Habitat Utilization of the Sichuan Hill Partridge *Arborophila rufipectus* in the Non-breeding Period in Laojunshan Nature Reserve

LIAO Wen-bo[1,2]   LI Cao[3] *   HU Jin-chu[1] *   LU Xin[2]

1. *Institute of Rare Animal and Plants   China West Normal University   Nanchong   637002   China*

2. *College of Life Science   Wuhan University   Wuhan   430072   China*

3. *Department of Bioengineering   Yibing College   Yibing   644007   China*

Abstract   The Sichuan Hill Partridge *Arborophila rufipectus* requires successional broadleaf forest and their populations have declined as a result of fragmentation of endemic bird areas in subtropical forest in the mountains of southwestern China. In this paper   habitat utilization of the Sichuan Hill Partridge was studied in replanted broadleaf forests   in Laojunshan Nature Reserve of Sichuan   to determine the importance of habitat features   during the non-breeding period from November to December 2005. The Sichuan Hill Partridge utilized habitats within elevations of 1 000 to 1 600 m and with a south-facing slope of two to 15 degrees   close to road and forest edges. The birds preferred sites with smaller bamboo density   lower bamboo cover and snow cover and shrub cover was greater at used sites than at random sites. Principal components analysis indicated that food on the ground layer   topographic condition   concealment and temperature were the first four components of bird habitat selection   and the load of the first component was 29.407%. The findings indicated that the Sichuan Hill Partridge might face the well-documented trade-off between food resource and predation risk when utilizing habitat. We suggest that the conservation and restoration of successional broadleaf forest habitats will benefit the Sichuan Hill Partridge.

Key words   Sichuan Hill Partridge   *Arborophila rufipectus*   Ecological factors   Non-breeding period   Habitat utilization

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　　　　　　　　　Arborophila rufipectus
　　　　　　　2005　11—12　　　　　　　　　　　　20
　　　　　10 m × 10 m　　　　4　　1 m × 1 m　　　　　　　　　12

　　　　　　　100 m　　　　　　　1—2　　　30

1 000—1 600 m　　　2—15°

Environmental factors can have profound influences on population processes Ferguson et al 1999 . All species are faced with variations in environmental conditions including variation that exceeds the limits of survival for individuals of the species. Habitat is any spatial unit that can be occupied by an individual animal no matter how briefly Baker 1978 . Analysis of habitat selection has been a common and important aspect of wildlife research Alldredge & Ratti 1986 . Habitat requirements of species initially are based on qualitative descriptions relating the presence or absence of a species to the general type or structure of vegetation Hiden 1965 . Ecological research often involves comparison of the use of habitat types or food items with the availability of those resources to the animal Johnson 1980 . A goal of resource selection studies is to identify the habitats that are selected by a species. However favorability of a particular habitat feature is likely to be contingent on such factors as predation risk and an individual′s resource needs. Thus habitat selection may vary depending on context and identifying causes of variability in habitat use can increase our understanding of functional aspects of a species′ habitat ecology Whitaker et al 2006 . The term habitat selection is described differently by different researchers. Svardson 1949 suggested that habitat selection involves two aspects primary selection of general environmental features under the different habitats and then further selection of specific habitat based on detailed features. Johnson 1980 defined habitat selection as a process in which an animal actually chooses the habitats and use of habitats is said to be selective if habitats are used disproportionately to availability. Wiens 1981 indicated that habitat selection may occur at different spatial scales and need not be based on the same criteria at each scale. Habitat selection of birds has been widely studied in recent years Zhang et al 2003 Lu & Zheng 2001 Liao 2006 Ward 2005 Endrulat et al 2006 . In addition the true processes of habitat utilization have been considered in a multivariate context Huston 2002 .

