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Habitat use by endangered Sichuan Partridges *Arborophila rufipectus* during the breeding season

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Abstract. A detailed understanding of habitat associations of threatened species is essential for the development of sound conservation and habitat management plans. The globally endangered Sichuan Partridge is endemic to montane southwestern China, where it inhabits subtropical broadleaf forest. Its use of various habitats within the forest is poorly known. Habitat use by Sichuan Partridges in Laojunshan Nature Reserve, Sichuan, was studied during the breeding season (April–October). Habitat characteristics at feeding places were compared with randomly selected sites. Auditory detection was used during transect surveys of calling males to locate birds and their feeding scrape sites. Partridges were recorded in primary and secondary broadleaf forest, but not in coniferous plantations or farmland and settlements. Birds occurred between 1400 and 1800 m a. s. l., typically on the ground with a gentle slope of between five and 15 degrees, close to paths and water sources. The habitats used by Sichuan Partridges differed from the random sites in that they had a denser shrub layer, greater tree cover, thicker deciduous leaf depth and lower abundance of bamboo. Principal Components Analysis identified factors interpretable as concealment, topography and leaf litter depth as key axes of variation in Sichuan Partridge habitats. We suggest that habitat management plans incorporating this new information can now focus more effectively on identifying, protecting and restoring those sites within protected areas that are most suitable for the Sichuan Partridge.

Key words: Sichuan Partridge, *Arborophila rufipectus*, conservation, habitat selection, Laojunshan Nature Reserve

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INTRODUCTION

The *Arborophila* are a galliform group native to Asia, with 21 species in China and southeastern Asia (Collar et al. 2001, Liao et al. 2007a). Sichuan Partridges are protected in China and classified as endangered by the IUCN (2005) because of their restricted range (1800 km^2), small population (< 2000 birds), and severely fragmented habitat (King & Li 1988, Dai et al. 1998, Li et al. 2003). As such, detailed information concerning habitat use is essential for generating sound conservation and habitat management plans (McGowan et al. 1995, Fuller et al. 2000). Surveys over the past decade have revealed that Sichuan Partridges are montane forest residents, confined to subtropical broadleaf evergreen vegetation, most notably primary forests (Li & Zhang 1974, Xu et al. 1994, Dai et al. 1998, Li et al. 2003, Liao et al. 2007b, Liao et al. 2008), but they are not recorded in coniferous plantations (Dai et al. 1998). However, those surveys focused on distribution and overall habitat requirements of the species and provided no concrete information of habitat use during the breeding season, except for of birds preferring open forest floor with sparse bamboo growth and a damp leaf-litter layer typically 5–10 cm deep (Dai et al. 1998).

Considering that diurnal birds spend as much as a half of their life foraging in habitat during

daylight, habitat use study is important for species conservation (Cody 1985). In this light, we examined habitat selection by Sichuan Partridges in Laojunshan Nature Reserve. Our objectives were to gain insights into Sichuan Partridge habitat use during the breeding season to determine the specific habitat requirements of the species. Such information will help minimize conflict between the needs of strategic conservation management and development within the region.

STUDY AREA

Field work was conducted during April–October 2005 in Laojunshan Nature Reserve in Sichuan province, China (103°48'–104°05'E, 28°38'–28°51'N; 10 213 ha; Fig. 1). This site was the first established by the Chinese government specifically for the conservation of Sichuan Partridges. The site ranges from 1100 to 2008 m a.s.l., has an annual average temperature of 12.5°C, and annual average precipitation of 1500 mm (with over 60% falling during June–August). A central core area for wildlife conservation (4600 ha) mainly consists of primary broadleaf forest (44%) and replanted ones (46%). Vegetation is characterized by Alangiaceae, Theaceae, Fagaceae, Teeracentraceae, Lauraceae, and Erieaceae. The tree layers are dominated by *Cinnamomum inunctum*, *Castanopsis delavayi*, *Carpinus fargesii*, *Cunninghamia lanceolata*, *Camellia oleifera*, *Cercidiphyllum japonicum*, *Davida involucrata*, *Machilus ichangensis*, *Magnolia officinalis*, and *Tetracentron sinense*, and the shrub layer is dominated by *Eurya loquiana*, *Alangium chinense*, *Rhododendron hunnewellianum*, and *Camellia oleifera*. Bamboo *Cnimonobambusa quadrahgu* forms a thick, low layer and is abundant throughout the area.

