CONSERVACIÓN DE LAS AVES ESTEPARIAS Y SU HÁBITAT

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IMPORTANCE OF STUDIES ON BREEDING BIOLOGY IN THE CONSERVATION PROGRAM OF HOUBARA BUSTARD IN SAUDI ARABIA

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SUMMARY.- *Importance of studies on breeding biology in the Conservation Program of Houbara Bustard in* *udi Arabia.* The drastic decline of local populations of Houbara Bustard (*Chlamydotis undulata macqueenii)* in audi Arabia led, in 1986, the National Commission for Wildlife Conservation and Development to implement nservation measures: studies of free ranging birds, establishment of protected areas, captive breeding and relea- programs. When a bird species is captive bred, knowledges of the factors triggering reproduction are of major nportance. Houbara breed in arid or semi-arid zones, and their reproductive biology is largely unknown. At the ational Wildlife Research Center, reproductive parameters of captive female housed in outdoor cages were exa- ined during seven successive years (1989-1995). Despite captive houbara showed a seasonal breeding pattern, ter-annual variations were observed in the onset and termination of laying, percentage of laying birds, age at first ying and clutch size, leading to inter-annual variations in chicks production. Inter-annual variations in these para- eters, and of rainfall and ambient temperature were examined with reference to environmental cues synchroni- ng breeding activity. Our believe is that the species could has developed an endogenous annual rhythm. Ambient mperature could be a proximate factor synchronizing sexual maturation. Rainfall could act as a subsidiary synch- nizer, with abundant rainfall modulating the reproductive period. The aim of this presentation is to show how nportant good knowledges on the reproductive biology are, when wildlife managers have to decide of an area here to implant captive breeding facilities.

Key words: Houbara, Saudi Arabia , conservation.

RESUMEN.- *Importancia de los estudios de la Biología Reproductora en el Programa de Conservación de la Hubara en Arabia Saudí.* El drástico declive de las poblaciones locales de Hubara (*Chlamydotis undulata macqueenii)* en Arabia Saudí llevó, en 1.986, a la Comisión Nacional para la Conservación y Desarrollo de la Vida Silvestre a llevar a cabo medidas de conservación: estudios de aves en libertad, establecimiento de áreas protegidas, cría en cautividad y programas de sueltas. Cuando se cría un ave en cautividad, el conocimiento de los factores que desencadenan la reproducción son de gran importancia. La Hubara cría en zonas áridas o semiáridas, y la biolagía reproductiva de las Hubaras silvestres es bien conocida. En NWRC, los parámetros de reprocucción de hembras cautivas de hubaras mantenidas en jaulas al aire libre fueron examinadas durante cinco años consecutivos (1990-1994). A pesar de que las hubaras cautivas mostraron un patrón de cría estacional, fueron observadas grandes variaciones interanuales en el comienzo y final de la puesta, el porcentaje de aves nidificantes, la edad en la primera puesta y el tamaño de la misma, que conllevan variaciones interanuales en la producción de pollos. Se examinaron variaciones interanuales en estos parámetros y en el régimen de precipitaciones y temperaturas en relación a señales medioambientales que sincronizan la actividad reproductora. Nuestra impresión es que la especie ha desarrollado un ritmo endógeno anual. El fotoperiodo no parece ser el factor primordial en la sincronización de la actividad gonadal. La temperatura ambiente parece actuar al menos como información suplementaria, pero podría ser un factor secundario, con la precipitación abundante modulando el periodo reproductor. El objetivo de esta presentación es mostrar lo importantes que son los buenos conocimientos de la biología reproductora cuando los gestores tienen que decidir dónde implantar la infraestructura necesaria para el mantenimiento de aves en cautividad.

Palabras clave: Hubara, Arabia Saudí, conservación.

