

Habitat use of Tibetan Eared Pheasant *Crossoptilon harmani* flocks in the non-breeding season

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Habitat use by Tibetan Eared Pheasant *Crossoptilon harmani* flocks in shrub vegetation was investigated in the Lhasa area of Tibet during the non-breeding season of 1995–1996. Home range composition varied considerably among flocks, but stream belts were consistently used as foraging grounds. Slope direction, altitude and vegetation had little effect on habitat selection. In the absence of supplemental food, core range size was positively correlated with flock size, suggesting that food supplementation could support larger flocks. Flocks regularly roosted on the ground at midday at two or three relatively fixed sites within core ranges. At night they used patches of relatively tall, dense vegetation at the year-round sites in areas near cliffs or in hollows. The size of the night-roost site was related to flock size. Our results strongly suggested that both foraging and night-roosting habitats in the shrub environment are crucial to the birds.

The Tibetan Eared Pheasant *Crossoptilon harmani* is endemic to Tibet and was originally treated as a subspecies of *C. crossoptilon* (Delacour 1977), but more recently as a full species (Sibley & Monroe 1990, Cheng 1994). The eared pheasants are usually found in forest habitats (Johnsgard 1999), but Tibetan Eared Pheasants also occur in relatively poor shrub vegetation typical of the mountains around the mid-Yaluzangbu River. This newly recognized species has not been studied and little historical information is available. To understand its ecology, and for its conservation, it is important to study how the Tibetan Eared Pheasant responds to this unique environment. In this paper, we examine three basic aspects of the bird/habitat relationship: (1) how the birds allocated their activities to different habitats that constitute home ranges; (2) what factors influence habitat preference; (3) effects of the spatial pattern and size of the preferred habitats on population size.

METHODS

Study area and birds

Fieldwork was carried out from October 1995 to March 1996 in two neighbouring study sites (Jiama

and Xiongse) in the Lhasa mountains (29°32'N, 91°40'E), Tibet. The vegetation in the study area is mainly shrub and meadow. On southern slopes, Rose *Rosa sericea* and Barberry *Berberis hemleyana* are found at 4000–4500 m, and Wilson Juniper *Sabina pingii* at 4500–4900 m. On northern slopes, Spiraea *Spiraea alpina* appears at 4000–4200 m, and Rhododendron *Rhododendron* spp. and Willow *Salix sclerophylla* at 4200–4900 m. Alpine meadow occurs between 4900 and 5200 m. Small streams are common on both slopes. The stream belts share some dominant plants with surrounding communities; however, Little-leaf Peashrub *Caragana microphylla*, Shagspine Peashrub *C. jubata* and Bush Cinquefoil *Potentilla fruticosa* are unique to them.

Tibetan Eared Pheasants lived in family flocks throughout the non-breeding season and flock size in autumn numbered from six to 22 birds, averaging 12.7 (se = ±1.8, n = 9). We recognized two types of flock: (1) field flocks, which foraged under natural conditions throughout; (2) monastery flocks, which searched for supplementary food at Xiongse monastery every day. There are no agricultural activities in the area and the birds were well protected by local Buddhists. Therefore, we believe that the pattern of habitat use by the field flocks reflected the natural situation, whereas the monastery flocks, with supplementary food, provided comparable data with the wild birds.

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Field observation

The open habitat and relative tameness of the birds allowed us to follow, and keep sight of, the birds for extended periods. Field observation included: (1) full-day observation, from dawn when a flock left to dusk when it returned to the night-roost site (in total 37 days for six flocks); (2) part-time observation, following a flock for some hours in a day (in total 245 h for all flocks). Four birds from different flocks were wing-tagged, but several birds in each flock were individually recognizable by their unique plumage. To locate flocks, we established a numbered grid with a 40-m interval, and used this to prepare field maps showing the habitat composition.

Habitat preference

Flock behaviour included foraging, day-roosting, moving and night-roosting. The birds spent 62.2–84.4% of the day devoted to foraging in the morning and afternoon, and 10.0–35.5% to day-roosting at midday (Lu 1997). When following a flock, we noted the duration of each activity in each habitat type. The selection index, i.e. % foraging time in a habitat type/% area occupied by the habitat type (Neu *et al.* 1974), was used to analyse the birds' preference for different habitats.

