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# Factors influencing the presence of the cinereous vulture *Aegypius monachus* at carcasses: food preferences and implications for the management of supplementary feeding sites

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We studied the factors that determine the presence of the cinereous vulture *Aegypius monachus* at 134 carcasses experimentally distributed in Special Protection Areas for Birds (SPA) in western and central Spain. Our goals were to assess the use of these carcasses and by-products in order to find out the cinereous vulture's food preferences and thus provide recommendations for the management of specific vulture restaurants for this species. Our results suggest that the number of cinereous vultures that come to feed on the carcasses is related to the quantity of biomass present and to the types of pieces of the provided food. Cinereous vultures prefer individual, medium-sized muscular pieces and small peripheral scraps of meat and tendon. The time that elapses before the cinereous vultures begin to consume a carcass depends on the biomass delivered, the number of pieces into which it is divided, and the type categories of the provided food. The population density of the species in our study area and the breeding stage seem to determine the time invested in feeding at the carcasses. These results may help managers to optimise the creation of vulture restaurants and favour their use by cinereous vultures.

*Key words: Aegypius monachus, carrion, cinereous vulture, feeding sites, food preferences*

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In Europe, vultures have mainly fed on carrion from wild and domestic ungulates. The main sources of the carcasses were the death of wild ungulates (natural and non-natural mortality through hunting practices) and extensive livestock grazing (Donázar et al. 2009a). Alternative food sources included the traditional 'muladar' (place where livestock carcasses were traditionally dumped so that scavenger birds could eat them and thus get rid of them) and, more recently, artificial supplementary feeding sites. The supplementary feeding sites were created in an effort to increase the vulture populations and their breeding parameters, as well as to facilitate the species' geographical expansion and reduce the risks of consumption of micro-pathogen/pesticide contaminated prey (Donázar et al. 2009a). However, since 2004, the appearance of Bovine Spongiform Encephalopathy (BSE) significantly reduced the presence of food in the field. The precautionary principle of banning the dumping of animals that died in the field in order to avoid zoonoses and livestock transmissible diseases spreading, and the decrease in trophic availability due to the closing of the 'muladares', may affect the feeding habits and foraging behaviour of scavengers and thus have major implications for the conservation of endangered vultures (Tella 2001, García de Francisco & Moreno-Opo 2009, Donázar et al. 2009b). In this respect, the sudden changes in the availability of food may cause changes in the species' population dynamics (Ostfeld & Keesing 2000). In the case of scavenger birds, a rapid significant reduction in food availability can have a negative impact on population parameters, since these are K-selected species characterised by long life cycles and low fecundity rates (Donázar 1993, Moreno 2002).

In Spain, the implementation of public health regulations has led to a reduction in the availability of livestock carcasses (Camiña & Montelío 2006, Moreno-Opo et al. 2007). This has resulted in an increase in the number of malnourished young vultures being taken to wildlife recovery centres, and an increase in the number of reports of attacks on neonatal and non-neonatal livestock by Eurasian griffon *Gyps fulvus* and cinereous *Aegypius monachus* vultures (see Donázar et al. 2009a).

The management of trophic resources is of great importance for the conservation of threatened species (BirdLife International 2004, Jones 2004) such as the cinereous vulture, a species considered 'Near Threatened' by IUCN (BirdLife International 2009). The Spanish cinereous vulture population is estimated at 1,845 pairs, which represents 98% of the European population and between 18-25% of the world population (De la Puente et al. 2007, Moreno-Opo 2007). Some of the main threats come from the lack of natural food and its poor quality (Sánchez 2004) as well as poisoning from the consumption of pesticide-contaminated prey (Hernández & Margalida 2008). Thus, the application of measures for the management of trophic resources through feeding stations may constitute an effective conservation tool.

The cinereous vulture mainly feeds on the carcasses of rabbits, sheep and wild ungulates (see Hiraldo 1976, Corbacho et al. 2007). However, changes in the availability of prey over the last 30 years have led to a decrease in the number of rabbits in its diet and an increase in the consumption of domestic ungulates (Corbacho et al. 2007, Costillo et al. 2007). For the conservation of this species, detailed knowledge of its diet and which specific anatomic parts of a carcass it prefers may constitute a fundamental tool for the design of conservation strategies (see for example Margalida et al. 2009).

