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ORIGINAL ARTICLE

Breeding ecology and behaviour of the last wild oriental Northern Bald Ibises (*Geronticus eremita*) in Syria

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Abstract A relict colony of Northern Bald Ibis (*Geronticus eremita*), a critically endangered species, was unexpectedly discovered in Syria in 2002. During six subsequent breeding seasons (2002–2007), the 3, and then 2, breeding pairs of Northern Bald Ibises have shown to be still vital and, when intensively protected, showed a higher average breeding success than that recorded in Morocco, the only other country where these birds still breed in the wild. During the six breeding seasons, a total of 24 chicks fledged and left the breeding area successfully. Between 2004 and 2007, a total of 5 immature ibises have made a return to the colony, separately and later than adults. As a consequence, two recruitment events have taken place (2006 and 2007), partly compensating for the gradual decrease in the number of adults. Breeding adults arrive from migration during the second half of February, separately, and leave together around mid-July. They nest in cavities and ledges of two limestone cliffs of the central Syria desert, located 20 km apart, well protected from the predominant wind. Breeding behaviour and the cycle are described, summarised and compared with data from the wild colonies of Morocco and the colony of Turkey before the extinction. Key threats still in place at the Syrian breeding quarters are human disturbance during settling and incubation, chick depredation by ravens, uncontrolled hunting and habitat degradation. Recommendations on how to enhance the breeding performance and ensure the survival of this colony in the future are given.

Keywords *Geronticus eremita* · Breeding ecology · Breeding success · Behaviour · Threats

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Introduction

The Northern Bald Ibis (*Geronticus eremita*) is an extremely rare colonial bird listed as critically endangered at a global scale since 1994 (BirdLife International 2004). This bird, traditionally revered in the Middle East and historically elusive (Kumerloeve 1984), has undergone a continuous decline over the last four centuries throughout its original distribution range; this decline accelerated during the twentieth century, with an estimated 98% of the species global population vanishing (Hirsch 1979; Collar and Stuart 1985). The decline of the species within the whole range seems linked to habitat loss, persecution, pesticides and climate change (Collar and Stuart 1985), but, according to some (Hirsch 1979; Bowden et al. 2003), the real reasons are still unclear.

Certainly, during its long-term decline which started centuries ago, the species has been gradually diverging into two disjunct populations (Collar and Stuart 1985), differing either morphologically (e.g. length and color of the bill; Siegfried 1972; Serra, personal observation) and genetically (Pegoraro et al. 2001): a western population surviving in Morocco and Algeria and an eastern one in Turkey and Syria. As the Syrian population had already been declared extinct around or soon after 1928 (Safriel 1980; Baumgart 1995), the Northern Bald Ibis apparently became extinct in

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the wild from the whole eastern range in 1989, when the last survivors of the colony of Birecik, southern Anatolia, were prevented from migrating and became semi-captive (Kasparek 1992).

At about the same time, the Northern Bald Ibis colonies known to still exist in Algeria vanished (Fellous 2006). Until 2002, the Northern Bald Ibis was known to survive in the wild, globally, in the western range only, with about 92 breeding pairs scattered in a few colonies in coastal Morocco (Bowden et al. 2003). That same year, a relict colony of seven individuals was unexpectedly discovered in Syria (Serra et al. 2003). Unlike the remaining western Northern Bald Ibises, which are largely resident, the recently discovered eastern Northern Bald Ibis survivors proved to be migratory, the same as the Turkish birds used to be. As the last survivors of their kind, their migratory behaviour is certainly unique on a global scale, reflecting a possibly unique genetic make-up and migratory experience. This behaviour exposes the Syrian colony to a wider set of threats from a conservation point of view.

In 2006, the migration route through the western Arabian peninsula and the wintering quarters of the relict colony (on the Ethiopian highlands) were discovered through satellite tracking (J. Lindsell et al. 2009). According to an extensive survey conducted in 2002, the sharp population decline in Syria started in the 1980s (Serra et al. 2003): before that, hundreds of Northern Bald Ibises were still breeding in the Syrian desert, scattered in a number of nesting sites, two of which were of remarkable size, amounting to hundreds of pairs (Serra et al. 2003), consistent with reports by Aharoni (1911). Probable causes of this dramatic decline in Syria were identified as chick collection for food by locals, uncontrolled hunting, human disturbance during incubation and also habitat degradation (Serra et al. 2003). The feeding ecology of the relict Syrian colony has been recently described by Serra et al. (2008), while the breeding ecology of the species in Turkey and in Morocco is quite well known (Kumerloeve 1967; Hirsch 1976; Hirsch 1979; Şahin 1982, Sahin 1983a, b, c; Pegoraro 1992; Bowden and Smith 1997; Bowden et al. 2003).

A typical cliff-nesting species, the selection of nesting site seems mainly determined by two key variables: sheer cliffs with natural ledges and holes, ensuring protection from terrestrial predators, at a distance of few kilometres away from suitable feeding terrains (Collar and Stuart 1985; Cramp and Simmons 1998). Nests in Morocco were described by Hirsch (1976) as of two types: open or overhung ledges and holes. In Morocco, surviving Northern Bald Ibises nest on ledges of sheer sandstone cliffs overhanging the Atlantic Ocean, in the Agadir region of south-western Morocco (Bowden and Smith 1997). The nesting habitat of the famous colony of Birecik was a vertical limestone cliff with large and long open ledges, towering above the village along the Euphrates and with a fortress on top (Hirsch 1979).

Old nesting sites in Algeria, reportedly occupied until the 1990s, were also vertical limestone desert cliffs (Fellous 2006). Gesner (1555) recorded breeding of Northern Bald Ibises on the "rocky walls" of the Danube valley at Kelheim and Passau, while Schenker (1977) reported historical records of ibises nesting on the castle rocks of Salzburg. The breeding cycle, breeding performance and behaviour of Birecik's colony until 1989 and of Moroccan colonies over several years have been described in detail (Hirsch 1979; Bowden and Smith 1997; Bowden et al. 2003 , 2008; Akçakaya 1990).

