# Conservation status and limiting factors in the endangered population of Egyptian vulture (Neophron percnopterus) in the Canary Islands

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Abstract

Egyptian vulture populations have decreased sharply in the Western Palearctic; island populations are almost extinct in the Mediterranean and the Macaronesian regions. In the Canary archipelago, the species only survives in the islands of Fuerteventura and Lanzarote. During 1998–2001 we examined population parameters and evaluated some potential limiting factors for this isolated and sedentary population. The total population (breeding and non-breeding birds) was monitored annually. In addition, 26 fledglings and 33 immatures (<6 years old) and adult birds were captured for individual marking with plastic rings. Twenty-three/twenty-four occupied territories were located in the island and the total population estimated at around 130 birds. Breeding success was lower than recorded elsewhere in the species' distribution area: only 0.43 fledglings/pair/year were produced. Adult (>6 years old birds) and immature annual survival rates were similar, around 90%. Adult survival was lower than expected as territorial birds seem more susceptible to poisoning. Immature survival could be favoured by the existence of regular feeding places. Casualties from power lines was the main cause of mortality (12 cases during the study period). Blood sampling revealed high frequencies of lead poisoning: 13.5 and 2.7% of individuals showed sub-clinical and clinical intoxication levels, respectively, probably caused by the ingestion of lead shot. Priority conservation measures should be directed to reduce electrocution risks, illegal poisoning, and lead contamination. Population reinforcement with birds coming from other populations is not recommended as previous information reveals morphological and genetic differentiation of Canarian Egyptian vultures compared with continental populations.

Keywords: Breeding success; Canary Islands; Communal roost; Conservation; Demography; Egyptian vulture; Electrocution; Lead poisoning; Population size; Survival

## 1. Introduction

The Egyptian vulture (Neophron percnopterus) is a small vulture that weighs about 2 kg and lives in varied habitats, mainly open landscapes in arid and rugged regions where it exploits carcasses of small and medium-sized animals. Breeding takes place in holes in cliffs of variable size; clutch size is usually two eggs but brood reduction results in only one chick fledging in 70% of successful breeding attempts (see Cramp and Simmons, 1980; Del Hoyo et al., 1994; for basic biology). It is an Indo-African species present in the circum-Mediterranean region (South Europe and North Africa), sub-Saharan Africa, the Middle East, and dry regions of Central Asia and India. There are numerous island populations: Mallorca, Menorca and Sicily in the Mediterranean, Socotra and Masira in the Arabian Sea, and the East-Atlantic archipelagos of Canary Islands and Cape Verde. In the Palearctic, island populations are sedentary whereas continental birds winter in the African Sahel region (see Cramp and Simmons, 1980; Del Hoyo et al., 1994; Levy, 1996; for reviews) .

Egyptian vulture populations of the western Palearctic have experienced a sharp decline since the end of the nineteenth century. The species has disappeared from broad regions of southern Europe, Middle East and

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North Africa; at present there are around 1500 breeding pairs in the area, most of them in Spain (Tucker and Heath, 1994). Declines have also been detected in other parts of its distribution such as Southern Africa and Central Asia (Mundy et al., 1992). Island populations have suffered strong reductions; the Egyptian vulture has vanished from Mediterranean islands such as Cyprus, Crete, and Malta (Levy, 1996). The species was abundant in the Macaronesic archipelagos but declined during the last half of the twentieth century (Bannerman, 1963; Bannerman and Bannerman, 1968). In the Canary archipelago the species disappeared from La Gomera around 1955, and from Gran Canaria and Tenerife in the late 1980s (Martın, 1987). It was also probably present in the western islands of El Hierro and La Palma as is suggested by local topographic names (Delgado, 1999). Today, it only survives on the islands of Fuerteventura and Lanzarote. There, strong declines (30% in 10 years) have been also noted since 1980 (Palacios, 2000, and unpublished). The Canary population has been recently described as a new subspecies (N. p. majorensis) on the basis of morphologic and phylogenetic differences from previously described subspecies (Donazar et al., 2002). This fact enhances the importance of the conservation of these isolated populations since they constitute an evolutionary significant unit (White and Kiff, 2000).

