4. Breeding performance of reintroduced female Asiatic houbara *Chlamydotis [undulata] macqueenii* in Saudi Arabia

Abstract

I found and followed 51 breeding attempts of reintroduced female Asiatic houbara of known identity, age, and experience. In general, houbara in this population are regular spring breeders, that have a high breeding effort. Female houbara rarely breed in their first year, and breeding effort, as measured by the proportion of females nesting and the propensity to re-nest, increased as females gain more experience. Older females had greater hatching success, but fledging and breeding success was greater for two-year-old females when compared with 3-5 year-old females. To offset high nest losses, females regularly replaced lost clutches of eggs, and occasionally lost broods of chicks, and there were two instances of double brooding. Predators caused most nest failures. Infertility was an important cause of hatching failure, and the maximum fertility rate was 78 %. Red foxes were recorded as egg predators, a hen harrier took a chick and a cat caught and killed a fledgling, otherwise the identity of predators was unknown. From 1996 – 1998, females laid 120 eggs in 46 nests, (mean clutch size of 2.61 eggs, range 1 – 4, mode = 3 eggs). The incubation period was 22.6 days, and the fledging period was 30 days. From 55 chicks that hatched, 10 of 15 females raised a total of 15 chicks to fledging age (hatching success rate 0.35, fledging success rate 0.27, overall breeding success 0.083). Fledglings were not followed to recruitment. Earliest nests were laid on 21 January, and the latest clutch was found on 24 May. In 1996, breeding started in April, but in 1997 and 1998, most females bred in February and March. Differences in onset of breeding and in the proportion of females nesting were correlated to spring minimum and maximum ambient temperatures, with fewer females nesting in warmer spring periods. Onset of breeding and proportion of females nesting were not related to rainfall or previous female breeding experience. Breeding data from this study are compared to the few studies that present data on breeding for this species throughout its range.

Introduction

Asiatic houbara (*Chlamydotis [undulata] macqueenii*) breed throughout central Asia and the Middle East, but despite their wide distribution, and the intensive focus of conservation programmes, very few quantitative data have been published on the breeding ecology, natural behaviour and population status of houbara (Dement'ev & Gladkov 1951, Heim de Balzac & Mayaud 1962, Ali & Ripley 1980, Cramp & Simmons 1980, Johnsgard 1991, del Hoyo *et al.*, 1996). Understanding the breeding ecology of houbara is important. Better knowledge of breeding parameters will help conservation management of the species, through protection of appropriate breeding habitat, and regulation of hunting activities to prevent population declines (Mian 1989, Gubin 1992, del Hoyo *et al.*, 1996, Seddon & van Heezik 1996). In addition, measures of breeding performance are important criteria for establishing the initial success of reintroduced populations.

Although houbara are currently classified by the International Union for Conservation of Nature as "not threatened" (IUCN red data book 2000), there have been significant decreases in numbers and range in southern populations, such as in Saudi Arabia, where over-hunting and over-grazing have all but eliminated houbara from former breeding grounds (Seddon *et al.*, 1995). This rapid and widespread level of change suggests the species is not secure throughout its range. Presently, other populations seem healthy, e.g., 40 – 50 000 houbara recorded on breeding grounds in parts of Central Asia (Gubin 1992), but this estimate was based on sightings of birds flushed when driving in localised sites multiplied over the expected range of the species, and at best is a crude estimate of relative abundance. Regardless of its accuracy, this type of survey adds few quantitative data to predictive models examining likely future population changes. Generally, accurate predictions of trends in houbara populations, and therefore the ability to identify and ameliorate key limiting factors, are hindered by the paucity of data on breeding ecology and performance: particularly breeding success and recruitment. These data are needed for realistic population modelling, and to guide restoration programmes for houbara in the future.

Published data on breeding ecology of houbara have relied mostly on incidental observation, or captive-breeding experience (e.g., Ponomareva 1983, Saint Jalme *et al.*, 1996a, Launay *et al.*, 1997), rather than detailed study of wild free-living birds (e.g., Lavee 1988). Few

detailed wild studies have been conducted, in part, because the species is cryptic in plumage and behaviour, hard to catch, is very difficult to observe, and occurs at low densities throughout most of its range (Seddon & van Heezik 1996, 1999, Launay *et al.*, 1999). In Central Asia, nests of houbara with eggs have been found between January and May, with a peak in March and April, and with peaks in chick hatching and sightings of fledged young occurring one and three months later (Cramp & Simmons 1980). Possible repeat clutches were reported by Launay *et al.*, *(*1997), but no females in that study, nor in any other, were individually identifiable. In Saudi Arabia, little is known about breeding by houbara, only a few houbara nests have been found by biologists (Symens 1988; P. Seddon pers. comm.; National Wildlife Research Centre (NWRC) unpubl. data; Gélinaud *et al.*, 1997), and none was monitored closely. Simply put, there have been no long-term studies of breeding houbara, anywhere in their range.

Conservation of houbara has been actively undertaken in Saudi Arabia, mostly through the establishment of reserves to protect habitat, the development of captive breeding and release techniques for supplementing natural populations, and the reintroduction of houbara to sites where they have been extirpated (Seddon *et al.*, 1995, Saint Jalme *et al.*, 1996b, Combreau & Smith 1998, Chapter 3). One such reintroduced houbara population has been established in Mahazat as-Sayd Reserve in west central Saudi Arabia. On-going releases began in that reserve in 1991 (Seddon & Maloney 1996, Combreau & Smith 1998), and first breeding was detected in 1995 (Gélinaud *et al.*, 1997). Once established, captive-reared and released houbara offer a unique opportunity to study breeding ecology, primarily because all birds are of known age and sex, and are fitted with radio-transmitters on release to facilitate regular location of birds and nests.

In this chapter, I present data on the breeding performance of houbara in Mahazat as-Sayd Reserve from 1996 to 1998. Specifically, I aimed to find and follow all breeding attempts by houbara within the reserve. For each individually identifiable female, I determined the number and fate of nests, timing of nesting, incubation and fledging periods, clutch size, egg size and double brooding attempts, and I calculate breeding success rates, by year and based on female breeding experience. Finally, I compare these data to observations from other houbara (*C. [u.]. macqueenii*) populations, and from *C. u. undulata* populations in North Africa.

Methods

Location of females and nests

Nesting females were identified by either having been located at the same site three times within a week with constant transmitter signals, or when flushed they did not move rapidly away from an area, or they returned to the area within an hour of being disturbed. Nests of females were found either by following the tracks of a female back to the nest-site, or by tracking a constant transmitter signal directly to a female on her nest. To reduce disturbance, no more than 20 mins was spent at nest sites, or searching an area for a nest on any one day. A list of all females included in this study is given in Appendix 4.

Assessing nest status and nest management

The status of nests (incubation, hatched, failed) was checked every one to three days by either monitoring the constant signal from an incubating female's transmitter at the nest site from more than 1 km distance, or by slowly approaching nests by vehicle to within 20 m. During my approach females occasionally remained on the nest, or more usually, ran and hid a short distance away. To reduce the risk of desertion, females were never deliberately flushed from the nest. Changes in nest status were readily determined. Females on nests had constant radio-transmitter signals because of long incubation stints during the day (Launay *et al.*, 1997, Maloney 1998, Appendix 5), whereas females with chicks initially stayed near to the nest but always had transmitter signals that indicated continuous activity. Females from nests that had failed always left the nest area, and following nest failure, were often found several kilometres from the nest site. In April and May 1998, nests were found and monitored by Jacky Judas, who was trained by me in March 1998 (see Acknowledgments).

In 1997 and 1998, eggs were removed from some nests, and were artificially incubated at the National Wildlife Research Centre (NWRC) in Taif. Where eggs were removed, dummy eggs (plaster-filled houbara egg shells) were placed in the nest, to encourage the female to continue "incubation". Hatching eggs were later returned to females sitting on dummy or infertile eggs. Egg removal was undertaken to prevent egg losses from predation, and thereby allow some females to attempt to raise chicks. Therefore, I define two types of nests: "wild nests" where eggs were left in the nest to hatch naturally, and "managed nests" where eggs were removed. Managed nests are excluded from hatching success data, because nests

with dummy eggs may have different rates of predation compared to real eggs, but are included in chick fledging data, because chicks hatching from wild and managed nests were exposed to the same set of conditions after hatching. One female (tx 5026) never laid eggs in three nests, but sat as if incubating. Dummy eggs were added to these nests, and the female was later given hatching eggs, sourced from captive stock. Data from these nests are treated as for managed nests.

Clutch size and incubation period

In captivity at NWRC, eggs are laid on alternate days (Saint Jalme *et al.,* 1996c). Therefore, completed clutch size was determined for nests by repeatedly visiting nests at intervals of two or more days until no extra eggs were found in the nest. Eggs were measured (maximal length and width to nearest 0.1 mm) using Vernier callipers whenever they were handled. Egg volume was calculated as length x width^2 x 0.51, following Harvey (1993). Incubation period was determined for those nests where the laying date was known, and where chicks were seen hatching in the nest.

Survival of chicks

Chicks were located by first finding the female parent, then finding and following her tracks and those of the chicks. Often, larger chicks were visible and remained with the female during her running escape. In 1997, some young chicks were caught to trial radio-transmitter attachment methods to enable intensive monitoring. Transmitter attachment in 1998 was only attempted for chicks just before fledging. Females with chicks were approached every one to four days by vehicle to record parental behaviour (wing displays, conspicuous running and hiding, reluctance to leave the area) that indicated that chicks were present. Most chicks or tracks of chicks were visually located every two to four days during these approaches. Once located, chicks were easily caught, weighed, and returned to their mothers with little disturbance. Chicks were placed individually onto electronic scales and their mass was recorded to the nearest 1.0 g. Chicks were not individually marked, and except for females that had only one chick, chicks within a brood could not be distinguished.

Results

From 1996 to 1998, breeding attempts were recorded from 15 different females. In 1996 only four of 12 females nested, whereas 11 of 13 females nested in 1997, and 11 of 18 nested in 1998. Only 4 % of one-year-old females, and 20 % of two-year-old females bred. In contrast, almost all females 3-5 years old (83-100 %) bred (Table 4.1). I found 46 nests with eggs. Five further breeding attempts were recorded: two females were located with chicks, and one female had three nests in which eggs were never laid (Tables 4.2a & b). Replacement clutches were recorded frequently following the loss of eggs (N = 12 clutches were replaced) and the loss of chicks (N = 6 clutches replaced), and one female had three replacement clutches within a season (i.e., laid four clutches in total). Clutch replacement following the loss of eggs and chicks was not restricted to the laying of second clutches following the loss of first clutches; third replacement clutches were laid following the loss of second clutches of eggs on four occasions. Similarly, following the loss of chicks from their previous clutches one female laid a second, and one a third, replacement clutch. In addition, two females double-brooded, fledging chicks from first clutches before laying second clutches (see below).

Table 4.1: Age distribution of females within Mahazat as-Sayd Reserve in each year from 1996 to 1998, and the number that bred.

Number and age of females	1996	1997	1998	Total females by age	Number breeding by age
Number of females in year 1 cohort	3	7	14	24	1
Number of females in year 2 cohort	6	2	7	15	3
Number of females in year 3 cohort	5	5	2	12	10
Number of females in year 4 cohort	1	5	5	11	10
Number of females in year 5 cohort	0	1	4	5	5
Total number of females by year	15	20	32		
Total number of females breeding by year	4	12	13		

Table 4.2: Number of breeding attempts by female houbara in Mahazat as-Sayd Reserve and number of nests by managed and wild nest categories, in each year (A), and for each female cohort (B). Letter codes are used in calculations in Tables 4.7a or b.

A) *Number of breeding attempts*	1996	1997	1998	All yrs
Total number of nests with eggs	**4**	**22**	**20**	**46**
Number of nests without eggs (female tx 5026)	0	1	2	3
Number of females found with chicks	0	0	2	2
Total number of breeding attempts (A)	**4**	**23**	**24**	**51**
Nests where eggs collected and replaced with artificial eggs, including one nest in which no eggs were laid ("managed nests")	0	13	5	18
Number of nests where eggs left in wild ("wild nests") (B)	4	10	17	31

B)	Female age (years)					
Number of breeding attempts	1	2	3	4	5	All ages
Total number of nests with eggs	**1**	**5**	**16**	**17**	**7**	**46**
Number of nests without eggs (female tx 5026)	0	0	0	1	2	3
Number of females found with chicks	0	1	0	0	1	2
Total number of breeding attempts (N)	**1**	**6**	**16**	**18**	**10**	**51**
Nests where eggs collected and replaced with artificial eggs, including one nest in which no eggs were laid ("managed nests")	0	1	5	7	5	18
Number of nests where eggs left in wild ("wild nests") (O)	1	4	11	11	4	31

Timing of nesting

The earliest nest found with eggs was located on 4 February 1998, and hatched on 13 February. With an incubation period of 23 days (see below) this clutch would have been laid on or about 21 January. All other clutches were laid in February (N = 21), March (N = 13), April (N = 9) and May (N = 4, Fig. 4.1). Clutches in 1996 were laid later than most clutches in 1997 and 1998 (Fig. 4.1). The latest clutch found was laid on 24 May 1998, and was a second clutch of a female that fledged chicks earlier that year. Three other nests were found in May; a third clutch in 1998, a fourth clutch in 1997, and a first clutch in 1996. Using a mean incubation period of 23 days and a fledging period of 30 days (see below), then the range of potential hatching and fledging dates in Mahazat as-Sayd Reserve would be 13 February – 18 May, and 17 March – 16 July, respectively.

