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Feeding ecology and behaviour of the last known surviving oriental Northern Bald Ibises, *Geronticus eremita* (Linnaeus, 1758), at their breeding quarters in Syria

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Abstract. The last handful of individuals from the eastern population of the critically endangered Northern Bald Ibis (*Geronticus eremita*) have been closely observed and monitored during the breeding seasons 2002-2004 and 2006 in their breeding quarters in the Syrian desert. The home range used by the ibises was estimated to be up to about 450 km², which was already partly included in a specific protected area established by the Syrian authorities in 2004. Their main feeding habitat was a stony and sparsely vegetated open and gently undulating steppe. This feeding habitat is heavily overgrazed by the sheep flocks of the Bedouin nomads, and the native shrub coverage has almost completely disappeared due to uprooting for firewood. Another key feeding habitat are the man-made reservoirs, where ibises fed on larvae of Eastern Spadefoot Toads (*Pelobates syriacus*), perhaps the most profitable prey occurring at their breeding quarters. The bulk of the diet of Syrian breeding ibises is estimated to be a mixture of beetles (mainly ground beetles, Tenebrionidae), grasshoppers (Acrididae) and young toads – all found to be preyed upon by ibises. A ground mantis and an isopod species, as well as lizards, may possibly be important components of the diet as well. A daily need for drinking water was found. Ibises seemed to hunt their prey both by sight and by probing with the tip of the bill in underground holes and under stones. The foraging behaviour of ibises was highly gregarious and quite conservative during each breeding season and over the years: they tended to use the same feeding areas from year to year, with a similar temporal sequence. Ibises fed at increasingly higher feeding areas throughout the breeding season, starting from about 400 m asl in February and reaching about 950 m asl in June-July.

Key words. *Geronticus eremita*, critically endangered, Syrian desert, Middle East, feeding habitats, diet, behaviour.

Introduction

The Northern Bald Ibis, *Geronticus eremita* (Linnaeus, 1758), is an extremely rare colonial cliff-nesting bird listed as Critically Endangered on a global scale (IUCN 2006). This bird has undergone a continuous decline over the last four to five centuries throughout its original distribution range (HIRSCH 1979, COLLAR & STUART 1985). During this period, the species has been gradually diverging into two disjunct populations (COLLAR & STUART 1985), differing morphologically (slightly) and genetically (PEGORARO et al. 2001).

The Bald Ibis was considered to have become extinct from the whole of its eastern range in 1989, when the last survivors of the colony at Birecik, southern Anatolia, were prevented from migrating and were held in semi-captivity (KASPAREK 1992). Until 2002, the Bald Ibis was known to survive only in its western range, with about 92 breeding pairs scattered in a few colonies in Morocco (BOWDEN et al. 2003). That same year, a relict colony of 7 indi-

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viduals was unexpectedly discovered in Syria (SERRA et al. 2003), even though the species had been regarded as extinct in that country around or soon after 1928 (SAFRIEL 1980, BAUMGART 1995).

Unlike the western ibises which are largely resident, the recently discovered eastern ibis survivors proved to be migratory, as the Turkish ibises used to be, a behaviour confirming a unique genetic make-up on the global scale. This behaviour makes the Syrian colony highly vulnerable at present from a conservation point of view.

The feeding ecology of the breeding Bald Ibis is known to be quite conservative across its recently known range: from Turkey to Morocco, where the preferred feeding habitats that have been observed were open terrains with low and sparse vegetation, sometimes stony and rocky or sandy, in addition to marshes, river banks, and cultivated areas (HIRSCH 1979, 1981). In Syria the species was considered to be a desert-dweller, apparently avoiding water (COLLAR & STUART 1985), and according to HIRSCH (1979) it rarely drank water at all in Turkey. The diet is reported to consist mainly of invertebrates (with a specific preference for ground beetles and grasshoppers), small amphibians and reptiles (COLLAR & STUART 1985). The feeding behaviour also appears to be conservative: birds usually feed in loose groups, searching for their prey on the ground either by visual contact or by searching in cracks and under stones and by probing in holes (COLLAR & STUART 1985).

The present study aims at providing some preliminary information about the feeding ecology and behaviour of the recently discovered Bald Ibis colony at its breeding quarters in the Syrian desert.

Material and methods

The environment included within the <120 mm/year rainfall limit is known regionally as *al badia* in the Arabic language, and corresponds to some 55% of the whole Syrian land surface: it is commonly defined either as a (semi-)desert steppe or a rocky desert. We will refer to it herein simply as Syrian desert or *al badia*. The present study was undertaken within the framework of an Italian-funded and FAO-run conservation project, based at the oasis of Palmyra (34.562°N, 38.280°E), in the middle of the Syrian desert.

