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During 1995-2004, we studied the nest site selection of the Chinese grouse *Bonasa sewerzowi* at Lianhuashan, Gansu, China. Of the 103 nests that we found, 56% were at the base of deciduous trees, mainly willow *Salix* spp. and birch *Betula utilis*, and 40% were at the base of coniferous trees. The Chinese grouse favoured northern and eastern slopes with steepness of 0-45°, averaging 15.5 ± 11.2° (SE; N = 97); 88% of nest sites were on slopes of < 30°. The average cover around the nest was 50.8 ± 20.3% (SE; N = 86). The degree to which the female was covered at successful nests was 51.4 ± 19.9% (SE; N = 45), which was not different from that of unsuccessful nests (43.1 ± 19.1% (SE); N = 17). Chinese grouse preferred to nest in coniferous and coniferous-deciduous mixed forests at sites with fewer trees and denser shrubs, compared with the available vegetation. Females nested on average 154.2 ± 109.0 m (SE; N = 19) from the previous year's nest. Compared with the hazel grouse *B. bonasia*, the Chinese grouse showed a greater preference for nesting at the base of trees or stems.

Key words: Bonasa sewerzowi, breeding ecology, Chinese grouse, Lianhuashan, nest site selection, People's Republic of China

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Natural selection favours individuals that choose resources that enhance breeding success. Because many grouse populations experience high rates of nest predation (Storaas & Wegge 1987, Wegge & Storaas 1990), habitat features that influence nest site quality may be important in nest site selection. Quality of nest sites can be affected by microclimate, food availability and nest predation. Nest predation is usually the primary source of nest mortality (reproductive loss) and is considered to be a strong selective force in nest site selection (Bergerud & Gratson 1988, Schieck & Hannon 1993). As a result, selection of nest sites with reduced risk of nest predation and protection from inclement weather should be preferred.

The Chinese grouse *Bonasa sewerzowi* is the only endemic tetraonid bird in China. It is distributed in the

conifer forests in the high mountains of west China and is listed as 'endangered' in the China Red Data Book (Zheng & Wang 1998). Our study is part of a larger conservation-oriented study of the ecology of the Chinese grouse. Documenting the factors affecting nest-site selection by Chinese grouse is important for conservation of the species, because Chinese authorities are reforesting previous Chinese grouse habitats (Sun et al. 2003). For this effort to be most beneficial for the endangered Chinese grouse, habitat selection must be documented. In addition, there is some illegal tree cutting in the protected forests inhabited by the grouse (Sun et al. 2003), but the effects of this on nesting habitat are unknown.

Study area

Our study was carried out at the Lianhuashan Nature Reserve (34°55'N, 103°43'E), the province of Gansu, China. The forest in this reserve is situated at altitudes of 2,600-3,500 m a.s.l., with the highest peak attaining 3,578 m a.s.l. The forest occurs on northern slopes and some northeastern or northwestern slopes. Only shrubs, mainly sea buckthorn *Hippophae rhamnoides* and willows *Salix* spp. grow on the southern slopes. Conifer forest, the most prevalent cover type in the study area, is characterised by spruce *Picea asperata* and fir *Abies fargesii*, mixed with birch *Betula utilis* and many species of willow. For a more detailed description of the study area, see Sun et al. (2003).

Methods

Nests were found by locating radio-tracked females, either by local people, who received a reward for not disturbing the bird, or by ourselves. For each nest site, we measured the following habitat variables: cover type, altitude, slope, exposure (east: 45-134°, south: 135-224°, west: 225-314°, and north: 315-44°), distances to free water and forest edge, nest tree species (if at the base of $\geq$ 2 tree species, all species were recorded), and cover (concealment). Cover was estimated as the average proportion, in 10% intervals, of the hen camouflaged by vegetation from three sides when viewed from a distance of 5 m. Overhead cover was defined as cover that prevented direct exposure of the nest to rain.