In our study, we aim to assess the use of carcasses and food preferences by cinereous vultures, and to provide recommendations for the future establishment of vulture restaurants. We obtained information directly in the field through the experimental placing of carcasses and by-products. Our results allow us to provide recommendations regarding how to optimise the future management of specific supplementary feeding stations for the management and conservation of the cinereous vulture.

## Material and methods

### Study area

The fieldwork was carried out in six Special Protection Areas for Birds (SPA, Fig. 1) in the regions of Extremadura and Castilla-La Mancha (western and central Spain). These are areas with rolling hills and mountains with vegetation dominated by holm oak *Quercus ilex* and cork oak *Q. suber*, in which most of the species' nests are located. In our study, the carcasses were delivered at altitudes ranging between 336 and 788 m a.s.l., in the proximity of six cinereous vulture breeding colonies, which included the four largest colonies in Spain: Sierra de San Pedro (336 pairs), Monfragüe (287 pairs), Cabañeros (165 pairs) and Umbría de Alcudia (129 pairs) (De la Puente et al. 2007). The distance between the


Figure 1. Study area with the six Special Protection Areas for Birds in which the carrion was delivered.

feeding sites and the nests occupied by the species ranged between 0.97 and 39.1 km.

### Fieldwork and variables studied

Our study was carried out between December 2003 and December 2006. We monitored 134 carcasses, spread out homogeneously over the different months and years. The remains were delivered to 67 different sites in 13 private estates. The feeding sites were chosen as randomly as possible and were in no case determined by the presence of fenced-in 'muladares'. The carcasses were monitored by the observers, using 20-60 x telescopes at distances of > 500 m, so that their consumption and the vultures' behaviour could be studied without disturbing the birds. The species delivered as carrion were all present in our study area. The following species were delivered: 2,945 carcasses of red deer *Cervus elaphus*, 113 of sheep *Ovis aries*, 178 of wild boar *Sus scrofa*, one of pig *Sus scrofa* var. dom., 21 of fallow deer *Dama dama*, 14 of mouflon *Ovis musimon*, one of cow *Bos taurus*, and two of red fox *Vulpes vulpes*. Each carcass delivered was monitored for a maximum of 48 hours after it was deposited (carcasses generally were eaten during this period), and until it was consumed. Five response parameters were considered in order to assess the presence of the cinereous vulture at the studied carcasses, in accordance with their characteristics: 1) the number of cinereous vultures that came to the carcass, 2) the ratio of cinereous vultures to griffon vultures, 3) the ratio of non-adult cinereous vultures (juveniles and subadults pooled) to the adults (> 5 years), 4) the time the vultures took to start eating, considering this to be the interval of time between the moment the carcass was delivered until the first cinereous vulture started to eat, and 5) how long the birds ate for, considering this to be the time that elapsed between the moment the first cinereous vulture started eating and the time when the last cinereous vulture at the carcass stopped eating. These parameters were related to a series of explanatory variables in order to analyse their influence on the presence of vultures (Table 1).

The number of nests around the site where the by-products were delivered was selected as an explanatory variable of the density of cinereous vultures, since, as a central foraging species, the nest is the origin of the foraging activity for territorial members of this species (Carrete & Donázar 2005). Based on the home ranges of individual cinereous vultures during the breeding season, which were obtained from the literature (Carrete & Donázar 2005, Costillo 2005, Vasilakis et al. 2006), we estimated the daily flight distance of the vultures at 16.4 km average radius ($N = 3$). Thus, this distance was considered a theoretical radius for calculating the number of nests present around the location of the delivered carcasses, in order to then divide the cinereous vulture population density into three categories (low, medium and high; see Table 1).

