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ORIGINAL PAPER

Linking sanitary and ecological requirements in the management of avian scavengers: effectiveness of fencing against mammals in supplementary feeding sites

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Abstract In order to ensure that the objectives behind the conservation of biodiversity are fulfilled it is essential that policies of all stakeholders are compatible. This is the case of the application of sanitary measures for the management of animal by-products and the negative effects that such restrictions had on the population dynamics and behavioural ecology of the avian scavengers' guild. Thus, measures that allow these species to feed and that reduce risks of disease transmission must be put into practice. This study aims to improve the technical implementation of one of the commonest tools employed in the conservation of avian scavengers: supplementary feeding stations. We evaluated the permeability of three types of fences in experimental feeding stations to determine which of the models prevent non-target species from accessing the food provided. We compared

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results from fenced-off feeding stations with those from random points in unfenced-off sites. The results showed that two of the models (*high* and *low nets*) were the most effective avoiding facultative mammal scavengers from gaining access into the exclosure for over two months and for 7–8 inputs of food. Avian scavengers were able to access food regardless of the type of exclosure, which did not determine the abundance of birds or the species present. The carrion consumption by non-target species can be reduced by affordable and sustainable means. We suggest proposals to optimize the management of supplementary feeding stations for threatened avian scavengers and for the design of fenced exclosures.

Keywords Animal by-products · Health legislation · Scavenger · Spain · Feeding programs · Vulture conservation · Vulture restaurant

Introduction

Avian scavengers provide important ecosystem services in balancing trophic chains by completing the processing cycle and assimilation of biomass of dead animals (DeVault et al. 2003; Şekercioğlu et al. 2004). Scavenger species have evolved behavioural and morphological mechanisms that enable them to optimize the way in which they exploit carrion (König 1983; Donázar 1993; Hertel 1994). The traditional presence of dead animals in the wild has led to the development of complex ecological relationships between soils, vegetation and primary and secondary consumers (DeVault et al. 2003; Whelan et al. 2008). Yet, various scientific sources have revealed that the interaction among wild and domestic animals and humans can lead to the spread of certain diseases (Caley and Hone 2004), which may negatively affect human and animal health and increase costs in farming practices, conservation actions and sanitary measures (Daszak et al. 2000; Horan and Wolf 2005; Gortázar et al. 2008). Furthermore, these interactions have been proposed as the cause of spreading of emerging diseases that are potentially threatening for the world's population health (Schiermeier 2001; Kilpatrick et al. 2006). In order to avoid sanitary risks it is vital that the management techniques of animal carcasses be as appropriate as possible (Gortázar et al. 2007; Maichak et al. 2009).

As a means of avoiding risks to human and animal health, sanitary authorities in the European Union (EU) have set up in recent years initiatives aimed at regulating the use and exploitation of animal by-products that could become potential vectors of transmittable diseases (Donázar et al. 2009b). EU legislation has been issued in the last decade whose intention is to control the management of animal by-products not intended for human consumption (Regulation CE 1774/2002); from the onset it was perceived that such controls were likely to affect the occurrence and availability of food resources as well as to the foraging patterns of avian scavengers (Tella 2001). In particular, such sanitary legislation only exempted the compulsory carcasses destruction in certain cases for allowing their transfer to only enclosed avian scavenger feeding stations whose fences would prevent access by mammals and thus the propagation of disease.

The management of food resources exclusively via specific enclosed feeding points has been shown to be insufficient in terms of availability for the Iberian avian scavenger populations (García de Francisco and Moreno-Opo 2009). Moreover, since the obligation of providing carrion in fenced feeding sites alterations in foraging patterns, dispersion and even behaviour have been detected (Deygout et al. 2009; Margalida et al. 2010; Zuberogoitia et al. 2010), which have led to changes in species' population dynamics, the appearance of the negative effects associated with predictable availability of food, and negative social and economic impacts on the interests of rural communities (Carrete et al. 2006; Robb et al. 2008; Margalida et al. 2011b). In light of this situation, as of 2011 the EU have loosened restrictions in certain circumstances and new aspects related to the natural patterns of feeding behaviour in avian scavengers have been incorporated into the legislation (Council of Europe 2009; European Commission 2011). As a result, some carcasses may be left in the wild without prior collection and without the obligation of placing in a fenced-off area.