Human disturbance was recorded as having negative effects on the Northern Bald Ibises breeding both in Turkey and in Morocco (Hirsch 1976; Collar and Stuart 1985; Bowden and Smith 1997; Bowden et al. 2008), along with raven depredation (Bowden et al. 2003, 2008). A marked sensitivity to human disturbance at breeding sites versus at roosting sites outside the breeding season was described by Bowden and Smith (1997). Provision of water in artificial water holes near the colony has been proved to enhance breeding performances in Morocco (Smith et al., unpublished).

The present paper aims at describing, discussing and putting the information collected during the period 2002–2007 about the breeding ecology and behaviour of the relict colony of Northern Bald Ibis in the Syrian desert into a conservation context.

Methods

Study area

The territory, included within the 120 mm/year isohyet (rainfall limit), is known regionally as *Al Badia* in the Arabic language (an area corresponding to about half the Syrian land surface): it is commonly defined either as a (semi-)desertic steppe or a rocky desert. We will hereinafter refer to it simply as Syrian desert or *Al Badia*.

The present study was undertaken in the framework of an Italian-funded and UN FAO-run conservation project, based in the millenary oasis of Palmyra (34.562°N, 38.280°E), in the middle of the Syrian desert and partly in the framework of several missions run by BirdLife International and supported by the Royal Society for the Protection of Birds (RSPB) and the National Geographic Society.

The UN-FAO project, in operation between 1996 and 2004, was aimed at assisting the Syrian Ministry of Agriculture and Agrarian Reform (MAAR) to develop the first

operational protected area (*Al Talila*) and at initiating biodiversity conservation in the country. After termination of the UN-FAO project in 2004, external technical assistance was provided to MAAR by BirdLife International in 2006 and 2007 (Serra and Peske 2006).

After the discovery of the Northern Bald Ibis colony in the Palmyra desert, upon a specific recommendation from the UN-FAO project (Serra 2002) a protected area totalling >400 km^2 was established by the Syrian authorities in 2004 over the breeding grounds. This is the area of the present study, located a few tens of kilometres north of Palmyra oasis in an eroded limestone rocky area, at an altitude ranging between 300 and 1,200 m asl, rich in sheer cliffs and *wadis*, inhabited since time immemorial by tribes of indigenous mobile pastoralists.

Temperatures during the Northern Bald Ibis breeding season vary from below zero in January–February (some snow can occur at times) to over 45°C in July. Spring and summer months are usually quite windy, with the direction of the predominant wind being W–NW. Rain falls erratically during November–February totaling an average of ≤120 mm per year.

For conservation reasons, local names and geographical coordinates of sites, and topographic maps are not disclosed here.

Data collection and analysis

During March–April 2002, an extensive ibis search was carried out within the Palmyra desert, through a standard questioning of nomads and hunters, which resulted in the detection of a number of historical nesting sites (Serra et al. 2003), some of which had already been mentioned by Aharoni (1911). Each site was GPS-recorded, photographed and described.

Following the Northern Bald Ibis colony discovery on 21 April 2002, a community-based protection program was established by the UN-FAO project in assistance to the Syrian MAAR which ran for three subsequent breeding seasons (2002–2004). Across these three breeding seasons, local MAAR rangers were in-service trained to protect, monitor and collect data on the ecology and behaviour of the birds at their breeding grounds.

During the period 2005–2007, activities, under BirdLife International umbrella, focused more on trapping and tagging the birds with satellite transmitters. Moreover, the protection of breeding was performed by local trained rangers without external scientific coordination nor assistance in 2005—while they received assistance in 2006 (quite intensive) and in 2007 (medium level).

After the year of the discovery (2002), in order to get the most precise date of arrival from migration, rangers have been daily waiting for the return of the birds to the nesting sites since early February, actively involving the nomads. At the end of the breeding season, extra attention was taken daily in order to obtain the most precise date of migration departure.

Data were collected by trained MAAR rangers supervised by an international biologist using binoculars and telescopes, in the framework of a protection program running from February to July (2002–2004 and 2006–2007). The program was running round-the-clock by establishing a tent in front of the nesting cliff. Distance of the tent was some 800–1,000 m from the nesting cliff. Standard sheets were used to record data. Most data were collected using a combination of opportunistic and systematic approach, given the staff and time constraints.

During the breeding season, birds were closely followed at ranges of 300–1,000 m while at their nesting sites, and most obvious behaviors were recorded, including departures from nests, arrivals, interactions of all types, vocalisations, disturbance events, etc. By closely observing the variation of behaviour at the nest, the date of the first egg laying was recorded quite precisely (assuming that incubation starts when the first egg is laid), as was the hatching of the first chick.

Due to difficulties in reaching a safe vantage point from which to observe the inside of nests, number of eggs and chicks at their earlier stages of development were not recorded systematically. Therefore, neither the incubation success nor the young survival rate could be thoroughly assessed. On the other hand, first flights of chicks around the cliff and the first flight to feeding grounds with adults were quite precisely recorded.

Data about early stages of breeding cycle are missing for 2002, as the colony was discovered on 21 April: the actual nests were in fact surveyed on 18 March 2002, but no birds were detected on that first visit.

Breeding success was calculated by dividing the number of successfully fledged and migrated chicks by the number of pairs which had laid eggs at the beginning of the season (breeding pairs). For sake of simplicity, we here refer to "migrated chicks" as being healthy juveniles observed leaving the breeding area together with the adults (which does not necessarily coincide with the actual start of the migration). Average breeding success was compared between Cliff 1 and 2, without using data from seasons 2002 and 2005, as no protection was in place during the key stage of incubation in 2002 (the month prior to the discovery) at Cliff 2 and protection was significantly reduced for the whole period in 2005 at Cliff 1, compared to the other breeding seasons. Testing a correlation between the breeding success and the rainfall was not sensible due to the small sample size, and the complication of the influence of the two different nesting cliffs. Also, for the same reason, a statistical comparison between breeding

success in Syria and in Morocco and Turkey could not be carried out.

Average duration of incubation (of first eggs), average duration of fledging time (of oldest chicks) and age of oldest fledglings at the time of nesting cliff departure were calculated taking into account the variability due to data imprecision.

Birds were not marked individually but in such a small colony the plumage and also other temporary traits could be used for identification purposes, not only for distinguishing breeding adults from immature ibises but also individual adults during the same season. Identification across seasons could be attempted due to the general pattern of head coloration, behaviour and, since 2006, also from tags and coloured rings placed on three breeding adults (two females, named by rangers "Salama" and "Zenobia", and one male named "Sultan").