We described the habitat structure at all nest sites by investigating vegetation characteristics in a 10×10 m sample plot with each nest as the centre. We estimated the canopy cover (amount of sky obscured) in 10% intervals, the numbers and species of trees with a diameter at breast height (dbh) of > 3 cm, and the number and diameter of cut stumps (illegal harvest). We estimated shrub cover in four 2×2 m sample areas within the large sample plot and recorded the average. We made similar measurements at randomly selected sites within male Chinese grouse spring territories for comparison. Nest site vegetation was classified into three types: conifer forest, conifer-deciduous mixed forest and shrubs. Availability of these three types was obtained from the local forestry map: 42.1% conifer forest, 25.5% conifer-deciduous mixed forest, and 32.4% shrubs. Availability of local exposure was obtained from the local topographic map: 11, 20, 28 and 41% for east, south, west and north exposures, respectively.

Nest success of 62 nests was recorded. Nests were classified as successful when at least one egg had hatched. We used χ^2 goodness-of-fit tests and the Bonferroni family of simultaneous confidence intervals to test use of nest site relative to availability (Neu et al. 1974). Means are presented with the SE of the mean. Differences in habitat characteristics between nest sites and random sites were analysed using Mann-Whitney U-tests. We considered differences significant if $P < 0.05$.

Results

During 1995-2004, 103 nests were found, 52 from radio-marked hens (one hen renested in 1997), 43 from unmarked hens, six after the breeding season, and two during the nesting period (abandoned). All the nests were found at elevations of 2,700-3,300 m a.s.l. Nest vegetation types were used disproportionately to their availability (χ^2-test, df = 2, $P < 0.001$), with the shrub type being avoided and conifer and conifer-deciduous types being used in proportion to their availability.

Of the nests, 89 were found at the base of trees, 13 at the base of stumps and one at the base of a broken trunk. The nests were more often at the base of deciduous trees (56% by willow or birch and 40% by spruce or fir; Fig. 1) than expected based on tree availability ($\chi^2 = 39.26$, df = 2, $P < 0.001$).

Mean concealment of the females at the nests was 50.8 ± 20.3% (N = 86, range: 10-93%). The concealment of successful nests was 51.4 ± 19.9% (N = 45) and that of unsuccessful nests was 43.1 ± 19.1% (N = 17). The higher concealment of successful nests was

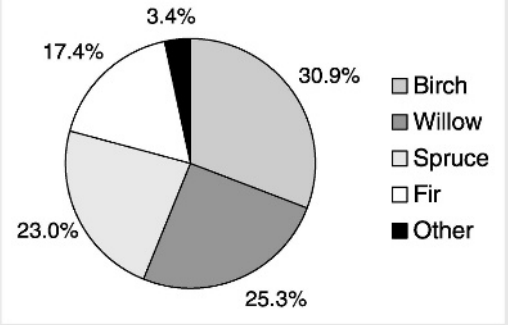

Figure 1. Nest tree selection (in %) by the Chinese grouse at Lianhuashan Nature Reserve, Gansu, China.

not significantly different from that of unsuccessful nests (t-test: $t = 0.043$, $P = 0.837$). The cover above the nests averaged 61.9 ± 18.3% (N = 21). Thus, most nests were protected from the weather.

The observed occurrence of nests by slope exposure was different from that expected ($\chi^2 = 43.9$, $df = 3$, $P < 0.001$). According to the χ^2 goodness-of-fit tests and the Bonferroni family of simultaneous confidence intervals, two exposures were used significantly differently; eastern exposures were used more than expected, and southern exposures were used less than expected (Fig. 2). The slope at the nest sites ranged within 0-45°, and averaged 15.5 ± 11.2° (N = 97) with 88% of nest sites being on slopes of < 30° (Fig. 3).

We compared the vegetation characteristics between the nest sites and control sites within Chinese grouse habitat (i.e. male territories). Significant differences were evident for several variables (Table 1). Nest sites had a lower spruce density, greater shrub cover, and larger fir and willow trees than control sites. In addition, there were more cut stumps near nest sites than expected; this may have been because cutting opened the forest and allowed more shrubs to grow. We suggest that the Chinese grouse preferred nest sites with fewer conifer trees and denser shrubs, the latter providing more concealment at the ground level.

