

Factors influencing the breeding density of Bearded Vultures, Egyptian Vultures and Eurasian Griffon Vultures in Catalonia (NE Spain): management implications

A. Margalida, D. García & A. Cortés–Avizanda

Margalida, A., García, D. & Cortés–Avizanda, A., 2007. Factors influencing the breeding density of Bearded Vultures, Egyptian Vultures and Eurasian Griffon Vultures in Catalonia (NE Spain): management implications. *Animal Biodiversity and Conservation*, 30.2: 189–200.

Abstract

Factors influencing the breeding density of Bearded Vultures, Egyptian Vultures and Eurasian Griffon Vultures in Catalonia (NE Spain): management implications.— Using multivariate analyses we examined differences in breeding density of the Bearded Vulture *Gypaetus barbatus*, the Eurasian Griffon Vulture *Gyps fulvus* and the Egyptian Vulture *Neophron percnopterus* in NE Spain (Catalonia) in relation to trophic, orographic–landscape and anthropic variables. Sampling units used were regional divisions (*comarques*). High density of Bearded Vulture was principally linked to areas with scant vegetation and low human population density. In contrast, high densities of both the Egyptian and Eurasian Griffon Vultures were associated with availability of trophic resources (sheep and goats). Positive effects were detected in relation to low density of inhabitants (Egyptian Vulture) and altitudes between 1,000–2,000 m and landscape with low tree cover (Eurasian Griffon Vulture). The Bearded Vulture seemed to be the most selective species in relation to environmental characteristics while the Eurasian Griffon and the Egyptian Vultures displayed a higher degree of ecological plasticity. Future conservation actions should bear these results in mind in order to optimise management. Food resources from extensive livestock farming, in particular, seem fundamental for the conservation of scavenger species. Preference monitoring and conservation efforts are needed in the regions with highest vulture densities (Alta Ribagorça, Pallars Jussà and Alt Urgell), while regions with low vulture populations should be managed in order to favour the geographical expansion and recolonisation of zones currently not occupied by these species. Conservation priorities should be based on favouring extensive livestock practices, and as an alternative to *muladares* (traditional animal carcass disposal sites) farmers should be encouraged to leave animal carcasses in the field, while ensuring compliance with health regulations.

Key words: Breeding density, Habitat requirements, *Gypaetus barbatus*, *Gyps fulvus*, *Neophron percnopterus*, Catalonia.

Resumen

Factores que afectan a la densidad reproductora del Quebrantahuesos, el Buitre Leonado y el Alimoche Común en Cataluña (NE de España): implicaciones para su gestión.— Utilizando análisis multivariantes examinamos las diferencias en la densidad reproductora del Quebrantahuesos *Gypaetus barbatus*, el Buitre Leonado *Gyps fulvus* y el Alimoche Común *Neophron percnopterus* en el NE de España (Cataluña), de acuerdo con diferentes variables tróficas, orográfico–paisajísticas y antrópicas, y tomando la división comarcal como unidad de estudio. Los modelos sugieren que la alta densidad de Quebrantahuesos está principalmente relacionada con la superficie de terreno no arbolado y poco humanizado. Por otro lado, las altas densidad de Alimoches comunes y Buitres Leonados se asocian a la alta disponibilidad de recursos alimenticios (ovejas y cabras), y además a una escasa densidad de habitantes en el caso del Alimoche Común y con la altitud (rango entre 1.000 y 2.000 m) y la ausencia de superficie arbolada en el caso del Buitre Leonado. El Quebrantahuesos parece la especie más selectiva con las características del medio, mientras que el Buitre Leonado y el Alimoche Común muestran una mayor plasticidad ecológica. Las medidas de conservación futuras deberían tener en cuenta estos resultados de cara a optimizar su gestión.

En este sentido, la importancia del alimento proporcionado por el ganado no estabulado parece fundamental para la conservación de las aves carroñeras. Las comarcas con mayor densidad poblacional (Alta Ribagorça, Pallars Jussà y Alt Urgell) son en las que deberían invertirse mayores medidas de control y protección puesto que albergan un porcentaje muy importante de la población de estas especies. Por otro lado, las comarcas con menor densidad poblacional deberían ser administradas de manera que su gestión y las acciones de conservación favorezcan la expansión geográfica y los procesos de recolonización de zonas no ocupadas por estas especies. Las prioridades de conservación deberían basarse en favorecer la ganadería extensiva y, como una alternativa a la creación de muladares, permitir a los ganaderos dejar las carcasas de animales en el campo, teniendo en cuenta la compatibilidad con las políticas sanitarias.

Palabras clave: Densidad reproductora, Requerimientos de hábitat, *Gypaetus barbatus*, *Gyps fulvus*, *Neophron percnopterus*, Cataluña.

(Received: 9 X 06; Conditional acceptance: 16 I 07; Final acceptance: 30 V 07)

A. Margalida, *Bearded Vulture Study & Protection Group*, Apdo. 43 E-25520 El Pont de Suert (Lleida) Spain.– D. Garcia, *Generalitat de Catalunya, Dept. de Medi Ambient i Habitatge*, c/ Dr. Roux, 80, E-08017 Barcelona, Spain.– A. Cortés–Avizanda, *Estación Biológica de Doñana (CSIC), Dept. of Conservation Biology, Estación Biológica de Doñana–CSIC, Avda. M^a Luisa s/n, 41013 Sevilla, Spain.*

Corresponding author: A. Margalida. E-mail: margalida@inf.entorno.es

Introduction

Knowledge of the ecological factors affecting the large-scale distribution and abundance of endangered species is an important tool for defining management recommendations and understanding population dynamics (e.g. Verner et al., 1986; Sutherland & Green, 2004). Moreover, in order to improve management measures, it is necessary to understand habitat preferences and the relationship between population density and habitat quality (Sutherland & Green, 2004).