Results

Nesting habitat

During breeding seasons 2004–2005 and 2007, the Northern Bald Ibis colony nested at Cliff 1 (Fig. 1), about 400 m asl, while during 2002–2003 and 2006 it nested at a different cliff about 20 km apart (Cliff 2) (Figs. 2, 3, 4, 5), about 800 m asl. Both cliffs are vertical limestone walls: Cliff 1 is S-oriented and about 25 m high while Cliff 2 is SE-oriented and about 50 m high. Both cliffs appear well protected from the predominant fierce W–NW-oriented wind which especially blow during spring and summer.

Nests at both sites were in holes or small terraces with overhanging rocks, 15–20 m from the bottom of both cliffs.

Fig. 1 Nesting Cliff 1 of Northern Bald Ibises (*Geronticus eremita*) (photo by L. Peske)

Fig. 2 Nesting Cliff 2 (photo by G. Serra)

Fig. 3 Nest no. 2 (the niche on the right) at Cliff 2 in 2002; the niche to the left was used by the unpaired 7th adult bird (photo by G. Serra)

Fig. 4 Nests no. 1 at Cliff 2 in 2003 (photo by M.S. Abdallah)

Both cliffs have a sloping escarpment of detritus and rocks at their base: the one from Cliff 2 is much bigger and longer than that from Cliff 1. Key feeding grounds are

Fig. 5 Nest no. 3 at Cliff 2 in 2002 (photo by G. Serra)

Fig. 7 Guano at a historical ibis nesting site (photo by G. Serra)

in a 35- and 13-km radius from Cliffs 1 and 2, respectively (Serra et al. 2008).

One nest from Cliff 2 was actually S-oriented but it had an overhanging rock providing cover from sunshine during the middle hours of the day. One of the two nests at Cliff 1 also had an overhanging rock (nest 1.1), while the other one was quite exposed to the sun (nest 1.2). For instance, in May 2002, two nests of Cliff 2 were in the shadow at noon, while in June the more exposed one was receiving not more than 4.5–5.5 h of direct sunshine per day. In contrast, nest 1.2 from Cliff 1 was receiving about 8 h of direct sunshine exposure per day in June 2004.

Careful observation revealed the possible occurrence of another 10 old nests at Cliff 2 and another 5–6 at Cliff 1, still recognisable by the white dropping marks, several of which were on the inner walls of a cave about 8–10 m high. Empty nests from old nesting sites (Fig. 6) were basically of two different types: holes or niches and ledges. At the two largest old colonies, described by Aharoni (1911), found during searches in 2002 (Serra et al. 2003), the main nest type was the ledge. At three old nesting sites, we found dry guano, with layers piling up to 20–50 cm (Fig. 7). In 2004, another atypical old nesting site was found: a natural open hole on the ground with diameter of about 70 m, formed due to erosion in a flat landscape. About three cavities with guano on the walls of the hole were recognized, although a local hunter reported there were at least eight active nests in the past.

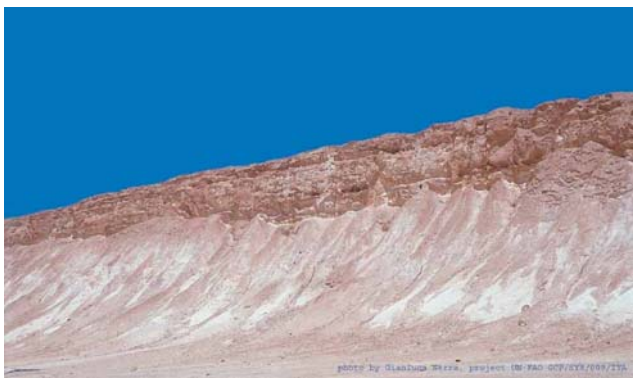

Fig. 6 Historical nesting site cited in Aharoni (1911), reportedly counting hundreds of ibis breeding pairs at the beginning of the previous century (photo by G. Serra)

All presently active nests appeared unreachable by terrestrial predators including humans without climbing gear. Due to the height and cliff structure, nests at Cliff 2 seemed significantly more challenging to be reached by humans equipped with climbing gear than those at Cliff 1. In both cases, humans at the base of the cliff would flush the incubating birds from the nests or could quite easily shoot the chicks before fledging.

Other birds recorded as breeders at Cliff 2 in 2003 and 2006 were: Egyptian Vulture (*Neophron percnopterus*, 1 pair), Lesser Kestrel (*Falco naumanni*, 2–3 pairs), Kestrel (*Falco tinnunculus*, 1 pair), Alpine Swift (*Apus melba*, 3–6 pairs), Pallid Swift (*Apus pallidus,* 5–10 pairs), Rock Dove (*Columbia livia*, 5–10 pairs), Chough (*Pyrrochorax pyrrochorax*, about 20–40 pairs), Brown-necked Raven (*Corvus ruficollis*, 1 pair) and Rock Sparrow (*Petronia petronia*, 10–20 pairs).

One pair of Golden Eagle (*Aquila chrysaetos*) was breeding on an adjacent cliff. Griffon Vulture (*Gyps fulvus*), Short-toed Eagle (*Circaetus gallicus*), Long-legged Buzzard (*Buteo rufinus*) and Cuckoo (*Cuculus canorus*) were sometimes detected in proximity of Cliff 2—at times even perching on it. A Nabatean-type craggy hermit refuge from Byzantine time, excavated inside the rock wall, was located at mid-height of Cliff 2, some 200 m from the ibis nests.

Breeding cycle, breeding success and recruitment

Tables 1 and 2 report the key dates and variability of parameters relative to the breeding cycle of the Palmyra

ibis colony across six seasons, while Table 3 shows a summary of the key figures concerning the breeding performance and recruitment. The number of breeding adults returning at the beginning of spring to the Syrian breeding quarters decreased steadily from seven (2002) to three (2006–2007), and the number of nests has decreased in parallel from three (2002–2003) to two (2004–2007).

All breeding seasons, except 2005, were successful, producing a total of 24 fledglings that went on to migrate. The average breeding success across whole study period is 1.72 ± 1.06 chicks per breeding pair ($n = 6$ breeding seasons). This figure is higher than that recorded in Morocco in the period 1986–1999 (1.00 ± 0.48, $n = 17$; Bowden et al. 2003) and in Turkey in the period 1964–1982 (0.97 ± 0.59, $n = 14$; Collar and Stuart 1985; Akçakaya 1990).