INTRODUCTION

The drastic decline of Arabian populations of Houbara Bustard (*Chlamydotis undulata macqueenii*), due to over-hunting and severe degradation of its habitat led, in 1986, the National Commission for Wildlife Conservation and Development (NCWCD) of Saudi Arabia to implement conservation measures (Seddon *et al.*, 1995; Saint Jalme & van

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Heezik, 1996; Saint Jalme *et al.*, 1996). These measures include habitat protection, ecological and behavioral studies of free ranging populations, foundation of a captive breeding population with studies on the reproduction biology of the species, and restocking programs. The houbara bustard restoration programme has the long-term goal of securing self-sustaining populations of houbara within a network of managed sites in Saudi Arabia.

Chlamydotis u. macqueenii is one of three sub-species. *Chlamydotis u. undulata* is thought to be resident in North Africa, *Chlamydotis u. fuertaventurae* lives only on the Canary Islands, and *Chlamydotis u. macqueenii* is probably a partial latitudinal migrant from the Nile Valley to Mongolia. (Cramp & Simmons, 1980). The houbara preferentially breed in undulating, flat arid plains, steppes and semi-deserts, often with little cover except for open or scattered desert shrubs, and receiving between 50-200 mm annual rainfall, mainly in the winter (Mendelssohn *et al.*, 1979; Haddane, 1985; Mian & Dasti, 1985). The reproductive cycle of wild Houbara is still largely unknown. Timing of nesting appears to be quite variable across the species' breeding range, but is concentrated in the spring months. Generally eggs are found between March and May, with laying occurring earlier in more southern and western localities (Heim de Balzac & Mayaud, 1962, Dementiev & Gladkov, 1968; Cramp & Simmons, 1980; Mendelssohn, 1980; Lavee, 1988; Gaucher, 1995). Occasionally, eggs have been found in Algeria as early as November, or as late as June (Cramp & Simmons, 1980). Age at first breeding is not known (Cramp & Simmons, 1980), although sexual maturity is thought to be reached after two years (Mendelssohn, 1983).

Captive breeding of houbara was initiated by the National Wildlife Research Center (NWRC) of Taif, in 1986. First breeding success was achieved in 1989 with the production of 17 chicks. This success was obtained mainly as a result of artificial insemination (Saint Jalme *et al.*, 1994) together with egg-pulling, which meant up to 30 eggs could be laid in a species known to lay only one clutch a year one to four eggs (Heim de Balzac & Mayaud, 1962; Etchécopar & Hue, 1978; Mendelssohn, 1980; Urban *et al.*, 1986). The captive breeding program achieved a self-sustaining captive population of houbara in 1992, permitting release experiments to begin. Production increased to almost 300 chicks in 1993, however, in 1994 only 94 chicks were produced. Despite the success of the breeding programme, the unexpected low production of chicks observed in 1994 was the result of our poor knowledge on the breeding biology of the Houbara, and especially on the factor triggering reproduction.

Following the example of Taif, during the last few years, captive breeding of Houbara has flourished all over the Arabian world. The aim of this paper is to contribute to the understanding of the factors triggering or/and synchronizing reproduction and to show how important good knowledges on the reproductive biology are, when one have to decide of an area where to implant captive breeding facilities.

Survival of a species in a semi-arid environment requires individuals to adjust to changing environmental conditions, and also to reproduce at a time of year which will be favorable for survival of young. Little is known about which parameters predict suitable environmental conditions, or control the timing of reproduction in arid climates. In this habitat it is generally accepted that breeding tends to be dissociated from photoperiodic control and is driven by other environmental variables (Vleck, 1993). Precipitation, food availability and temperature, are probably of importance. For houbara, some authors have suggested that rainfall is important to trigger reproduction: breeding does not occur during dry years in Africa (Etchécopar & Hue, 1978) and in Israel most houbara do not breed after winters with little or no rain (Mendelssohn, 1980). In order to research information on these factors controlling breeding activity, the reproductive parameters of captive female houbara were examined during seven successive years (1989-1995): annual cycle of laying; age at first laying; and clutch size. Inter-annual variations in the reproductive parameters were analyzed and associated with variations in rainfall and ambient temperature.

