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How to manage human-induced mortality in the Eagle Owl *Bubo bubo*

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Summary

The Eagle Owl *Bubo bubo*, which feeds mainly on rabbits and partridges, has been persecuted widely for causing damage to game interests. Although it is a protected species throughout Europe, there is a noteworthy gap in the scientific literature on the causes of mortality in this top predator. Here, we assess the relative importance and the geographical and temporal variation of human-related causes of death by reviewing 1,576 files of individuals admitted to wildlife rescue centres in Spain, a stronghold for Eagle Owls. The main known cause of death was interaction with powerlines followed by persecution and collisions with game fences and cars. There were within-year variations in the distribution of persecution, electrocution and collisions with game fences. Some man-induced causes of mortality were seen to depend on both the geographical region and the period of the year; moreover, mortality within each region was also year-dependent. Since there are strong socio-economic and ethical components involved, management guidelines are discussed bearing in mind such points of view.

Introduction

The Eagle Owl (*Bubo bubo*) is one of several birds singled out by governments and hunters as the cause of problems to game interests (Kenward 2002). It is a top avian European predator (Mikkola 1983) and it is known to live at high and increasing densities throughout Spain (Martínez and Zuberogoitia 2003a, Penteriani *et al.*, 2005). Several studies have pointed to the importance of rabbits and Red-legged Partridges in the diet of the Eagle Owl in Spain (Hiraldo *et al.* 1976, Donázar and Ceballos 1984, Serrano 1998, 2000, Martínez and Zuberogoitia 2001, Martínez and Calvo 2001). However, the extent of predation is still largely unknown: for example, it remains to be determined whether Eagle Owls reduce the number of young rabbits or partridges to the point of reducing pre-harvest (autumn) hunting bags (Redpath and Thirgood 1999). Small game hunting is a socio-economically important activity (Lucio and Purroy 1992, Villafuerte *et al.* 1998), and hunters blame Eagle Owls (among others) for depleting their bags, which on many occasions are the result of expensive re-stocking operations. Consequently, Eagle Owls are persecuted across the Iberian peninsula, and are locally culled (Zuberogoitia *et al.* 1998, Martínez *et al.* 2003b).

Persecution was deemed responsible for the extinction of the Eagle Owl in large areas of Europe, such as northern Germany in 1830, the Netherlands in the late nineteenth century, Luxembourg in 1903, Belgium in 1943, central and western Germany in the 1960s (Niethammer and Kramer 1964, Herrlinger 1973) and the north of Spain (Zuberogoitia *et al.* 2003), although electrocution and collision with powerlines emerged as a new, more worrying cause of mortality during the last century (Marchesi *et al.* 2002, Mañosa 2002). Energy demands have increased exponentially and the number of avian fatalities due to dangerous pole design or siting lines in environmentally sensitive areas continues to increase, with consequent effects on bird populations (Mañosa 2002, Sergio *et al.* 2004a). However, to our knowledge, there is no specific agency in Europe (equivalent to the PIREA in the United States) which deals with developing cost-effective approaches for evaluating and resolving the impact of energy generation, transmission and use on bird populations.

The aims of this study were: (a) to ascertain the main causes of mortality of Eagle Owls in Spain; (b) to detect possible elements affecting spatio-temporal patterns of such human-induced mortality; and (c) to propose management guidelines in an attempt to reduce such mortality.

Methods

We collected records of dead or fatally injured Eagle Owls from bird rehabilitation centres and birding associations across Spain over the period 1989–2003 ($n = 1{,}576$). Three variables were considered for analysis: cause of death (persecution, electrocution, other causes), region (South: Andalusia; East: Catalonia, Community of Valencia and Region of Murcia; Centre: Community of Madrid, Castilla-León, Castilla-La Mancha and Extremadura; North: Galicia, Asturias and Basque Country) and year. Due to the small sample size, data from Extremadura were pooled with those from Castilla-La Mancha. Not all these variables were available for every entry and, therefore, sample size varies between analyses.

We also considered within-year variations in owl mortality. Although some studies divide the year into 3-month periods to study seasonal patterns in mortality (Rubolini *et al.* 2001), such division does not match the annual cycle of the Eagle Owl in southern latitudes (courtship: October–January, 4 months; laying: February–March, 2 months; post-fledging dependence period and dispersal: April–September, 6 months; Martínez and Zuberogoitia, 2003b; authors' unpublished data). Therefore, we studied variations of the main causes of death per month.

We tested for possible interactions between causes of death, region and year by means of log-linear models (Real *et al.* 2001). Models were selected using the backwards stepwise method. Factors were retained or not according to the likelihood ratio χ^2. Then, we built contingency tables for the interacting variables achieving statistical significance ($\alpha = 0.05$) by χ^2 tests. We considered that the observed cell frequencies were significantly different from the expected frequencies when the absolute value of the standardized residuals was greater than $z_{\alpha/2}$.