The 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 nature reserve (*al talila*) and to initiate biodiversity conservation in the country. The study area is located a few tens of kilometres north of Palmyra oasis in a limestone rocky plateau area, at altitudes ranging between 300 and 1200 m asl, rich in sheer cliffs and *wadis*, inhabited since time immemorial by a tribe of indigenous mobile pastoralists. For reasons of conservation, local names, geographical coordinates of sites, and topographic maps are not disclosed here.

After the discovery of the relict Northern Bald Ibis colony in the Palmyra desert and upon a specific recommendation from the FAO project (SERRA 2002), a protected area was established by MAAR in 2004 for the ibis breeding grounds, covering a total area of about 230 km². During the three subsequent breeding seasons of 2002-04, and in 2006, an intensive community-based protection programme was established in the ibis breeding area, coordinated by GS, running from February throughout July. Local MAAR rangers were in-service trained to monitor and collect data on the ecology and behaviour of the birds at their breeding grounds, using telescope, binoculars and standard log datasheet. When the FAO project was terminated in spring 2004, no external technical assistance could be provided to the Syrian authorities during the 2005 breeding season.

The study period thus comprised a total of four breeding seasons: 2002-04 and 2006. Sites with a surface area >100-200 m² used by birds for feeding for >30 min were considered as feeding

sites (*sensu* BOWDEN & SMITH 1997), and they were therefore closely observed, described, mapped by means of a GPS device, and photographed. Birds were followed to feeding sites by visual contact. In fact, the open terrain, the limited numbers and distance of feeding sites used by the birds, their conservative and predictable behaviour during the day and from day to day, the significant amount of time invested in observation by rangers and guards by means of good quality binoculars and telescope, made this low-tech method feasible and cost-effective.

Bald Ibises were followed by rangers to the feeding sites at least 3-4 times per week by means of a 4x4 vehicle, or sometimes by motorbike. The behaviour of the birds was observed for variable periods according to the time available, and identification of the prey taken was sometimes attempted from a distance by means of a telescope. Special attention was paid to disturbance events and to any other interaction of birds with humans and livestock that took place at the feeding areas.

Dry droppings and pellets were collected under the three ibis nests on four subsequent occasions during the breeding season 2002 (12 May, 27 May, 15 June, 30 June 2007). Due to the extreme dryness of the samples, keeping each single collected item separated was not feasible. In 2002, macro-invertebrates, amphibians and reptiles were sampled between May and June within the most used observed feeding sites, ensuring that all types of feeding habitats were covered.

Straight-line transects of 20 minutes were walked, collecting all macro-invertebrates; amphibians and reptiles were visually detected while walking and were also detected by turning stones, imitating the foraging behaviour of ibises and using approximately their same perceptive channels. Identification of remains isolated from ibis droppings and pellets and of specimens collected at the feeding sites was carried out to varying taxonomic levels in the laboratory, through comparisons with specimens in the FAO project macro-invertebrate, amphibian and reptile collections. Identification of the macro-invertebrates in this collection, to varying taxonomic levels, had previously been undertaken by specialists coordinated by Luca BARTOLOZZI (Natural History Museum "La Specola", University of Florence, Italy). Some identifications of common insect species were carried out by GS using the literature available locally. Amphibians and reptiles were identified locally using the available literature, with support from Roberto SINDACO, University of Genoa, Italy (SINDACO et al. 2006).

The macro-invertebrate, amphibian and reptile species collected at ibis feeding sites were ranked according to four arbitrarily-defined size classes: "Large", "Medium", "Small" and "Very Small". Numeric values of 4, 3, 2 and 1 were assigned to these four size classes, respectively, as an indication of their relative biomass ("relative biomass" herein). The relative abundance of macro-invertebrate, amphibian and reptile families occurring at the two main ibis feeding habitats was determined and indicated as both: 1) their frequency of occurrence over the total number of individuals collected, and 2) the relative biomass over the total relative biomass collected.

An indication of profitability (*sensu* KREBS & DAVIES 1981) of each prey family (or potential prey family) was then calculated by multiplying the indication of relative biomass for its relative frequency of occurrence over the total. An average indication of relative biomass and frequency of occurrence were used when a family included more than one species.

Results

Feeding habitat

Since the year of their discovery (2002), Northern Bald Ibises have nested at two distinct cliffs, about 20 km apart, one at a lower altitude (about 400 m asl), "Cliff 1" herein (in 2004, 2005), and the other higher, at about 800 m asl, "Cliff 2" herein (in 2002, 2003 and 2006). During the yearly seasonal occurrence of ibises in the study area – typically from

Table 1. The two left columns give the list of identified faunal species sampled in Habitats 1 and 2, subdivided by those proved to be preyed upon by Northern Bald Ibises (A) and those not proved to be preyed upon by ibises (B). In the central and right columns, an indication of the relative abundance of each taxon and its associated relative profitability is reported.

