

THE DIET OF THE BLACK VULTURE *AEGYPIUS MONACHUS* IN RESPONSE TO ENVIRONMENTAL CHANGES IN EXTREMADURA (1970 - 2000)

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SUMMARY.—*The diet of black vulture Aegypius monachus in response to environmental changes in Extremadura (1970 - 2000).*

Aims: The main aim of the present study was to determine how the black vulture *Aegypius monachus* has adapted in the past to the decline and eventual scarcity of the populations of its principal prey, the rabbit *Oryctolagus cuniculus*, and how it is adapting now to the new availability of food in its environment.

Location: The study was carried out in the Sierra de San Pedro (Extremadura, SW Spain).

Methods: To achieve the aim, the diet of this carrion feeder in the 1970s (Hiraldo, 1976) was compared with that recorded in the period 1998 - 2000. The method used was based on analyzing fur-ball pellets collected in visits to nests over an annual cycle (125 pellets, 167 preys).

Results: In the 1970s in the Sierra de San Pedro, this carrion feeder based its diet on carcasses of medium and small sized animals, with the rabbit constituting the key food item. In response to the growing scarcity of this prey, the black vulture has changed its feeding habits and now the percentage of rabbits in its diet is very low, having been replaced by sheep *Ovies aries* supplemented with other prey (swine and deer).

Conclusions: The major growth of these resources and the protection of the species have led to the recovery of its populations. This capacity of the black vulture to adapt to change in the availability of prey may be a key element in the future conservation of the species, since new changes have recently been taking place in the availability of these resources (greater control of livestock carcasses and new European Community policies).

Key words: *Aegypius monachus*, black vulture, diet, Mediterranean ecosystems, scavengers, trophic plasticity.

RESUMEN.—*La dieta del buitre negro Aegypius monachus en respuesta a cambios ambientales en Extremadura (1970 - 2000).*

Objetivos: El objetivo de este trabajo fue analizar como el buitre negro *Aegypius monachus* se ha adaptado a la rarefacción de las poblaciones de su principal presa en el pasado el conejo *Oryctolagus cuniculus*, y a la nueva disponibilidad de alimento existente en el medio.

Localidad: El presente estudio se llevó a cabo en la Sierra de San Pedro (Extremadura, SO. de España).

Métodos: Para ello se comparó la dieta de este carroñero en los años 70 (Hiraldo, 1970) con la existente en el periodo 1998 - 2000. La metodología empleada estuvo basada en el análisis de egagrópilas recogidas en visitas a los nidos a lo largo del periodo anual (125 egagrópilas, 167 presas).

Resultados: En los años 70 este carroñero en la Sierra de San Pedro basaba su alimentación en cadáveres animales de mediano y pequeño tamaño, donde el conejo constituía su pieza clave. Ante la rarefacción

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ción de esta presa el buitre negro ha cambiado su dieta, siendo actualmente muy bajo el porcentaje de conejos en la misma. Este carroñero basa su alimentación en la oveja *Ovies aries*, que complementan con otras presas (Suidos y Cérvidos).

Conclusiones: El fuerte crecimiento de estos recursos y la protección de la especie han propiciado la recuperación de sus poblaciones. Esta capacidad del buitre negro para adaptarse a cambios en la disponibilidad de presas puede llegar a ser un elemento clave para la conservación futura de la especie pues recientemente se están produciendo nuevos cambios en la disponibilidad de estos recursos (mayor control en los cadáveres ganaderos y nuevas políticas comunitarias).

Palabras claves: *Aegypius monachus*, buitre negro, dieta, ecosistemas mediterráneos, carroñeros, plasticidad trófica.

INTRODUCTION

The black vulture *Aegypius monachus* extends throughout the Palearctic, with the populations in the Iberian Peninsula being the largest of the western half (Cramp and Simmons, 1980; Del Hoyo *et al.*, 1994). It is a species of great interest for conservation, both at a worldwide level (Collar *et al.*, 1994) and in Europe (Tucker and Heath, 1994) and Spain (Madroño *et al.*, 2004). In this context, the Extremadura populations have a fundamental role to play since they are the largest of the Iberian Peninsula and are among those that have undergone greatest growth (Sánchez, 1998; Costillo *et al.*, 2001). In Extremadura, the Sierra de San Pedro colony is one of the largest known colonies of the species (248 pairs; Costillo *et al.*, 2001). Hence, knowledge of the basic aspects of this population's ecology, including diet, is of evident importance for the conservation of the species.