Knowledge about male territories was obtained by radio-tracking the males of five females that nested. All of their nests were at the border of the males' territories. During 1996-2004, we found the nests of 14 females in two consecutive years, those of one female in three years, and those of one female in four years. In addition, one radio-tracked female renested after her first nest with three eggs was destroyed. Of these 17 females, eight changed nest trees, thus increasing nest

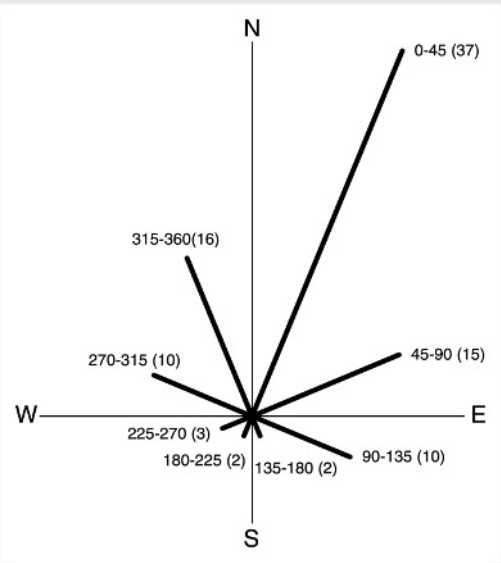

Figure 2. Distribution of slope directions of the nests of Chinese grouse at Lianhuashan Nature Reserve, Gansu, China. The number of nests is given in parentheses.

concealment by, on average, 25.8% (N = 20). Of 14 successful females, six changed their nest trees between deciduous and coniferous. Females moved their nest sites an average of 154.2 ± 109.0 m from one year to the next (N = 19, range: 40-390 m). Two females stayed with the same male in the same territory in two consecutive years, the distance between their nests in those two years being 180 m and 60 m, respectively; six females stayed in the same territory (status of the male unknown), and one female nested in the neighbouring male's territory. The average female territory size is 2.2 ha (N = 8; unpubl. data), with a territory diameter of about 170 m. We suggest that females are philopatric, preferring to nest within the same territory from year to year, either within the

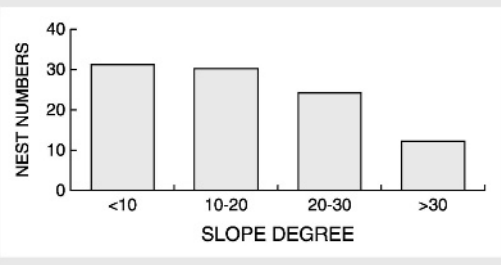

Figure 3. Distribution of slope steepness (in degrees) at the nest sites (N = 97) of Chinese grouse at Lianhuashan Nature Reserve, Gansu, China.

Table 1. Habitat characteristics of nest sites (N = 59) of Chinese grouse at Lianhuashan Nature Reserve, Gansu, China, during 1995-2004 in comparison with random vegetation samples (N = 38) from male territories. Tree diameter was measured at breast height (dbh).

	Nest sites		Random sites		
Habitat components	Mean	SE	Mean	SE	P
Canopy cover (%)	57	2.00	55	3.00	0.70
Conifer density (trees/ha)	574.58	75.32	673.68	66.48	0.06
Spruce density (trees/ha)	277.97	63.69	513.16	70.78	0.00
Spruce dbh (cm)	16.74	1.28	17.52	1.45	0.71
Fir density (trees/ha)	296.61	57.11	160.53	42.26	0.17
Fir dbh (cm)	19.23	1.41	14.10	1.65	0.04
Birch density (trees/ha)	386.44	62.46	328.95	59.14	0.73
Birch dbh (cm)	9.54	0.97	7.86	0.77	0.30
Willow density (trees/ha)	405.08	102.78	550.00	153.61	0.87
Willow dbh (cm)	7.10	0.77	4.52	0.27	0.02
Shrub cover (%)	41	2.00	32	4.00	0.02
Cut stem density (trees/ha)	320.34	52.95	263.16	70.50	0.06
Cut stem dbh (cm)	12.67	0.88	13.75	0.74	0.19

territory of the same male or that of a neighbouring male.