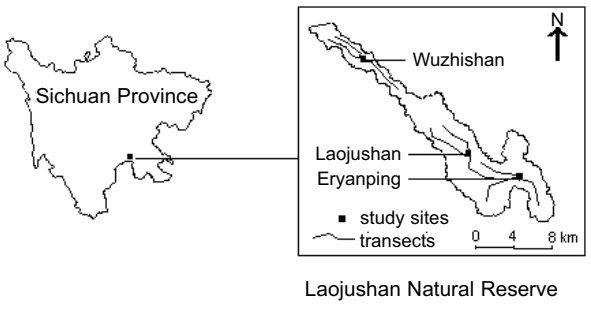

Fig. 1. Location of Laojunshan Natural Reserve (Sichuan Province, China) and the positions of the nine transects used in the study.

METHODS

At the time of our study, the Sichuan Partridge population at Laojunshan Nature Reserve was up to a maximum of 230 birds (estimated by counting the calling males along 10 different fixed-width transects across the reserve; Liao 2006). During the winter, the partridges live in coveys of 4–6 birds and, beginning in late March and early April, the coveys break up and males initiate territorial behavior (Liao et al. 2007b). The unique male calls and sexually dimorphic plumage allowed us to determine spatial patterns of territory (1.5–2.6 ha in size) for different individuals (our unpublished data). Males call until hatching (mid-March to mid-July), and again from late August (when males separate from the family group) until mid-October (Liao et al. 2007c). Foraging partridges create characteristic scrapes useful for confirming their presence because, with experience, they can be distinguished from those created by other sympatric Galliformes. Scrapes are typically about 2–5 m long, 1–3 m wide, and 4.3–6.5 cm deep (Liao 2006).

We defined the partridges' habitats based on vegetation variables, and used aerial photographs, ground surveys, and Pingshan County Forestry Department consultations to quantify habitat type within and surrounding the study area. At each of three sites within the reserve (Eryanping, Laojunshan, and Wuzhishan), we established three 4–5 km long transects, resulting in a total of nine transects (Fig. 1). All transects were in areas with no hunting, as this might have generated artefacts in any detected patterns of habitat use. The transect routes were chosen to provide coverage of four habitats — 42% of primary broadleaf forest, 40% of replanted broadleaf forest, 5% of coniferous plantations, and 3% of farmland with nearby human settlements. Because the vocalizations of Sichuan Partridges are not audible beyond 0.5 km (Liao 2006), distances between adjacent transects always exceeded 1 km to minimize the likelihood of detecting the same individual more than once. Using vocalizations heard within 100 m of transects, we located individual males foraging scrapes.

Characteristics of foraging sites and dust bathing were determined using 10×10 m plots established using either the feeding scrape (in the case of a feeding bird) as the center. For each site, we measured altitude (with a GPS), slope direction (with a compass), slope degree (with an

altimeter), shrub height (m; with altimeter), number of trees, number of shrubs, distance to path and distance to water, and estimated tree and shrub cover. In each quadrate, four subsamples of 1×1 m area, one at each corner, were used to measure number of bamboo plants, bamboo height and depth of the leaf litter (cm), and to estimate bamboo cover. To compare the characteristics of sites used for foraging a with those of surrounding areas, we established two 10 × 10 m habitat sampling plots 100 m from the central plot, one to the east and one to the west. Hereafter termed random plots, we took the same measurements as those at the central plot.

