Seasonal changes in habitat use by Houbara Bustards
Chlamydotis [undulata] macqueenii in northern
Saudi Arabia

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Habitat preferences by Houbara Bustards Chlamydotis [undulata] macqueenii in Harrat al-Harrah reserve, in northern Saudi Arabia were determined from sightings of birds in all seasons over three years. Vegetation and crawling invertebrate abundance were sampled in each habitat. Houbara Bustards showed seasonally changing habitat preferences that appeared to be influenced primarily by vegetation phenology, abundance and cover. More densely vegetated areas (10–17% cover) were preferred. Seasonal and inter-habitat variations in invertebrate numbers were not reflected in differential habitat use by Houbara Bustards. The highest selection ratio for a single habitat (dry lakes) occurred in summer, coinciding with the fruiting of Shafallah Capparis spinosa. Selectivity of habitats was least in spring, when green vegetation was most widespread. Changes in Houbara Bustard habitat preferences in response to marked seasonal changes in habitats brought about by well-defined patterns of rainfall indicate that studies of habitat selection should consider the entire annual cycle. The importance of vegetative cover and the sensitivity of Houbara Bustards to human disturbance suggest that reserves set aside for Houbara Bustards should be extensive, diverse and largely free of livestock, human occupation and its associated disturbances.

The high profile of the Houbara Bustard Chlamydotis [undulata] macqueenii (Gaucher et al. 1996) as the preferred target for Arab falconry, and its ongoing decline due largely to hunting and increasing habitat disturbance, have focussed attention on the status of this species, resulting in the first meeting of the International Union for Conservation of Nature Houbara Bustard Working Group (HBWG) in Oman in early 1996. The HBWG identified as a research priority the description of habitat use by Houbara Bustards (IUCN Species Survival Commission 1996). It is recognized that more information is needed on this poorly studied species before effective recovery plans can be drawn up and implemented. The cryptic, wary behaviour of the Houbara Bustard, the difficulties involved in capturing and marking birds and its existence at low densities throughout large parts of its range (Lavee 1988, Mian 1989, Gubin 1996, Seddon & van Heezik 1996) have resulted in few detailed or long-term studies; published information is qualitative or largely anecdotal.

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seasonal changes in vegetation and invertebrate availability, in response to clear and consistent patterns of rainfall.

**STUDY AREA AND METHODS**

**Study area**

Harrat al-Harrah (850 m asl) is the southern portion of a 45 000 km² harrat which extends from northern Saudi Arabia into Jordan and Syria. The reserve comprises undulating plains strewn with basalt boulders, volcanic ash, aeolian sand, dry lakes, extinct volcanic cones and low rocky outcrops. Trees are mostly absent and the sparse vegetation is concentrated in dry watercourses and on the margins of silty depressions and dry lakes. Ambient temperatures range between -8°C and 44°C. Mean annual rainfall is in the range 50-100 mm, falling mainly between October and April, and is patchy and unpredictable in its distribution. Sheep and goats have been excluded from the reserve since its creation, although untended camels graze freely. A permanent force of rangers based at eight camps patrols the perimeter of the reserve, apprehending and expelling intruders.

**Study animals**

Throughout their range, Houbara Bustards inhabit undulating flat arid plains, steppes and semi-deserts (Fig. 1). Xerophytic or halophytic shrubs 1–2 m high provide scattered cover, growing on sandy or stony substrata, but reproducing despite persistent drought (Coles & Collar 1980, Mendelssohn 1980, Mian & Surahio 1983, Alekseev 1985, Surahio 1985).

Very few quantitative studies have been made on Houbara Bustard diet; qualitative accounts describe it as omnivorous and opportunistic with a large vegetative component to the diet (Ali & Ripley 1980, Gallagher & Woodcock 1980, Mian & Surahio 1983, Alekseev 1985). Crawling invertebrates (predominantly tenebrionid beetles and ants) are eaten as they are encountered.

**Methods**

We recorded Houbara Bustard sightings in different habitats in a core study area of about 750 km² between December 1991 and December 1994. We surveyed vegetation during December 1992 and invertebrates at monthly intervals from November 1992 to October 1993, but not during May, June and September.

**Habitat types and availability**

The study area mainly comprised the following habitats. (1) Harrat: weathered basalt rock fragments, usually on low hills; (2) gravel: coarse chert gravels on undulating hills; (3) wadi: major ephemeral watercourse, often over 1 km in length, with a broad bed of sand, clay or gravel; (4) wash: minor ephemeral watercourse usually draining into a wadi; (5) drainage line: short runnel less than 100 m long; (6) silty depression: low-lying vegetated basin receiving runoff from washes or drainage lines; (7) dry lake: low-lying basin of packed silt, occasionally holding water for several weeks at a time, vegetated around the perimeter only.