The Sichuan Hill Partridge *Arborophila rufipectus* is one of the four threatened members of the suite of five bird species that are entirely restricted to the" Chinese Subtropical Forests Endemic Bird Area". The threats to and conservation measures for this species have been profiled by Stattersfield et al 1998 . It is a nationally protected animal in China and classified as Endangered in the IUCN Red List IUCN 2004 because of its largely restricted range 1 800 km² very small population < 2 000 birds and severely fragmented habitat Dai et al 1998 Li et al 2003 . Forest coverage in Sichuan was estimated to have been reduced from 19.0% in the early 1950s to 12.6% in 1988 which effected the habitat utilization population status and population size of the birds Li 1991 Smil 1993 . To date although the distribution population density conservation status vocalization and habitat utilization of Sichuan Hill Partridges in the breeding period has been studied in recent years Dai et al 1998 Li et al 2003 Liao et al in press little information of habitat utilization of the species in the non-breeding period has been reported. This paper focuses on how Sichuan Hill Partridges utilize habitat and which parameters significantly influence habitat utilization in the non-breeding period.

1　Methods

1.1　Study area

Fieldwork was carried out from 5 November to 25 December 2005 in Laojunshan Nature Reserve 103° 48′E 28°38′N total area about 10 213.3 ha . The Reserve ranges in altitude from 1 100－2 008 m has an annual average temperature of 12.5℃ and annual average precipitation of 1 500 mm over 60% of which falls during June-August . In the non-breeding period the minimal temperature is －10℃ and average temperature is 0.5±1.0℃. The distance from the east edge to the west edge of the Reserve is 27.23 km and is 22.89 km from the south edge to the north edge. The core area is divided into two parts by the Longdongping tea-field and the No. 213 national road. The vegetation

covering the reserve is characterized by Alangiaceae Theaceae Fagaceae Teeracentraceae Lauraceae and Erieaceae. The tree layers are dominated by *Cinnamomum inunctum Castanopsis omeiensis Cunninghamia canceolata Davida involucrate Tetracentron sinense Carpinus fargesii Cercidiphyllum japonicum Machilus ichangensis Magnolia officinalis Cyclobalanopsis glauca* the shrub layers are dominated by *Eurya loquiana Camellia oleifera Elaeagnus bockii Actinidia callosa Rubus cockburnianus Alangium chinense Rhododendron hunnewellianum Dendrobenthamia angustata Hedera nepalensis Lonicera giraldii Prinus conadenia Aphis citricola Cnimonobambusa quadrahgu* and characteristic species in the ground layer are *Plantago asiatica Paris verticillata Juncus setchuensis Goodyera repens Dryopteris* spp. Detailed habitat data of the birds were collected in core areas of the reserve where no hunting or agriculture activities are conducted.

1.2　Study method

　　Owing to the thick shrub cover it was difficult to accurately find and count the birds. Calling became less frequent as the season progressed and encounter rates were low. Feeding traces and faeces decayed rapidly because of wet soil during the season so these were not suitable as indicators of the birds' occurrence. In the study area fresh faeces from the Sichuan Hill Partridge could be easily distinguished from sympatric galliformes and Laughing-thrushes based on shapes and sizes in the non-breeding period. The shape of the faeces of Laughing-thrushes was a column which differed from the elliptical shape of the Sichuan Hill Partridge. There were many sub-adult Temminck's Tragopans *Tragopan temminckii* in the reserve during the period whose faeces sizes were significantly larger than those of the Sichuan Hill Partridge. Although faeces shapes of the Sichuan Hill Partridge were similar with those of the Chinese bamboo Partridge *Bambusicola fytchii* the sizes of the Sichuan Hill Partridge's faeces 12.5 ± 1.6 mm × 9.2 ± 0.9 mm were larger than those of the Chinese Bamboo Partridge 10.3 ± 0.8 mm × 7.6 ± 0.5 mm Mann-Whitney U test $Z = 2.24$ $n_1 = 30$ $n_2 = 15$ $P < 0.05$. Therefore fresh bird faeces allowed us to quantify habitat utilization. Random transect lines were walked at a speed of 1.5 km/h to investigate the habitat utilization of birds $n = 9$ transects. Once faeces had been found within 100 m of either side of the transect

habitat sampling plots were established using a 10 m × 10 m quadrat with the faeces at the center of the plot. Counting bouts lasted 2 – 3 h and all surveys were conducted among the replanted broadleaf forest during the study period. Sampling was conducted according to the method of Lu & Zheng 2001. The measured parameters included altitude measured using GPS slope direction measured with a compass slope degree measured with an altimeter and distance to the nearest road measured with an altimeter. Tree canopy cover shrub density shrub height shrub cover and distance to the forest edge were estimated. Within each sample site four sub-samples of 1 m × 1 m quadrats at each corner were selected for measuring bamboo density bamboo cover and snow cover.