Excluding the breeding failure in 2005, the breeding success of the Syrian colony would have been 2.06 ± 0.72 ($n = 5$). Moreover, Cliff 2 has been more productive (2.10 ± 1.01 migrated chicks per breeding pair, $n = 2$) than Cliff 1 (1.33 ± 1.15, $n = 2$).

No return of immature birds was recorded during years 2002 and 2003, while a total of eight immature ibises have returned to their breeding quarters in Syria desert in 2004 (1), in 2006 (3) and in 2007 (4), separately from adults. Using photos of captive ibises of known age (Proyecto eremita, Spain: M. Quevedo, personal communication; Alpenzoo and Waldrapp project, Austria: K. Kotrschal, J. Fritz and K. Pegoraro, personal communication), we could estimate the age of the 2006 returnees at 2–3 years old.

In fact, those returning for the first time are most probably only five in total: three of the four returning in 2007 are most likely the same three that returned for the first time in 2006. First evidence of actual recruitment took place in 2006 and the second in 2007, when one of the four returnees (returning alone before the other adults) successfully bred with Salam, whose previous year's partner failed to return from migration.

The other three ibis returnees from 2007 showed signs of being stimulated to breed: two mated and built a nest which then failed, while the third copulated with both the two breeding males and built a nest alone which also failed.

A survival rate of young ibises during their first 2–3 years could be estimated across three generations (cohorts from 2002–2003 and 2004)—assuming that all living 3-year-old birds returned—to be around $5/14 = 36\%$.

Behaviour

Northern Bald Ibises returned to their Syrian breeding grounds scattered in groups or even alone. Soon after arrival from migration, the birds typically shifted between the two potential nesting cliffs about 20 km apart. Cliff 1, at a lower altitude than Cliff 2, is always used as a roost by birds during the first weeks after return from migration, given also the low temperatures still often persisting at that time of the year. In a couple of instances, birds were detected at their very moment of arrival from migration: first, they visited Cliff 1 and then Cliff 2, giving calls, possibly scanning for other birds.

During the six breeding seasons observed, ibises chose Cliffs 1 three times and Cliff 2 three times. Since 2004, when the number of breeding pairs became 2, some sort of antagonism was observed between them regarding the selection of nesting site.

In 2004, they started building the nests at Cliff 2 up to mid-March, but then we were surprised to discover that one pair laid at Cliff 1 on 19 March. In 2006, the opposite happened: despite the fact they had already started building nests at Cliff 1, birds at the last moment laid at Cliff 2. In fact, the change of nesting cliff took place the day following an event of human disturbance at Cliff 1 (19 March), at a key stage of the nest settling.

Courtship displays and mating behaviour were recorded soon after arrival from migration. Copulation was observed either at the roosting site or at the feeding grounds. Nest building, carried out by both sexes, started a few weeks before the onset of incubation and continued another couple of weeks after it. Nest material stealing, during the absence of the nest owner, was a commonly recorded behaviour.

Incubation is shared between the two partners. Parents also alternated at the nest during the early chick raising with change-over periods of about 2–4 h.

Typically 3–5 weeks after hatching, sometimes even 8 weeks, chicks started to be left alone in the nest, for short periods to start with. For instance, on 11 May 2002, the chick of one nest was left for the first time unattended for at least half an hour in the early morning; the chick already had primary and secondary feathers developed, and looked restless and was already flapping its wings at the edge of the nest. The same day, the chicks of the other nest were also left unattended for 25 min in the early morning. In the second half of May 2002, the duration of the absence from the nest of the parents was variable, on average 2 h 30 min ± 41 min ($n = 10$).

At a later stage, when the chicks had reached a larger size, they were left alone at the nest most of the time, while the two parents were away together at the feeding grounds, despite the presence of Egyptian Vultures and Brown-necked Ravens patrolling the cliff. For instance, on 23 May 2002, the chick from one of the two nests stayed about 4 h, continuously, unattended at the nest. In parallel, the foraging trips of parents become increasingly longer, sometimes totalling half a day; at this stage, we recorded only 2 or 3 feeding visits at nest by each parent per day.

Table 1 Key dates of breeding seasons of Northern Bald Ibises (*Geronticus eremita*), 2002–2007

Breeding season	Spring migratory return	Cliff	Nests	First egg laying	First egg hatching	Chicks seen in nests	Chicks left alone in nest for first time	First flight from nest of older chick	First flight of chicks to feeding grounds	Departure from nesting site
2002	N/A[a]	2	no. 1	after 18 Mar	26 Apr	2	11 May	3 Jun	10 Jun 3 chicks	7–10 Jul (6 ad and 3 chicks), 12 Jul (1 ad)
			no. 2	after 18 Mar	23–24 Apr	2[b]	11 May	5 Jun		
			no. 3		N/A	N/A[c]				
2003	22 Feb (4 ad), 24 Feb (2 ad)	2	no. 1	19–20 Mar	16–17Apr[d]	4[e]	2 May	2 Jun[f,g]	13 Jun 1 chick, 15 Jun 4 chicks, 16 Jun 6 chicks, 17 June 7 chicks	9 Jul (5 ad and 7 chicks)[h]
			no. 2	23 Mar	24 Apr	N/A	17–20 May	8 Jun[g]		
			no. 3	24–25 Mar	22–23 Apr	N/A	6–10 May	8 Jun[g]		
2004	17 Feb (3 ad), 20 Feb (2 ad), 9 May (1 imm)	1	no. 1	21–22 Mar	21 Apr	3	N/A	3–8 Jun	11 Jun 2 chicks?	13 Jul (5 ad, 1 imm and 4 chicks)
			no. 2	19 Mar	N/A	1	N/A	N/A	N/A	
2005	14 Feb (1 ad), 19 Feb (2 ad), 24 Feb (1 ad), 2 Mar (1 imm)	1	no. 1	19 Mar	N/A	2	N/A[i]			19 Jun (5 ad)
			no. 2	23 Mar	after 6 May	3	7 May	29 May[j]	1 Jun 2 chicks[k]	
2006	18–19 Feb (3 ad), 22 Feb (1 ad), 1 May (2 imm), 7 May (1 imm)	2	no. 1	26 Mar	N/A	3	16 May	6 Jun[l]	15–17 Jun 6 chicks	18 Jul (4 ad, 3 imm, 6 chicks)
			no. 2	1 Apr	N/A	3	26–29 May	6 Jun[l]		
2007	31 Jan–1 Feb (1 subad), 25 Feb (Sultan), 28 Feb (Zenobia), 12 Mar (Salam)[m], 1 Apr (1 imm), 6 Apr (1 imm), 12 Apr (1 imm)	1	no. 1 (Sultan & Zenobia)	29–30 Mar	N/A	2[n]	N/A	10 Jun[o]	17–21 Jun 4 chicks	12 Jul (4 ad, 3 imm and 4 chicks)
			no. 2 (Salam & subad)	26 Mar	N/A	3	N/A	12 Jun[p]		