After this modification of the sanitary legislation, it is expected that supplementary feeding programs could allow a higher availability and wider occurrence of carcasses, improving the food quality, more consistent with the ecological requirements of avian scavengers (Margalida et al. 2010). Similarly, no obligation of fencing all the supplementary feeding points is likely to reduce the economic costs to administrations and managers as well as the negative effects that food concentration at a few points implies in the behavioural ecology of avian scavengers (Carrete et al. 2006; Francisco de García and Moreno-Opo 2009; Cortés-Avizanda et al. 2010; Margalida et al. 2010). On the other hand, it may be advisable in certain circumstances the use of technical systems that prevent the access of potential disease vectors to the provided carcasses. In these cases, and in order to provide a quick and healthy consumption of by-products by avian scavengers, it would be necessary to have effective, manageable and affordable designs to limit access to the carcass only to the target species.

This study aims to contribute to making sanitary requirements compatible with ecological needs in the supplementary feeding of threatened avian scavengers. It tries to implement the new EU legislation on the management of animal by-products, proposing best practical fencing models and meeting certain positive requirements for all the involved stakeholders: threatened scavengers feed on a sustainable way, health risks are avoided and economic costs are reduced in relation to conventional feeding stations. The specific objectives of the study are thus as follows: 1) to evaluate the permeability of different types of exclosures and the ability of different scavenger species to enter fenced-off areas and 2) to promote cheap, mobile and easily manageable models of exclosures that not only prevent facultative mammalian scavengers from entering feeding stations, but also replicate as much as possible the natural appearance of carrion for avian scavenger species.

Materials and methods

Studied area and species

Two supplementary feeding areas were chosen in Castilla-La Mancha in central Spain (Fig. 1): in Los Yébenes (Montes de Toledo) food was provided in exclosures (treatment), whilst four sites at Almodóvar del Campo and Fuencaliente (Sierra Morena) were treated as controls.

Similar scavenger communities in terms of composition and relative abundance exist in both areas (Del Moral and Martí 2003). The following avian scavenger guild were studied: Eurasian griffon vulture *Gyps fulvus* (<20 breeding pairs in a radius of 10 km around the feeding stations, although there are also many non-breeding present in both treatment and control areas throughout the year); cinereous vulture *Aegypius monachus* (the feeding stations are less than 5 km from the two largest colonies of this species in Castilla-La Mancha: 165 pairs in the treatment area and 129 in the control area; De la Puente et al.

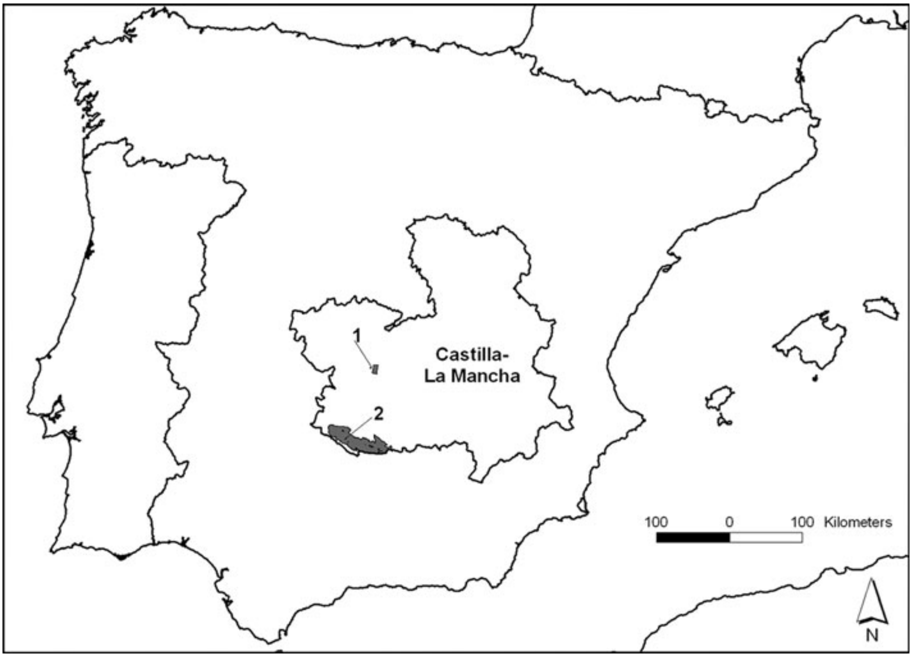

Fig. 1 Location of study sites in Castilla-La Mancha, central Spain. Study sites were in Montes de Toledo (1) and in Sierra Morena (2)