We estimated habitat availability for the core study area by flying in a plane at 130 m altitude along transects using a global positioning system and sampling habitat at 25” intervals of latitude, through a fixed ‘quadrat’ attached to the aircraft’s rear window, equivalent to about 3 m x 3 m ground area. Altogether, 21 transects were flown, each of 20° latitude, yielding 1701 data points, of which 1688 were used in the

![Figure 1. Adult male Asiatic Houbara Bustard. Photo: NWRC Photo Library.](https://unibiblio.uniovi.es/papers/208-215)
analysis (the remaining 13 were sand and rocky hills, which occurred infrequently).

Habitat use

We determined habitat use of Houbara Bustards by sightings during standardized ground survey drives, which visited all habitat types in proportion to their availability.

Vegetation sampling

We measured perennial plant cover along 20 m transect lines during winter. In non-linear habitats, placement was random, but in linear habitats (watercourses) placement was along the longitudinal axis of the feature, away from habitat boundaries. We determined adequate sample sizes by plotting the running mean of percentage cover for each habitat against sample size. When this value reached and maintained an asymptote, we considered that sufficient transects had been sampled.

We recorded the identity and number of all plant species occurring under the transect line, and quantified cover by recording the number of centimetres occupied by each species along the transect (Kershaw 1973). We recorded the presence of annuals and a qualitative assessment of their abundance in each season, as well as the phenology of annual and perennial species.

Invertebrate sampling

Pitfall trapping was used to assess the relative abundance and availability of the most common surface-active invertebrates in different seasons and habitats. Traps were placed flush with the ground for a minimum of five nights during at least one month of each season. Trap-nights per habitat per season ranged from 15 to 165. Independent locations were sampled, and, in the case of wadis, traps were distributed around four vegetation assemblages dominated by: (i) Rimth Haloxylon salicornicum, (ii) Shih Artemisia sieberi, (iii) Qaysum Achillea fragantissima and (iv) a mixture of the above. Trap contents were identified to class (Arachnida), order (Coleoptera) or family (Formicidae). These three groups comprised 87% of the total number of specimens collected. Seddon and van Heezik (1996) presented the results of this pitfall trapping in terms of invertebrate numbers by month for all habitats combined. In this analysis, we consider seasonal and habitat variation in invertebrate abundance.

Data analysis

We treated groups of birds as single sightings, to avoid problems of dependence. This had the effect of underestimating the degree to which certain habitats were used, if the resource in a particular habitat was more patchily distributed than resources used in other habitats, causing the birds to form fewer but larger flocks. We found no significant difference in the frequency of flocks compared to single birds across five habitats (harrat and gravel plain not included due to frequencies less than five; \( \chi^2 = 2.58, \) ns), suggesting any bias was distributed equally among the habitats. Treating all individuals as separate sightings revealed a similar pattern of habitat selection.

We determined habitat selection by calculating the log-likelihood statistic, expressed as \( \chi_1^2 \) (Manly et al. 1993). Selection ratios were calculated for each habitat type and compared, correcting for mounting error probabilities by using Bonferroni’s inequality. Selection ratios – defined such that the value for each resource unit (habitat) is proportional to the probability of that unit being used, given that the selecting organism (Houbara Bustard) has unrestricted access to the entire distribution of available units – are special cases of selection functions. The concept of the resource selection function is the basis of a unified statistical theory for the analysis and interpretation of resource selection data, which Manley et al. (1993) propose to replace the many ad hoc statistical methods used in the past.

Values for proportions of Houbara Bustards observed in each habitat in each month were arcsine-transformed for regression analyses.

The influx of migrating bustards between November and March, and a second influx of unknown origins in summer (Seddon & van Heezik 1996), ensured that we were not repeatedly sampling the same small group of individuals, and weighting our analyses towards the preferences of a select few.