Nesting attempts related to rainfall

Rainfall was infrequent, and fell in only 14 of 30 month periods from December 1995 to March 1998 (Fig. 4.1). Predictably, in each year, rain fell somewhere in the period between October and January, and in March. From May to September-October little rain fell. More than 20 mm of rain fell per month on six occasions over that period, in November 1996, in December 1995, in March in all three years and in April 1996. At the other extreme, less than 6 mm of rain per month was recorded for seven months of each year (Table 4.3). Rainfall was not correlated to number of nests laid per month when data from all months was included (Spearman Rank Correlation r_s = 0.201, P = 0.279, N = 30 months), or when only data from spring months (January to April) was used (r_s = 0.041, P = 0.897). In general, before or during the 1996 breeding period there was good rainfall throughout the reserve in three months (December 1995, January and March 1996), yet onset of breeding was delayed until mid-April and few females bred. In comparison, in the 1997 breeding season, when rain fell in the previous November and December, but no rain fell in January or February, most females nested in February, and replacement nests later in the season were common. In the 1998 breeding season, no rain fell in preceding November or December, and some rain fell in January, yet as for 1997, breeding started in February.
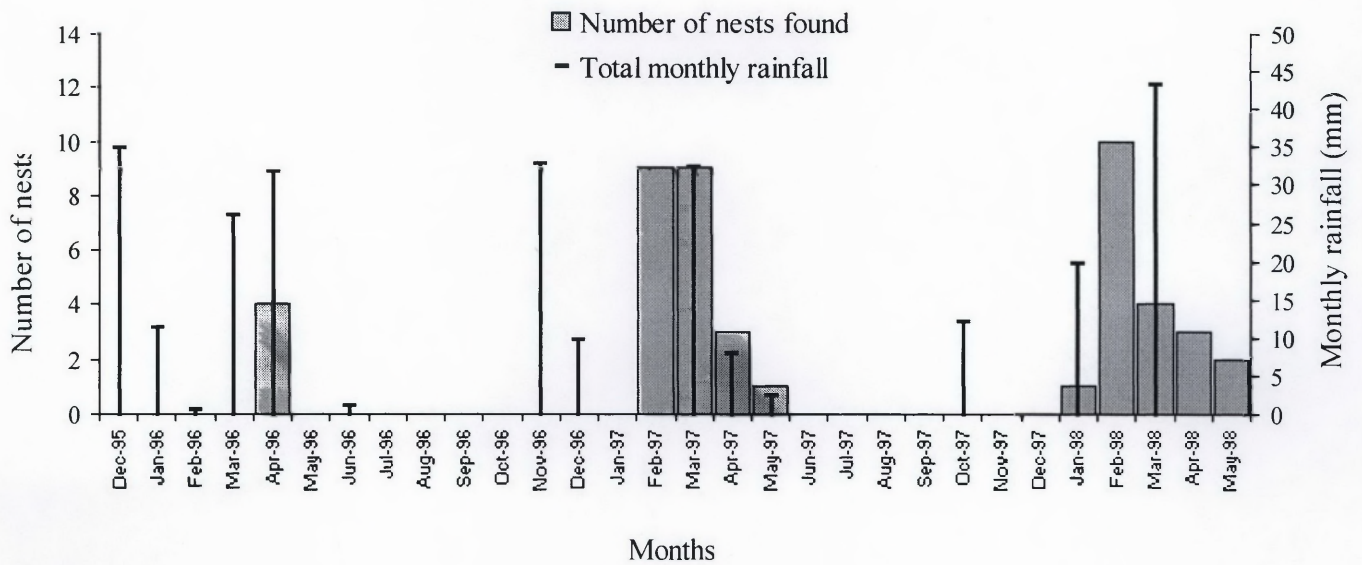
Figure 4.1: Number of houbara nests found per month in Mahazat as-Sayd Reserve from 1996 to 1998 (grey bars), and the total monthly rainfall (black lines). Except for April and May 1998 (no data), absence of black rainfall lines indicates that no rain fell in that month.

Table 4.3: Total rainfall (mm) and months in which no rain fell from January 1995 to March 1998.

	1995	1996	1997	1998*	Total
Total annual rainfall	110.8	118.5	67.2	57.5	405.0
Number of rainfall days	36	28	21	7	94
No. months rain < 6 mm	7	7	7	1	
Months < 6 mm of rain	Feb, May to Oct	Feb, May to Oct	Feb, May to Sep, Dec	Feb	
No. months rain > 20 mm	3	3	2	1	
Months > 20 mm of rain	Mar, Apr, Dec	Mar, Apr, Dec	Mar, Nov	Mar	

*Jan-Mar only

Clutch size

Complete clutches were determined for all 46 nesting attempts in which eggs were laid. In total 120 eggs were laid. The mean ($\pm$ 95 % C.I.) clutch size was 2.61 $\pm$ 0.21 eggs per clutch (range 1 – 4 eggs) for the three seasons. There was no difference in number of eggs laid in first ($\bar{x}$ = 2.63 $\pm$ 0.28 eggs per nest) clutches, compared with first ($\bar{x}$ = 2.69 $\pm$ 0.41) and second ($\bar{x}$ = 2.4 $\pm$ 0.48) replacement clutches (Kruskal Wallis test, H = 1.38, D.F. = 2, P = 0.513). Overall, 7 % of 46 clutches had one egg, 33 % had two eggs, 54 % had three eggs, and 7 % had four eggs. Most nests found were either first (59 %) or first replacement clutches (28 %). Within a breeding season the greatest number of eggs laid by a single female was 10 (clutches of 2, 3, 3, 2 eggs for female tx 5240, and 3, 4, 3 eggs for female tx 5496, both in 1997).

Egg size

Thirty-eight eggs from 10 females were measured. Mean ($\pm$ S.D.) egg length was 61.3 $\pm$ 3.10 mm, mean width was 43.4 $\pm$ 1.64 mm, and mean egg volume was 59.2 $\pm$ 6.31 cm^3. Egg length (Kruskal-Wallis test, H = 18.26, P = 0.032), mean egg volume (H = 18.05, P = 0.035), but not width, were significantly different among females. Excluding eggs taken by predators, there were no significant differences in egg size (volume, length, or width) between eggs that hatched and those that did not hatch (infertile, failed during incubation; Mann-Whitney U tests, P > 0.05).

Eggs from Mahazat as-Sayd Reserve were similar in length and breadth to the mean egg size of eggs recorded from eggs in five other studies of *Chlamydotis [u.] macqueenii*. Mean egg volume of houbara eggs from Mahazat as-Sayd Reserve was greater than that of eggs from Uzbekistan, and from the founder group in captivity in Taif, Saudi Arabia, but less than those of eggs from India and Pakistan, and from a captive population in Israel. The 95 % C.I. for Mahazat egg volumes overlapped with egg volumes from all other populations (Fig. 4.2, references in figure legend).
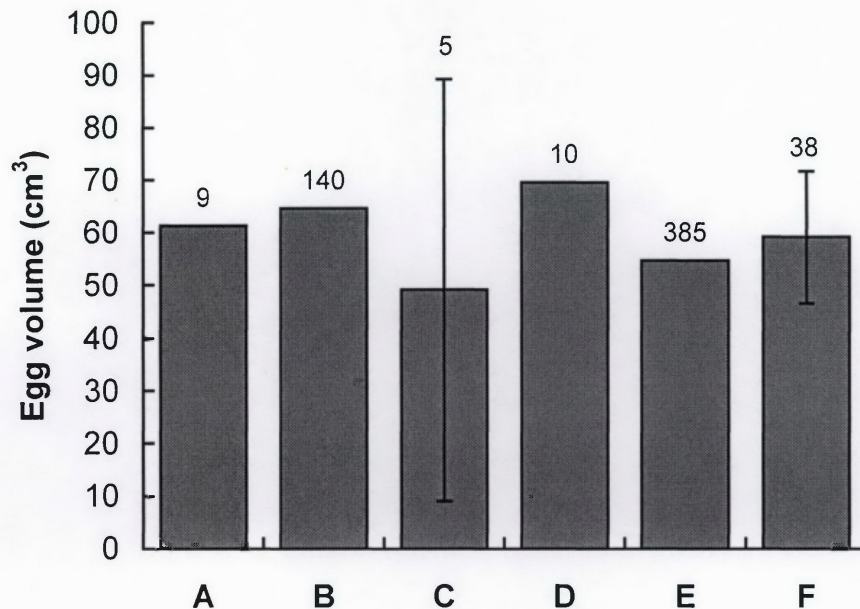
Figure 4.2: Comparison of egg volumes of houbara (*C. [undulata] macqueenii*) eggs from seven sites. A = Russia (Dement'ev and Gladkov 1951), B = India/Pakistan (Ali and Ripley 1980), C = Uzbekistan (Launay *et al.,* 1997), D = captive Israel (Mendelssohn 1980), E = captive Saudi Arabia (Biquand *et al.,* 1992), F = this study. Numbers above bars are sample size. ± 95 % C.I. are given where data were available).

Incubation period

Incubation period was determined for five clutches which were found during the egg laying period and then seen hatching in the nest. Incubation was assumed to start following the laying of the second egg (pers. obs.). Mean incubation period was 22.6 days, S.D. = 1.14 days, range = 21 – 24 days). Six other nests had known hatch but not lay dates, and therefore estimated laying dates could be determined. With one exception, I found all of these nests within 2 – 5 days of laying, indicating that my techniques for determining incubation behaviour and in locating nests were effective. The exception was one female that began incubation before monitoring could begin in 1998. Incubation period was not determined for other nests because nests failed before hatching, or because eggs were artificially incubated.

Fledging period

Fledging period was not determined precisely for any of the 15 chicks known to have reached flying age, because behaviourally, chicks would run or hide rather than fly. Of 10 chicks closely monitored, one chick first managed sustained flight aged 25 days, and eight chicks were able to fly for 100 + m by age 30 days, if chased. Nine of these 10 chicks flew well at age 35 days, but the tenth chick never chose to fly. Running is a normal escape response for this species, and in frequent encounters with these chicks when they were older, and with adults, they rarely flew. Therefore, given that I could confirm flight for 80 % of chicks by age 30 days, I consider that 30 days is a realistic estimate of the fledging period in this study.

Chick weights

In 1997, five chicks were each weighed once, and in 1998, 14 chicks were weighed a total of 20 times. Chicks ranged in age from one day to 30 days of age (Fig. 4.3, Fig. 4.4). All three chicks aged 30 days were able to fly for distances of more than 100 m, and were considered to have fledged. Chick weights ranged from 39 to 409 g, and weight was linearly correlated with chick age (Pearson's Product-Moment correlation, r^2 = 0.966, P < 0.0001, N = 19 weights from 19 chicks, extra weights from four chicks randomly chosen and excluded). On average chicks increased in weight by 12.8 g per day. When unknown, chick age in Mahazat as-Sayd Reserve can be estimated from chick weight using the following equation: Chick age = (Weight − 24.75)/11.96.
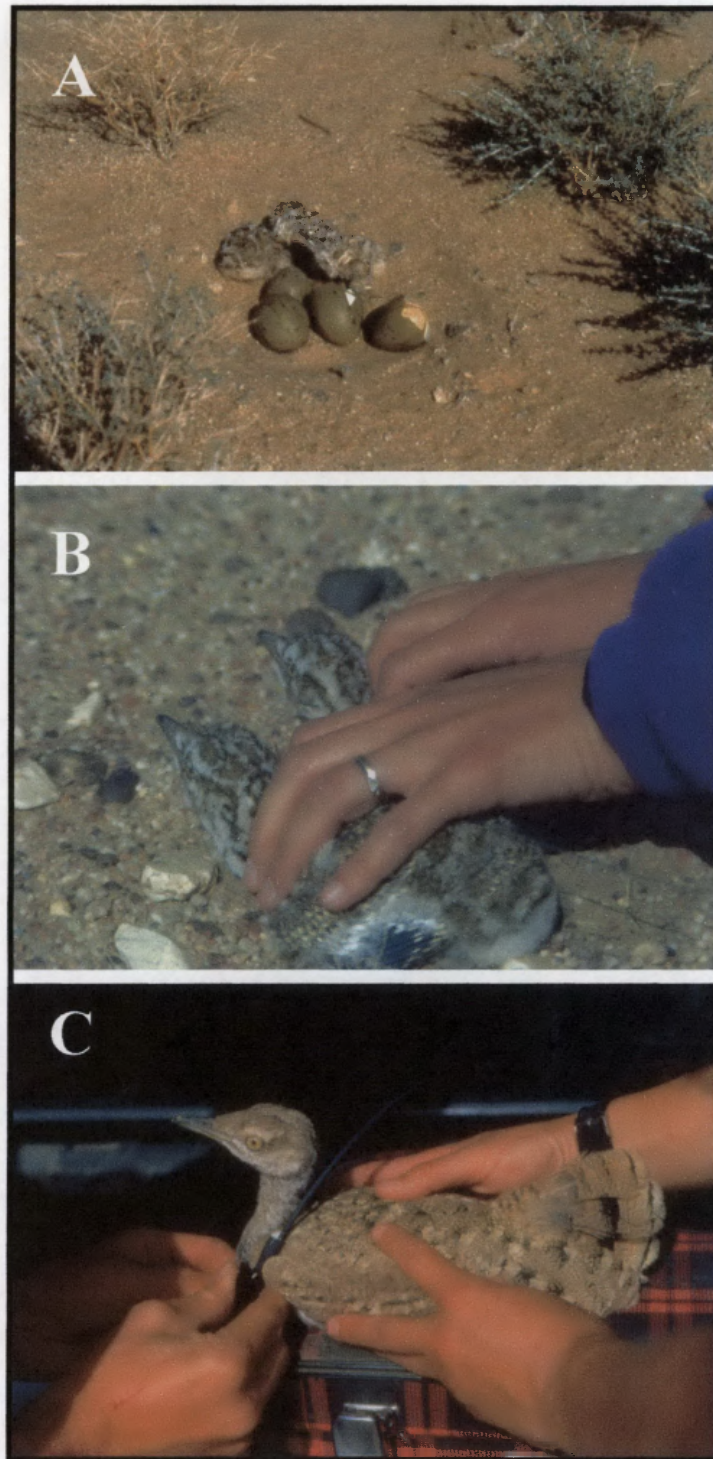
Figure 4.3: Houbara chicks at three different ages: (A) < 1 day, (B) 10 days, and (C) 30 days.
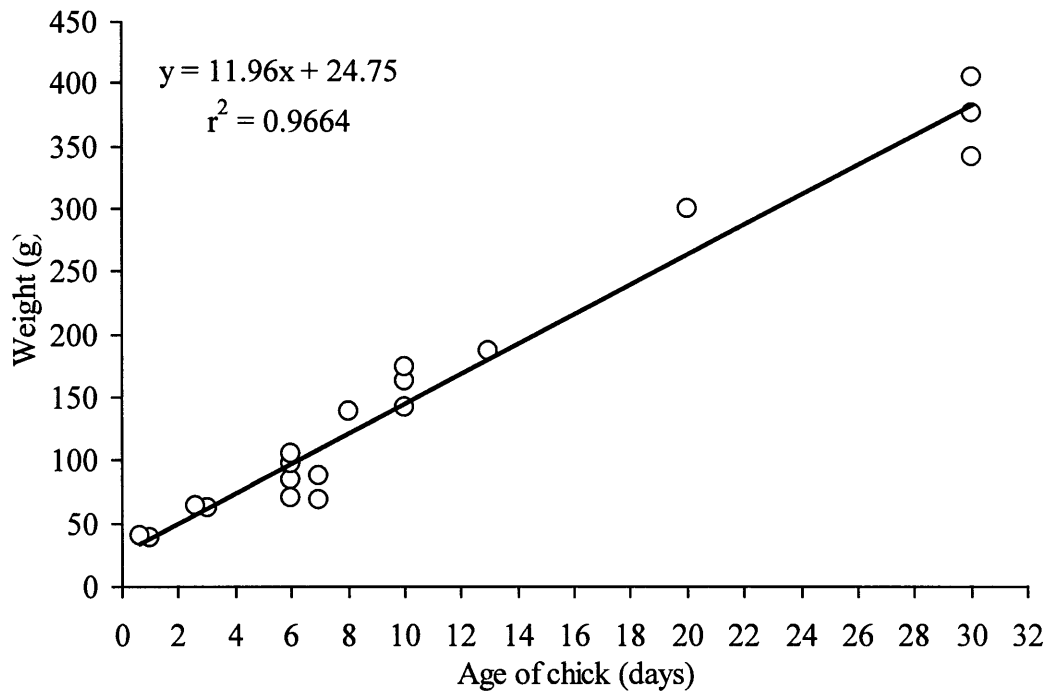
$$y = 11.96x + 24.75$$
$$r^2 = 0.9664$$

