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The seasonality of group size and group composition of sand partridge (*Ammoperdix heyi heyi* Temminck, 1825) in the Ibex Reserve, Saudi Arabia

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Abstract: The seasonality of group size and composition in sand partridges was studied at the Ibex Reserve in central Saudi Arabia. Mean group size and flock encounter rate were significantly related to rainfall and temperature. During winter and the breeding season (March to April), the encounter rate on the valley floors was distinctly lower than that observed during summer. Although encounter rates did not differ significantly between valleys, sand partridges were more likely to be encountered in narrow, stony valleys. Correcting for valley width, encounter rates did not differ between valleys. Male and female encounter rates were constant throughout the reserve, indicating a constant sex ratio throughout the year. Results are in line with earlier findings reported from more northern habitats such as the Eilat Mountains (Israel) and the Rum Wildlife Reserve (Jordan). Human disturbance in parts of the reserve is high and may have an impact on group size and composition.

Key words: Sand partridge, group size, Ibex Reserve, Saudi Arabia

Introduction

The sand partridge (*Ammoperdix heyi*) is a widespread phasianid, inhabiting the desert and semidesert areas of the Arabian Peninsula, north-eastern Africa (east of the Nile River), the Sinai Peninsula, and the southern Levant (Cramp et al., 1983; Urban et al., 1986; Del Hoyo et al., 1994). The species prefers steep, rocky slopes with sparse vegetation, but it forages in rocky and sandy bottoms of steep-sided valleys and depends on accessible surface water (Cramp et al., 1983; Pinshow et al., 1983; Kam et al., 1987). In the Kingdom of Saudi Arabia, sand partridges of the nominate subspecies *Ammoperdix heyi heyi* are recorded from the western and central highland plains (Jennings, 1995), although only a few records report on sand partridges occurring in the central mountains, i.e. the Jebel Tuwaiq (Child and Grainger, 1990; Jennings, 1995), in which the Ibex Reserve is situated. Although sand partridges are a preferred game bird species and are locally persecuted throughout their range, they are still common and frequently encountered on the Arabian Peninsula (Del Hoyo et al., 1994; Evans et al., 2005). At certain locations on the Arabian Peninsula (Hadhramut, Yemen), the species locally comprises >10% of total bird numbers and 15%-20% of avian biomass (Urban et al., 1986).

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In the high elevations of the Eilat Mountains in southern Israel, sand partridges disperse into the nearby lower levels after the breeding season (Shirihai, 1996), where they spend the entire winter (nonbreeding season), but are absent during the breeding season. Many studies on birds have indicated that the critical factor determining the success of breeding is the amount of food available to parents for building up body reserves prior to birth or egg-laying (Perrins, 1970; Schifferli, 1973; Sinclair, 1978). The better this prebreeding period, the more successful the avian mother is at laying more and larger eggs and at feeding the juveniles. If this is applicable to sand partridges in the Ibex Reserve, the animals should spend the breeding season (March to early May; Jennings, 1995) in their preferred breeding habitats (rocky, steep slopes) and the nonbreeding season in the well-vegetated valleys where food, consisting mainly of seeds (80%) and some green vegetation (18%), is abundant prior to breeding (Kam et al., 1987). Moreover, this study hypothesised that narrower valleys with rocks and stones providing shelter and shade are preferred to those that are more open and sandy. This hypothesis was tested on 2 valleys in the Ibex Reserve, Mutim Valley and Nukhailan Valley. The former is rocky and stony, with a considerable degree of human disturbance (recreation), while the latter is sandy and wide with almost no disturbance.

Recreational activities in natural areas (sensu Salafsky et al., 2008: threat level 6.1) can affect wildlife by disturbing foraging and social behaviour (Burger, 1981, 1986; Skagen et al., 1991), feeding animals (Edington and Edington, 1986), and disrupting pair bonds and group cohesion (Tindle, 1979). Increasing human use of otherwise undisturbed habitats can also decrease the length of foraging sessions (Kaiser and Fritzell, 1984) and therefore negatively affect breeding success, especially when special foraging habitats are disturbed by human activities. The data presented in this study are therefore particularly important to the wildlife managers and rangers of the Saudi Wildlife Authority (SWA), who have to control human activities in the valleys of the Ibex Reserve and ensure coexistence among feeding sand partridges, ibex, and the human need for recreation.