Habitat data were collected from April–early October. Persistent male territoriality through the duration of the study and the relatively slow vegetation dynamics typical of the subtropics meant that data across the season could be pooled. We used non-parametric procedures (Mann-Whitney test) to test for differences between sampled and random sites. χ^2 tests were used to test for the goodness-of-fit of utilized habitats to available habitats. A principal components analysis (PCA) was used to identify the most important axes of variation in habitat characteristics. We removed one of any pairs of strongly inter-correlated variables prior to PCA analysis based on a correlation matrix with varimax rotation. We retained roots >1 to identify principal components. Values are presented as mean ± SE, and statistical tests were two-tailed.

RESULTS

Habitat use by 60 territorial males was examined, with 46 (including 15 pairs) examined in April–June and 14 in August–October. The distribution and abundance of Sichuan Partridges were influenced by forest type, elevation, slope degree, and slope aspect (Fig. 2). Sichuan Partridges were found in primary broadleaf forest (n = 33) and

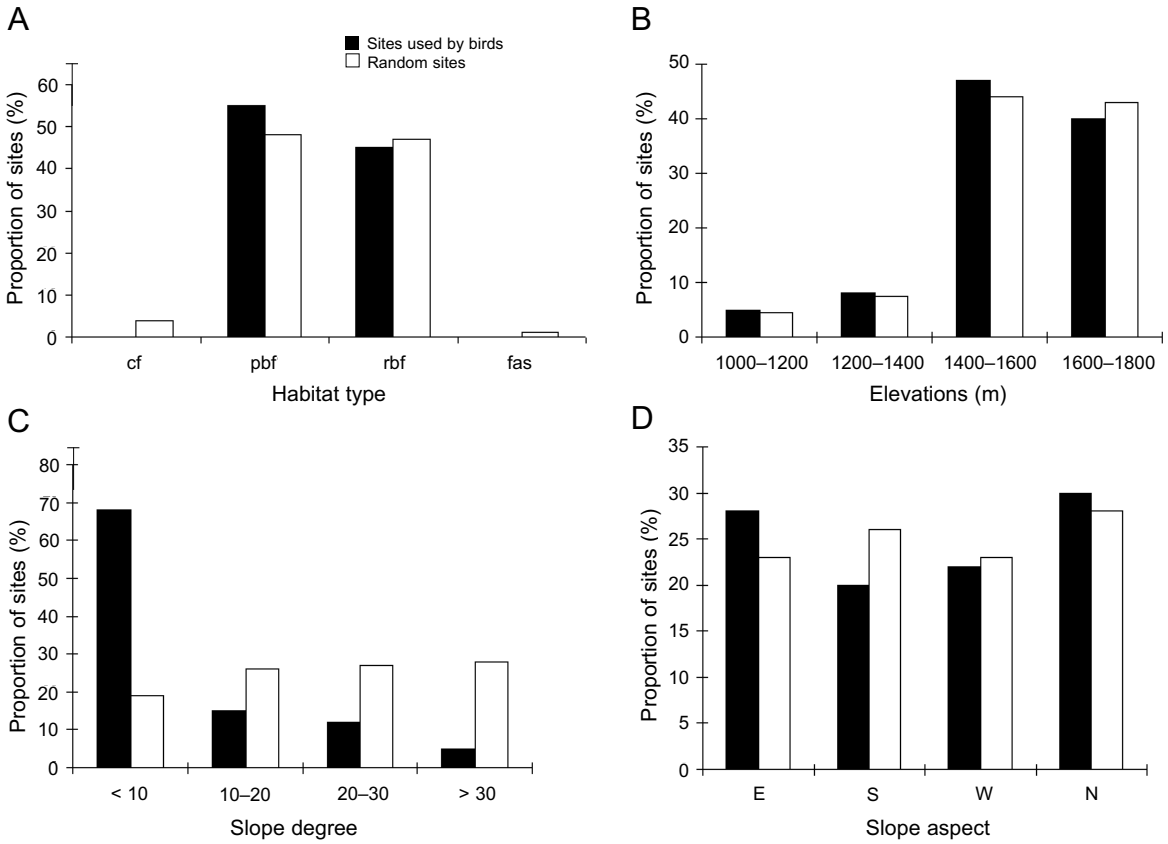

Fig. 2. Habitat use during the breeding season Sichuan Partridge in comparison with random sites. Relative occurrence in areas differing in (a) broad habitat type: pbf — primary broadleaf forest; rbf — replanted broadleaf forest; fas — farmland and settlements; cf — coniferous forest, (b) elevation, (c) slope, and (d) aspect: E — East, 16–135°; S — South, 136–225°; W — West, 226–315°; N — North, 316–360° and 0–45°.

replanted broadleaf forest with an open bamboo understory (n = 27), but not in coniferous plantations, farmland, and settlements. Frequency of occurrence in the two types of broadleaf forests did not differ (χ^2_1 = 1.0, p = 0.32). Most Sichuan Partridges were found at altitudes from about 1400–1800 m, with a slope of 5–15° and near paths and water sources. We found no evidence that birds selected slopes facing a specific direction during the breeding season (χ^2_3 = 1.2, p = 0.32).

