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Poison-related mortality effects in the endangered Egyptian vulture (*Neophron percnopterus*) population in Spain

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Abstract A total of 211 poisoning incidents registered over the period 1990–2007 and affecting 294 Egyptian vultures (*Neophron percnopterus*) were studied to address the impact of poison-related mortality in the Spanish population. Poison-related mortality mainly affected the birds on an individual level, with low numbers of individuals being found in each incident (mean 1.39) with 94.9% being adults. Deaths were largely recorded (81.8%) during the breeding season, with mortality peaking during May and June (52.1%). In contrast with other raptor species, a high proportion of adult individuals (74.2%) were found in the nest or its surroundings. Age-related differences in the poisoning rate are probably related with different feeding and behavioral strategies between age classes. The illegal use of poison to control predators was the main cause of mortality (93.8%), and particularly in small hunting reserves (74.9%), since the kind of food resources that adults exploit are coincident with the type of baits employed to illegally control predators and the preferred habitat coincides with areas of small game hunting. Our results suggest that poisoning is probably one of the main causes of Egyptian vulture mortality in Spain. The eradication of the illegal use of poisoning and supplementary feeding in specific territories to provide safe food seems priority for its conservation.

Keywords Egyptian vulture · Mortality · *Neophron percnopterus* · Poisoning · Population decline

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Introduction

Over the last few decades, Egyptian vulture (*Neophron percnopterus*) populations have been declining in several countries as a consequence of poisoning, human disturbance or the reduction in food availability (Liberatori and Penteriani 2001; Sarà and Di Vittorio 2003; Cuthbert et al. 2006; Carrete et al. 2007). The Spanish Egyptian vulture population, estimated at around 1,400 breeding pairs, is considered the most important in Europe (80% of the breeding pairs, Donázar 2004), and the species is classified as endangered in Europe (BirdLife International 2004). In Spain, Egyptian vulture populations experienced a sharp decline (around 25%) during the last two decades (del Moral and Martí 2002; Donázar 2004). It seems that the combined effects of habitat features, human persecution and the species' social behavior could explain the recent large-scale territory extinction (Carrete et al. 2007).

Mortality resulting from illegal poisoning has unique characteristics that make its surveillance and the effects on the population somewhat different from other non-natural causes of mortality (Guitart et al. 1999; Hernández 2006; Berny 2007; Martínez-Haro et al. 2008). Several studies have documented the detrimental effects of illegal poisoning on population dynamics, especially in those long-lived species with low reproductive rates and delayed maturity (Real and Mañosa 1997; Whitfield et al. 2004a, b; Ortega et al. 2009). Direct persecution, including illegal poisoning,

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affects adult survival, so increasing the replacement of adult breeders creates ecological traps, which attract adult floaters and immatures and increases pre-adult mortality in birds that may originate from persecution-free areas (Whitfield et al. 2004a, b).

The study of population or life history parameters is a common procedure that has been used to assess the effects of human persecution on several raptor species (Real and Mañosa 1997; Whitfield et al. 2003, 2004b; Margalida et al. 2008b; Ortega et al. 2009). Nevertheless, the study of specific causes of mortality for a species in a region and period of time, when available, is a more realistic approach to quantifying the effects of persecution.

In this paper, we use data on Egyptian vulture poisonings, gathered during the monitoring (1990–2007) of the illegal use of poisoning by the Ecotoxicology Working Group (Ministry of Environment, Madrid), to quantify the impact of illegal poisoning on the Egyptian vulture population in Spain. The aims of this study were: (1) to describe the routes of exposure, baits, poison used and their effects on Egyptian vulture population in Spain; (2) to propose conservation measures to reduce or eliminate illegal poisoning practices that affects this and other carrion eating species.

Material and methods

The study species

The Egyptian vulture is a medium-sized, cliff-nesting, long-lived, monogamous vulture species that inhabits a variety of habitats, mainly open landscapes in rugged regions where it exploits the carcasses of small and medium-sized animals (Donázar et al. 2002). In the Palaearctic, island populations are sedentary whereas continental birds winter in the African Sahel region (del Hoyo et al. 1994; Donázar et al. 2002). Egyptian vultures defend long-term established territories during the breeding season, nests are occupied year after year over long periods of time and breeding dispersal is rare (Donázar et al. 1996; Carrete et al. 2007). Nevertheless, individuals may forage and roost socially and these roosting sites are located near predictable food sources and play an important role in conspecific attraction and social relationships between individuals (Donázar et al. 1996; Margalida and Boudet 2003; Carrete et al. 2007).