Bearded Vultures, Eurasian Griffon Vultures and Egyptian Vultures are threatened birds of prey in Europe (Annex I, EU Wild Birds Directive 79/409/EEC, Appendix II of the Bern Convention, Bonn Convention and CITES) and a great deal of quantitative studies about habitat requirements and nest-site selection of these species have been carried out (e.g. Ceballos & Donazar, 1989; Donazar et al., 1993; Liberatori & Penteriani, 2001; Sarà & Di Vittorio, 2003; García-Ripollés et al., 2005; Xirouchakis & Mylonas, 2005; Gavashelishvili & McGrady, 2006). However, few studies have examined factors influencing breeding density (e.g. Ceballos & Donazar, 1989; Donazar et al., 1993) and, to our knowledge, no studies using a quantitative approach in the same geographic region have been conducted previously. As the three scavenger species have similar habitat needs (cliffs for nesting sites) and trophic requirements (carrion), it is necessary to determine those factors that most influence their breeding density in order to optimise and design strategies for their conservation and habitat carrying capacity. Quantitative analyses of the geographical distribution of these three species in relation to trophic, structural, climatic and anthropic variables may provide useful information concerning variations in their densities.

Using multivariate analyses, this article examines differences in breeding density of the Eurasian Griffon, Egyptian and Bearded Vultures in NE Spain (Catalonia) according to the regional divisions (*comarques*) and different trophic, orographic-landscape and anthropic variables. As opposed to similar studies that include areas with abundant feeding stations (*muladares*, i.e. traditional sites where livestock carrion is intentionally discarded for elimination by scavenger species and referred to as "vulture restaurants" in several papers), the area of study (Catalonia) is characterized by extensive livestock that is semi-stabled most of the year, allowing spatially widespread food resources in a more homogenous and unpredictable way. This setting therefore provides more natural conditions that allow us to evaluate the factors influencing breeding density. Quantitative analyses of the geographical distribution and density in relation to structural and climatic variables has been used previously to determine which environmental conditions affect the density and distribution of species (Carrascal et al., 1993). The limitations of a biogeographical model

in the case of vulture species are obvious due to the arbitrary division into regions whose boundaries do not correspond to those of the birds' ranges. Nevertheless, studies using administrative divisions may be useful from a management point of view because each region may make decisions and work independently according to their specific interests and conservation policies. This approach may be a useful tool for managers and would allow recommendations to be applied in small spatial scales.

Material and methods

The study was carried out in Catalonia (NE Spain, fig. 1), an autonomous community where monitoring of the scavenger bird population began in the 1980s (Marco & García, 1981). The Bearded Vulture population has since been monitored annually (see Margalida & García, 2002). The Eurasian Griffon Vulture population has been censused every 10 years (1979, 1989 and 1999; Arroyo et al., 1990; Del Moral & Martí, 2001) as part of the National Censuses for Spain. The Egyptian Vulture population was monitored in 1987–88 and in 2000 (Perea et al., 1990; Del Moral & Martí, 2002, respectively). For this study, we used only data from the most recent censuses (2005 census for the Bearded Vulture, 1999 census for the Eurasian Griffon Vulture, Del Moral & Martí, and in 2001 and 2004 for the Egyptian Vulture, updating data obtained in Del Moral & Martí, 2002 with our own data). A partial monitoring of Eurasian Griffon Vulture colonies was carried out in 2004 and results suggested a stabilisation in the number of breeding pairs (authors, pers. observ.). The data collected about the Bearded Vulture and the Egyptian Vulture refer to occupied breeding territories. In the case of the Eurasian Griffon Vulture, we considered the number of pairs present following a count in the breeding colonies.

The distribution of nesting pairs for the Eurasian Griffon Vulture was determined by subdividing Catalonia into regions (*comarques*, fig. 1). Density of birds was calculated and expressed in pairs/10 km². The variables considered to characterise the conditions in each of the regions where the scavenger species occur were selected taking into account the following criteria: 1) trophic level (food availability should regulate the density of species present); 2) climatological factors (low temperatures or a higher rainfall pattern can make it difficult for birds to fly and prevent thermophilous species from negatively selecting these zones); 3) orographic-landscape characteristics (the steep gradient of the terrain can condition the greater presence of rocky cliffs on which the birds can nest and provide peaceful conditions for the nesting birds, whilst a larger forested area can make trophic resources hard to find); and 4) anthropic conditions (high-density human population or infrastructures can lead to disturbance, implying negative selection by nesting birds). All data are taken from the 2004 reports of IDESCAT (Institut

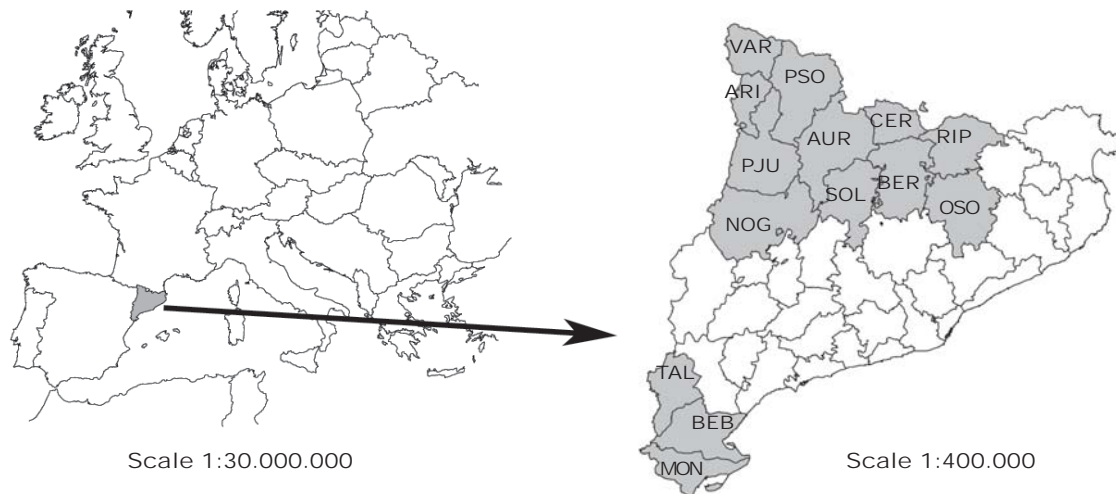


Fig. 1. Study area and regional distribution of the three scavenger species in Catalonia (NE Spain). The acronyms used for the 14 regions studied are: ARI (Alta Ribagorça), AUR (Alt Urgell), PJU (Pallars Jussà), VAR (Val d'Aran), PSO (Pallars Sobirà), NOG (La Noguera), CER (La Cerdanya), RIP (Ripollés), OSO (Osona), TAL (Terra Alta), BEB (Baix Ebre), MON (Montsià), SOL (Solsonés) and BER (Berguedà).