Because partridges were not observed outside broadleaf forest, we used only random plots located in this type of habitat to compare them with sites used by the birds. Compared to random sites (n = 114), areas used by Sichuan Partridges (n = 60) had deeper leaf litter, greater tree cover, denser shrubs, and less bamboo cover (Table 1). PCA reduced the habitat variables into four principal components that explained 78.1% of the total variance. The first component (explaining 30.4% of the variation) could be interpreted as a con-cealment factor, with higher scores on this axis indicating denser coverage by trees and shrubs and higher shrub density. The second component (explaining 20.7% of the variation) described topography, in particular slope and elevation. The third component (explaining 17.8% of the variation) could be interpreted as a food availability factor, correlating with deciduous leaf depth. A fourth component incorporated information on bamboo condition, scaling with decreased bamboo abundance and cover (9.2%; see Table 2).

Table 2. The oblique solution structure from a PCA on attributes of 60 habitat samples by Sichuan Partridge. Values are correlations between each principal component and each of the independent variables, with the highest correlates of each principal component (> 0.7) shown underlined.

Variable	Principal component axis			
	PC 1	PC 2	PC 3	PC 4
Altitude	0.18	0.78	0.32	-0.02
Slope direction	-0.33	0.22	0.48	0.17
Slope degree	0.42	0.82	-0.11	0.28
No. of tree	-0.26	-0.44	0.63	0.14
Tree cover	0.87	-0.24	0.46	-0.08
No. of shrub	0.78	0.32	-0.06	-0.31
Shrub cover	0.73	-0.16	0.03	0.29
No. of bamboo	0.13	0.06	-0.62	0.76
Bamboo cover	-0.11	0.38	0.16	0.83
Distance to water	0.09	-0.14	-0.71	-0.22
Deciduous leaf depth	0.45	-0.27	0.81	0.09
Distance to path	-0.17	0.42	-0.75	-0.24
Eigenvalue	3.70	2.52	2.17	1.12
Proportion of values	30.4%	20.7%	17.8%	9.2%
Cumulative	30.4%	51.1%	68.9%	78.1%

DISCUSSION

Our study demonstrated that Sichuan Partridges foraged on the ground in broadleaf forest, as noted by Li & Zhang (1974). The habit of this foraging habitat use is similar with that of Common Hill Partridges *Arborophila torqueola* in south Sichuan (Liao et al. 2007a). In the study, we found that *A. rufipectus* use primary broadleaf forest and replanted ones rather than coniferous forest or farmland and human settlements, with no significant difference in partridge occurrence in

Table 1. A comparison of habitat features (mean ± SD) between locations (10×10 m quadrats) in which Sichuan Partridges were recorded feeding or dust bathing (N = 60), and random sites (N = 114) situated 100 m to the E and W of each sampled site.