Results

Causes of mortality

Within the three major causes of death, mortality was distributed as follows (Table 1): (1) powerlines (20.1%), i.e. electrocution (16.3%), collision (1.8%) and unknown causes related with powerlines (2%); (2) persecution (19.2%), with shooting (11.8%) prevailing over nest robbery or captivity (6.2%) and poisoning (1.2%); and (3) other

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Table 1. Causes of death of Eagle Owls in several regions of Spain between 1989 and 2003.

	South	East			Centre				North			
	Andalusia	Community of Valencia	Catalonia	Region of Murcia	Community of Madrid	Castilla-La Mancha	Castilla-León	Extremadura	Galicia	Asturias	Basque Country	Total
Persecution												
Shooting	32	77	21	8	28	15	1	0	0	0	4	186
Nest robbery or captivity	15	24	8	9	29	11	0	0	2	0	0	98
Poison	8	3	2	1	3	2	0	0	0	0	0	19
Total	55	104	31	18	60	28	1	0	2	0	4	303
Powerlines												
Collision	6	0	5	0	2	10	1	0	0	0	4	28
Electrocution	89	46	40	15	39	23	5	0	0	0	0	257
Unknown	4	29	0	0	0	0	0	0	0	0	0	33
Total	99	75	45	15	41	33	6	0	0	0	4	318
Others												
Drowning	10	8	3	2	1	0	0	0	0	0	0	24
Accidentally trapped	4	6	2	2	11	2	0	0	1	0	0	28
Game fences	38	1	6	1	17	2	0	2	0	0	0	67
Car crash	29	10	20	1	12	16	3	0	1	0	1	93
Trauma (unknown origin)	113	99	35	16	18	19	1	0	1	0	2	304
Starvation	10	6	3	0	11	6	0	0	0	0	0	36
Other anthropogenic causes	3	0	0	0	0	0	0	0	0	0	1	4
Other natural causes	13	2	13	2	2	0	0	0	0	0	1	33
Unknown	90	115	45	17	49	42	0	1	0	3	4	366
Total	310	247	127	41	121	87	4	3	3	3	9	955
Total	**464**	**426**	**203**	**74**	**222**	**148**	**11**	**3**	**5**	**3**	**17**	**1,576**

causes (60.6%), the most frequent being traumas of unknown origin (19.3%), collision with game fences (5.9%) and collision with cars (4.3%) (Table 1).

Geographical distribution of mortality

Powerlines were responsible for the highest number of deaths in Castilla-León (54.5%), Castilla-La Mancha (22.3%), Catalonia (22.2%) and Andalusia (21.3%). Persecution was the main cause of death in the Community of Madrid (27.0%), Community of Valencia (24.4%) and Region of Murcia (24.3%). In the Basque Country powerlines and persecution totalled 47.1%.

Within-year variations in causes of death

There were significant monthly variations in mortality resulting from persecution (Figure 1), electrocution (Figure 2) and collision with game fences (Figure 3; χ^2 = 67.85, d.f. = 22, $P < 0.001$). Moreover, within each of the three above cited causes of death, there was a significant monthly variation (persecution: χ^2 = 76.83, d.f. = 11, $P < 0.001$; electrocution: χ^2 = 26.38, d.f. = 11, P = 0.006; collisions with game fences: χ^2 = 27.75, d.f. = 11, P = 0.004).

Interactions between causes of death, region and year

A log-linear model allowed us to analyse the 1,196 records for which complete information was available for cause of death, region and year, showing significant interactions between region and year, region and cause of death, and year and cause of death (Table 2). Low and high frequencies of persecution in Andalusia and in Eastern Spain, respectively, high frequencies of powerline impact in the Centre, as well as the

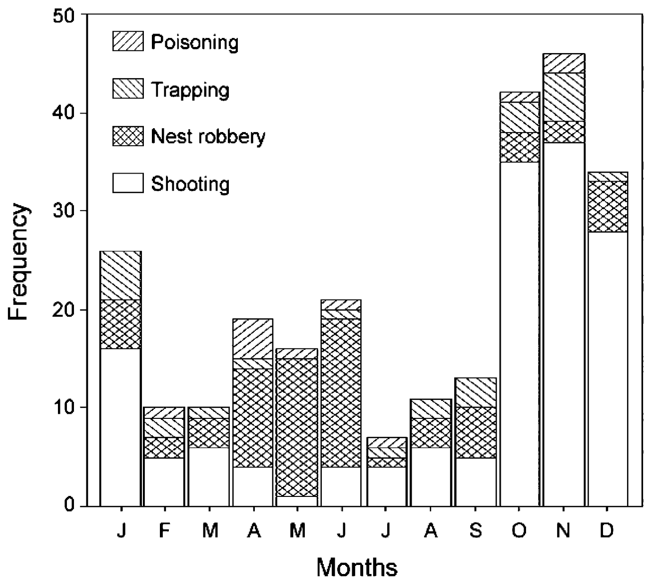

Figure 1. Monthly variation of Eagle Owl persecution in Spain.