Fig. 1. Área de estudio y distribución comarcal de las tres especies de aves carroñeras en Cataluña (NE España). (Para los acrónimos, ver arriba.)

d'Estadística de Catalunya [Catalan Statistics Institute], <http://www.idescat.net>) and Meteocat (Servei Meteorològic de Catalunya [Catalan Meteorological Service], <http://www.meteocat.com>). Data referring to the period 2001–2004 were averaged out in order to provide a good representation of the climatological conditions in each region (*comarca*). In order to calculate the availability of biomass we established the minimum mortality rates of the different livestock–breeding units and the average weight of each carcass (see Margalida & Bertran, 1997; Margalida et al., 1997). The conversion was as follows: animal biomass = livestock–breeding units present \times mortality rate / 100 \times carcass weight. Bovine mortality was estimated at 0.45%, equine mortality at 1.42%, porcine at 4% and ovine/caprine at 1.5% in comparison with the total amount of livestock present in each of the regions inhabited by these species. The biomass produced per carcass was estimated at 350 kg for a cow, 300 kg for a mare, 150 kg for a pig and 35 kg for a sheep / goat.

The analysis included only those regions where at least one of the scavenger species studied was presented during the year of the census as breeding, with the exception of La Cerdanya (CER), a region with regular presence of the three species of vultures but without breeding pairs in the area. Nevertheless, this region was included because it is situated between the breeding distribution area of the three avian scavenger species (fig. 1).

Statistical analyses

A Principal Component Analysis was applied to the variables (table 1) to obtain independent factors describing geographical variation. This technique transforms a number of correlated quantitative variables into fewer uncorrelated (orthogonal) variables termed PC (Chatterjee & Price, 1991). Each PC is a linear combination of the original variables with coefficients equal to the eigenvectors of the correlation or the covariance matrices. The percentage of the variation of the original traits explained by each PC is equal to the associated eigenvalue, and the weights of the traits in each PC are the terms in the associated eigenvectors. Variable loadings higher than 0.5 were considered significant.

Taking into account the results of the PC analysis (table 2) we selected five variables for further multivariate analysis: a) OVIS / CAPRA; b) INHA; c) LAND 1,000–2,000 m; d) RAD1, and e) FORE. These were those having both high loadings in PC I and II and strong biological significance as potential limiting factors: availability of preferred food resource, human presence, and habitat characteristics (Factor I: a, b, c; Factor II: d, e). Considering them as explanatory variables we fitted Generalized Linear Models (GLM, McCullagh & Nelder, 1989) to identify their influence on the density (breeding pairs / km²) of the three studied scavenger species. We used log as link function and Poisson as error distribution. Only models

Table 1. Descriptive variables used to characterise the regions containing scavenger bird species in Catalonia.

Tabla 1. Variables descriptivas utilizadas para caracterizar las comarcas con presencia de aves carroñeras en Cataluña.

Variables	
Food	
OVIS / CAPRA	Theoretical available biomass of <i>Ovis aries</i> / <i>Capra hircus</i> (kg / km ²)
BOS / EQUUS	Theoretical available biomass of <i>Bos taurus</i> and <i>Equus caballus</i> (kg / km ²)
SUS	Theoretical available biomass of <i>Sus scrofa</i> var. <i>domestica</i> (kg / km ²)
Climatology	
TEMP	Mean annual temperature (°C)
RAIN	Annual rainfall pattern (mm)
RADI	Mean annual solar radiation (MJ / m ²)
Landscape	
LAND < 1,000 m	Percentage of land at heights of under 1,000 m
LAND 1,000–2,000 m	Percentage of land at heights of between 1,000–2,000 m (%)
LAND > 2,000 m	Percentage of land at heights of above 2,000 m
OROG < 20%	Percentage of land with gradients of under 20%
FORE	Percentage of land with tree cover
NO FORE	Percentage of land devoid of vegetation (includes crags, scree, escarpments, rivers, lakes and reservoirs)
Humanisation	
INHA	Density of inhabitants (inhab / km)
URB	Land that has been or could be developed and infrastructures (includes industrial zones, low-density urban zones and road infrastructures) (%)

permitting plausible ecological interpretations were considered. For each significant model, we calculated the percentage of deviance explained as $(100 - (100 \times (\text{deviance}_{\text{model}} / \text{deviance}_{\text{null model}})))$.

Results

Distribution and density

Numbers of breeding pairs were 431 Griffon Vultures (1999), 42 Egyptian Vultures (2004) and 35 Bearded Vultures (2005). As shown in figure 2, the distribution of these species was not uniform. The Pyrenean regions hold the highest populations of all three species. The majority were concentrated in the western regions (ARI, PJU and NOG) and in the central sectors (AUR), whilst the regions of southern Tarragona (mainly TAL and MON) contained only a small population of Eurasian Griffon Vultures (a total of 46 pairs) and Egyptian Vultures (one pair), and no Bearded Vulture as this species be-

came extinct in this area during the first half of the 20th century (García et al., 1996). The regions of PJU, ARI and AUR contained over half the population of scavengers (60% of the Bearded Vulture population, 57% of the Egyptian Vulture population and 78% of the Eurasian Griffon Vulture population) (table 3). Accordingly, the highest breeding densities were found in ARI and PJU (fig. 3). In ARI the density of Bearded Vulture was 0.0014 pairs / 10 km² vs 0.0007 in PJU, 0.0203 pairs / 10 km² of Eurasian Griffon Vulture vs 0.0161 and 0.0016 pairs / 10 km² of Egyptian Vulture vs 0.0007 pairs / 10 km².