2007); common raven *Corvus corax* (2–5 pairs in a radius of 10 km from the feeding points and presence of flocks in winter in treatment and control areas); and the Spanish imperial eagle *Aquila adalberti* (3–5 pairs in a radius of 10 km of the feeding station and presence of non-breeders in treatment and control areas). The facultative mammalian scavengers present are red fox *Vulpes vulpes* and wild boar *Sus scrofa*. The relative abundance of these mammals in both the treatment and control areas were not calculated, although they were considered to have similar values given the similarities between both areas in terms of their socio–economic models, habitats, hunting statistics and the potential abundance of available resources (Virgós 2002; Vicente et al. 2007; Mangas and Rodríguez-Estival 2010). Dogs *Canis familiaris* were also considered during this study given the presence at the end of the hunting season of animals escaped from hunters (R. Moreno-Opo, A. Arredondo and F. García, unpublished data). The presence of red deer *Cervus elaphus* was also taken into account given that, despite not being a scavenger, it is attracted to carrion and as such could become a vector of transmittable diseases (Gortázar et al. 2008).

Field work and variables

Exclosure models were chosen from livestock and other properties mobile protection systems, among the best available options. Then, three models were selected according to their compliance of the prior requisites of the study: (a) low economic cost in comparison with conventional feeding stations—that typically have fences of 2 m high with overhangs, fixed posts and cover c. 1 ha (i.e. Consejería de Medio Ambiente 2006), (b) a surface area of at least 0.5 ha and (c) can be easily set up and removed. The following types of exclosures were tested:

- *Ribbons*: electrified ribbons (5–8 volts) and metal posts enclosing a 75 × 75 m; four parallel lines of white polythene ribbons with 20 mm steel conductors attached by means of plastic insulators to posts; as well, a galvanized steel wire (diameter 0.4 mm) placed 20 cm from the ground and 20 cm in front of the tapes; gate kit and Viper S250 solar-powered fence charger equipped with rechargeable battery (Fig. 2A).
- *Low net*: a 90 cm high electrified mesh fence (5–8 volts), enclosing an area of 75 × 75 m; orange polythene net woven with three 0.25 mm wire conductors; 17 cm^2 mesh sized; plastic posts and Viper S250 solar-powered fence charger equipped with rechargeable battery (Fig. 2B).
- *High net*: a 170 cm high electrified mesh fence (5–8 volts), enclosing an area of 75 × 75 m; orange polythene mesh woven with three 0.25 mm wire conductors; 17 cm^2 mesh sized; plastic posts and Viper S250 solar-powered fence charger equipped with rechargeable battery (Fig. 2C).

The conventional feeding stations authorized by official bodies (Consejería de Medio Ambiente 2006) were not studied since they do not fulfil the previously established requisites regarding cost, mobility and size.

The three tested models were set up and activated for a period of 4 months (Table 1), by using one exclosure of each model at one site. Between April 2010 to April 2011 carrion was supplied every fortnight to control sites (without fencing; $n = 4$ sites and $n = 40$ inputs of food) and treatment areas ($n = 46$ whole inputs of food for all the exclosures, see Table 1 for details) to test their respective permeability to scavenger species. Inputs of food consisted of remains of red deer and wild boar in both control and treatment areas ($n = 66$), as well as goat *Capra hircus* ($n = 3$) and rabbit *Oryctolagus cuniculus* var. dom. ($n = 17$) carcasses. The average quantity of carrion supplied each time was 75.0 ± 37.8 kg (range 40–180) for *ribbons*, 74.4 ± 48.7 kg (range 30–200) for *low net*, 55.9 ± 25.6 kg (range 25–120) for *high net* and 85.5 ± 147.8 kg (range 5–450) for the *controls*.