Data collection

The main sources of information were poisoning incidents involving wildlife documented by authorities in Spain between 1990–2007, including reports from authorized staff and official agents, from records held by wildlife rehabilitation centers, veterinary medicine schools, and public and private laboratories, as well as cases compiled and records held by the Forensic Laboratory of Wildlife (LFVS, Madrid, Spain) and collated annually by the Ecotoxicology Working Group from the Fauna and Flora Committee (Ministry of Environment, Madrid, Spain). Although sources of information involved the participation of different administrations and staff, and details supplied with each incident may vary somewhat, the methodology used for gathering information was consistent over the study period.

Following the methodology of Whitfield et al. (2003), a poisoning incident was considered to be when evidence was found of poison-laced bait being used to attempt to kill a scavenging or predatory animal. Evidence involved the discovery of poisoned baits and dead or sick animals containing levels of poison sufficient to cause the death or illness, and/or typical symptoms or other clinical evidence of poisoning. Data included incidents where birds of prey were involved, but excluded records of poison use in urban and suburban areas. Most poisoning incidents were discovered by chance and by members of authorized staff and official agents, and were thus based on a passive information system. We used data on all poisoning incidents in Spain involving Egyptian vultures and details supplied with the incident record gathered during the official investigation. The cause of death was established following standard necropsy and pathology procedures, including the estimation of the post-mortem interval, throughout post-mortem examination by a pathologist and routine bacteriological, histopathological and toxicological investigations (for more details see Hernández and Margalida 2008). The diagnostic results and conclusion by the pathologists were used to categorize incidents (see Margalida et al. 2008a; Hernández and Margalida 2008). We used details supplied with incident records and necropsy reports such as date, number of vultures involved, their age class, the presence of other species affected in the incident, geographical location of the incident and any other relevant information gathered during the official investigation. These included clinical signs or post-mortem findings, the likely route of exposure, further toxicological analysis of baits or carcasses, toxicants investigated and whether other likely causes of death (e.g., disease, electrocution, shooting) had been eliminated. Since laying out poisoned baits is illegal in Spain, regardless of the target, incidents were investigated by members of authorized staff and official agents to establish their causes: approved use, misuse or deliberate abuse, and the likely causes of use or misuse, land use, pesticide treatments in the area, conflicts with human interests and investigations carried out to identify the likely authors. We also extended the time period backwards and forward to report other incidents in the area when these offered useful insights.

Toxicological analyses were carried out in several public and private laboratories. These included the National

Institute of Toxicology (Madrid), the Carlos III Health Institute (Madrid), the Regional Agricultural Laboratories of Algete (Madrid), León and Córdoba, as well as the Livestock Health Laboratory at Zaragoza, and the Wildlife Forensic Laboratory (Las Matas, Madrid). At the toxicology laboratories, samples were analyzed according to internal procedures, either or both published or official techniques for the analyses of residues in animal tissues (for a general review of techniques see Berny and Gaillet 2008). Screening for poisons included insecticides (organophosphates and carbamates, organochlorines, and pyrethroids), rodenticides, and other vertebrate poisons such as alfachloralose, strychnine, metaldehyde, arsenic, cyanide, and euthanasia agents. Methodology for toxicological analyses was described elsewhere (Henny et al. 1987; Warnock and Schwarzbach 1995; Allen et al. 1996; Elliot et al. 1996, 1997; Wobeser et al. 2004; Hernández et al. 2008). Laboratories had set up a quality assurance/quality control policy including the analysis of blanks, spiked samples, or both and calibration curves. Lead was not analyzed due to the lack of clinical and post-mortem or acute exposure evidence in any of the cases examined.

Since most of the open landscape in Spain is suitable, and thus exploited, for small game hunting and intense poisoning is mainly likely to occur in intensively managed small game exploitations, a classification of the habitat where carcasses were found seemed unsuitable to further categorize causes of the illegal use of poison. Furthermore, carcass location does not necessary reflect the location of intended use. We thus used information on the bait and poison used, which was supplied with the incident investigation to further categorize the causes of illegal use of poisoning involving Egyptian vultures.