TABLE I

Percentage of laying females per age classes comparison between 1989-1995

Years		Classes of age						
		1 year	2 years	3 years	4 years	5 years	6 years	> 6 Y
	n =	14	23	10				
1989	laying	0	10	5				
	%	0	43	50				50
	n	3	14	22	9			
1990	laying	0	4	15	7			
	%	0	29	68	78			50
	n	6	3	14	20	7		2
1991	laying	0		11	17	4		2
	%	0	33	79	85	57		100
	n	10	6	3	11	17	7	2
1992	laying	0	1	2	9	12	6	1
	%	0	17	67	82	71	86	50
	n	28	9	6	2	11	14	9
1993	laying	3	4	3	2	9	10	8
	%	11	44	50	100	82	71	89
	n	37	26	9	2		9	20
1994	laying	0	4	1	0		6	6
	%	0	15	11	0	50	67	30
	n	6	30	24	9	2	2	27
1991	laying	2	6	8	4	0	2	18
	%	33	20	33	44	0	100	67

MATERIAL AND METHODS

The study was conducted between 1989 and 1995 at the National Wildlife Research Center, Taif, Saudi Arabia (Lat.: 21.15°N; Long.: 40.41°E; Alt.: 1450 m). The difference between shortest and longest day lengths at Taif is 2 hr and 40 min.

The captive stock originated from eggs collected in Baluchistan (around 28°N), (43 females aged one to three years in 1989), birds obtained from private collections in Jordan (around 32°N),(two females aged seven years in 1989), and birds collected as chicks in the northern part of Saudi Arabia (around 30°N) (four females aged three years in 1989). Added to these founders are first generation houbara captive bred at Taif (birds aged one year in 1990, one and two years in 1991, from one to three years in 1992, from one to four years in 1993, and from one to five years in 1994, and from one to six years in 1995).

Birds were housed in individual outdoor cages (6 m x 4 m x 2.3 m) during winter, spring, and part of summer. For sanitary reasons (disinfection of the breeding unit and annual prophylaxis), birds were transferred into heterosexual groups of about 10 males and 10 females in outdoor aviaries (30 m x 10 m) for the remainder of the year. Dates of transfer of birds to individual cages were the third week of January in 1989 and in 1990, December 20 in 1991, and arround the November 15, in the following years. Date of

TABLE 2

Mean week of onset of laying and maximum clutch size for females which laid in at least one season pr iously, mean week of termination of laying for all females.

Years	N	Mean week onset of laying ± SD	Mean maxi. clutch size ± SD	Mean week termination c laying ± SD
1990	12 (26)	12.5 ± 2.2	2.7 ± 0.5	20.·± 4.3
1991	22 (35)	12.9 ± 1.5	2.5 ± 0.7	18.4 ± 3.5
1992	27 (30)	12.4 ± 3.0	2.6 ± 0.7	18.2 ± 2.3
1993	29 (38)	10.5 ± 2.8	2.9 ± 0.7	19.4 ± 3.5
1994	16 (18)	14.8 ± 5.0	1.9 ± 0.7	21.2 ± 2.8
1995	26 (40)	13.4 ± 3.1	2.1 ± 0.7	19.8 ± 2.8
		$P < 0.001$	$P < 0.001$	$P = 0.031$

transfer to the wintering pens was in the beginning of August, each year.

Food and water were provided ad-libitum throughout the year. From 1989 to August 1992, birds were fed with a high protein food (22-30% of protein). From August 1992 onward, in the wintering pen birds were fed with poultry pellets (14% protein), and fresh alfalfa provided every morning. In the breeding unit, birds were fed with poultry pellets containing 22-28% protein; fresh alfalfa growing in each cage was freely available. A polyvitaminic complement was provided with water twice a week. Females were checked every day in the morning and in the evening to collect the eggs, and so encourage the laying of replacement clutches. A meteorological station was installed at the NWRC towards the end of 1989. Air temperature and rainfall were recorded systematically from 1990 onwards.