A) Prey taken by ibises		**Relative abundance**				Profitability
Order	Family	**Rel. frequency**		**Rel. biomass**		
		N	**%**	**N**	**%**	
Coleoptera	Tenebrionidae *(Trachiderma hispida, Erodius* sp., *Mesostena* sp., *Akis* sp., *Adesmia* sp., *Pimelia* spp., *Zophosis* sp.)	248	7.32	408	26.86	12.04
	Carabidae *(Calosoma chlorosticum)*	4	0.12	8	0.53	0.24
	Buprestidae *(Julodis distincta)*	4	0.12	12	0.79	0.35
	Scarabeidae *(Scarabeus sacer)*	1	0.03	2	0.13	0.06
	Curculionidae *(Ammocleonus aschabadensis)*	11	0.32	22	1.45	0.65
	Coccinellidae *(Coccinella septempunctata)*	6	0.18	6	0.39	0.18
Lepidoptera	Larvae	4	0.12	8	0.53	0.24
Hymenoptera	*Formicidae* spp.	2680	79.1	268	17.64	7.91
	Flying spp.	8	0.24	8	0.53	0.24
Orthoptera	Acrididae spp.	227	6.7	420	27.65	12.40
	Gryllotalpidae sp.	3	0.09	9	0.59	0.27
Stylommatophora	Helecidae sp.	2	0.06	6	0.39	0.18
Scorpiones	Scorpionidae *(Scorpio mauro)*	4	0.12	12	0.79	0.35
Solifugae	Solphugidae spp.	2	0.06	6	0.39	0.18
Anura	Pelobatidae *(Pelobates syriacus)*	Locally extremely abundant		size class = 3		high
Sauria	Agamidae *(Laudakia stellio* or *Trapelus ruderatus)*	5	0.15	15	0.99	0.44
Ophidia	Colubridae *(Coluber ventromaculatus, Eirenis* spp.) or Viperidae *(Pseudocerastes persicus)*	3	0.09	9	0.59	0.27
B) Fauna not observed to be taken by ibises						
Coleoptera	Tenebrionidae *(Tentyrina* sp., *Blaps* sp. + other)	41	1.21	51	3.36	1.51
	Carabidae *(Graphipterus minutus* + other 2 unid. spp.)	11	0.32	11	0.72	0.32
	Curculionidae *(Larinus* sp.)	2	0.06	2	0.13	0.06
	Meloidae sp.	4	0.12	4	0.26	0.12
Hemiptera	Unidentified	3	0.09	3	0.2	0.09
Dictyoptera	Mantidae *(Belpharopsis* sp.)	52	1.53	104	6.85	3.07
Orthoptera	Grillidae sp.	3	0.09	6	0.39	0.18
Isopoda	Trachelipodidae *(Hemilepistus reaumuri)*	36	1.06	72	4.74	2.13
Pseudoscorpiones	Buthidae *(Androctonus crassicauda)*	9	0.27	22	1.45	0.65
Aranea	Unidentified	2	0.06	4	0.26	0.12
Sauria	Lacertidae *(Lacerta* spp.)	2	0.06	6	0.39	0.18
	Unidentified	11	0.32	15	0.99	0.44
	TOTAL	**3,388**	**100**	**1,519**	**100**	/

Fig. 1. Northern Bald Ibis in feeding area 1 (FA-1) in early spring 2004 (photo by M. S. ABDALLAH).

mid February until mid July– temperatures usually ranged between below zero (February-March) and >45°C (June-July). During the first month soon after the return migration, until the end of March, it is still quite cold and temperatures can still drop below zero at night. Usually at the beginning of April, spring starts and the insect population boom takes place. During the study period, ibises used two main feeding habitat types, both quite anthropized relative to the average human density of the desert: stony and sparsely vegetated, over-grazed, open and undulating steppe (Habitat 1), and man-made irrigation reservoirs (Habitat 2).

Habitat 1. Ibises were observed feeding >90% of their time on the gently inclined slopes bordering drainages (*wadis*) of varying sizes. The dry soil, almost without organic matter (<1%), is composed of a mix of loam, gypsiferous and calcareous rock broadly covered by gravel and stones. Sparse and very scattered perennial and annual dwarf shrubs, not exceeding 10-15 cm in height, are the only vegetation, dominated by *Salsola vermiculata* (perennial) and *Salsola volkensi* (annual). Annual grasses occur sparsely along larger *wadi* beds whose dominant, although scattered, vegetation is *Tamarix* spp.

Three main feeding areas at different altitudes, containing this same kind of habitat, have been typically used by the ibis colony during the course of the four breeding seasons observed:

- Feeding Area 1 (FA-1) at about 400 m asl, within a 50-100 m radius from Cliff 1 (Fig. 1);
- Feeding Area 2 (FA-2) at about 800 m asl within a 3.5 km radius from Cliff 2 (Figs 2-3);
- Feeding Area 3 (FA-3) at about 950 m asl, about 13 and 34-35 km away from Cliff 2 and Cliff 1, respectively.

