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Spatio-temporal variations in mortality causes of two migratory forest raptors

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Summary

Analysis of the 949 and 434 cases of mortality of Booted Eagle and Short-toed Snake Eagle, respectively, recorded by wildlife rescue centres in Spain over a 16-year period (1990–2006) shows that power lines (19.5% and 35.2%, respectively) and killing (32.5% and 22.9%, respectively) were the main known causes of death. There were marked within-year variations in the distribution of killing and power line casualties by both species. Multinomial regression models were used to analyse geographical and temporal variations in the causes of death. For the Booted Eagle, both factors (zone and year) were statistically significant, while there were only significant temporal variations for the Short-toed Snake Eagles. In the Booted Eagle, killing occurred more frequently than expected in the east and north of the country compared to the other regions. Power line casualties were significantly more frequent in the southern and eastern regions, and less common in the north. In both species, the multinomial models indicate that while the number of cases of killing significantly decreased during the 16 years studied, line casualties increased. Our study suggests that human-induced mortality continues to be the main factor contributing to non-natural mortality for Spanish Booted Eagles and Short-toed Snake Eagles. Differences in the mortality causes by shooting and power lines were found between sedentary and migratory raptors. Since a reduction in the mortality caused by human activities is a priority in the conservation strategies for raptor species, management guidelines are discussed bearing in mind several points of view.

Keywords: *Aquila pennata*, *Circaetus gallicus*, Spain, mortality factors, electrocution, persecution.

Introduction

In recent decades, biodiversity conservation actions and environmental policies undertaken by the European Union have favoured an increase in European raptor populations (BirdLife International 2004). However, many species are still subjected to high levels of human induced mortality, mainly associated with deliberate or accidental human killing, conflicts with game or livestock interests (Pedrini and Sergio 2001, Whitfield *et al*. 2003, Hernández and Margalida 2009, Thompson *et al*. 2009, Valkama *et al*. 2005, Park *et al*. 2008, Blanco-Aguiar *et al*. 2012, Pohja-Mykrä *et al*. 2012) or accidents with human-made infrastructures, such as power lines or wind farms (Lehman *et al*. 2007, Ferrer *et al*. 2012). Studying spatial and temporal variations in the causes of mortality is a fundamental aspect for increasing our knowledge of population dynamics prior to the implementation of management measures (Etheridge *et al*. 1997, Whitfield *et al*. 2004, Margalida *et al*. 2008). Although radio-tracking is the most suitable method for studying mortality causes in birds of prey (Kenward 1993), it is expensive in terms of time and effort and often beyond the spatial scope and urgency of conservation needs (Real *et al*. 2001). The analysis of fatalities recorded at wildlife rehabilitation centres therefore emerges as a suitable alternative method that provides new contributions on the causes of mortality and allows the assessment of the health status of wild bird populations, especially in human-induced causes (Martínez *et al*. 2006, Kalpakis *et al.* 2009, Rodríguez *et al*. 2010, Molina-López *et al*. 2011).

The Iberian Peninsula is a stronghold of most threatened birds of prey species in Europe (BirdLife International 2013), and much effort has been put into ascertaining the sources of threat (Real *et al*. 2001, Martínez *et al*. 2006, González *et al*. 2007, Molina-López *et al*. 2011). Most of these studies have focused on sedentary species, and few have looked at migratory species (Zwarts *et al*. 2009). Due to the migration process itself, and also because mortality factors are season-related (Bildstein *et al*. 2006, Angelov *et al*. 2013), it can be hypothesized that such species are subject to different mortality factors in Europe than sedentary species.

The Booted Eagle *Aquila pennata* and the Short-toed Snake Eagle *Circaetus gallicus* are two long-lived trans-Saharan migrant raptors which breed in Mediterranean forests of the western Palearctic (Del Hoyo *et al*. 1994), with relevant breeding populations in Spain (Birdlife International/ European Bird Census Council 2000). Both are listed in Annex I of Birds Directive and their conservation status is considered as Least Concern (LC), according to the categories defined by the International Union for Nature Conservation (IUCN; BirdLife International 2013). Population estimates in Spain are approximately 2900 and 2800 pairs, respectively (Martí and Del Moral 2003). Previous studies suggest that both species are subject to high levels of human induced mortality (Mañosa 2001, Martí and Del Moral 2003, García-Dios 2004). They are also highly vulnerable to the impact of potential wind energy developments (BirdLife International 2013). However, until now, no detailed studies have analysed spatial and temporal variations in the causes of mortality of these species. The aims of this study, therefore, were: (i) to ascertain the main causes of mortality of Booted Eagle and Short-toed Snake Eagle in Spain; (ii) to detect possible elements affecting spatio-temporal patterns of mortality; and (iii) to propose management guidelines to reduce such mortality.

Methods

Data collection

We examined 1383 cases (949 Booted Eagles and 434 Short-toed Snake Eagles) of fatalities recorded at wildlife rehabilitation centres and birding associations across Spain between 1990 and 2006. Most cases were examined by veterinary pathologists to determine the cause of death and injury. For each recorded case we used, whenever possible, the information contained in individual reports: the cause of injury or death, locality, date, age class and sex. The causes of death were registered according to the following five categories and were considered as mortality factors regardless of the fact that any birds did not die but were rehabilitated and released back to the wild (Xirouchakis 2004): 1) *killing*, including shooting, nest-robbery, trapping, captivity and poisoning or intoxication; 2) *power line casualties*, including electrocution or collision with power lines; 3) *other anthropogenic causes*, including drowning, collision with game fences, car crash, trauma of unknown origin and other (reaping machine, found inside a building); 4) *natural causes* (starvation, chicks fallen from nests, diseases and predation); and 5) *unknown.*

To describe the geographic variation in the causes of mortality, Spain was divided into four zones, each one corresponding to a particular combination of environmental and socio-economic factors: South (Andalusia), East (Autonomous Community of Valencia, Región de Murcia, Catalonia and the Balearic Islands), Centre (Autonomous Community of Madrid, Castile-La Mancha, Castile-Léon and Extremadura) and North (Galicia, Asturias, Basque Country and La Rioja).