RESULTS

Habitat use in relation to availability

Proportions of habitats in the study area and numbers of sightings of groups of one or more Houbara Bustards made in each habitat are given in Table 1. Harrat dominated the study area, with a large part of the remainder made up of gravel plains and wadis. These proportions remained the same throughout all seasons. Habitat use by Houbara Bustards differed signifi-
Houbara Bustard habitat use in Saudi Arabia

Table 1. Habitat availability (random points) and use (sightings of groups of one or more birds) by Houbara Bustards in Harrah al-Harrah.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Percentage of habitat available</th>
<th>Number of sightings (%)</th>
<th>Winter</th>
<th>Spring</th>
<th>Summer</th>
<th>Autumn</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi</td>
<td>11.9</td>
<td>77 (33.6) +</td>
<td>25 +</td>
<td>18</td>
<td>7</td>
<td>27 +</td>
</tr>
<tr>
<td>Wash</td>
<td>8.4</td>
<td>28 (12.2) +</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Drainage line</td>
<td>3.4</td>
<td>37 (16.1) +</td>
<td>8</td>
<td>22 +</td>
<td>0</td>
<td>7</td>
</tr>
<tr>
<td>Dry lake</td>
<td>4.6</td>
<td>30 (13.1) +</td>
<td>5</td>
<td>4</td>
<td>15 +</td>
<td>6</td>
</tr>
<tr>
<td>Silty depression</td>
<td>5.6</td>
<td>35 (15.3) +</td>
<td>13 +</td>
<td>13</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Harrat</td>
<td>51.1</td>
<td>20 (8.7) -</td>
<td>2</td>
<td>15 -</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Gravel plain</td>
<td>15.0</td>
<td>2 (0.9) -</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
<td>229 (99.9)</td>
<td>63</td>
<td>82</td>
<td>29</td>
<td>55</td>
</tr>
</tbody>
</table>

Winter = December, January; spring = February, March, April; summer = July, August, September; autumn = October, November. Habitat selection as indicated by confidence intervals of selection ratios is shown: +, used more than in proportion to its availability; -, used less than in proportion to its availability.

Table 2. Selection ratios, listed vertically from least to most selected, and comparison between selection ratios for overall Houbara Bustard sightings in different habitats in Harrat al-Harrah. Confidence limits were chosen so that the probability of all the pairwise intervals including the population difference is 0.95.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Selection ratio</th>
<th>Gravel plain</th>
<th>Harrat</th>
<th>Wash</th>
<th>Silty depression</th>
<th>Wadi</th>
<th>Dry lake</th>
</tr>
</thead>
<tbody>
<tr>
<td>Harrat</td>
<td>0.17</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wash</td>
<td>1.50</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silty depression</td>
<td>2.71</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wadi</td>
<td>2.80</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Dry lake</td>
<td>2.83</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Drainage line</td>
<td>4.85</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

+, Significant difference between row habitat and column habitat; no significant difference.

Seasonal habitat use by Houbara Bustards

The probabilities of selection for different habitats varied with the season (Fig. 2). Whether habitats were used more or less than in proportion to their availability is summarized in Table 1. There was strong evidence for selection in all seasons (winter, \( \chi^2_{1,4} = 95.8, P < 0.001 \); spring, \( \chi^2_{1,3} = 183, P < 0.001 \); summer, \( \chi^2_{1,2} = 62.8, P < 0.001 \); autumn, \( \chi^2_{1,4} = 50.5, P < 0.001 \)). In winter, the selection ratios of wadis (3.3) and silty depressions (3.7) were significantly higher than for the dry lake/harrat/gravel plain group (0.180; lumped together to increase the sample count to five or more). No other comparisons were significant (wash 1.7; drainage line 3.7). The value for drainage lines was the highest recorded, but the confidence intervals were wide, due to a relatively low number of sightings in a habitat that comprises only 3.4% of the total area.

In spring, dry lake and gravel plain habitats were grouped to increase the sample count up to five. The probability of selection for drainage lines was higher than for all other habitats except silty depressions (Table 3). Selection ratios of silty depressions, wadis and washes were not significantly different, and ratios for harrat, washes and the dry lake/gravel plain group were lowest.

In summer, washes, gravel plains, silty depressions,
Selection ratios were: wash 1.6; silty depression 2.0; dry lake 2.5; drainage line 3.9; wadi 4.3.

Vegetation

Common perennial plants were: Shih Artemisia sieberi (all habitats), Quaysum Achillea fragrantissima and Rimth Haloxylon salicornicum (all dry watercourses, dry lakes and silty depressions), Shibriq Zilla spinosa and Kidad Astragalus spinosus (silty depressions and drainage lines), Adhir Artemisia monosperma (all dry watercourses) and Shafallah Capparis spinosa (dry lake edges). Gravel plains and harrat were almost bare of vegetation in winter. Given adequate rainfall, all habitat types support a variety of annuals. Perennials flower and fruit in summer and autumn; annuals may begin to grow as early as October or November; flowering and fruiting peak in March and early April.