According to the available information, in 130 incidents (61.6%), clinical signs or post-mortem findings of at least one of the affected vultures, with further chemical identification in tissues, gut contents or bait material or cholinesterase (ChE) inhibition evidence (plasma or brain ChE determination) supporting diagnosis were considered for diagnosis. In 41 incidents (19.4%), investigations were limited to toxic identification of gut contents or bait material. In five incidents (2.4%), investigations were limited to characteristic post-mortem findings with no further chemical identification or determination. Lastly, in 35 incidents (16.6%) diagnosis was gathered through circumstances clearly indicative of poisoning, such as mass mortality or mortality of several species (but where no pathological or chemical analysis data were available), the presence of suspicious bait material, adult death at the nest during the breeding process and other causes of death having been ruled out.

Vultures affected in poisoning cases were classified according to their age as follows: *adults*, vultures with full or nearly full adult plumage characteristics (>4 years) and breeding activity; *immatures*, vultures between 1 and 3 years old and distinguished by plumage, and *juveniles*, first year vultures after fledging. Since in some incidents, records did not include a clear differentiation between adults and subadults (>4 years), both age classes were considered as adults. Egyptian vultures winter in the African Sahel region after breeding on the Iberian Peninsula (Gómara et al. 2004). In accordance with breeding phenology, incidents were grouped in four periods: *pre-laying* (February–March), *incubation* (April and May); *chick-rearing* (June, July, and first fortnight of August) and the *post-fledging* period (second fortnight of August, September, and October). Incidents registered during winter in sedentary populations (islands) were excluded from phenology-related calculations.

Statistical analyses

Analyses of 2×2 contingency tables and χ^2 tests were carried out to analyze the dependency between pairs of factors. Observed cell frequencies were considered to be significantly different from the expected frequencies when the absolute value of the standardized residual was greater than $Z_{\alpha/2}$ (α=0.05). We tested inter-group differences using one-way analyses of variance (ANOVA) and the Spearman rank correlation to test the relationship between variables (Sokal and Rohlf 1995). The statistical analyses were carried out using NCSS and PASS software (Hintze 2001).

Results

A total of 211 poisoning incidents were registered during the period 1990-2007, affecting a total of 294 Egyptian vultures (Fig. 1). Individuals dying from other causes (n=116), including electrocution or collision with power lines (n=50), shooting (n=25), trauma (n=5), disease (n=4), road collision (n=3), trapping (n=3), and unknown causes (n=26), were not used for the study. A total of 285 (96.9%) poisoned vultures were found dead and nine (3.1%) alive. Poison-related mortality was mainly individual, with 22.3% (n=47) of the incidents affecting just one individual, and with a mean number of 1.39±0.79 (range 1–8) vultures affected in each incident. Dead chicks were found in 24 incidents, and in 14 of these cases either one or both adults were also dead. Chick mortality was not taken into account since causes of breeding failure were beyond the scope of this study.

Age and temporal variation in mortality

A total of 279 (94.9%) individuals were adults, 12 (4.1%) immatures and three (1%) juveniles. Reproductive status was determined in 128 (43.5%) out of 279 adult vultures,

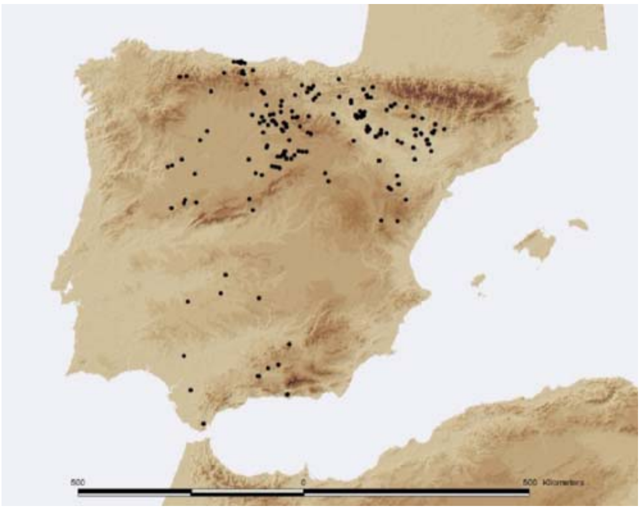

Fig. 1 Distribution of reported incidents (*dots*) of Egyptian vulture poisonings in peninsular Spain in the period 1990–2007