In order to discover how often the carcasses were used by different age classes (juvenile, subadult and adult) in accordance with breeding stage, observations were grouped into three periods: incubation (I: February-April), chick-rearing (CR: May-August), and the non-breeding period (NB: September-January), partially corresponding to post-fledging and pre-laying periods.

In parallel, in order to determine the most consumed parts of the supplied carcasses, a series of categories were established to approximate food preferences: 1) all kinds of remains from the carcass (vultures feeding indistinctly on all kinds of remains available, from the whole carcass to muscular pieces, entrails, etc. both concentrated in one place and/or scattered), 2) muscular pieces extracted from a whole carcass, 3) loose medium-sized muscular pieces (0.2-5 kg), 4) entrails in a whole carcass, 5) entrails scattered around a carcass, and 6) small peripheral scraps of meat and tendons. The observations of the different carcasses were independent and more than one category was noted, in accordance with the feeding activity displayed by the birds studied.

### Statistical analyses

We conducted three different statistical analyses based on ecological issues considered in the study. First, in order to determine the appearance patterns of the cinereous vultures in accordance with the different explanatory variables considered, we fitted General Linear Models (GLM). This analysis aims to establish an applicable and predictable relationship between the presence of the cinereous vulture at carcasses (expressed as five response parameters) related to the different predictor explanatory variables (see Table 1). All the explanatory variables were included in the analysis as independents. The independent variables 'estate' and 'SPA' were nested as they were integrated, since the different estates were grouped together in each of the SPAs

Table 1. Independent variables assessed to analyse the presence of the cinereous vulture at carcasses through GLM analysis (* = continuous variable, ** = categorical variable), and description of the categories and the field of study referred to by the variables.

| Variable | Categories | Description of the category or variable | Field of feeding ecology study |
|---|---|---|---|
| Format** | 1 | Whole carcass(es) | Carrion typology |
| | 2 | Whole carcass(es) and piled up scraps | |
| | 3 | Whole carcass(es) and scattered scraps (radius of up to 50 m) | |
| | 4 | Piled up scraps | |
| | 5 | Scattered scraps (radius of up to 50 m) | |
| Biomass (kg)* | | Weight (kg) of the carcass delivered | |
| Number of items* | | Number of different items into which the carcass delivered was divided | |
| Breeding period** | Non-breeding | Outside of the breeding period, post-fledging and pre-laying periods (September-January) | Time |
| | Incubation | Incubation period (February-April) | |
| | Chick-rearing | Period when chicks are reared in the nest (May-August) | |
| Time** | | Time when the animal by-products were delivered | |
| Plant cover* | | Percentage (%) of land covered by vegetation > 50 cm high in a 100 m radius around the centre of the carcass | Habitat |
| Cinereous vulture density ** | Low | < 25 cinereous vulture nests within a 16.4 km radius around the feeding station | Population density |
| | Medium | 26-75 cinereous vulture nests within a 16.4 km radius around the feeding station | |
| | High | > 75 cinereous vulture nests within a 16.4 km radius around the feeding station | |
| Estate** | | Private estate in which the carcass was delivered | Location |
| SPA** | | Special Protected Area (SPA) in which the carcass was delivered | |

studied. The dependent variables were fitted to a binomial error, and a log link function was used. The normality of residuals of the response parameters analysed was studied, in order to check the required hypothesis to fit a GLM analysis. Five multi-relation parameter-independent response variable analyses were arranged to identify statistical significance of the variables. We first analysed the number of cinereous vultures attending to the carcasses in relation to the considered variables. The initial model included: 'format of the carcass', 'biomass delivered', 'number of items', 'plant cover', 'population density', 'breeding period', 'time' and 'SPA*estate' (nested). Then, we analysed four other response parameters: the ratio of cinereous vultures to griffon vultures at carcasses, the ratio of non-adult to adult cinereous vultures at carcasses, the time to arrival of cinereous vultures to begin feeding and the time spent by cinereous vultures feeding on the carcass. The initial model was the same as that described for the number of cinereous vultures attending to the carcasses. For the sake of clarity, in our presentation, we reported only the significant terms (factors and their interactions). All other factors not reported were non-significant ($P > 0.05$).