RESULTS

Laying cycle

Houbara showed a seasonal breeding pattern (Fig. 1). Laying began in January each year, with the maximum number of eggs laid in March-April. Females generally stopped laying in May, except in 1990 and 1993 when clutches were laid in July by one and two females respectively. The post-breeding moult, which is complete, started as soon as the females stopped laying.

Age at first breeding and percentage of la females

We recorded the age of sexual maturity in females (first egg laid) between 1989 and 1995, for both founders and birds hatched in captivity at Taif. No founders laid at the age of 1 year. Thirty two percent of them began to lay at two years of age. By three years of age 72% had reached sexual maturity, and 89 % a the age of four. At six years old, only abou 10% of females had not begun to lay. Seve percent (n = 72) of the females hatched in cap tivity laid at one year old, 75 % (n = 16) ha reached sexual maturity at four. The differen ce with the founders was not significant. I each class of age, the percentage of layin females did not differ significantly betwee 1989, 1990, 1991, 1992, 1993 and 1995. I 1994, in each classe of age, the percentage laying females was much lower than in t previous year (Table 1). Differences betwe 1993 and 1994 was significant for the bir aged less than four years (X2 test, $p < 0.0$ and birds aged more than three years (P 0.001).

Start of laying

Independent of age-class, females w laid for the first time, tended to lay later in season than females which had laid previo (Saint Jalme *et al.*, in press). In birds w had laid at least one year previously. observed inter-annual variation in the patt