Multivariate analyses

The first three factors of the PCA explained the 77.49% variance in the 14 original variables (table 4). The first component (Factor I, 46.5% of the variance) can be interpreted as an altitudinal axis, which basically appears to explain the differences found between locations at higher and lower alti-

Table 2. Generalized Linear Models (GLM) for breeding density of the three studied scavenger species: S.E. Standard error; % D. Percentage of deviance.

Tabla 2. Modelos Lineales Generalizados (GLM) para la densidad reproductora de las tres especies carroñeras estudiadas: S.E. Error estándar; % D Porcentaje de devianza.

	Coefficient	S.E.	Chi-square	P	% D
<i>Gyps fulvus</i>					45.5
Intercept	1.1188	0.2357			
OVIS / CAPRA	0.1541	0.0079	383.53	< 0.0001	
LAND 1,000–2,000 m	0.034	0.0025	184.67	< 0.0001	
FORE	–0.0655	0.0074	78.28	< 0.0001	
<i>Neophron percnopterus</i>					41.4
Intercept	0.2729	0.4797			
OVIS / CAPRA	0.0958	0.0211	20.67	< 0.0001	
INHA	–0.0263	0.0088	8.99	0.0001	
<i>Gypaetus barbatus</i>					92.9
Intercept	6.402	1	1.1276		
INHA	–0.2526	0.0612	17.05	< 0.0001	
FORE	–0.0775	0.0228	11.57	< 0.0001	

tudes. This component was mainly associated with the differences between higher regions, with extreme values in the positive axis of the regional surface area percentage with altitudes between 1,000–2,000 m and > 2,000 m. These higher zones are characterised by the abundance of open areas, which facilitate the location of carrion due to the lack of tree cover (alpine meadows and crags) and have a higher level of rainfall (typical of mountainous zones). In the negative part of Factor I we found the lower localities (below 1,000 m) and those with gentler orography (< 20% slope), higher temperatures, higher population density and a larger number of human infrastructures, as well as greater trophic availability from pig, sheep and goat farms.

Positive values of the second component (Factor II, 17.5% of the variance), denoted zones with the largest amount of forest cover (the most mountainous zones), greatest availability of bovine / equine biomass and the highest solar radiation.

The third component (Factor III; 13.5% of the variance) can be interpreted as the anthropic impact axis, going from negative values denoting high population density and areas without tree cover (less mountainous and more humanised areas) to positive values indicating zones with increasing solar radiation (more mountainous and therefore less humanised zones).

Final models fitted for the breeding densities of the three studied scavenger species accounted for important proportions of the initial deviance (table 2). For the Eurasian Griffon Vulture, the model

obtained explained 45.5% of deviance and showed that it is more abundant in regions with high availability of sheep and goat biomass, a landscape at between 1,000–2,000 m and with low tree cover. The model fitted for the Egyptian Vulture explained 41.4% of deviance, revealing that its density was higher in regions with greater availability of sheep and goat biomass and with low human presence. The model fitted for the Bearded Vulture showed that its breeding density was superior in regions with low human presence and low tree cover, explaining a 92.9% deviance.

Discussion

Factors influencing the breeding density of the three avian scavenger species studied differ. The Eurasian Griffon Vulture was associated with the availability of food (biomass provided by sheep and goats) and altitudinal landscape with low tree cover, the Egyptian Vulture was linked to availability of food and low human presence, and the Bearded Vulture was associated with low human presence and landscape with low tree cover. Our results suggest that the Bearded Vulture seems to be the most selective species in relation to the environmental characteristics. This species is linked to mountain environments (Hiraldo et al., 1979) and high altitude areas with low vegetation cover (to obtain food), steep orography for nesting and preparing food (ossuaries) and low human disturbance.