Figure 4.4: Comparison of weights for 19 houbara chicks of known age caught in Mahazat as-Sayd Reserve in 1997 and 1998. Four chicks were weighed two or more times, but extra weights are not independent and randomly chosen extra weights are excluded.

Nest fate

Exchanging real eggs for dummy eggs may have affected nest predation rates. In 1997, of 23 breeding attempts, I exchanged eggs in 13 nests, and left 10 nests undisturbed. One (10 %) "wild nest" hatched, whereas eight (62 %) "managed nests" survived the full incubation term and were given hatching eggs. Because sample sizes were small, this difference was not statistically significant (Fishers Exact Test). However, given that managed nests appeared to be less susceptible to predation, I excluded them from data on incubation parameters.

Of 31 wild nests found with eggs, 11 (36 %) hatched, and 20 (64 %) failed (Table 4.4). Cause of failure was attributed to predation (nest definitely not hatched, and eggs missing from the nest, and with or without shell remains or predator tracks around the nest site) for 16 (52 %) nests. Three nests (10 %) had infertile clutches, and minimum fertility rates were similar between years (33-55 %) and female age cohorts (23-48 %). The cause of loss of one nest could not be determined (Table 4.4, Table 4.5). None of four nests hatched in 1996, but

10 % of 10 nests hatched in 1997, and 59 % of 17 nests hatched in 1998. The Mayfield method calculation for daily survival probability for successful nests was 0.925 (T=308, Y=21, K=44), and for unsuccessful nests was 0.917 (T=251.5), where T = total number of nest-days observed, Y = the number of successful nests, and K = the total number of nests left in the wild plus the number of managed nests that had real eggs for some period of time (Aebischer 1999).

Table 4.4: Fate of wild nests laid in Mahazat as-Sayd Reserve from 1996 to 1998.

Fate of wild nests	1996	1997	1998	Total
Number of wild nests failed – predation	3	9	4	16
Number of wild nests failed – all eggs infertile	1	0	2	3
Number of wild nests failed – unknown cause	0	0	1	1
Number of wild nests that hatched one or more eggs	0	1	10	11
% of wild nests where one or more chicks successfully hatched	0	10 %	59 %	36 %

A total of 55 chicks hatched and 15 (27 %) of these fledged. Eleven of 14 females that hatched chicks went on to fledge at least one chick, including the female that never laid eggs. Only one female in the reserve never hatched chicks. Older females hatched most chicks (95 % of 55 chicks hatched), whereas two-year old females hatched on three chicks, and no chicks hatched from the one breeding attempt by a one-year-old female (Table 4.6). Annually, females were very productive and each breeding female hatched a mean of 1.56 chicks per annum over the three-year period. (Table 4.7a). Similarly, while the probability of an individual chick fledging once hatched was variable (0.14 in 1997, 0.35 in 1998, 0.27 overall), the fledging success rate per female per year was high. Over the three years, a mean of 0.47 fledglings were produced for every breeding female. In total, 15 chicks were fledged. Overall, yearly breeding success, defined as the product of egg, chick and fledging survival, varied from 0 – 16 %. Compared to 1998, breeding success was lower in 1996 because hatching success was low (0), and lower in 1997 because both hatching and fledging success were lower (Table 4.7a). Comparison of productivity values with female age revealed few age-related patterns (Table 4.7b). Although older females (4-5 yrs old) had higher hatching

success, the fledging success and overall breeding success by age cohort was highest for two-year-olds compared with older females. Overall, 8.3 % of eggs laid survived to become fledged chicks.

Table 4.5: Fertility of eggs in all nests laid in Mahazat as-Sayd Reserve: A) each year from 1996 to 1998; B) for each female cohort. Letter codes are used in calculations in Table 4.7.

A) *Fertility of eggs*	1996	1997	1998	All yrs
Number of eggs laid in all nests (C)	6	58	56	120
Number of unknown fertility eggs from all nests	5	39	12	56
Number of infertile eggs from all nests (D)	1	0	13	14
Number of fertile eggs from all nests	0	19	31	50
% fertile eggs from all eggs (minimum fertility rate)	0	33 %	55 %	42 %
% fertile eggs including eggs with unknown fertility (maximum fertility rate)	0	100 %	77 %	88 %

B)	Female age (years)					
Fertility of eggs	1	2	3	4	5	All ages
Number of eggs laid in all nests (P)	3	13	39	46	19	120
Number of unknown fertility eggs from all nests	3	10	20	21	2	56
Number of infertile eggs from all nests (Q)	0	0	2	3	9	14
Number of fertile eggs from all nests	0	3	17	22	8	50
% fertile eggs from all eggs (minimum fertility rate)	0	23	44	48	42	42
% fertile eggs including eggs with unknown fertility (maximum fertility rate)	0	100	95	94	53	88

Table 4.6: Number of nests that hatched chicks, number of females that were found with chicks, and the fledging rate of those nests for: A) each year from 1996 to 1998; B) each female cohort. Letter codes are used in calculations in Table 4.7.

A) *Fate of chicks*	1996	1997	1998	All yrs
Number of females that attempted to breed (E)	4	12	13	15
Number of managed nests given hatching chicks	0	8	5	13
Number of wild nests that hatched naturally (F)	0	1	10	11
Number of females found with chicks (G)	0	0	2	2
Total number of nests that hatched chicks (H)	0	9	17	26
Total number of chicks hatched (I)	**0**	**21**	**34***	**55**
Total number of chicks fledged (≥ 30 days) (J)	**0**	**3**	**12**	**15**
Number of chicks that failed to fledge	0	18	22*	40
Number of females that hatched chicks	0	9	13	14
Number of females that fledged one or more chicks	0	2	10	11

* two females found with a total of three chicks may have laid 3 – 5 more eggs between them, and therefore these values are a minimum

B) *Fate of chicks*	Female age (years)					
	1	2	3	4	5	All ages
Number of females that attempted to breed (R)	1	3	10	10	5	15
Number of managed nests given hatching chicks	0	0	4	4	5	13
Number of wild nests that hatched naturally (S)	0	1	2	5	3	11
Number of females found with chicks (T)	0	1	0	0	1	2
Total number of nests that hatched chicks (U)	0	2	6	9	9	26
Total number of chicks hatched (V)	**0**	**3**	**15**	**21**	**16**	**55**
Total number of chicks fledged (≥ 30 days) (W)	**0**	**2**	**3**	**6**	**4**	**15**
Number of chicks that failed to fledge	0	1	12	15	12	40
Number of females that hatched chicks	0	2	6	9	5	14
Number of females that fledged one or more chicks	0	2	3	3	4	11

Table 4.7: Egg, hatching and fledging success rates and overall productivity for females in Mahazat as-Sayd Reserve: A) by year, from 1996 to 1998; B) by female age. Letter codes from Tables 4.2, 4.5, and 4.6.

A) Measures of productivity	1996	1997	1998	All years
K. Egg success rate[1] ((C-D)/C)	0.83	1.00	0.77	0.88
L. Hatching success[2] (F/B)	0	0.10	0.59	0.35
M. Fledging success[3] (J/I)	0	0.14	0.35	0.27
Breeding success[4] (K*L*M)	**0**	**0.014**	**0.159**	**0.083**
Female nesting success[5] (A/E)	1.0	1.92	1.85	1.68
Female hatching success[6] (I/E)	0	1.75	2.62	1.56
Female fledging success[7] (J/E)	0	0.25	0.92	0.47

B) Measures of productivity	Female age (years)					
	1	2	3	4	5	All ages
X. Egg success rate[1] ((P-Q)/P)	1.0	1.0	0.95	0.94	0.53	0.88
Y. Hatching success[2] (S/O)	0	0.25	0.18	0.45	0.75	0.35
Z. Fledging success[3] (W/V)	0	0.67	0.20	0.29	0.25	0.27
Breeding success[4] (X*Y*Z)	**0**	**0.17**	**0.03**	**0.12**	**0.10**	**0.083**
Female nesting success[5] (N/R)	1.0	2.0	1.6	1.8	2.0	1.68
Female hatching success[6] (V/R)	0	1.0	1.5	2.1	3.2	1.56
Female fledging success[7] (W/R)	0	0.67	0.30	0.60	0.80	0.47

[1] *Probability of an egg hatching in a nest if it survives (number of fertile eggs / total number of eggs laid). All preyed upon eggs considered fertile, and egg success rate is therefore a maximum value.*

[2] *Probability of one or more eggs in a nest surviving until they hatch (number wild nests that hatched one or more eggs/total number of wild nests). Nests are used here because eggs in the nest are not independent.*

[3] *Probability of a chick fledging once it hatches (number of chicks fledged from all nests/total number of chicks hatched from all nests).*

[4] *Probability that an egg will successfully survive, hatch and fledge*

[5] *Number of nests per breeding female*

[6] *Number of chicks hatched per breeding female*

[7] *Number of fledged chicks produced per breeding female*

Causes of chick and fledgling mortality

I was able to determine causes of loss of chicks and fledglings on only two occasions. One chick was seen being taken by a Hen Harrier (*Circus cyaneus*) in 1997, and tracks in the

sand indicated that a cat stalked and caught a fledgling. Transmitter attachment to chicks in 1997 did not provide evidence for chick loss, all transmitters fell off living chicks. Transmitters attached to fledged chicks were more useful, and remains of three fledglings were found. However, apart from the fledgling taken by a cat described above, the causes of death of the other two fledglings were inconclusive: both fledglings were preyed-upon or scavenged by predators. All chicks that disappeared were assumed to have died because they are unlikely to have left their mothers, whereas fledglings that disappeared may have dispersed or died.

Double brooding attempts

There were two instances of double brooding, where a clutch was raised to fledging, then the female nested for a second time, by two females. In the first, female (tx 5240) began incubation of a clutch of four eggs on 3 February 1998. Four chicks hatched and one chick successfully fledged on or before 3 April. This fledgling was still with the female on 20 April, 52 days after hatching, when its transmitter failed, and visual contact was lost. The female was subsequently found with two young chicks (< 10 days old), and probably began incubation on or about 27 April, seven days after the last sighting of the fledgling, and hatched about 18 May. One chick from this second attempt survived until age 22 days but probably did not fledge. The second female (tx 5590) laid three eggs on 15 February 1998, hatched two eggs on 8 March and fledged one chick, that was located by transmitter signal until 16 May (aged 69 days) when its transmitter failed. This female was later found incubating one egg on 24 May, eight days after the fledgling was last observed. The egg from the second clutch was deserted by the female and when examined was considered infertile.

Nesting attempts and success related to female experience

Except for fledging rates and dates of clutch initiation, females with no prior breeding experience had lower rates of all breeding parameters than did females with 1 – 3 years prior experience (Table 4.8, Table 4.9): fewer inexperienced females attempted to breed, and those that did had fewer nests. Specifically, only 33 % of 33 females without prior breeding experience bred, whereas 11 of 12 females with one year of prior experience and all females with two or three years experience, attempted to breed. Inexperienced females had significantly fewer nests ($\bar{x}$ = 1.3 attempts per female) than did females with 1 – 2 years

experience (1.8 – 2.5 attempts, χ^2 = 11.2, D.F. = 2, P = 0.004). Hatching success also appeared to improve with experience: twice as many females with two years prior experience successfully hatched nests (43 %) compared to females with no prior experience (22 %). However, fledging success was not dependent on prior breeding experience of the female: only 18 % of nesting attempts by females with no experience fledged one or more chicks, similar to rates for females with one (14 %) and two years (0 %) prior experience. Nor did females with prior breeding experience fledge a greater number of chicks (20 % of 30 chicks that hatched) than inexperienced females (25 % of 16 chicks; wild nests only, Fishers Exact test, P = 0.72).

