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FORAGING RANGE AND DIET OF CINEREOUS VULTURE *AEGYPIUS MONACHUS* USING LIVESTOCK RESOURCES IN CENTRAL SPAIN

ÁREA DE CAMPEO Y ALIMENTACIÓN DEL BUITRE NEGRO *AEGYPIUS MONACHUS* SEGÚN RECURSOS GANADEROS EN EL CENTRO DE ESPAÑA

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Summary.—*Foraging range and diet of cinereous vulture* Aegypius monachus *using livestock resources in central Spain.*

We analysed the foraging area of cinereous vultures from a breeding colony of central Spain which were feeding on livestock carcasses by an indirect method that estimated movement ranges and feeding locations. Between 2004 and 2008 we checked the origin of 377 cattle tags, collected at nests and perches of the species. Using the individual codes of tags, we obtained the location (livestock exploitation) where the vultures fed. The average distance of the locations was 26.3 km (SD = 36.1). The linear flight routes ranged from 7.9 km to 342 km from the point of tag collection. The minimum convex polygon of all locations was 66,732.28 km^2. The home range of cinereous vultures feeding on carcasses (95 %, analysis Kernel) was 152,290.13 ha. We discuss the methodology used in this study compared to others using radiotracking as the location technique. Differences between methods probably explain why estimates of foraging areas and distances varied widely. These differences are analysed in relation to the different prey categories, the economic land use, type of habitat and the presence of predictable sources of food.

Key words: *Aegypius monachus*, carcass, cattle tags, cinereous vulture, diet, livestock, foraging range.

Resumen.—*Área de campeo y alimentación del buitre negro* Aegypius monachus *según recursos ganaderos en el centro de España.*

Se analizan las áreas de campeo del buitre negro en las que se alimenta de cadáveres de ganado doméstico, en una colonia del centro-sur de España, mediante un método indirecto de estima de las zonas de movimiento a través de localizaciones de alimentación. Entre 2004 y 2008 se recogieron 377 crotales en las inmediaciones de nidos y posaderos de la especie, y se averiguó su procedencia geográfica. Los códigos individualizados de los crotales permitieron obtener localizaciones donde los buitres negros se alimentaron, a escala de explotación ganadera. La distancia media entre los lugares de recogida y de procedencia del crotal fue de 26,3 km (SD = 36,1). Los vuelos lineales oscilaron entre los 7,9 km y los 342 km. El polígono mínimo convexo de todas las localizaciones resultó de 66.732,28 km^2. El área de campeo en que los buitres negros se alimentaron de carroñas de ganado (al 95 % de probabilidades, según el análisis Kernel) alcanzó 152.290,13 ha. Se discute la metodología empleada en este trabajo

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comparándolo con otros estudios similares que usaron el radioseguimiento como técnica de localización. Las diferencias de método han supuesto probablemente que las áreas de campeo y las distancias de vuelo obtenidas resultaran distintas. Estas consecuencias se analizan en relación a los tipos de presa disponibles, a los aprovechamientos económicos del medio, al tipo de hábitat y a la presencia de fuentes predecibles de alimento.

Palabras clave: *Aegypius monachus*, área de campeo, buitre negro, carroña, crotal, dieta, ganado.

Introduction

Prey abundance, distribution, ocurrence and size are likely to influence foraging areas and home range characteristics of scavenging raptor species (Costillo *et al.,* 2007; Margalida *et al*., 2009) and, therefore, determine their feeding behaviour and associated territoriality (Hiraldo, 1977; Donázar, 1993). Foraging areas of the cinereous vulture have been studied in different regions where the species occurs (Carrete and Donázar, 2005; Costillo, 2005; Vasilakis *et al*., 2006). Efforts have been mainly directed to knowing the extension of these areas and to evaluate the impact that food availability has on them, as well as variations depending on the season and invidual age classes. This knowledge is the basis for assessing food resource availability, habitat selection patterns and the influence of different threats.

We report the locations where cinereous vultures fed on livestock carcasses in relation to their breeding colony in south-central Spain. The aim is to define the extension and location of feeding areas of the species in order to implement efficient management and conservation strategies.