To describe the within-year variations in mortality in Booted Eagles and Short-toed Snake Eagles, the causes of death were analysed on a per month basis.

Statistical analyses

To investigate the factors influencing variations in mortality causes, we modelled "*cause*" as a nominal response variable with four classes: *killing*, *power lines*, *other anthropogenic* and *natural*. A multinomial regression analysis (Venables and Ripley 2002) and Type II likelihood-ratio tests (Fox and Weisberg 2011) were then performed to examine the significance of two potential explanatory variables: zone and year (treating the first as factor and the last as quantitative). Multinomial regression is a simple extension of binary logistic regression that allows for more than two categories of the dependent variable, and is considered suitable for analysing multiway contingency tables. The analyses were performed using the "nnet" (Venables and Ripley 2002) and "car" (Fox and Weisberg 2011) packages in R version 3.1.1 (R Core Team 2014).

Results

Causes of mortality

Of the 1383 cases of mortality, it was possible to determine the cause of death in 73.1% of the individuals of both species. For the Booted Eagle, the three major causes of death were distributed as follows (Fig. 1; Table 1): **1)** other anthropogenic causes (34.4%), with trauma of unknown origin (21.2%) prevailing over car crash (2.6%), drowning (2.3%) and fences (1.7%); **2)** killing (32.5%), with shooting (19.5%) prevailing over nest robbery or captivity (9.7%), trapping (1.7%) and poison/intoxication (1.6%); and **3)** power line casualties (19.5%), with electrocution (15.3%) prevailing over collision (1.1%).

For the Short-toed Snake Eagle, the major causes of death were (Fig. 1; Table 2): **1)** power line casualties (35.2%), with electrocution (25.8%) prevailing over collision (5.5%); **2)** other anthropogenic causes (28.7%), with trauma of unknown origin (19%) prevailing over car crash (2.3%), drowning (1.6%) and fences (0.3%); and **3)** killing (22.9%), with shooting (12.9%), prevailing over nest robbery or captivity (7.4%), trapping (1.6%) and poison/intoxication (1%).

Within-year distribution in causes of mortality

There were monthly variations in mortality resulting from killing (Fig. 2) and power lines (Fig. 3). As expected for both species, high frequencies of shooting were observed during the hunting season (August-February), but shooting persisted outside the hunting season (March-July). Nest robbery or captivity principally occurred in July-August for both species. Trapping occurred in June and during the hunting season (August-November) for the Booted Eagle, whereas for the Short-toed Snake Eagle trapping mainly occurred in July and during the hunting season (August-November). Poisoning mainly occurred during May-July and the hunting season (September and December) for Booted Eagles and during August-September for Short-toed Snake Eagles.

Electrocution showed low values for both species during the January-March period, and high peaks between July and September (Fig. 3). Collisions with power lines were lower during January-April.

Geographical distribution of causes of mortality

For the Booted Eagle (Fig. 4a), other anthropogenic causes were responsible for the highest number of deaths in South (40.7%) and Centre (38.6%). Killing was responsible for the highest number of deaths in East (40.5%) and North (37.5%), and power lines casualties were the main cause of death in South (22.7%) and East (22.3%). The multinomial analysis for this species showed that these geographical differences were statistically significant (χ^2 likelihood ratio = 43.39; d. f. = 9; $P < 0.001$; Table 3). In contrast, no significant differences between zones were found for the Short-toed Snake Eagle (χ^2 likelihood ratio = 8.76; d. f. = 9; $P < 0.460$; Table 3; Fig. 4b).

Evolution of the cause of mortality over time

The multinomial regression analyses for both species showed significant variations in the causes of death over time (Table 3, Fig. 5). The proportion of deaths caused by killing suffered a pronounced decline over time for both species, while the proportion of fatalities related to power lines increased notably, especially in the case of the Short-toed Snake Eagle. The interaction term *zone* × *year* was not statistically significant in any case (Table 3).

Discussion

In agreement with the results obtained for other raptors and owl species in Spain (Real *et al*. 2001, Martínez *et al*. 2006, González *et al*. 2007, Margalida *et al*. 2008, Tenan *et al*. 2012), our results showed that mortality causes in the Spanish population of both studied species were still closely related to direct persecution and power line casualties. Persecution is a major problem for raptors even in other European countries (Smart *et al*. 2010, Mustin *et al*. 2011, Martínez-Abraín *et al*. 2013, Elston *et al*. 2014). Shooting was the first and the second most important cause of death for Booted Eagle and Short-toed Snake Eagle, although the incidence was less common than that found in other sedentary eagle such as the Bonelli's Eagle (*Aquila fasciata*) in Spain (Real *et al*. 2001). These differences could be associated with a higher proportion of game birds (principally Red-legged Partridges) and rabbits in Bonelli's Eagle diets (Moleón *et al.* 2009). In these sedentary eagle, one of the most important underlying causes is non-natural mortality directly related to hunting and game management (Real 2004). In contrast, birds and reptiles are the principal groups taken for migratory eagles in Spain (Gil and Pleguezuelos 2001, Martínez and Calvo 2005, García-Dios 2006, Petretti 2008), so it is striking that they are shot even though they are not a risk to game. Even though birds of prey are legally protected under Spanish and European law, shooting is still a major concern mainly due to conflicts with hunters (Valkama *et al*. 2005, Bro *et al*. 2006, Kenward 2006, Martínez *et al*. 2006, Margalida *et al*. 2008, Amar *et al*. 2012), especially in the case of Bonelli's Eagle (Real *et al*. 2001) despite a recent study showed that the potential role of this large eagle as a limiting factor for partridges and rabbits at the population scale was very poor (Moleón *et al*. 2011). Until recently, it was generally believed that killing raptors was opportunistic, i.e. it took place during the hunting season and was not deliberately aimed at reducing the raptor predation (Viñuela and Arroyo 2002). However, our results indicate that although the maximum incidence of shooting was detected during the first weeks of hunting season, it also occurred outside this period, during the breeding season (March to July). These results suggest that killing birds of prey is proactive (Fig. 2).