[a] As reported by locals, birds were seen in February for the first time in the season: the nesting site (Cliff 2) was found empty on 18 March and then, on 21 April, three incubating pairs were discovered

[b] One chick was lost between 20 and 22 May

[c] Perhaps found chick remains below the nest in May

[d] Last egg hatched on 26 April

[e] Four eggs seen on 10 April; one chick disappeared before 2 May

[f] Second oldest chick flew on 7 June

[g] By 11 June all chicks had undertaken the first flight

[h] One adult disappeared in early July: reportedly, it was shot by foreign poachers

[i] Nest destroyed on 11 May, most probably by ravens

[j] Two chicks fledged

[k] Two chicks disappeared the same day

[l] Last chick fledged on 13 June

[m] As shown by satellite tracking, return of Salam was delayed most probably due to having lost her partner during migration

[n] A third chick was lost early due probably to raven (or Egyptian Vulture) depredation

[o] Second chick fledged on 14 June

[p] Second chick fledged on 13 June and third chick on 20 June. The third and youngest chick fledged well, left the nest and flew without problems: it stayed around the nesting cliff for 2 days, alone, and then disappeared

Table 2 Variability of key breeding parameters from seasons 2002–2007

Breeding parameter	Calendar variability	No. of breeding seasons (years)	Notes
Earliest/latest spring migratory arrival of adults at breeding grounds	14–25 Feb/20 Feb–12 Mar	5 (2003–2007)	1. Not including subadult arrived between 31 Jan and 1 Feb 2007 2. The earlier sighting of ibises reported by locals for year 2002 was in February
Spring migratory arrival of immature at breeding grounds	2 March–9 May	4 (2004–2007)	
Colony departure from nesting site	7/10–18 Jul	5 (2002–2004 and 2006–2007)	In 2005, the colony failed the breeding and left the nesting site on 19 June at the same time when an intensive trapping scheme was in operation
Earliest/latest dates of first egg laying	19–26 March/22 March–1 April	5 (2003–2007)	In 2002, first egg laying started not earlier than 18 March
Earliest/latest dates of first egg hatching	16 or 17–23 or 24 April/24–26 April	2 (2002–2003)	
Earliest/latest dates of chicks left alone in the nest	2–16 May/17 or 20–26 or 29 May	3 (2002–2003 and 2006)	
Earliest/latest date of first fledging from nest	29 May–10 June/ 5–12 June	6 (2002–2007)	
Oldest chicks following adults to feeding grounds for first time	1–17 June	6 (2002–2007)	
Earliest date of all fledged chicks following adults to feeding grounds	1–21 June	6 (2002–2007)	

Breeding parameter	Error variability (data imprecision)	No. of breeding seasons (years)	Sample size
Average duration of incubation (of first eggs)	30.25 ± 2.22–31.5 ± 1.29 days	2 (2003–2004)	$n = 4$ nests
Average duration of fledging time (of oldest chicks)	44.33 ± 3.08–45.67 ± 3.72 days	3 (2002–2004)	$n = 6$ nests
Average age of oldest fledglings at the time of departure from nesting cliff	77.67 ± 3.77–80.83 ± 5.08 days	3 (2002–2004)	$n = 6$ chicks

In 2002, the whole flock of seven adult birds would usually leave the nesting cliff before sunrise. The last feeding trip of the day was regularly concluded with the return to the breeding cliff at dusk, about half an hour after sunset.

After following the adults to the feeding grounds, the whole colony would leave the nesting site early in the morning and spend the whole day at the feeding grounds, returning for roosting at the nesting site about half an hour before dark. At the feeding grounds, adults were observed still feeding the chicks, and the chicks begged for food using the typical posture with wings kept low to the ground and their vibrating neck and bill extended.

Soon after the chicks followed the adults to the feeding grounds, the roosting site could become different from the actual nesting site: due to the significant difference of the distance of Cliffs 1 and 2 from key feeding grounds, during years of nesting at Cliff 1, birds would start roosting at

Table 3 Summary of key figures relatively to breeding seasons 2002–2007

Breeding season	Adults returned in spring	Immature returned	Immature returned for the first time	Nests (n)	Fledglings departing from nesting site in summer	Average breeding success
2002	7	0	0	3	3	1
2003	6	0	0	3	7	2.3
2004	5	1	1	2	4	2
2005	4	1	0	2	0	0
2006	3 + 1 recruit	3	3	2	6	3
2007	3 + 1 recruit	3	1	2	4	2

Cliff 2, soon after the chicks were able to follow the adults to the feeding grounds. This habit created a severe problem for the third and youngest fledgling from nest no. 2.2 in 2007 which was, for this reason, lost (see next section). Immature ibis returnees often tended to stay on their own, while perching at the cliff or feeding, especially those returning together, indicating a quite strong social bond—in fact most likely they belonged to the same cohort.

From satellite tracking, it was known that, soon after leaving the breeding area on 12 July 2007, the whole ibis flock moved to a large cliff, a historical ibis nesting site, about 53 km to the west of Cliff 2, which was used as a roost for about 1 week before departure on the migration southward.

Mortality and threats

Reportedly, in the past, it was a common practice among Bedouin nomads of Palmyra desert to collect chicks from nests as food, by descending the nesting cliffs from the top using ropes: we cannot exclude that this practice was still alive in the years before the colony was discovered. During the study period, we recorded several events of human disturbance during the pair settling, incubation and chick raising. In early April 2003, young truffle collectors were detected throwing stones at the incubating birds from the bottom of the cliff: in response to this, a bird from one nest left the eggs unattended for 15 min, which apparently did not cause any major harm to them.