Material and methods

Fieldwork was carried out in the Umbría de Alcudia cinereous vulture breeding colony, in Ciudad Real province (figure 1). This colony holds the fourth largest aggregation in Spain, with 129 pairs in 2006 (De la Puente *et al*., 2007). This is an area mainly covered by Mediterranean forest, with tree species including *Quercus suber*, *Quercus rotundifolia*, *Junniperus communis* and *Arbutus unedo*, and a thick bush and understory development. Nests are located on mountain slopes ranging in altitude between 736 and 1.178 m a.s.l. This area is inhabited by significant populations of wild ungulates (i.e., red deer *Cervus elaphus* and wild boar *Sus scropha*) and lagomorphs, while in the surrounding areas there are *dehesas* –parkland with varying densities of trees and agricultural land with abundant livestock populations. Between 2004 and 2008, in the period October-December, cinereous vulture food remains were collected from close to 88 nests and 11 perches in the colony. 480 cattle tags were found among the food remains. The origin of animals that wear cattle tags can be identified, because these plastic marks have the individual codes of the farm of origin and the municipality in which it is located. The cinereous vultures ingest these tags, which are later regurgitated in pellets. Therefore, cattle tags show at a livestock farm scale the location where cinereous vultures have ingested the prey.

In order to know the exact origin of the cattle tags an information request was addressed to the Official Livestock Administrations. This search revealed the origin of 377 units (78.5 % of the total). The species that carries the plastic tag is known based on the use described in the official databases of the farms and/or through the written code on the tag.

Cinereous vulture individuals that ingested cattle tags were any individuals that had been

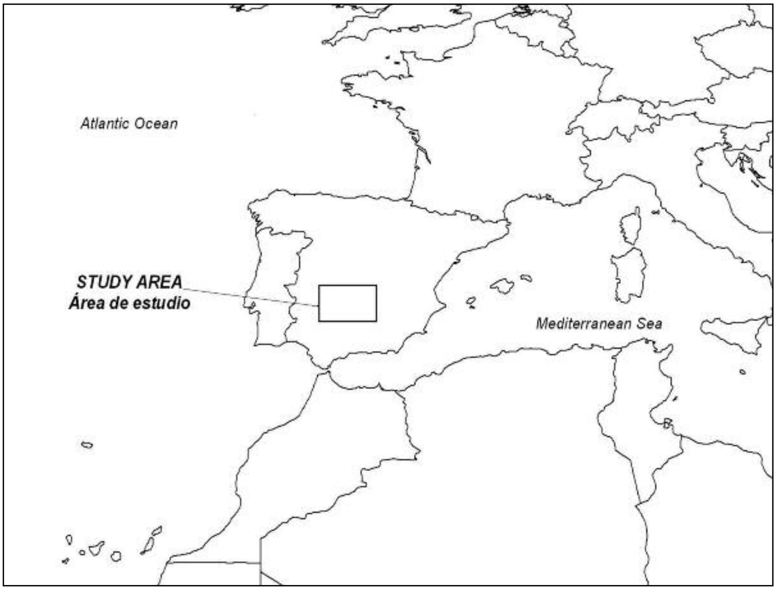

FIG. 1.—Study area in the Iberian Peninsula, including the cinereous vulture *Aegypius monachus* breeding colony and the foraging locations obtained through the collection of livestock tags.
[Área de estudio del presente trabajo, incluyendo la colonia de buitre negro Aegypius monachus *objeto de seguimiento y las localizaciones de presencia obtenidas.]*

presented in the breeding colony during the study period. Results do not show the foraging areas of specific age classes or sexes. However, given that 95 % of the cattle tags had been collected directly under nest sites, these suggesting that individuals that had ingested the tags were probably established as breeders in the colony.

The feeding area has been considered as the total surface where feeding locations have been registered. It has been expressed through the Minimum Convex Polygon (MCP; Mohr, 1947). MCP is defined as the area formed by the outer polygon encompassing all the points where the studied animals have been located. The foraging range is referred to as the probability of finding locations using Kernel polygons (Worton, 1989; White and Garrot, 1990). These are surfaces delimited by probability isolines of finding the locations of the studied animals; in most studies it is shown the 95 % of probability though the present work also offers other probability values. The spatial analysis has been conducted with ArcView GIS 3.1. software, Animal Movement extension. Similarly, distances travelled by the birds were obtained, taking as point of origin the location where cattle tags had been collected in the colony and as destination the geographic centre of the farm of origin of the tag.

RESULTS

Cinereous vultures of the Umbría de Alcudia colony feed in an area of 66,732.28 km^2 (table 1). There have been feeding points in the provinces of Ciudad Real, Córdoba, Badajoz, Jaén, Cuenca and Cáceres. The foraging range of the studied individuals, in a 95 % probability Kernel polygon (White y Garrot 1990), has resulted 152.290,13 ha (table 1, figure 2).

