen broadleaf forests. These roosting sites were located across the whole altitudinal range of the reserve, 1,400 m–1,900 m. Relative to random plots, roosting sites had more shrub species,

Table 1. Number and location of roost sites used by different social groups of Sichuan Hill-partridges in relation to time of season in 2005.

Time of season	Single male	Pair	Brood
April	7	2	0
May	3	0	3
June	4	0	0
July	0	0	1
August	1	0	0
September	4	0	0
October	3	0	0
Total	22	2	4
Location	All on elevated perch	All on elevated perch	All on the ground

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heavier shrub cover and poorly-developed bamboos (Mann-Whitney *U* test, $z > 2.60$, $n_1 = n_2 = 24$, $P < 0.01$, Table 2). However, these three variables sampled from the study area are correlated with one another, with more shrub species in association with greater shrub cover ($r_s = 0.29$, $P = 0.047$) but less bamboo cover ($r_s = -0.34$, $P = 0.018$). Other habitat variables did not differ between roosting and random sites.

Six plant species were chosen by male partridges for roosting, including three trees and three shrubs (Table 3). These roosting plants accounted for only 7.2% of the total number of species available (32 tree and 52 shrub species) within sample habitats and for 29.0% in species occurrence, suggesting a strong preference for these species (Chi-Square test, $\chi^2_1 = 61.71$ for number of plant species, $\chi^2_1 = 17.64$ for species occurrence, $P < 0.001$). Among the selected plants, *Eurya loquiana* was used most often ($\chi^2_1 = 9.93$, $P = 0.002$). All trees and shrubs used had a median height of 6.9 m (range = 3.8–10.5, IQR = 2.1) and diameter of 19.0 cm (range 7.0–34.6, IQR = 7.0). They were similar in the two physical traits to the trees within roosting site samples (Mann-Whitney *U* test, height, $z = 0.95$, $n_1 = n_2 = 24$, $P = 0.34$; diameter, $z = 0.39$, $P = 0.70$, Table 2), but taller and thicker relative to the average of shrub species (height, $z = 5.60$, $P < 0.001$; diameter, $z = 4.31$, $P < 0.001$). The final perch sites, usually had horizontal limbs and had a median diameter of 1.8 cm (range = 1.0–4.0, IQR = 0.7, $n = 24$), were 2.7 m (range = 1.7–6.4, IQR = 0.4) from the ground and 4.0 m (range = 1.4–9.7 m, IQR = 1.8) to the top of the canopy. Regardless of species, perch height did not correlate with roosting plant height (Spearman's correlation coefficient $r_s = 0.12$, $n = 24$, $P = 0.57$), showing the existence of an optimum height when roosting.

Discussion

We demonstrated that the Sichuan Hill-partridges in our study foraged on the ground all day and roosted in elevated perches during the night, as noted by Li and Zhang (1974). This roosting habit is consistent with that of White-collared Hill-partridge (*A. gingica*) in southeast China (Rickett 1900, Caldwell and Caldwell 1931), Common Hill-partridge (*A. torqueola*) in south Sichuan (our unpublished data) and captive Hainan Hill-partridge (*A. ardens*) (Gao 1991).

All but two of the above-ground roosting sites located were used by solitary male partridges. The solitary roosting behaviour reflected the strong territoriality of this species. Once paired, males guarded their mate both during the day (three different pair bonds followed for a total of 2 hr) or at night ($n = 2$), a paternity defence strategy typical of socially monogamous birds

Table 2. Habitat characteristics of roost sites ($n = 24$) for Sichuan Hill-partridge compared with random sites ($n = 24$) within male territories. The values are presented as medians ± inter-quartile ranges.

Parameters	Roosting site	Random site	Mann-Whitney *U* test	
			z	*P*
Bamboo cover (%)	59.0 ± 20.0	82.0 ± 10.0	5.52	< 0.001
Shrub cover (%)	86.0 ± 9.0	58.5, 27.0	5.07	< 0.001
No. of shrub	13.0 ± 41.0	5.0, 6.0	2.60	0.009
Tree height (m)	7.6 ± 2.3	8.6 ± 4.6	1.82	0.07
Tree cover (%)	85.0 ± 9.0	83.0 ± 5.0	1.57	0.12
Tree diameter(cm)	20.2 ± 10.2	21.8 ± 15.5	1.42	0.16
Bamboo height (m)	1.7 ± 0.4	1.8 ± 0.3	1.37	0.17
Slope degree	7.5 ± 9.0	14.0 ± 12.0	1.13	0.26
Altitude (m)	1638 ± 275	1815 ± 255	0.73	0.47
No. of tree	6.0 ± 6.0	6.0 ± 6.0	0.68	0.50
Shrub height (m)	2.9 ± 1.1	3.2 ± 1.3	0.43	0.67
Slope direction	150.0 ± 145.0	152.5 ± 159.0	0.30	0.76

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Table 3. Plant species selected by Sichuan Hill-partridges for roosting and their occurrence within male territories. The records of roosting plants used by two males in different nights were included.