The second analysis was conducted to determine the differences in the percentage of visits by different age classes of cinereous vultures over the three phenological periods considered (non-breeding, incubation and chick-rearing). This was tested using analysis of variance (ANOVA). When the ANOVA results proved to be statistically significant, a post-hoc analysis was made employing the Scheffé test to identify differences between groups.

Finally, frequencies obtained in the observations of the type of categories fed on by the cinereous vultures were analysed using the $\chi^2$ test. Values are presented as means ± SD.

## Results

Of the 134 carcasses monitored, a total of 3,136 visits of cinereous vultures and 10,610 visits of

Table 2. Statistically significant relationships between the explanatory variables studied in relation to the response parameters, resulting from the GLM analysis.

| Response parameter | Explanatory variable | Sum of squares | df | F | P |
|---|---|---|---|---|---|
| Cinereous vulture (N) that came to the carcass | Biomass delivered (kg) | 55245.40 | 1 (114) | 103.49 | 0.00001 |
| | Format of carcass | 6468.58 | 4 (114) | 3.03 | 0.0215 |
| Time (minutes) elapsed until starting eating | Biomass delivered (kg) | 165054.30 | 1 (75) | 7.22 | 0.0097 |
| | Format of carcass | 230198.16 | 4 (75) | 2.52 | 0.0520 |
| | Number of items of the carcass | 238988.11 | 1 (75) | 10.45 | 0.0022 |
| Time (minutes) that cinereous vulture spent eating | Cinereous vulture density | 87514.39 | 2 (74) | 4.51 | 0.0158 |
| | Breeding period | 60211.66 | 2 (74) | 3.11 | 0.0535 |
| | Special Protected Area for birds | 190670.06 | 7 (74) | 2.81 | 0.0151 |

griffon vultures were recorded. The average number of cinereous vultures observed at each carcass was 23.40 ± 52.25 individuals (range: 0-400, N = 134), with the average maximum number of cinereous vultures observed simultaneously at a carcass being 21 ± 26 (range: 2-110, N = 87). The average time that elapsed between the carcass being delivered and it being eaten was 236.64 ± 134.42 minutes (range: 10-780, N = 79). The average time the birds spent at the carcass was 165.18 ± 113.68 minutes (range: 12-606, N = 78). The ratio of cinereous vultures vs griffon vultures present at the carcass was 1.29 ± 0.75 (range: 0-6.19, N = 95).

The results of the GLM analysis were significant for three of the five response parameters analysed in relation to the total number of studied variables: the number of cinereous vultures that visited the carcasses (F = 23.05, df = 24, 114, P = 0.00001, adjusted $R^2 = 82.27\%$), the time that elapsed between the delivery of the carcass until the first cinereous vulture started eating (F = 1.83, df = 24, 75, P = 0.035, adjusted $R^2 = 21.06\%$) and the time invested by the cinereous vultures in eating each carcass (F = 2.17, df = 24, 74, P = 0.010, adjusted $R^2 = 27.47\%$).

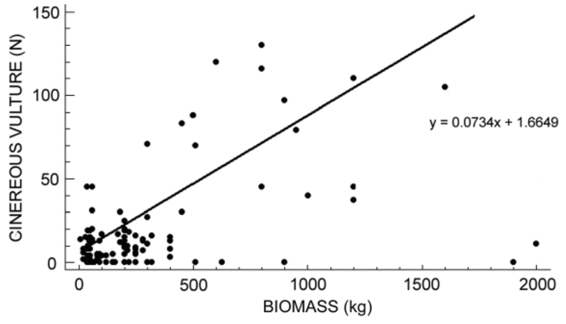


Figure 2. Relationship between the total number of cinereous vultures and the biomass present (kg) at the carcasses studied.