FA-1 appeared to be significantly stonier and rockier than FA-2 and FA-3 (see Fig. 1). The three feeding areas were usually used at different stages of the breeding season, following the temporal progression of spring and summer: during the weeks soon after arrival from

migration, between February and March, when it is still quite cold, ibises usually started using FA-1. Afterwards, they used to switch to using FA-2, and at a later stage (between mid-April and May) they started typically using FA-3, until the time for departing on migration (mid July).

Habitat 1 is traditionally used by the local Bedouin indigenous community as pasture for the grazing of their sheep; the scattered slow-growing shrubs on pastures are traditionally uprooted and used as firewood by these people, who are nomadic or semi-nomadic. The period of the year when these pastures hold the highest density of nomads overlaps with the ibis breeding season. During wet years, as in 2003, the same habitat is flooded by a multitude of people coming from all over the country to search for much-valued desert truffles (Terfeziaceae spp.), in the period February-April.

When nesting at Cliff 2, ibises used FA-1 only during the first weeks after arrival from migration, as in this specific period they usually roost at Cliff 1 which enjoys milder weather conditions than Cliff 2. When nesting on Cliff 1, ibises used FA-1 for a longer period than when nesting at Cliff 2, but after mid-March they started increasingly using FA-2, and by early April onward they used mostly FA-2, and later on also FA-3. The topographic configuration of FA-2 appears more complicated than FA-1 and FA-3, as these latter feeding sites border smaller *wadis* than does FA-2. Cliff 2 is in fact located at one side of a large drainage area composed of a central *wadi* and a complex system of lateral and almost parallel micro-*wadis*, more or less at right-angles to the central main one and separated from each other by low flat and slow-rolling micro-ridges.

Some selected flat tops of these micro-ridges, sloping both towards the central *wadi* and also towards the lateral micro-*wadis*, form the FA-2: birds are actually very conservative in using the higher third portion of these gently sloping micro-ridges. In fact, this behaviour was not equally evident at FA-1 and FA-3, perhaps because the latter feeding areas are less sloping than FA-2. We could recognise at least 5-6 different feeding sites within FA-2, all within a 3.5 km radius from Cliff 2, that were used by ibises during the observed breeding seasons.

On the contrary, ibises appeared extremely conservative in the use of a very restricted area of FA-3. The time at which Bald Ibises started to use the higher altitude FA-3 varied from year to year due to the extremely variable and unpredictable rainfall events occurring in the Syrian desert. From March to early/mid-June, the dwarf shrub coverage was quite green at FA-2 in 2002. Although 2002 was a year perceived by locals as a drought, a late rain in mid-May took place, reinvigorating the pastures which were, for instance, still green in early June 2002. They dried out during the second half of June.

After that, following the movement of nomads to higher pastures, the ibises started to use FA-3. In 2003, although perceived by locals as a wet year, the pastures started to dry out earlier than in 2002, at the end of April, and birds started to use FA-3 from around mid-May. In 2006 the Bedouin started leaving the lower pastures at FA-2 during the first half of May (a year defined as "quite dry" by the herders), and during the second half of May they all left. Similarly, Bald Ibises started to use FA-3 during the first ten days of May in 2006.

Habitat 2. During the study period, ibises were observed regularly using at least 2 different artificial reservoirs for drinking, feeding and also for relaxing and grooming each other. Human disturbance at the reservoirs was quite intense as they are used by Bedouin herders to provide drinking water for their livestock.

The desert reservoirs were built by the Syrian irrigation authorities during the 1960s and 70s to support the Bedouin herders with the provision of water for their livestock and also

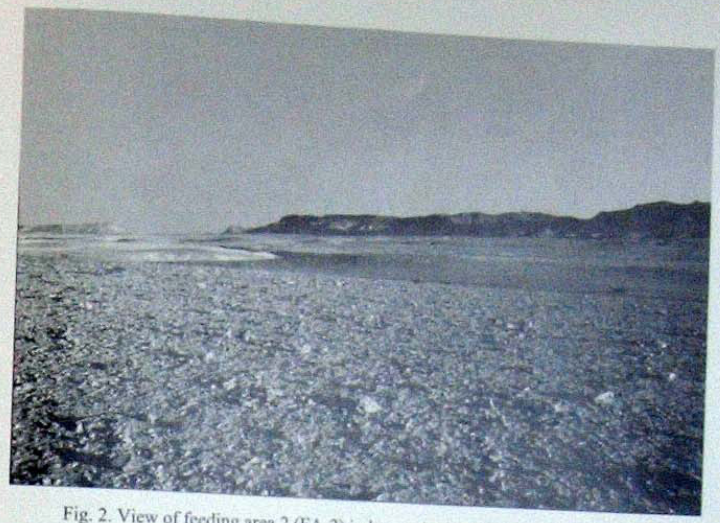

Fig. 2. View of feeding area 2 (FA-2) in late spring 2004 (photo by G. SERRA).