Our results indicate that sedentary eagles are more likely to die from power lines than migratory eagles (Real *et al*. 2001, González *et al*. 2007). Spanish Imperial Eagle and Bonelli's Eagle use predominantly treeless and open areas with high densities of rabbits, coincident with areas with a higher degree of human exploitation and the presence of a high number of power lines (Guil *et al*. 2011, 2015), unlike the ranges occupied by migratory eagles characterized by most forested areas and with lower degree of human occupation and fewer power lines (Mañosa 2003). Thus, differences in the mortality causes by shooting and power lines were found between migratory and sedentary raptors.

The captivity of birds of prey is currently an important reason for birds being admitted to wildlife rehabilitation centres in Spain (Molina-López *et al*. 2011). Our results indicate that this illegal practice affected individuals of both species, which were probably captured when they were nestlings and fledglings (principally July-August) and held as pets in captivity (Molina-López *et al*. 2011). The trapping of individuals of both raptor species principally occurred during the hunting season (August-November) and may be a result of opportunistic killing in traps of generalist meso-predators on hunting estates.

The use and abuse of phytosanitary substances and other poisons to kill predators of small game and domestic animals is still frequent and widespread in Spain

(Mateo-Tomás *et al*. 2012, Tenan *et al*. 2012, Márquez *et al*. 2013) and other regions of Europe (Mañosa 2002, Guitart *et al*. 2010). Previous studies have also shown that deliberate poisoning may be an important cause of death in Booted Eagles but not Short-toed Snake Eagles (Mañosa 2002, Viada and De Pablo 2009, Márquez *et al*. 2013). Our results suggest that poisoning occurs mainly in late spring and during the summer, before the start of the hunting season, which suggest that it is a measure used against generalist predators (Márquez *et al*. 2013). Nevertheless, our study suggests that both species are being affected by this practice, although with a low incidence. This result is interesting since neither species exhibits scavenging habits (Del Hoyo *et al*. 1994), so that both species may be poisoned by eating live bait impregnated with toxic substances.

Electrocution by power lines is one of the principal problems facing raptors and other medium and large-sized birds at global scale (Ferrer and Janss 1999, Lehman *et al*. 2007, Pérez-García *et al*. 2011) and one of the threats to the conservation of both study species in Spain (Martí and Del Moral 2003). Power line casualties were recorded in every month of the year in both species but they were most frequent during July and September (Fig. 3), affecting both breeding individuals and less experienced juveniles. In addition, this cause of death affects individuals of both species outside the breeding season, especially during wintering in the Spanish Mediterranean regions (Martínez and Sánchez-Zapata 1999).

Likewise, our results indicate that Short-toed Snake Eagles suffer proportionately more accidents with power lines than Booted Eagles, which agrees with previous studies in which Short-toed Snake Eagle was seen to be one of the raptor most affected by electrocution (Mañosa 2001, Moleón *et al*. 2007, Tintó *et al*. 2010, Guil *et al*. 2011). The foraging behaviour is not sufficiently known in either species, but the few studies conducted to date indicate that these raptors attack their prey fundamentally from the air using diverse techniques, descending from a perch being a little used alternative (Cramp and Simmons 1980, Bakaloudis 2010). However, these observations contrast with the high number of electrocutions recorded for both species in our study, which leads us to suspect that both species use electricity pylons more frequently than was previously thought. Previous studies have shown a differential susceptibility of birds to electrocution which may be consequence of their feeding habits, morphological traits and behaviour (Janss 2000, Guil *et al*. 2015). Thus, we suspect that Short-toed Snake Eagles would be more susceptibility to suffer accidents in power lines than Booted Eagles because of their greater use of electric pylons and size. In fact, large raptors exhibit higher electrocution rates due to their greater biomass and wingspan (Lehman *et al*. 2007, López-López *et al*. 2011).

The factors zone and year explained the variation in causes of mortality in Booted Eagles, whereas the year was the only significant factor for Short-toed Snake Eagles. In the Booted Eagle, killing tended to be significantly higher in the east and north of Spain than in the other two zones. Previous studies focusing on other birds of prey such as Bonelli's Eagle and Eagle Owl (*Bubo bubo*) reported a higher incidence of persecution in the north and east than in other Spanish regions (Real *et al*. 2001, Martínez *et al*. 2006).