Discussion

Most grouse species often place their nests beside trees or clumps of vegetation, suggesting advantages of this behaviour, such as protection from weather and concealment from predators (Bergerud & Gratson 1988). Chinese grouse showed a high preference for nesting at the base of trees in our study area, as was also found in Qilianshan (Liu & Geng 1994, Wang et al. 1987), although Beick (1927) found that one of two females placed her nest on a rocky ledge. The related hazel grouse *Bonasa bonasia* seems to show a lower preference for nesting at the bases of trees (Table 2). The abundance and diversity of predators decreases with increasing latitude (McCoy & Connor 1980), and as the abundance of predators increases, the nesting success of grouse hens decreases (Bergerud & Gratson 1988). The Chinese grouse has the most southerly distribution of all grouse. Thus, we suggest that the higher preference that Chinese grouse females show for placing their nests at the base of trees might be to obtain better concealment from predators. Chinese grouse also preferred to nest at the base of deciduous trees. One explanation for this could be that females cover their eggs with leaves during the egg-laying period, and it probably is easier for the birds to find the necessary leaves at the base of willow or birch trees.

Keppie & Herzog (1978) found that young female spruce grouse *Falcipennis canadensis* occupied nest sites with very poor concealment, and raised the question of whether young females might learn to improve the concealment of their nests. We found no significant difference between the cover of successful and unsuccessful nests of the Chinese grouse, although the former was a little higher. Wiebe & Martin (1998) suggested that concealed nest sites were less often detected by predators, but were more risky for incubating hens, so the females might need to balance this trade-off.

Chinese grouse nested at the edge of a male territory, similar to what has been reported for other galliform birds. Hill & Robertson (1988) found that female ring-necked pheasants *Phasianus colchicus* nested at the edge of their home range. Jia et al. (1999) found that

Table 2. Location of nest sites (in %) of hazel grouse (above the dashed line) in different areas of the world, compared with those of Chinese grouse at Lianhuashan Nature Reserve, Gansu, China.

	Base of trees	Base of stumps	Combined	Other	N	Reference
Finland	23	27	50	50	22	Pynnönen 1954
Germany-Poland	57	0	57	43	7	Bergmann et al. 1996
Northeast China			25	75		Gao & Zhu 1991
Sweden	54[a]	0	54	46	13	J.E. Swenson, unpubl. data
Chinese grouse	86	13	99	1	103	Our study

[a] Two of seven nests were at the base of both a tree and a rock.

one blood pheasant *Ithaginis cruentus* nested at the edge of the home range of the paired male and female, and that most activities during incubation recesses took place at locations 100-300 m from the nest. Predators might follow the activities of nesting birds to find the nest, so avoiding activities around the nest might help birds decrease the risk of predation on the female and her eggs.

About 51% percent of nests were found by radio-tracking the females. With cryptic plumage well in harmony with the surroundings, the females would not leave the nests when people were as close as 1-2 m. Thus, it is quite difficult to find their nests without the assistance of radio-telemetry. Storaas et al. (1999) reported that the nests of capercaillie *Tetrao urogallus* and hazel grouse were difficult to detect by humans and dogs, with detection distances averaging 1.1 m for capercaillie and 1.6 m for hazel grouse nests.

Almost all nests were found in the conifer or conifer-deciduous mixed forest types, whereas the shrub type was avoided for nesting. Thus, these forest types should be conserved for nesting habitats for the Chinese grouse and should also be prioritised when reforesting areas adjacent to Chinese grouse habitats. Even though the shrub type was avoided, sites with higher than average shrub cover were preferred as nesting sites. Thus, it is also important that shrubs are present in the forest understorey. Although we documented illegal cutting of trees in the forest reserve, this did not seem to affect nest sites negatively. In fact, the grouse selected nest sites with more cut stumps than expected, perhaps because more shrubs are found at sites that have been opened up by cutting.

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