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Short communication

Temporally unpredictable supplementary feeding may benefit endangered scavengers

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The monitoring of an experimental feeding station established in northern Spain allowed the evaluation of how this type of resource, predictable in space but not in time, was exploited by a guild of avian scavengers in relation to factors such as season, hour of disposal and presence of the dominant species. The presence of Egyptian Vultures *Neophron percnopterus* at carcasses was more likely during spring, and richness and diversity of avian scavengers was lower during the summer and when Griffon Vultures *Gyps fulvus* arrived earlier. The temporal unpredictability of the resource may favour exploitation by smaller and less competitive scavengers. New European regulations may present an opportunity to develop effective conservation measures to support functional scavenger assemblages.

Keywords: supplementary feeding, Egyptian Vulture, scavengers, resource monopolization, carrion.

Due to the outbreak of bovine spongiform encephalopathy (BSE) in the late 20th century, EU sanitary regulations mandated the removal of livestock carcasses from the field, leading to a reduction in resources for avian scavengers (Tella 2001, Donázar *et al.* 2009, Olea & Mateo-Tomás 2009, Margalida *et al.* 2010). Consequently, livestock carcasses came to be exclusively disposed of and concentrated in a few intensive feeding stations with a high predictability of food, both in space and in time. This led to important negative consequences at the population and guild levels, mainly derived from the monopolization of the resource by dominant species (Cortés-Avizanda *et al.* 2012).

New European regulations acknowledge the ecological flaws in this approach and progressively have allowed farmers to dispose of livestock by-products at their farms without the prior collection and without the need for transportation of the carcasses, resembling the dumping sites traditionally found in long-established agro-grazing systems and the natural occurrence of carcasses of wild ungulates and extensive livestock (Donázar *et al.* 2009, Margalida *et al.* 2012). Given the irregular mortality dynamics of livestock on small farms, carcasses become predictable in space but not in time. Thus, it is necessary to evaluate carcass consumption patterns by avian scavengers to assess whether the same negative conditions found at intensive feeding stations, where resources are monopolized by dominant Griffon Vultures *Gyps fulvus*, are occurring (Cortés-Avizanda *et al.* 2012).

We take advantage of an experimental feeding station created in 2009 in northern Spain to assess how avian scavengers respond to the disposal of carcasses at a fixed point but with random temporal frequency. This feeding place is mainly devoted to the recovery of the local population of the globally threatened Egyptian Vulture *Neophron percnopterus*, a species that has undergone a severe population decline in the study area (Cortés-Avizanda *et al.* 2009) and throughout the Mediterranean (Iñigo *et al.* 2008). Our main goals were to examine how Egyptian Vultures use the experimental feeding station, and to assess whether the richness and diversity of scavengers at the experimental feeding station are affected by the management of carcasses (season and hour of disposal) as well as by the arrival of dominant Griffon Vultures.

METHODS

Study area, focal species and feeding station management

The study was undertaken in the Bardenas Reales Natural Park (middle Ebro Valley, northern Spain). This region holds one of the healthiest avian communities of scavengers in the Mediterranean Basin (79 and 23 breeding pairs of Griffon and Egyptian Vultures, respectively, in 2012). The experimental feeding station (EFS) has been active since 2009 but monitoring did not begin until 2012. It is an open enclosure area of 650 m^2 located far from main roads and urbanized areas (> 5 km) and is fenced to exclude carnivores.

Between March and July 2012, once or twice per week (range: 1- to 8-day intervals between inputs, mean 4.1 ± 2.1), the experimental feeding station was supplied

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with sheep carcasses and/or viscera ($n = 25$, weight inputs: 10–90 kg) and disposal occurred randomly during daylight hours. This management, which is relatively similar to the 'light feeding stations' found in France (Duriez *et al.* 2012), mimics traditional disposal of livestock carcasses now carried out by small farmers following new European regulations.

The EFS was monitored by two camera traps (5MP Ultra Compact Digital Scouting/Trail Camera) programmed to record two photographs (at intervals of 20 s) when movement was detected. Data collection was undertaken on the basis of photographs grouped into 20-min intervals. For each interval, we recorded the presence and maximum abundance of scavengers.

Data analysis

Using generalized linear models (McCullagh 1984) with normal errors and an identity link, we assessed the factors influencing the presence of Egyptian Vultures (Fig. 1) (1/0 binomial error and logit link function); the richness (number of scavenger species recorded, Poisson error and log link function) of scavengers; and the diversity of scavengers, using the Shannon Index (Magurran 2003). We fit three categorical explanatory variables: 'Season' (Early: 22 March to 15 May (14 carcasses); Late: 16 May to 30 July (11 carcasses)); 'Hour' (carcass disposed of before midday (12 carcasses) or after midday (13 carcasses)); and 'Landing of dominant species', distinguishing between whether Griffon Vulture was the first species landing or not (1/0). Model evaluation was done on the basis of the Akaike information criterion (AIC). All statistical analyses were performed in R STUDIO program (R Development Core Team 2012).