The number of perennial plants counted along 20 m transect lines ranged from a mean of 2.8 on gravel plains to 33 on silty depressions (Fig. 3). Cover of perennials was very low, ranging between 0.4% on gravel plains to 18% in wadis (Fig. 3).

Habitats differed significantly in the degree of plant cover (Kruskal–Wallis, $H_s = 62.3$, $P < 0.001$) and in the number of plants ($H_s = 44.1$, $P < 0.001$). Wadi/washes, drainage lines and silty depressions had the greatest cover and plant numbers, harrat and gravel plains the least; dry lakes had intermediate cover and plant numbers (multiple comparison test; Siegel & Castellan 1988). There was a positive regression between the proportions of groups of Houbara Bustards sighted in different habitats and both plant cover ($r^2 = 0.61$, $F_{1,5} = 7.73$, $P < 0.05$) and plant numbers ($r^2 = 0.67$, $F_{1,5} = 10.1$, $P < 0.05$) in those habitats, indicating more vegetated areas were used more often.

The number of bustards sighted in each habitat varied whether sightings were made in ‘greener’ months (December to April) or ‘drier’ months (July to November), $X^2_s = 26.7$, $P < 0.001$; Fig 4). Proportionately more birds were seen on dry lakes in the drier months, whereas in the greener months more birds were seen in drainage lines, silty depressions and harrat.

Houbara Bustard habitat use in relation to invertebrate abundance

Two-way ANOVA on log-transformed data showed that the abundance of beetles (habitat, $F_s = 4.58$, $P < 0.01$; season, $F_s = 48.5$, $P < 0.001$), ants (habitat, $F_s = 2.50$, $P < 0.05$; season, $F_s = 3.81$, $P < 0.02$) and spiders (habitat, $F_s = 9.08$, $P < 0.001$; season, $F_s = 7.47$, $P <
Table 3. Selection ratios, listed vertically from least to most selected, and comparison between selection ratios for Houbara Bustard spring sightings in different habitats in Harrat al-Harrah. Confidence limits were chosen so that the probability of all the pairwise intervals including the population difference is 0.95.

<table>
<thead>
<tr>
<th>Habitat</th>
<th>Selection ratio</th>
<th>Dry lake/ gravel plain</th>
<th>Harrat</th>
<th>Wash</th>
<th>Wadi</th>
<th>Silty depression</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry lake/gravel plain</td>
<td>0.31</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Harrat</td>
<td>0.36</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wash</td>
<td>1.31</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Wadi</td>
<td>1.85</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Silty depression</td>
<td>2.83</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Drainage line</td>
<td>7.89</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

+, Significant difference between row habitat and column habitat; –, no significant difference.

0.001) varied significantly between seasons and between habitats. A multiple regression showed Houbara Bustard abundance to be independent of beetle, ant and spider abundance (mean value calculated for each season and each habitat; n = 24, r² = 0.13, F₃,₂₀ = 1.03, ns).

DISCUSSION

Houbara Bustards in Harrat al-Harrah were not randomly distributed; they showed marked seasonal changes in their preferences for certain habitats. On a broad scale, harrat and gravel plains, together comprising 65% of the study area, were least likely to be selected. In contrast, the more vegetated areas such as wadis, washes, drainage lines, dry lakes and silty depressions (35% of the area) were often used. Houbara Bustards were found more often in habitats with relatively high plant cover (10–17%) and plant abundance. Cover in habitats used by Houbara Bustards in Baluchistan ranged between 9 and 16% (Mian 1986) and for a reintroduced group in central Saudi Arabia between 5 and 25%; Combreau & Smith 1997).

Although abundance, or availability, of surface-active invertebrates varied significantly between habitats and between seasons, we did not find a relationship between invertebrate abundance and Houbara Bustard sightings, suggesting habitat preference is based on some factor other than availability of invertebrate food. Rather, Houbara Bustard distribution appeared to be dictated primarily by cover, density.
and phenology of vegetation. Combreau and Smith (1997) also failed to find a relationship between arthropod abundance and Houbara Bustard habitat use, but identified plant phenology, specifically the availability of plants with green shoots and flowers, as the principal factor motivating habitat choice of reintroduced Houbara Bustards in central Saudi Arabia. In the United Arab Emirates, Houbara Bustards appeared to select areas with higher grass cover and plant density (Launay et al. 1997).