TABLE 1

Foraging and feeding areas and distances of the foraging locations of cinereous vultures *Aegypius monachus* in central Spain.
[Áreas de alimentación y distancias entre las localizaciones de alimentación de buitres negros Aegypius monachus *en España central.]*

Feeding area (MPC, km^2) *Área de alimentación (MPC, km^2)*		66,732.28
Foraging range (ha) *Área de campeo (ha)*	95 %	152,290.13
	90 %	83,516.97
	80 %	51,172.54
	70 %	40,640.08
	60 %	32,463.15
	50 %	25,401.11
Average distance among foraging and tags collection locations (km) *Distancia promedio de localizaciones de alimentación al punto de recogida de crotales (km)*		26.3 (± 36,1)
Maximum foraging distance (km) *Distancia máxima de alimentación (km)*		342
Minimum foraging distance (km) *Distancia mínima de alimentación(km)*		7.9

It was possible to determine the species for 74.8 % of the tags. 54.6 % of the tags were put in pigs, 37.1 % in sheep/goats and 8.3 % in cattle.

DISCUSSION

The method assigning feeding locations in this study is novel and different with respect to the majority of previous works (Corbacho *et al.,* 2004; Carrete and Donázar, 2005; Costillo, 2005; Vasilakis *et al*., 2006) which determined foraging areas based on the telemetry of specific individuals. Radiotracking allows a larger number of locations of the different studied cinereous vultures -1.219 (Corbacho *et al*., 2004), at least 673 (Carrete and Donázar, 2005) and 929 (Vasilakis *et al*., 2006) vs. 377 cattle tags recovered over five years of work in the present study. Moreover, and taking into account the errors assigned to the technique (White and Garrot, 1990; Kenward, 2001), telemetry enables precise location of the foraging areas of the studied species. Furthermore, radiotracking specific individuals allows assessment of possible variations in foraging ranges among age classes and sexes and at different times of the year (Corbacho *et al.,* 2001; Costillo *et al*., 2007), while the impos-

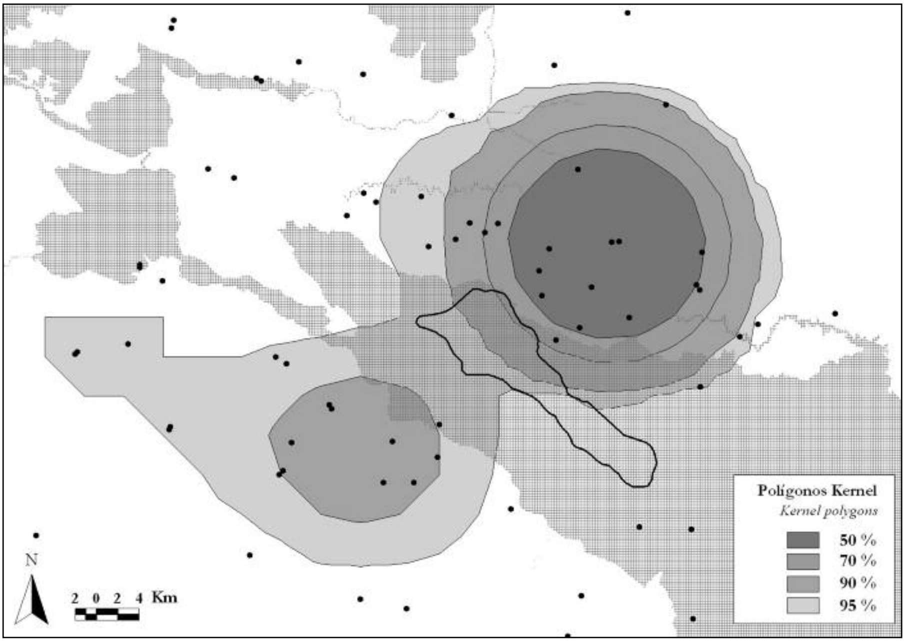

FIG. 2.—Home range of cinereous vulture *Aegypius monachus* in the studied breeding colony. It includes the different probabilities of occurrence in Kernel polygons (ArcView GIS 3.0, Animal Movement), the outline of the studied colony (thick black line), the origin of the cattle tags (black dots) and the Natura 2000 network in the area (grey shading).
[Áreas de campeo de los buitres negros Aegypius monachus *presentes en la colonia objeto de estudio, expresado según las distintas probabilidades de aparición en polígonos Kernel (ArcView GIS 3.0, Animal Movement). Se muestra el contorno de la colonia estudiada (línea negra gruesa), las localizaciones de procedencia de los crotales (puntos negros) y la trama de espacios incluidos en Natura 2000.]*

sibility of knowing which individual has ingested the cattle tag prevents carrying out these comparisons. Finally, the main limiting factor for using cattle tags in these studies is that it is not possible to track the searching movements for finding non ear-tagged dead animals, mainly wild ungulates and lagomorphs, which are of great importance in the diet of the cinereous vulture (Corbacho *et al*., 2007). This limits the general conclusions about the entire foraging area used by the species. Nevertheless, the use of cattle tags as location technique has several methodological advantages. The samples correspond to the foraging pattern of a large number of individuals, since they were collected in 88 different nests and 11 perches over five consecutive years of work. In the previously cited works, the maximum number of tracked cinereous vultures was 14 (Carrete and Donázar, 2005). In addition, to know the origin of the tags involves locating an unmistakable feeding point; scavengers ingest these tags along with the whole biomass.