RESULTS

We recorded 10 scavenger species (Table S1). Griffon Vultures were present at all of the monitored carcasses (100%, $n = 25$); up to 48 individuals were recorded simultaneously in a single photo. Egyptian Vultures visited 14 (56%) of the carcasses, with a maximum of two individuals (Table S1), with their presence being marginally associated with Season ($P = 0.077$; Estimate ± se: Early Breeding Period = 1.476 ± 0.862; Late Breeding Period = −0.560 ± 0.627). Modelling for Richness and Diversity showed that the most parsimonious models only included a single variable, Season, despite the variable Landing of dominants having a significant value as a negative predictor for both dependent variables (Table 1).

DISCUSSION

These results provide evidence of the importance of the period of the year in the community of feeding stations visitors. This finding is visibly influenced by the presence of small and medium-sized facultative scavengers (corvids and raptors) during the early breeding period. In these species, breeding tasks such as chick feeding should determine maximum trophic requirements during the early spring favouring their presence at feeding stations. In contrast, the breeding season of vultures extends well into the summer (Donázar 1993). Although not included in the best supported model, the significance of the variable Landing of dominants demonstrates that the early arrival of dominant species can be disadvantageous for both richness and diversity, and

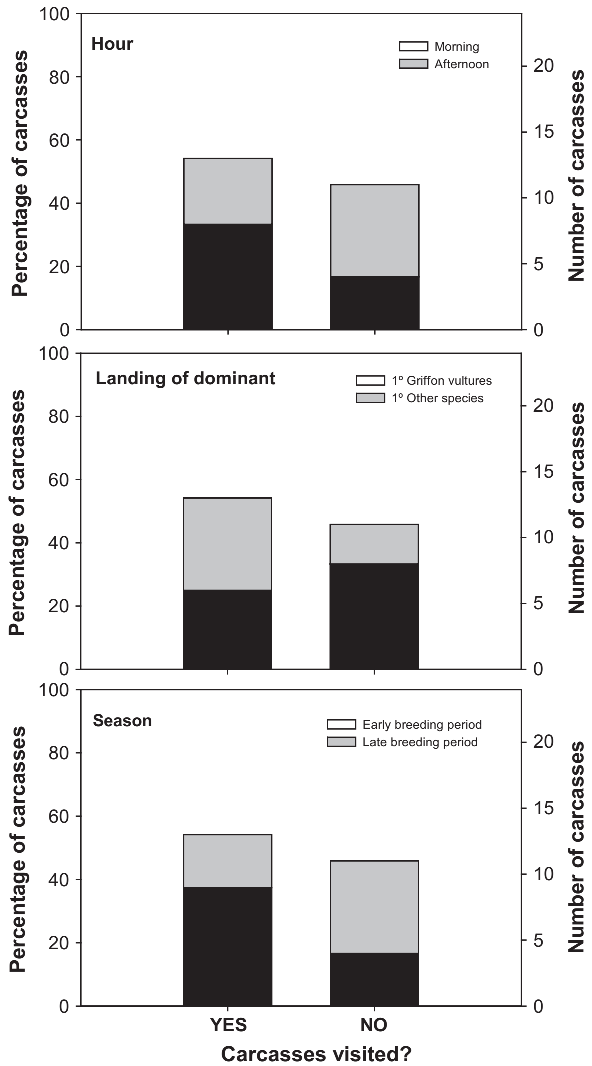

Figure 1. Frequency of the presence of Egyptian Vultures at the carcasses studied in the EFS ($n = 25$) in relation to: 'Hour' (morning and afternoon), 'Landing of dominant' (Griffon Vultures) and 'Season' (Early Breeding period: 22 March to 15 May; Late Breeding period, 16 May to 30 July).

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Table 1. Results of Generalized Linear Models to explain richness and diversity of scavengers at the experimental feeding station. 'Season': Early – from 22 March to 15 May; Late – from 16 May to 30 July. 'Hour': carcasses disposed of in the morning, before 12:00 h, or in the afternoon, after 12:00 h. 'Landing of dominant': Griffon Vultures were or were not the first species landing.