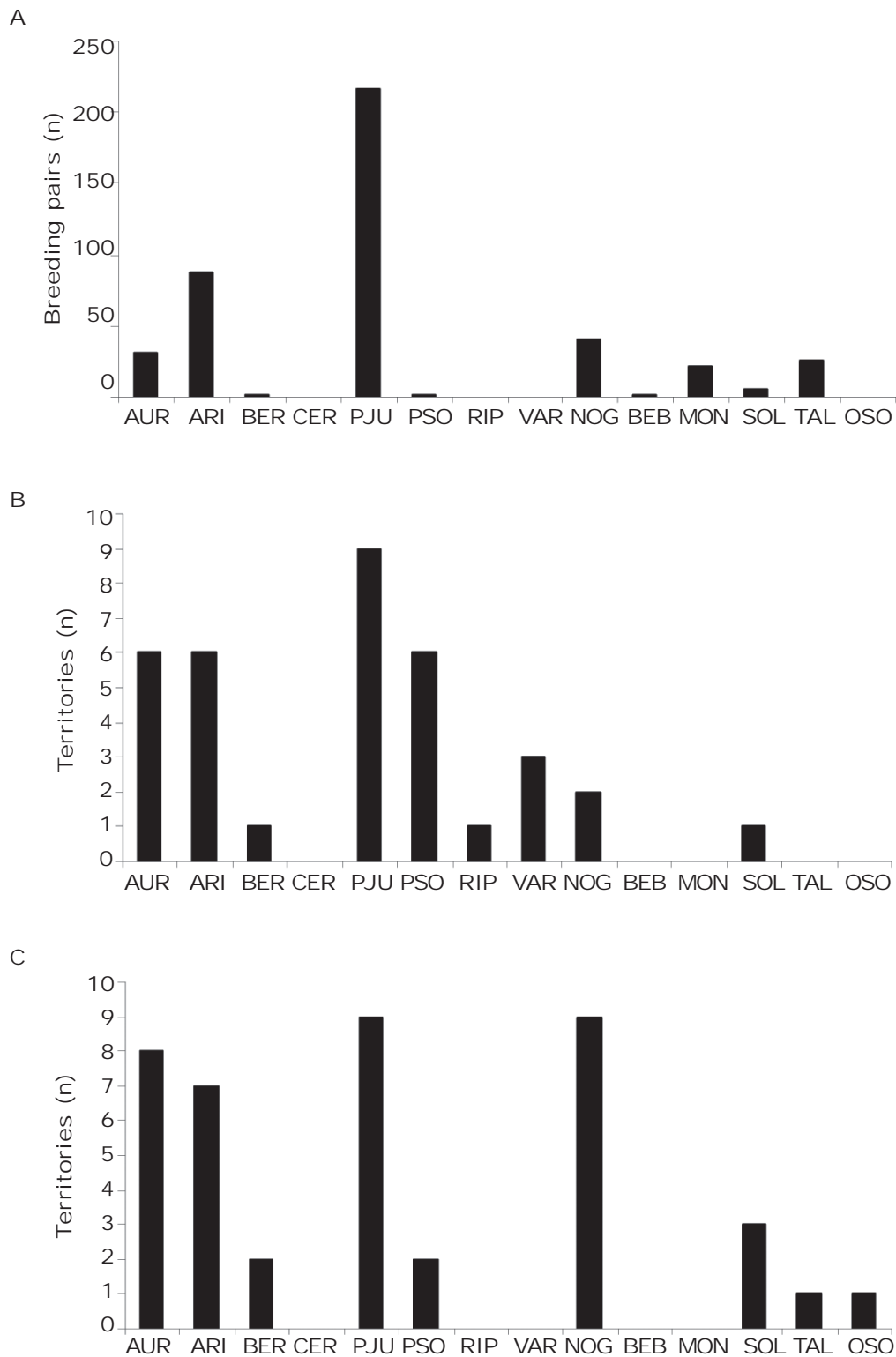


Fig. 2. Regional distribution of the breeding population of Eurasian Griffon Vulture (A), Bearded Vulture (B) and Egyptian Vulture (C) in Catalonia. (For abbreviations see fig. 1.)

Fig. 2. Distribución comarcal de la población reproductora de Buitre Leonado (A), Quebrantahuesos (B) y Alimoche común (C) en Cataluña. (Para las abreviaturas ver la fig. 1.)

Table 3. Regional percentage of the presence of breeding units of Bearded Vulture (BV), Egyptian Vulture (EV) and Eurasian Griffon Vulture (EGV) compared with the total population (T) in Catalonia. (For abbreviations see fig. 1.)

Tabla 3. Porcentaje comarcal de la presencia de unidades reproductoras de Quebrantahuesos (BV), Alimoche común (EV) y Buitre Leonado (EGV) en comparación con el total de la población en Cataluña. (Para las abreviaturas ver la fig. 1.)

	AUR	ARI	BER	CER	PJU	PSO	RIP	VAR	NOG	BEB	MON	SOL	TAL	OSO	T(n)
BV	17.1	17.1	2.9	0	25.7	17.1	2.9	8.6	5.7	0	0	2.9	0	0	35
EV	19	16.7	4.8	0	21.4	4.8	0	0	21.4	0	0	7.1	2.4	2.4	42
EGV	7.2	20.2	0.5	0	50.3	0.5	0	0	9.3	0.2	4.9	1.1	5.8	0	431

These are the main variables that explain the distribution and higher density of this species (Donázar et al., 1993; Margalida et al., 2008). On the other hand, the Eurasian Griffon Vulture and the Egyptian Vulture display a higher degree of ecological plasticity. The model fitted for the Eurasian Griffon Vulture appears less selective and shows an association between biomass provided by sheep and goat density, altitude and open areas. In the case of the Egyptian Vulture, in addition to food availability, the model suggests that, like the Bearded Vulture, this species tends to avoid regions with high human pressure components. These results do not coincide with those obtained by Ceballos & Donázar (1989) in NW Spain, which showed that the species tolerated the proximity of human activity. One possible explanation for this apparent contradiction could be related to the density of this species in Catalonia, which is much lower than the density observed in Navarra (average of 0.47 pairs / 100 km² in the present study vs 1.53 pairs / 100 km² in Navarra in 2000, authors' unpublished data and C. Fernández and O. Ceballos in Del Moral & Martí, 2002, respectively). Another possibility is that at low breeding densities, this species might have favoured quieter areas for nesting but later began to occupy more humanised sites, which were less suitable, when the carrying capacity of the area became saturated. In the areas investigated in the present study, food resources appear scattered on the landscape rather than aggregated at certain predictable sites (*muladares*) as in other more humanised regions; this likely favors Egyptian Vultures, like Bearded Vultures, selecting breeding areas with low human pressure.

The relationship between the available biomass of sheep and goats and the density of Eurasian Griffon and Egyptian Vulture species contrasts with previous studies. In the case of the Eurasian Griffon Vulture, it seems that the presence of cliffs and their quality are a more important limiting factors than food availability (Donázar & Fernández, 1990; Xirouchakis & Mylonas, 2005), although the increase in vulture numbers in limestone areas in Spain has

been related to the increase in livestock biomass (Parra & Tellería, 2004). In the case of Egyptian Vultures, the availability of cliffs and intraspecific interferences seem to limit its distribution and density. However, there is no direct relationship between the availability of food resources and the population density (Ceballos & Donázar, 1989). In view of our results, these differences in the distribution of these species in Catalonia are likely explained by the important role of extensive grazing and the lower presence of vulture restaurants (*muladares*). This scenario could permit scavenger species to select areas with sheep and goats to obtain food. Food provided by vulture restaurants could disguise the possible importance of extensive livestock for the conservation of scavenger species and for this reason, the relation of the contributed biomass and the density of the Griffon and Egyptian Vultures is not as evident as in other studies.