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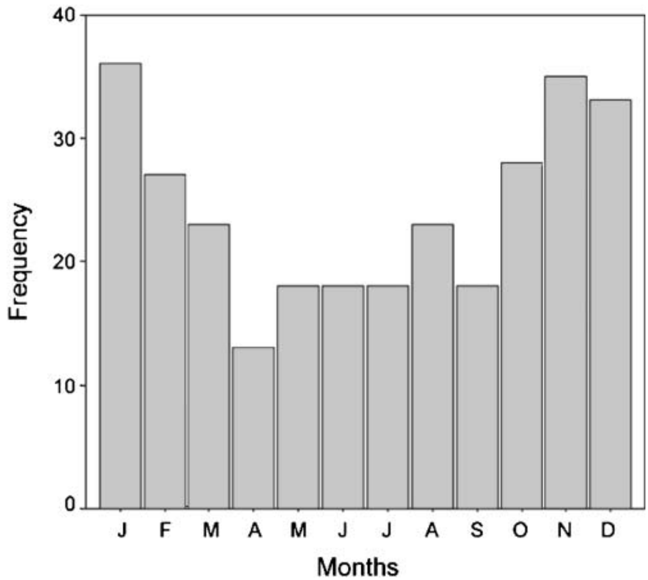

Figure 2. Monthly variation of Eagle Owl electrocution in Spain.

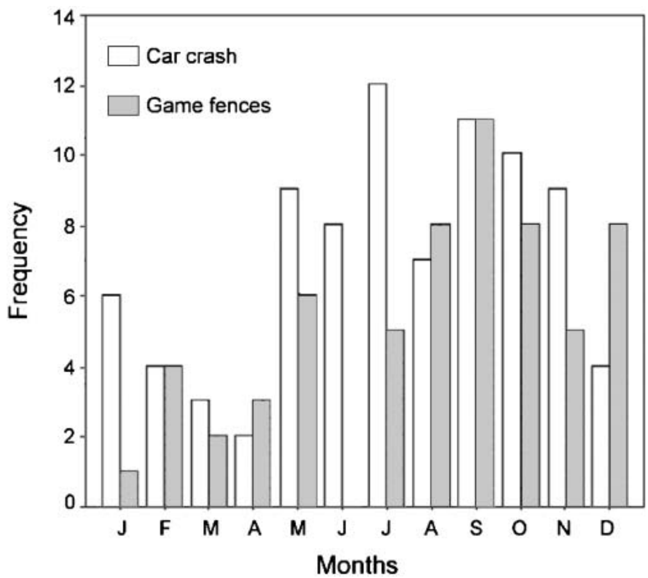

Figure 3. Monthly variation of Eagle Owl collision with game fences and with cars in Spain.

relatively high frequencies of other causes in the South, were responsible for the significance of the region–cause interaction (Table 3; $\chi^2 = 24.25$, d.f. $= 6$, $P < 0.001$). The significance of the year–cause interaction was due mainly to the increase in recorded powerline mortality. (Table 4; $\chi^2 = 107.34$, d.f. $= 28$, $P < 0.001$). The frequencies of the three causes of death were remarkably high between 2000 and 2003. The significance of the region–year interaction was due to a higher number of

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Table 2. Marginal association χ^2 values of the three factorial independence tests between cause, region and year.

Factor	d.f.	Partial χ^2	*P*
Region × year	45	192.30	<0.001
Region × cause	6	28.55	<0.001
Year × cause	30	103.05	<0.001
Region	3	603.03	<0.001
Year	15	945.96	<0.001
Cause	2	115.54	<0.001

Table 3. Contingency table relating region and cause of death.

	South	East	Centre	North
Persecution	55*	153*	89*	6*
Interaction with powerlines	99*	134*	80	4
Others	310*	415*	215*	15

*Significant difference between observed and expected frequencies ($P < 0.05$).

Table 4. Contingency table relating year and cause of death.

Year	Persecution	%	Interaction with powerlines	%	Others	%	Total
1989	0*		0*		1*	100	1
1990	9*	39.1	0*		14*	60.9	23
1991	16*	37.2	2*	4.7	25*	58.1	43
1992	13*	31.7	0*	0.0	28	68.3	41
1993	10*	35.7	5	17.9	13*	46.4	28
1994	7*	21.9	2*	6.3	23*	71.9	32
1995	25*	24.3	4*	3.9	74	71.8	103
1996	19*	21.6	13*	14.8	56*	63.6	88
1997	20	18.9	25*	23.6	61	57.6	106
1998	38	19.8	40	20.8	114	59.4	192
1999	37	17.5	37	17.5	138	65.1	212
2000	38*	15.0	53	21.0	162*	64.0	253
2001	19*	14.6	38*	29.2	73*	56.2	130
2002	33*	18.4	44*	24.6	102	57.0	179
2003	19*	13.1	55*	37.9	71*	49.0	145

*Significant difference between observed and expected frequencies ($P < 0.05$).

casualties recorded in the South, East and some areas of Central Spain in the period 1995–2003 than in previous years. An exception was the Community of Valencia, where high numbers were generally maintained throughout the study period. This might also mirror to a certain extent the distribution and abundance of Eagle Owls in Spain, with low densities in the north and abundant populations elsewhere (Martínez and Zuberogoitia 2003a).