Habitat variable	Sampled sites	Random sites	Z	p
Altitude (m)	1665.3 ± 17.5	1688.9 ± 19.5	0.16	0.77
Aspect	194.6 ± 2.6	130.5 ± 1.8	0.88	0.32
Slope	9.2 ± 0.6	34.9 ± 1.2	7.64	0.00
No. of trees	3.6 ± 0.2	3.7 ± 0.1	0.86	0.65
Tree cover (%)	95.2 ± 3.4	72.9 ± 1.2	2.66	0.04
No. of shrubs	12.6 ± 0.8	8.8 ± 0.6	2.80	0.03
Shrub height (m)	4.5 ± 0.3	3.7 ± 0.3	0.75	0.42
Shrub cover (%)	82.1 ± 0.4	84.1 ± 0.6	1.08	0.30
No. of bamboos	12.4 ± 0.8	23.2 ± 1.7	5.12	0.00
Bamboo height (m)	1.6 ± 0.6	1.8 ± 2.1	1.33	0.44
Bamboo cover (%)	72.5 ± 1.4	86.4 ± 1.5	2.55	0.07
Distance to water (m)	21.2 ± 1.3	61.2 ± 1.7	3.30	0.00
Deciduous leaf depth (cm)	9.4 ± 0.8	4.5 ± 0.4	2.91	0.01
Distance to path (m)	24.5 ± 0.9	60.6 ± 1.7	6.51	0.00

primary broadleaf and replanted broadleaf forest. Similarly, Dai et al. (1998) found that the densities of calling males in these two habitat types did not differ over two successive years. In addition, studies of radio-tagged Sichuan Partridges in Leibo County, southern Sichuan, indicates that Sichuan Partridges consistently select primary and older planted secondary broadleaf forest over forest degraded by human activity or scrub (Dai et al. in press).

Variables that influenced microhabitat selection by Sichuan Partridges in our study included dense shrub layer, high levels of tree cover, thick deciduous leaf depth, and low bamboo abundance. Because we used feeding scrapes and dust-bathing sites to identify used habitats, our results refer only to selection of habitat for these activities, rather than for breeding site selection in general. Use of areas with a dense canopy as foraging sites might reduce predation risk (e.g. Cody 1985). We also found that Sichuan Partridges occurred in areas with low bamboo density and sparse understory cover, perhaps because their predominant foraging mode involves searching for food in the damp leaf litter layer on the forest floor (MacKinnon et al. 2000). The fact that the first three axes of the PCA explained relatively little of the variance in habitat characteristics suggests that habitats used by Sichuan Partridge may vary in complex ways.

Although previous studies of habitat use by Sichuan Partridges (Li et al. 2003) identified gently sloping terrain as an important factor, Dai et al. (1998) also found birds on steeper slopes. In our study area, where shallow slopes predominate, Sichuan Partridges typically used gently sloping areas (5–15°). Dai et al. (1998) reported apparently suitable subtropical broadleaf forest up to about 2400 m on east-facing slopes, but only up to about 1800 m on west-facing slopes, but we found aspect had no effect on partridge occurrence during the breeding season. However, during the non-breeding season, birds select habitats at elevations of 1000–1600 m with a south-facing slope (Liao et al. 2007b), suggesting that distribution in relation to aspect might be seasonal in this species. Disproportionate use of areas 1400–1800 m a.s.l., away from the disturbed valley bottoms, suggests a significant aversion to direct human disturbance (Dai et al. in press).

