Activity rhythms of houbara bustards (Chlamydotis undulata macqueenii) in relation to some abiotic factors

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Activity rhythms of captive-bred introduced houbara bustards (Chlamydotis undulata macqueenii) were studied in the Mahazat as-Sayd reserve in Saudi Arabia. Birds were radio tagged with solar powered transmitters and activity was recorded with an automatic recording station over several weeks in the summer of 1993. Peaks of diurnal activity were observed at dawn and dusk. Daytime activity was negatively related to solar radiation and soil surface temperature. Nocturnal activity was triggered by moonlight. Food consumption, the duration of night-time activity and the minimum distance moved at night by houbara were positively correlated to the duration of moonlight.

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Introduction

The houbara (Chlamydotis undulata) is a member of the Bustard family (Otididae) inhabiting arid and semi-arid desert areas of west Asia and North Africa. The Asiatic subspecies ranges from the Middle East, through Arabia and Pakistan to the western and central part of the former U.S.S.R. (Dementiev & Gladkov, 1951; Meinertzhagen, 1954; Cramp & Simmons, 1980; Johnsgard, 1991).

Much of the biology of the houbara bustard remains unknown. This is mainly due to the exceptional ability of the species to hide in nature and its pronounced intolerance of man (Mian, 1988; Schultz, 1992). Therefore, only brief descriptions of the biology and behavioural ecology of the species in its natural habitat have been published. The houbara bustard is said to be crepuscular in habit (Surahio, 1985) and is known to be active in the early morning and late afternoon with a long period of rest during the hottest part of the day (Collins, 1984; Mian, 1988; Hinz & Heiss, 1989). Indications of nocturnal activity, possibly focused towards foraging, have been recorded in the wild (Mian & Surahio, 1983; Mian, 1988). In Pakistan, houbara are said to be largely nocturnal in their feeding when human disturbance is high (Roberts, 1991). An alternative approach to understanding houbara behaviour is to study captive birds, though this can be confounded by abnormal behaviour that may appear in
Some studies on time-budgets of the species in semi-captivity have been conducted in the National Wildlife Research Center in Taif (Saudi Arabia) where houbaras are captive-bred. Symens (1987) obtained results with seven houbara observed for 4 days from sunrise to sunset. Activity took place in the morning, after sunrise, and in the evening, before sunset. Houbara rested during the hottest period of the day. Changes in seasonal activity patterns were observed (Symens, 1987; Launay, 1989) with a noon resting period increasing considerably towards summer, presumably due to the increase in air temperature. A comparison of activity patterns of two houbara bustards between new-moon and full-moon nights have also been reported by Anegay (1994). Houbara appeared to develop an important active period during moonlit nights which was not present during moonless nights.

The National Commission for Wildlife Conservation and Development (NCWCD) in Saudi Arabia is undertaking a programme to restore the houbara population in the Kingdom (Combreau et al., 1995). The first step in this programme was to protect areas from hunting and grazing, and the second was to introduce captive-bred houbara into such protected areas. The first successful introductions were achieved in 1993 (Combreau et al., 1995) in the NCWCD Mahazat as-Sayd Reserve, thus providing researchers with another opportunity to study houbara behaviour.

**Material and methods**

Houbara bustard release experiments were conducted in the 2300 km² fenced Mahazat as-Sayd Reserve (Saudi Arabia) from 1991 to 1993 (Combreau & Rambaud, 1994). Releases took place in a 4 km² enclosure (22° 10'N, 41°55'E) free of mammalian predators where three plots of alfalfa totalling 1000 m² were grown. Houbara released remained free to fly in the reserve or to stay in the predator-free enclosure. In 1993, 10 out of the 17 houbara successfully introduced (Combreau & Rambaud, 1994) were randomly chosen for the study.

All birds studied were fitted with backpack-mounted solar powered transmitters with a mercury switch providing two activity modes, fast or slow. When the mercury switch was on, a fast pulse rate (1·2 to 2·5 pulse per s according to the transmitter) was emitted; when the mercury switch was off, a slow pulse rate (0·6 to 1·2 pulse per s) was emitted. Variations in pulse rates for a transmitter in a given position of the activity switch were small (± 0·1 pulse per s). Previous observations showed that the mercury sensor was switched either to on or to off when the houbara was roosting, thus providing fast or slow signals for this behaviour (Combreau & Rambaud, 1994). It was thus impossible to utilize the speed of pulse rates for monitoring activity. However, when the bird was roosting, for fast or slow signals emitted, the standard deviation of pulse rates was low because the mercury switch stayed in the same position. On the contrary, when the bird was moving, the mercury sensor was switched from on to off during movements, modifying the speed of pulse rates and thus increasing the standard deviation of pulse rates. In addition, the more frequently the mercury sensor was switched from on to off, the higher the standard deviation. Consequently, the standard deviation recorded was normalized and used to calculate a quantitative index of houbara activity. This index cannot discriminate the type of activity shown by birds but can estimate how active birds are.