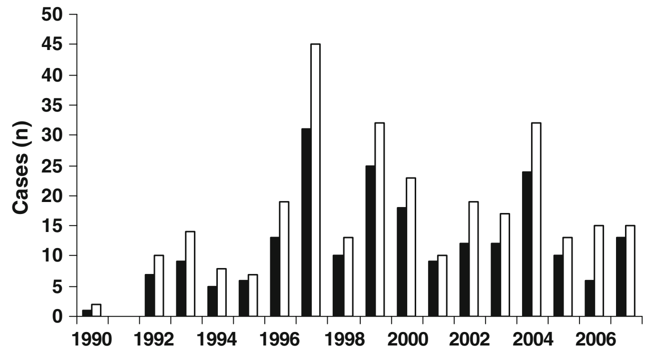

Fig. 3 Annual variation in the number of poisoning incidents (*black columns*) and individuals (*white columns*) of Egyptian vulture found during the period 1990–2007

95 of them (32.3%) found dead in active nests, corresponding to 65 (30.8%) incidents, and 33 (11.2%) of them determined at necropsy.

Most of the episodes took place during the incubation period (April–May, 53.4%) whereas most of the individuals were found during the incubation (34.3%) and chick-rearing period (June, July and first August fortnight, 40.3%, Fig. 2); 79.1% of the episodes took place during the breeding season and involved 74.6% of the individuals. No significant differences in the number of individuals per incident were found when we compared the different periods (pre-laying: 1.14±0.15; incubation: 1.14±0.07; chick-rearing: 1.53±0.11; post-fledging: 1.27±0.20, ANOVA F=1.60, df=3, 205, P=0.190).

Mortality arising from poisoning increased after 1996, being especially high in 1997, 1999, 2000 and 2004, with variations among years since 1996 (Fig. 3). Annually, the number of cases correlated positively with the number of individuals found dead (r_s=0.929, P<0.0001). The annual mortality variation in the number of cases shows an increase along the study period, although non-statistically significant (r=0.374, P=0.057). However, the comparison of 6-year periods shows the existence of significant differences with respect the expected values in the number of episodes (χ^2=25.74, df=2, P<0.0001) and the number of individuals found (χ^2=32.25, df=2, P<0.0001, Table 1). Most of the incidents (80.6%, n=170) and affected individuals (79.6%, n=234) occurred in the period 1997–2007, i.e., in the last decade a mean rate of 15.5 incidents or 21.3 individuals per year were recorded.

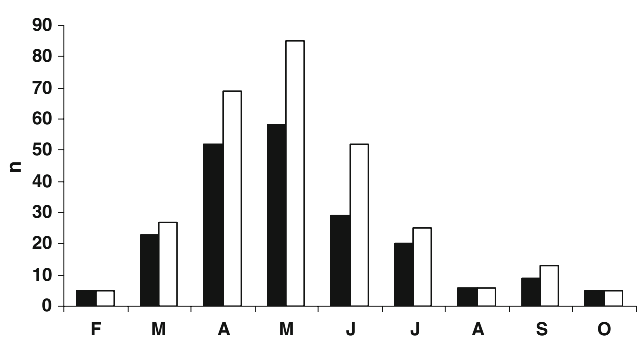

Fig. 2 Seasonal variation of mortality in Egyptian vulture incidents studied. Poisoning incidents (*black columns*); individuals (*white columns*)

Causes, routes of exposure, and baits and poison used

Causes of illegal poison use were known in 187 incidents (88.6%). Most of the deaths seem to be related to the illegal control of predators in the management of hunting properties (76.5% of the incidents of known causes), mainly in small game hunting properties (74.9% of the incidents, n=140). Conflicts with livestock breeding constituted another important cause of poison use (16.6%, n=31). The number of individuals affected in each incident, according to the causes of the illegal poison use, did not show statistically significant differences (ANOVA F=1.76, df=2, 205, P=0.122). The causes of toxicosis were determined in 187 (88.6%) of the incidents studied. All but two incidents (1.07%) were the result of the illegal use of pesticides as poison, which represented 98.9% of the investigated incidents. The intentionality of death was determined in 137 incidents. Secondary poisoning due to the consumption of carcasses of previously poisoned animals was identified in 18 incidents (13.1%). Nevertheless, the frequency of secondary poisonings may be even higher since in 74 incidents (35.1%) the origin of exposure could not be identified. Most of them could more likely be linked with the birds feeding on carcasses where pesticide