　　A total of 30 random sites with 10 m × 10 m quadrats were sampled for comparison. Random sample sites were placed 100 m away from sample site in a random direction and the same habitat parameters were measured. Statistical analyses were performed with SPSS 12.0. We used non-parametric procedures that tested the difference between sample and random plots Mann-Whitney U test when sample size is small or the data distribution is abnormal. Principal component analysis a multivariate technique that can produce a simplified reduced expression of original data with a complex relationship has been widely applied in research on wildlife habitats when Kaiser-Meyer-Olkin measures of sampling plots were adequate James & McCulloch 1999. Correlation between variables for the 12 habitat parameters were analyzed using Spearman' rank correlation coefficients before using principal component analysis because correlation coefficients between parameters would influence the result of habitat utilization. All tests were two-tailed and results are shown as mean ± SD.

2　Results

　　There were 86 species of plant counted in 20 habitats which consisted of the tree layer shrub layer and grass layer. During the non-breeding period Sichuan Hill Partridges were mainly concentrated in habitats at an altitude of approximately 1 100 – 1 500 m having a south-facing slope of five to 15 degrees and close to road and forest edges Fig. 1. Sichuan Hill Partridges preferred sites with smaller bamboo density and lower bamboo cover and snow cover than that of random sites and shrub cover was greater at used sites

than at random sites Tab. 1 . Correlation analysis indicated that any two variables for the 12 parameters was insignificant. Therefore we used principal component analysis to identify major trends in habitat utilization and the relative importance of habitat measurements. Principal component analysis Tab. 2 showed that there were four principal components and 72.688% of accumulated variance among plant communities was attributed to these four components only tree cover and shrub height were poorly represented. The varimax rotated factor matrix showed significance for each principal component. The first principal component reflected
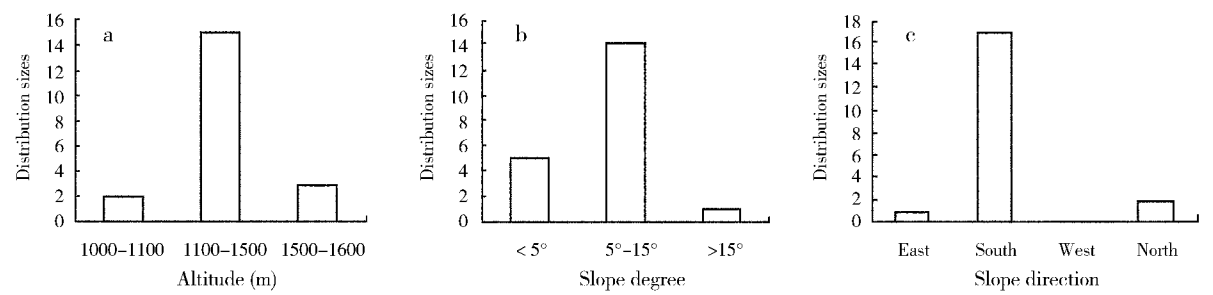

Fig. 1   The habitat distribution of altitude a   slope degree b and slope direction c of the Sichuan Hill Partridge in the non-breeding period

Tab. 1   The difference of habitat measures 10 m × 10 m sampling and random sites i. e. 100 m away in a random direction