The foraging area of the cinereous vulture estimated herewith is larger compared with that obtained in other studies (table 2). The size of the foraging range could be related to the number of studied individuals, as well as to the relatively large population size of the studied colony, the period of the annual cycle or the availability of food resources (Costillo, 2005; Costillo *et al*., 2007). In this work, the number of vultures carrying cattle tags to the collection points is unknown. Therefore, results are expressed as the total of all the individuals of the breeding colony. For this reason, as there is greater potential variability in the foraging behaviour, the foraging range should have been larger than that obtained by tracking a few individuals (Carrete and Donázar, 2005; Vasilakis *et al*., 2006). When pooling breeding and non-breeding birds, the size of the feeding area increases (Corbacho *et al.,* 2004), giving similar values to those obtained in the present work. However, the reported areas could have been overestimated by not registering the feeding on potential wild prey species abundant in the close vicinity of the colony. The Kernel probability polygons are determined by the number of locations, so that when no records exist in the close surroundings of the colony, these polygons could cover wider and remote areas based exclusively in the presence of livestock. The nearest areas around the breeding nuclei offer only wild prey to cinereous vultures – rabbit *Oryctolagus cuniculus*, Spanish ibex *Capra hispanica*, red deer and wild boar. These areas are covered by mature Mediterranean forests and rangelands with no livestock exploitation. Therefore, these two factors (type of available prey and habitat) are of great importance for the configuration of the foraging areas because they determine search patterns (Carrete and Donázar, 2005) and could reflect an increase in their extension (table 2).

The distances travelled while foraging are on average higher than those of other similar studies (26,3 ± 36,1 –SD– km, as compared to 16,1 ± 14,0 –SD– km in Corbacho *et al*., 2004).

It has to be noted that 54.5 % of the obtained locations came from a single vulture restaurant, with a continuous input of food; this illustrating the importance of these places for the management and conservation of scavenging birds (Donázar, 1992; Camiña and Mon-

TABLE 2

Home range (ha) of cinereous vulture *Aegypius monachus* individuals, in 95 % Kernel polygon (Arc View GIS 3.1). References: [1] Costillo, 2005; [2] Carrete y Donázar 2005; [3] Vasilakis *et al.* 2006; [4] present study.
[Área de campeo (en ha.) de individuos de buitre negro Aegypius monachus*, considerando el polígono Kernel al 95 % (Arc View GIS 3.1). Fuentes: [1] Costillo, 2005; [2] Carrete y Donázar 2005; [3] Vasilakis* et al. *2006; [4] presente estudio.]*

Study area *Área*	**Breeding Seaton** *Época reproductora*	n	**Non breeding Seaton** *Época no reproductora*	n
Sierra de San Pedro[1]	66,755 ± 71,397	6	15,526 ± 4,240	4
Sierra Pelada[2]	135,430 ± 58,965	14	77,775 ± 35,021	6
Dadia National Park[3]	61,203 ± 22,391	6		
Umbría de Alcudia[4]	152,290.13			

telío, 2006; Carrete *et al*., 2006; Moreno-Opo *et al*., 2007). This has probably altered the natural foraging and movement patterns, these being routinely directed towards a specific point where food is abundant and predictable (Robb *et al*., 2008; Carrete *et al.,* 2009). On the other hand, it would be interesting to evaluate the relationship between livestock availability in the foraging areas and the diet proportion obtained in the present work (Savage, 1931) in order to check the selection of some prey categories or to test the influence of the official management procedures towards different kind of carcasses (García de Francisco and Moreno-Opo, 2009; Moreno-Opo *et al.* 2010).

Cinereous vulture conservation depends on the land management where it is to be found. While breeding sites have a strictly enforced protection level (Moreno-Opo, 2007), management efforts in foraging areas are still incipient (Carrete and Donázar, 2005). The main threats to this and other scavenging raptor species come from the scarcity and poor quality of the food, including poisoning (González and Moreno-Opo, 2008; Hernández and Margalida, 2008; Margalida *et al*., 2008, Hernández and Margalida, 2009). Therefore, one of the most effective conservation measures is evaluating food resources, ensuring their availability and quality (Donázar *et al*., 2009). The first step to undertake these conservation actions is to know and to delimit areas where the species is present at different life cycle periods.

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