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Manipulating size, amount and appearance of food inputs to optimize supplementary feeding programs for European vultures

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ABSTRACT

Supplementary feeding is one of the most common techniques used to alleviate threats to scavengers species related to the quality and availability of food resources. Because supplementary feeding may have undesired effects, the management of supplementary sites should be optimized from an ecological and conservation perspective. We installed high-resolution videocameras at six Spanish feeding stations recording more that 7500 h of observations at 105 feeding events. We analyzed food preferences in the four European vulture species (Eurasian griffon vulture *Gyps fulvus*, Egyptian vulture *Neophron percnopterus*, bearded vulture *Gypaetus barbatus* and cinereous vulture *Aegypius monachus*) as they relate to the characteristics of the food remains and carcasses provided at feeding sites. Our results suggest that carrion features (format, scattering, prey species, biomass and items) influence differential selection between species and age-classes. At a species level, large inputs of unscattered carrion increased the abundance of actively feeding griffon vultures. The ratio of the abundance of bearded vultures, Egyptian vultures and cinereous vultures with respect to griffon vultures was favored when less biomass was supplied and when the food provided was not presented as whole carcasses. Thus, using medium-size ungulates (i.e. sheep and goats) presented as small, abundant and scattered pieces favors the consumption of the resource by the most endangered species. Our findings can be used to optimize the supplementary provisioning of vultures in cases where this conservation tool is considered essential for managing targeted species or population groups.

1. Introduction

The application of sound and effective conservation measures based on scientific evidence requires an analysis of the characteristics of the threat and an assessment of the impact and ecological effects of proposed conservation actions (Arlettaz et al., 2010). Supplementary feeding is a common management tool consisting of the provision of safe and high quality food to particular populations to mitigate anthropogenic impacts that cannot be otherwise eliminated in the short term and that may affect the conservation status of a species (González et al., 2006; Oro et al., 2008; Robb et al., 2008). It aims to increase survival rates, reduce the risk of ingestion of contaminated food (Oro et al., 2008), and improve breeding performance, even contributing to the settlement of new breeding territories (González et al., 2006; Schoech et al., 2008). In addition to these positive effects, undesired impacts on non-target species may occur (Cortés-Avizanda et al., 2009). Similarly, unintended impacts on demographic and behavioral parameters of the target species may occur when applied protocols do not integrate all of the appropriate variables (Carrete et al., 2006; Robb et al., 2008; García-Heras et al., 2013).

Vultures play a key role in temperate ecosystems due to their consumption of carrion, a trophic resource with an unpredictable occurrence in the wild but of great importance given its high energy transfer (Wilson and Wolkovich, 2011, Moleón et al., 2014). Four vulture species occur in Europe: the bearded vulture (*Gypaetus barbatus*), the cinereous vulture (*Aegypius monachus*), the Egyptian vulture (*Neophron percnopterus*) and the Eurasian griffon vulture (*Gyps fulvus*; Table 1). In Europe, the conservation

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status of these species differs: while the first three are considered threatened, the griffon vulture exhibits larger and unthreatened populations (Table 1). Spain is the greatest vulture stronghold in the Western Palearctic hosting 67%, 96%, 70% and 91% of the European breeding pairs of the bearded, cinereous, Egyptian and griffon vultures, respectively (BirdLife International, 2013; Deinet et al., 2013). One of the main limiting factors for these birds is food due to changes in its geographic occurrence, quality and unavailability as a result of changes in agro-grazing systems and repeated poisoning events (Donázar et al., 2009a; Margalida and Colomer, 2012; Ogada et al., 2012; BirdLife International, 2013). To counter these threats, there are several official ongoing conservation programs in different European countries with supplementary provisioning constituting one of the primary activities (see review in Donázar et al., 2009a; Margalida et al., 2010). This occurs primarily through the provision of carrion at specific locations close to breeding sites, in accordance with requirements of sanitary regulations for the management of animal by-products not intended for human consumption (Donázar et al., 2009b; Margalida et al., 2010). This supplementary provisioning has partly mitigated the negative effects of widespread and compulsory removal of livestock carcasses from the wild, though it has been shown to be insufficient in meeting the ecological requirements of scavenger species, populations and age-classes at a global scale (Donázar et al., 2009b; Margalida et al., 2012a).