Therefore, the data on the black vulture's feeding habits indicate a diet that varies greatly between locations, both worldwide (Cramp and Simmons, 1980; Del Hoyo *et al.*, 1994), and in the Iberian Peninsula (Valverde, 1966; Garzón, 1973; Hiraldo, 1976; Guzmán and Jiménez, 1998; Moleón *et al.*, 2001; Grefa, 2004). The diet is fundamentally based on carcasses of small and medium sized animals, with the rabbit *Oryctolagus cuniculus* being a key item in all colonies except in the Sierra de Guadarrama (Grefa, 2004). The Extremadu-

ra populations in particular seem also to follow this general pattern, with the published studies showing the importance of the rabbit in their diet (Garzón, 1973; Hiraldo, 1976). These studies of the Extremadura colonies were carried out in the 1970s. Since then, there have been notable changes in Mediterranean ecosystems. Two changes have been of especial importance for raptor communities: (1) The decline of rabbit populations has been implicated as a cause of the regression of many species (Madroño *et al.*, 2004); (2) there have also been both qualitative and quantitative transformations in domestic livestock production and big game species (Arroyo *et al.*, 1990).

The current availability of food is therefore presumably very different from what it was some decades ago. These food resources are presently being again subjected to new changes. On the one hand, there is an ever stricter control of livestock carcasses due to new outbreaks of livestock and human diseases. And on the other, livestock raising will undergo changes as part of the new reform of the Common Agricultural Policy (CAP).

The main aim of the present study was to determine how the black vulture has adapted in the past to the decline and eventual scarcity of the populations of its principal prey, the rabbit, and how it is adapting now to the new availability of food in its environment. To achieve this aim, the diet of this carrion feeder in the 1970s was compared with that recorded in the period 1998-2000.

MATERIAL AND METHODS

The study was carried out in the Sierra de San Pedro (Extremadura, Spain), located in the western half of the Iberian Peninsula. For a more detailed description, see Morán *et al.* (2006).

The method used was based on analyzing fur-ball pellets collected in visits to nests over an annual cycle of the years 1998-2000, and was the same as that used in other studies on the species (Hiraldo, 1976). To identify the hairs in the pellets, identification keys were used (Teerink, 1991) and a specifically constructed reference collections. To determine the number of prey items per pellet, a conservative criterion was applied (minimum number of prey) in the sense that the presence of a prey species in the pellet was interpreted as meaning that the vulture had eaten once from one individual of that species (Hiraldo, 1976). Prey species that were difficult to distinguish from the hairs because of their phylogenetic proximity were classified into higher taxonomic categories. This was the case for swine - wild boar *Sus scrofa* and domestic pigs *Sus domesticus* - which were classified together under their common family "Suidae", and for the lagomorphs -rabbit and Iberian hare *Lepus granatensis* - which were classified together under their family "Leporidae" in the order Lagomorpha. When it was impossible to reliably determine to which mammal species hair belonged, it was classified under "Unidentified mammals".

The data presented are: (i) the total number of fur-balls, (2) number of prey and their species, (3) an index of the trophic diversity of the diet, and (4) a dominance index for the most abundant prey. The diversity index used was that of Shannon, and the dominance index that of Berger-Parker (Mangurran, 1988).

To study how the species' diet has adapted to the changes in Mediterranean ecosystems, the data which Hiraldo (1976) presented as corresponding to a colony of the Province of Badajoz in the area of Sierra de San Pedro was cho-

sen. In this way, differences could be attributed to temporal changes rather than geographical variability.

A χ^2 test was used to analyze the differences in the composition of the diet between periods and between the frequencies of presence of the different categories of prey considered (Zar, 1989). For this comparison, it was necessary to group together certain different prey classes (Zar, 1989). In particular, equids, carnivores, unidentified mammals, and birds were binned together into a category of Other Prey, and, because of their similarity in many aspects, sheep *Ovis aries* and the domestic goat *Capra hircus* were binned into a category of Caprinae. A Hutcheson test was used to analyze the differences in dietary diversity (Mangurran, 1988).

RESULTS

Table 1 presents the data for the current composition of the diet of the black vulture in the Sierra de San Pedro. Nowadays, sheep constituted the basic component of the diet (58.07 %). Swine (domestic pig and wild boar) were the second most abundant group of prey in the diet (15.57 %), but with considerably less importance. Also important was the presence of deer (14.37 %). The rest of the preys were of minor importance. In particular, lagomorphs (rabbit and Iberian hare) were of very little importance in the vultures' diet at the present time (3.60 %).

In the 1970s, Hiraldo (1976) analyzed the diet of different colonies in the Iberian Peninsula, finding that the rabbit was a basic prey in all of them. In the Sierra de San Pedro, this lagomorph was the most frequently consumed species, and predominated in the diet together with medium sized ungulates (Table 1). Of these, the domestic goat was present to a greater degree than sheep (Table 1).

The comparative analysis showed that the diet of the black vulture has undergone notable changes in the Sierra de San Pedro over the last

TABLE 1

Frequencies of presence (%) of the different prey classes in the black vulture diet in the colony of Sierra de San Pedro in the 1970s (Hiraldo, 1976) and 2000s (ns: not significant; * $P < 0.001$).