Habitat sampling was carried out using a 4 × 4-m quadrat at different altitudes in habitats constituting the home range of each flock (220 quadrats in total). We measured the following parameters: altitude, slope direction, slope degree, tree cover, higher (over 150 cm) and lower (below 150 cm) shrub cover, grass cover, tree height, higher and lower shrub height, grass height, frequency (presence or absence) of dominant shrub, species diversity (Shannon-Weaver index) of commoner species only, soil water content (percentage mass of water in 100 g soil, 5–10 cm under the ground surface). Within each sample, five subsamples of 1-m² quadrat, one at each corner and one at the centre, were selected for measuring per cent cover (with an ocular tube), shrub height (randomly located), species frequency and soil water content. At night-roost sites and random sites (randomly chosen from all samples), plant diameter (at breast height) and height, and the presence or absence of cliffs were also measured.

Daily range, core range and home range

We defined the daily range as the area a flock covered on any day, core range as a combination of all the

daily ranges, and home range as the area enclosed by all the outermost locations that the flock ever reached throughout the study period.

Flock locations were determined every 5–10 min by visually estimating the distances from the approximate centre of the flock range to two nearby markers on the grid system. These records were plotted on the field maps. Daily movement of a flock was tracked by linking all locations. Because each bird in a flock had its own space requirement within the flock, we measured the flock location as an area rather than a point. The average diameters of the areas covered by three flocks, with 15, seven and 22 members, respectively, were 9.8, 5.4 and 11.2 m. We calculated the daily range by multiplying the length of daily foraging movement (including repeated observations) with the average diameter of the flock area, and the core and home range sizes using the minimum convex polygon method (Odum & Kuenzler 1955).

Statistics

To examine the significance of differences between variables, we used parametric procedures (*t*-test and ANOVA) when samples were adequate, and non-parametric procedures (χ^2 and Mann-Whitney *U*-tests) when they were not. Correlation between variables was estimated with Spearman's rank correlation coefficient. Discriminate function analysis was employed to determine which variables had the major influence on night-roost habitat selection. All results in the text are shown as mean \pm se.

RESULTS

Foraging habitat

Although the vegetation of home ranges varied greatly among flocks (Fig. 1 and Table 1), all the field flocks (selection index = 5.67 ± 0.96 , range = 3.91–5.88) concentrated their foraging activity more on narrower stream belts than other habitats (0.49 ± 0.23 , range = 0.04–2.09) (Mann-Whitney *U*-test, $z = -2.54$, $n_1 = 3$, $n_2 = 13$, $P = 0.01$). The monastery flocks (20.41 ± 1.45 , range = 18.96–21.85) remained closer to the 0.5 ha monastery ground than the field flocks (0.26 ± 0.09 , range = 0.05–0.67) (Mann-Whitney *U*-test, $z = -2.00$, $n_1 = 2$, $n_2 = 6$, $P = 0.046$).

The core range centres of field flocks varied in altitudes (one < 4200 m, two between 4200 and 4450 m and four > 4450 m) and in slope directions