The number of cinereous vultures that visited the carcasses was positively related to the biomass delivered, and significantly related to the format of the carcass (Table 2, Figs. 2 and 3a). The time that elapsed between the delivery of the carcass until the first cinereous vulture started eating was significantly related to the biomass delivered and the number of items (see Table 2), and marginally related with the format (see Table 2 and Fig. 3). The

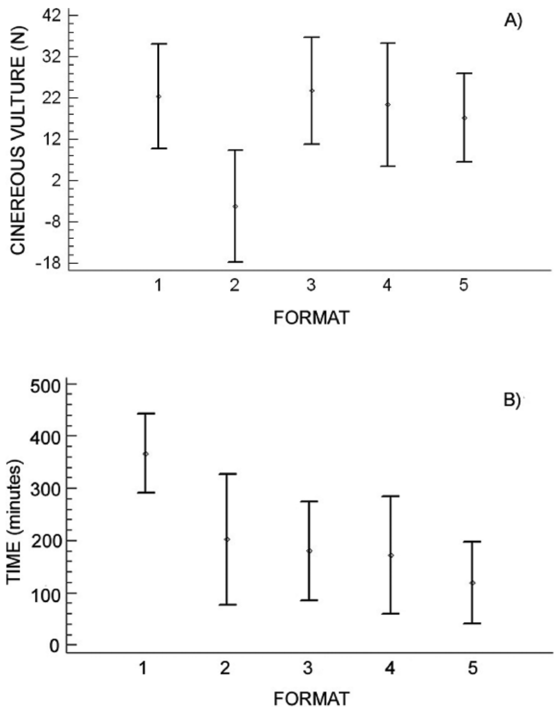


Figure 3. Number of cinereous vultures at carrion (A), and time difference between carrion delivery and vulture feeding (B) in relation to carrion format. 1) Whole carcass(es), 2) whole carcass(es) and piled up scraps, 3) whole carcass(es) and scraps scattered over a radius of up to 50 m, 4) piled up scraps, and 5) scraps scattered over a radius of up to 50 m.

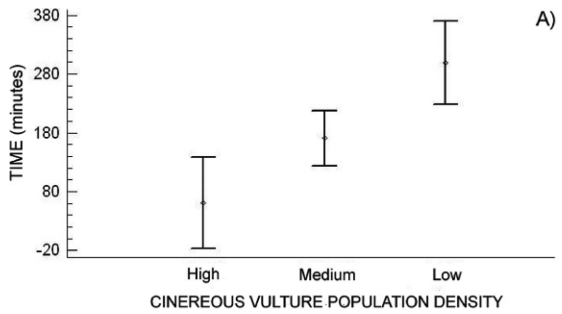



Figure 4. Time differences between carcass delivery and vulture feeding in relation to A) population density and B) breeding stage (CR: chick rearing, I: incubation, NB: non-breeding).

time that the cinereous vultures spent feeding depended significantly on the vulture density, and on the SPA*estate interaction, and marginally on the phenology (see Table 2 and Fig. 4).

With regard to age classes, the ratio of non-adult cinereous vultures to adult cinereous vultures was 1.77 $\pm$ 2.08 (range: 0-9, N=61). When we compared the proportion of different age classes in the carcasses through the breeding season, the adults visited the carcasses significantly more frequently

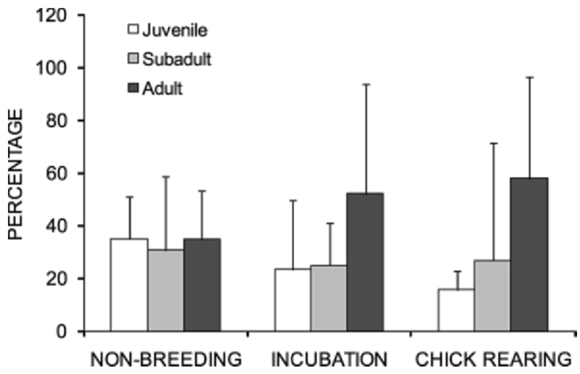


Figure 5. Variation in the ratio of age classes of the cinereous vultures present at the carcasses in accordance with breeding stage.