In contrast, power line casualties tended to be higher in the East and South than in the other two zones (Fig. 4a), possibly due to the increase in electrification in rural areas during recent decades and, especially, the substitution of olive groves by irrigated crops in Andalusia (Madero 2008) and the expansion of infrastructures in the east of Spain (Symeonakis *et al*. 2007, López-Iborra *et al*. 2011). A recent study has shown that there are electrocution-prone species which are more common in semi-urban habitats

(Guil *et al*. 2015). Palomino and Carrascal (2007) found that urban development had a positive influence on the Booted Eagle, probably through an increase in the availability on its potential prey within urban areas. A third explanation involves that Booted Eagle accidents may occur in areas where monitoring and correcting of power lines are not carried out, principally outside protected areas in East Spain (Pérez-García *et al*. 2011). These authors found that most electrocution casualties occurred outside Special Protection Area (SPA) boundaries, probably because of the higher density of both power lines and susceptible birds, and the use of pylons for perching and roosting in areas surrounding the SPA. Recent studies have shown how Booted Eagles breeding within protected areas frequently use hunting areas outside them (Martínez *et al*. 2007, Migra 2014).

The temporal factor (year) explained the variation in causes of mortality in both species (Fig. 5). Accidents involved power lines and other infrastructures showed an increasing trend in the case of the Booted Eagle while persecution exhibited a decreasing tendency. This result is similar to that obtained for other Spanish vertebrates over the period 1990-2006 (Fajardo 2001, Real *et al*. 2001, Martínez *et al*. 2006, Margalida *et al*. 2008, Martínez-Abraín *et al*. 2013, Guil *et al*. 2015). According to Martínez-Abraín *et al*. (2009, 2013) this situation is reflected by: (i) the relative increase in infrastructures in the last 20 years clearly reflects the rapid and deep change in Spanish socio-economic indicators, with most people gathered in cities, far from the rural world, and (ii) the decrease in hunting pressure resulting from the decrease in hunting licences issued annually in Spain. However, time trends in wildlife mortality rates by man-made infrastructures might be not constant (López-López *et al*. 2011, Martínez-Abraín *et al*. 2013). Thus, we assumed that time trends in Booted Eagles and Short-toed Snake Eagles electrocution rates could undergo a decrease trend from 2006

(Guil *et al*. 2015), due to an increase in retrofitting the most dangerous power lines and regulation enactment implemented in Spain.

Management implications: persecution and power lines

The findings of this study have several implications. Most importantly, in spite of legal enforcement and the efforts of conservation agencies and the progress made in the last two decades in Spain, anthropogenic causes of mortality are still operating in most of the range areas of the Booted Eagle and Short-toed Snake Eagle. Action plans should be encouraged to minimize the number of cases of persecution and accidents with power lines. Direct persecution persists over a 16 year period (1990-2006) in Spain, especially in the form of shooting, poisoning and trapping in hunting estates and private lands (Márquez *et al*. 2013, Martínez-Abraín *et al*. 2013). In this respect, the implementation of public education programmes might have a positive effect on reducing the mortality by these causes (Martí and Del Moral 2003). Likewise, in order to reduce the illegal use of poison, which may be the main cause of death in some populations (Carrete *et al.* 2007, Margalida *et al*. 2008, Tavecchia *et al*. 2012) and the extinction of highly susceptible predators (Márquez *et al*. 2013), it might be interesting to include measures complementary to prevention, surveillance and punishment for this type of crime, such us research into potential techniques to reduce the damage caused by generalist predators but which are compatible with the conservation of endangered species (González *et al*. 2007). Finally, the correction of dangerous power line and the subsequent evaluation of the efficiency of the measures taken must be priority measures in order to minimize bird accidents involving power lines (Tintó *et al*. 2010, López-López *et al*. 2011, Guil *et al*. 2015).

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Table 1. Causes of death of Booted Eagle in Spain between 1990 and 2006. Data are expressed as number of cases

	South	**East**				**Centre**				**North**				
	Andalusia	Community of Valencia	Catalonia	Region of Murcia	Baleares	Community of Madrid	Castilla-La Mancha	Castilla-León	Extremadura	Galicia	Asturias	Basque Country	La Rioja	**Total**
Killing														
Shooting	15	64	19	3	1	10	0	8	3	1	0	9	4	137
Nest robbery or captivity	16	16	4	5	2	9	0	2	11	0	0	1	2	68
Trapping	1	6	0	1	0	4	0	0	0	0	0	0	0	12
Poison/intoxication	4	1	0	2	0	2	0	1	0	0	0	0	1	11
Total	36	87	23	11	3	25	0	11	14	1	0	10	7	228
Power lines														
Collision	1	1	1	0	1	1	0	1	2	0	0	0	0	8
Electrocution	30	28	8	9	2	17	2	1	8	0	0	0	2	107
Unknown	3	18	0	0	0	0	0	1	0	0	0	0	0	22
Total	34	47	9	9	3	18	2	3	10	0	0	0	2	137
Other anthropogenic causes														
Drowning	2	6	0	0	6	0	0	0	2	0	0	0	0	16
Fences	0	0	0	1	1	0	0	0	10	0	0	0	0	12
Car crash	2	0	1	0	1	1	0	3	5	0	0	1	4	18
Trauma (unknown origin)	49	28	13	6	2	19	0	22	8	0	0	1	1	149
Other	8	11	3	5	3	2	0	0	4	4	0	4	2	46
Total	61	45	17	12	13	22	0	25	29	4	0	6	7	241
Natural causes														
Starvation	10	7	0	5	6	9	0	3	3	0	0	3	4	50
Other	9	4	0	0	5	7	0	4	12	0	0	3	1	45
Total	19	11	0	5	11	16	0	7	15	0	0	6	5	95
Unknown	25	55	2	14	3	25	9	11	103	0	1	0	0	248
Total	175	245	51	51	33	106	11	57	171	5	1	22	21	949

Table 2. Causes of death of Short-toed Snake Eagle in Spain between 1990 and 2006. Data are expressed as number of cases.