Habitat factors	Habitats $n = 20$	Random sites $n = 30$	Z	P
Altitude m	1381.4 ± 173.2	1418.9 ± 611.2	1.04	0.023
Slope direction	259.6 ± 32.6	162.6 ± 16.2	2.94	0.002
Slope degree	7.7 ± 5.1	33.7 ± 13.2	3.29	0.002
Tree cover %	61.8 ± 14.3	54.1 ± 15.2	1.32	0.252
Shrub cover %	67.7 ± 13.3	56.6 ± 12.5	1.40	0.032
Shrub density	20.5 ± 17.2	14.5 ± 13.5	0.62	0.637
Shrub height m	4.1 ± 0.6	3.9 ± 0.7	0.81	0.531
Bamboo cover %	53.8 ± 13.3	73.8 ± 9.5	2.48	0.000
Bamboo density	6.9 ± 4.3	13.5 ± 3.5	2.37	0.000
Distance to road m	13.3 ± 11.3	64.9 ± 30.5	2.83	0.000
Distance to forest edge m	110.0 ± 75.5	179.2 ± 86.6	1.67	0.007
Snow cover %	31.6 ± 11.4	43.9 ± 20.7	1.62	0.011

Tab. 2   Factor loads of habitat parameters of 20 samples on the first four principal components Component factors listed in bold type

| Habitat factors | Factor loading | | | |
	First principal component	Second principal component	Third principal component	Forth principal component
Altitude	−0.087	−0.129	0.069	**0.863**
Slope direction	−0.494	**−0.621**	−0.407	−0.184
Slope degree	−0.537	**0.611**	−0.234	−0.086
Tree cover	0.038	−0.370	0.222	0.243
Shrub cover	0.009	−0.184	**0.808**	0.137
Shrub height	0.189	−0.083	0.025	−0.018
Shrub density	−0.250	0.147	**0.729**	−0.078
Bamboo cover	**0.907**	−0.137	−0.151	0.086
Bamboo density	**0.744**	0.060	−0.330	0.273
Snow cover	0.240	0.122	−0.001	**0.744**
Distance to road	**0.787**	0.103	0.085	−0.041
Distance to forest edge	0.051	**0.773**	0.168	0.184
Eigenvalue	3.235	1.778	1.691	1.071
% of variance	29.407	17.164	16.369	9.272
% Cumulative	29.407	46.572	62.941	72.688

factors relating to food on the ground layer explaining 29.407% of overall variation and had heavy loads for low bamboo cover small bamboo density and close distance to the nearest road. The second principal component reflected topographic factors explaining 17.164% of variation consisting of a gentle gradient proximity to the forest edge and south-facing slopes. The third principal component 16.369% may be generalized as concealment with dense shrub cover and high shrub density. The fourth principal component 9.272% reflected temperature factors and suggested that Sichuan Hill Partridges utilized habitat with relatively low elevation and low snow cover.

3   Discussion

Sichuan Hill Partridges preferred gentle slopes of 2–15 degrees and near forest edges. Our findings are unanimous with reports that the partridges select areas with gentle slope gradients Xu et al 1994 Li et al 2003 . However Dai et al 1998 found that the partridges utilized most forest habitats with steep gradients. They utilized south-facing slopes because these were probably related to decreasing wind velocity. Dai et al 1998 also recorded apparently suitable subtropical broadleaf forest up to approximately 2 400 m on east-facing slopes but only up to approximately 1 800 m on west-facing slopes. The different results may be related to the altitude of the study area and the season.

Sichuan Hill Partridges mainly occupied elevations between 1 000 and 1 500 m in the non-breeding period and did not use elevations between 1 600 and 2 000 m because temperature was lower at higher elevation. The maximum temperature we observed at high elevation of 2 000 m was 3.2℃ in the daytime and less than 0℃ for 60% of the night by contrast the maximum and minimum temperatures at low elevation of 1 200 m were 5.6℃ and 3.2℃ respectively. Sichuan Hill Partridges utilized low elevation habitats to avoid energetically costly microclimates at high elevation. At times wind chill may be greater at higher elevations due to increased exposure.

Snow cover had a significant effect on habitat utilization. Areas with little snow cover had higher temperatures than areas with a large amount of snow. Under these circumstances the birds would reduce their energy expenditure. Xu et al 1994 indicated that Sichuan Hill Partridges select sites in winter which have no snow cover. Gates & Hale 1974 also postu-

lated that snowy winters may have been partially responsible for reciprocated movements of ring-necked pheasants *Phasianus colchicus* that relocated to the study area in search of secure winter habitat with appropriate temperatures.