Table 4.8: Breeding parameters of female houbara in Mahazat as-Sayd Reserve from 1996 to 1998, based on prior breeding experience of the female. Females were considered to have had prior experience if they were found with a nest or chicks in any previous year, including three females who bred in 1995.

Prior breeding experience of females	0 yr	1 yr	2 yr	3 yr
Number of females per category	33	12	4	1
Number females found with egg nests	11	11	4	1*
Number females found with chicks	1	0	0	1*
Total number of egg nests found	15	20	10	1
Total number of eggs laid	36	54	26	4
Mean clutch size	2.4	2.7	2.6	4.0
(± 95 % C.I.)	0.46	0.25	0.32	-
Clutch size range	1 – 4	2 – 4	2 – 3	4
Mean number of breeding attempts per female	1.25	1.81	2.50	2.00
Mean number of nests per female	0.33	0.92	1.00	1.00
Proportion of females that nested more than once per season	0.27	0.64	0.75	0
Hatching rate: proportion of females with wild nests that successfully hatched one or more chicks	0.22	0.36	0.43	1.00
Fledging rate: proportion of all nesting attempts that successfully fledged one or more chicks	0.18	0.14	0	0.50
Proportion of all females that successfully fledged one or more chicks	0.23	0.25	0	1.00

* the same female

There was little difference between experienced and inexperienced females in either the initiation date of first clutches, or the latest date that a female had a first clutch in each year (Table 4.9). Overall, clutches in 1996 were laid much later than clutches in 1997 and 1998: the latest date of a first clutch was 4 March in 1997 and 16 February in 1998, whereas the earliest first clutch in 1996 was not found until 8 April (Table 4.9). Mean lay dates for first clutches were 16 April in 1996, 21 February in 1997 and 7 February in 1998. There was a difference of 68 days between mean first clutch lay dates in 1996 compared to 1998. Fewer females in 1996 (25 %) had prior experience than in 1997 (39 %) or 1998 (85 %, Table 4.10).

Table 4.9: Timing of laying of first clutches in each year for females with no prior breeding experience, compared to those with 1 – 3 years prior experience. Lay date was unknown for many nests, but when known was 2 –5 days prior to date found (see text for further details).

		Years of prior breeding experience			
Year		0	1	2	3
1996	Earliest date nest found	10 April	8 April	-	-
	Latest date nest found	25 April	15 April	-	-
1997	Earliest date nest found	17 February	12 February	12 February	-
	Latest date nest found	4 March	3 March	13 February	-
1998	Earliest date nest found	15 February	3 February	21 January	3 February*
	Latest date nest found	15 February	16 February	5 February	

* = only one female and therefore date nest found is the earliest and latest in that category.

Table 4.10: Number of years of prior breeding experience of females in each year from 1996 to 1998. Note that the number of females varies between years, as new females enter the breeding population and as some females die.

Prior breeding experience of females	1996	1997	1998	All yrs
Total number of females	15	20	32	35
Breeding females with no prior experience	3	8	2	13
Breeding females with 1 year prior experience	1	3	7	12
Breeding females with 2 years prior experience	0	2	3	4
Breeding females with 3 years prior experience	0	0	1	1
Number of individual female breeding attempts	4	13	13	30
% breeding females with $\geq$ 1 years experience	25 %	39 %	85 %	57 %

Table 4.11: Mean monthly temperature minima and maxima for each month and for two and three consecutive month combinations, over the three breeding seasons. November and December temperatures are those in the year preceding each breeding season. N = November, D= December, J = January, F = February, M = March. Significant Spearman Rank Correlation coefficients (= 1.0 or −1.0) where in: **bold** = proportion of females that bred; and where in underline = initiations of first clutch.

Month combination	Mean monthly minimum (°C)			Mean monthly maximum (°C)		
	1995/96	1996/97	1997/98	1995/96	1996/97	1997/98
N	13.0	12.6	16.1	**29.4**	**26.3**	**27.1**
D	12.8	12.1	13.3	23.5	26.0	25.8
J	11.0	9.8	9.3	23.6	23.5	20.2
F	**12.7**	**11.2**	**11.6**	**27.6**	**25.5**	**26.3**
M	14.9	12.7	15.0	30.3	29.2	28.3
ND	12.9	12.4	14.7	26.5	26.2	26.5
DJ	**11.9**	**11.0**	**11.3**	23.6	24.8	23.0
JF	11.9	10.5	10.5	25.6	24.5	23.3
FM	**13.8**	**12.0**	**13.3**	29.0	27.4	27.3
NDJ	12.3	11.5	12.9	25.5	25.3	24.4
DJF	**12.2**	**11.0**	**11.4**	24.9	25.0	24.1
JFM	**12.9**	**11.2**	**12.0**	27.2	26.1	24.9

Differences in onset of laying and in the proportion of females breeding were significantly related to ambient temperatures. Proportionately fewer females bred when mean monthly minimum temperatures were high: in February, and in most combinations of December, January, February, and March temperatures. For comparisons of maximum mean monthly temperatures, fewer females bred when maximum temperatures were high in November and February (Spearman Rank Correlations, Table 4.11). The onset of laying of first clutches was delayed when mean monthly minimum temperatures in January were high, and when maximum temperatures in January and March (and mainly combinations of December, January, February, and March) were high. Correlations of temperature with date of latest laying of clutches was not determined, because all females had only one clutch each in 1996.

Discussion

Nesting attempts

It was encouraging to find many females attempting to breed. Houbara in Mahazat as-Sayd Reserve have been captive-reared and released, and that females are regularly nesting augurs well for future goals of establishing a self-sustaining population based on captive-reared stock. Houbara eggs laid in the reserve were similar in size to those laid by houbara from their founder population in captivity, and were about in the middle of the means for measurements of eggs from across the range of all Asiatic houbara bustards. Eggs from Mahazat as-Sayd Reserve had considerably thicker shells than those of captive eggs from the founder population (S. Hemon pers. comm.). Eggs might be expected to be smaller if conditions in Mahazat were unsuitable for houbara breeding, e.g., if food supplies were limiting. This was not the case, and these results are further evidence that houbara can be successfully captive-reared and released to establish new populations. Similarly, evidence from growth rates of chicks suggests that the habitat in the reserve is of high quality for houbara. Growth rates were fast, and although growth rates of chicks from other populations are unknown, fledgling age has generally been considered to be about 35 days (del Hoyo *et al.*, 1996). In Mahazat as-Sayd Reserve, some chicks were flying well by 30 days of age, and one flew at 25 days. Growth curves for other chicks showed that most obtained similarly high and sustained levels of growth.

Nest losses were high, and with eggs from over half of all nests preyed upon, predation of eggs and chicks may ultimately limit the success of this reintroduction. Predation rates of houbara nests were different between years, with a much greater rate of nest predation in 1997 than in 1998. There are several explanations for this difference. Differential predation may be because of differences in relative densities or impacts of many different predator species, or because of a decline in numbers of one species, red foxes (*Vulpes vulpes*), following a rabies outbreak in late 1997 (NWRC unpubl. data). Alternatively, higher nest survival in 1998 may be because of increasing experience of female houbara, either in their ability to defend their nests from predators, by locating nests in sites that reduced the probability of predator encounters (Chapter 5), or by being better at being cryptic around their nests. Certainly, females in this study who had some prior breeding experience had

greater hatching success than did inexperienced females. It is likely that a combination of all of the above factors may be important in determining differences in nest losses among years.

Potential predator species are numerous (Gélinaud *et al.*, 1997, Combreau & Smith 1998), but direct evidence of which predators are responsible for taking houbara eggs is scarce (e.g., Launay *et al.*, 1997). In Mahazat as-Sayd Reserve, I was able to video foxes (*Vulpes* spp) removing all the eggs from two nests, and tracks of foxes and cats were found at preyed upon nests. Foxes (red fox *V. vulpes* and Rueppell's fox *V. rueppelli*), brown-necked ravens (*Corvus ruficollis*), wild cats (*Felis catus*), and monitor lizards (*Varanus griseus*) are common potential predators within the reserve. Of five videoed nests (unpubl. data), four failed at night, implicating nocturnal, rather than diurnal predators in houbara nest predation. A long-term night and day infra-red video or predator exclusion study is required to provide evidence of differential rates of predation on houbara nests. Such long-term video studies have been attempted on other ground nesting birds, and have shown that several years of data, and many nest predation events, are needed to determine the relative importance of various predator species (Sanders & Maloney 2002).

Few other studies have quantified nest survival results in houbara, and none have followed known-age individually identifiable females over several breeding seasons. Lavee (1985) found 16 nests and followed 10 continuously in Israel in 1984. She reports a hatching rate for 26 eggs as 0.35, and a rate of loss of chicks before age 2 – 3 months of 0.66, with a combined probability of an egg reaching adulthood of 0.1. The value for hatching success reported by Lavee (1985) was the same as that recorded this study (0.35). Overall Lavee (1985) reports a 10 % recruitment rate, even though she apparently had no method of marking and following young post-fledging for the one to two years before young houbara begin to breed. Following recruitment in this species is extremely difficult and would involve intensive radio-tracking. However, attaching radio-transmitters to chicks prior to flight is risky because the chicks are not fully grown, and there are no reliable methods of catching flying houbara (and see discussion below). Recruitment will be lower than this 10 % value in Mahazat as-Sayd Reserve, because over the three years breeding success was 8.3 %, and it is unlikely that every fledged chick will reach adult age. However, success may improve with experience, and many of the females in this population were known to be first time breeders. The only other study of nesting survival on houbara has been by Launay *et al.*,

(1997), who followed three chicks and monitored one of two nests found with eggs in Uzbekistan in 1994. All chicks survived seven days until transmitters fell off, and a monitor lizard preyed upon the nest.

There are other potential short-comings with breeding success measures reported for cryptic species such as houbara. Breeding success measures are strongly influenced by the detectability of nesting attempts, and in particular, the detection of failed attempts. In Mahazat as-Sayd Reserve, some females were not found until they had chicks, indicating that others may have failed without being detected. This would result in an over-estimation of hatching success. In this study few nests were undetected because all females had radio-transmitters, but in other studies of wild, unmarked populations, failure to detect significant numbers of failed nesting attempts could lead to breeding success being reported at unrealistically high levels.

For two reasons, I consider that predation of nests is not a critical factor in determining the future survival of the houbara population in this reserve. First, houbara appear well adapted to cope with nest losses, and are able to replace clutches following the loss of both eggs and chicks, and following the successful fledging of young. This means that in most years females are maximising their chances of successfully hatching at least one brood of chicks. Second, in some years, such as in 1998, predation rates were low, and breeding success was correspondingly high. At the same time, because adult female mortality is low (5.3 % per annum), then very few young need be recruited to offset mortality rates. Therefore, not all females need to produce young in every year, and bad years with high nest predation will have little impact, if interspersed with the occasional good year when many chicks hatch and recruitment is high. Rather, key limiting factors for population growth and tenacity are likely to be the failure of most females to raise chicks to fledgling age, and failure of fledglings to be recruited into the breeding population. Success may be further limited by density dependent factors as the population increases, or by an increase in predation rates. Further study of this population is required to determine the frequency of such good and bad years, and the recruitment rates of fledglings, before population survival and expansion rates can be accurately predicted.

I was unable to quantify survival rates of fledglings, and recruitment rates in this study. While the fate of some fledglings with radio-transmitters was known, because they died within two to three months of fledging (i.e., within the lifespan of the radio-transmitter battery), most other fledglings were unable to be followed once they stopped closely associating with female parents. Two instances of predation on chicks and fledglings (by a cat and hen harrier) were recorded, but the importance of these observations in determining the impact of predators in general and of these predator species in particular, is unknown. Cats are common throughout the reserve, but foxes are more numerous (Olfermann 1996, Lenain 1997), and although hen harriers have been recorded in the reserve as passage migrants they are less commonly recorded compared with other similar sized raptors, such as marsh (*Circus aeruginosus*), pallid (*C. macrourus*) and Montague's (*C. pygargus*) harriers (Newton & Newton 1997). If predation rates of chicks and fledglings are linked to predator abundance then further study should detect a greater number of predation events by other species. Further close monitoring would require the development of radio-transmitters that can be attached to chicks before fledging, that remain functional for several years, and that do not impinge on the growth of young birds. Alternatively, observers could replace small temporary transmitters on young birds with larger permanent solar transmitters as birds reach adult-size (aged two months or more). None of the current methods for capturing houbara (Launay *et al.*, 1999, Seddon *et al.*, 1999) guarantees reliable and safe capture of free-living juvenile birds. Thus, direct evidence of causes of chick and fledgling mortality will remain difficult to obtain.

Timing of nesting

In Mahazat as-Sayd Reserve the breeding season extended for more than six months. First eggs were laid in late January, and last eggs four months later, at the end of May, with extrapolated fledging rates extending the breeding season into mid-July. Initiation of nesting was markedly later in 1996 than in later years. There are several overlapping hypotheses that may explain the annual differences in onset and intensity of breeding that I observed in this study. First, seasonal differences in climate (temperature, rainfall) may influence breeding behaviour either directly, via hormonal changes, or indirectly, through variation in food availability. There is direct evidence that laying activity of captive birds is synchronised with seasonal variation in luteninizing hormone and progesterone, and is mutually exclusive of moulting periods (Saint Jalme *et al.*, 1996c). These authors suggest that houbara breeding

activity stops when maximum ambient temperatures reach 32 °C, and that rainfall stimulates gonadal activity (but does not necessarily induce laying). Certainly, in spring 1996, the mean monthly ambient temperatures in the reserve were 1.5 – 1.7 °C higher than in 1997 and 1998, and this was a key climatic difference between the three years. Few females nested in that year and those that did delayed initiation of nests until April, perhaps indicating that conditions had not been suitable earlier in the season. However, the 32 °C threshold temperature suggested by Saint Jalme *et al.,* (1996c) was exceeded in March, April, May in the reserve in each year from 1996 to 1998, and in 1998 reached this level by February (Appendix 1). In addition, by May in each year, the mean monthly maximum temperature was 39 – 40 °C, well above the threshold temperature considered limiting by Saint Jalme *et al.,* (1996c). Therefore, while differences in relative temperature may be important here in explaining when houbara breed, evidence that there is a standard temperature threshold that pre-determines breeding activity was not supported in this study.