Plant species	Type of plant	*n*	Proportion of roosting sites (%)	Occurrence of roosting plants (%)
Cunninghamia lanceolata	Tree	1	2.9	2
Castanea omeiensis	Tree	2	5.9	4
Tetracentron sinense	Tree	1	2.9	3
Rhododendron hunnewelliana	Shrub	5	14.7	5
Eurya loquiana	Shrub	19	55.9	12
Alangium chinense	Shrub	6	17.7	3
Total		34	100	29.0

(Birkhead and Møller 1992). Communal roosting of pair members has also been observed in other monogamous galliforms, e.g. 11.4 m in neighbouring trees for Blood Pheasant (*Ithaginis cruentus*) (Jia *et al*. 1999) and < 1 m in the same tree for Tibetan Eared Pheasant (*Crossoptilon harmani*) (Lu 1997). However, when female Sichuan Hill-partridges were incubating, the males seemed not to roost close to the nest. This may have been a strategy to reduce the possibility of nest predation. The separation of male roosts from nesting sites was also reported in Blood Pheasant (around 300 m, Jia *et al*. 1999) and Tibetan Eared Pheasant ($>$ 200 m, Lu 1997). After hatching, male partridges joined their families and took part in caring for the young. Like other galliforms, during the night the females brooded the chicks and roosted on the ground (Mentis and Bigalke 1980, Hill 1985, Liu *et al*. 1991, Jia *et al*. 2001). Such plasticity in roosting height is uncommon for galliform birds. For example, males of Temminck's Tragopan (*Tragopan temminckii*, P. H. Cong pers. comm.), Blood Pheasant (Jia *et al*. 2001) and Tibetan Eared Pheasant (Lu 1997) accompanied their brood during the day, but at night the former two roosted in trees near to the ground-roosting, brooding females, while the latter traveled hundreds of meters to return to their permanent tree roosts, leaving their broods unattended. The male Sichuan Hill-partridges only accompanied their families for 1–2 weeks and then they foraged and roosted solitarily within their breeding territory, in which they called frequently as they did in the early breeding period. This is in contrast to many monogamous galliforms who cooperate with females in caring for their young for at least two months: e.g. Crested Francolin *Francolinus sepnaena* and Grey-winged Francolin *F. africanus* (Mentis and Bigalke 1980, Van Niekerk 2001); Tibetan Snowcock *Tetraogallus tibetanus* (Xin Lu unpubl. data); Tibetan Partridge *Perdix hodgsoniae* (Lu *et al*. 2003); Blood Pheasant (Jia *et al*. 1999); eared pheasants (Liu *et al*. 1991, Lu and Zheng 2005).

We found that Sichuan Hill-partridges showed a strong preference for thick shrub cover when selecting their roost sites. This is likely to reduce the chances of predation on the roost site (Cody 1985). However, the birds avoided dense bamboo when selecting roost sites and this may be associated with limitation of the lower vegetation to bird movement. However we observed that the birds rarely used the tall trees within breeding territories as roosts. The reason for this may be attributed to the poorly developed ability of the species to take off within the forest, as suggested by our observations that the birds were unable to fly up $>$ 2 m directly from the ground.

A habitat management plan for the Sichuan Hill-partridge should take roosting habitat into account. Prior to 1998, the major threat facing the Sichuan Hill-partridge was habitat destruction due to clearing of primary forest (Dowell and Dai 2000). Since 1998, commercial deforestation within the species' range has been prohibited with the full implementation of a ban on logging in the upper Yangtze basin. This has led to the establishment of nature reserves such as Laojunshan where this study was carried out. Management of reserves like this one should ensure that shrubby vegetation with less bamboo is maintained. Within the species' range, forestry practices now include replanting native broadleaf trees. This will facilitate recovery of the Sichuan

Hill-partridge population if preferred tree species for roosting are replanted. Based on our results, the tree and shrub species that are selected as roosting sites by the partridge (Table 3) should be included in the replanting list.

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