On 27 April 2003, a Bedouin shepherd with his herd passed the base of the nesting cliff during the early chick raising; the ibis parents flew away, giving calls, when the shepherd reached 50–80 m from the base of the cliff. Soon after the shepherd had moved about 80 m away, the parents came back to nests. The total duration of the parents' absence from the nest was 13 min; during this time, the chicks flattened on the bottom of the nest almost disappearing from sight. In a similar situation, on 15 May 2003, parents returned to nests after 2 h and 10 min. Disturbance of breeding pairs and chicks by immature non-breeding ibises was also observed both at Cliffs 1 and 2 in 2006 and 2007, respectively.

At least two chicks were lost at an early stage, about 2–3 weeks after hatching, to unknown causes in 2002 (possibly due to intense spring late rain), and 1 chick was lost while still in the nest in 2007, possibly due to raven (or Egyptian Vulture) depredation. Severe raven disturbance and depredation was observed in 2005 and in 2007 at Cliff 1. On 11 May 2005, soon after chicks were first left alone, nest no. 1 at Cliff 1 was probably visited by ravens during the absence of parents and all chicks disappeared from it. There were at least two pairs of ravens, rearing their chicks, near the ibis nests. On the other hand, in 2007, breeding failure was narrowly averted by trained rangers thanks to intensive dawn-to-sunset guarding of ibis nests and to focused disturbance at raven nests for about 20 days in May.

Two chicks were lost the same day they followed the adults to feeding grounds in 2005 for unknown reasons, and another one, the youngest chick fledged last, was lost in 2007 as it was abandoned by parents because it was apparently unable to fly all the distance to feeding grounds like the older chicks; and because the whole colony stopped returning to the nesting cliff for roosting. Soon after losing the fledglings in 2005, adults avoided both nesting cliffs and started roosting on a sub-optimal short cliff adjacent to Cliff 2, and finally left the breeding site earlier than usual, on 19 June, during the time an intensive ibis trapping scheme was in operation. Finally, one breeding adult was most likely killed at an artificial reservoir not far from Cliff 2 in early July 2003, according to locals' reports, by a party of foreign hunters.

Overall, the most severe threats against the breeding (and survival) of Northern Bald Ibis in the Syrian desert, recorded during the study period and reported from the past, were:

- chick collection as food (not occurring any more due to protection and scarcity of birds)
- human disturbance during nest settling and incubation (still ongoing; controllable through intensive protection)
- disturbance and depredation by ravens and possibly by other birds (still ongoing; controllable through intensive protection)
- trophy poaching combined with a lack of safe drinking points (reduced but still ongoing; controllable through intensive protection)
- degradation of feeding habitats (still ongoing; acute especially during dry years)
- degradation and/or destruction of feeding sites due to development (e.g. building of infrastructures or oil companies prospecting operations and drilling).

In addition to the above threats, due to the extremely low numbers of breeding pairs, a high inbreeding genetic depression should also be expected in the short and medium term and should be added to the list.

Discussion

Nesting habitat

The two nesting sites occupied in Syria since 2002—and all the old nesting sites discovered during the extensive search in 2002 (Serra et al. 2003)—correspond to the

descriptions made by Aharoni (1911) for Syria: ledges and holes on sheer cliffs, sometimes extending for long distances through flat open desert, steep gorges and sometimes even short rock faces. This nesting habitat seems very similar to that used in Algeria until the early 1990s (Fellous 2006), and it is ecologically equivalent to that used in Turkey, Morocco and, centuries ago, in southern Europe (Hirsch 1979; Collar and Stuart 1985; Bowden and Smith 1997).

Both currently used nesting sites in Syria are oriented in such a way as to avoid the predominant wind, consistent with what was reported by Akçakaya (1990): in fact, the wind in Palmyra can be very fierce during spring and summer. All three nests on Cliff 2 and one nest on Cliff 1 seem to receive max 4–5 h per day of direct sunshine during the early summer, consistent with what was reported by Hirsch (1976, 1979) for Turkey and Morocco. On the other hand, nest 2.2—the most exposed one of all—did not show any significantly lower breeding success compared to the others.

During the 2002–2004 searches, three interesting nesting sites were found. In one instance, we recognised a small old nesting site of about 5 nests on a limestone wall only 5–7 m high (see Collar and Stuart 1985), originated by the erosive action of a medium sized *wadi* (see Collar and Stuart 1985). Another nesting site was found inside a vertically shaped cave with entrances from the bottom and at the top, consistent with a Moroccan colony described by Géroudet (1965) and with old nesting sites along the Euphrates in Turkey described by Kumerloeve (1967). The detection of old nests on the walls of an underground hole, over a quite flat terrain, is also an atypical nesting site, apparently never recorded before.

An interesting observation, apparently not mentioned before in the specific literature, is that of the occurrence of guano found in at least four different old nesting sites, the same kind observed in a picture presented by Fellous (2006) relative to Algeria's old nesting sites. It seems unlikely that this guano was produced by any bird species other than the Northern Bald Ibis. The height of Cliff 2 is in the range of those used in Morocco, while the height of Cliff 1 appears substantially smaller (Bowden and Smith 1997). However, the height of nests, measured from the base of the cliff, recorded in Syria at both currently used nesting sites is in the same range reported for Morocco (Bowden and Smith 1997).

The altitude of both nesting sites in Syria is significantly higher than that of remaining colonies in Morocco and the semi-captive colony of Birecik. The distances of key feeding grounds from both nesting sites in Syria (Serra et al. 2008) are comparable to those reported in the literature relating to Turkey and Morocco (Hirsch 1979; Bowden et al. 2008). The feeding areas used by ibises at their breeding grounds are heavily degraded in line with the general ecological degradation of the Syrian desert (Serra et al. 2008).