Two automatic photo-cameras were placed at 5 m from the carrion to detect and identify which species were feeding on and thus which species were able to penetrate into the feeding station. Specifically, Scoutguard SG550 (HCO Outdoor Products, Norcross, USA) cameras were used, equipped with movement and infrared sensors for night-time use, and programmed in phases of three photos with a delay of one minute between phases. The cameras were checked and images downloaded every fortnight. After images were analysed, the following variables were noted: type of exclosure, date on which food was supplied, quantity of biomass supplied (these three variables not obtained from the photo analysis), maximum number of each feeding species present simultaneously, and number of days elapsing between the food supply and the arrival of each feeding species.

Statistical analyses

Differences between the different types of exclosure were analyzed in terms of the number of days (from the beginning of the food supply) until each of the study species was detected for the first time and in relation to the number of individuals accessing the food. As a result, two response variables were selected: 1) the number of days that the scavengers took to come to feed since the input of the food, and 2) the maximum number of individuals of

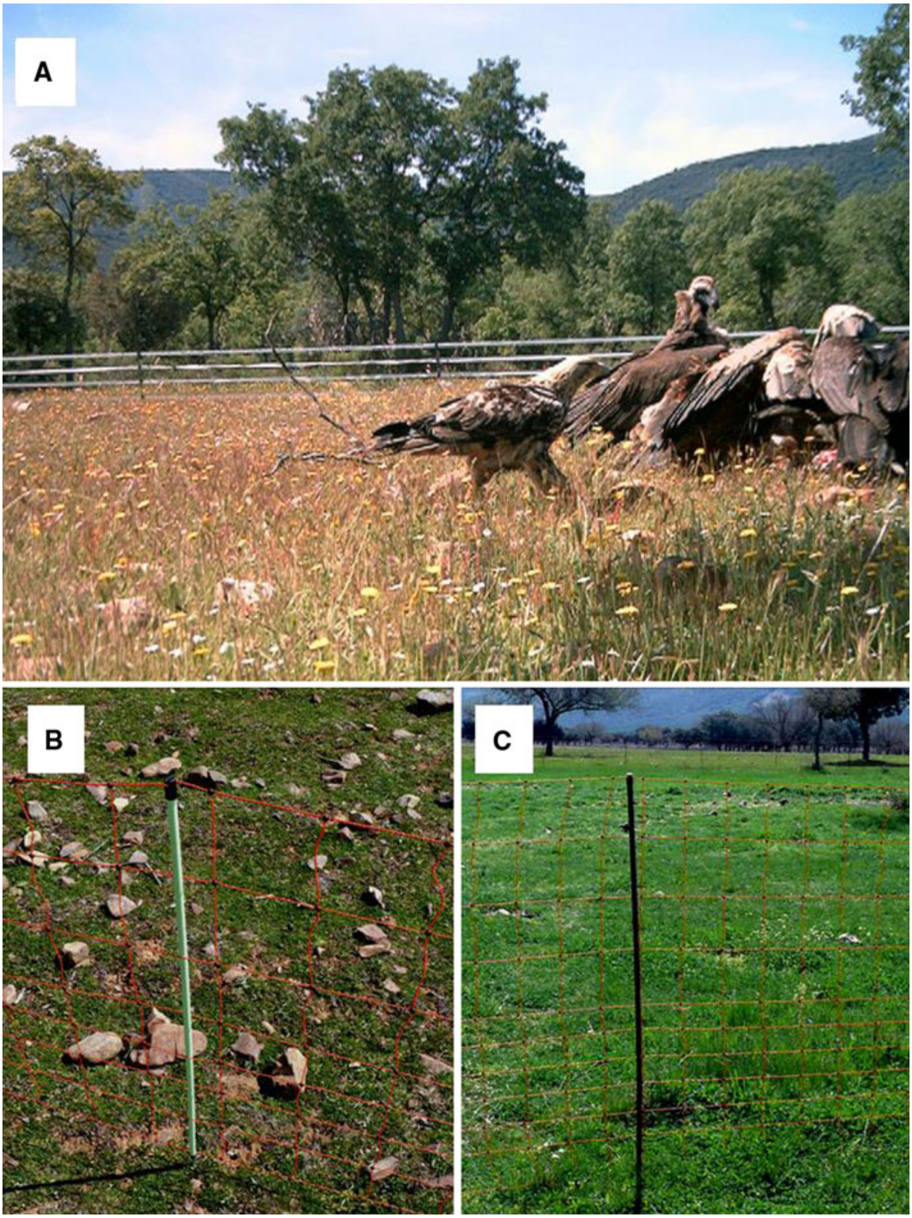

Fig. 2 Examples of the fence types used for exclosures: **A** *Ribbons*—this can be seen behind the foraging birds (*Aquila adalberti*, *Aegypius monachus* and *Gyps fulvus*); **B** *Low net*; **C** *High net* (see text for detailed descriptions of each fence type)

each species counted at each input of food, as the maximum simultaneous number registered in the photos.