Table 1 Inter-annual variation in the poisoning incidents and individuals of Egyptian vulture found in the Iberian Peninsula during the period 1990-2007

	Period		
	1990–1995	1996–2001	2002–2007
Incidents	28	106	77
Average individuals per incident (n)	1.464±0.881 (41)	1.349±0.618 (142)	1.429±0.938 (111)

may be taken up more slowly, thus allowing the birds to digest food and preventing the correct identification of gastrointestinal contents.

There were only two incidents arising from the approved use of drugs and pesticides. In one incident, secondary poisoning due to the consumption of woodpigeons poisoned with lindane, an authorized seed insecticide, by then was identified as the cause of poisoning. One further incident was caused by poisoning with pentobarbital after its use for the sacrifice of one sheep. In 197 (93.4%) incidents, the bait used was known. Of these, 177 incidents (89.9%) were as a consequence of the direct consumption of a bait that was not targeted at vultures, and in ten incidents (5.1%), the bait was directed at scavenger birds.

Of the 211 cases studied, in 137 (64.9%) the type of bait used could be identified. Pesticide-laced raw or processed cold meat was found in 64 incidents (46.7%), pesticide-laced chicken carcasses in 25 (18.3%), small ruminant pesticide-laced carcasses in 15 (11%), poison-laced eggs in nine (6.6%) and pesticide-laced woodpigeon carcasses in eight (5.8%). In the remaining five cases, the baits used were pesticide-laced carcasses of red-legged partridge *Alectoris rufa* (two cases), or a wild ruminant, large domestic animal or rabbit (one case each). In 10 cases (7.3%) Egyptian vultures were poisoned through the consumption of carcasses of previously poisoned animals (secondary poisoning) other than pigeons. In all, small-sized baits accounted for 101 incidents (73.7%).

The poison involved was determined in 166 (78.7%) incidents. A total of 17 different compounds were involved in these incidents. The majority of the poisons involved in Egyptian vulture deaths were agricultural pesticides (80.1%, n=133). The three compounds found to be most abused in incidents that accounted for 85.5% (n=142) of the poisoning cases were, aldicarb (38.6% of incidents), carbofuran (31.3% of incidents), and strychnine (16.3% of incidents). Other compounds involved in incidents include cyanide, monocrotophos and arsenic (each 1.2% of incidents), fenthion, chlorfenvinphos, lindane, dimethoate, fonofos, terbufos, cumaphos, malathion, dichlorvos, and chlorpyrifos (each accounting for 0.6% of the incidents). According to the pesticide used, no significant differences were found in the average number of individuals that died in each incident (lethality) (aldicarb, 1.42±1.04 vultures/incident; strychnine, 1.41±0.69; carbofuran, 1.22±0.42 (ANOVA, F=0.91, df=2, 142, P=0.405).

Discussion

Direct persecution has been found to be one of the most important factors of non-natural mortality affecting populations of many birds of prey (Etheridge et al. 1997; Whitfield et al. 2003, 2004a; González et al. 2007; Margalida et al. 2008a). The illegal use of poison is of conservation concern since several wild and domestic species, including birds of prey, are targeted by poisoning (Mineau et al. 1999; Roy et al. 2005; Berny 2007). Vultures are especially susceptible to the introduction of toxicants in the food chain (Hernández and Margalida 2008, Margalida et al. 2008a). Our results suggest that poisoning is probably the main cause of mortality in the Egyptian vulture in Spain, since no other non-natural cause of mortality shows similar figures and trends (see Lemus et al. 2008), despite the lack of comparative studies on the effect of different causes of mortality on the population (Donázar 2004). The Egyptian vulture population in Spain has declined sharply over the last 20 years (Del Moral and Marti 2002) and most of the incidents (80.6%) occurred in the last decade. However, it is necessary to take into account spatial and temporal biases. For example, in the Ebro valley, poisoning events increased after the rabbit hemorrhagic diseases in the early nineties, as an illegal response to control predators, and coincided with a sharp population decline of the Egyptian vulture population (Carrete et al. 2007). In the beginning, many poisoning events remained unnoticed by wildlife agencies; while in further years, the concern on the effects of poison increased as well the efficiency looking for (and reporting) poisoning events. Therefore, the lower frequency of episodes detected in the first years may be partially explained by a biased sampling. Later on, after the BSE crisis (Tella 2001) many small feeding stations where carrion was predictable for breeding vultures were closed. As a result, breeding vultures may have been forced to look for food out of these relatively secure feeding points and thus be more vulnerable to dispersed small poisoned baits, generating a new upsurge of mortality. Thus, the likelihood of finding a poisoning event largely depends on the interest/