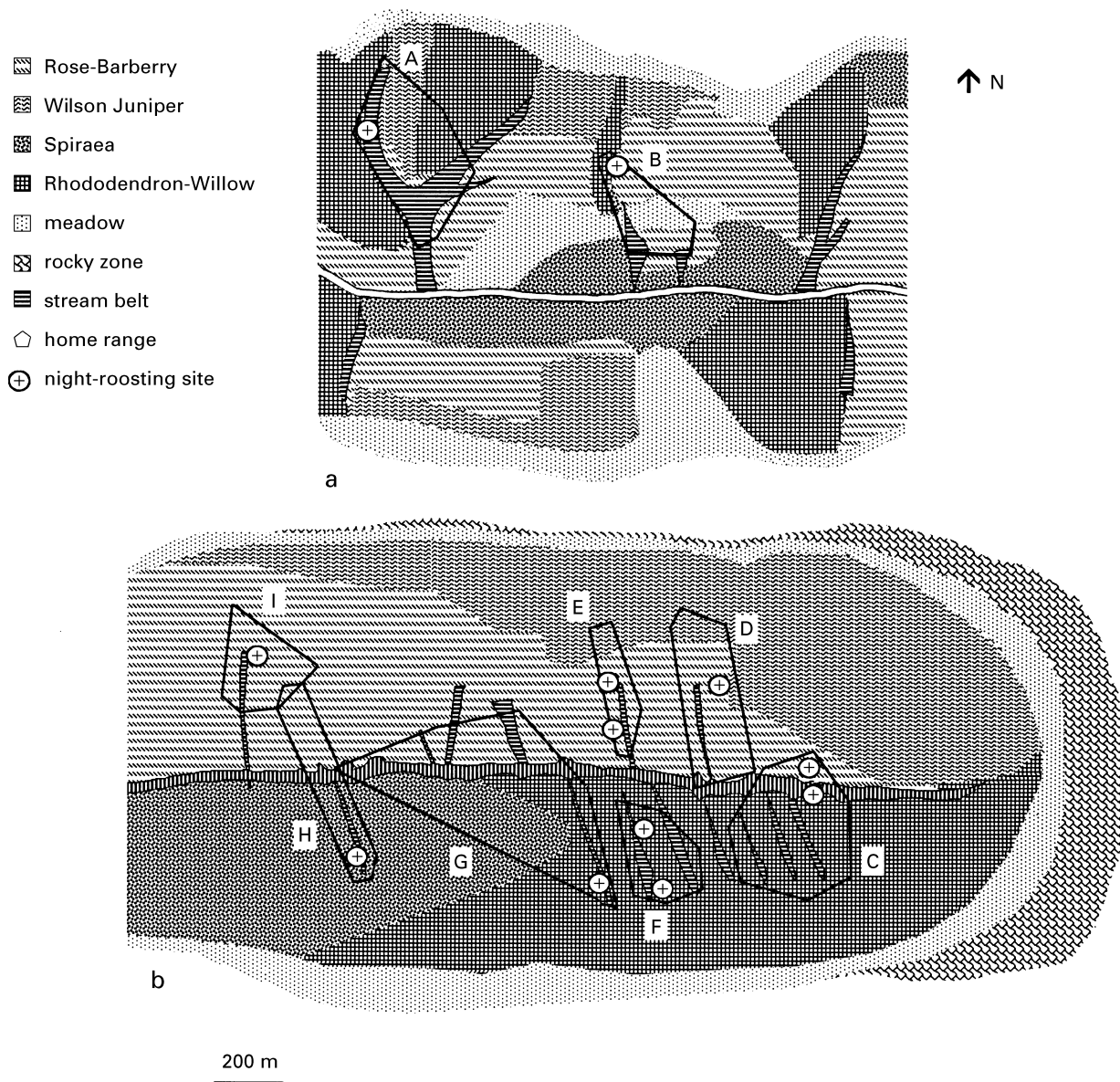


Figure 1. Spatial patterns of home ranges of Tibetan Eared Pheasant flocks in Jiama (a) and Xiongse (b) during autumn to early spring.

(one on western slopes, two on southern slopes and four on northern slopes). Relative to other habitats, the soils of the foraging area were damper ($t_{218} = 39.3$, $P < 0.001$), and the inclusion of several plant species typical of a damp environment caused a higher species diversity of the core ranges (Mann–Whitney U -test, $z = -2.65$, $n_1 = 4$, $n_2 = 7$, $P = 0.008$).

Besides soil water content (ANOVA, $F_{6,133} = 0.27$, $P = 0.95$), habitat parameters differed among core ranges (ANOVA, $F_{6,133} = 18.91$, 21.34 , $P < 0.001$ for higher and lower shrub cover, species diversity index

range = 1.46–2.02). But we were unable to detect any significant relationship between either vegetation cover ($r_s = -0.11$, $P = 0.82$ for higher shrub; $r_s = -0.68$, $P = 0.09$ for lower shrub) or species diversity ($r_s = -0.43$, $n = 7$, $P = 0.34$) and flock size.

The daily ranges of a flock varied considerably (Table 2). Under field conditions, core range size was positively correlated with flock size ($r_s = 0.79$, $n = 7$, $P = 0.036$, $y = 2.23x + 4.32$, Fig. 2), but when two monastery flocks were included in the analysis, the relationship was lost ($r_s = 0.27$, $n = 9$, $P = 0.49$).

Table 1. Per cent components of home ranges of Tibetan Eared Pheasant flocks and daily time budgets (in parentheses, for five full-day observing flocks).

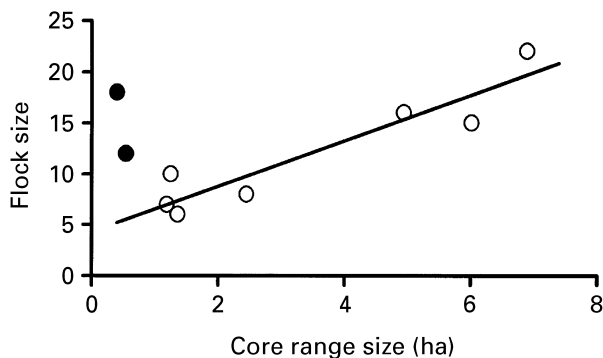
Flock ^a	A	B	C	D	E	F	G	H ^b	I ^b
Flock size	15	7	15	8	10	6	22	12	18
Stream belts	15.5 (91.1)	12.6 (90.8)	19.0	21.4	13.7	20.0	22.8 (89.1)	5.3 (1.8)	3.6 (2.4)
Rose-Barberry	8.2 (1.9)	45.3 (2.4)	9.8	55.6	61.8		28.5 (0.8)	47.4 (7.1)	91.5 (4.7)
Wilson Juniper	21.8 (2.6)		9.3	17.8	26.5		10.1 (1.5)		
Spiraea	3.9 (0)	2.1 (1.2)					33.6 (0)	32.9 (2.5)	
Rhododendron-Willow	49.5 (2.1)	6.3 (0)	62.0	1.5		78.7		5.0 (1.2)	
Grassland	1.1 (2.3)	33.7 (4.2)		3.7		2.9	5.0 (7.7)		
Monastery area								4.0 (87.4)	4.9 (92.9)
Core range size (ha)	9.2	1.6	5.3	3.9	0.8	2.0	7.4	0.4	0.5
Home range size (ha)	59.5	12.8	27.7	18.3	5.6	10.1	32.5	10.3	11.1