Both of these variables were analyzed in relation to the following independent variables: 1) exclosure type, 2) the total number of days that the supplementary feeding site

Table 1 Summary of carrion inputs used during the study by treatment type. Inputs (n) = total number of carrion inputs; Days = number of days carrion was available; Date = the dates on which the treatments remained active; Biomass (kg) = the total mass of carrion provided in kilograms

Fence models	Inputs (n)	Days	Date	Biomass (kg)
Ribbons	17	125	6th May to 8th Sept 2010	1,275
Low net	17	142	19th April to 7th Sept 2010	1,265
High net	11	110	14th Dec 2010 to 5th April 2011	615
Control (no fenced)	40	202	24th April 2010 to 31st Jan 2011	3,420

was active (Table 1) and, 3) the total biomass (kg) of food supplied in each exclosure type (Table 1).

The analysis consisted of a General Linear Model (GLM) with a Poisson-type family of errors, using as fixed factors each of the three independent variables and with a confidence interval of 95 %. Only the significant results and those that approach significance are presented. The analyses were carried out using the software Statistica 6.1 (StatSoft 2002).

Results

In total, 6,655 kg of carrion on 86 different inputs were supplied, and a total of 2,561 griffon vultures, 617 cinereous vultures, 127 ravens, nine Spanish imperial eagles, 45 foxes, 33 wild boars, nine dogs and 24 red deer could be counted (obtained by summing the maximum number of simultaneous individuals present at each input of food).

Only significant values are presented due to the great amount of models performed ($n = 16$). In terms of the accessibility into the different exclosures, there were no significant differences in the number of days it took for the birds to accede to the carrion. On the other hand, the time taken by foxes to get to the carrion after its supply was greatest when the feeding site had a *low net* and *high net* fence ($F = 9.04$, df = 4, $P = 0.001$). Thus, these two models resulted more successful in delaying the entrance of the fox for a greater number of inputs and for a longer period (Table 2, Fig. 3); wild boar, dogs and red deer, on the other hand, did not get into the exclosures and were only recorded at control

Table 2 Time taken by different mammal species to access the supplied carrion, expressed as both the ordinal number of carrion inputs and the number of days prior to entrance of each species since activation of the feeding site. For the controls, each input was considered as independent for the four different study sites so mean values (±S.D.) are shown for the day of first recorded entrance to feed

	Fox		Wild boar		Dog		Red deer	
Fence models	Input	Day	Input	Day	Input	Day	Input	Day
Ribbons	1st	0	No access	No access	No access	No access	No access	No access
Low net	7th	62	No access	No access	No access	No access	No access	No access
High net	8th	64	No access	No access	No access	No access	No access	No access
Controls (no fenced)	1st	3.1 ± 4.6	2nd	7.2 ± 9.8	1st	9.0 ± 1.4	1st	2.3 ± 0.5

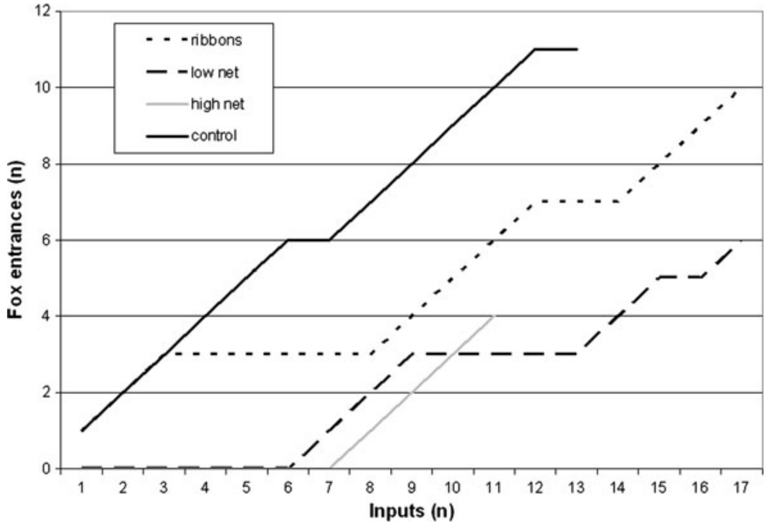

Fig. 3 Number of fox *Vulpes vulpes* entrances to the carrion provided within each site using different types of fencing in relation to the number of carrion inputs to each site

sites without fences. Time needed for foxes to access the food was less when the amount of biomass was greater ($F = 4.66$, df = 1, $P = 0.037$).