The reasons for this catastrophic decline in the Canary Islands remain uncertain. As in western Europe (Tucker and Heath, 1994), illegal persecution, poisoning, electrocution, habitat destruction and reduction of food supplies have been claimed as primary factors. In particular, the substitution of traditional agro-grazing by large-scale tourist developments could have caused the reduction of food (livestock carcasses), the loss of breeding areas and the increase of electrocution risk from power lines. Moreover, large amounts of pesticides were employed in the 1950s–1960s to eradicate locust plagues (Schistocerca gregaria; see Palacios, 2000). The main objective of this study was to determine the conservation status of the Egyptian vulture population remaining in the island of Fuerteventura and Lanzarote. Our particular objectives were to: (1) estimate the size of the current population and its basic demographic parameters, including breeding success, survival rates and mortality causes; (2) measure levels of heavy metals, paying particular attention to lead, in the blood of live-trapped Egyptian vultures. On the basis of our results, some basic conservation measures are suggested to conserve this endangered and isolated population.

## 2. Study area and vultures population

The Canary Islands lie in the Northeast Atlantic ocean, between 27°37′ and 29°25′ N, and 13°20′ and 18°10′ W. Fuerteventura is the nearest island to the African continent (100 km). The island is ca. 100 km long—25 km width (1662 km$^2$). In contrast to other islands of the archipelago, mean altitude is low; 54% of the land is below 200 m a.s.l., and 87% below 400 m a.s.l. Some mountain ridges have steep slopes and cliffs. The climate is extremely dry, with 105 mm of annual rainfall and aridity is increased by strong northerly winds. The landscape is dominated by grassland and scrublands (Pegano-salsoletea; Rodrıguez et al., 2000) and there is a total absence of woodland. Cultivated lands are very scarce (0.3% of the territory) and limited to some valleys with fertile soils. Human resident population in 1998 was almost 70,000, mostly living in the town of Puerto del Rosario. In addition, around a million tourists visit the island every year, concentrated in some coastal urbanised areas such as Corralejo, El Castillo and Penınsula de Jandıa (Anonymous, 1998).

In 1998 there were estimated to be 20 occupied territories in Fuerteventura (Palacios, 2000) but today this figure is considered an underestimate. The species breeds in caves of cliffs of variable height and some nests are easily accessible to terrestrial predators (feral dogs and cats). The diet is based on the carcasses of small and medium-sized animals, mainly wild rabbits (Oryctolagus cuniculus) and feral pigeons (Columba livia) but carcasses of domestic and feral goats (Capra hircus) form an important food resource (Medina, 1999; C.J. Palacios, unpublished). A ''vulture restaurant'' in the central part of the island, where goat carcasses are dumped twice a week, has been in operation since 1998. There it is possible to see up to 50 Egyptian vultures, simultaneously feeding along with numerous common buzzards (Buteo buteo insularum) and ravens (Corvus corax tingitanus). There is a nearby communal roost on a power line crossing the central plains of the island (C.J. Palacios, unpublished).

## 3. Methods

### 3.1. Population Monitoring

We surveyed the islands of Fuerteventura and Lanzarote in 1998–2000 and first months (January–April) of 2001, visiting all places with appropriate conditions for breeding, i.e. where cliffs are present. Special attention was paid to the monitoring of old breeding sites known from the literature or accounts from local people. Nests were located and monitored with the help of telescopes (20–60—), to avoid disturbance during the breeding season. The exact location of each nest was plotted on 1:25,000 maps. Each nest territory was visited at least three times during the breeding season. The first visit, between December and February, helped to determine territory occupation. The second visit, between March and April, tried to determine if egg-laying had taken place. Finally, visits in late June or early July were made to record brood size, and to ring fledglings with conventional metal and plastic rings with alphanumeric codes, which enable individual identification of individuals up to a distance of 300 m. Plastic ringing started in 1998, and during 1998–2001 we monitored marked birds by making frequent visits (at least once a week) to the communal roost and the vulture restaurant. Roosting adult and immature birds were distinguished on the basis of plumage features, young showing a full brownish plumage pattern with increasing amounts of white with each moult. Full adult plumage is acquired when the bird is 5 years old (see Cramp and Simmons, 1980).