Fig. 3. Pastures between micro-wadis at feeding area 2 (FA-2) in late spring 2003 (photo by G. SERRA).

for irrigation purposes (now mainly in the past). They were designed by building a concrete dam, trapping the rainfall. Reservoir A (R-A), about 5.3 km away from Cliff 2, was 30-40 cm deep in 2002 and about 200-250 m wide when completely full of water. Vegetation at R-A is dominated by sparse *Tamarix* spp. and *Phragmites* reeds.

R-A filled up suddenly after a late rainfall in mid-May 2002, and after that slowly dried up completely by 10 July. Birds started to use this site regularly in 2002, also for feeding, soon

after the chicks had fledged (from 10 June onwards), when the availability of young toads was high. During 2003 (a wet year), the outbreak of toads took place earlier, between 12 and 19 May, and the R-A had dried out by the last days of June: in that year birds started to use R-A by 20 April, at first for drinking and resting only.

The R-A dam was considered by locals to be damaged and in need of maintenance work, and it was expected that it would become unable to hold water in the near future. In fact, in 2006 R-A was completely dry from the very beginning of spring. That same year, the birds became habituated to using an artificial concrete-made pond (2.5x2 m) built by rangers in front of Cliff 2 with the aim of trapping and tagging them.

Ibises were also observed using the other irrigation reservoir, Reservoir B (R-B), 13 km away from Cliff 2, which is smaller but deeper than R-A. It is rectangular in shape, about 35-40x15 m in size, with no surrounding vegetation (Fig. 4). We also collected some reports of ibises using temporary ponds along the *wadis* after rainfall, if they were not too disturbed, as reported by locals and also as seen by project staff. Unconfirmed information, provided by local farmers, seemed to indicate that during the breeding season 2002 ibises were also using cultivated fields in the vicinity of Palmyra as a feeding area, some 23-25 km away from Cliff 2. Reportedly, ibises used at least two different types of cultivated area during that season: one cultivated with crops (barley, wheat, cotton, *Tripholium* spp.), garden vegetables, orchards and vineyards, while the other was cultivated with *Salsola vermiculata* and *Atriplex* spp. (wild *Artemisia* spp., *Harmala* spp., *Achillea articulatum*, *Tamarix* spp., with trees and annual grasses also sparsely present).

Diet

A total of 59 prey items was identified from remains found in ibis dry droppings and pellets, while 3 were identified through direct observation of feeding ibises. Table 1 gives a list of macro-invertebrate, amphibian and reptile families sampled at the two main feeding habitats. A good portion of this faunal list (portion A in the table) was found as remains (and later identified) in the ibis droppings and pellets, or was directly observed being captured by ibises in the pastures.

The same table gives information on the relative abundance and profitability for each faunal family, relative to the second part of the breeding season (May-June) at Habitats 1 and 2. Tenebrionid ground beetles and Acridid grasshoppers, both seen to be taken by ibises, seem to be the most profitable prey items in the overgrazed pastures (Habitat 1). In particular, *Trachiderma hispida* seems to be the species among those definitely taken by the ibises that scores the highest profitability indication relative to the period May-June, due to its size and frequency of occurrence. When at the irrigation reservoirs (Habitat 2), ibises were observed feeding constantly on young Eastern Spadefoot Toads (*Pelobates syriacus*), which seem to be the most profitable prey in absolute terms during the second half of the breeding season, due to their body size and their high concentration locally.

Interestingly, the Bald Ibis may be able to integrate their primarily animal diet with desert truffles, when they are available, and in the past possibly also with pistachios, as reported by locals, at the time when *Pistacha atlantica* woodlands were still a common sight within *al badia*, which is no longer the case (NAHAL 1996). In 2003, a truffle year, birds were directly observed by rangers sometimes extracting desert truffles from the ground and feeding on them. This observation was confirmed by a local inhabitant from Palmyra and also by a further observation made by MSA in 2006.

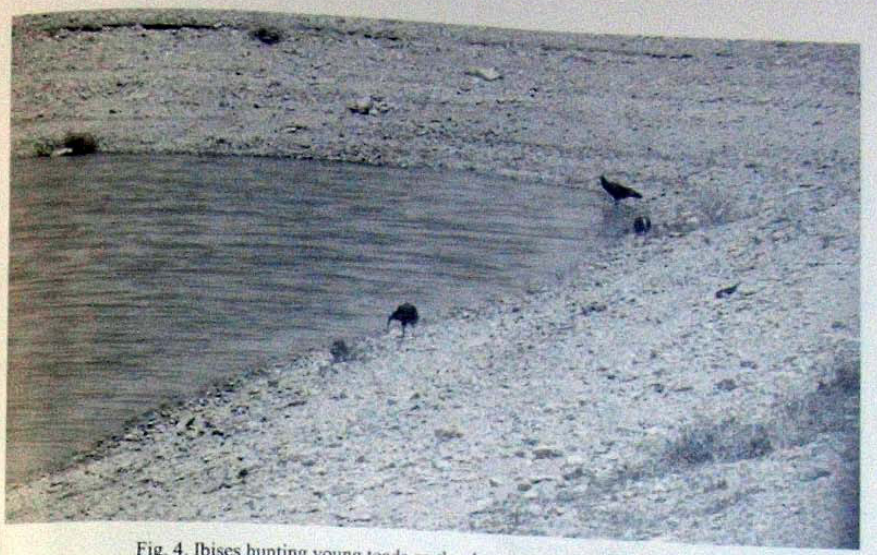

Fig. 4. Ibises hunting young toads on the shore of Reservoir B (R-B) in early summer 2006 (photo by L. PESKE).