Our results also suggest that a well-developed leaf litter is important in explaining microhabitat choice in Sichuan Partridges. To our knowledge, diet of birds foraging in the leaf litter is poorly described. The topic clearly deserves further study, as we frequently observed birds searching for food in thick leaf litter. It would also be interesting to study spatial patterns of variation in litter quality and hence food availability for Sichuan Partridges. This could be done through collection of fecal samples at roost sites combined with radio telemetry. Such techniques have been used in Mamize Nature Reserve and are still being developed at Laojunshan Nature Reserve.

Prior to 1998, the primary threat facing Sichuan Partridges was habitat destruction due to clearing of primary broadleaf forest (Dowell & Dai 2000). Indeed, much recently planted forest in Laojunshan consists of fir species that are unsuitable for Sichuan Partridges. However, since 1998, commercial deforestation has been prohibited with the full implementation of a ban on logging in the upper Yangtze basin. This has led to the establishment of some Nature Reserves such as Laojunshan, Mamize and Heizhugou. Laojunshan was designated as a Local Nature Reserve in 2000, becoming a Provincial Nature Reserve in 2002, and is currently being expanded by an additional 67 km^2 with a small quantity of primary broadleaf forest and abundant replanted broadleaf forest. Given that replanted broadleaf forest is apparently used by Sichuan Partridges, such habitats should feature in habitat management plans for the species. There is some evidence that the Sichuan Partridge population in Laojunshan has increased, with a count of about 35 birds in 2000 and 130 in 2002 (Dowell & Dai, after Sichuan Academy of Forestry 2004). To expand the area of habitat available to the birds, there are plans to reconnect a number of remnant patches of primary forest in its western extension. Our habitat studies suggest that, given time, replanted broadleaf forest might eventually support viable populations of the species.

Now that the forest is protected, the main threat to Sichuan Partridges appears to be disturbance from human activities, including collecting bamboo shoots, livestock grazing, and medicinal plant harvesting. Particularly in the breeding season, these activities may destroy the birds' nests and directly affect reproductive success. Although natural resource managers have devoted considerable energy and resources to habitat restoration and reducing human disturbance in the reserve, there is still some illegal poaching of wildlife and wood cutting near the reserve. Clearly, some anthropogenic disturbances are a direct consequence of difficult economic conditions for local

people, and development projects that might help reduce forest resource use could be promoted in this area. This study provides significant support for researchers mapping and assessing the distribution of suitable Sichuan Partridge habitat. Selection of corridor sites can be further refined using our results, as can the identification of potentially important areas at the edge of the reserve.

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STRESZCZENIE

[Wybiórczość środowiskowa pstropióra syczuańskiego w sezonie lęgowym]

Należący do kurowatych gatunek jest endemitem górskich terenów południowo-zachodnich Chin. Zamieszkuje subtropikalne lasy liściaste, jednak wybiórczość środowiskowa w mikroskali nie jest znana. Badania prowadzono w rezerwacie Laojunshan w prowincji Syczuan (Fig. 1), w okresie kwiecień–październik 2005. Wytyczono trzy transekty długości 4–5 km każdy (Fig. 1). Na podstawie głosów ptaków wyszukiwano ślady żerowania ptaków i następnie w tych miejscach (w kwadracie 10x10 m, oraz 4 mniejsze kwadraty 1x1 m) opisywano zmienne środowiskowe. Zebrane dane porównywano z tymi, uzyskanymi dla kwadratów zlokalizowanych 100 na wschód i zachód od miejsca żerowania, które były traktowane jako miejsca losowe.

Ptaki stwierdzano w pierwotnych i wtórnych lasach liściastych, na wysokości 1400–1800 m n. p. m., o lekkim nachyleniu (Fig. 2) blisko ścieżek i wody (Tab. 1). Miejsca żerowania charakteryzowały się gęstszymi krzakami, grubszą ściółką i mniejszym pokryciem przez bambusy (Tab. 1, 2). Uzyskane wyniki należy wziąć pod uwagę w działaniach mających na celu ochronę tego gatunku.