Despite the fact that vultures share a common food source, there are ecological, morphological and behavioral adaptations that have led to specialization in the consumption of carrion and evolutionary resource-partitioning by the different species (König, 1983; Houston, 1988; Hertel, 1994). This includes interspecific co-existence and facilitation processes in the exploitation of geographically and temporally limited resources (Jackson et al., 2008; Moleón et al., 2014), generating intra- and interspecific competition and hierarchical relationships (Wilmers et al., 2003; Kendall et al., 2012). This is particularly relevant in European vulture species of which one, the griffon vulture, monopolizes the largest quantity of biomass at carcasses due to its competitiveness, larger population size and morphological features allowing it to feed from the inner parts of cadavers (Hertel, 1994; Cortés-Avizanda et al., 2010). This has meant that, due a the lack of detailed knowledge about patterns of resource consumption, most supplementary provisioning programs (mainly in Spain) have primarily favored the species of least conservation interest (Parra and Tellería, 2004; Cortés-Avizanda et al., 2010).

Outside of the aforementioned knowledge on adaptations to scavenging, there are few studies in which the type and format of carrion selected by each species have been experimentally assessed within controlled observational conditions (Moreno-Opo et al., 2010). Moreover, no previous studies provide accurate information on the four vulture species together in sampling areas with sufficiently abundant populations (Cortés-Avizanda et al., 2010; Duriez et al., 2012). Detailed information on the prey typology selected by different age-classes and species should be considered in supplementary provisioning initiatives, considering the relevance of this management technique in a global scenario with ongoing changes in landscape characteristics, sanitary policies, illegal poisoning, veterinary drugs and lead poisoning (see reviews in Donázar et al., 2009a; Ogada et al., 2012).

This paper aims to determine the selection patterns of different types and formats of carrion provided at supplementary feeding sites by different age-classes of European vultures. Through an accurate and detailed observational process in which a variety of carrion characteristics such as the size, amount and appearance were experimentally manipulated, we hypothesized that according to the different scavenging adaptations, vulture species and ages should diverge in their feeding performance. Thus, feeding patterns of vultures with regards to their relative abundance and their relationship to the main monopolizing species (i.e. the griffon vulture) were expected to vary according to the food characteristics in supplementary feeding sites. Accordingly, we hypothesized that the most endangered species (i.e. Egyptian and bearded vultures), being the most specialized for particular carrion characteristics, should reduce competition with other vultures selecting more specific, small and dispersed food remains. On the contrary, the most abundant and behaviorally dominant vultures (i.e. cinereous and griffon vultures) should adapt their feeding to inputs with a greater biomass. Based on our findings, we provide recommendations to facilitate the implementation of management protocols in supplementary provisioning programs.

2. Methods

2.1. Study area

The study was carried out at six sites in the Iberian Peninsula (Spain), three in the northeast (Pyrenean Mountain range) and three in the central-west (Sierra Morena, Montes de Toledo-Sierra de San Pedro ranges, Fig. 1). Active supplementary feeding points

Table 1
Population and main biological traits of the four vulture species inhabiting Europe.

Species	Breeding pairs (n) in Europe[a]	Trend of European populations[b]	Breeding behaviour[c]	Social behaviour[c]	Nesting habitat selection[c]	Morphological specialization for feeding[c,d]	Migratory status[c]
Bearded vulture	200	+	Territorial	Individualists except non-breeders	Caves in mountain cliffs	Gulper (bones, small pieces of meat)	Sedentary
Cinereous vulture	2147	+	Colonial and territories within colonies	Partially gregarious	Trees in mature forests	Ripper (tendons, muscle)	Sedentary
Egyptian vulture	~2000	–	Territorial	Individualists except non-breeders	Caves in cliffs and gorges	Scrapper (small pieces)	Long-distance migrant
Eurasian griffon vulture	28 088	+	Colonial	Gregarious	Ledges in cliffs and gorges	Gulper (all meat parts)	Long-distance -only ~20-30% of juveniles- and sedentary

Main sources.
[a] Deinet et al. (2013).
[b] BirdLife International (2013).
[c] Cramp (1998).
[d] Hertel (1994).