Discussion

The samples presented in reviews on the causes of mortality, such as the present study, do not represent a cross-section of all deaths (Newton *et al.* 1997, Mañosa 2002), and it

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is therefore desirable to carry out further studies aimed at gathering specific information (such as in Sergio *et al.* 2004a). However, compilation studies provide valuable quantitative information on the causes of mortality of wild bird populations, particularly as regards human-related causes (Mikkola 1983, Newton *et al.* 1997, Martínez *et al.* 2001, Real *et al.* 2001, Mañosa 2002). For example, this study showed that the killing of Eagle Owls is still a common practice throughout Spain, where the legal protection of birds of prey seems to have had a limited effect. As shown by the interaction cause_year (Table 4), a moderate number of owls were registered as killed between 1996 and 1999, but this figure rose again in 2000–2003. A similar trend has been found for several raptors in Spain throughout the 1990s, with persecution peaking in 1990–1994 and reaching a minimum in 1997–2000 (Mañosa 2002). Shooting was consistently the main cause of mortality in the north of Spain during the 1990s for Peregrine Falcons (*Falco peregrinus*) (Zuberogoitia *et al.* 2002). It is also possible that more care has been put into concealing casualties after law reinforcement (Mañosa 2002), leading to the underestimation of the actual extent of persecution. The Eagle Owl's main prey in Spain are rabbits and Red-legged Partridges. Therefore, the conflict which results in the killing of this predator might be especially acute in areas where game shooting relies on re-stocking operations. This will be particularly true in areas where habitat alteration and game stock mismanagement occur. Re-stocking is a widespread practice (e.g. in eastern Spain) as a consequence of decreased hunting bags due to epizootics (Martínez and Zuberogoitia 2001, Martínez and Calvo 2001), habitat degradation and overhunting (Arques 2000), which would help to explain the high incidence of persecution recorded in these areas (Table 3).

It is generally believed that killing raptors is opportunistic, i.e. it takes place during the hunting season and is not deliberately aimed at reducing raptor predation (Viñuela and Arroyo 2002). However, our finding that 12.6% of the shooting occurred outside the hunting season (March to July) indicates that killing birds of prey is proactive to a remarkable extent (Figure 1). The hypothesis that cropping avian predators is still proactive in Spain is further supported by several studies. For example, Martínez *et al.* (2001) found that 11.5% ($n = 329$) of the raptors hunted in the Community of Valencia were shot outside the hunting season. Up to 47% of Barn Owls (*Tyto alba*) and 21% of Bonelli's Eagles (*Hieraaetus fasciatus*) killed were shot when hunting is not allowed (Martínez and López 1995, Real *et al.* 2001, respectively). The Eagle Owl's tendency to breed repeatedly in the same nests would make it more prone to being killed by gamekeepers or hunters (authors' personal observations).

Many birds of prey die due to secondary poisoning, i.e. a non-desired effect of the use of products used for pest control (Mañosa 2002, Whitfield *et al.* 2003, Mateo *et al.* 2004, Sergio *et al.* 2005). However, intentional poisoning in Spain is frequent (e.g. 70 Egyptian Vultures *Neophron percnopterus* between 1995 and 1998; Del Moral and Marti 2002) and can be especially suspected when the target species is not a carrion-eater, such as the Bonelli's Eagle (Real *et al.* 2001, Mañosa 2002) or the Eagle Owl. Poisoning occurred throughout the year at low frequencies (Figure 1), but the lack of funding to run expensive analyses to detect phytosanitary substances and other poisons may mask the real impact of this practice on raptors.

Alternatively, the apparent reduction in the frequency of persecution in the second half of the 1990s could be related to an increase in powerline casualties (Table 4). Quantitatively, electrocution is the main cause of death of Eagle Owls in Spain (Table 1) and is an important cause in Europe (Table 5). In a non-exclusive way, this

Table 5. Main causes of mortality of Eagle Owls reported in Europe.

Country	No. of individuals	Causes of mortality (%)				Source
		Interaction with powerlines	Persecution	Car crash	Others	
Finland	75	16.0	17.3	13.3	53.3	Saurola (1979)
France	8	12.5	50.0	0.0	37.5	Blondel and Badan (1976)
France	17	35.3	47.1	5.9	11.8	Choussy (1971)
Germany	211	23.7	25.1	10.9	40.3	Wickl (1979)
Germany	606	26.6	2.8	26.9	43.7	Radler and Bergerhausen (1988)
Italy	10	70.0	30.0	0.0	0.0	Penteriani and Pinchera (1990)
Italy	34	47.1	0.0	11.8	41.2	Marchesi *et al.* (2002)
Italy	92	53	0.0	0.0	39	Rubolini *et al.* (2001)
Spain	14	57.1	42.9	0.0	0.0	Beneyto and Borau (1996)
Spain	84	17.9	78.6	0.0	3.6	Martínez *et al.* (1992)
Spain	134	9.7	80.6	5.9	3.7	Hernández (1989)
Spain	126	0.0	42.8	4.0	53.1	Martínez *et al.* (1996)
Spain	1,576	20.0	19.2	5.93	54.9	This study
Sweden	101	19.8	5.0	12.9	62.4	Olsson (1979)
Switzerland	29	55.2	0.0	44.8	0.0	Haller (1978)