Behaviour

The maximum home range estimated for Bald Ibises at their breeding quarters in the Syrian desert is about 450 km². The number of main feeding sites found per season is 6-10. During a typical day, birds would visit 2-4 different feeding sites, spending on average approximately 1-3 hours at each (minimum 30-40 minutes, maximum 4 hours), depending on season and food availability. The feeding site closest to the nesting cliff was just at the base of the nesting cliff (i.e. some tens of metres away), while the furthest one was some 34-35 km away, i.e. the distance from Cliff 1 to FA-3.

At the feeding sites, birds were seen during the day mostly grouped together, in a more or less loose fashion, with birds typically a few metres away from each other. Only occasionally were they spotted feeding alone, mainly during the chick-raising stage. They appeared to be hunting by sight, walking quickly, silently, the head going back and forth, pecking and probing under stones, in holes, in crevices and in tufts of vegetation.

At times they appeared to be running as if chasing fast-moving fauna (e.g. macro-invertebrates and reptiles). Sometimes they inserted the whole bill into holes, sensing and tracking underground prey and in early spring extracting what were most probably beetle larvae. Ibises foraged almost all day long, only resting and relaxing at times: according to the season, they would rest 2-3 times a day for periods varying between 10 minutes and 1 hour. Grooming behaviour between mates was observed in 2002 during periods of relaxation by the flock on the shores of R-A.

No direct non-human predation was observed or reported on Bald Ibises while feeding in pastures and at reservoirs. Human disturbance at feeding Habitat 1 was at times and locally intense, in the form of pastoralists flushing the foraging birds by driving trucks or motor-

bikes across the pastures or by herding sheep. In general terms, ibises seemed quite accustomed to the Bedouin camps and associated activities around them. Ibises certainly appeared to be very accustomed to sheep flocks and young shepherds in the pastures. In 2003, human disturbance at the feeding areas significantly increased due to truffle collectors.

Wariness of the flock due to our presence in a vehicle was observed: the fleeing distance increased from 50-80 m to >100 m when the flock included recently fledged chicks. An adult was most likely shot by hunters at R-B in 2003, as reported by nomads. As already mentioned, ibises readily located and learned to use small artificial ponds built in front of the nesting cliff with the aim of of trapping and tagging them in 2004 and 2006 (SERRA & PESKE 2006). In June 2006, after disturbance due to attempts to trap them for satellite tagging, birds stopped using the artificial pond built in front of Cliff 2 and started using the R-B intensively. After being disturbed with another trapping attempt at R-B, the ibises returned to use the reservoir after about 10-15 days.

The establishment of artificial ponds at the feeding areas in the vicinity of both nesting cliffs (SERRA & PESKE 2006) showed that the ibises are keen to drink on a regular basis, starting during the earlier stages of the breeding cycle (at a time when weather conditions are not at all dry). Differences were noted at an individual level: for instance, in 2006 the four breeding adults showed a liking to drink at least on a daily basis, while the three sub-adults appeared to be much less dependent on water and more "neophobic" than adults.

Discussion

Feeding habitat. Stony, sparsely vegetated and overgrazed undulating steppe, ranging between 400 and 950 m asl, is the key feeding habitat of the last surviving Northern Bald Ibises still breeding in the Middle East. The preference for low vegetation and open terrain is consistent with observations made on Birecik's birds (HIRSCH & SCHENKER 1977, HIRSCH 1978) and in Morocco (BOWDEN & SMITH 1997). It is not clear why the ibises tend to use the higher, third portion of the steppe slopes: it could be due to the specific vegetation composition (and associated invertebrate community) or to an anti-predatory strategy. In fact, this specific positioning could enable ibises to have the most commanding view and better control over their surroundings.

In particular, the observation by HIRSCH (1979) that Birecik's Bald Ibises preferred semi-arid grounds with little vegetation for feeding and were rarely observed where plants exceeded 25-30 cm is confirmed by our observations both in Syria and in the over-wintering grounds in Ethiopia (SERRA et al. 2007). In fact, the vegetation cover was very probably much higher and abundant in the Syrian *al badia* until only 15-20 years ago, as recounted by older nomads who also reported that at that time hundreds of ibises were breeding on several cliffs scattered around the Palmyra desert (SERRA et al. 2003).