effort of particular wildlife agents and regional programs. These figures suggest a worse scenario when considering the kind of individuals affected by the illegal use of poison, since 94.9% of the individuals were adults and 82% of the deaths were recorded during the breeding season, with both proportions being significantly higher than those recorded in other raptor species (González et al. 2007; Margalida et al. 2008a; Hernández and Margalida 2008). A possible explanation may be related with the migratory habits of the species and because a proportion of juveniles birds remains in winters ground. In addition, most Spanish immature Egyptian vultures feed on a few feeding points close to a few communal roosts, where the risk of poisoning is low. This hypothesis is supported by the fact that survival decreases just at the age when these vultures abandon communal roosts looking for a breeding territory across large areas, where poisoning risk increases (Grande et al. 2008) as has been observed in bearded vultures *Gypaetus barbatus* (Oro et al. 2008).

Studies based on passive systems of gathering information have the disadvantage that the results obtained only represent a fraction of those really produced (Mineau et al. 1999). In the case of the Egyptian vulture, like the bearded vulture (see Margalida et al. 2008a) but in contrast to other vultures (Muzinic 2007; Hernández and Margalida 2008), the average number of individuals found dead in each incident (1.39 individuals/incident) was low. This decreases the chance of carcass detection, thus the number of undetected incidents in the Egyptian vulture may be even higher. In addition, a high proportion of adult birds (32.3% of the total number of individuals and 74.2% of the adults recovered) were found dead in their nest or close to the nest during reproduction monitoring. This high proportion suggests that an undetermined number of dead adults may remain undetected unless nests are monitored, and that mortality out of the breeding area could remain largely undetected. Another bias could also be motivated by the fact that in some cases, deaths may occur far away from or sometime after exposure. These cases are more likely to be secondary poisonings since baits in primary poisonings often contents high concentration of toxicants, and thus death occurs near the site where the bait is placed and shortly after exposure (Elliot et al. 1997; Mineau et al. 1999). Our results suggest that secondary poisonings are found in the Egyptian vulture (13.1%) at a similar frequency to that of the bearded vulture (12%, Margalida et al. 2008a) but more frequently than in other vulture species as the cinereous vulture *Aegypius monachus* (4.5%, Hernández and Margalida 2008) and may also explain the high proportion of cases of adult mortality found in nests or close to nests. On the other hand, the high percentage of unknown bait used (35.1%) may suggest that secondary poisonings were underestimated since those cases corresponded mainly to cases where gut contents could not be identified properly.

A lack of significant differences in the number of Egyptian vultures found dead between different types of baits and toxicants used in illegal poisonings may be the result of either or both the low average number of Egyptian vultures found per incident and the susceptibility of this species to the introduction of toxicants in the food chain (Villafuerte et al. 1997; Carrete et al. 2007). This is the case of poison-laced eggs that represented less than 0.02% of the baits studied between 1990 and 2006 in Spain (Hernández 2006).

Our results also suggest that the majority of the poisons that are affecting the Egyptian vulture are cholinesterase-inhibiting agricultural insecticides (carbamates and organophosphates) approved for agricultural and, to a lesser extent, *classic* wildlife poisons (strychnine, cyanide, and arsenic). However, in accordance with the exposure route, type of food, concentration of toxicant and the place of discovery of the carcasses, it has proved impossible to link its presence with legal use (labeled or misuse) in agriculture. For this reason, with the exception of the two incidents arising from the approved use of pesticides and drugs, all studied cases were intentional poisonings. The Egyptian vulture's main source of exposure to pesticides was the direct consumption of a meat source that had been treated or contaminated with a toxic product. Thus, the illegal use of poison in order to control predators, irrespective of what activity led to this action, was the main cause of poisoning. Only in 5.2% of the cases was the bait directed specifically at scavenger species, which shows the scarce selectivity of the illegal, indiscriminate use of poison for the control of wild populations, whether they be due to conflicts with hunting, agriculture, or livestock.