Second, nest initiation and breeding intensity may be related to rainfall (e.g., in zebra finches *Taenopygia guttata* in Australia, Zann *et al.,* 1995). Despite the markedly different breeding seasons, I could find no clear relationship between the onset and intensity of breeding of houbara in Mahazat as-Sayd Reserve and winter or spring rainfall. Similarly, van Heezik *et al.,* (2002) found that for a flock of captive houbara held at the NWRC, Taif, 220 km south west of the reserve, the occurrence of rainfall was not positively correlated with the production of eggs: significant rainfall actually led these captive females to stop laying eggs within two weeks. Certainly, rainfall did not immediately stimulate breeding in Mahazat as-Sayd Reserve, but whether a similar stopping effect occurs in Mahazat as-Sayd Reserve following rain is unknown, because in the wild females were left to raise chicks, and the drop in nest numbers in April and May in 1997 and 1998 is a result of the numbers of females with chicks at that time, and not to the rain event in March (see Fig. 4.1).

Third, late onset of nesting by females in 1996 may be because females were recently introduced into the reserve, and had no prior breeding experience. However, in captivity, at the NWRC van Heezik *et al.,* (2002) found that fewer young females nested, but those that did started and finished at the same time as experienced breeders, although experienced breeders laid more eggs in a season. In the reserve, I found that fewer young birds bred than older birds, indicating that after gaining some experience, houbara then become regular

breeders. Inexperienced breeders had similar clutch sizes and had similar success in fledging young as did experienced females. In all years, experienced and inexperienced females bred at the same time, and further, breeding in 1997 and 1998 was two months earlier than in 1996, by both inexperienced and experienced females. This indicates that factors other than female experience are important in determining the onset of laying.

From this, I suggest that higher than normal temperatures in 1996, rather than rainfall or prior breeding experience, best fitted the pattern of breeding reported here. Fewer females bred when monthly minimum temperatures were high from December to March, and when monthly mean maxima were high in November and February. In addition, the onset of laying was delayed when minima were high in January, and when maxima were high from December to March. This is similar to results from captive houbara housed at the NWRC (van Heezik *et al.*, 2002). These captive birds laid more eggs and bred earlier when the winter prior to the breeding season was cooler (mainly November, December), and stopped laying following significant rainfall. However, while egg laying began in February in both the captive and wild populations, November temperatures were rarely correlated with either the proportion of females breeding, or the onset of laying in the wild. Instead, houbara appeared to respond to proximate temperature cues, and did not breed during February and March 1996, because it was unusually warm during that period. I suggest that houbara females are regular spring breeders, with onset of breeding determined by photoperiod and perhaps body weight cues, tempered during periods of high mean ambient temperatures in spring.

Nesting attempts and success related to female age

During this study, a single one-year-old female and only 20 % of two-year-old females attempted to nest in Mahazat as-Sayd Reserve, almost all females that were three years and older attempted to breed. No females in this population were older than five years, and I could not determine reproductive senescence of older females. One-year-old female houbara are capable of laying and hatching eggs. Although the nest of the one-year-old female in this study was preyed upon, a one-year-old female has previously successfully hatched fertile eggs in Mahazat as-Sayd Reserve in 1995 (Gélinaud *et al.*, 1997). In general, the proportion of young females that attempted to breed in this study is close to that reported for a much larger number of females held in captivity at NWRC in Taif, Saudi Arabia (Saint Jalme *et*

al., 1994, van Heezik *et al.,* 2002). These authors found that no one-year-old captive females, 25 % of two-year-olds, 65 % of three-year-olds, and 85 % of those aged four years bred. These differences in breeding attempts relative to female age may partially explain why few females nested in 1996: there were three one-year-olds, six two-year-olds, five three-year-olds and only one four-year-old in the population in that year, and thus the majority of the population were young.

Age-related differences in breeding parameters have been reported for other birds. In American goldfinches (*Carduelis tristis*), older females nested earlier, had larger clutches and higher breeding success than did young females (Middleton 1979). Potentially then, the biological implications of the role that female age and experience plays in determining recruitment rates are important, especially in the context of a reintroduction project. Small differences in successful breeding due to age differences, such as in hatching success, can have major effects on recruitment rates and potentially population viability. Having a better understanding of differential breeding abilities of different age classes of females will help refine population models, and will allow greater accuracy in predictions of time to successful establishment of reintroduced populations.

Comparison of clutch measurements, hatching and fledging rates

Few data on egg sizes, hatching and fledging rates based on large sample sizes are available from other parts of the range of houbara. Where comparable data exist (Table 4.12), houbara from Mahazat as-Sayd Reserve have similar breeding parameters to those in other populations in Russia, Uzbekistan, India and Pakistan, to those of captive birds from Saudi Arabia and Israel, and for wild *Chlamydotis u. undulata* from Morocco (see Table 4.12 for references). In addition, houbara in Mahazat as-Sayd Reserve apparently exhibit the normal range of cryptic behaviours, diet, habitat use and movements as described for wild birds throughout their range (e.g., Mian 1989, Gubin 1992, Seddon & van Heezik 1996, Combreau & Smith 1998), and I conclude that breeding parameters for the reintroduced Mahazat as-Sayd Reserve population are similar to that of other wild houbara populations.

One difference between my data and those reported in Table 4.12 is in hatching dates. I recorded a hatching date for one nest in Mahazat as-Sayd Reserve in February, making it one of the earliest recorded in the wild. Because houbara in the reserve nest into May, the

breeding season of this population is apparently longer than in most other sites. February nesting has also been reported in Oman (Gallagher & Woodcock 1980), and I suggest that early nesting may be a feature of non-migratory populations found at lower latitudes. Although del Hoyo *et al.,* (1996) reported that nesting began in November, I have been unable to find source publications for nesting dates in either November or December in the literature to confirm this. More recent unpublished data (IFCDW annual report, Vol. 2, 1998 – 1999, B. Dawson *in litt.*) indicates that two chicks of *C. u. undulata* found in Morocco would have hatched from eggs laid in September, well outside a spring breeding period.

Many breeding parameters for houbara have not previously been recorded in detail, or from sufficient birds to allow general trends to be noted. For example, data on fledging age of chicks have rarely been reported, yet 35 days is considered the age at which houbara chicks fledge. Because chicks are rarely seen, and more frequently run and hide than fly, true fledging dates are difficult to determine. I found that some chicks in Mahazat as-Sayd Reserve were flying at age 25 days, and consider that most chicks were capable fliers and had fledged by 30 days. Similarly, I have found that houbara in Mahazat as-Sayd Reserve frequently lay replacement clutches when earlier clutches of eggs, or chicks are lost. I recorded double brooding on two occasions, but it was unclear whether double brooding occurred because females lost their first clutch juveniles, or whether those juveniles dispersed. The age of independence of juveniles is unknown. Successful fledging of young from two successive clutches was not recorded, but one chick from a second clutch was last seen at age 22 days, indicating that houbara should have no difficulty in successfully raising two broods to fledging age within a season.

In conclusion, houbara have been successfully reintroduced, and are now breeding, in Mahazat as-Sayd Reserve. I was able to follow and monitor the fates of nests and chicks from nearly all breeding attempts within the population, and have quantified nest success, replacement clutch frequency, chick survival and double brooding rates. I was unable to examine recruitment rates of juveniles into the adult population because I could not follow flying young. Further research on houbara breeding should focus on determining juvenile survival and recruitment rates. Similar studies on other populations are needed to determine whether breeding parameters reported here are consistent for the species throughout its range.

Table 4.12: Comparison of other published studies with this study for various breeding parameters for *Chlamydotis [undulata] macqueenii* (C.u.m.) and *C. undulata undulata* (C.u.u.). Italicised text in the table is my interpretation of data.

Author	Location	Species	Clutch size	Incubation by	Timing of nesting	Incubation period	Egg size (mean length x width)	Hatch	Fledge:Time to fledge
Dharmakumarsinhji (1963)	India	C.u.m.	Range = 2 – 3, rarely 4	-	-	-	-	-	-
Dement'ev & Gladkov (1951)	Russia	C.u.m.	Normally 3, rarely 2, 4 reported	Nest in pairs, only female incubates, male not seen at nest	Early April, 10 April earliest to 22 May	-	58.6 x 45.3, N=9	May-June, late ones July	-
Gallagher & Woodcock (1980)	Oman	C.u.m.	Range = 1 – 4, usually 3	Female	From February in some years	-	-	-	-
Ali & Ripley (1980)	India & Pakistan, Baluchistan	C.u.m.	Range = 3 – 4	-	-	-	62.3 x 45.1, N=140	-	-
Meinertzhagen (1954)	Arabia	C.u.m.	Range = 2 – 3	-	-	-	-	Late March	-
del Hoyo *et al.*, (1996)	Across range	C.u.m., C.u.u.	Range = 2 – 3, up to 5	-	November to June, mostly March – April, depends where in range	24 days, up to 28 days	-	-	c. 35 days:?
Gaucher (1995)	Algeria	C.u.u.	1 of 1, 36 of 2, 19 of 3 *(therefore mean = 2.32, S.D. = 0.51)*	Female only	5 March – 23 April, plus 2 in May, hatching end of April	22-23 days	-	End April	-
Lavee (1985, 1988)	Israel	C.u.m.	Range = 1 – 4, mean = 2.7, S.D. = 0.8, N = 16	?	Beginning of March – end of April	-	-	29 March - 14 May	-
Gélinaud *et al.*, (1997)	Mahazat as-Sayd Reserve, Saudi Arabia	C.u.m	1 of 1e, 1 of 2e, 1 with 3c	-	April and May	-	-	*25 April – 1 May*	Flying at 38 days: Before 12 June
This study	Mahazat as-Sayd Reserve, Saudi Arabia	C.u.m	Mean = 2.61, 95 % C.I. = 0.21, N = 46, range =1 – 4, 3 of 1e, 15 of 2e, 25 of 3e, 3 of 4e	Female only	23 January – 24 May	Mean = 22.6, S.D. = 1.14, N = 5, range 21 – 24 days	61.3 x 43.4 ± 3.10 x 1.64, N = 38 from 10 females	13 February – 18 May	30 days, range = 25 – 35 days, N = 9: 17 March – 16 July, 121 days

5. Location of Asiatic houbara (*Chlamydotis [undulata] macqueenii*) nests in relation to vegetation and substrate characteristics

Abstract

Understanding nest site characteristics is of particular importance for conservation managers in determining the location of reserves, and for reintroduction practitioners in choosing release sites. Failure to include suitable nesting habitat may severely limit the success of reintroduction projects. For Asiatic houbara, nest sites have not been described in detail and little is known about nest site preferences or characteristics. I mapped the locations of 49 nesting attempts in Mahazat as-Sayd Reserve, from 1996 to 1998, to determine whether nest sites are distributed evenly by habitat type. For 22 of these nests in 1997, detailed descriptions of vegetation and substrate characteristics in a 2 – 3.1 ha area near to nests, in a 100 m quadrat surrounding the nest, and in a 2 m quadrat at the nest bowl, were made. These data were compared to mean values for vegetation and substrate cover, as determined at 98 step-point transects located throughout the reserve. Houbara nests were found more often in the south and north east of the reserve in areas of basalt and chert gravels, in the presence of patches of sand with *Acacia spp.* trees, and *Panicum turgidum* and *Ochthochloa compressa* grasses. No nests were located in areas of sabka (salt plains), or in areas of *Haloxylon salicornicum* (hammada). Vegetation cover at nest sites was 11.4 %, similar to overall cover (12.5 %) throughout the reserve. Nests were sited on edges of vegetation, 4 – 60 m from dense vegetation patches, and were surrounded by low-growing plants (mean height of 174 mm). Nest placement among vegetation was not related to prevailing wind conditions or sun angles. Plant species found near and at nest sites were in the same proportions as in the general reserve, except for *Zygophyllum simplex* and Hammada, which were not found at nest sites. The occurrence of houbara nests near to areas of *Acacia spp.* may be atypical for the species, reflecting a degree of mis-imprinting of captive-reared and released birds, or it may be a typical behaviour in the southern part of the species' range, where taller tree species occur. In general, houbara are adaptable in their nesting requirements, and show few preferences for particular vegetation types.

Introduction

Asiatic houbara (*Chlamydotis [undulata] macqueenii*) nest sites are rarely described in the literature, primarily because few nests are found by researchers (e.g., Launay *et al.,* 1997). Nests that have been described are commonly situated in sites that are flat or moderately undulating, have only sparse grass and herbaceous vegetation cover, and with low densities, or no tall woody shrub vegetation (e.g., Lavee 1988, Launay *et al.,* 1997). However, most desert regions in north and east Asia where houbara are presently found are dominated by flat or undulating relief, with scattered low vegetation, and without tall shrubs (Dement'ev & Gladkov 1951, Vaurie 1965, Alekseev 1980, Ali & Ripley 1980, Mirza 1985, Mian & Dasti 1985, Mian *et al.,* 1988). Therefore, these features may simply reflect general conditions of the range in which houbara currently nest, rather than true habitat preferences.