### 3.2. Trapping, measuring and sampling Egyptian vultures

We marked six fledglings in 1998, nine in 1999 and 10 in 2000, but monitoring of the roosting and feeding areas showed that a further 6–8, 3–5 and 4 birds, respectively, fledged without ringing. During 1998–2001 we captured 34 birds (24 immature and 10 adults) with cannon-nets baited with goat carcasses. Eleven birds (four adults, four immature, and three fledglings) were equipped with radiotransmitters (Biotrack L.T.D.) for determination of survival and mortality causes and further studies on habitat selection.

From each captured bird, including fledglings in the nests, we took basic body measurements and small blood samples (5 ml) from the brachial vein using heparinized syringes. Several drops were stored in Eppendorff tubes containing 1.5 ml of pure Ethanol for genetic analyses and sex determination. Two aliquots of 1 ml were used to analyse heavy metal concentrations while the remainder (3 ml) was centrifuged (3000 rpm for 10 min) and the resulting plasma divided into three aliquots for biochemical analysis. All samples of either whole blood or plasma were immediately frozen at —20 °C.

### 3.3. Heavy metal analyses

Twenty-six blood samples were used for heavy metal analyses following usual procedures (see e.g. Benito et al., 1999). Analyses of Zn and Cu were performed by Flame Atomic Absorption Spectrometer (AAS). Pb, Cd and As were analysed by longitudinal AC Zeeman AAS equipped with Transversely Heated Graphite Atomiser. All specimens were analysed in batches, with method blanks, known standards, and reference materials, DORM-2 (dogfish muscle Squalus acanthias, TORT-2 (lobster hepatopancreas), from NRCC, mussel (Mytilus edulis) (NSC, ZC), blood (BCR, Nª 195) and serum (CMR, UZ). Accepted recoveries of reference material ranged from 88 to 110%. Detection limits for each metal were Pb (0.06 mg/l), Cd (0.008 mg/l); As (0.2 mg/l); Zn (0.01 mg/ml); Cu (0.03 mg/l). In addition, we examined 424 pellets regurgitated at the roost-site during shooting season (October–November) using X rays to determine whether lead shots in game posed a threat of lead poisoning (Pain et al., 1997). Pellets showing lead shots were dissected and examined with a magnifying lens.

### 3.4. Survey of power lines

Since Egyptian vultures used to roost on some power lines (up to 66 kV) crossing the centre of the Fuerteventura island, we made a mortality survey on 60.5 km of power line and 253 poles during August 2000. The base of each pole was checked for electrocuted birds within a 10-m radius. In addition, we searched for collisions covering a 50-m wide zone centred along the power line (Janss, 2000).

### 3.5. Survival analyses

Monthly resighting data were used for survival analyses following Burnham (1993). Data from adults (>5 years old) and immature individuals were analysed separately. Models yield information about (i) month to month survival probability ($\$$) and (ii) probability (p) of resighting of a marked bird. The software package MARK (White and Burnham, 1999) was used for model fitting and parameter estimation. Separated models were fitted for adult and immature birds so we did not consider age as a factor. We compared models with survival and recapture probabilities independent of and dependent on time (t). In consequence four models were fitted, respectively, for adult and immature birds: $\$$, p (survival and recapture probabilities independent of time), $\$$, $p_t$ (survival independent of and recapture dependent on time), $\$_t$, p (survival dependent on and survival independent of time), and $\$_t$, $p_t$ (survival and recapture dependent on time). We used QAIC (Quasi-likelihood Akaike's Information Criterion) which permits objective selection of the ''best'' model (Burnham and Anderson, 1998). AIC was calculated as the deviance of the model plus twice the number of parameters. The ''best'' model was that showing the lowest AIC value. Previously, Test 2 and 3 in Program RELEASE were used to test whether the data set met the basic assumptions of the global capture-recapture model: $\$_t$, $p_t$, i.e. whether fates of individuals were independent (Burnham et al., 1987). The combined result of test 2 and 3 gives the overall goodness-of-fit of the data to the model. These tests are computed as numerous component chi-squared tests. Each begin independent so the component chi-squares within and among tests are additive.