	South	**East**				**Centre**				**North**				
	Andalusia	Community of Valencia	Catalonia	Region of Murcia	Baleares	Community of Madrid	Castilla-La Mancha	Castilla-León	Extremadura	Galicia	Asturias	Basque Country	La Rioja	**Total**
Killing														
Shooting	5	20	5	1	0	1	0	1	3	0	0	2	2	40
Nest robbery or captivity	10	8	1	0	0	1	0	2	0	0	0	0	1	23
Trapping	1	3	0	0	0	1	0	0	0	0	0	0	0	5
Poison/intoxication	0	1	1	0	0	0	0	1	0	0	0	0	0	3
Total	16	32	7	1	0	3	0	4	3	0	0	2	3	71
Power lines														
Collision	1	2	4	1	0	1	0	2	0	1	0	1	4	17
Electrocution	28	16	18	4	0	7	0	2	3	0	0	0	2	80
Unknown	1	10	0	0	0	0	0	0	0	0	0	1	0	12
Total	30	28	22	5	0	8	0	4	3	1	0	2	6	109
Other anthropogenic causes														
Drowning	0	4	0	0	0	0	0	0	1	0	0	0	0	5
Fences	0	0	1	0	0	0	0	0	0	0	0	0	0	1
Car crash	0	0	0	0	0	0	0	2	1	0	0	0	4	7
Trauma (unknown origin)	11	12	21	2	0	3	0	7	0	0	0	0	3	59
Other	6	6	0	2	0	0	1	0	1	0	0	1	0	17
Total	17	22	22	4	0	3	1	9	3	0	0	1	7	89
Natural causes														
Starvation	5	4	3	3	0	1	0	3	0	0	0	4	1	24
Other natural causes	7	1	4	0	0	0	0	1	3	0	0	1	0	17
Total	12	5	7	3	0	1	0	4	3	0	0	5	1	41
Unknown	20	21	11	13	0	8	7	4	39	0	0	1	0	124
Total	95	108	69	26	0	23	8	25	51	1	0	11	17	434

Table 3. Summary of the multinomial regression models used to explain the causes of death of Booted Eagle *Aquila pennata* and Short-toed Snake Eagle *Circaetus gallicus* between 1990 and 2006 in Spain.

Species / factor	d. f.	χ^2 likelihood ratio	*P*
Aquila pennata			
zone	9	43.39	< 0.001
year	3	22.43	< 0.001
zone × year	9	4.51	0.875
Circaetus gallicus			
zone	9	8.76	0.460
year	3	33.11	< 0.001
zone × year	9	11.86	0.221

Figure 1. Observed major causes of mortality in Booted Eagle and Short-toed Snake Eagle. Vertical lines represent 95% confidence intervals.

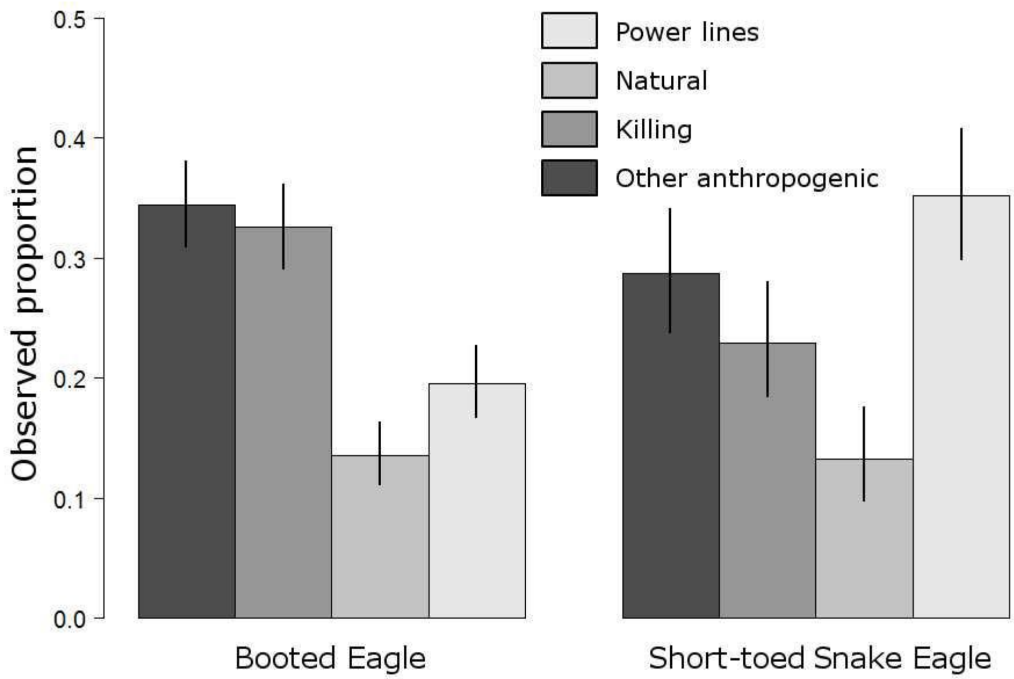
Figure 2. Monthly distribution of Booted Eagle (a) and Short-toed Snake Eagle deaths (b) due to killing.

Figure 3. Monthly distribution of Booted Eagle (a) and Short-toed Snake Eagle (b) deaths due to power line casualties.

Figure 4. Observed major causes of mortality of Booted Eagle (a) and Short-toed Snake Eagle (b) in relation to the four geographical zones considered (South, East, Centre and North of Spain). Vertical lines represent 95% confidence intervals.