could also be due to better line monitoring or to an increase in the length of powerlines (Penteriani 1998, Janss and Ferrer 1999, Sergio *et al.* 2004a). The interaction region–cause (Table 3) suggests that although dangerous poles and power distribution lines will always present a risk of death for raptors, physiognomic factors that increase avian use or concentrate birds in the vicinity of hazardous poles can significantly add to this risk and create a population-level effect (Sergio *et al.* 2004a). Our results seem to support this hypothesis in several ways. The Eagle Owl is a sit-and-wait hunter (Mikkola 1983) and, consequently, may frequently use poles in areas where they are the most suitable perches. This characteristic of Eagle Owl hunting behaviour can increase the number of fatalities due to electrocution (Benson 1980), as already demonstrated for Eagle Owls in an Italian study (Sergio *et al.* 2004a). Because the poles that provide the best view over the widest areas are potentially very attractive perch-sites during hunting, this could explain the high frequency of electrocuted owls from Central and Southern Spain (Table 3), where the terrain is largely undulating and agricultural (Real *et al.* 2001). Moreover, high prey abundance may contribute to an increased electrocution risk by sustaining locally high raptor populations and exposing more birds to hazardous pole designs (Woodbridge and Garrett 1993), as is the probably case on the border between the Community of Valencia and the Region of Murcia (Table 3).

Among the other known causes of death, it is worth mentioning collisions with game fences and cars (Figure 2), the former recorded as an increasing menace (Tucker and Heath 1994, Heath *et al.* 2000). The frequency of collisions with game fences could be underestimated if some of the deaths attributed to traumas had been caused by impact with game fences (Table 1). Eagle Owls would be prone to impacts when flying low after their prey (Muñoz-Cobo and Azorit 1996). The Eagle Owl prefers open areas on the perimeter of mountains in shrubland or close to agro-pastoral landscapes (Marchesi *et al.* 2002, Penteriani *et al.* 2002, Martínez *et al.* 2003b, Sergio *et al.* 2004b), which largely overlap with hunting areas in Spain. Fencing off hunting estates was also frequent before our study period, when it accounted for most of the known causes of Eagle Owl deaths in certain areas of Southern Spain (31.7%; Muñoz-Cobo and Azorit 1996).

There seems to be some slight between-cause variation in the seasonal pattern of mortality. Persecution and interaction with powerlines peaked between October and February (Figures 1 and 2; Rubolini *et al.* 2001, Sergio *et al.* 2004a), i.e. between courtship and laying, and mostly adult birds died. This finding may support the hypothesis that human-induced mortality can create deleterious population effects by eliminating territorial individuals (Sergio *et al.* 2004a).

Management implications: shooting

Theoretical law reinforcement by itself has had no noticeable effect on reducing the number of casualties of birds of prey (Mañosa 2002). Even if the law were strictly applied, problems such as habitat and game mismanagement would still remain to be dealt with. However, a set of ecological, sociological or economic tools exists that can be promoted to reduce the conflict surrounding illegal killing (Kenward 2002).

Ecological tools

Eagle Owls may respond functionally and numerically to variations in the abundance of their main prey (Martínez and Zuberogoitia 2001, Martínez and Calvo 2001). Additionally, they may or may not prey upon other raptors as a consequence of such variations (Serrano 2000, Martínez and Zuberogoitia 2001, Martínez and Calvo 2001) or due to intra-guild effects (Sergio *et al.* 2003). Therefore, further studies are needed to determine the type of response of the Eagle Owl to changing prey densities and to locate areas where detrimental population effects, if any, on prey or raptors occur. Zoning with quotas (Watson and Thirgood 2001) could also be implemented. This would require further political commitment because: (a) effective control of persecution and regular monitoring of shooting would have to be carried out in restricted and non-restricted areas, respectively, and (b) previous research would be needed to designate such areas.

Sociological tools

While there is mounting evidence that raptor persecution persists in Spain there is a lack of consensus between hunters and conservationists about how to use such information (Herranz-Barrera 2001). If both parties could come to an understanding, research-based educational campaigns among hunters and conservationists should be implemented. These campaigns must deal with the spectrum of conservation possibilities, whose limits may be shooting raptors on the one hand or refusing to treat them as renewable resources on the other (Kenward *et al.* 1991, Thirgood *et al.* 2000).

Economic tools

One of the aims of the agri-environmental schemes of the Common Agricultural Policy (CAP) is to protect biodiversity. Thorough evaluation of how resources are allocated and tests on the effectiveness of such policies in promoting the sustainability of rabbits and red-legged partridges and their habitats are needed because: (a) they are the main prey for Eagle Owls in Iberia and (b) they are a major economic issue (Lucio and Purroy 1992, Villafuerte *et al.* 1998). However, Spain has not yet endorsed the collection of baseline data for this appraisal (Kleijn and Sutherland 2003). Joint initiatives between national institutions and hunters aimed at restoring agro-pastoral mosaics and prey stocks locally have provided acceptable solutions for raptors, game, conservationists and hunters (Sánchez 2004), stressing the need to reinforce control over the implementation of the CAP in Spain.