Materials and methods

Study area

The Ibex Reserve (23°30′N, 46°30′E) near Hawtat Bani Tamim in the Jebel Tuwaiq Mountains of central Saudi Arabia was established in 1988 by the SWC to protect the last Nubian ibex (*Capra ibex nubiana*) in the central parts of the Kingdom. Annual rainfall in the study area is low and highly variable (1991-2008, average = 78.2 mm, SD = 60.55 mm; Robinson, 2008) and precipitation occurs mainly during winter and spring. Run-off is very high in all sloping areas and the valleys serve as reservoirs, with subterranean water storage providing water for deeply rooted plants well into the dry periods (Robinson, 2001). Apart from a few permanent water holes in the valley heads, surface water is sparse and not readily available. Summers are dry and hot (the mean monthly temperature is 40 °C), and winters are mild, with a monthly minimum temperature around 10 °C and night extremes of 0 °C (Child and Grainger, 1990; Campbell, 1996). The reserve covers 1870 km² and comprises an undulating, stony, limestone plateau, 800-1100 m above sea level and deeply incised by valleys. Plant standing crop is sparse on the plateau, but greater in the valleys, where *Acacia* spp. bushes and trees dominate the vegetation. This study was predominantly carried out in 2 valleys of the Ibex Reserve: Nukhailan Valley in the south and Mutim Valley in the east. The valley floor in Nukhailan Valley covers 19.26 km², and that of Mutim Valley is 44.4 km². Mutim Valley is a narrow valley with a rather coarse, stony soil texture (Robertson, 1999), while Nukhailan Valley is a wider and lower-lying valley with a more sandy soil texture. A few sand partridge records were obtained from other valleys in the reserve (Gauwath, Humiyath, and Jidr).

Data collection

Sand partridge flocks were encountered randomly during daily patrols (4 to 30 days per month, each lasting 2-12 h) in both study areas. Vehicle patrols were carried out equally throughout summer and winter, in both valleys, following existing accessible tracks with constant speed. The visibility in both valleys was similar. Tracks followed the course of the valley, mostly along riverine vegetation, but more open areas such as flood banks and gravel plains were approximately evenly included in the survey

route. Data were obtained over a period of 18 months (February 2008 to July 2009). For each sighting, location (using a Garmin III Plus GPS), time, date, valley width, and the number of males and females in the group were recorded.

Data analyses

Group size records were expressed as the mean group size (MGS) and typical group size (TGS; sensu Reiczigel et al., 2008: crowding) for male, female, and mixed groups. The MGS is the total number of animals divided by the total number of groups sighted. If the effect of group size on an average individual's life within a group needs to be considered, then MGS may be misleading, because in a finite population, small groups are inevitably more common than large ones. Under certain circumstances, the TGS (i.e. the group size in which, on average, an animal finds itself most frequently) represents a more meaningful estimate of grouping tendencies than the MGS (Jarman, 1982). TGS or crowding refers to group size as experienced by an individual; it equals 1 for a solitary individual, 2 for both individuals in a group of 2, and 3 for all 3 individuals in a group of 3 (Reiczigel et al., 2008), and is therefore provided as an additional measure for group size in sand partridges (Table). Group sizes were determined for Mutim Valley, Nukhailan Valley, and for the entire Ibex Reserve, including predominantly the 2 valleys plus arbitrary sightings from other valleys.