[Frecuencia de presencia (%) de los distintos tipos de presas en la dieta del buitre negro de la colonia de la sierra de San Pedro en la década de los años 1970 (Hiraldo, 1976) y 2000 (ns: no significativo; * $P < 0.001$).]

	1970	2000	χ^2_2
F. <i>Suidae</i> (swine)	4.55	15.57	3.10 ns
Subfam. <i>Caprinae</i>	45.45	58.07	1.80 ns
<i>Ovis aries</i>	6.82	58.07	
<i>Capra hircus</i>	38.64	0.0	
F. <i>Leporidae</i> (lagomorphs)	40.91	3.60	45.96 *
Other prey	9.09	22.77	3.00 ns
F. <i>Cervidae</i> (deer)	0.0	14.37	
F. <i>Equidae</i> (equids)	4.55	0.0	
Orden <i>Carnívora</i> (carnivores)	2.27	0.60	
Unidentified mammals	0.0	7.20	
Birds	2.27	0.60	
Nº of prey	44	167	
Nº of pellets	unknown	125	
Diversity (H')	1.18	1.22	
Dominance	45.46	58.07	

decades ($\chi^2_3 = 51.68$; $P < 0.001$), basically because of the decline in importance of the rabbit as prey (Table 1).

No statistically significant differences were observed for the other prey categories (Table 1). In particular, sheep and goats together (*Caprinae*) formed a very important part of the diet of this colony, being the principal prey category both in the past and present. However, whereas in the past the domestic goat was in the majority, today it is sheep. While the difference in Other Prey did not reach statistical significance, it must be borne in mind that this category included the least frequently represented classes of prey in both periods, and one can observe changes in the frequency of presence of these species (Table 1). Deer *Cervus elaphus*, for instance, were not present in the 1970s, whereas now they represent one of the

most notable elements in the diet of the Sierra de San Pedro colony. Equids, on the contrary, were present in the 1970s, even though in small numbers within the dietary spectrum, while they were never detected in the present study. The diversity of the diet in the past was similar to that of today, with no significant differences being found between the two periods (Table 1).

DISCUSSION

The diet of the black vulture has evolved in Extremadura in response to the change in the availability of prey that has been occurred over the last few decades. At present, in Extremadura the species feeds mainly on carcasses of small and medium sized animals, with

sheep forming the basis of its diet not only in Sierra de San Pedro but also in other Extremadura colonies (Sierra de Gata, Granadilla, Ibores, and Cijara; Costillo, 2005). In the 1970s, however, rabbits were its key food item in the Extremadura region (Garzón, 1973; Hiraldo, 1976). The principal difference between the two dietary patterns is this high percentage of rabbits in their diet in the past. Rabbits predominated to such an extent in the 1970s that their presence in the diet correlated negatively with the dietary diversity index: a correlation analysis of the different studies of the time (Garzón, 1973; Hiraldo, 1976) showed that a high frequency of presence of lagomorphs in the diet of the different colonies was associated with a low value of the diversity index ($r_s = -0.90$; $P < 0.05$; $n = 5$). No such situation was found with the rest of the prey classes. At the present time in Extremadura, this negative correlation is observed with sheep. There also exists a strong negative correlation between the percentage of sheep in the diet in the different subcolonies of Extremadura and the diversity of their diet (Costillo, 2005). Such a correlation indicates that, of all the prey categories considered, the correlated category is selected actively (Schoener, 1971) in the sense that, when this prey becomes scarce, there is an increase in the number of classes of prey consumed (Herrera, 1974). Today, this situation with respect to rabbits is still the case in areas where the rabbit maintains abundant populations. In those areas, the rabbit continues to form an important percentage of the diet of the black vulture (Guzmán and Jiménez, 1998; Moleón *et al.*, 2001).

In extensive zones of the Iberian Peninsula, however, rabbit populations have undergone a drastic decline due mainly to diseases such as myxomatosis and viral haemorrhagic pneumonia (Sumption and Flowerdew, 1985; Villafuerte *et al.*, 1995). These zones include a great part of Extremadura and the surroundings of the Region's colonies of black vulture (Junta de Extremadura, 1992). Even though these out-

breaks of epidemics in the rabbit can favour certain carrion feeders, such as the black kite *Milvus migrans* (Viñuela and Veiga, 1992), they have been one of the causes of the decline in the populations of many Iberian predators (Madroño *et al.*, 2004).