An automatic activity recording system (Aktiv500, Gesellschaft für Teleme-triesysteme mbH, Germany) was installed within the enclosure to monitor activity of the free-ranging released birds. The Aktiv500 was set up to scan 10 transmitters and to record the activity of each successive transmitter for 1 min. Therefore, every 10 min, 1 min of data was collected by the system for all birds monitored. Recorded parameters were: date, starting time, finishing time, number of fast signals received, number of slow signals received, average and standard deviation of pulse rate received. When the
normalized standard deviation was above 0·2, the bird was considered to be active for the corresponding 10 min period.

Activity was recorded continuously for 16 days, from 29 June 1993 to 14 July 1993. Another incomplete day of activity was recorded on 23 July 1993. The exact timing of appearance and disappearance of the moon and the sun were calculated with software integrating latitude, longitude and altitude (Ciel, developed by J.J. Nguyen & F. Marcelet, Association Française d’Astronomie, Paris). No cloud which could have noticeably modified solar or lunar radiation was recorded during the observation period.

Houbara were located twice at night: 2 h after sunset (around 2200h) and 2 h before sunrise (around 0330h). This was done by taking directional radio bearings from two observation towers placed around the enclosure. A confidence area was calculated by triangulation and superimposed on a map using UTM coordinates (White & Garrott, 1990). Centres of confidence area were used to compute minimum distances moved by houbara between two successive locations.

In addition, the food consumption of three groups of four captive houbara was also measured for a 24-h period with full-moon and a 24-h period with no moon. No distinction was made between males and females. The food was composed of standard maintenance pellets (Paillat & Gaucher, 1995) normally utilized in the houbara captive-breeding in Taif. The plates were replenished with pellets at 0800h and weighed every day.

Weather records were obtained using an automatic recording station (Squirrel, Grant Instruments Ltd., U.K.). Air temperature was measured under shadow at 1 m height. Soil temperature was measured on the soil surface. Solar radiation was measured with a silicon cell pyranometer (Skye Instruments Ltd., U.K.) calibrated in the waveband 300–3000 nm. Dawn and dusk were defined as 2-h periods centred on sunrise and sunset and the duration of daytime comprised the time from sunrise to sunset plus 2 h.

Results of food consumption were analysed with a Mann Whitney test (Siegels & Castellan, 1988). A two tailed $t$-test was computed to compare activity indices between two periods (Zar, 1984).

**Results**

**Diurnal activity rhythms**

For all days of observations, daylight activity patterns were similar and showed two peaks of activity ($t > 20$ for everyday comparisons between peaks of activity and resting periods, $p < 0·001$). At dawn, birds increased their activity rate 1 h before sunrise, using the very first light of the day (Fig. 1). Activity then decreased continuously from 0800h to 1200–1300h and remained low until noticeably increasing again at about 1500h, to peak before sunset.

A high negative correlation ($r = 0·936$, $t = 8·4$, $p < 0·001$) was observed between daytime activity index and solar radiation (Fig. 2). Similarly, daylight activity was negatively correlated to soil surface temperature ($r = 0·904$, $t = 8·1$, $p < 0·001$) and to a lesser degree, to air temperature ($r = 0·736$, $t = 3·4$, $p < 0·01$). Resting time was observed when insolation was at a maximum and peaks of activity when solar radiation was less than 500 W.m$^{-2}$.

**Nocturnal activity**

Nocturnal activity appeared to be linked to intensity and duration of moonlight. When
the moon was up just after sunset, activity remained high in the evening (Fig. 1, 29 June to 3 July). Periods without moonlight directly after sunset had reduced activity indices (5 to 13 July and 23 July). When the half-moon appeared towards the middle of the night, activity indices increased after 1 h of moonlight (4 to 13 July).