Breeding cycle

Adults often arrived separately to the Syrian breeding quarters but left for migration all together. Taking into account possible biases due to the small number of individuals in Syria, dates of arrivals from migration are consistent with those reported for Birecik (Hirsch 1979). Interestingly, the ibises in Morocco are also reported to return to the nesting site by mid-February (Hirsch 1979). Dates for the start of nest building and its duration are also consistent with figures reported for Birecik (Hirsch 1979). Timing for first egg laying in Syria overlap with those reported for Birecik, while it is delayed a couple of weeks compared with Moroccan colonies (Bowden et al. 2003).

Incubation period recorded in Syria appears as 3 days longer than that recorded in Turkey (Hirsch 1979; Sahin 1983b), although this may be due to the small samples involved in both Syria and Turkey. Our data clearly confirm that the report of chicks in March in Syria was erroneous (Collar and Stuart 1985). Fledging time of 44–45 days matches well with the time reported for Birecik (Hirsch 1979; Cramp and Simmons 1998; Akçakaya 1990). However, the period reported by Hirsch (Hirsch 1978, 1979) between the first time chicks accompanied adults to feeding grounds and the departure from the nesting site is shorter in Turkey (18 and 28 June, respectively) and half that recorded in Syria (Akçakaya 1990; Pegoraro 1992).

This could be explained by the very different feeding ecology conditions in Syria and in Turkey. On the other hand, as satellite tracking revealed in Syria in 2007, the departure from the nesting site does not necessarily imply the actual start of the migration. The quite early departure from Birecik's breeding quarters, when the ibis colony was still fully wild, could be explained by a transfer of the colony to a different roosting cliff within the region—perhaps even joining the Syrian colonies some hundreds of kilometres south for a few weeks before starting the actual migration. The early departure from the breeding quarters recorded in 2005 in Syria (19 June) might be better explained by the disturbance associated to the intensive attempts of trapping for the sake of satellite tagging than to the breeding failure itself.

Breeding success and recruitment

The relict colony of Palmyra is tiny but remarkably vital: when intensively protected—through external technical assistance (2002–2004 and 2006–2007)—the average breeding success recorded was higher than the records from

Morocco and Turkey—the difference being even more evident when calculating the breeding success using the chicks fledged from nests instead of those fledged and migrated.

However, the comparison with the breeding success in Turkey is not necessarily a meaningful one, as the breeding performance of the Northern Bald Ibises of Birecik during the period 1960s–1980s was already quite negatively affected by several human factors which ultimately caused the colony's extinction (Akçakaya 1990; Pegoraro 1992).

The average breeding performance certainly appears lower at Cliff 1 than at Cliff 2 probably due to at least two factors: a higher vulnerability of Cliff 1 to raven depredation and a significantly longer distance of Cliff 1 to the main feeding grounds. Most likely due to this latter reason, three chicks were lost in two different breeding seasons (2 in 2005 and 1 in 2007), consistent with similar observations made in Morocco (C. Bowden, personal communication).

It is in fact one of the two ibis pairs which apparently "force" the other one to nest at Cliff 1; this pair, which is probably dominant over the other, seems to regularly occupy the best nest, leaving the other pair with a nest more exposed to sunshine (although other factors may be involved), consistent with Akçakaya (1990).

The fact mentioned by Hirsch (1976), that long daily sun-exposure depressed the breeding success in Birecik, seems not to be confirmed from the preliminary observations made in Syria.

The immature ibises returning in 2004 could have either hatched in 2001, before the discovery, or in 2002—the year when three chicks fledged and migrated. Most probably this same immature finally recruited into the colony in 2006, by mating with one of the tagged breeding females (Salam). However, it did not come back from its wintering quarters in 2007.

The three immature ibises that returned in 2006 could well have been the survivors from the 2003 cohort—when seven chicks migrated successfully—based on the following observations:

- the apparent same age and close kinship of the three returnees
- the remarkably high number of fledged and migrated chicks during that breeding season seems to match well with the high number of returnees
- the number of returnees is consistent with the expected mortality rates starting from an initial number of seven chicks migrated
- their estimated age of 2–3 years old according to plumage.

The subadult that returned on its own to the breeding grounds in early February 2007 could also have been a 3-year-old survivor from the breeding season 2004, when four chicks had migrated successfully; it is most likely the bird which recruited into the colony by mating with the tagged female (Salam). The fact that it returned much earlier than the other returnees suggests its use of separated wintering grounds relative to those used by different cohorts of immature ibises.

The fact that no occurrence nor return of immature ibises were recorded during breeding seasons 2002 and 2003 could be interpreted as a breeding difficulty experienced by the ibises in the years prior to the discovery. In fact, during the study period, human disturbance at nest, raven depredation and uncontrolled hunting were recorded every year.

Behaviour

The Northern Bald Ibises breeding in Syria were observed arriving from migration in smaller units, consistent with what used to be observed for Turkish ibises in the past (Akçakaya 1990), while the migratory departure seems to occur in a more synchronised fashion. The observation that the roosting site soon after arrival from migration often did not coincide with the actual nesting site is consistent with reports from Birecik (Hirsch 1979).

Courtship behaviour of mates involving mutual billing and preening was observed in line with the records from Birecik (Hirsch 1979, Pegoraro 1992). The observed changes of nesting site just shortly before the egg laying is consistent wigh what has been reported from Morocco (Bowden et al. 2003). The last-minute change of nesting cliff in 2004 might have been caused either by the quite late low temperatures in the area or by the occasional presence of Griffon and Egyptian Vultures at ibis nests, while the change observed in 2006 was most probably due to human disturbance. Disturbance to breeding pairs and chicks by unmated adults and by immature ibises were also recorded (Bowden and Smith 1997).

Mortality and threats

Brown-necked Raven seems the most serious nest-predator of Northern Bald Ibis at its Syrian breeding quarters (Aharoni 1911; Heim de Balsac 1924; Jourdain 1929; Ruthke 1966). In fact, this is the only clear disturbance and depredation—other than human—we recorded in Syria, similar to what was recorded in Morocco for Common Raven (Bowden and Smith 1997; Bowden et al. 2003, 2008). Eagle Owls (*Bubo bubo*) occur in the ibis breeding area but it is not easy to collect evidence for this kind of depredation. Predation by Egyptian Vulture on young ibis chicks at the nest is suspected but not confirmed. Human disturbance in Syria, inducing desertion, was recorded as early as Aharoni (1911).