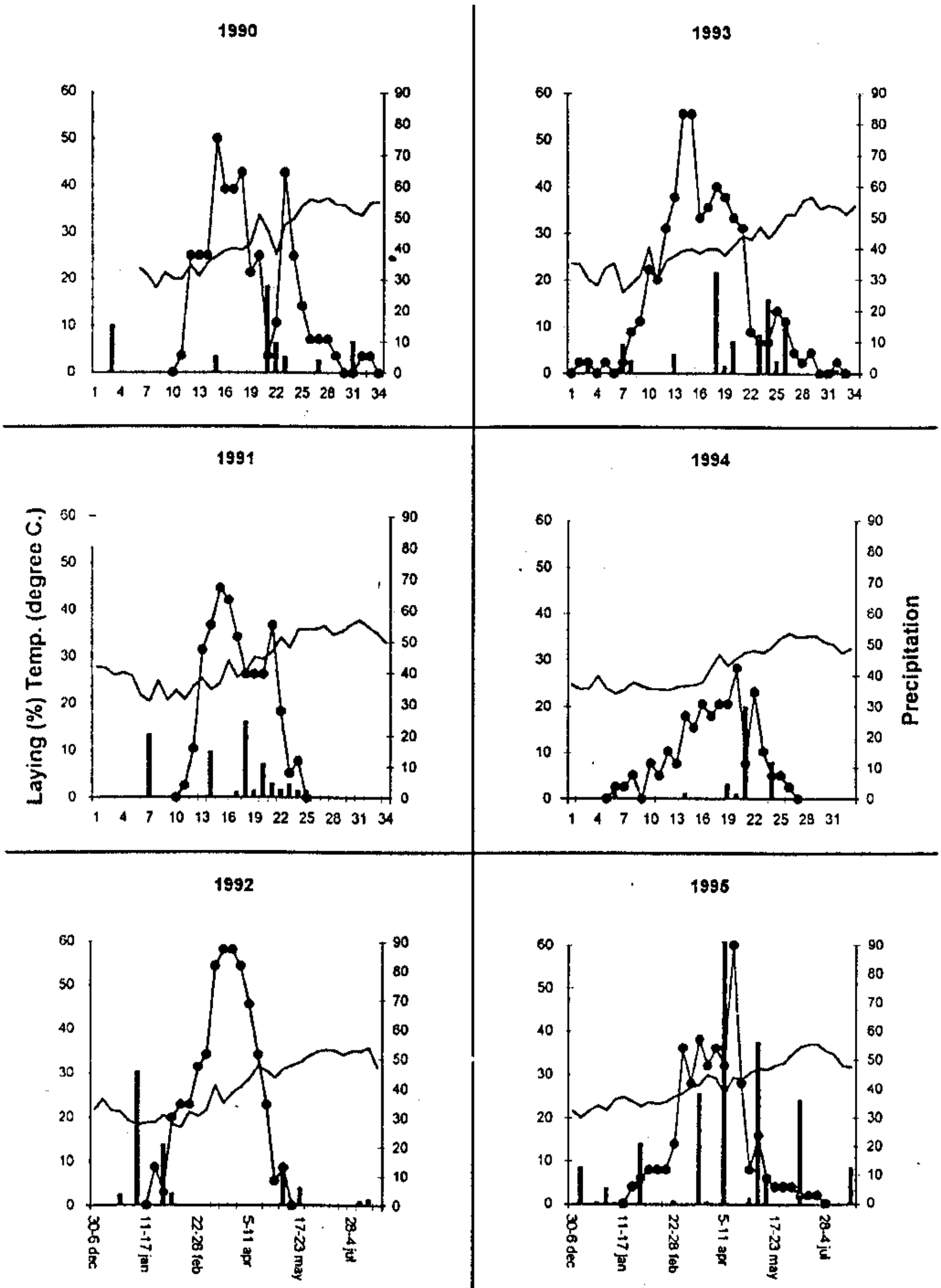

Fig. 1.- Seasonal variation in the percentage of laying females *Chlamydotis undulata macqueenii* housed in outdoor conditions •, mean weekly maximum ambient temperature _____, and rainfall in mm / week (histogram).

and timing of the onset of laying. When taking into account only those females which had laid in previous years. There was a significant difference in the timing of the start of laying between years (Table 2; F = 4.72 df = 5, P < 0.001). On average, females began to lay at the same time between 1990, 1991, 1992 (mean = last week of February), earlier in 1993 (mean = second week of February) and later in 1994 (mean = second week of March). Differences were significant between 1992 and 1993 (Mann-Whitney test: P = 0.012); and between 1992 and 1994 (P = 0.05). For this parameter, 1995 was situated between 1990-1992 and 1994. Despite this inter-annual variability, the order followed by individual females in the start of laying was relatively similar between years (Spearman rank correlation test: 1991-1992, n = 17, Rs = 0.71, P = 0.0044; 1992-1993, n = 23, Rs = 0.65, P = 0.0023).

Clutch size, inter-clutch interval and laying capacity

Large inter-individual variability was observed in clutch size. Within a clutch, eggs (1-4) were laid on alternate days, in 80% of the cases. With egg-pulling and replacement clutches, the mean interval between clutches was 9.3 days (range 5-30). The laying capacity, i.e. the total number of eggs laid by a female within one year ranged between one and 30. The mean maximum clutch size of the females which laid at least during one season previously (Table 2) differed significantly between 1990 and 1995 (F = 5.1, df = 5, P < 0.001). Maximum clutch size was similar between 1990 and 1992; higher in 1993 (t = 2.25, df = 49, P = 0. 029), and lower in 1994 (t = 3.37, df = 21, P = 0.0029). As for the onset of laying, for the size of the clutch, 1995 was situated between 1994 and 1990-1992.

Termination of laying

As for the onset of laying, there was a large inter-individual variation in the termination of laying. The first females stopped laying in the first week of March; the last females in the second week of July. Inter-annual variation was also observed for this parameter. The mean week when females stopped laying, i.e. when they laid their last egg, varied significantly between years (F= 2.45, df = 5, P = 0.036). As for the onset of laying, the order followed by individuals when they stopped laying was similar each year (Spearman rank correlation test: 1992-1993; n = 26, Rs = 0.647, P < 0.01).