## 4. Results

### 4.1. Population monitoring and demography

We located 20, 23, 21, and 25 occupied Egyptian vulture territories in Fuerteventura island during 1998–2001. Additionally, during these years, a pair held a territory in the north of Lanzarote island, and a further pair bred on the small island of Alegranza. In 2001, four pairs in Fuerteventura (17% of the breeding territories) had one member showing immature plumage (birds between 4–5 years old) and another pair was composed of two individuals of this age. The number of birds that were observed in the communal roost in the centre of Fuerteventura showed strong seasonal variations (Fig. 1). Maximum numbers of birds were observed during the winter when up to 109 individuals roosted together in November 2000. In this month, however, as many as 63 adults and 62 immatures were observed in single counts, which showed that the number of vultures using the roosting area involved at least 125 individuals. Minimum numbers of 40–50 individuals were found during the breeding season (March–September) and during these months most of the observed birds were in immature plumage (Fig. 1).

Breeding success was low (Table 1) mainly due to extremely high clutch failure. These breeding parameters are the lowest known for western Palearctic populations (Table 2). In 2001, 95.2% of pairs in 21 monitored territories laid eggs. Four of these clutches (19%) had failed in April.

Adult mortality rates were calculated on the basis of eight captured birds (Table 3), four of which were equipped with radiotransmitters. In addition, three birds captured when they were 4–5 years old reached adult age (>5 years) during the study period. One adult individual (captured in September 1999) probably died during the study as it was never seen after release. The calculation of monthly survival rates yielded a Jolly-Seber result indicating that our data met the general model assumptions and individual data were independent (Test2+Test3: ç$^2$=15.783, P=0.397), although availability of data was certainly scarce for this analyses. The best survival model (that with the lowest value of Akaike Information Criterion, AIC) was independent of age and time: (AICs): $\$, p=187.65; \$, p_t=204.61; \$_t, p=237.15; \$_t, p_t=346.84$. This model yields a monthly survival rate of 0.991 (S.E.=0.009, confidence intervals=0.936–0.999. Recapture rate was 0.368 (S.E.=0.042, 95% C.I.=0.289–0.454). In consequence, adult annual survival rate in the study population would be ca. 0.897 (10.3% annual mortality).

Table 1
Breeding success of Egyptian vultures in the Canary islands[a]

| | 1998 | 1999 | 2000 |
|---|---|---|---|
| % of pairs laying[b] | 66.9 (9) | 71.4 (14) | 89.5 (19) |
| % of successful clutches[c] | 58.3 (12) | 60.0 (15) | 40.0 (20) |
| % successful pairs[d] | 55.5 (9) | 37.5 (16) | 31.6 (19) |
| Productivity[e] | 0.55 (9) | 0.50 (16) | 0.42 (19) |
| Fledgling rate[f] | 1.11 (9) | 1.22 (9) | 1.33 (9) |

[a] Sample sizes, equivalent to number of monitored pairs, are given in brackets. Some nesting sites were found late in the breeding season and therefore sample sizes may be higher for those parameters involving fledgling counts than those related to clutch monitoring.
[b] n of pairs with clutch/n of monitored pairs (—100).
[c] n of pairs with fledglings/n of pairs with clutch (—100).
[d] n of pairs with fledglings/n of pairs with clutch (—100).
[e] n of fledglings/n of monitored pairs.
[f] n of fledglings/n of pairs with fledglings.