The group encounter rate was established as the number of sand partridge flocks encountered during a sampling session (1 day) divided by the time the observer spent in the study area during that day. The encounter rate was used to provide information on differences in valley utilisation between seasons, i.e. hot dry (late April to September), cold moist (November to the end of January), and hot moist (February to late April; Robinson, 2009). For convenience, data from the hot moist and the cold moist seasons were combined and compared with those of the hot dry season. Encounter rates were established for each month, pooling those observations that were collected in the same months of 2 consecutive years. To allow for a comparison between sexes, the animal encounter rate was determined, i.e. the number of males or females encountered during a sampling session divided by the total time spent in that study area during that day. To allow for a comparison between Mutim Valley and Nukhailan Valley, representing different habitat types (Wronski, 2009), the group encounter rate described above was multiplied by a factor correcting for valley width. This provided an encounter density estimate for both areas. Mean valley width was measured using a satellite image of the study area. Assuming a strip width of 100 m in which sand partridges could be spotted, the valley width was divided by the strip width to obtain the correction factor (Bothma, 2002). Differences between study areas, between sexes, and between seasons were tested using the Mann-Whitney U test.

Rainfall data were collected using Snowdon standard rain gauges placed in both study areas over the entire study period. The amount of rain was pooled and averaged for the same months of consecutive years. A monthly maximum temperature was estimated based on inchoate measurements quoted by Child and Grainger (1990), Campbell (1996), and Robinson (2009). Rainfall and temperature data were related to the MGS and group encounter rate using a Spearman rank correlation. For graphical presentation, rainfall and temperature were log-transformed.

Results

The overall MGS (mean ± SE) was 3.63 ± 0.20 animals, while the overall TGS was 5.40 animals (Table). Sand partridge groups (MGS) in Mutim Valley were not significantly larger than those in Nukhailan Valley (Table; Mann-Whitney U test: t = 4729, N_{Mutim} = 353, $N_{Nukhailan}$ = 212, P = 0.217). There were also no differences in MGS (mean ± SE) between the hot season (4.77 ± 1.04; random selection) and cold season (2.85 ± 0.55; Mann-Whitney U test: t = 807, N_{hot} = 13 (random selection), N_{cold} = 13, P = 0.182). The maximum group size (13 individuals: 6 males, 7 females) was observed in Mutim Valley during July 2008. MGS was related to group encounter rate (as explained below), to rainfall, and to the estimated temperature using a Spearman rank correlation (Figure 1). There was a significant correlation between MGS and temperature (r = 0.69, N_{months} = 12, P = 0.013), as well as between MGS and the group encounter rate (r = 0.75, N_{months} = 12, P = 0.002). The

Table. Mean group size (MGS) and typical group size (TGS) of male, female, and mixed sand partridge groups in Mutim Valley, Nukhailan Valley, and the entire Ibex Reserve.

Area	Group type	No. of groups	No. of individuals	Total no. of animals in given group type	MGS	TGS
	Male	21	82	31	1.48 ± 0.19	2.65
Mutim Valley	Female	9	23	13	1.44 ± 0.16	1.77
	Mixed	90	2101	353	3.92 ± 0.30	5.95
	Male	11	37	19	1.73 ± 0.19	1.94
Nukhailan Valley	Female	13	31	19	1.46 ± 0.14	1.63
	Mixed	65	980	212	3.26 ± 0.26	4.62
	Male	32	119	56	1.75 ± 0.14	2.13
Total (Ibex Reserve)	Female	22	54	33	1.50 ± 0.11	1.64
	Mixed	159	2112	576	3.63 ± 0.20	5.40

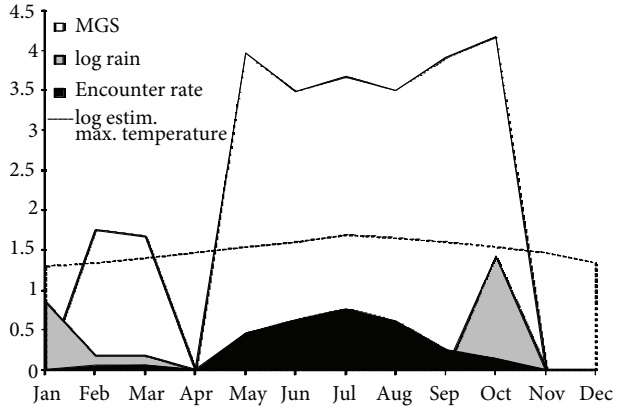

Figure 1. Relations between mean group size (MGS), monthly group encounter rate of sand partridges, rainfall (log), and estimated maximum temperature (log) in the Ibex Reserve, central Saudi Arabia.

group encounter rate was also significantly correlated with the estimated temperature ($r = 0.85$, $N_{months} = 12$, $P < 0.0001$).