^aSee Fig. 1 for spatial distribution of the flock home ranges.

^bThe monastery flock.

Table 2. Daily range sizes of three field flocks and their percentages in core range and home range.

Flock	No. of days	Daily range size (ha)	% of core range	% of home range
A	12	0.50 ± 0.02	8.23 ± 3.71	0.83 ± 0.38
		0.21–0.94	2.57–11.77	0.35–1.59
B	6	0.07 ± 0.02	6.24 ± 1.52	0.58 ± 0.14
		0.05–0.09	4.12–7.73	0.38–0.72
G	8	0.74 ± 0.30	10.68 ± 4.29	2.27 ± 0.91
		0.36–1.29	5.17–18.74	1.10–3.98

**Figure 2.** Relationship between core range size and flock size in Tibetan Eared Pheasant. Field flock, open circles; Monastery flock, closed circles.

Day-roosting habitat

Flocks had between one and three (2.0 ± 0.6 , $n = 8$ flocks) day-roosting sites at relatively fixed locations within core range. These sites had better higher shrub cover (52.1 ± 1.9) but less dense lower shrub (27.5 ± 2.3 , $n = 14$) than did random sites (44.5 ± 1.4 , 50.4 ± 1.7 ,

$n = 28$) (Mann–Whitney U -test, $z = -4.50$, -4.45 , $P < 0.001$, for higher and lower shrubs). The soil at the day-roosting sites (22.36 ± 0.91) was drier than that at the random sites (29.00 ± 1.03) (Mann–Whitney U -test, $z = -3.82$, $P < 0.001$).

Night-roosting habitat

Night-roosting sites of all flocks in the two study sites were found. In Jiama where no tree was available, the flocks roosted in higher, denser, willow bushes at the upper mountain. In Xiongse, the roost sites were larger willow trees concentrated in hollows. Flocks usually had either one or two to three night-roosting sites. Thirteen close night-roosting sites were found within the home range of one flock and they were alternately used in different periods. Discriminant function analysis (Table 3) showed that in Jiama the presence of a cliff had the highest weighting, followed by plant diameter and higher shrub cover. In Xiongse, willow tree diameter, higher shrub cover and willow tree height made a greater contribution to discriminating power, with a much lower misclassification of cases (0 of 100 in Jiama and 1 of 100 in Xiongse). A positive correlation was found between night-roosting site area and flock size ($r_s = 0.90$, $n = 9$, $P = 0.001$, $y = 194.98x - 86.97$, Fig. 3).

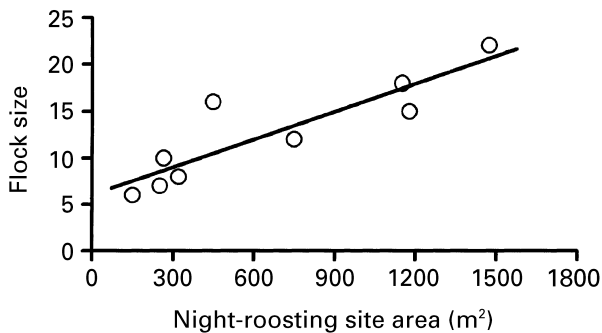
Spatial patterns of home range elements

The distances between the centres of home range (605.8 ± 95.9 , $n = 6$, range = 260–975 m), core range (594.2 ± 85.9 , range = 260–825 m) and night-roosting site (565.7 ± 100.5 , range = 160–840 m) of two neighbouring field flocks were similar (Friedman

Table 3. Standardized canonical discriminate function coefficients^a, Wilks' λ statistic, F significance between night-roosting sites and randomly chosen sites.