Management implications: powerlines

There is a consensus of opinion that electrocution hot-spots should be mapped and accounted for (Sergio *et al.* 2004a). Reducing the risk of death of birds of prey through interaction with powerlines has mostly involved *a posteriori* actions, i.e. mitigating the impact of existing designs, improving the design of existing structures or replacing dangerous poles (Janss and Ferrer 1999, Mañosa 2001, Rubolini *et al.* 2001). However, abiding by the current environmental impact laws (EC Directive 85/337/EEC) and developing strategic environmental assessments of plans and programmes of development would prove a better approach to account for the negative impact of powerlines and other hazards to birds of prey (Díaz *et al.* 2001, Martínez *et al.* 2003a). Hence, with regard to killing through inadequate pole design, or setting lines in inadequate areas, the power corporations, the environmental companies that produced flawed environmental impact reports or the managers who passed on such reports could be considered responsible for the offence (Martínez *et al.* 2003a).

The results of the present study suggest that law reinforcement concerning bird protection is still far from being efficient in some areas of Spain. The statistical significance of the region_cause interaction underlines the fact that area- and species-specific mitigation and remediation measures should be developed, all in a framework of biologically meaningful spatial and temporal scales. Maintaining low levels of what, currently, seem to be secondary causes of mortality is of special interest because this mortality is additive to the main, increasing cause of loss across Europe – habitat deprivation (Tucker and Evans 1997).

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References

Arques, J. (2000) Ecología y gestión cinegética de una población de conejos en el Sur de la provincia de Alicante. Unpublished PhD thesis, Universidad de Alicante, Spain.

Beneyto, A. and Borau, J. A. (1996) El Búho real (*Bubo bubo*) en Cataluña (NE de España). Pp. 477–483 in J. Muntaner and J. Mayol, eds. *Biology and conservation of Mediterranean raptors, 1994*. Madrid: Sociedad Española de Ornitología (Monograph no. 4).

Benson, P. C. (1980) Large raptor electrocution and power pole utilization: a study in six western states. *Raptor Res.* 14: 125–126.

Blondel, J. and Badan, O. (1976) La biologie du Hibou grand-duc en Provence. *Nos Oiseaux* 33: 189–219.

Choussy, D. (1971) Etude d'une population de Grand-ducs *Bubo bubo* dans le Massif Central. *Nos Oiseaux* 31: 37–56.

Del Moral, J. C. and Marti, R. (2002) *El Alimoche Común en España y Portugal. I Censo Coordinado. Año 2000*. Madrid: SEO/BirdLife (Monograph no. 8).

Díaz, M., Illera, J. C. and Hedo, D. (2001) Strategic environmental assessment of plans and programs: a methodology for biodiversity evaluations. *Environ. Manage.* 28: 267–279.

Donázar, J. A. and Ceballos, O. (1984) Datos sobre status, distribución y alimentación del búho real (*Bubo bubo*) en Navarra. Pp. 246–254 in *Rapinyaires Mediterranis II*. Barcelona.

Haller, H. (1978) Zur populationsökologie des Uhus *Bubo bubo* im Hochgebirge: Bestand, Bestandsentwicklung und Lebensraum in den Rätischen Alpen. *Ornithol. Beob.* 75: 237–265.

Heath, M., Borggreve, C. and Peet, N. (2000) *European bird populations. Estimates and trends.* Cambridge, U.K.: BirdLife International.

Hernández, M. (1989) Mortalidad del búho real en España. *Quercus* 40: 24–25.

Herranz-Barrera, J. (2001) *Efectos de la depredación y del control de predadores sobre la caza menor en Castilla-La Mancha*. PhD thesis, Universidad Autónoma de Madrid, Madrid.

Herrlinger, E. (1973) Die Wiedereinbürgerung des Uhus *Bubo bubo* in der Bundesrepublik Deutschland. *Bonn. Zool. Monogr.* 4: 1–151.

Hiraldo, F., Parreño, F. F., Andrada, J. and Amores, F. (1976) Variation in the food habits of the European Eagle Owl (*Bubo bubo*). *Doñana Acta Vert.* 3: 137–156.

Janss, G. F. E. and Ferrer, M. (1999) Mitigation of raptor electrocution on steel power poles. *Wildlife Soc. Bull.* 27: 263–273.

Kenward, R. E. (2002) Management tools for reconciling bird hunting and biodiversity. Unpublished report to REGHAB Project. European Commission. Available from <http://www.uclm.es/irec/Reghab/informes_4.htm>.

Kenward, R. E., Marcström, V. and Karlbom, M. (1991) The goshawk *Accipiter gentilis* as predator and renewable resource. *Gibier Faune Sauvage* 8: 367–378.

Kleijn, D. and Sutherland, W. J. (2003) How effective are European agri-environment schemes in conserving and promoting biodiversity? *J. Appl. Ecol.* 40: 947–969.

Lucio, A. J. and Purroy, F. J. (1992) Caza y conservación de aves en España. *Ardeola* 39: 85–98.