The overall encounter rate (mean ± SE) of sand partridge groups was 0.33 ± 0.04 sightings per day. The encounter rate in Mutim Valley (0.41 ± 0.06) was distinctly higher than that in Nukhailan Valley (0.27 ± 0.06; Mann-Whitney U test: $t = 2197$, $N_{Mutim} = 41$, $N_{Nukhailan} = 51$, $P = 0.02$), indicating a higher likelihood of encountering flocks in the narrow, rather stony habitat of the upper valley heads. During the hot season (April to September), encounter rates (mean ± SE) were considerably higher (0.54 ± 0.06) than during the cooler months between October and March (0.07 ± 0.02; Mann-Whitney U test: $t = 1116$, $N_{hot} = 53$, $N_{cold} = 40$, $P < 0.001$), indicating that the valley floors represent the summer habitat of sand partridges following the breeding season between February and April (Figure 2). The encounter rate corrected by valley width (encounter density; mean ± SE) of sand partridge groups was lower in Mutim Valley but not distinctly different from that in Nukhailan Valley (1.42 ± 0.32; Mann-Whitney U

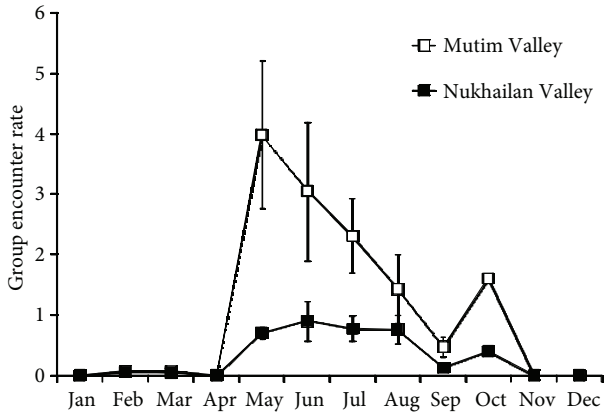

Figure 2. Monthly group encounter rate of sand partridges (combined data from 2 consecutive years) as observed in Mutim Valley and Nukhailan Valley, Ibex Reserve.

test: t = 2027, N_{Mutim} = 41, $N_{Nukhailan}$ = 51, P = 0.346), indicating that neither habitat type is preferred.

The encounter rates (mean ± SE) of males (0.68 ± 0.11) were not different from those of females (0.52 ± 0.08; Mann-Whitney U test: t = 9521.5, N_{male} = 96, N_{female} = 96, P = 0.504), indicating that almost every group was mixed with an almost equal male-to-female ratio (Figure 3). Although male encounter rates (mean ± SE) were higher during the hot season (1.16 ± 0.17) than those of females (0.88 ± 0.12), this difference was not significant (Mann-Whitney U test: t = 2979, N_{male} = 53, N_{female} = 53, P = 0.366). During the cold season, encounter rates of both sexes were almost equal (Figure 3).