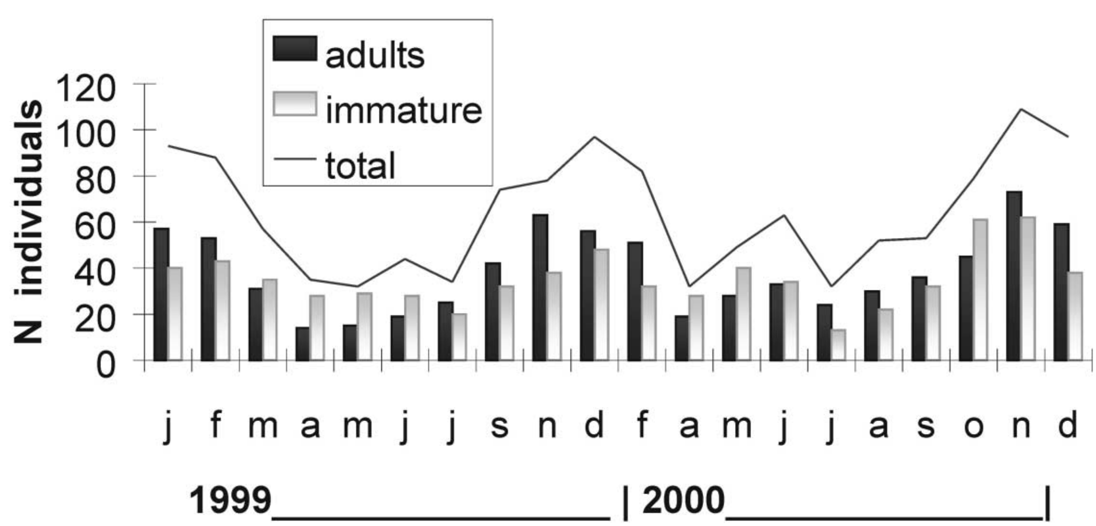


Fig. 1. Variation in the number of Egyptian vultures observed in the roost area during 1999–2000. The maximum numbers of adult, immature and total birds observed during weekly surveys carried out in each month is shown. No information for August and October 1999, and January and March 2000.

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Table 2
Breeding success for some Egyptian vulture populations of the western Palearctic

| | % pairs laying[a] | % successful pairs[b] | Productivity[c] | Fledging rate[d] |
|---|---|---|---|---|
| Portugal | | | | |
| Douro (Espinha de Almeida, 1995) | 86.6 (n=31) | 88.4 (n=26) | 0.78 (n=31) | 1.10 (n=23) |
| France | | | | |
| Provence (Bergier, 1985) | 80.0 (n=71) | 92.0 (n=100) | 1.00 (n=42) | 1.40 (n=25) |
| Pyrenees (Braillon, 1979) | – | – | 1.10 (n=117) | 1.26 (n=27) |
| Italy | | | | |
| Calabria (Liberatori and Penteriani, 2000) | 65.1 (n=126) | 75.6 (n=82) | 0.99 (n=126) | 1.27 (n=62) |
| Spain | | | | |
| Catalonia (C.R.P.R., 1984) | – | 91.4 (n=35) | – | 1.75 (n=32) |
| Navarra (Donazar and Ceballos, 1988) | 79.2 (n=72) | 76.4 (n=55) | 0.81 (n=117) | 1.29 (n=79) |
| Segovia (Fernandez, 1994) | 84.5 (n=129) | 67.9 (n=74) | 0.86 (n=129) | 1.5 (n=74) |
| Canary Islands (This study) | 78.6 (n=42) | 51.1 (n=47) | 0.48 (n=44) | 1.22 (n=27) |
| C.I.S. | | | | |
| Transcaucasia (Abuladze and Shergalin, 1998) | 85.5 (n=83) | 76.0 (n=71) | 1.06 (n=54) | – |

[a] n of pairs with clutch/n of monitored pairs (—100).
[b] n of pairs with fledglings/n of pairs with clutch (—100).
[c] n of fledglings/n of monitored pairs.
[d] n of fledglings/n of pairs with fledglings.

During the period 1998–2000 five unmarked adult birds were found dead in breeding territories; this suggests a minimum annual mortality rate of ca. 3% for an estimated population of 24 occupied territories.

Preadult survival was calculated on the basis of fledgling and immature capture-recapture data summarised in Table 3. In total, 25 fledglings and 24 immatures were ringed between 1998 and 2001, seven of which carried radiotransmitters. Six individuals (12.2%) died or disappeared during the study period. The calculation of survival rates yielded a Jolly-Seber result indicating independence between individual data (Test2+Test3: ç$^2$=31.018, P=0.745). The best model showed that survival and recapture rates were respectively independent and dependent of time: AICs: \$, p=1059.50; \$, $p_t$=899.36. The model yields a monthly survival rate of 0.990 (S.E.=0.00421, 95% C.I.=0.977–0.996). Recapture rates varied monthly between 0 and 0.912. In consequence, immature annual survival rate in the study population would be ca. 0.887 (11.2% annual mortality). Summarising, adult and immature annual survival were virtually similar in our study population oscillating around 89–90%.