In relation to the number of individuals accessing to the carrions, fewer foxes were recorded in the exclosures, mainly in the *low net* and *high net* models ($F = 2.36$, df = 4, $P = 0.058$) than at the unfenced (control) sites. Wild boar became more abundant when the feeding point was active longer (in the case of non-fenced points, $F = 6.15$, df = 1, $P = 0.015$). Only in the case of the cinereous vulture the number of individuals resulted related to the type of fence where carrion was provided ($F = 5.06$, df = 4, $P = 0.011$, Fig. 4); this species was more abundant at control feeding sites without perimeter fences. An increase in the number of days a feeding station was operative ensured that the number of cinereous vultures, ravens and Spanish imperial eagles also increased ($F = 19.58$, df = 1, $P = 0.001$; $F = 6.05$, df = 1, $P = 0.016$; $F = 3.82$, df = 1, $P = 0.054$, respectively). Likewise, the supply of a greater quantity of biomass involved that more griffon and cinereous vultures were present at the feeding site ($F = 179.00$, df = 1, $P = 0.001$; $F = 49.73$, df = 1, $P = 0.001$, respectively).

Discussion

Feeding of targeted and non-targeted species

These results constitute the first obtained from an experiment aimed at optimizing the management of supplementary feeding sites for scavenger species, and throw light on the patterns of access to carrion protected by different types of perimeter exclosures by a scavenger guild. To date only few studies have been published on this subject (Cortés-Avizanda et al. 2010) and so we are unable to contrast our results with others from other

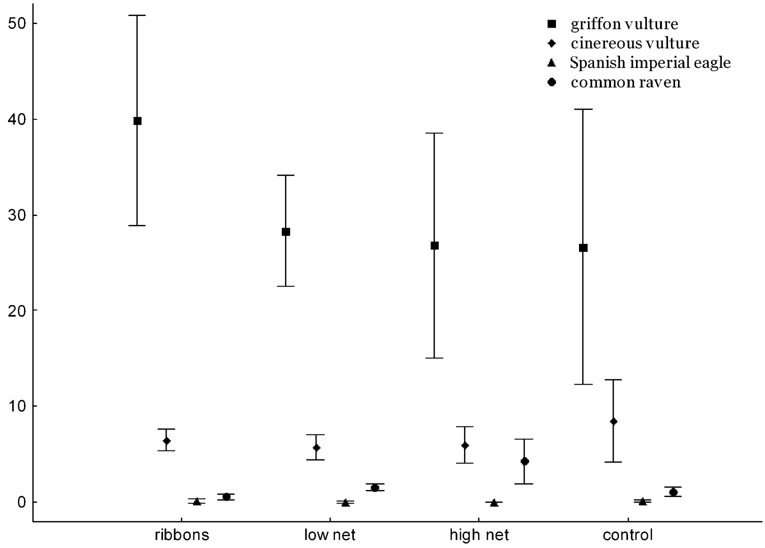

Fig. 4 Mean number of individuals of each scavenger bird species (±95 % confidence interval) recorded in each exclosure type

geographical areas or other types of exclosures. The reasons for this lack of previous global comparative studies may be due to the fact that only within the EU the recent legal sanitary framework has lead to avian scavengers to several conservation problems associated with changes in the availability of food resources (Donázar et al. 2009a; Margalida et al. 2012). In this sense, given the serious conservation problems affecting vulture populations in the South Asian region in recent years (Oaks et al. 2004; Shultz et al. 2004; Gilbert et al. 2007) and the incipient detected threat for African vulture populations due to loss of food quality (Naidoo et al. 2009; Virani et al. 2011), the information contained in our study could be of interest for managing of supplementary feeding sites as an effective conservation tool (Markandya et al. 2008).