Females which did not lay in 1994 were the birds which stopped laying the earliest in 1993. The difference between the timing of termination of laying in 1993 between the birds which did not lay in 1994 (n = 18, Mean = 17.0, SD = 3.8) and the females which laid during the two seasons (n = 21, Mean = 22.[illegible] SD = 4.9) is significant (Mann and Whitney test: P < 0.001). The birds which stopped laying earlier in the season showed a tendency to lay smaller clutches. In 1992, a year with almost no rainfall in March and April, clutch sizes of the birds which stopped laying in March (Mean = 1.9, SD = 0.7) were significantly smaller than the clutch size of the birds terminated laying later (Mean = 2.7, SD = 0.4 Mann-Whitney test: P = 0.01).

Weather parameters

Temperature and rainfall data are pres ted in Figure 1, as the annual variation maximum ambient temperature (mean m mum per week), and precipitation in num of millimeters per week. Each year, minin temperatures occurred in January, and m ma were reached in June. The ambient ten rature started to decrease at the beginnin October. Rain falls each year between M and May, but during the remainder of the y rainfall was unpredictable. Inter-annual va tion was observed in the distribution of r fall and in temperature. The winters prece 1992 and 1995 laying seasons were par larly wet (Table 3), 1990, 1991 and 1993 w preceded by small rain and 1994 was Springs 1993 and 1995 received heavy r and 1992 was dry. Winters preceding 1 and 1993 were particularly cold (Table 1990 was intermediary, 1991 and 1995 warmer, and in 1994 the winter was par larly warm. Each year, temperature star increase slowly from the beginning of M and the mean maximum ambient temper

TABLE 3

Mean maximum temperature during the coldest week, number of days with maximum ambient temperature than 20°C., temperature variation between December 15 and March 15, winter rainfall (December 1-March 15) mm/sqm, and spring rainfall (March 16 - June 15).

	Mean max. temp. cold. week (°C)	Number of days with t. < 20°C	temperature variations Dec.-Mar.	Winter rainfalls in mm	Spring rainfalls in mm
90	18.1	12	6.6	20	56.1
	20.5	6	3.8	34.6	55.2
	17.6	38	8.9	73	18
	17.4	36	9.3	23.8	100.2
94	23.5	1	2.4	3.4	47.9
95	20.1	5	7.1	41.1	196

ached 30°C. in the middle of April.

Relationship between weather and the laying parameters

The 1994 reproductive season differed significantly from all the other years on record by having the smallest percentage of laying females (Table 1), the smallest clutch sizes, the latest laying season (Fig. 1, Table 2), but also the warmest winter (Table 3). In contrast, 1993 was the coldest year (Table 3) and also the season were birds started laying earlier than in any other year. Clutch size, was also significantly the largest during 1993 laying season. 1992 was similar to 1993 for the laying parameters as well as for the winter temperatures. 1990, 1991 and 1995 were intermediary for temperature as well as for laying parameters. Significant correlations were found between onset of laying (week when the first egg was laid, Table 2) and the mean maximum temperature during the coldest week (Table 3; $R = 0.81$, $P < 0.01$); onset of laying and temperature variation between Decembre and March ($R = -0.91$, $P < 0.01$), and mean maximum clutch size and mean maximum temperature during the coldest week ($R = -0.89$, $P < 0.01$). We did not find any relationship between onset of laying and occurrence of rainfall during the same period.