Figure 5. Evolution of the causes of mortality of Booted Eagle (a) and Short-toed Snake Eagle (b) between 1990 and 2006 in Spain. The lines represent the trends in proportions estimated by the multinomial regression model for each species.

Figure 1



0.5
0.4
0.3
0.2
0.1
0.0
Observed proportion
Power lines
Natural
Killing
Other anthropogenic
Booted Eagle
Short-toed Snake Eagle

Figure 2

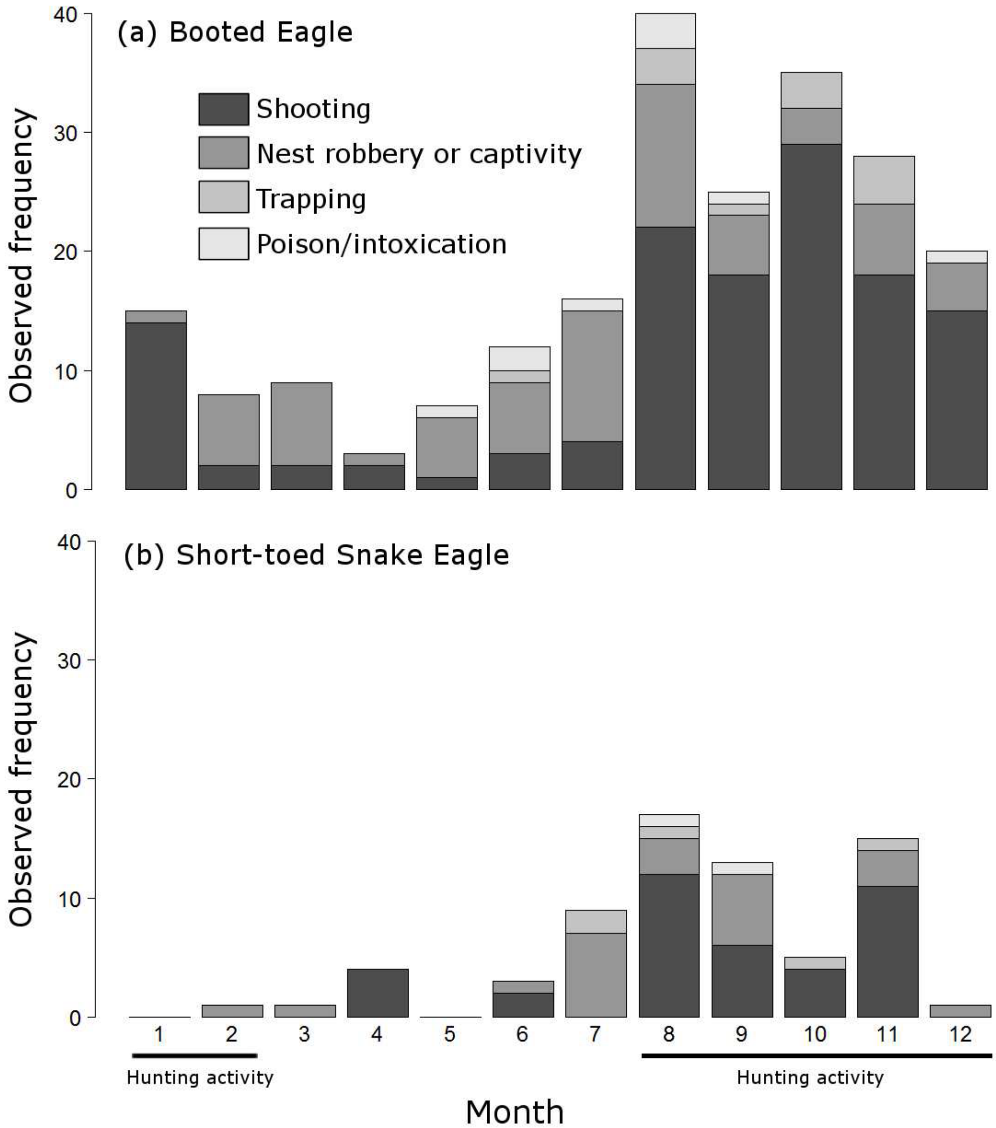

(a) Booted Eagle
Shooting
Nest robbery or captivity
Trapping
Poison/intoxication
Observed frequency
0
10
20
30
40
(b) Short-toed Snake Eagle
Observed frequency
0
10
20
30
40
1
2
3
4
5
6
7
8
9
10
11
12
Hunting activity
Hunting activity
Month