For the Bearded Vulture, the altitude and ruggedness of the topography correspond to an increase in breeding density, whilst snowfall corresponds to a decrease (Donázar et al., 1993). Our results match those of these authors, and the non-existent relation between density and food availability may be due to several factors. Firstly, this opportunistic species seems to have a larger trophic diversity (small mammals, micromammals and birds may constitute > 20% of their diet, Margalida et al., 2007), making them less dependent on biomass from extensive grazing. However species such as wild ungulates (e.g. the Pyrenean Chamois *Rupicapra pyrenaica*, the Red Deer *Cervus elaphus*), which can constitute an important part of its diet (Margalida et al., 2007) in some mountainous regions, were not considered. Finally, although "vulture restaurants" in Catalonia are not as common as in other regions of Spain, several feeding stations have been established for Bearded Vultures (7 such stations in the study area). They may provide an amount of food above that estimated in this study. These aspects and the difficulty in calculating the real amount of available biomass for Bearded

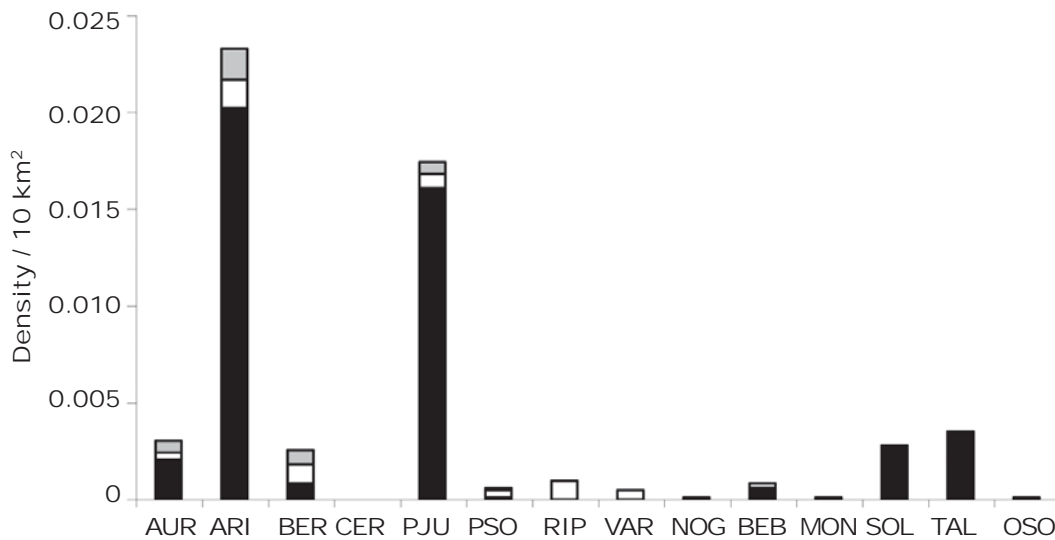


Fig. 3. Regional population density (pairs / 10km²) of scavenger birds in Catalonia: black, Eurasian Griffon Vulture; white, Bearded Vulture; grey, Egyptian Vulture. (For abbreviations see fig. 1.)

Fig. 3. Densidad comarcal de la población (parejas / 10km²) de aves carroñeras en Cataluña: negra, Buitre Leonado; blanca, Quebrantahuesos; gris, Alimoche común. (Para las abreviaturas ver la fig. 1.)

Table 4. Results of the PCA of the 14 variables studied: * Values over 0.50.

*Tabla 4. Resultados del Análisis de Componentes Principales (ACP) de las 14 variables estudiadas: * Valores superiores a 0,50.*

VARIABLES	Factor I	Factor II	Factor III
OVIS / CAPRA	-0.543737*	-0.089399	0.187435
BOS / EQUUS	-0.276947	0.830664*	0.383380
SUS	-0.707012*	0.387573	0.385413
TEMP	-0.779274*	-0.494565	-0.091760
RAIN	0.685555*	-0.048065	0.428309
RADI	-0.150849	0.542938*	-0.708493*
LAND < 1,000 m	-0.947906*	-0.212798	-0.099997
LAND 1,001-2,000 m	0.870865*	0.363833	0.005496
LAND > 2,000 m	0.857458*	-0.043271	0.216191
OROG < 20%	-0.905445*	-0.104010	-0.115747
FORE	0.166264	0.767248*	-0.074320
NO FORE	0.580450*	-0.435647	0.540765*
INHA	-0.711111*	0.094204	0.567606*
URB	-0.673828*	0.294480	0.414170
Eigenvalue	6.51	2.45	1.89
Variance explained (%)	46.49	17.53	13.47
Accumulated variance (%)	46.49	64.02	77.49

Vultures needed for detailed studies, probably prevent us from determining the cause/effect relationship between food availability and the presence of this species.

Conservation implications

Population dynamics and viability of the conservation of these species will depend on the protection of the western regions, where the highest numbers of these avian scavengers in Catalonia are found. As our results suggest, the regulation of human disturbance (by means of protection of nesting sectors) and maintenance of resources (e.g. by revitalising extensive livestock management and leaving carcasses in the field as occurred until recently) may be fundamental for the maintenance and/or growth of their populations. It should also be kept in mind that the health regulations established as a result of the bovine spongiform encephalopathy crisis have made supplies of carrion from unstabled livestock very scarce (Tella, 2001), significantly reducing the availability of food. Extensive livestock management not only guarantees the conservation of scavenger species, but can also avoid problems associated with *muladares* (mainly stabled livestock carrion) as a consequence of the residues of antimicrobial agents and other drugs which may be consumed by vultures and cause death or diseases (Green et al., 2006; Blanco et al., 2007). In addition, preliminary research in Namibia is providing some evidence that vultures may be less dependent on feeding stations than previously thought (see Anderson & Anthony, 2005).