Mañosa, S. (2001) Strategies to identify dangerous electricity pylons for birds. *Biodiv. Conserv.* 10: 1–16.

Mañosa, S. (2002) The conflict between game bird hunting and raptors in Europe. Unpublished report to REGHAB Project. European Commission. Available from <http://www.uclm.es/irec/Reghab/informes_3.htm>.

Marchesi, L., Sergio, F. and Pedrini, P. (2002) Costs and benefits of breeding in human-altered landscapes for the eagle owl *Bubo bubo*. *Ibis* 144: 164–177.

Martínez, J. A. and López, G. (1995) Dispersal and causes of mortality of the Barn Owl (*Tyto alba*) in Spain. *Ardeola* 42: 29–37.

Martínez, J. A. and Zuberogoitia, I. (2001) The response of the eagle owl (*Bubo bubo*) to an outbreak of the rabbit haemorrhagic disease. *J. Ornithol.* 142: 204–211.

Martínez, J. A. and Zuberogoitia, I. (2003a) Búho real *Bubo bubo*. Pp. 316–317 in R. Marti and J. C. del Moral, eds. *Atlas de las aves reproductoras de España*. Madrid: Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología.

Martínez, J. A. and Zuberogoitia, I. (2003b) Factors affecting the vocal behaviour of eagle owls *Bubo bubo*: effects of season, density and territory quality. *Ardeola* 50: 255–258.

Martínez, J. A., Izquierdo, A., Izquierdo, J. and López, G. (1996) Causas de mortalidad de las rapaces nocturnas en la Comunidad Valenciana. *Quercus* 126: 18–19.

Martínez, J. A., Izquierdo, I. and Zuberogoitia, I. (2001) Causes of admission of raptors in rescue centres of the East of Spain and proximate causes of mortality. *Biota* 2: 163–169.

Martínez, J. A., Martínez, J. E., Zuberogoitia, I., García, J. T., Carbonell, R., De Lucas, M. and Díaz, M. (2003a) La evaluación de impacto ambiental sobre las poblaciones de aves rapaces: problemas de ejecución y posibles soluciones. *Ardeola* 50: 85–102.

Martínez, J. A., Serrano, D. and Zuberogoitia, I. (2003b) Predictive models of habitat preferences for the Eurasian eagle owl: a multiscale approach. *Ecography* 26: 21–28.

Martínez, J. E. and Calvo, J. F. (2001) Diet and breeding success of the Eagle Owls in southeastern Spain: effect of rabbit haemorrhagic disease. *J. Raptor Res.* 35: 259–262.

Martínez, J. E., Sánchez, M. A., Carmona, D., Sánchez, J. A., Ortuño, A. and Martínez, R. (1992) The ecology and conservation of the Eagle Owl *Bubo bubo* in Murcia, south-east Spain. Pp. 84–88 in C. A. Galbraith, I. R. Taylor and S. Percival, eds. *The ecology and conservation of European owls*. Peterborough, U.K.: Joint Nature Conservation Committee.

Mateo, R., Blanco, G. and Jiménez, B. (2004) Riesgos tóxicos para las aves rapaces en España. In *Actas del XVII Congreso Español de Ornitología*. Madrid: SEO/BirdLife.

Mikkola, H. (1983) *Owls of Europe*. Calton, U.K.: T. & A. D Poyser.

Muñoz-Cobo, J. and Azorit, C. (1996) Amenazas de los cercados para la fauna. *Ecosistemas* 16: 22–25.

Newton, I., Wyllie, I. and Dale, L. (1997) Mortality causes in British Barn Owls (*Tyto alba*), based on 1,101 carcases examined during 1963–1996. Pp. 299–306 in J. R. Duncan, D. H. Johnson and T. H. Nicholls, eds. *Biology and conservation of owls of the Northern Hemisphere*. General Technical Report NC-190. St Paul, MN: USDA Forest Service.

Niethammer, G. and Kramer, H. (1964) Zum Aussterben des Uhus in der Eifel. *Der Falke* 11: 189–190.

Olsson, V. (1979) Studies on a population of Eagle Owls, *Bubo bubo* (L.), in southeast Sweden. *Viltrevy* 11: 1–99.

Penteriani, V. (1998) *L'impatto delle linee elettriche sull'avifauna*. Rome: WWF Italia (Scientific Series no. 4).

Penteriani, V. and Pinchera, F. (1990) Censimento del Gufo reale, *Bubo bubo*, in un'area dell'appennino abruzzese. *Riv. It. Ornitol.* 60: 119–128.

Penteriani, V., Gallardo, M. and Roche, P. (2002) Landscape structure and food supply affect the Eagle Owl (*Bubo bubo*) breeding performance: a case of population heterogeneity. *J. Zool.* 357: 365–372.

Penteriani, V., Delgado, M. M., Maggio, C., Aradis, A. and Sergio, F. (2005) Development of chicks and pre-dispersal behaviour of young in the Eagle Owl *Bubo bubo*. *Ibis* 147: 155–168.