The Northern Bald Ibis protection program in place in years 2002–2004 and 2006–2007 was certainly able to halt the nest depredation by humans—if any was still occurring prior to the discovery—and curb the depredations by ravens. After the breeding failure of 2005, special care was taken in 2006 and 2007 to protect the nests from ravens and other predators, and this was successful. Intensive protection certainly significantly diminished human disturbance during settling and incubation periods. Also, the risk of hunting was addressed at the nesting cliff, and it was significantly decreased at the frequented artificial reservoir and at feeding grounds. Nonetheless, these threats are still present.

Conservation implications

Based on the above discussed information, the following recommendations are formulated.

Institutionalise sound protection at breeding quarters The lack of returning of immature ibises in the years soon after the discovery together with the failure of breeding in 2005 seems to be clear evidence that the survival of this relict Northern Bald Ibis colony directly depends on intensive protection at the breeding grounds in Syria. The protection program must be carried out by trained rangers and guards, and scientifically coordinated by an experienced ornithologist. The ibis protected area is in urgent need of clear demarcation and stricter enforcement of the protection measures; it is recommended that it is developed in terms of staff capacity and equipment, and in terms of sound management. Until this is achieved, external technical assistance is needed. It is urgent to act, as recent development pressures emerged within the protected area in the form of oil concessions, building of infrastructures and urbanisation plans. The protection program should also be extended to the roosting cliff outside the protected area for the brief period after the ibises leave the breeding grounds (July–August).

Management measures at breeding quarters The provision of artificial ponds with fresh water in front of the nesting cliff has already proven to be attractive for breeding ibises in Syria (Serra and Peske 2006), similar to what has already been extensively tested in Morocco, where provision of water was shown to significantly improve breeding performance (Smith et al., unpublished). In addition, this measure prevents birds from using an artificial reservoir as a drinking source, which can be a dangerous site due to occurrence of hunters. Control or targeted disturbance of ravens nesting close to ibis nesting site should be carried out every year, before the return of ibises, following advice from Bowden et al. (2003) for Morocco. Another possible measure that should be discussed is to induce the two remaining pairs to nest at Cliff 2, instead of at Cliff 1: in fact, Cliff 2 is the nesting site closer to key feeding sites and less vulnerable to raven depredations, as reflected by the higher breeding success. Also, any form of provision of additional food during periods of severe drought should be taken into serious consideration in the short term.

Reinforcement with Turkish semi-captive Northern Bald Ibises Because the number of individuals of the Syrian ibis colony remains dangerously low, and because the risk of inbreeding is high, a reinforcement operation is currently under discussion at the level of International Advisory Group for Northern Bald Ibis. The proposed idea would be to release at the Syrian colony a few chicks raised by semi-captive ibises of the Birecik colony (Turkey)—or from derived captive stock placed in Palmyra in the near future—benefiting from the know-how developed in the past years by the Konrad Lorenz Forschungsstelle (Kotrschal 2001; Fritz 2004). The Turkish semi-captive ibis are likely to belong to the same genetic pool as the Syrian ones.

Involving the local community Because the Northern Bald Ibis breeding quarters in Syria are traditionally inhabited by indigenous mobile pastoralists (Bedouin) since time immemorial, any attempt to develop a protected area without involving them and without addressing their socio-economic needs will be clearly ineffective in the medium and long term.

Rehabilitation of pastures The Northern Bald Ibis breeding quarters are ecologically degraded similarly to the rest of *Al Badia* (Serra et al. 2008). Overgrazing by sheep and shrub uprooting for firewood are the proxy causes for the degradation of ibis breeding quarters, while the land tenure regulation seems the most important underlying cause for it. A rehabilitation of pastures cannot be conceived without addressing the national land tenure issue (Rae 2000, 2002) and without a full participation of the local community (Mirreh et al. 2001).

Research Further research at Northern Bald Ibis breeding grounds is needed to acquire a better understanding of:

- the auto-ecology of the colony: diet, feeding ecology and behaviour, etc.
- the factors affecting breeding success
- social behaviour and the feasibility of a future reinforcement option.

National Action Plan All the above listed and most urgent recommendations should be incorporated in a National Action Plan for Syria, with full involvement of the Syrian authorities and stakeholders; this was done in

Morocco in 1997 (Bowden et al. 2003) where it is currently being updated, and it is a specific recommendation of the International Action Plan for Northern Bald Ibis (Jimenez Armesto et al. 2006).

Zusammenfassung

Brutökologie und Verhalten der letzten wildlebenden Waldrappe (*Geronticus eremita*) in Syrien

Eine kleine Kolonie von Waldrappen, einer stark gefährdeten Vogelart, wurde 2002 überraschend in Syrien entdeckt. In sechs aufeinander folgenden Brutjahren (2002–2007) zeigten die drei, später zwei, Brutpaare der Waldrappe, dass sie überlebensfähig sind, und sie zeigten bei intensivem Schutz einen höheren durchschnittlichen Bruterfolg als aus Marokko bekannt, dem einzigen anderen Land, in dem diese Vögel wild brüten. Während der sechs Jahre der Beobachtung schlüpften insgesamt 24 Küken und verließen das Brutgebiet erfolgreich. Zwischen 2004 und 2007 kehrten fünf immature Waldrappe in die Kolonie zurück, unabhängig von und später als die Adulten. Zwei dieser Jungvögel rekrutierten (2006 und 2007), so dass damit der Rückgang an Adulten teilweise kompensiert werden konnte. Brutvögel kehren vom Zug in der zweiten Februarhälfte einzeln zurück und verlassen das Gebiet gemeinsam um Mitte Juli. Die Vögel nisten in Hohlräumen und Vorsprüngen zweier Kalksteinklippen in der zentralen Syrischen Wüste, etwa 20 km auseinander und gut geschützt vor den vorherrschenden Winden. Brutverhalten und -zyklus werden beschrieben, zusammengefasst und verglichen mit Daten aus den Kolonien aus Marokko und aus der Türkei (inzwischen erloschen). Entscheidende Bedrohungen der syrischen Kolonie sind Störung durch Menschen während der Revierinbesitznahme und der Brut, Predation auf Küken durch Raben, unkontrollierte Jagd und Habitatsverschlechterung. Es werden Empfehlungen gegeben, wie die Brutleistung erhöht werden kann und wie der Bestand dieser Kolonie für die Zukunft sichergestellt werden kann.

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