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Breeding Habitat Selection by the Houbara Bustard *Chlamydotis* [*undulata*] *macqueenii* in Mori, Xinjiang, China

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Wei-Kang Yang, Jian-Fang Qiao, Olivier Combreau, Xing-Yi Gao and Wen-Qin Zhong (2003) Breeding habitat selection by the Houbara Bustard *Chlamydotis* [*undulata*] *macqueenii* in Mori, Xinjiang, China. *Zoological Studies* **42**(3): 470-475. In order to define the features that determine breeding habitat suitability for the Houbara Bustard (*Chlamydotis undulata macqueenii*), a study of nest-site selection by this species was carried out in Mori, Xinjiang, China during the breeding seasons in April-June 1998-2000. Most habitats chosen for nest sites were open areas with short shrubs close to patches of tall shrubs. The nesting female Houbara Bustard clearly prefers areas with sparse vegetation and avoids densely covered sites with tall vegetation. The vegetative species richness, number of fruiting species, and density of fruiting species at nest sites were significantly lower than those at other randomly selected sites. Vegetation density, plant species richness, density of *Anabasis salsa*, distance to the nearest fox den, distance to shrubby patches, and vegetative cover are possibly the most important factors determining nest-site selection by the Houbara Bustard. The distance to the closest fox den may be one of the important factors determining the destiny of the nests.
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The Houbara Bustard (*Chlamydotis undulata*) is a medium-sized desert- and semi-desert-dwelling member of the Otididae, classified as vulnerable by the IUCN. The Asiatic form (*Chlamydotis* [*undulata*] *macqueenii*) ranges from the Middle East to the western and central part of the former USSR, through Pakistan, Afghanistan, and Kazakhstan (Dementiev and Gladkov 1951, Meinertzhagen 1954, Cramp and Simmons 1980, Johnsgard 1991). In Xinjiang, China, it occurs on the fringe of Junggar Basin in northern Xinjiang (Gao et al. 1994). The Houbara Bustard is traditionally hunted by falconers throughout its wintering distribution range, which is from Arab countries to Uzbekistan, Turkmenistan, and Kazakhstan.

Houbara populations have steadily declined in recent decades throughout its range (Collar 1980, Cramp and Simmon 1980, Alekseev 1985, Mirza 1985, Troshchenko 1992). This decline is thought to have been due to expansion of agricultural land, overgrazing by domestic animals, and hunting (Lavee 1985 1988, Malik 1985). Several studies have documented their summer habitats (Combreau and Smith 1997), winter habitats (Launay et al. 1997, Osborne et al. 1997), and seasonal changes in habitats (van Heezik and Seddon 1999). Despite this research, our knowledge of the breeding habitats of the Houbara Bustard, especially nest-site selection in Xinjiang Province, China remains unknown. However, it is important to understand breeding habitat characteristics that determine suitable sites for the breeding Houbara and their distribution in the landscape. In Mori, Xinjiang Province, an important breeding area for the Houbara (Gao et al. 1997), the Houbara Bustard is a regular spring and sum-

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mer visitor from mid Apr. to late May, until mid Sept. to mid Oct. Mori is thus both an important breeding area and an important summering area. Breeding Houbaras make extensive use of the northeastern region of Mori (44°7'N, 90°55'E) in summer. The purpose of this study was to quantify the vegetation structure of nests of the Houbara Bustard, in order to describe its preferred habitat and determine how habitat factors influence nest-site selection. Knowledge of the breeding habitat use by the Houbara Bustard can help in developing management strategies for this vulnerable species.

MATERIALS AND METHODS

Study area

Fieldwork was conducted from 1998 to 2000 in Mori, Xinjiang Province, China. The area is a flat plateau with an average elevation of 800 m. The soil is predominantly clay and gravel, and sand in the north. The climate is arid and cold (20°C on average in July, and -15°C on average in Jan.). The mean annual rainfall is 150 mm, mostly falling in spring and winter. Although ephemeral pools may persist in alluvial wadis for several weeks following a heavy rainfall, there is no permanent surface water in the area.