Known causes of deaths seemed to be man-induced. All the five adults found dead presented typical symptoms of poisoning and strychnine, carbofuranes and aldicarb were detected in corpses. With respect to immature birds we detected two killed by accident from power lines. A 3-year-old female was seriously injured after entanglement for a whole day in a stabiliser of the power line groundwire where the communal roost was located. In addition, a 1-year-old bird died after collision with the same power line. Another four immature birds died of unknown causes. Finally, the examination in August 2000 of 60.5 km of power lines used for roosting by Egyptian vultures resulted in the discovery of 11 bodies of apparently electrocuted individuals. Only feathers and bones were present in all cases so these birds could have died over the preceding 2 years.

Table 3
Age of individual Egyptian vultures marked during the study period[a]

| | Age (years) | | | | | | |
|---|---|---|---|---|---|---|---|
| | Fledglings | 0–1 | 1–2 | 2–3 | 3–4 | 4–5 | >5 (Adults) |
| June 1998 | 6[b] | – | – | – | – | – | – |
| June 1999 | 8[b] | – | – | – | – | – | – |
| September 1999 | – | 1 | 3 | 3 | 2[c] | 2 | 5[d] |
| February 2000 | – | – | – | 3 | 3 | 1 | 2 |
| July 2000 | 10[e] | – | – | – | – | – | – |
| September 2000 | – | – | – | 2 | 2[f] | 3 | – |
| February 2001 | – | – | – | – | – | 2 | 1 |

[a] Fledglings were ringed in the nests during the last phase of the breeding period. Other birds were captured by cannon-nets. Information about mortality given in the footnotes.
[b] One individual disappeared (unknown causes) after fledging.
[c] One individual disappeared (unknown cause) three months after the capture.
[d] One individual was never resighted after release.
[e] One individual killed by collision against power line and another disappeared (unknown cause) six months after fledging.
[f] One individual with irreversible injuries after incidental entanglement in a power line.

### 4.2. Heavy metal contamination

Blood analyses showed the following ranges of arsenic and heavy metal concentrations, mean T S.D. (mg/l; except 2n: mg/ml) and range in parentheses; n=11 for Cu and 26 in all other cases: Cu=0.472 T 0.110 (0.260–0.717); Cd=1.134 T 0.804 (0.200–3.849); Zn=3.615 T 0.655 (2.559–4.467); Pb=146.0 T 293.8 (not detected–1780.0); As=18.88 T 27.44 (not detected–42.30). The levels producing sub-lethal effects are unknown for Cu, Cd, Zn, and As, but according to Benito et al. (1999) values of Cu and Zn from Canary Egyptian vultures were well below those found in birds living in areas with contamination. In addition, values of Cd and As were those considered as normal in non-polluted zones (1 mg/l and 20 mg/l respectively); values surpassing those levels were never as high as those found in polluted regions. In contrast, levels of lead contamination provoke some concern. There were five birds with Pb above that considered to indicate abnormal exposure (>200 mg/l), and in one individual it reached a level well above that indicating lead poisoning (>500 mg/l) (Pain, 1996).

Lead shot was often found in pellets: 10 (5.3%) of 190 examined pellets collected under roosting places in January 2000 contained at least one piece of shot. A single pellet had ten lead shot. In November 2000 we collected 234 pellets; three of them (1.3%) contained shot, with a maximum number of three shot per pellet.

## 5. Discussion

The population of Egyptian vultures at Fuerteventura and Lanzarote has decreased during the last two decades (see Introduction). During the study period (1998–2000) the Egyptian vulture population of the islands seems to have remained almost stable at 23–25 breeding territories. The number of Egyptian vultures concentrated in the communal roost (up to 125 in winter) probably represented almost the whole population of the island because there were at least 50 breeding adults and almost 70 immature individuals according to the census of occupied territories and maximum numbers of birds in brown plumage observed at the roost. In addition, there were probably some non-breeding adults visiting the roost every day. We therefore estimate the Egyptian vulture population of Fuerteventura to be 130 birds. Roost dynamics seem very similar, although seasonally inverse, to that detected in parts of the Iberian peninsula (Donazar et al., 1996). The possibility that some European and/or African birds join Canary roosts during winter cannot be discarded but we think that, if it occurs, it is infrequent. Roost counts did not suggest a regular influx of wintering birds and we never detected unidentified unmarked birds of cohorts raised during 1998–2000. Finally, none of the birds that we captured during the winter period (September–February) abandoned the island during the following breeding season.