A direct link was found between Egyptian vulture mortality and the illegal control of predators, mainly in small hunting properties (74.9% of incidents of known cause). The type of baits used also correlated with the type of activity generating the illegal use of poison (Hernández 2006). Together, all small-sized baits (poison-laced raw meat and chicken, partridge, woodpigeon, and rabbit carcasses) accounted for 73.7% of the incidents. Adult Egyptian vultures are highly opportunistic and may change their diet in accordance with the available resources (Donázar 1993), exploiting small wild prey carcasses. Juvenile and immature vultures, on the other hand, seem to be more closely linked to predictable food sources, as occurs generally in other vulture species (Donázar et al. 1996; Carrete et al. 2006). These different foraging strategies may result in differences in poison-related mortality between age classes as the types of bait used for predator control in small hunting properties are, precisely, the kind of food resources that adults are able to exploit. The fact that survival decreases in correlation with the age (at least in the Egyptian and bearded vultures, see Grande et al. 2008 and Oro et al. 2008, respectively), can be explained by the increase of the risk of poisoning when individuals depend to a lesser degree on supplementary and predictable feeding points. The direct effect on Egyptian vulture mortality of the illegal control of predators in small hunting properties is also reflected in the seasonality of the incidents. Predator control peaks in April, May, and June, out of the hunting season and when predator reproduction takes place (Hernández 2006).

Although livestock farming has a lower impact on Egyptian vulture mortality, its incidence will probably increase in the near future as the current trend in overall poisoning events in Spain is for an increase in the illegal use of poison to control livestock predators, mainly the wolf (*Canis lupus*) in northern Spain (Villafuerte et al. 1997; Hernández 2006).

As has been documented, mate loss during reproduction may be difficult to detect in the Egyptian vulture, since lost reproductive birds are quickly replaced (Donázar 2004). As all population surveillances refers to the number of active territories and breeding pairs rather than to productivity and breeding success, it is difficult to assess the impact of reproductive adult mortality on the population. In large raptor species, mate loss affects fecundity producing lower productivity and breeding success (Whitfield et al. 2004a; Margalida et al. 2003, 2008b).

Conservation measures

Poisoning, a decrease of food availability (as a result of recent EU carcass disposal regulations) and electrocution have been considered the most important causes of non-natural mortality in Egyptian vultures in Spain (Donázar et al. 2002). Although direct persecution of predators may have decreased in Spain compared to the past (Martínez-Abraín et al. 2008), the case of large-scale unintentional poisoning reported here must play a key role on the species decline. On the other hand, the decrease of direct persecution is followed by an increase of mortality due to infrastructures (power lines, windfarms). In addition, recent studies showed that lead-poisoning also can affect this species (Gangoso et al. 2009) and there is evidence that climate changes in wintering areas may also lower survival of Egyptian vultures (Grande et al. 2008). Our results suggest that the numbers and effects of poisoning may be underestimated and the mortality of the adult breeding population seems significant and their implications in population dynamics could be important. In an endangered species, adult mortality may have significant consequences because population stability demands high adult survival rates (Meretsky et al. 2000; Oro et al. 2008; Ortega et al. 2009). As poison-related mortality affects principally breeding adults, the eradication of illegal poisoning from the field should be the first priority for managers and conservationists. On the other hand, supplementary feeding could be used as a specific tool to provide safe food in regions in which poisoning carcasses are abundant (Gilbert et al. 2007). Nevertheless, restoring the traditional feeding sites does not seem as difficult as eliminating the illegal use of poison, since it contradicts current sanitary laws that were established as a result of the BSE crisis. A great effort bridging the large gap between wildlife conservation and sanitary agencies is needed to assure sufficient and safe food for vultures (see Lemus et al. 2008) without posing risk to human health. In this sense, the revitalization of extensive livestock production and the presence of carrion in the field has been suggested as an important management tool for the maintenance and growth of the scavenger populations (Margalida et al. 2007, 2009). Finally, supplementary feeding in specific territories could be a useful conservation tool to provide safe food to breeding pairs and to avoid poisoning risks.

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