In Saudi Arabia, the recent breeding range of houbara has been restricted to the northern corner of the country, where a remnant, probably resident, population still resides in Harrat al-Harrah Reserve (Seddon & van Heezik 1996). Researchers in this reserve have recorded few nests, and few nest site data were collected (Symens 1988; P. Seddon pers. comm., NWRC unpubl. data). Much of the northern region is undulating basalt cobble hills, dissected with sandy wadis (watercourses) and silt depressions (van Heezik & Seddon 1999). Breeding was once more widespread throughout the country in eastern, northern and central regions (Seddon & van Heezik 1996 and references therein), and oral tradition records houbara nests on the Nadj pediplain, near Afif, in the vicinity of Mahazat as-Sayd Reserve. Vegetation patterns within the Nadj region between Harrat Nawasit and Harrat Kisb are quite different from those in the north. Northern region vegetation is dominated by low growing annual and perennial herbs (less than 1 m in height, typically less than 0.1 m) with large areas of *Artemisia spp., Achillea fragrantissima, Capparis spinosa, Zilla spinosa, Astragulus spinosus,* and *Haloxylon salicornicum* (hammada, Seddon & van Heezik 1996), whereas the vegetation in Mahazat as-Sayd Reserve is a mosaic of low growing herbs (e.g., *Indigofera spinosa, Fagonia indica, Zygophyllum simplex*), woody shrubs and trees (e.g., *Salsola spp., Acacia tortilis, Lycium shawii,* and *Maerua crassifolia*) and grasses (e.g., *Panicum turgidum, Lasiurus scindicus, Ochthochloa compressa, Stipogrostis plumosa*). Within the reserve, patches of sabka occur in the south east, in the centre and in the north

west, and two areas of salt-tolerant bushes (principally hammada) are present in the north east and north west (Launay 1990, this Chapter).

The aim of this chapter is to test whether houbara choose nest sites on the basis of substrate type, or extent and type of vegetation cover, and therefore provide conservation managers with a tool to assess whether nesting habitat is present at future release sites or in proposed reserves. If houbara have preferences for nest sites in certain substrata, in open flat sites devoid of trees, or within areas of salt-tolerant bushes, then I predict that nests found in Mahazat as-Sayd Reserve should be located in regions of the reserve where these features occur. Specifically, I compare habitat features at and surrounding nest sites with the proportions of each habitat type found throughout the reserve to determine patterns in the location of houbara nest sites within Mahazat as-Sayd Reserve.

Methods

Methods used in locating nests are described in Chapter 4. All nest locations were recorded by GPS. Nest site characteristics were recorded after the nest ceased to be active (hatched chicks or failed). I used all 49 nesting attempts from 1996 to 1998 (see Table 4.2) to compare proportion of nesting attempts per habitat type against eight habitat types described by Launay (1990). I used 22 of 23 nests from 1997 for more detailed analyses of nest site characteristics. For two reasons, I considered all nesting attempts to be spatially independent, and for all comparisons I included all nesting attempts of all females. First, females were observed to have home ranges that were large (over 16660 ha, see Fig. 6.1) with daily movements that sometimes exceeded 10 km (e.g., see Fig. 6.4), and therefore females had many site types available to them within their home range. Second, females occasionally moved from their normal home range areas to completely new sites at the onset of nesting (e.g., female tx5026 flew 35 km west to breed in a site where she had never been recorded previously), and thus were able to sample all available habitats.

Description of vegetation and substrates in the reserve

For comparison against nest site characteristics I needed detailed data on cover of substrate types and plant species throughout the reserve. In the only previous attempt to quantitatively describe vegetation in the reserve, Launay (1990) described large-scale habitat types from point sampling of aerial photos, but the method lacked resolution. Therefore, I described substrate and vegetation on a reserve-wide basis using a modified step-point transect method (Cunningham 1975, Catchpole & Wheeler 1992). Substrate and vegetation availability was determined in a stratified random manner by sub-dividing the reserve into 5 x 5 km grids (see Chapter 8) and randomly locating linear transects at points within each grid in Mahazat as-Sayd Reserve and in 11 sites adjacent to the reserve. At each site a 600 step-point sampling method was used, with the direction of transects determined using random compass directions prior to arrival at the site. At each step the plant species or type of substratum touching a marked point on the toe of my shoes was recorded. Long transect lines were used because vegetation is patchy and patches are small, and quadrat sampling would under-represent vegetation components of this environment. Number of steps was determined in trial data from 1000 steps, where values for most substrata and common plants reached an asymptote after the first 600 steps. Stride length was calibrated to 1 m in these transects, and thus transects were approximately 600 m in length. In a total of 98 sites I therefore sampled 58800 points, in 58.8 km of transect length. Substrata were divided into silt, sand, gravels, cobbles, boulders, bedrock, and sabka, and into chert and basalt parent materials. Plants were identified to species, and genera with multiple species were lumped. Percent cover was calculated as the total number of steps of each substrate or plant species divided by 600 (the total numbers of points per transect).

Description of vegetation and substrates at nest-sites

Three scales of sampling were used at nest sites. These were (1) general site data at a 2 – 3 ha scale using aerial photography, (2) data *near* the nest from 100 x 100 m quadrats centred on nests to compliment aerial photos, and (3) data *at* the nest-site using 2 x 2 m quadrats centred on nests.

I described general nest sites by photographing the sites of 22 nesting attempts in 1997 from the air, using an Olympus SLR camera with 35 – 105 mm Tokina zoom lens set at 70 mm aperture length. Photographs were taken by flying a Maule single engine plane at

approximately 300 m a.g.l., then tipping the wing to obtain a vertical image through the open passenger window. Because not all photographs were taken from exactly the same height, scale for aerial photographs was determined by either measurement of a 3 m x 0.5 m white board placed on the ground near the nest site prior to flights, or measurement of distances between recognisable landscape features (e.g., tracks, distinctive shrubs or rocks) seen on the photograph. The mean area of nest sites on standard 150 x 100 mm print images was 2.8 ± 0.04 ha (mean ± 95 % C.I., range = 2 – 3.1 ha). Images were scanned into Lotus Freelance Graphics (Ver 2.1), then adjusted to a constant scale, and overlaid with a 5 x 5 mm grid such that every 400 grid squares equalled 1 ha. For each nest site the boundaries of each of six habitat (substrate/vegetation) types were drawn directly onto the scanned image, forming a series of polygons. Habitat types were based on common substrate and vegetation associations, and were: (1) gravels of chert origin, (2) gravels of basalt origin, (3) sandy patches with tall grasses and scattered acacia, (4) undulating basalt cobbles and boulder fields, (5) sabka, and (6) low grasses and herbaceous plants on either sand or gravel. The area (ha) of each habitat type was calculated by summing the area of all polygons of each habitat type, and was expressed as a proportion of the total area surveyed at each site. In addition, densities of trees (mainly *Acacia spp.*, 1 – 5 m tall) in the vicinity of the nest were calculated by counting all trees on the image and dividing by the total image area (see Fig. 5.1 for examples of aerial images).

I further described vegetation and substrate characteristics near nests by visiting each nest site, and recording the percentage of vegetation cover for each of shrubs, grasses, and herbaceous plants and for bare ground within a measured 100 x 100 m quadrat centred on the nest. Vegetation cover values were estimated visually in 5 % increments, except that when vegetation that was present at very low densities but was less than 5 % of the total area, a value of 1 % was assigned.

I described habitat at each nest site by centring a 2 x 2 m steel-frame quadrat over each nest bowl and recording: (1) a list of species of plants, (2) the height (mm) and distance (mm) from the nest bowl of features of relief (plants, debris and rocks) greater than 100 mm in height, that may have provided cover or camouflage for a sitting houbara female, and (3) the percentage of vegetation cover for each of shrubs, grasses, and herbaceous plants and for

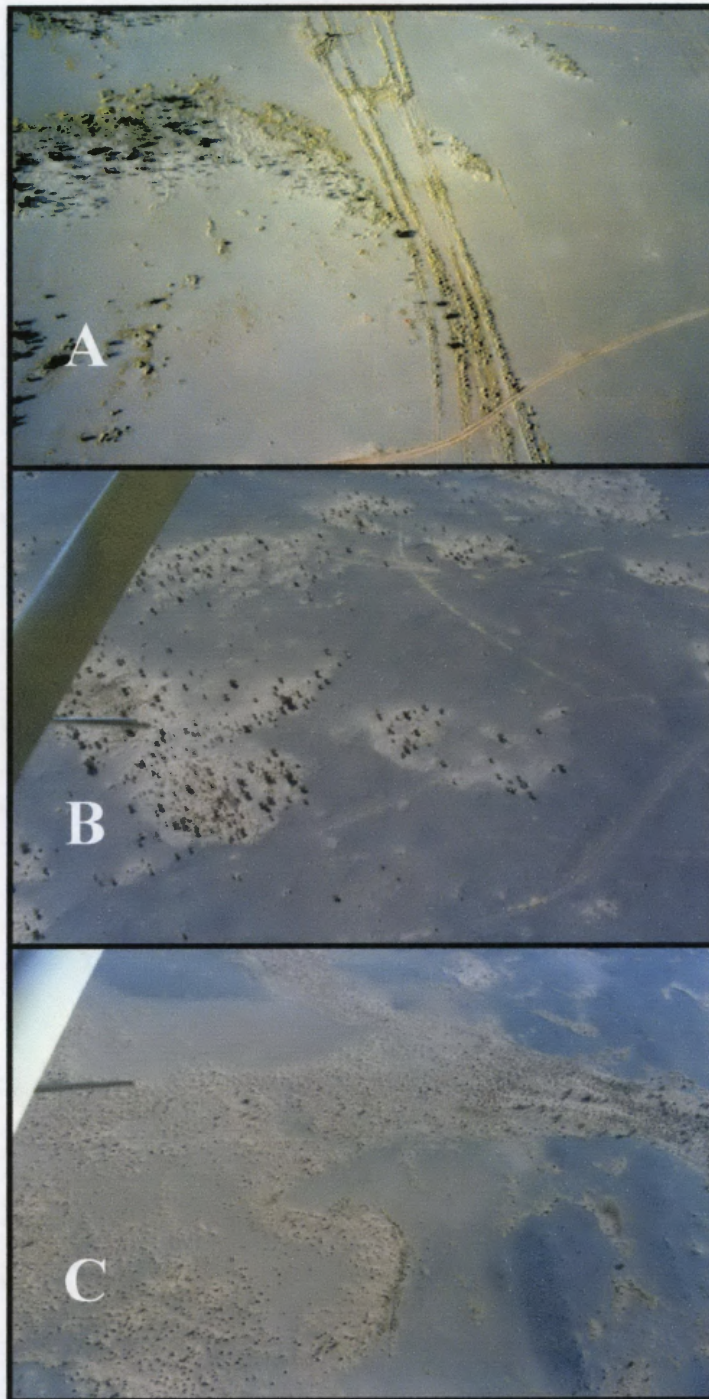bare ground. Vegetation cover values were estimated using the same criteria as described above.

Figure 5.1: Typical examples of vegetation and nest sites from aerial images taken in 1997. (A) tx5240 nest 4. Nest was in the east of the reserve on a chert gravel plain with patches of sand and *Acacia tortilis* (36 *Acacia spp.* ha^{-1}), and with *Panicum turgidum* and *Ochthochloa compressa* grasses along old vehicle tracks and at edge of sand areas; (B) tx5515 nest 1. Nest was in the south of the reserve in basalt gravels with small areas of basalt bedrock outcropping, and sand patches with *Acacia spp.* (209 ha^{-1}), and some tall grasses (*P. turgidum, O. compressa*); (C) tx5419 nest 3. Nest was in the north of the reserve in sand with mainly *O. compressa, P. turgidum, Salsola spp., Indigofera spinosa*, and with basalt gravel and a large eroded bedrock outcrop, with few *Acacia spp.* (19 ha^{-1}).

Results

Locations of nests relative to Launay's (1990) habitat types

A total of 49 nesting attempts by 15 females were recorded from 1996 to 1998 (Fig. 5.2, Fig. 5.3, Chapter 4). Compared to the proportion of area within the reserve described by Launay (1990), there were significantly more nests than expected located in two habitat types: sandy areas with *Acacia spp.* in low density associated with *P. turgidum* grasslands, and black basalt relief with *Acacia spp.* at high density; and for fewer nests than expected to be located in gravel with low density or no *Acacia spp.*, and in undulating areas with *A. nubica* (χ^2 = 14.8, D.F. = 5, P = 0.011, Fig. 5.2, Table 5.1, gravel without *Acacia spp.* and gravel with low density *Acacia spp.* combined, and Hammada area excluded from the analysis because of low numbers of nests found in those areas).