The breeding success of the Egytian vulture in Fuerteventura was notably lower than in other regions of the Western Palearctic (Table 2). In particular, almost half the breeding attempts failed in Fuerteventura, although a high fraction of pairs started breeding. There are several factors potentially explaining such low breeding rates. First, the increasing urbanisation around the territories can cause desertion and breeding failure in large birds of prey (White and Thurow, 1985; Steidl and Anthony, 2000). Fuerteventura, however, is an island with relatively little development and most vulture nests are in desert areas without human presence. We know some cases of breeding failure caused by humans but we do not think that this factor alone can explain the extremely low breeding success found in this study.

The amount of food available to vultures is probably high. Livestock censuses of 1990 gave figures of 51,329 goats, 10,822 sheep, 1221 pigs, 657 cows, and 20,850 hens (Domınguez, 1992). The number of goats and sheep in the island has increased in the last 30 years from 20,040 in 1970 to 34,030 in 1984, 62,151 in 1990, and 70,938 in 1998 (Gonzalez Morales, 1989; Domınguez, 1992; Anonymous, 1998). In addition, there are in the island around 4000–20,000 feral goats living in unproductive lands, their numbers varying in relation to pasture availability. Most of the corpses of the feral goats and a significant proportion of those from livestock farming are abandoned in the fields, and are therefore available to vultures and smaller scavengers (Authors, unpublished). Therefore, it seems difficult to imagine that low breeding success and subsequent population decline of vultures in the island is caused by food scarcity. We cannot discount the possibility that food scarcity could be affecting some breeding territories in the peripheral areas of the island but further research seems necessary. Finally, as has been found for other wild and captive vertebrate populations low breeding success could also result from high levels of inbreeding (see review in Hedrick and Kalinowski, 2000). We lack information about this but the low population size suggests that this is a real possibility. Long-term studies of individual marked birds are necessary to assess the actual impact of this factor on productivity.

Adult mortality in Fuerteventura seems to have been around 10% per annum during the study period. Healthy populations of large birds of prey have annual adult rates lower than this figure (see Hiraldo et al., 1979; Sarrazin et al., 1994). A nearly stable population of Egyptian vultures in northern Iberian peninsula showed annual adult mortality <2% (J.A. Donazar and O. Ceballos, unpublished). In contrast, immature survival was similar to that found in adults, which is much higher than expected. In other large birds of prey it is estimated that, in natural conditions, pre-adult mortality can total 95% (see Hiraldo et al., 1979), although this may be lower when environmental carrying capacity is well above the requirements of the population (Donazar and Fernandez, 1989). Egyptian vulture populations of the Iberian peninsula, exploiting more irregular food resources and having migration risks, have mortality rates of ca. 50% in the first two years of life and 80-90% over the whole pre-adult stage (O. Ceballos and J.A. Donazar, unpublished).

Low immature mortality in Fuerteventura could be favoured by the existence of important livestock numbers and the provisioning of the ''vulture restaurant'' (see also Riley et al., 1993; Donazar and Fernandez, 1989). In contrast, adult birds, less attached to predictable food resources, could be prone to unusual mortality by poisoning as they are able to find baits and bodies of poisoned small vertebrates such as carnivores and ravens (Donazar, 1993). A similar problem of age-dependent mortality risk from poisoning has been detected in the bearded vulture (Gypaetus barbatus) population of the Pyrenees (R. Antor, personal communication). Adult poisoning mortality seems to be mainly the indirect result of human persecution against presumed livestock predators such as feral dogs, cats, common buzzards and ravens.