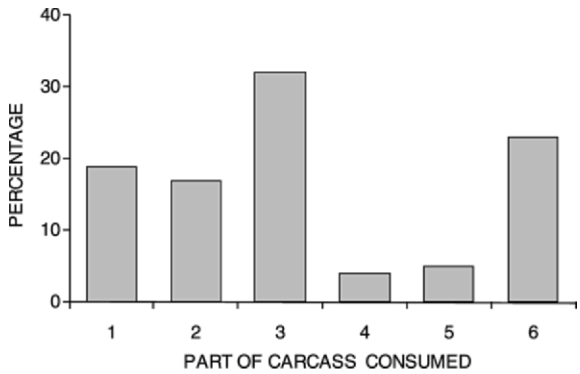


Figure 6. Categories of pieces ingested by cinereous vultures on different carcass parts: 1) all kinds of remains available at the carcass, 2) muscular pieces in a whole carcass, 3) scattered, medium-sized, muscular pieces, 4) entrails in a whole carcass, 5) entrails lying around a carcass, and 6) small peripheral scraps and tendons.

during the chick-rearing period ($F = 4.75$, df = 2, 73, $P = 0.001$, Fig. 5), whereas the juveniles visited the carcasses more frequently during the non-breeding season ($F = 4.81$, df = 2, 73, $P = 0.011$). The subadults did not show significant differences among periods ($F=0.30$, df=2, 73, $P=0.74$; see Fig. 5).

Carcass parts or remains most consumed among the six categories considered showed significant differences ($\chi^2=30.96$, df=5, $P=0.004$, N=99; Fig. 6). Cinereous vultures mostly fed on medium-sized muscular pieces and small remains and peripheral scraps, tendons etc. from the centre of the carcass, with observations of individuals eating entrails being rare, both at the carcasses and in the surrounding areas.

## Discussion

The variables that explained the higher abundance and optimisation of the consumption of carrion by the cinereous vulture depended on several factors. Firstly, the quantity of biomass fed correlates directly with the total number of cinereous vultures that congregated as found for griffon vultures (Bosé & Sarrazin 2007), and also inversely with the time that elapsed before they began to eat. The average time the birds took to come to the carcass (214 minutes) was much lower than the time estimated for the cinereous vultures in the Caucasus (1,122 minutes, Gavashelishvili & McGrady 2006). This may be due to the proximity of the population nuclei and the high population density in our study area. In this respect, the high average number of individuals observed per carcass in our study (23.4 individuals), suggests that the use of conspecifics as cues to food location probably improves foraging success (Jackson et al. 2008). Secondly, the format of the food remains appeared to determine the access time and the total number of cinereous vultures attending the carcasses. Thus, when scattered, small or medium-sized remains were available, the cinereous vultures started eating more quickly than when large quantities of carrion were delivered to the same feeding station, which could favour other species such as the griffon vulture. This aspect could be of interest in relation to interspecific competition, dominance or ability to exploit food, which may explain differing selection of the type of remains (Hertel 1994, DeVault et al. 2003). Thus, the species would appear to be favoured by the consumption of medium-sized, relatively tough pieces, due to their external morphological adaptations to this type of food (König 1983).

The ratio of cinereous vultures compared with that of griffon vultures feeding at the carcass can constitute a measurement of the carrion consumption efficiency, since the griffon vulture will take more of the food at the carcass due to its numerical dominance and the species' adaptations to large numbers of individuals consuming big carcasses (König 1983). Our results suggested that the ratio of cinereous to griffon vultures is 1.29. These results suggest a ratio favourable for the cinereous vulture in comparison to all populations that live in the Iberian Peninsula, presumably because the study was carried out near large population nuclei of cinereous vultures, where their relative density is potentially greater (Carrete & Donázar 2005), and due to the abundance of wild ungulates and extensively reared livestock.