Response	Explanatory	Pr (>Chi)	Levels	Estimate (se)	*Z* value	Pr (>|*z*|)	AIC
Richness	Model 1		Early breeding period	0.872 ± 0.246	3.551	< 0.001	88.629
	Season	< 0.001	Late breeding period	0.693 ± 0.213	3.251	0.001	
	Model 2		Other species land first	1.591 ± 0.136	11.69	< 0.001	92.945
	Landing of dominant	0.001	Griffon Vulture lands first	−0.674 ± 0.217	−3.11	0.002	
	Model 3		Morning	1.149 ± 0.156	7.355	< 0.001	101.65
	Hour	0.262	Afternoon	0.238 ± 0.213	1.118	0.264	
	Model 4		(Intercept)	0.758 ± 0.381	1.988	0.046	91.408
	Hour	0.001	Morning	0.727 ± 0.353	2.063	0.039	
	Season	0.683	Early breeding period	−0.171 ± 0.312	−0.547	0.584	
	Landing of dominant	0.305	Griffon Vulture lands first	0.220 ± 0.215	1.025	0.305	
Diversity	Model 1		Early breeding period	0.788 ± 0.108	7.298	< 0.001	9.024
	Season	< 0.001	Late breeding period	0.229 ± 0.081	2.835	< 0.001	
	Model 2		Other species land first	1.008 ± 0.113	8.914	< 0.001	25.836
	Landing of dominant	< 0.001	Griffon Vulture lands first	−0.603 ± 0.151	−3.991	< 0.001	
	Model 3		Morning	0.611 ± 0.134	4.557	< 0.001	38.559
	Hour	0.527	Afternoon	0.123 ± 0.194	0.633	0.533	
	Model 4		(Intercept)	0.167 ± 0.200	0.832	0.415	12.273
	Hour	0.443	Morning	0.803 ± 0.182	4.423	< 0.001	
	Season	< 0.001	Early breeding period	0.024 ± 0.182	0.13	0.897	
	Landing of dominant	0.816	Griffon Vulture lands first	0.086 ± 0.112	0.766	0.452	

it clearly reflects the well-known intraguild competition for the resource in the scavenger community (Cortés-Avizanda *et al.* 2010).

The numbers of Griffon Vultures observed in our study greatly contrast with those reported by Cortés-Avizanda *et al.* (2012) for intensive feeding stations, where food availability is practically permanent. There, the numbers of Griffons simultaneously observed were usually above 200, reaching up to more than 600 individuals (García-Ripollés *et al.* 2004, Cortés-Avizanda *et al.* 2010). These concentrations were never observed at our experimental site during the study period. Additionally, although the study methodologies are not directly comparable (camera trap in our case vs. direct observations), other data from Cortés-Avizanda *et al.* (2012) suggest that conditions in the experimental site are more similar to those found at randomly distributed carcasses than those found at intensive feeding stations. Thus, we found in the experimental station (only for the study period coincident with Cortés-Avizanda *et al.* 2012) a mean value of diversity of 0.23 (sd = 0.196, n = 11) against 0.142 (sd = 0.117, n = 30) in the intensive feeding station and 0.291 (sd = 0.254, n = 27) at random carcasses. Carcasses from traditional management at small farms (reproduced at the experimental station) would represent a better option than intensive feeding stations to avoid monopolization of the resource by dominant scavengers, thus allowing the maintenance of intraguild processes (Cortés-Avizanda *et al.* 2012).

It can be argued that our results may have been influenced by local conditions. No other experimental feeding station exists in the region, so the study was by necessity restrained to a single location. For this reason, the relative abundance of small facultative scavengers in the vicinity of the study location may have influenced the probability of their presence (Brown 1984). This would not be true, however, for large specialists such as Egyptian Vultures, which are capable of travelling tens of kilometres to visit feeding places (García-Heras *et al.* 2013, López-López *et al.* 2013), and, above all, Griffons, whose home-range can cover hundreds of square kilometres (Monsarrat *et al.* 2013). In other words, the abundance of large and medium-sized vultures is probably independent of the location of the experimental sites within the region. Thus, we are confident of our findings.

In summary, our study demonstrates that small feeding stations where the supply of food is temporally unpredictable may counteract some negative effects deriving from monopolization by dominant species found in more intensive feeding sites where resources are more predictable. Nevertheless, their management should be adapted to local conditions. In the case of Egyptian Vultures, networks of feeding places should be designed to maximize the number of territories that potentially would benefit. Plastic rings and individual plumage features allowed us to determine that all the Egyptian Vultures visiting the experimental station

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belonged to three territories situated within a radius of 15 km, an expected result given that the probability of visits decreases with distance (Carrete *et al.* 2006, García-Heras *et al.* 2013). At a larger ecological scale, it must be not forgotten that Egyptian Vultures and other scavengers feed heavily on the carcasses of small vertebrates (Donázar *et al.* 2010) and that supplementary feeding is not likely to replace the availability of these wild prey items because of the need for different qualitative requirements. As a whole, the maintenance of landscape biodiversity with rich vertebrate communities and extensive livestock exploitations must be prioritized (Carrete *et al.* 2007).

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SUPPORTING INFORMATION

Additional Supporting Information may be found in the online version of this article:

Table S1. Number of individuals and presence at carcasses (number and percentage) recorded by both cameras at the EFS.

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