Faced with a lack of prey, raptors may follow different strategies: remain in the zone without breeding (Southern, 1970; Korpimäki *et al.*, 1990), change their diet (Anderson and Erlinge, 1977; Steenhof and Kochert, 1988), or adjust their breeding strategies (Bortolotti *et al.*, 1991; Viñuela and Veiga, 1992; Steenhof *et al.*, 1997). Thus, the decline of the rabbit populations in the Iberian Peninsula has led to major changes in the breeding success and diet of many other raptors (Donazar, 1990; González, 1991; Fernández, 1993; Serrano, 1998). For the black vulture in Extremadura, there seems to have been no negative impact on breeding success. The breeding parameters of these colonies are considered normal within the range found in the biology of the species (Costillo, 2005), and furthermore these are some of the populations whose numbers have undergone the greatest growth (Sánchez, 1998; Costillo *et al.*, 2001).

Thus, in response to the rabbit becoming scarce, the black vulture in Extremadura has modified its diet. This is not only a case of the bird changing its feeding habits to concentrate on other resources that already formed a part of its diet, but is also because the availability of these resources has increased from the 1970s to the present.

In this sense, sheep raising in Spain, contrary to the decline in the populations of rabbit, has undergone major growth following the crisis that it went through in the 1970s and 1980s (MAPA, 2002). The census has gone from 17 million head in 1970 to almost 25 million in 2000, with Extremadura (4.5 million) being the Region with the greatest number of head in the country (MAPA, 2002). In addition, the current CAP maintains a system of livestock subsidies per head, which, according to the MAPA's censuses, has led to the aging

of the flocks (Álvarez, 2002). This may mean that there are more carcasses available for vultures, since the ever fewer old individuals are being removed from the flocks.

Likewise, the red deer *Cervus elaphus* today constitutes an important item in the black vulture's diet (Table 1), but, in the 1970s, Hiraldo (1976) did not cite it in the species' diet in any of the colonies that were studied, and Garzón (1973) found it to be only very occasionally present (2.10 %) in the diet of other Extremadura colonies. In the Iberian Peninsula, red deer populations have undergone major growth (Braza *et al.*, 1989; Soriguier *et al.*, 1994). This species is also very abundant in the Sierra de San Pedro, where it is the object of an intense and growing hunting sector. This activity normally involves active management of the species including fencing, resulting in a marked increase in the densities of these populations (Carranza, 1999). High densities and fencing of the populations have meant a decline in health and genetic quality, with the result of higher mortality rates (Ballou and Ralls, 1982; León, 1991; Carranza, 1999). Hunting activities increase the availability of deer carcasses for the black vulture in these areas.

The numbers of swine, another important item in the current diet of the vulture, have also increased in the area. From the 1970s until the present, the pig sector has undergone a major growth (MAPA, 2002). Similarly, wild boar have increased in numbers in the Iberian Peninsula, paralleling the case of deer (Sáez-Royuela and Tellería, 1986; León, 1991), since boar are also the object of a major hunting sector in the Sierra de San Pedro.

The present study has thus shown that the black vulture has been capable of changing its diet in response to the abrupt fall in the populations of its basic prey (the rabbit) and feeding on other resources whose availability has been increasing. Thus, the growth in extensive livestock production and especially in game management today provides more food resources than in the 1970s. These two reasons - a change

in diet and greater availability of those prey - may have contributed to the species' strong population increases in Extremadura, so that, in spite of the crash in the populations of its basic prey, it has been able to benefit from growing social awareness and the protection of the species.

This capacity of the black vulture to adapt to prey availability changes may become a key element for its future conservation. Although there is a greater availability of food thanks to extensive livestock farming (De Juana and De Juana, 1984; Arroyo *et al.*, 1990), if there continues to be increasing control of livestock carcasses, the result may be a reduction in these resources for the species. Such a new situation that seems to be foreseeable in the not too distant future may have different effects on each colony according to the local availability of alternative prey. Hence, vultures need to be considered as part of a suite of veterinary strategies, permitting livestock farmers in zones around vulture colonies to dispose of the carcasses of their livestock appropriately whenever this represents no danger to the health of the area's livestock overall. Special care needs to be taken in areas where the species depends to a large degree on livestock.

ACKNOWLEDGEMENTS.—The data used were collected under the financial sponsorship of the Project LIFE-Nature 97/250 (Gestión de ZEPAs en Extremadura. Recuperación y conservación del Buitre Negro y del Águila Perdicera, subproject Biología y Plan de Manejo del Buitre Negro en Extremadura) of the General Directorate for the Environment, Board of Agriculture and the Environment, Junta of Extremadura. Our special acknowledgements to Juan Manuel Sánchez Guzmán who directed the project and made valuable suggestions that helped us to improve this study. We thank Manuel Flores Cid de Rivera and Francisco Acedo Balsera very much for assistance throughout the research. We would particularly like to express our gratitude to the professionals of the Environmental Ranger Service and to the private individuals who allowed us access to their estates.

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[Recibido: 10-07-06]

[Aceptado: 26-08-07]

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