Discussion

The distinct difference between group encounter rates in the hot and cold seasons indicates a clear seasonality in the movement patterns and habitat requirements of sand partridges in the Ibex Reserve. This confirms the prediction that breeding habitat and foraging habitat depend on seasonal changes in climate (Shirihai, 1996). During the hot dry season between late April and September, when temperatures exceed 45 °C and precipitation is absent, sand partridges prefer the shady valley floors with dense vegetation, large boulders, and available surface water (Etchécopar and Hüe, 1967). During the cold season between October and March, when temperatures are moderate and rainfall provides surface water on the plateau and slopes, the birds are widely dispersed and frequent their breeding habitat. The main breeding season on the Arabian Peninsula is March and April (Del Hoyo et al., 1994). April was the month in which no group encounters were observed, in both valleys studied (Figure 2). In May, after breeding, a sharp increase in the number of sightings was observed in both valleys, corresponding with observations from the dry areas of southern Israel (Shirihai, 1996). At the high elevations of the Eilat Mountains in the southern Negev, the sand partridges tend to disperse to the lower levels after breeding, while in winter, when temperatures are lower, the birds are more widely dispersed and group sizes are smaller (Shirihai, 1996). The winter season appears to be the most stressful time of the year for sand partridges. Their adaptations to hot, dry conditions may be accompanied by constraints on their abilities to cope with cold weather conditions, and this may restrict them to arid and very arid habitats (Kam et al., 1987). Although there was no significant difference in the MGS between seasons, the MGS tended to be higher in the hot season than in the cold season. No differences in group size (Figure 2) or male-to-female ratio (Figure 3) were detected between the 2 valleys,

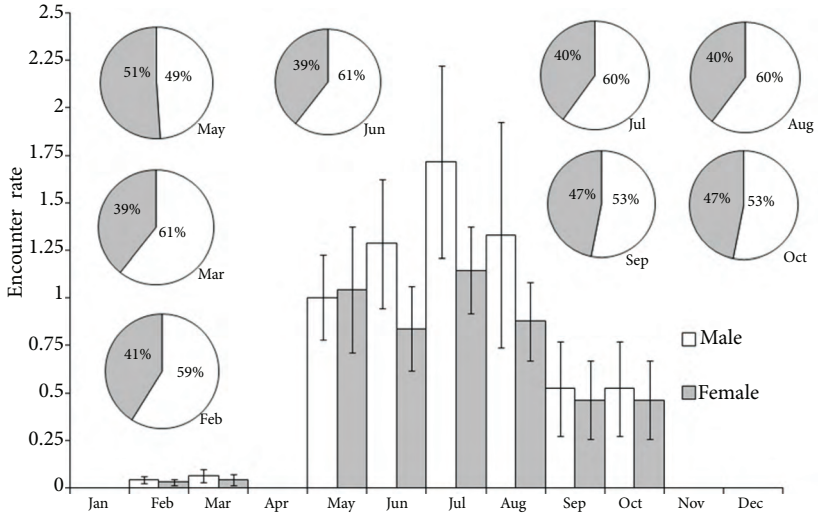

Figure 3. Monthly group encounter rate of male and female sand partridges (combined data from 2 consecutive years) in the Ibex Reserve. Pie charts show sex ratios for those months in which partridge groups were encountered in the valleys.

indicating that group size and composition are stable throughout the year. This corresponds with findings of other authors, who stated that sand partridges almost always live in small parties with a maximum group size of up to 12 or even 15 individuals (Hollom, 1959; Urban et al., 1986). Similarly, the maximum group size observed in the Ibex Reserve was 13 individuals. Comparing the large number of group encounters in Mutim Valley with those in Nukhailan Valley shows that the likelihood of encountering sand partridges is higher in the narrow Mutim Valley. This fact is not surprising and did not allow for statements on valley or habitat preferences. A comparison of encounter rates corrected for valley width provided a better estimate of valley preferences and revealed no significant difference between the areas, implying that the narrow, rocky Mutim Valley was not preferred to the more open and sandy Nukhailan Valley. The fact that encounter densities were even higher in Nukhailan Valley may be attributed to the higher degree of human disturbance in Mutim Valley. Human activity is most common in the morning and afternoon, when sand partridges also show activity peaks; the main feeding activity is around sunrise and before sundown (Raethel, 1988; Wronski, 2009). However, other valleys in the reserve may also provide important foraging habitat and therefore represent a compensation for the loss of habitat due to increased human activity in Mutim Valley. Regular counts of sand partridges in the Ibex Reserve will provide such information and assist with management recommendations regarding human activity in different valley systems. It is therefore recommended that this species be included in a regular monitoring program throughout the year to assess the health of the valleys. In other words, a change in number of individuals and group sizes could indicate a change in the health of the valleys that managers should notice and act upon.

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