Table 5.1: Number (%) of houbara nests found from 1996 to 1998, for each of eight substrate/vegetation categories described by Launay (1990) in Mahazat as-Sayd Reserve. Bold nest totals are trends where nests occur in higher proportions than reserve area available, underline = where lower than expected proportions occur.

| Substrate/vegetation type	Proportion of reserve area (%)	Number (%) of nests			
		1996	1997	1998	Total
Gravel without *Acacia spp.*	10.4	0	1	0	<u>1 (2.0)</u>
Gravel *Acacia spp.* at low density	20.7	1	2	8	<u>11 (22.4)</u>
Gravel with *Acacia spp.* at high density	8.6	1	2	1	4 (8.2)
Basalt relief with *Acacia spp.* at low density	22.3	1	8	2	11 (22.4)
Basalt relief with *Acacia spp.* at high density	10.2	1	3	5	**9 (18.4)**
Hammada (salt bush) areas	2.3	0	0	0	0 (0)
Undulating with *Acacia nubica*	12.0	0	3	0	<u>3 (6.1)</u>
Sandy areas with *Acacia spp.* at low density and *Panicum turgidum* grasslands	13.3	0	4	6	**10 (20.4)**
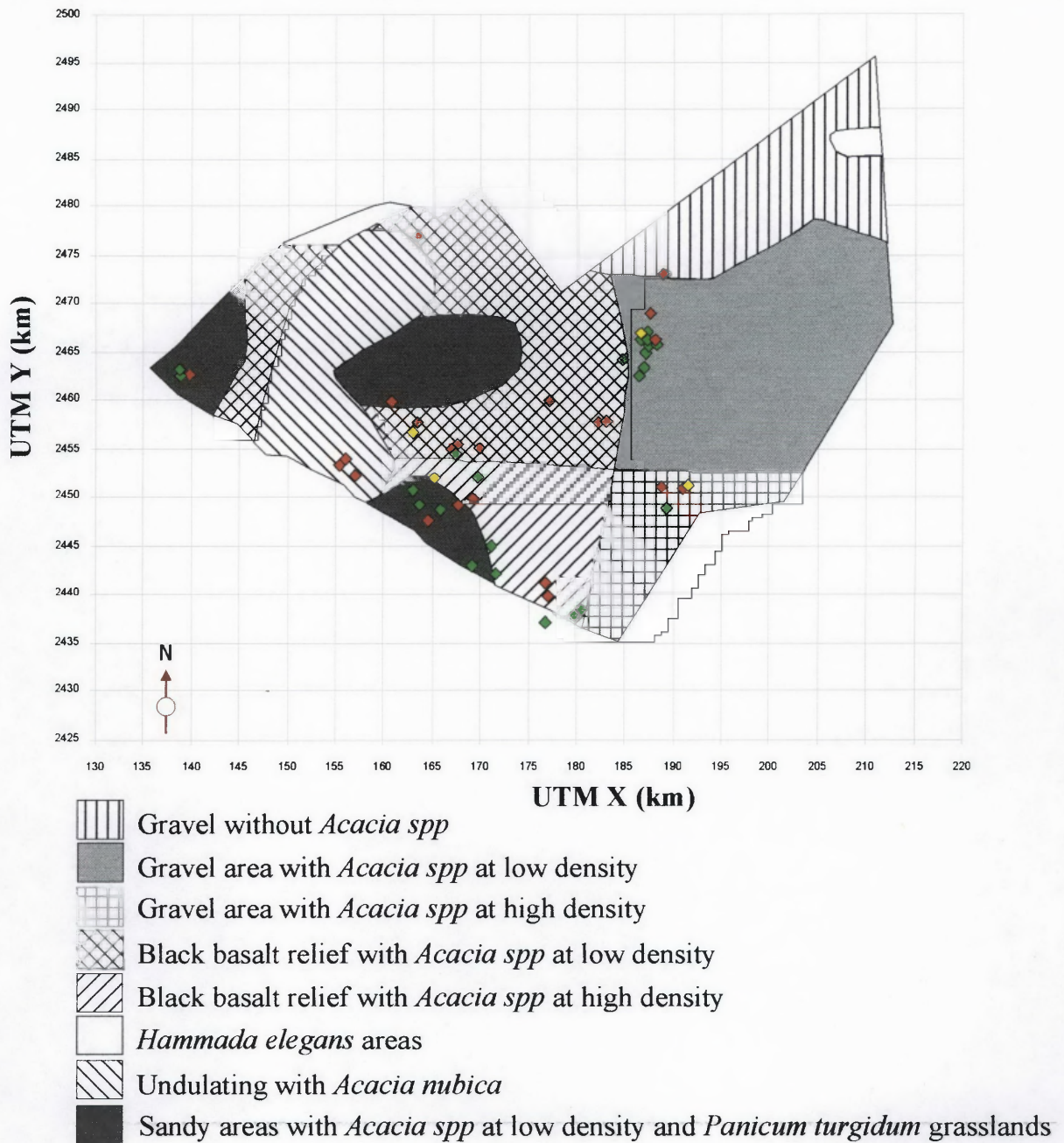
Figure 5.2: Location of 49 nests sites in Mahazat as-Sayd Reserve from 1996 to 1998. Habitat boundaries are redrawn from Launay (1990). Scale is in km. Symbols for nests are 1996= yellow diamonds, 1997= red diamonds, 1998= green diamonds. UTM co-ordinates as per Figure 3.3.

Description of habitat near nest sites

For 12 (52 %) of 22 nest sites in 1997, habitat in the 2 – 3.1 ha area surrounding nests was basalt or sand substrates with *Acacia spp.* and tall grasses, either with (N = 9) or without (N = 3) grass and herbs (Table 5.2, Fig. 5.1). Five (22 %) sites were basalt and chert substrata that had only small areas of sand and trees, and five sites were chert substrate with less than

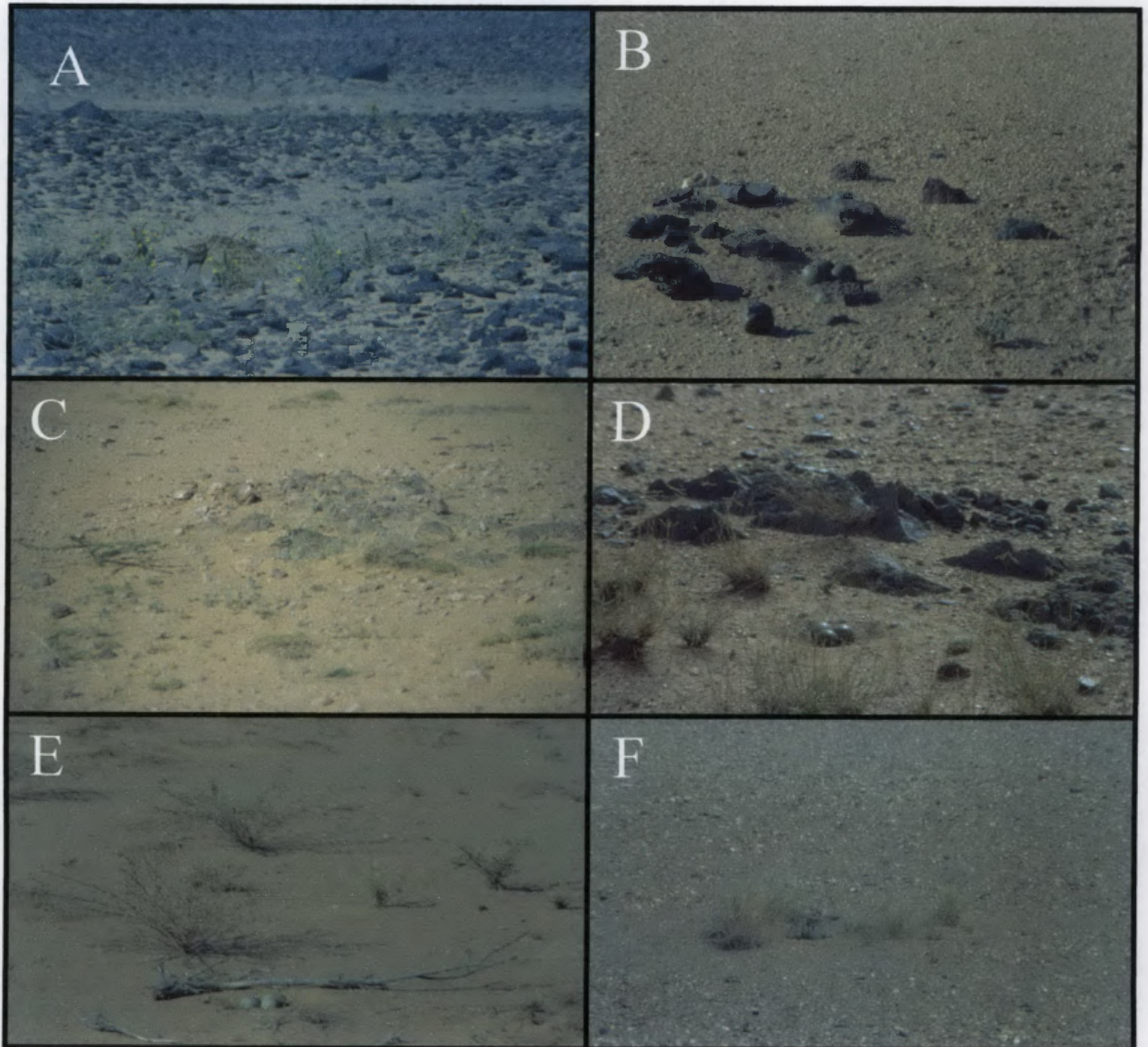10 % sand and trees, either with or without low growing grasses and herbs, and without basalt.

Figure 5.3: Typical examples of nest sites of houbara in Mahazat as-Sayd Reserve. Nests belong to: (A) tx5026 in the west of the reserve, (B) tx5131 in the centre-west, (C) tx5598 in the south, (D) tx5496 in the south, (E) tx5210 in the south and, (F) tx5441 in the north east.

Table 5.2: Presence (+) or absence (-) of five substrate and vegetation types identified from aerial photographs taken at 22 houbara nest sites in 1997.

Sabka	Basalt gravels and bedrock	Chert gravels and bedrock	Sand areas with *Acacia spp.* and tall grasses	Low grasses and herbs on sand or gravel	Number of nest sites
-	+	-	+	+	9
-	+	-	+	-	3
-	+	+	+	-	5
-	-	+	+	-	4
-	-	+	+	+	1

Mean (± 95 % C.I.) distance of nests from cover was 22.8 ± 6.1 m. No nest was closer than 4 m, and one nest was 60 m from the nearest area of cover. There was a large variation in the number of trees found near nest sites, from as few as 19 trees ha^{-1}, in the north east, to 437 ha^{-1} in the south of the reserve. On average, nests were located in sites with tree densities of 158 ha^{-1} (± 95 % C.I. = 142 – 174 ha^{-1}).

Substrate and vegetation characteristics at and near nest sites

Overall, the proportions of bare ground (88.4 %), woody plants (2.1 %), grasses (6.0 %) and herbs (3.5 %) was similar within 2 m of nest sites as throughout the reserve, whereas the general area within 100 m of nest sites had less bare ground (78 %) and more woody plants (8.7 %) and grasses (11 %, Table 5.3). Most of this difference was because cover of a grass, *Panicum turgidum*, and a woody plant, *Acacia spp.*, covered proportionally more ground near to nest sites (both more than 6 % cover near nests compared to ~1 % reserve-wide), and because chert gravels was proportionally less common near nest sites (26 % c.f. 41 % in the reserve, Table 5.3). Except for *Zygophyllum simplex*, *Haloxylon salicornicum*, and *Blepharis ciliaris*, all other species that had the high cover values in the reserve were also recorded at and near nest sites. Only two species that were uncommon in the reserve (*Maerua crassifolia*, *Lycium shawii*) were found near to nest sites. No nests were near sabka. Silt and basalt boulder areas (4.9 % of reserve) were under-represented near (0.4 %) and at nest sites (2 %), whereas sand was over-represented at nest sites. Basalt and chert gravels were both under-represented at nest-sites (Table 5.3).

Table 5.3: Comparison of % cover of (A) substrate, (B) woody, (C) grass and (D) herb vegetation types reserve-wide with that found within 100 m and 2-m quadrats centred on nest sites. Reserve-wide data is from 98 transects each with 600 sample points distributed throughout the reserve.

(A) Bare ground	% reserve-wide	% in 100 m of nest sites	% in 2 m of nest sites
Sabka	2.6	0	0
Silt	1.4	0.4	0.4
Sand	16.2	26.4	40.5
Basalt gravel	16.7	13.9	6.4
Chert gravel	41.2	26.4	31.4
Cobble	8.1	6.3	5.7
Basalt boulder	0.9	0	1.6
Bedrock	0.4	4.6	2.4
% cover bare ground	**87.5**	**78.0**	**88.4**
(B) Woody plants			
Indigofera spinosa	1.0	1.7	1.4
Acacia spp.	0.9	6.4	0.5
Salsola spp.	0.2	0.5	0.1
Haloxylon salicornicum	0.2	<0.001	<0.001
Woody debris	0.04	<0.001	0.2
Anvillea radiata	0.03	<0.001	<0.001
Heliotropium spp.	0.03	<0.001	<0.001
Lycium shawii	0.02	0.1	<0.001
Maerua crassifolia	0.01	0.1	<0.001
Rhazya stricta	0.003	<0.001	<0.001
Ochradenus baccatus	0.002	<0.001	<0.001
% cover woody plants	**2.4**	**8.7**	**2.1**
(C) Grass			
Stipogrostis spp.	2.6	1.6	1.7
Panicum turgidum	1.1	6.6	0.5
Ochthochloa compressa	0.6	2.0	3.4
Lasiurus scindicus	0.3	0.7	0.5
Tragus racemosus	0.1	<0.001	<0.001
Unidentified grasses	0.1	<0.001	<0.001
Enneapogon spp.	0.02	<0.001	<0.001
% cover grass	**4.8**	**11.0**	**6.0**

Table 5.3: Continued

(D) Herbs	% reserve-wide	% in 100 m of nest sites	% in 2 m of nest sites
Fagonia indica	2.5	1.1	1.8
Morettia parviflora	0.8	0.6	0.8
Zygophyllum simplex	0.7	0.2	<0.001
Arnebia hispidissima	0.4	0.1	0.1
Farsettia stylosa	0.2	0.1	0.5
Blepharis ciliaris	0.2	<0.001	0.1
Polycarpaea repens	0.1	0.1	0.1
Tribulus macropterus	0.1	0.1	0.1
Cleome brachycarpa	0.03	<0.001	<0.001
Tephrosia spp.	0.03	<0.001	<0.001
Ajuga arabica	0.02	<0.001	<0.001
Corchorus depressus	0.01	<0.001	<0.001
Astragalus spp.	0.01	<0.001	<0.001
Crotalaria spp.	0.01	<0.001	<0.001
Monsonia nivea	0.01	<0.001	<0.001
Cassia spp.	0.01	<0.001	<0.001
Centaurea pseudosinaica	0.01	<0.001	<0.001
Pulicaria spp.	0.01	<0.001	<0.001
Anastatica hierochuntica	0.01	<0.001	<0.001
Atractylis carduus	0.01	<0.001	<0.001
Unidentified herb	0.01	<0.001	<0.001
Seetzenia lanata	0.003	<0.001	<0.001
Euphobia spp.	0.003	<0.001	<0.001
Citrullus colocynthis	0.003	<0.001	<0.001
Polycarpia spp2.	0.002	<0.001	<0.001
Lotononis platycarpia	0.002	<0.001	<0.001
Sclerocephalus arabicus	0.002	<0.001	<0.001
Indigofera sessiliflora	0.002	<0.001	<0.001
% cover herbs	**5.3**	**2.3**	**3.5**