In the westernmost and southernmost regions of the current distribution range, management facilitating geographic expansion and therefore recolonisation could be based on giving priority to conservation actions in the less densely populated regions and/or those that do not contain scavenger species. If extensive grazing and food availability is scarce, supplemental feeding is a commonly used tool in management of vultures (Terrasse, 1985; Heredia, 1991; Camiña, 2004; Piper, 2006) and other endangered species (e.g. Elliott et al., 2001; Jones, 2004; González et al., 2006) as it can help increase breeding success and prevent non-natural mortality due to poisoning. Such tactics should be based on solid scientific evidence so as to avoid the positive effects being detrimental (for pros and cons of establishing vulture restaurants see Anderson & Anthony, 2005; Piper, 2006), for example, preventing the development of normal foraging behaviour (Houston, 2006) or affecting fecundity as a consequence of demographic pressures (Carrete et al., 2006a, 2006b). Conservation priorities should therefore be based on favouring extensive livestock and, as an alternative to *muladares*, farmers should be encouraged to leave livestock carcasses in the open as long as health regulations are taken into account.

Acknowledgements

Thanks to the Cos d'Agents Rurals, Guardes de Reserva, technicians of the Departament de Medi Ambient i Habitatge and members of the Grup d'Estudi i Protecció del Trencalòs for their help during fieldwork, and especially M. Arilla, J. Bolado, A. Bonada, J. Bonfil, J. Canut, P. Capella, E. Edo, J. Feixa, J. García-Petit, J. Jové, F. J. Macià, D. Mañas, J. Martín, Ll. M. Martín, R. Martínez, J. Medina (†), A. Monsó, X. Parellada, P. Pelayo, R. Pelayo, J. Perelada, J. Ruiz-Olmo, J. Solduga and E. Vega. O. J. Arribas, M. Carrete, J. A. Donázar and an anonymous reviewer improved a first draft of this manuscript. S. Hardie translated the text into English. This study was supported by Departament de Medi Ambient i Habitatge of Generalitat de Catalunya.

References

- Anderson, M. D. & Anthony, A., 2005. The advantages and disadvantages of vulture restaurants versus simply leaving livestock (and game) carcasses in the veldt. *Vulture News*, 53: 42–53.
- Arroyo, B., Ferreira, E. & Garza, V., 1990. *II Censo Nacional de Buitre leonado (Gyps fulvus): población, distribución, demografía y conservación*. Colección Técnica. ICONA, Madrid.
- Blanco, G., Lemus, J. A., Grande, J., Gangoso, L., Grande, J. M., Donázar, J. A., Arroyo, B., Frías, O. & Hiraldo, F., 2007. Geographical variation in cloacal microflora and bacterial antibiotic resistance in a threatened avian scavenger in relation to diet and livestock farming practices. *Environmental Microbiology*, 9: 1738–1749.
- Camiña, A., 2004. Consequences of Bovine Spongiform Encephalopathy (BSE) on breeding success and food availability in Spanish vulture populations. In: *Raptors Worldwide: 27–44* (R.D. Chancellor & B.-U. Meyburg, Eds.). WWGBP/MME, Berlin.
- Carrascal, L. M., Bautista, L. M. & Lázaro, E., 1993. Geographical variation in the density of the White Stork *Ciconia ciconia* in Spain: Influence of habitat structure and climate. *Biological Conservation*, 65: 83–87.
- Carrete, M., Donázar, J. A. & Margalida, A., 2006a. Density-dependent productivity depression in Pyrenean Bearded Vultures: implications for conservation. *Ecological Applications*, 15: 1674–1682.
- Carrete, M., Donázar, J. A., Margalida, A. & Bertran, J., 2006b. Linking ecology, behaviour and conservation: does habitat saturation changes mating system in bearded vultures? *Biology Letters*, 2: 624–627.
- Ceballos, O. & Donázar, J. A., 1989. Factors influencing the breeding density and nest-site selection of the Egyptian Vulture (*Neophron percnopterus*). *Journal für Ornithology*, 130: 353–359.
- Chatterjee, S. & Price, B., 1991. *Regression analyses by example*. 2nd ed. Wiley-Interscience, New York.