Figure 3

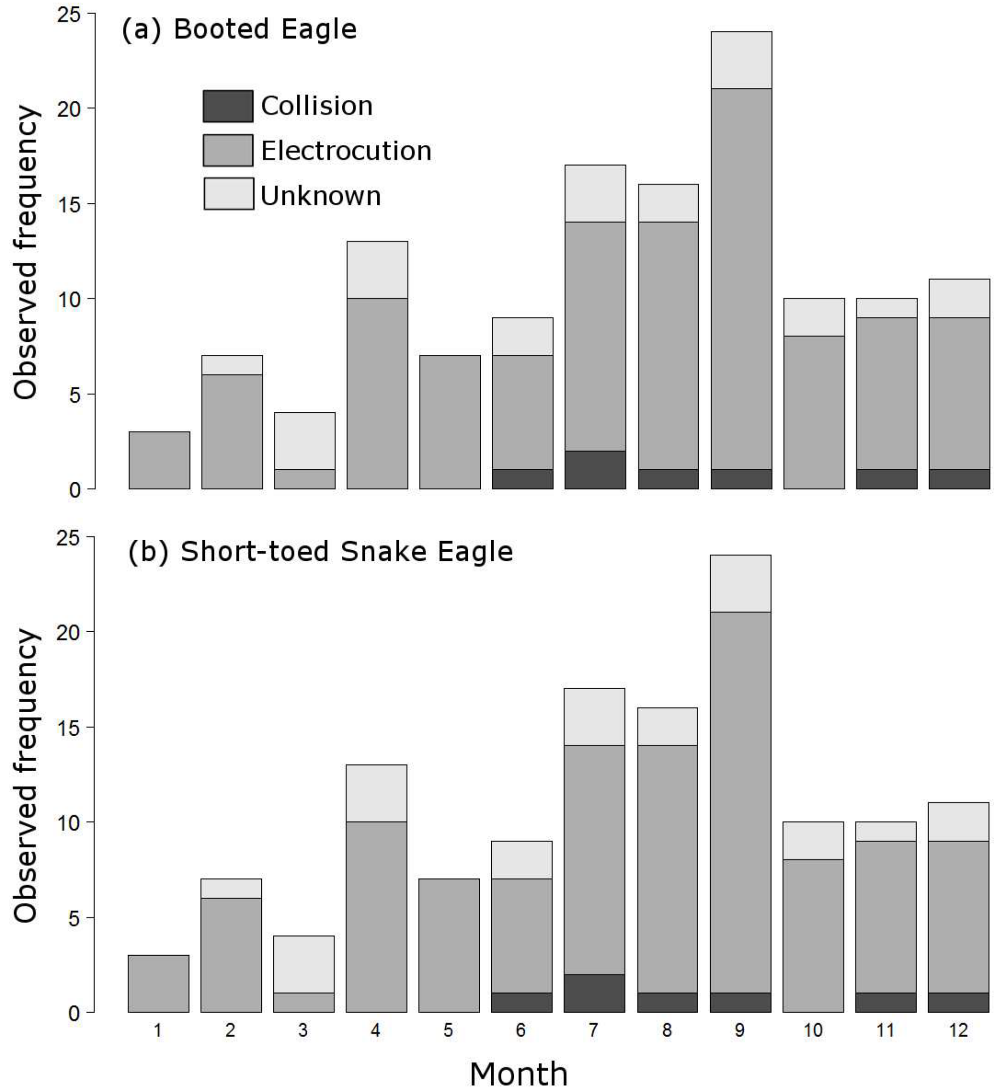

(a) Booted Eagle
Collision
Electrocution
Unknown
Observed frequency
0
5
10
15
20
25
(b) Short-toed Snake Eagle
Observed frequency
0
5
10
15
20
25
1
2
3
4
5
6
7
8
9
10
11
12
Month