In each season, habitat selection reflected the distribution and state of development of green vegetation among habitats. In winter, when green vegetation is in its early stages of development, Houbara Bustards were 5.5 times more likely to select silty depressions, drainage lines, and wadis (20.9% of the area) where runoff is most likely to collect and growth of annuals is therefore more advanced, than dry lakes, harrat, gravel plains and washes (79.1% of the area). By spring, a wider range of habitats (drainage lines, silty depressions, dry lakes, wadis; 25.5% of the area) was equally likely to be selected, reflecting widespread growth of annuals in response to more frequent rainfall. In summer, growth of annual vegetation is almost over, but perennial species that are most dense in wadis become green, flower and fruit. Dry lakes, which made up only 4.6% of the total area, were five times more likely to be selected than all other habitats grouped together. The predominant plant species on the dry lakes at this time is the perennial Capparis spinosa, which produces small seed-filled melons in the middle of summer. Houbara tracks surrounding these plants indicate its importance as a source of food for the Houbara Bustard. Habitats selected in autumn reflect distributions of both late-fruiting C. spinosa (dry lakes) and patches of initial green growth in areas that receive and hold runoff (wadis, silty depressions, washes). In Sind, Pakistan, Houbara Bustards were also observed to favour dry stream channels or small valleys where rainwater gathers, resulting in better growth of plants (Surahio 1985).

The decision to use a particular habitat is likely to be influenced not just by the desire to find food, but also by the desire to associate with conspecifics, a behaviour which may vary throughout the year (Seddon & van Heezik 1996). Between January and April, males may choose habitats on the basis of whether they are good display sites, or the presence of other males, and female distribution may focus on these sites (R. Maloney pers. comm.). In summer, birds tend to be found in larger flocks (Seddon & van Heezik 1996), probably because food species are fewer and more patchily distributed. Nevertheless, we found a significant preference in all months for well-vegetated habitats, suggesting that habitat selection is never entirely disassociated from vegetative parameters.

Implications for protected area management

Habitats preferred by Houbara Bustards in Harrat al-Harrah made up less than 25% of the available area, raising the question of whether habitat availability is a limiting factor on population size. Densities of Houbara Bustards in Harrat al-Harrah are low compared with estimates from other parts of their range (Seddon & van Heezik 1996). In the Central Asian Republics, such as Kazakhstan, where Houbara Bustard numbers reach tens of thousands (Gubin 1996), they occupy extensive, sparsely vegetated areas. In Harrat al-Harrah, expanses of volcanic boulder fields have limited the more vegetated habitat to linear dry watercourses and depressions, so that little of the total area contains adequate vegetation. Large areas of open vegetated plains are found in the Kingdom, where Houbara Bustards are known to have been relatively abundant in the past. These are now regions of intensive agriculture, and public attitudes towards Houbara Bustards are such that the conservation of bustards is not possible in these areas. In Harrat al-Harrah, the number of breeding attempts does not appear to be increasing, despite ten years of protection (pers. obs.). It is possible that the reserve does not provide optimal habitat; it may have contained the last breeding birds because of its relative inaccessibility to hunters and shepherds.

Houbara Bustard movements appear to be dictated primarily by the distribution of patches of green vegetation; annuals throughout winter and spring, and reproducing perennials in summer and autumn. Stock and their shepherds, which also seek out patches of green vegetation, adversely affect Houbara Bustards both by competing for food and from disturbance by shepherds and accompanying dogs. The presence of livestock in Baluchistan caused a reduction in Houbara Bustard density (Mian 1986), and in Kazakhstan and Israel, stock are known to cause nest abandonment through trampling, while shepherds’ dogs raid nests (Lavee 1988, Gubin 1996).

Areas selected as reserves for the Houbara Bustard should supply diverse habitats and key plant species that can be exploited by Houbara Bustards at different times of the year. In northern Saudi Arabia, Capparis spinosa may be an important determinant of year-round occupancy. Vegetation in degraded ecosystems...
needs to be given time to recover before Houbara Bustards are reintroduced or released into these areas. The movements of one radio-tagged individual during one year in Harrat al-Harrah (unpubl. data) and movements of three with transmitters in Abu Dhabi, followed for between 12 and 57 days during winter (Osborne et al. 1997) suggest that Houbara Bustards are constantly exploring their environment, quickly moving to exploit new patches with better quality vegetation. Unless protected areas for Houbara Bustards are extensive enough always to contain large patches of vegetation, despite irregular patterns of rainfall, Houbara Bustards may leave the protection of these areas temporarily, moving to unprotected sites where hunting may occur.

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