A comparison of the vegetation cover and height inside the *al talila* reserve (some 60 km away from the study area), subject to a 15-year protection tenure by MAAR, *versus* that of the surrounding steppe sadly illustrates the dramatic effect of overgrazing and uncontrolled shrub uprooting. The same evidence is provided by the abundant vegetation cover of some terraces that cannot be reached by livestock, observed on the cliffs surrounding FA-2. Also worth mentioning is the total destruction of the *Pistacha atlantica* woodland which once covering most of the plateau where the ibises breed and which was completed during the first half of the 20th century (NAHAL 1996).

In fact the Syrian Bald Ibises have shared their feeding areas with the sheep of the indigenous nomadic herders since time immemorial. It is due to a complex cocktail of human-related reasons (including technological progress, exponential population growth, disruption of traditional customary management of pastures etc) that the Syrian *al badia* has experienced an unprecedented process of ecological degradation and destruction during the past 15-20 years. While a number of large game species have already vanished over this recent period (e.g. *Gazella gazella, Acinonyx jubatus, Panthera pardus nimr, Capra nubiana, Struthio camelus, Uromastyx aegyptius*), a number of other species, once common within *al badia*, are presently on the verge of local, regional and global extinction (e.g. *Gazella subgutturosa, Ardeola ralloides, Gyps fulvus, Torgos tracheliotus, Neophron percnopterus, Otis tarda, Chlamydotis undulata*).

The Bald Ibis could be regarded as an ecological keystone species of the Syrian *al badia*. In fact, until not so long ago, this bird which occurred in large colonies probably played an important ecological role within the Syrian desert: being an insectivore, it was probably key in controlling the invertebrate populations, and in so doing maintaining the ecological health and productivity of the pastures. Interestingly, MAAR recognised the beneficial role of the ibises for agriculture with the issuance of decree no. 28 in 1967.

Ibises now breed in a very degraded steppe environment, under heavy and on-going desertification, compared to only 15-20 years ago. This fact could explain the remarkable difference in foraging distances travelled by ibises in Syria on the one hand and Morocco and Turkey on the other, when there are chicks in the nest (see below). Birds are often disturbed by locals when feeding: the maximum disturbance seems to take place during the wet years, when truffle collectors flood the steppe in numbers.

Surprisingly, ibises can still raise quite a high number of chicks per nest: for instance, 6 successfully fledged chicks from two nests in 2006 (SERRA et al. *in prep.*), which is a higher figure than the average recorded in Morocco and Turkey (COLLAR & STUART 1985, BOWDEN et al. 2003). It is interesting to note that ibises, following the progression of the hot season, gradually switch from low to high feeding grounds: this behaviour is similar to the altitudinal short-range migration performed by the local Bedouin pastoralists in late spring. Ibises in Syria endure considerable temperature extremes, as has also been recorded in Morocco (GÉROUDET 1965).

Artificial irrigation reservoirs play an important role for breeding ibises as a source both of drinking water and of highly profitable food. This information disproves the speculation that Syrian Bald Ibises are desert creatures without need of water (COLLAR & STUART 1985) or that they do not need drinking water at all (HIRSCH 1979); while it is consistent with the observation that ibises also occur around aquatic environments (COLLAR & STUART 1985). The construction of reservoirs within the breeding area during the 1960s and 1970s may somehow have compensated for the increasing degradation of the rangelands in terms of ibis food availability.

An additional type of feeding habitat reported as being used is the agricultural fields (HIRSCH & SCHENKER 1977, HIRSCH 1978). This habitat may have a complementary role for the Syrian ibises in relation to the open steppe and the reservoirs: while it is uncertain whether the Palmyra ibises used or did not use cultivated fields in 2002, as reported by locals, this habitat was certainly used by one lone early returnee ibis in early February 2007, when winter was not over yet and the temperatures were still quite low. The bird was observed for about a week, using on several occasions a small and enclosed cultivated area in front of Cliff 1, a kind of cultivated garden (about 30 x 20 m) surrounded by a mud-brick wall (MSA, pers. obs.).

Diet. Although the information presented in this study on the diet of the Syrian ibises is undoubtedly preliminary and incomplete, it is nevertheless invaluable from a conservation perspective, given the hyper-threatened status of this relict colony and also the difficulty in obtaining the authorizations and funds to work *in-situ*. These data are also a valuable basis for designing and planning future much-needed research and as a scientific base for advocating urgent conservation measures for the benefit of the last surviving Bald Ibises in the Middle East.

As the diet of the Bald Ibis is reported to be quite conservative across its geographic distribution range (HIRSCH 1981), an estimate of the diet of the Syrian birds can be attempted by combining and integrating the information gained through the preliminary sampling described in the present study and that reported about the diet of Turkish and Moroccan birds (COLLAR & STUART 1985, BOWDEN & SMITH 1997).