In spring , the percentage of laying females started to decrease significantly by the end of March and the beginning of April when the maximum ambient temperature reached or increased up to 28°C (Fig. 1). Each year, around 30% of the females stopped laying in March when maxima ambient temperatures were between 23 and 28°C, except in 1994. The birds which stopped laying early in the season the previous years, did not lay in 1994 when the maximum ambient temperature did not go below 23°C. When rainfall occurred at the beginning of April (1991, 1993, 1995) the laying activity seemed to be extented for several weeks. Each year, in the last week of April laying activity was almost nil. When rainfall occur at the end of April, as in 1990, 1993, 1994 and 1995, the laying activity restarted in a certain proportion of females. In 1990, rainfall was followed by a decrease in temperature from 34°C (mean weekly maximum temperature third week of April) to 25°C in the first week of May. Quantity of rainfall in April was less important in 1990 than in 1993 and 1995, the difference in the proportion of females restarting laying activity could be explained by this decrease in temperature. We did not find any relationship between the termination of laying and the annual variation in spring temperature. Nevertheless in 1992, a year with no rainfall in April, all the birds stopped laying before the maximum ambient temperatures reached 30°C.

DISCUSSION

Any environmental factor functionally connected with the oncoming improvement of environmental conditions could act as a synchronizer of reproduction. If the optimum season is annually periodic, fixed annual phenomena could be used, whereas in those areas in which breeding occurs at irregular intervals the synchronizer must be related to the irregular improvement of living conditions and consequently must be independent of the cycle of the sun (Immelmann, 1971). There has been a tendency to claim that birds in arid areas have broken free of the rigidity of regular breeding seasons and that rainfall and its effects are substituted for day length as the supreme synchronizer in arid lands. It appears however, that this may be generally true only in the arid areas of Australia (Serventy, 1971). In contrast, in South West Africa, the reproductive season is more regular, indicating a more obvious internal rhythm of reproduction and less dependence on a single external stimulus such as rain (Immelmann & Immelmann, 1968).

The breeding range of Houbara is characterized by semi-desert habitat in which the occurrence of rain is relatively predictable, with a high probability of rainfall between November and April each year. In the wintering range, temperatures reach a minimum in January and begin to increase in February (Serventy, 1971; Grenot, 1974; Mendelssohn *et al.*, 1979; Haddane, 1985; Mian & Dasti, 1985; Yom-Tov & Tchernov, 1988). Eggs laid in winter and spring will hatch when rainfall and the subsequent increase in food availability are most likely to occur.

In captivity, houbara showed a seasonal breeding pattern, therefore an endogenous rhythm could have evolved to regulate the annual reproductive cycle, comparable to that of species occurring in highly predictable environments. If an endogenous rhythm exists in the houbara bustard, which are the factors synchronizing the reproductive season? Our evidence for the possible action of photoperiod as a proximate factor synchronizing houbara reproductive activity is limited. The latitude of the breeding range (25-40°N) is not incompatible with a photo-induction of gonadal development (Gwinner & Dittami, 1985; Tewary & Dixit, 1986). Nethertheless, photoperiod does not explain inter-annual variations.

Obtaining adequate water is the most vital factor behind physiological and ecological adaptations for animals in semiarid and desert regions (Serventy, 1971). In our captive birds we did not observe any relationship between the onset of laying and rainfall in winter. Prolongation or recommencement of laying in April-May followed significant rainfall, with maximum laying activity recorded around 15 days after rains. In houbara, rainfall could be considered as a subsidiary factor modulating laying activity. Rainfall could also be a limiting factor affecting gonadal development when related to food availability. In captivity, as houbara are fed ad-libitum, the importance of the rainfall could be hidden.