Radler, K. and Bergerhausen, W. (1988) On the life history of a reintroduced population of Eagle Owls (*Bubo bubo*). Pp. 83–94 in D. K. Garcelon and G. W. Roemer, eds. *Proceedings of the International Symposium on Raptor Reintroduction, 1985*. Arcata, CA: Institute for Wildlife Studies.

Real, J., Grande, J. M., Mañosa, S. and Sánchez-Zapata, J. A. (2001) Causes of death in different areas for Bonellis eagle *Hieraaetus fasciatus* in Spain. *Bird Study* 48: 221–228.

Redpath, S. and Thirgood, S. (1999) Numerical and functional responses in generalists predators: hen harriers and peregrines in Scottish grouse moor. *J. Anim. Ecol.* 68: 879–892.

Rubolini, D., Bassi, E., Bogliani, G., Galeotti, P. and Garavaglia, R. (2001) Eagle owl *Bubo bubo* and power line interactions in the Italian Alps. *Bird Conserv. Int.* 11: 319–324.

Sánchez, C. (2004) Custodia del territorio, una vía para la conservación del Águila-azor Perdicera. *La Garcilla* 119: 37.
Saurola, P. (1979) Rengastettujen petolintujemme löytymistavat. *Lintumies* 14: 15–21.
Sergio, F., Marchesi, L. and Pedrini, P. (2003) Spatial refugia and the coexistence of a diurnal raptor with its intraguild owl predator. *J. Anim. Ecol.* 72: 232–245.
Sergio, F., Marchesi, L., Pedrini, P., Ferrer, M. and Penteriani, V. (2004a) Electrocution alters the distribution and density of a top predator, the Eagle Owl *Bubo bubo*. *J. Appl. Ecol.* 41: 836–845.
Sergio, F., Marchesi, L. and Pedrini, P. (2004b) Integrative individual habitat choices and regional distribution of a biodiversity indicator and top predator. *J. Biogeogr.* 31: 619–628.
Sergio, F., Blas, J., Forero, M., Fernández, N., Donázar, J. A. and Hiraldo, F. (2005) Preservation of wide-ranging top predators by site-protection: black and red kites in Doñana National Park. *Biol. Conserv.* 125: 11–21.
Serrano, D. (1998) Diferencias interhábitat en la alimentación del búho real (*Bubo bubo*) en la valle medio del Ebro (NE de España): efecto de la disponibilidad de conejo (*Oryctolagus cuniculus*). *Ardeola* 45: 35–46.
Serrano, D. (2000) Relationship between raptors and rabbits in the diet of Eagle Owls in southwestern Europe: competition removal or food stress? *J. Raptor Res.* 34: 305–310.
Thirgood, S., Redpath, S., Newton, I. and Hudson, P. (2000) Raptors and red grouse: conservation conflicts and management solutions. *Conserv. Biol.* 14: 95–105.
Tucker, G. M. and Evans, M. I. (1997) *Habitats for birds in Europe: a conservation strategy for the wider environment*. Cambridge, U.K.: BirdLife International.
Tucker, G. M. and Heath, M. F. (1994) *Birds in Europe: their conservation status*. Cambridge, U.K.: BirdLife International.
Villafuerte, R., Viñuela, J. and Blanco, J. C. (1998) Extensive predator persecution caused by population crash in a game species: the case of red kites and rabbits in Spain. *Biol. Conserv.* 84: 181–188.
Viñuela, J. and Arroyo, B. (2002) The conflict between game bird hunting and raptors in Europe. Unpublished report to REGHAB Project. European Commission. Available from <http://www.uclm.es/irec/Reghab/informes_3.htm>.
Watson, M. and Thirgood, S. (2001) Could translocation aid hen harrier conservation in the UK? *Anim. Conserv.* 4: 37–43.
Whitfield, D. P., McLeod, D. R. A., Watson, J., Fielding, A. H. and Haworth, P. F. (2003) The association of grouse moor in Scotland with the illegal use of poison to control predators. *Biol. Conserv.* 114: 157–163.
Wickl, K. H. (1979) Der Uhu (*Bubo bubo*) in Bayern. *Garmischer Vogelkundliche Berichte* 6: 1–47.
Woodbridge, B. and Garrett, M. (1993) Electrocution mortality of golden and bald eagles in an area of high prey concentration. *J. Raptor Res.* 27: 85.
Zuberogoitia, I., Campos, L. F., Crespo, T. and Ocio, G. (1998) Lechuza Común, Autillo, Búho Real, Mochuelo, Cárabo Común, Búho Chico y Chotacabras Gris. Pp. 224–233 in J. A. Fernández de Mendiola and A. Bea, eds. *Vertebrados continentales. Situación actual en la Comunidad Autónoma del País Vasco*. Gasteiz-Vitoria: Servicio Central de Publicaciones del Gobierno Vasco.
Zuberogoitia, I., Ruiz-Moneo, J. F. and Torres, J. J. (2002) *El halcón peregrino*. Bilbao: Departamento de Agricultura, Diputación Foral de Bizkaia.
Zuberogoitia, I., Torres, J. J. and Martínez, J. A. (2003) Reforzamiento poblacional del Búho Real *Bubo bubo* en Bizkaia (España). *Ardeola* 50: 237–244.

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