Various associations of *Anabasis salsa* and *Artemisia borotalensis* dominate the vegetation in the study area, where the common annual herbs are *Ceratocarpus arenarius*, and *Plantago* sp. The vegetation is typically short (10-15 cm) with scattered tall shrubs (50-80 cm), predominately *Salsola arbuscula* and *Ceratoides latens*, which occasionally form dense patches up to 300 m across. Ephemeral plants are abundant and common in early spring under the shrub patches. The vegetative cover is relatively dense and abundant in wadis and depressions.

The principal terrestrial predator is the fox (*Vulpes corsac*). The breeding season of the Houbara in Mori coincides with the breeding season of foxes. Foxes were seen searching for food throughout the study area even during the day. From 1998 to 2000, we found 45 Houbara nests in the study area, among which 23 (51%) had been preyed on by foxes.

Methods

During the breeding seasons from 1998 to 2000, we located nests by driving at a low speed (30 km/h) in the study area. Once we flushed a female, she would run away with obvious breeding behavior, i.e., moving very rapidly with her neck extended and her head low. The female tries to maintain a sufficient distance from the nest, thereby making it rather difficult for an intruder to spot the eggs. In this situation, the car was driven back at least 400 m from the assumed nest location, and a telescope was used to observe the female. After the female had returned to the nest and the nest location was precisely defined, another person was guided to the nest by the observer. Once the nest was found, its accurate location was determined using a GPS.

At all nest sites, a 10 × 10-m (100-m^2) sampling quadrat was established at the center of the site; this was compared to a similar-sized quadrat randomly located elsewhere in the study area. From each nest site, we drove 500-700 m in a randomly selected direction and a 10 × 10-m (100-m^2) sampling quadrat was established 30 m away from the car as the random site. Three small 1 × 1-m quadrats were randomly placed in each of the quadrats (Young et al. 1991). All sampling quadrats at nest sites were established only after the eggs had hatched or the nest had been depredated, because we did not want to disturb the incubating female.

Variables recorded in the 10 × 10-m quadrats were vegetative density, plant species richness, bush species richness, herb species richness, vegetative cover, vegetative structure, and phenology (shoot, flowering, or seeding). Among them, the number of plants in the 10 × 10-m quadrats was transformed to vegetative density (individual plants/m^2), and the number of plants > 40 cm high in the 10 × 10-m quadrats was defined as the density of plants > 40 cm (/100m^2). Vegetative cover was estimated on a scale where 0 = 0%-1%, 1 = 2%-4%, 2 = 5%-10%, 3 = 11%-25%, 4 = 26%-50%, and 5 = > 51%. In the 1 × 1-m quadrats, the number of plants < 40 cm tall was defined as the density of plants < 40 cm (/m^2). Species density (individuals of every species/m^2) was respectively recorded. All fox dens in the study area were located by GPS (longitude and latitude) in 1999 and 2000. The distance from every Houbara nest to the nearest shrub patch was measured using the GPS. The distance of every nest from the nearest fox den was measured using GPS in 1999 and 2000.

Nest-site characteristics were analyzed in 3 steps. First, Mann-Whitney U-tests were used to determine any differences in nest-site variables between nest sites and random sites. Here, we considered p values < 0.01 to be significant. Second, a correlation analysis and a principal component analysis (PCA) were used for multivariate analysis of nest-site variables. Third, logistic regression analysis (LRA) with the 17 nest-site variables was used to determine which variables differed between successful and depredated nests, in order to assess nesting habitat quality. For all analyses, we used the Software Package for the Social Statistics (SPSS for Windows 8.0).