Description of habitat at nest sites

Generally, nests were sited near to scattered plants, and sometimes debris or large rocks, but away from dense vegetation areas. In total, 21 of 22 nests had some type of vegetation, rocks or debris, or combinations of these three features, within a 2-m quadrat centred on nest sites. Nineteen (83 %) of the nests had plants, five (22 %) had debris, and seven (30 %) had rocks at the nest site. Two nests had only rocks, and nine nests only vegetation. Only one nest (female 5419, nest 2), in the north east of the reserve, was completely in the open with no plants, rocks or debris within 3 m of the nest. Nearest vegetation, rocks or debris were located in a random direction from the nest bowl (Fig. 5.4), and was not consistently placed to shelter from prevailing westerly or easterly winds, or from the sun (east to west through

the southern sky). Plant height at nest sites was generally low: mean (± 95 % C.I.) plant height of those plants greater than 100 mm tall was only 176.5 ± 23.3. Only two females (5441 nest 1, 5419 nest 1) nested at sites where mean vegetation height was greater than 300 mm (Fig. 5.5a). Although the nearest rocks (30 mm), debris (20 mm) and plants (0 mm) were close to or at the nest bowl, nests were not generally situated against isolated clumps of vegetation or rocks, and mean ± 95 % C.I. distances to plants, debris and rocks were 482 ± 38, 377 ± 260 and 356 ± 132 mm, respectively (distance to plants shown on Fig. 5.5b).
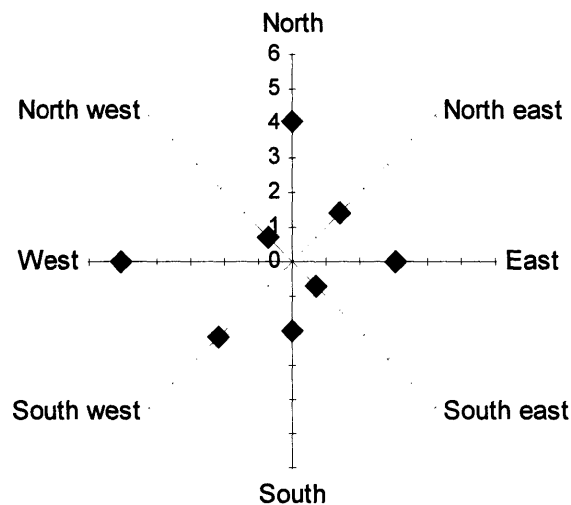

Figure 5.4: Compass directions for location of the nearest vegetation, debris, or stones, for 21 nests in 1997. One further nest did not have vegetation or objects within 2 m of the nest site. All axes are the numbers of nests found in each axis direction.

Fourteen plant species were recorded at nest sites, but only four species of plant were recorded at more than four of the 22 nest sites: two grasses (*Ochthochloa compressa*, 9 nests, *Stipagrostis plumosa*, 8 nests), one woody plant (*Indigofera spinosa*, 8 nests) and one herb (*Fagonia indica*, 5 nests; Table 5.4). Three of these species (not *O. compressa*) had the highest % cover values of grasses, herbs and woody vegetation throughout the reserve (Table 5.3).
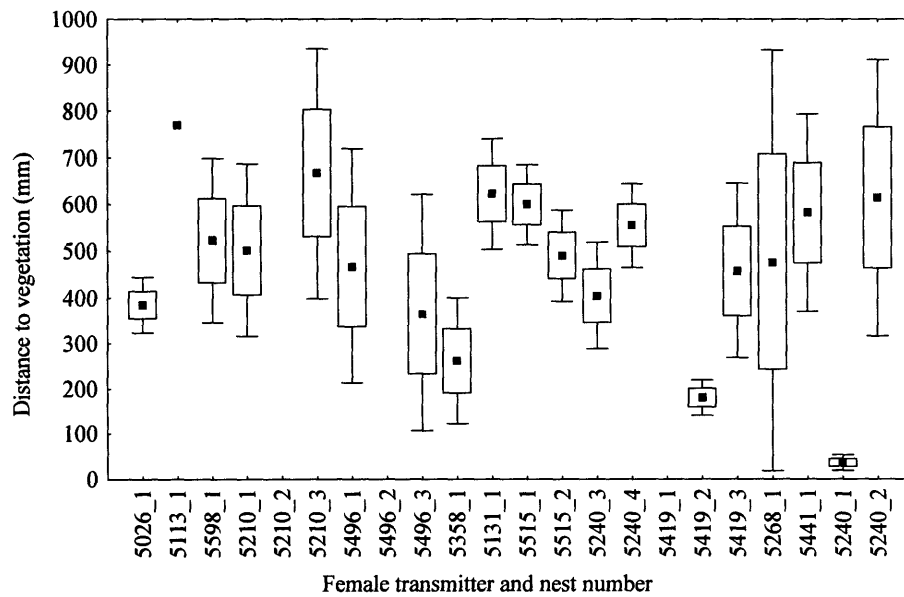
(A)
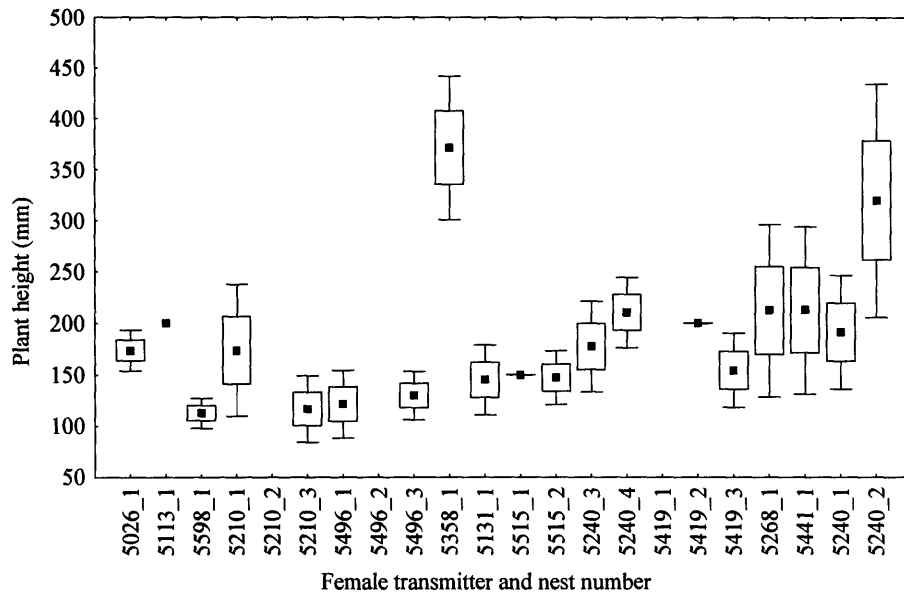
(B)

Figure 5.5: Box plots (black squares = means, boxes = S.D., lines = ± 95 % C.I.) of (A) vegetation height and (B) distance to vegetation, within a 2-m quadrat at 22 nest sites in 1997. Females are ordered by location (west = 5026, south west = 5113, 5598, 5210, 5496, 5358, 5131, south = 5515, north east = 5240_3, 5240_4, 5419, 5268, 5441, east = 5240_1, 5240_2).

Table 5.4: Plant species, number of plants, mean (± 95 % C.I.) per site, for plants recorded at 22 nest sites 1997. Plants are ordered from the largest to smallest mean number of plants per nest site.

Type	Plant species	Number of nest sites	Number of plants recorded	Mean number of plants per site	-95 % C.I.	+ 95 % C.I.
Grass	*Ochthochloa compressa*	9	100*	11.1	2.9	19.3
Grass	*Stipagrostis plumosa*	8	45	5.6	2.5	8.8
Herb	*Morettia parviflora*	3	9	3.0	-3.6	9.6
Herb	*Arnebia hispidissima*	1	3	3.0	-	-
Herb	*Farsetia stylosa*	4	11	2.8	1.2	4.3
Grass	*Panicum turgidum*	4	7	1.8	-0.6	4.1
Low shrub	*Indigofera spinosa*	8	12	1.5	0.6	2.4
Grass	*Lasiurus scindicus*	2	3	1.5	-4.9	7.9
Herb	*Fagonia indica*	5	6	1.2	0.6	1.8
Tree	*Acacia spp*	2	2	1.0	-	-
Herb	*Polycarpaea repens*	2	2	1.0	-	-
Herb	*Blepharis ciliaris*	1	1	1.0	-	-
Herb	*Tribulus macropterus*	1	1	1.0	-	-

*all rooted tufts were considered separate plants

Discussion

Houbara nests were not distributed randomly throughout the reserve. On a general scale, nests were most often located in areas of basalt substrata in the south and centre of the reserve, or in chert gravel plains in the east and north east of the reserve. Most nests were sited near to, but not in, dense patches of woody vegetation and tall grasses. No nests were found in sabka or in the limited area dominated by hammada, even though hammada sites are commonly recorded as preferred habitat in other parts of their range (Cramp & Simmons 1980, Surahio 1985). It is unclear why nests were not more evenly distributed across the reserve. Possibly, houbara are still expanding in their range within the reserve and as the number of females in the reserve increases then all habitats will eventually be selected.

Females were not just selecting sites that were adjacent to where they were released, indicating that range expansion is not simply a function of females expanding out from release areas, but that some areas have been passed over for other more distant sites. I suggest female nesting distribution may be determined by other factors such as access to males (Chapter 8), the absence of other females, or food availability.

Females certainly appeared very adaptable in their nest site preferences, and selected a wide range of habitat types, including those not typically reported in other parts of their range (Cramp & Simmons 1980, del Hoyo *et al.,* 1996). Females were not favouring certain vegetation types as nest sites. Except for the absence of *Zygophyllum simplex* and hammada at or near nest sites, nest site vegetation was in similar proportions to that found throughout the reserve. *Zygophyllum* is a succulent species that is generally widespread in hard sand (Collenette 1999) and in Mahazat as-Sayd Reserve was most often recorded in samples from the centre and north west of the reserve (perhaps in saline soils), where no houbara nested. Similarly, hammada is a salt-tolerant species that is widespread in saline and alkaline soils (Collenette 1999), and was found in two areas in the north east and north west of the reserve in locations where females did not nest. Females had the choice of using any habitat within, and outside the reserve, as demonstrated by their ability to move large distances, and have large home ranges (Chapter 6), but they never chose to nest in vast areas of hammada covering hundreds of km^2 just to the north of the reserve. These results combined show that houbara are not preferentially seeking out nesting sites in hammada areas, nor, given the choice of a wide variety of habitats including shrub, dense grass and tree-covered landscapes, are they choosing the most open or low growing vegetated areas as nest sites. This result is important for determining whether nest sites within Mahazat as-Sayd Reserve will become limiting in the future, and in assessing whether other reserves may have sufficient suitable nesting sites to support a new released population (e.g., in a proposed reserve in the At Taysiyah region near Hayil, in north eastern Saudi Arabia, Fig. 2.1). I consider that, because nest site characteristics described here are relatively broad, then nest sites *per se* are unlikely to be limiting in other locations that have a variety of habitats available.

The presence of tall shrubs and trees (e.g., *Acacia spp., Lycium shawii, Maerua crassifolia*) in moderate to high densities in the south of the reserve did not deter houbara from nesting

in those regions, and nests were found at sites that had up to 440 trees ha^{-1}. Although these trees are not tall (1 – 5 m), they are not limiting houbara breeding distribution even at high densities. On the contrary, nests are more likely to be located near to sites where *Acacia spp*, densities are higher than the mean values for the entire reserve, than in sites with low tree density. Similarly, nests were located near to (but not in) sites where *Panicum turgidum* grass had higher cover values than for the reserve-wide mean values. Nesting close to dense vegetation may reflect a degree of inexperience or mis-imprinting of the Mahazat as-Sayd Reserve population, all of whom were captive-reared and released into the reserve. More likely, nesting near to areas of dense cover is a natural feature of houbara populations in the southern area of their breeding range, where the species range overlaps with the African origin *Acacia spp*., a widespread tree over much of Saudi Arabia (Collenette 1999). That houbara have been rarely recorded nesting in such habitats before may reflect the paucity of such sites within their current remnant range, rather than any biologically meaningful avoidance of such sites.

Nests were not actually located within patches of dense vegetation (grasses or trees), but instead were placed along patch margins, 4 – 60 m from patch edges. In addition, where vegetation occurred at the nest site, it was always low growing (< 200 mm) and not clumped around the nest itself. Nests were not placed as far from dense vegetation patches as was possible in the reserve. In the south of the reserve opportunities for placing nests large distances from cover were restricted because patches were usually separated by no more than 100 m. However, in the north and east of the reserve there was more than 180 km^2 of reserve area where distances to vegetation patches were 100 – 1000 m, yet nests were never more than 60 m from vegetation patches. Presumably, nests are sited far enough from dense cover to allow nesting females maximum visibility to detect approaching predators, but close enough to use the cover to escape quickly and hide. Patches of vegetation also offer greater feeding opportunities because the greatest diversity of plants, and highest densities of insects, are found on patch edges (Combreau & Smith 1997). Therefore, nesting near patches is probably a deliberate strategy aimed at maximising the benefits gained from the patch (food and cover), while minimising the risk of predation.