Variable	Jiama night-roosting sites = 14, random sites = 28				Xiongse night-roosting sites = 10, random sites = 20			
	C	Wilks' λ	F	Sig.	C	Wilks' λ	F	Sig.
Altitude	-0.25	0.94	2.45	0.13	-0.58	0.97	0.67	0.42
Slope direction	0.69	1.00	0.01	0.82	-0.30	0.91	2.52	0.12
Slope degree	-0.30	0.91	4.05	0.05	0.96	1.00	0.08	0.78
Tree cover					0.53	0.40	38.14	0.00
Higher shrub cover	0.82	0.58	29.02	0.00	2.17	0.97	0.84	0.37
Lower shrub cover	0.05	0.99	0.34	0.56	0.56	0.92	2.04	0.17
Grass cover	-0.22	0.73	14.98	0.00	-0.59	0.58	18.10	0.00
Plant diameter	0.92	0.70	17.46	0.00	2.10	0.71	10.25	0.00
Plant height	-0.06	0.77	11.75	0.00	1.27	0.80	6.06	0.02
Higher shrub height	0.04	0.77	11.75	0.00	0.35	0.93	1.78	0.19
Lower shrub height	0.33	0.80	9.81	0.00	-0.02	0.99	0.33	0.57
Grass height	-0.72	0.95	7.36	0.16	-0.41	0.95	1.26	0.27
Cliff	1.20	0.71	16.57	0.00	-0.29	0.92	2.08	0.16

^aBold typeface indicates values of best discriminating variables.

**Figure 3.** Relationship between night-roosting site size and flock size in Tibetan Eared Pheasant.

test, $\chi^2_2 = 0.36$, $P = 0.83$). The positions of night-roosting sites were either within (two flocks), close to (100–120 m) (three flocks) or far from (290–620 m) (five flocks) the core ranges (Fig. 1). The distances from the core range centre to the night-roosting site centre were positively correlated with home range size ($r_s = 0.68$, $n = 9$, $P = 0.042$). For the field flocks, we found a weak relationship between home range size and flock size ($r_s = 0.68$, $n = 7$, $P = 0.09$).

DISCUSSION

For all field flocks, stream belts were found to be the preferred foraging habitat. The principal foraging method of the birds consisted of digging up plant roots. We believe that the drier harder ground of

the habitats away from stream belts, through lower precipitation from autumn to early spring and strong solar radiation on the plateau, makes it difficult for the birds to dig. Our observations showed that components of either the flock home ranges or the core ranges differed strikingly among flocks in their topography and vegetation, suggesting a wide ecological tolerance range of the species. However, vegetation cover and height must be sufficient to provide these conspicuous birds with some minimum shelter against predators. Our study sites are confined to the valleys where better vegetation occurs. The eared pheasants disappeared from the areas with less than 40% vegetation cover and less than 1.2 m vegetation height. A large patch can support a larger flock (cf. Pearson 1989). Schoener (1968) and Mace *et al.* (1983) demonstrated a positive relationship between an animal's home range size and its body weight. In the Tibetan Eared Pheasant, the core range needs to include an area in which the food supply is sufficient to meet the minimum energy requirements of all flock members during a given period. Therefore, core range size, rather than home range size, was positively correlated with flock size. In some bird species it has been shown that individuals with additional food have smaller home ranges (Boutin 1990). Our results support this in that the monastery flocks with supplementary food had smaller core ranges.

When day-roosting, almost all flock members reduced their vigilance against predators to the

lowest level (Lu 1997). High bushes at the day-roosting sites should play a key role in giving refuge to the birds. Additionally, the high bushes could shade the birds against strong sunlight. Several authors (e.g. Eiserer 1984, Cody 1985) have demonstrated that birds night-roosting in environments with good canopy cover expend less energy than those exposed to the sky. This may explain why Tibetan Eared Pheasants selected areas with cliffs and denser cover as night-roosting sites. Several dead birds were found in the night-roosting sites, probably killed by Siberian Weasels *Mustela sibirica*, suggesting a greater predation risk during night-roosting. Selecting night-roost sites with higher shrubs might help the birds to avoid predators.

Despite communally night-roosting, the birds maintained their individual spacing: the positive correlation between roost site size and flock size seems to be principally attributed to the demand for space.

We did not detect a significant correlation between home range size and flock size, but the distance from the core range to the night-roosting site was correlated with flock size. This shows that the spatial location of foraging and night-roosting habitats was the only determinant of home range sizes. All stream belts in the two study sites had been occupied. Discriminant function analysis indicated that the sites suitable for night-roosting were very uncommon. Therefore, protection efforts for the birds should focus on these two crucial habitats.

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