RESULTS

Vegetative characteristics of nest sites of the Houbara Bustard

We located 45 nests from 1998 to 2000. Among these, 40 nest sites and 40 random sites were sampled from May to July. Due to deficient data from 3 of the random sites, only data collected from the other 37 random sites were used for further analysis. Most of the nest sites (n = 36) were in open, flat areas close to patches of shrubs (n = 36; mean distance, 89 m; S.D., 70), where various associations of *Anabasis salsa*, *Artemisia borotalensis*, and ephemeral plants (*Ceratocarpus arenarius* and *Plantago* sp.) about 10-15 cm in height and 15%-25% in percentage cover, dominated the vegetation. Only 1 nest site was in a flat, open area far from a shrub patch (distance of 530 m). Of the 17 variables, 7 significantly differed between nest sites and random sites (Table 1). Nest sites had lower vegetative density (z = 3.13, p < 0.01), lower herb species richness (z = 3.45, p < 0.01), lower average vegetative cover (z = 4.67, p < 0.001), and lower density of shrubs > 0.4 m high (z = 4.95, p < 0.001). The density of *Anabasis salsa* was significantly higher at nest sites than at randomly selected sites (z = 3.75, p < 0.001). The number of fruiting species (z = 3.85, p < 0.001) and the density of fruiting plants assumed to serve as Houbara food (z = 2.90, p < 0.01) were lower at nest sites than at random sites (Table 1).

Table 1. Habitat characteristics at nest sites utilized by Houbara and at random sites at Mori, Xinjiang, China, April-June 1998 to 2000

Characteristic	Nest sites (n = 40)		Random sites (n = 37)		
	Mean	S.D.	Mean	S.D.	z
Plant species richness	4.40	1.55	6.49	3.36	2.48^{NS}
Vegetative cover score	3.13	0.52	3.86	0.67	4.67^{**}
Vegetative density (/m^2)	73.78	51.86	136.40	95.53	3.13^{*}
Vegetative structure					
Density of plants < 40 cm (/m^2)	73.78	51.86	125.46	93.37	2.22^{NS}
Density of plants > 40 cm (/100 m^2)	0	0	11.22	14.47	4.95^{**}
Bush species richness	2.70	0.99	2.81	1.15	0.21^{NS}
Herb species richness	1.70	1.04	3.65	2.64	3.45^{*}
Species density					
Artemisia sp. density (/m^2)	4.88	6.26	8.62	9.85	1.50^{NS}
Anabasis sp. density (/m^2)	17.56	8.39	9.05	10.84	3.75^{**}
Ceratocarpus sp. density (/m^2)	20.90	45.14	43.49	73.63	2.04^{NS}
Plantago sp. density (/m^2)	20.7	30.50	17.78	38.32	0.98^{NS}
Phenology of species					
No. of species with shoots	2.90	1.01	3.38	1.69	0.86^{NS}
No. of flowering species	0.23	0.53	0.59	0.86	2.25^{NS}
No. of fruiting species	1.28	0.68	2.51	1.63	3.85^{**}
Density of plants with shoots (/m^2)	30.48	16.92	21.92	10.84	2.24^{NS}
Density of flowering plants (/m^2)	0.60	1.63	6.43	28.52	2.16^{NS}
Density of fruiting plants (/m^2)	42.70	46.99	98.97	89.62	2.90^{*}

^{NS}Mann-Whitney U-test, non-significant difference, p > 0.01.
*Mann-Whitney U-test, significant difference, p < 0.01.
**Mann-Whitney U-test, significant difference, p < 0.001.