- Del Moral, J.C. & Martí, R. (Eds.), 2001. *El Buitre leonado en la Península Ibérica. III Censo Nacional y I Censo Ibérico Coordinado. 1999*. Monografía nº 7. SEO/BirdLife, Madrid.
- (Eds.), 2002. *El Alimoche común en España y Portugal (I Censo Coordinado). Año 2000*. Monografía nº 8. SEO/BirdLife, Madrid.
- Donázar, J. A. & Fernández, C., 1990. Population trends of the Griffon vulture *Gyps fulvus* in Northern Spain between 1969 and 1989 in relation to conservation measures. *Biological Conservation*, 53: 83–91.
- Donázar, J. A., Hiraldo, F. & Bustamante, J., 1993. Factors influencing nest site selection, breeding density and breeding success in the bearded vulture (*Gypaetus barbatus*). *Journal of Applied Ecology*, 30: 504–514.
- Elliott, G. P., Merton, D. V. & Cansen, P. W., 2001. Intensive management of a critically endangered species: the kakapo. *Biological Conservation*, 99: 121–133.
- García, D., Margalida, A., Parellada, X. & Canut, J., 1996. Evolución y parámetros reproductores del Quebrantahuesos (*Gypaetus barbatus*) en Catalunya (NE España). *Alauda*, 64: 339–238.
- García-Ripollés, C., López-López, P., García-López, F., Aguilar, J. M. & Verdejo, J., 2005. Modelling nesting habitat preferences of Eurasian Griffon Vulture *Gyps fulvus* in eastern Iberian Peninsula. *Ardeola*, 52: 287–304.
- Gavashelishvili, A. & McGrady, M. J., 2006. Breeding site selection by bearded vulture (*Gypaetus barbatus*) and Eurasian griffon (*Gyps fulvus*) in the Caucasus. *Animal Conservation*, 9: 159–170.
- González, L. M., Margalida, A., Sánchez, R. & Oria, J., 2006. Supplementary feeding as an effective tool for improving breeding success in the Spanish imperial eagle (*Aquila adalberti*). *Biological Conservation*, 129: 477–486.
- Green, R. E., Taggart, M. A., Das, D., Pain, D. J., Kumar, C. S., Cunningham, A. A. & Cuthbert, R., 2006. Collapse of Asian vulture populations: risk of mortality from residues of the veterinary drug diclofenac in carcasses of treated cattle. *Journal of Applied Ecology*, 43: 949–956.
- Heredia, R., 1991. Alimentación suplementaria. In: *El Quebrantahuesos (Gypaetus barbatus) en los Pirineos: 101–108* (R. Heredia & B. Heredia, Eds.) Colección Técnica, Instituto para la Conservación de la Naturaleza, Madrid.
- Hiraldo, F., Delibes, M. & Calderón, J., 1979. *El Quebrantahuesos Gypaetus barbatus (L.)*. Monografías nº 22. ICONA, Ministerio de Agricultura, Pesca y Alimentación, Madrid.
- Houston, D. C., 2006. Reintroduction programmes for vulture species. In: *Proceedings of the International Conference on Conservation and Management of Vulture Populations: 87–97* (D. C. Houston & S. E. Piper, Eds.). Natural History Museum of Crete & WWF Greece, Thessaloniki.
- Jones, C. G., 2004. Conservation management of endangered birds. In: *Bird ecology and conservation: 269–301* (W. J. Sutherland, I. Newton & R. E. Green, Eds.). Oxford Univ. Press, Oxford.
- Liberatori, F. & Penteriani, V., 2001. A long-term analyses of the declining population of the Egyptian vulture in the Italian peninsula: distribution, habitat preference, productivity and conservation implications. *Biological Conservation*, 101: 381–389.
- Marco, X. & García, D., 1981. Situation actuelle des populations de nécrophages (*Gyps fulvus*, *Gypaetus barbatus* et *Neophron percnopterus*) en Catalogne. *Rapaces Méditerranéens*, 1: 119–129.
- Margalida, A. & Bertran, J., 1997. Dieta y selección de alimento de una pareja de Quebrantahuesos (*Gypaetus barbatus*) en los Pirineos durante la crianza. *Ardeola*, 44: 193–199.
- Margalida, A., Donázar, J. A., Bustamante, J., Hernández, F. & Romero-Pujante, M., 2008. Application of a predictive model to detect long-term changes in nest-site selection in the Bearded Vultures *Gypaetus barbatus*: conservation in relation to territory shrinkage. *Ibis*.
- Margalida, A. & García, D., 2002. *Pla de Recuperació del Trencalòs a Catalunya: biologia i conservació*. Documents dels Quaderns de Medi Ambient. Generalitat de Catalunya, 7. Departament de Medi Ambient, Barcelona.
- Margalida, A., García, D. & Heredia, R., 1997. Evaluación de la disponibilidad trófica para el quebrantahuesos (*Gypaetus barbatus*) en Cataluña (NE España) e implicaciones sobre su conservación. *Doñana, Acta Vertebrata*, 24: 235–243.
- Margalida, A., Mañosa, S., Bertran, J. & García, D., 2007. Biases in studying the diet of the Bearded Vulture *Gypaetus barbatus*. *Journal of Wildlife Management*, 71: 1621–1625.
- McCullagh, P. & Nelder, J. A., 1989. *Generalized Linear Models*. Chapman & Hall, London.
- Parra, J. & Tellería, J. L., 2004. The increase in the Spanish population of Griffon Vulture *Gyps fulvus* during 1989–1999: effects of food and nest site availability. *Bird Conservation International*, 14: 33–41.
- Perea, J. L., Morales, M. & Velasco, J., 1990. *El Alimoche Neophron percnopterus en España*. ICONA, Colección Técnica, Madrid.
- Piper, S. E., 2006. Supplementary feeding programmes: how necessary are they for the maintenance of numerous and healthy vulture populations? In: *Proceedings of the International Conference on Conservation and Management of Vulture Populations: 41–50* (D. C. Houston & S. E. Piper, Eds.). Natural History Museum of Crete & WWF Greece, Thessaloniki.
- Sarà, M. & Di Vittorio, M., 2003. Factors influencing the distribution, abundance and nest-site selection of an endangered Egyptian vulture (*Neophron percnopterus*) population in Sicily. *Animal Conservation*, 6: 317–328.
- Sokal, R. R. & Rohlf, F. J., 1981. *Biometry*. W. H. Freeman and Company, New York.
- Sutherland, W. J. & Green, R. E. 2004. Habitat

- assessment. In: *Bird ecology and conservation*: 251–268 (W. J. Sutherland, I. Newton & R. E. Green, Eds.). Oxford Univ. Press, Oxford.
- Tella, J. L., 2001. Action is needed now, or BSE crisis could wipe out endangered birds of prey. *Nature*, 410: 408.
- Terrasse, J. F., 1985. The effects of artificial feeding on Griffon, Bearded and Egyptian Vultures in the Pyrenees. In: *Conservation Studies on Raptors*: 429–430 (I. Newton & R. D. Chancellor, Eds.). Paston Press, Norwich.
- Verner, J., Morrison, M. L. & Ralph, C. J., 1986. *Modelling habitat relationships of terrestrial vertebrates*. University of Wisconsin Press, Madison, Wisconsin.
- Xirouchakis, S. M. & Mylonas, M., 2005. Selection of breeding cliffs by Griffon Vultures *Gyps fulvus* in Crete. *Acta Ornithologica*, 40: 155–161.
-