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity Indices</th>
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<tbody>
<tr>
<td>June 29 1993</td>
<td>0.8</td>
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<tr>
<td>June 30 1993</td>
<td>0.3</td>
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<tr>
<td>July 01 1993</td>
<td>0.7</td>
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<tr>
<td>July 02 1993</td>
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<td>July 03 1993</td>
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<td>July 04 1993</td>
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<td>July 05 1993</td>
<td>0.2</td>
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<tr>
<td>July 06 1993</td>
<td>0.1</td>
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<tr>
<td>July 07 1993</td>
<td>0.8</td>
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<tr>
<td>July 08 1993</td>
<td>0.3</td>
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<td>July 09 1993</td>
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<td>July 10 1993</td>
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<td>July 11 1993</td>
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<td>July 12 1993</td>
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<td>July 13 1993</td>
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<td>July 14 1993</td>
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<td>July 15 1993</td>
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<td>July 23 1993</td>
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</table>

**Figure 1.** Examples of circadian activity patterns of a group of 10 free-ranging houbara bustards according to moonlight (Mahazat a-Sayd reserve, June and July 1993). (■) = darkness; (□) = moonshine; (▲) = daytime.
moon set during the night, activity indices decreased (30 June and 1 to 3 July). Activity indices during full-moon were different to indices during darkness (t test, $t = 28.1$, $p < 0.001$). Independent of moonlight, activity indices decreased just before rising again at dawn. During the no-moon night (23 July) activity remained low until the first daylight.

A high positive correlation ($r = 0.908$, $t = 8.4$, $p < 0.001$) was found between duration of moonlight and duration of nocturnal activity (Fig. 3). The duration of nocturnal activity varied from less than 50 min when there was no moon to more than 250 min when the moon shone all night.

Relationship between nocturnal and diurnal activity

The duration of diurnal activity was found to be related to the duration of nocturnal
activity and a negative correlation \( (r = 0.665, t = 3.2, p < 0.01) \) between time spent active at night and time spent active during the day was observed (Fig. 4). Similarly, a negative correlation was observed between duration of moonlight and duration of diurnal activity \( (r = 0.667, t = 3.2, p < 0.01) \). Therefore, the longer the duration of moonlight, the greater the period of nocturnal activity at the expense of diurnal activity. However, a positive correlation was present between the duration of moonlight and the duration of the total daily activity \( (r = 0.729, t = 3.8, p < 0.01) \) resulting in an excess of about 100 min of total daily activity for full-moon periods compared with no-moon periods. In addition, the consumption of food pellets by captive birds was considerably increased when the moon was full \( (z = 144, df. = 1, p < 0.001) \) suggesting that the excess in the duration of activity was directed towards foraging. The average food consumption was 51.2 ± 3.4 g during a 24-h period with full-moon and of 32.2 ± 3.7 g during a 24-h period with no moon.

The intensity of the peak of activity recorded at dawn was negatively correlated \( (r = 0.761, t = 3.9, p < 0.01) \) with the duration of moonlight (Fig. 5). On the contrary, duration of moonlight had no effect on the intensity of the peak at dusk.

*Figure 4.* Duration of night-time activity in relation to the duration of daytime activity in houbara bustards (Mahazat as-Sayd reserve, June and July 1993).

*Figure 5.* Intensity of the peak of morning activity in houbara bustards in relation to the duration of moonlight (Mahazat as-Sayd reserve, June and July 1993).
Duration of moonlight (min)

Minimum distance moved per night (m)

Figure 6. Minimum distance moved nightly by houbara bustards in relation to the duration of moonlight (Mahazat as-Sayd reserve, June and July 1993).

(r = 0·123, t = 1·3, NS). The minimum distance moved at night by houbara was also found to be strongly positively correlated (r = 0·943, t = 9·0, p < 0·001) with the duration of moonlight (Fig. 6).

Discussion

The present study confirms the existence of crepuscular activity peaks previously observed in wild or semi-captive houbara bustards (Mian & Surahio, 1983; Paz, 1987; Symens, 1987; Mian, 1988; Launay, 1989). We have established that houbara adjust their activity patterns to minimize their exposure to the sun and to optimize their activity rate in moonlight.

A long period of resting was observed around noon. Combreau & Rambaud (1994) showed that at this time, birds remained under the shade of A. tortillis, Salsola spp. or Panicum turgidum. Rather than avoiding high air temperature as suggested by Symens (1987) and Mian (1988), houbara primarily avoided high insolation, preferring to display high activity rates when solar radiation was less than 500 W m\(^{-2}\). During the course of the observations, peaks in air temperature lagged about 3 to 4 h behind peaks in solar radiation and the correlation calculated between air temperature and solar radiation was low (r = 0·672, t = 3·5, p < 0·01); air temperature actually remained at a maximum during the sunset activity period. On the contrary soil surface temperature was closely correlated to insolation (r = 0·904, t = 8·2, p < 0·001).