Our results showed that no avian scavenger avoided entering the tested exclosures. This is highly relevant for the development of management protocols for feeding stations, despite considerations about their suitability and usefulness (Piper 2006; Robb et al. 2008). Although very few studies have tackled the subject of the availability of food resources and their effects on population dynamics of scavenger species (Colomer et al. 2011; Margalida et al. 2011a), different public administrations have already set up supplementary feeding programmes through conventional feeding stations in order to palliate the problems regarding carrion availability (García de Francisco and Moreno-Opo 2009). Such conventional structures of feeding station comply with sanitary regulations and prevent non-target mammal species from entering (if the appropriate maintenance is carried out). These models have had positive effects and have helped mitigate the shortage of carrion and its lack of quality that has occurred in recent years (Gilbert et al. 2007; Hernández and Margalida 2008; Oro et al. 2008; García de Francisco and Moreno-Opo 2009). In addition, for threatened species such as the Egyptian vulture *Neophron percnopterus* these feeding stations have performed a fundamental role in the exchange of information among birds and the substitution of individuals in breeding pairs via the establishment of communal roosting sites (Donázar et al. 1996; Benítez et al. 2009) and probably by reducing the high mortality rates related with the illegal use of poisoning baits (Hernández and Margalida 2009).

Management of supplementary feeding sites

The two models that best prevent facultative scavenger mammals from entering the exclosures were the *low net* and *high net* (Figs. 3, 4) and are the most recommendable structures for fulfilling the objectives proposed at the beginning of this study. Furthermore, both types are highly manageable and easy to install, remove and move to another site given that there is no need to fix posts permanently or to set up a system of insulators. The cost of each exclosure (0.5 ha) is 900 €, as opposed to ~9,000 € in the case of fixed conventional feeding stations.

In terms of the efficiency, we recommend that exclosures are checked and maintained for a suitable working. Moreover, regarding the permanence, exclosures may be kept at the same site for a maximum of around 2 months so as to prevent opportunist mammals such as red foxes learning how to find a way in. The presence of abundant food resources at the same site for an over-long period of time will also increase its attraction vis-a-vis other foraging areas and thus modify certain ecological processes and relationships (Cortés-Avizanda et al. 2009; Deygout et al. 2009; Donázar et al. 2009b). Once the two-month period finishes, it is advisable to then move the feeding point elsewhere, preferably as far away as possible. In this way the temporal and spatial unpredictability of the natural appearance of carrion is imitated, sanitary conditions are guaranteed and the management of supplementary feeding of avian scavengers can be optimized (Olea and Mateo-Tomás 2009).

The suggested models could be highly appropriate for sectors that are directly involved in the management of livestock and game animal by-products. Farmers and hunting managers could perceive as positive these types of installations and hence may encourage their implementation. In this way, the territorial scope of these models could be broadened. This active participation may help lessen any reticence regarding the presence of avian scavengers and deter the use of certain types of illegal predator control methods (Koenig 2006; Hernández and Margalida 2008, 2009; Margalida et al. 2011b), since these carrion provided in the proposed exclosures, unlike those occurring naturally in the field (Cortés-Avizanda et al. 2010), are not accesible to opportunistic predators and do not favor the growth of their populations. The fact that 1) the cost of purchasing and installing this type of feeding stations is much less than that of conventional exclosures, that 2) the possibility of their use in periods that are beneficial for the management and exploitation in the estates (hunting, culling for sheeps and goats, and lambing seasons), and that 3) it is not necessary to intend permanently a large land surface of the settlement of a feeding station (up to 1 ha) are three reasons that could forward that the use of these types of feeding stations are practical; generalizable and appropriate to many rural scenarios (Piper 2006; Margalida et al. 2010).

Regardless questions arising from management issues, it is important to monitor the supplementary feeding measures arranged (Buckland et al. 2005; Oro et al. 2008) with regard to the presence of scavenger species, their relative abundance, their feeding selection patterns and the detection of possible conservation problems as human disturbances or the lack of available food in the surrounding areas (Cortés-Avizanda et al. 2010; Moreno-Opo et al. 2010). This could be essential if we aim to evaluate the efficacy of the implemented measures and, if necessary, modify certain aspects of the management protocols in order to increase the positive effects on target species (McCarthy and Possingham 2007).

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