Environmental factors that dominated nest-site selection by the Houbara Bustard

A correlation analysis was performed with all variables (distance to the closest fox den, distance to the closest shrub patch, and the 16 variables except density plants > 40 cm listed in Table 1) before PCA analysis. The density of plants < 40 cm was excluded from the PCA analysis due to its strong relationship with vegetative density. The remaining 17 nest-site variables were analyzed by principal component analysis (PCA). The first 6 principal components met the criterion of an eigenvalue > 1 and together explained 87.2% of the variance in the nest microhabitat (Table 2). The 1st principal axis ordered sites by vegetative density. The 2nd principal axis ordered sites by plant species richness. The 3rd principal axis arranged sites by number of fruiting species. The 4th principal axis arranged sites by *Anabasis salsa* density. The 5th principal axis arranged sites by distance to the nearest fox den and distance to the nearest shrub patch. The last principal axis arranged sites by density of *Plantago* sp. and vegetative cover (Table 2).

Successful nests versus depredated nests

Because we did not record the location of fox dens in 1998 in the study area, we could not calculate the distance from each nest to the nearest fox den. However, we think that this factor may be an important habitat factor influencing the destiny of nests. Data for nest sites in 1998 were not used in the logistic regression analyses. The logistic regression analyses with the 17 nest-site variables (distance to the closest fox den, distance to the nearest shrub patch, and the 15 variables except vegetative structure listed in Table 1) were used to determine which variables differed between successful (n = 9) and depredated (n = 16) nests in 1999 and 2000. Only the factor of distance to the nearest fox den entered the regression model and 84% (n = 21) of the overall nests were distinguished correctly by the logistic regression model (Table 3). t-Tests showed that the average distance to the closest fox den (m) was significantly farther at successful nests (n = 9; mean, 2567 m;

Table 2. Correlation of habitat variables with the first 6 principal components derived from 40 nest sites of the Houbara Bustard recorded in Mori, April-June 1998 to 2000

Variable	Principal component					
	1	2	3	4	5	6
Plant species richness	0.63	0.72	-0.14	-0.08	-0.02	0.20
Vegetative cover score	0.19	0.65	-0.20	0.37	0.04	-0.46
Vegetative density (/m^2)	-0.71	0.62	0.30	-0.09	-0.04	-0.001
Shrub species richness	-0.70	0.47	0.19	0.30	0.15	-0.01
Herb species richness	0.20	0.61	-0.50	-0.42	-0.15	0.24
Species density						
Density of *Anabasis* sp. (/m^2)	-0.33	0.27	-0.43	0.64	0.14	-0.25
Density of *Artemisia* sp. (/m^2)	0.47	-0.04	0.52	-0.11	0.41	0.19
Density of *Ceratocarpus* sp. (/m^2)	-0.72	0.35	0.23	0.16	-0.33	0.20
Density of *Plantago* sp. (/m^2)	-0.04	0.36	0.19	-0.57	0.36	-0.56
Phenology of species						
No. of species with shoots	0.50	0.66	-0.30	0.18	0.08	0.18
No. of flowering species	0.58	0.33	0.54	-0.06	-0.12	0.11
No. of fruiting species	0.12	0.48	-0.64	-0.47	-0.04	0.03
Density of plants with shoots (/m^2)	-0.57	0.37	-0.01	0.31	0.04	0.45
Density of flowering plants (/m^2)	0.63	0.31	0.59	0.13	-0.13	0.05
Density of fruiting plants (/m^2)	-0.64	0.58	0.34	-0.24	-0.06	-0.19
Distance to the closest shrubby patch (m)	0.41	0.15	0.14	0.39	-0.57	-0.31
Distance to the closest fox den (m)	-0.24	0.22	0.02	0.32	0.80	0.11
Eigenvalue	4.80	4.05	2.34	1.87	1.49	1.15
Percent of total variance (%)	26.67	22.52	13.00	10.40	8.27	6.38
Percent of cumulative variance (%)	26.67	49.19	62.19	72.59	80.86	87.24

S.D., 846) than at depredated nests (n = 16; mean, 1848 m; S.D., 608) (t = 2.465, df = 23, $p <$ 0.05).