Moonlight was a primary factor that induced nocturnal activity in houbara bustards. It seems that the waxing and waning of the moon had no effect on the quantity of activity showed by houbara but activity was displayed whenever moonlight permitted. Nocturnal activity patterns were found to be adjusted to the appearance and disappearance of the moon over a threshold of 200 min of moonlight (less than 200 min of moonlight corresponding to illumination by less than one-fourth of the moon). As duration of moonlight is linked to brightness, activity in houbara bustards was probably triggered by moon brightness rather than moonlight duration.

We have shown that houbara moved considerable distances during full-moon nights, and it is believed that birds crossing the United Arab Emirates mainly migrate during clear nights. This nocturnal activity could be directed towards foraging as suggested by Roberts (1991) and by some of the results presented here. Houbara eat both plants
and animals, consuming leaves, buds and flowers of various plants including Lycium, Farnesia, Indigofera, Haloxylon and alfalfa in this study, as well as large-sized species of Tenebrionidae, ants, Orthoptera and lizards (Mian & Surahio, 1983; Collins, 1984; Mian, 1988; Combreau & Rambaud, 1994). The hypothesis of foraging at night is supported by the discovery that several major large insect species eaten by houbara, such as Pimelia spp., Blaps kollari and Prionoteca coronata, which represent a great part of the arthropod biomass in Mahazat as-Sayd, exhibit twilight as well as nocturnal activity patterns (Combreau & Rambaud, 1994), especially in summer (Ayal & Merkl, 1994).

We have shown that the intensity of the peak of activity recorded at dawn was negatively correlated with the duration of moonlight and that food consumption was greater during days with full-moon than during days with no-moon. These results suggest that the more active houbara were at night, the more they ate and the less they looked for food in the morning. On the contrary, when the night was dark, houbara were not active, did not eat at night and were consequently avidly looking for energy and nutrients at dawn.

The duration of moonlight clearly modified the circadian activity patterns of houbara bustards. The greater the duration of moonlight, the greater the nocturnal and the less the diurnal activity rates. However, when considering 24-h periods of activity, about 100 min more activity was recorded when the moon was full than when there was no moon. These results suggest two hypotheses: (1) feeding rates were not similar by sunlight and by moonlight; houbara were active during clear nights but showed reduced feeding rates due to the limits of their visual sensitivity. Martin (1990) stated that nocturnal visual acuity in birds, even in bright moonlight, is always substantially below that achieved in daylight. In that case, the excess of activity observed could compensate for a low nocturnal feeding rate. (2) Feeding rates were similar by sunlight and by moonlight; in that case, and if, as suggested by the food consumption of captive birds, the excess of activity was used for foraging, free-ranging houbara may exhibit variations of weight or body condition linked to the moon cycle.

The presence of alfalfa fields within the study area did not inhibit the use of natural food and the maximum utilization of alfalfa was found to occur at minimum natural food availability (Combreau & Rambaud, 1994). In early July 1993, the quantity and quality of natural plant and animal food items decreased resulting in an increase in utilization of alfalfa by free-ranging houbara (Combreau & Rambaud, 1994). However, no evidence was found that birds reduced the time normally spent foraging on natural food. Moreover, how may one explain both the increase in nocturnal activity and the high minimum distance moved when there is moonlight if birds fed exclusively in the alfalfa fields? Captive-bred houbara introduced in Mahazat as-Sayd primarily looked for natural plant and animal food but utilized alfalfa to get part of their food and water when the natural food availability was low.

In periods of drought in the wild, when the habitat and all plant material dries out and senesces, houbara which have left the enclosure can obtain water by feeding at night on large nocturnal insect species and moister vegetation. Desert insects retain an average of 50% water in their body during dry conditions (Edney, 1974) and remain a vital source of water for insectivores. A large part of the arthropod population is active at dusk or at night (Combreau & Rambaud, 1994) presumably for the same abiotic reasons as houbara. Houbara, then, have to adjust their activity patterns to match those of insects and thus develop a nocturnal activity period whenever moonlight permits. However, potential predators of houbara bustards such as red foxes (Vulpes vulpes) tend to show twilight and nocturnal activity patterns as well (E. Offerman, pers. comm.), suggesting that a risk is taken by the birds when they forage at night. This risk is increased by the fact that houbara tended to forage in the preferred habitat of red foxes (Combreau & Rambaud, 1994), i.e. wadi systems with relatively
dense vegetation (E. Olferman, pers. comm.). Such a risk may be countered by the benefits of obtaining water and energy from food sources unavailable during the daytime.

The study presented here indicates that nocturnal activity is very important to houbara and that more work is needed to gain a full understanding of houbara nocturnal ecology so that efficient conservation measures may be implemented.

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References