Although we did not directly measure parameters in relation to food resources we found Sichuan Hill Partridges utilized sites with low bamboo cover small bamboo density and close to roads. This may be because the well-developed deciduous leaf layers in the habitats can provide abundant food supplies. We observed some feeding traces and faeces and many Robur fruits near fresh faeces. In winter we found that the birds mainly depended on plant food such as fruit rather than on invertebrates in the deciduous leaf layer. Xu et al 1994 reported that the partridges select habitats with thick leaf litter in which the amount of food including insects and weeds is high. Therefore the Sichuan Hill Partridge did not utilize habitats with great bamboo cover and large bamboo density because they can neither provide abundant food nor decline the risk of predators. The Common Hill Partridge *A. torqueola* also utilizes foraging habitat with low bamboo cover and small bamboo density in the breeding season unpublished data .

The Sichuan Hill Partridge′s preference for habitats approaching the road is probably related to abundance of food resource. In the non-breeding season we found that there were five flocks of partridges each with 3–6 individuals ranging between 5–10 m from the roads when foraging at an elevation of approximately 1 200 m. Sichuan Hill Partridges utilized habitats close to roads which is similar to other studies of galliforms. For example Schumacher 2002 found that ruffed grouse *Bonasa umbellus* in North Carolina forage closer to roads than would be expected at random. Whitaker 2003 reported that selection of roads in female ruffed grouse is positively related to selection of clear cut areas in oak-hickory forests female ruffed grouse use roads more frequently following poor fall mast crops signifying the importance of roads as foraging areas when other food supplies are scarce. Sichuan Hill Partridges firstly utilize habitats with abundant food. Some other galliforms also firstly select habitats with ample food resources Xu et al 2002 Li et al 2006 .

The preference of the Sichuan Hill Partridge for habitats with high shrub cover may be due to increased

concealment and avoidance of predation risk. Some studies suggest that predation risk is an important factor effecting habitat selection Walsberg 1983 Johnson 1980 Whitaker et al 2006 . Liao 2005 reported that shrub cover is positively correlated with Sichuan Hill Partridge habitat quality due to reduced predation this is widely viewed as a cornerstone of the species habitat needs. Zhang et al 2005 suggested that the Brown-eared pheasant *Crossoptilon mantchuricum* selects concealment as the most important factor in winter habitat selection. Lu & Zheng 2002 studied the habitat selection of Tibetan eared pheasants   *C . harmani* in the non-breeding period which suggested that there is a greater predation risk during night-roosting. Therefore selecting night-roosting habitats with higher shrub coverage might help the birds to avoid predators.

Sichuan Hill Partridges may face the well-documented trade-off between food resource and predation risk when utilizing a good habitat in the non-breeding period. Some studies have indicated that animals not only searched for food but also assessed predator pressure when selecting good habitats Randler 2006 Arenz & Leger 1997 Baack & Switzer 2000 . Currently we do not understand the mechanisms that Hill Partridges use to assess the trade-off between foraging and avoiding predators when utilizing habitats. It is necessary to study this relationship in the future.

The population of the Sichuan Hill Partridge in the Laojunshan Nature Reserve is likely to continue to decrease without management of the reserve and the conservation and restoration of successional broadleaf forest habitats Liao 2006 . Before the reserve was established a large number of primary broadleaf forests were logged which decreased the number and range of the birds Smil 1993 . The number of birds has significantly increased with renewal of the habitat since the reserve was established in 2000. Although natural resource managers have devoted considerable energy and resources to improve the condition of habitats for the Sichuan Hill Partridge in core terrain some poachers seek larger galliforms which leads to the trapping of Sichuan Hill Partridges Liao 2006 . We suggest that alternative mechanisms for improving local resident earnings are introduced and outlawing poaching in the reserve as well as in adjacent areas should be considered by local governments.

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