DISCUSSION

Nesting Houbara Bustards in the study area typically utilized open areas or areas with scattered shrubby vegetation. Typically, vegetation at nest sites utilized by females was dominated by xerophytic or halophytic plants. Such general habitat affinities are consistent with those described for the species elsewhere in its range (Cramp and Simmons 1980, Mian 1988a). In Mahazat (Saudi Arabia), Combreau (1997) reported that phenology was the primary factor influencing summer habitat choice. Plants in various phenological stages during summer provide palatable food, such as green shoots, flowers, and fruits. However, results of our study showed that phenology was of little importance in nesting habitat selection.

Nest sites of female Houbara in the study area were not randomly distributed. Areas covered by less vegetation were often used by females. A nesting female clearly preferred areas with sparse (15%-25%) vegetative cover and sites with low herb abundance and avoided areas with tall bushes (Table 1). These observations are remarkably similar to those reported by Mian (1985). His paper indicated that the Houbara laid eggs on open flat plains in Pakistan. We can explain the selection method as follows: We found that the birds have very good eyesight, and an incubating female would frequently extend its neck and peer around vigilantly. Thus, a high coverage of vegetation and depressions would restrict their vision. Gubin (1992) reported that Houbara Bustards tended to choose flatter areas with good visibility. Thus, Houbara Bustards were found in 8 sparsely vegetated places and areas completely devoid of vegetation in Kazakhstan. In general, such vegetative cover is consistent with that described for the species elsewhere in its range (Goriup 1983, Collins 1984, Mian 1986, Combreau and Smith 1997, Van Heezik and Seddon 1999).

We analyzed the nest sites of Houbara along 6 habitat components derived by a principal component analysis. The 1st nest-site component represented the openness. Lower plant species richness characterized the 2nd nest-site component. The 3rd nest-site component represented the number of fruiting species. The 4th component represented the topography, because *Anabasis salsa* never occurs in depressions. The 5th component was interpreted as foraging requirements and avoidance of predation. The last nest-site component represented the activity habits (Tables 1, 2). Most of the nest sites (90%) were chosen at the edges of dense patches of high shrubs, which occur along wadis or depressions. Similarly, Combreau and Smith (1997) reported that introduced Houbara concentrated their foraging at the edge of wadis and other well-vegetated areas, but they were rarely found in dense vegetation. Such selection of habitat edges is apparently typical of Houbaras (Launay et al. 1997). In Saudi Arabia, it is reported that Houbara utilized open sites for roosting at night, in order to reduce encounters with foxes and other nocturnal mammalian predators, which hunt in the cover of wadis and depressions (Combreau and Smith 1997). Similarly, Mian (1988b) reported that Houbara always selected a roosting place which was on an open plain, from where the bird could spot an approaching predator at a reasonable distance. However, being close to high-density shrubby patches of *Salsola arbuscula* is advantageous to Houbara. Houbara preferentially consume *Salsola arbuscula*. *Salsola* spp. is frequently listed as an important food of the Houbara (Alekseev 1985, Mian 1988a, Launay 1989). Combreau and Smith (1997) suggested that Houbara selected habitat during summer for the water content of its forage. We think that the Houbara can obtain necessary water from consuming the succulent leaves of *Salsola arbuscula*. In addition, we have observed Houbara foraging

Table 3. Results of logistic regression models comparing successful nest sites (value of the response variable = 0) and depredated nest sites (value = 1)

Variable	Beta coefficient	SE	Wald chi-squared	p	Percent correctly classified
Distance to the closest fox den (m)	-0.0015	0.0007	4.3648	0.037	84
Constant	3.8341	1.6862	5.1700	0.023	

on leaves of *Salsola arbuscula* in the field.

Fox (*Vulpes corsac*) is the principal mammalian predator and was commonly seen in the study area. Logistic regression analysis showed that the distance to the nearest fox den was perhaps 1 important factor determining the destiny of nests. Because we had unequal and relatively small numbers of samples for analysis, it is possible that we did not find other important factors which in fact might exist. This question needs further study.

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