The species' breeding stage did not determine the number of individuals that came to a carcass, but was related to the duration of the consumption of the food. Moreover, when the age classes were separated in accordance with breeding stage, the results suggested that the juvenile age class exploited carcasses preferably during the winter, whereas adults increased their consumption during the chick-rearing period. This temporal segregation could be explained by the breeding population's greater energy requirements during the breeding season (Corbacho et al. 2007). In the case of the juvenile age class, the greater concentration during September-January could coincide with the post-fledging period before the start of juvenile dispersal. The fact that young birds have less foraging experience makes them more dependent on the movement of other scavengers such as the griffon vulture (see Jackson et al. 2008). Thus, the juveniles congregated in greater numbers during this period. During the spring and summer, the greater availability of trophic resources, milder weather and the start of the juvenile dispersal period could facilitate the birds leaving the breeding sites, and, therefore, could explain a lower number of birds at the feeding sites. In addition, these variables could have an impact on the time the cinereous vulture takes to search for food and its flight efficiency (Hiraldo & Donázar 1990).

Neither the number of nests in the radius around the feeding stations nor the plant cover appeared to determine the presence of cinereous vultures at carcasses. However, as central-place forager, the probabilities of obtaining food increase with the proximity to breeding nuclei (Carrete & Donázar 2005). In addition, the cinereous vulture is better adapted than other vulture species to detect prey in more overgrown areas (e.g. scrub, wasteland, 'dehesas' (pastureland with holm and cork oaks, grazed by livestock) and grazing land), although at all times this is related to prey availability (Carrete & Donázar 2005, Costillo 2005). The type of food consumed was mainly small or medium-sized items, tough or relatively tough pieces (e.g. muscles, tendons and skins), preferably scattered and not concentrated in one place (König 1983).

In summary, the cinereous vulture benefits from carcasses being delivered with significant biomass, broken up into small and medium-sized pieces that are scattered and not concentrated in one place. In order to increase the cinereous vulture's use of this resource, the delivery of a higher number of separate pieces of carrion would favour the birds' presence. In this respect, the relatively tough, medium-sized remains and pieces of muscle and tissue, and the small, scattered pieces are those that the cinereous vulture eats most efficiently.

## Implications for conservation

The management of the feeding of threatened avian scavengers is a major challenge currently facing conservationists (Deygout et al. 2009, Donázar et al. 2009a). In endangered species, supplementary food has been proved useful for increasing pre-adult survival (Oro et al. 2008) and breeding parameters (González et al. 2006, López-Bao et al. 2008). Vulture restaurants also may help to reduce vulture mortality by providing safe food (not contaminated by pesticides and confirmed not to contain transmissible agents of zoonosis or livestock diseases because of the human control of the deliveries, see Gilbert et al. 2007, Margalida et al. 2008b, Hernández & Margalida 2009). However, supplementary feeding can also have negative effects (see Robb et al. 2008). The creation of supplementary feeding stations in which large quantities of food are delivered and pile up, does not favour the most threatened avian scavengers. In this respect, it can influence the spatial distribution of the breeding population (Margalida et al. 2008a). It can also attract facultative scavengers, which could predate on species living in the surrounding area (Cortés-Avizanda et al. 2009), and thereby have a detrimental effect on fecundity (Carrete et al. 2006). Moreover, recent studies show a potential increase in levels of antibiotics in the birds' blood as a consequence of feeding on carcasses from intensive farming feeding stations (Lemus et al. 2008). Thus, this procedure of feeding should be based on rigorous information that allows the pros and cons of this type of management to be evaluated. In this regard, managers must assess what type of remains the cinereous vulture prefers, how the remains should be laid out in order to optimise their consumption, and how to discourage less endangered species such as the griffon vulture using this resource. However, there is still a need for more studies about these subjects in the scientific literature, which can provide guidelines regarding the use of feeding stations for the whole scavenger raptor community.

When managing supplementary feeding stations for cinereous vultures, managers should focus on quantity, format and the number and dispersal of the pieces, in order to optimise the birds' consumption of the carrion. Moreover, carrion should be mainly supplied during the chick-rearing period within the breeding areas, in order to increase the species' productivity and avoid the above-mentioned negative side effects (Deygout et al. 2009). These results suggest that the feeding of the species should be based on the appropriate sustainable measures, such as carcasses from extensively reared livestock, which occur more heterogeneously on spatial and temporal levels (Bosé & Sarrazin 2007, Margalida et al. 2007).

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