Ibises seem to take most of the macro-invertebrates of a certain size that they can detect on the overgrazed pastures. Most of the faunal families observed to be preyed upon by Syrian ibises were already reported for the Bald Ibises of other areas (HIRSCH 1981, 1985, BOWDEN & SMITH 1997, CRAMP & SIMMONS 1998). The need for a mixed diet based on both steppe and marsh fauna (BROSSET 1961, COLLAR & STUART 1985, CRAMP & SIMMONS 1998) is confirmed by the observation of ibises commuting daily between stony fields and the irrigation reservoir during the period when the steppe becomes drier (from May-June onwards).

The young toads occurring at the reservoirs are certainly among the most, if not the most, profitable prey available in the ibis breeding grounds at that time of the year, which coincides with the raising and fledging of the chicks. Young toads have been reported as ibis prey in other areas of the range (COLLAR & STUART 1985). The prey most frequently taken by the ibises in the stony overgrazed pastures seem to be Tenebrionidae beetles and Acrididae grasshoppers.

The beetle *Julodis distincta* (Buprestidae), whose remains in dry droppings were particularly abundant, may well be another important component in the diet of the ibises, especially when its remarkable size is taken into account (i.e. a thick body up to 3 cm long). The low profitability indication in Table 1 is due to the low frequency of its occurrence at the time of sampling: in fact, this prey item is more abundant during the early spring, i.e. in March-April.

Despite their considerable relative profitability, the ground mantis *Belpharopsis* sp. and the isopod *Hemilepistus reaumuri*, as well as spiders, were not found during analysis of droppings and pellets. This may simply be a bias due to the lack of any sufficiently hard anatomical parts of a certain size that can resist the digestion process. Another bias could relate to ants, which were observed to be preyed upon at the wintering grounds (SERRA et al. 2007). Ants and their eggs were reported to be taken by ibises in other parts of their range (COLLAR & STUART 1985). However, the relative abundance of ants in the breeding grounds may not be as high as in the wintering grounds due to the general scarcity of prey observed in the latter environment (SERRA et al. 2007). The failure to detect the remains of lizards could also be a bias, taking into account that at least an agamid lizard and a small *Coluber* snake were certainly preyed upon: but the relative profitability of reptiles does not appear to be so high, due to the relatively low frequency of their occurrence, not to mention the difficulty of capture.

In fact, another bias in this preliminary analysis is the fact that capture and handling efforts were not included in the profitability estimation. Direct observation and reports of feeding on truffles is a unique information which links with observations of ibises feeding on vegetation matter including the rhizomes of aquatic plants (RENCUREL 1974). In conclusion, the bulk of the diet of Syrian ibises is certainly composed mainly of ground beetles, grasshoppers and young toads, with the possible addition of ground mantids, isopods and lizards.

Behaviour. Despite the difference in numbers of individuals and colonies, the size of the ibis home range at its breeding quarters in Syria – about 450 km² – is highly consistent with that reported for Morocco, which is about 340 km² (BOWDEN et al. 2003). Syrian birds seem to travel longer distances when with eggs and young than do the Turkish ibises, which were reported to obtain food within a radius of 5 km (HIRSCH 1979, CRAMP & SIMMONS 1998). This fact could be explained by the lower productivity (or higher on-going ecological degradation rates) of the Syrian desert compared with the breeding quarters in Turkey.

The observed gregarious foraging behaviour in loose groups and occasional solitary foraging are consistent with literature reports (COLLAR & STUART 1985). Foraging techniques are consistent with those described by RENCUREL (1974) and HIRSCH (1981). Overall, the foraging behaviour of the last surviving Bald Ibises of the eastern range is quite conservative from year to year. They tend to use the same feeding sites and areas every year, with the same temporal sequence (adjusted to annual variations of rainfall). They use increasingly higher altitude steppe grounds from February through July, in parallel with the increasingly drying conditions of the desert.

The fact that at their over-wintering quarters the same birds took significantly less resting time during the day than at the breeding quarters (SERRA et al. 2007), despite the fact that they have to raise chicks at the latter site, seems to be an indication that the food supply may be more abundant at the breeding quarters or, in other words, that the breeding quarters are less degraded than the over-wintering ones. Irrigation reservoirs seem to be the only constant sources of drinking water for the birds. These reservoirs are intensively used by local pastoralists and also at times by hunters: threats and disturbance at these sites are therefore very high. It is not by chance that an adult breeding ibis was shot in 2003 at R-B.

The quick habituation of ibises in using undisturbed artificial ponds that we observed is evidence of the importance of a reliable and safe source of drinking water for these birds. In fact, it is also important information for conservation: the provision of undisturbed water ponds and young toads could help increase the survival and breeding performance – and hence the population size – of this hyper-threatened Bald Ibis colony. This is consistent with an increased breeding performance observed in Morocco after the provision of artificial water points had taken place (SMITH et al., in prep.).

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