Figure 4

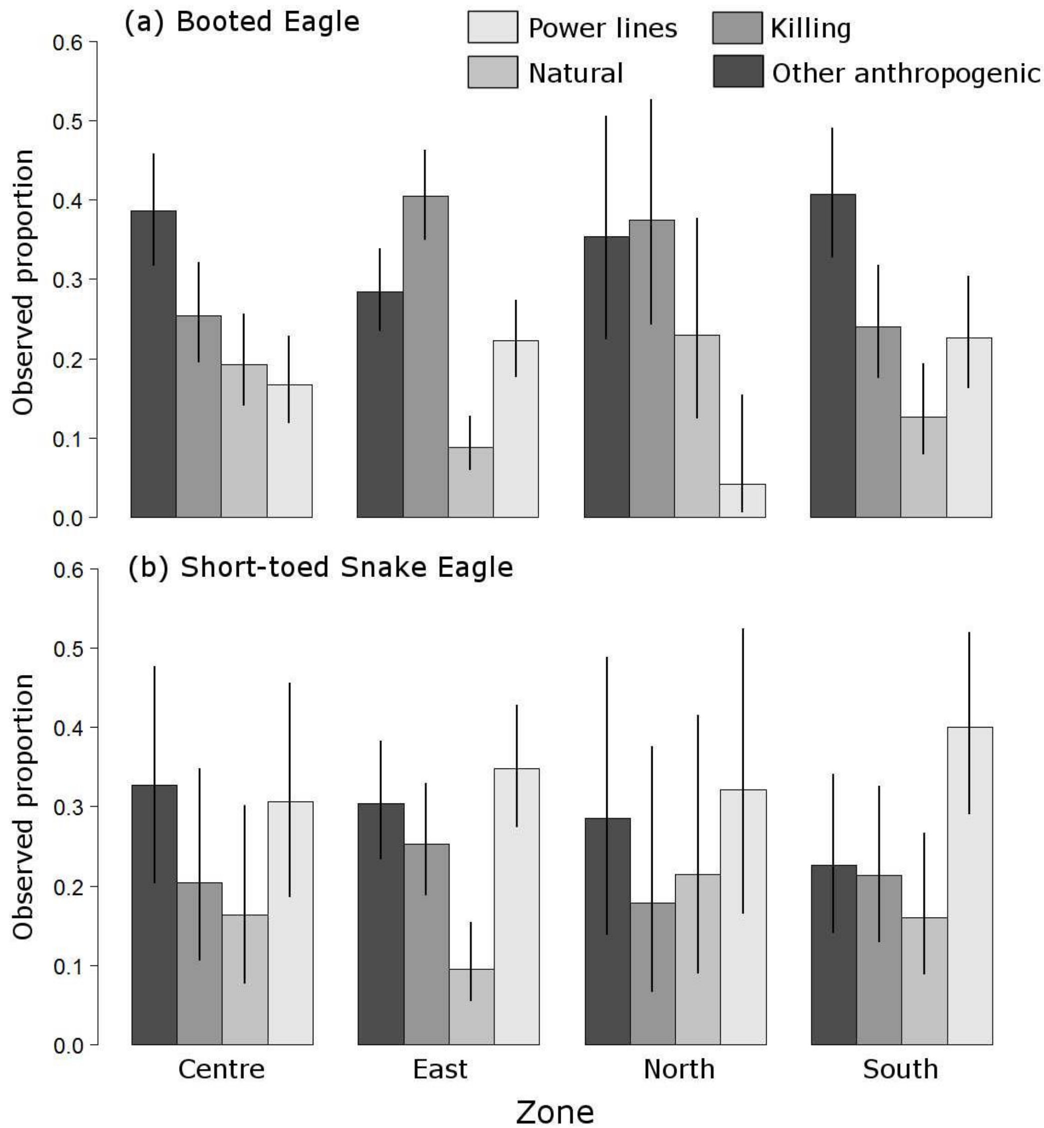
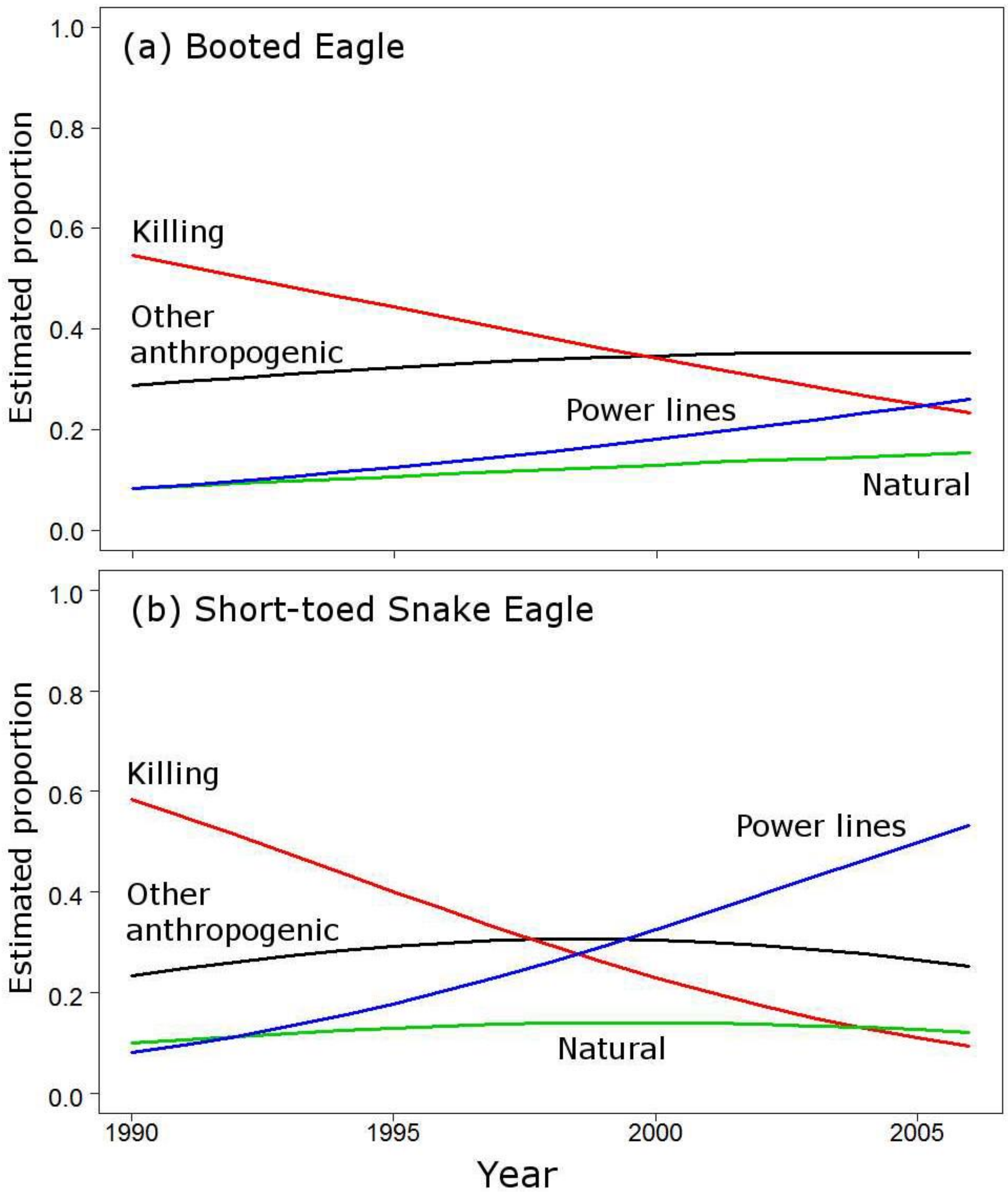

(a) Booted Eagle
Power lines
Natural
Killing
Other anthropogenic
Observed proportion
0.0
0.1
0.2
0.3
0.4
0.5
0.6
(b) Short-toed Snake Eagle
Observed proportion
0.0
0.1
0.2
0.3
0.4
0.5
0.6
Centre
East
North
South
Zone

Figure 5


(a) Booted Eagle
Killing
Other anthropogenic
Power lines
Natural
(b) Short-toed Snake Eagle
Killing
Power lines
Other anthropogenic
Natural
Estimated proportion
1.0
0.8
0.6
0.4
0.2
0.0
1990
1995
2000
2005
Year