Finally, in Fuerteventura, as in other desert areas (Sigismondi and Politano, 1996), Egyptian vultures seem frequently to select power lines for roosting, contrary to that found in temperate regions (Donazar et al., 1996). This behaviour makes them extremely vulnerable to accidents by collision or electrocution (Janns, 2000). In a survey carried out in 1993 six dead Egyptian vultures were found along 12 km of power lines (four by electrocution and two by collision; Lorenzo, 1995). In our study period 12 casualties were detected. Thus, this cause of death may have a decisive role in the demography of the Fuerteventura's Egyptian vultures as in other large raptor populations (Ferrer, 1993). Electrocution episodes may be rare but each could affect a number of birds (Mundy et al., 1992; Ferrer and Janss, 1999).

A particular conservation concern for our study population is the high lead levels found in the blood of captured immature and adult individuals. We found 16% of birds with $>0.2$ ppm of Pb, levels potentially causing a decrease of the productivity (Ochiai et al., 1992; Burger, 1995), potential physiological injuries and finally death. In birds of prey, lead intoxication is frequently derived from ingestion of lead shot when the bird eats injured prey (Miller et al., 2000). After ingestion, some lead shot are rejected within pellets. In these cases, the frequency of pellets carrying shot were between 2 and 70% (Patte and Hennes, 1983; Pain and Amiard-Triquet, 1993; Miller et al., 2000). To detect all lead shot it is necessary to make a radiological study of the pellets as they usually escape visual detection. This could explain why Medina (1999) did not find bullets in 523 pellets. In addition, the hunting season in Fuerteventura is short (2 months during autumn) so shot will only appear during those months (see also Mateo, 1998). The other potential sources of lead, such as the ingestion of lead paint (Sileo and Fefer, 1987), intense automobile traffic (Jenkins, 1975), and mining industries (Henny et al., 1994) are absent in Fuerteventura.

Since the Canary population of Egyptian vulture seems to have been stable during the study period, the population may be sustained by the extremely high pre-adult survival compensating for the relatively high adult mortality. Necessarily, some efforts should be made to increase adult survival and productivity. This could permit the recovery of the population in the future. Such population increase would be favoured by the relatively low age of initial reproduction (4–5 years old). This figure is considerably lower than that found in the Iberian peninsula (7–8 years old, J.A. Donazar and O. Ceballos, unpublished; see Newton, 1979, for discussion about demographic implications of the age of first reproduction). In contrast, further increases in adult mortality could be extremely dangerous, as it is well known that demography of long-lived species is very sensitive to variation in probability of death of breeding individuals (Hiraldo et al., 1979).

## 6. Conservation

The importance of islands within global conservation strategies has gained support with the enunciation of new species concepts (Hazevoet, 1996). Vertebrate island populations are frequently considered as Evolutionary Significant Units (ESUs); that is, well differentiated populations from historical and phylogenetic point of views. This concept may ultimately be more useful for classifying and preserving biodiversity (White and Kiff, 2000). The relict Canary population of Egyptian vultures can be considered as an ESU worthy of strict conservation efforts. The existence of local Egyptian vulture populations in different archipelago and islands of the Macaronesian, Mediterranean and Indian regions (Cramp and Simmons, 1980) may favour differentiation into genetic units.

The present stability of the population seems to depend on high preadult survival. Efforts are therefore needed both to ensure that this is maintained and that the unusually high mortality of adults is reduced. Measures for the latter would involve: (1) identification and modification of power lines regularly causing deaths of birds of prey; (2) substitution of lead pellets by steel or molybdenum/tungsten alloys; (3) public campaign against the use of poisoned baits to control feral dogs and cats. In addition it is necessary to avoid human disturbance in the vicinity of breeding areas, to maintain and perhaps increase the number of ''vulture restaurants'' and to educate the island's inhabitants on the ecological and cultural importance of the species. As the Canary population has unique phenotypic and genotypic characteristics (Donazar et al., 2002) it seems inadvisable to enhance the population with individuals of foreign origin. Finally, serious consideration should be given to combining the existing captive stock (five birds at present in zoos of Fuerteventura and Tenerife) to achieve a captive breeding program aimed to preserve genetic variability and to form a nucleus for future reinforcement programs in Lanzarote and reintroduction in other Canary islands.

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