Ambient temperature has been always presented more as supplemental information or as an ultimate factor affecting reproduction (Immelmann, 1971; Wingfield, 1980; Wingfield *et al.*, 1993) than as a proximate factor. Low temperature may act indirectly by reducing the abundance of food for production of eggs, or more directly by diverting energy that would otherwise be used in egg formation (Wingfield, 1980). Rainfall and temperature could be related because tolerance to dehydratation in birds is related to temperature (Serventy, 1971). In our captive Houbara, laying generally began after maximum ambient temperatures decreased to below 20°C. In contrast with north temperate birds, houbara bred earliest in cold and early winters. Moreover, after a warm winter, around 60% of the females did not lay. In the Canary Islands, von Thanner (1910, in Collar & Goriup, 1983) observed that in years without autumn and winter rainfall, houbara bred more than one month early, with the result that offsprings could find a rich supply of insect food before the onset of the heat. Data from two expeditions in Baluchistan during spring 1987 and 1988 (P. Paillat pers. comm.) indicated, that after a winter with almost no rainfall (1988) houbara laying started 15 days earlier (first week of March) and finished one month earlier (first week of April), than after a wet winter (1987). In the Japanese quail, Wada *et al.* (1990), and Tsuyoshi & Wada (1992) showed that ambient temperature is involved in the termination of reproductive activity. The results indicated that in addition to a change from long to short days, low temperatures act as supplementary regulator in causing regression of the gonads. In houbara, temperature could act in the same way, could be the major factor terminating ..ng activity. Detrimental effects of high perature on gonadal activity have been monstrated in birds in which activity signi- antly declines when temperatures rise ove 32°C (For review: Ricklefts & nesworth, 1968; Wingfield, 1980; Simons Martin, 1990). Currently, we believe that nperature has an impact on the onset of the roductive season, and that relatively high nperatures during winter have a detrimental pact on laying activity.

In deserts, where rich resources are short- ed and episodic, one should predict bree- ng adaptations for a rapid activation of productive behaviour and a high reproducti- e rate. Where food and water resources are arce but relatively predictable, efficient use f these resources should be mediated by nechanisms that activate reproduction seaso- ally, but with low reproductive output, cou- led with adaptations to increase longevity of ndividuals (Vleck, 1993). This is the case in houbara, in which seasonnal reproduction, delayed maturity and small clutch-size are characteristic. Clutch size results from a complex interaction of environmental and ontogenetic factors, and models of clutch size evolution assume heritable variation (Cade,1984). Although we did not calculate repeatability in this parameter, it appears that relative clutch size is an individual characteristic in houbara. Environmental factors affecting clutch-size have been extensively studied. These factors could be availability of food and subsequent female body condition, or predictability of clutch predation (Hussell &Quinney, 1987; Martin *et al.*, 1989; Wingfield, 1980; Erikstad *et al.*, 1993). Inter-annual variations of clutch-size that we observed in captive houbara seems not being related to food availability as our birds were fed each year ad-libitum. Haywood (1993) showed that clutch-size in the blue tit (*Parus caeruleus*) is related to ambient temperature. In houbara, we found the largest maximum clutches in 1993 and the smallest clutches in 1994; two years characterized by having the coldest and the warmest winters respectively. As females stopped laying early in the season, and laid on average, smaller clutch-sizes, a relationship between these two parameters reinforces the temperature influence hypothesis.

The complexity of environmental information makes it difficult to separate the effects of one environmental cue from another. While we have developed hypotheses concerning the environmental factors that may synchronize gonadal development in houbara, experiments in controlled conditions are necessary to test these hypotheses. First results of experiment started in 1995 in the National Avian Research Centre of Abu Dhabi (J. Jacquet, pers. comm.) seems to confortate the importance of ambient temperature in the reproductive cycle of the houbara.

In conclusion, the Taif captive breeding Center was built at the southern limit of the breeding range of the houbara, with the result that in some years environmental conditions for reproduction may be far from optimal. This could explain the inter-annual variation in eggs production. Subsequently it is difficult to build estimations, management plan and prospective based on the number of chicks available for release each year. This illustrate the importance of understanding the proximate factors synchronizing gonadal development, in order to correctly siting a captive-breeding facility and to avoid the large expenses involved in creating artificial climatic conditions. In the last few years, captive breeding of Houbara has flourished all over the Arabian world: Saudi Arabia, United Arab Emirates, Morocco. As at Taif, the decision as to where these facilities were built seems not to have always taken into account the environmental factors required for optimal production of eggs.

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