Global Ecology and Conservation xx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Global Ecology and Conservation

journal homepage: www.elsevier.com/locate/gecco

Case studies

Space–time trends in Spanish bird electrocution rates from alternative information sources

Q1 Francisco Guil[a,*], M. Àngels Colomer[b], Rubén Moreno-Opo[c], Antoni Margalida[d,e]

[a] C/ Luis Ruiz 111, 28017, Madrid, Spain
[b] Department of Mathematics, University of Lleida, Av. Alcalde Rovira Roure, 191. 25198 Lleida, Spain
[c] Vertebrate Biology and Conservation Group, University Complutense of Madrid, Madrid 28049, Spain
[d] Department of Animal Production, University of Lleida, Av. Alcalde Rovira Roure, 191. 25198 Lleida, Spain
[e] Division of Conservation Biology, Institute of Ecology and Evolution, University of Bern, Bern 3012, Switzerland

GRAPHICAL ABSTRACT

ARTICLE INFO

Article history:
Received 11 November 2014
Received in revised form 13 January 2015
Accepted 13 January 2015
Available online xxxx

Keywords:
Electrocution assessment
Bird ringing

ABSTRACT

Interaction with man-made infrastructures is one of the main sources of non-natural bird mortality. Here, we use a long-term study (1980–2010) to analyse spatial and temporal patterns in avian electrocution in Spain, using ringed birds as well as published reports and articles as information sources. Electrocution rates of ringed birds differ from rates obtained in unringed species. Electrocution rates are likely seasonally asymmetrical and are not constant across study periods: between 1990 and 2005 an annual rising trend of 5% was observed, whereas between 2006 and 2010 this trend decreased (16% annually). From the literature, we confirmed this decreasing trend. However, when we consider large eagles (*Aquila* genus), which include several of the most threatened bird species in Spain, this

* Corresponding author. Tel.: +34 617147238.
E-mail addresses: francisco.guilcelada@gmail.com (F. Guil), colomer@matematica.udl.es (M. Àngels Colomer), rmorenoopo@gmail.com (R. Moreno-Opo), amargalida@prodan.udl.cat, antoni.margalida@iee.unibe.ch (A. Margalida).

http://dx.doi.org/10.1016/j.gecco.2015.01.005

Raptors
Ringing recoveries
Spain

decreasing trend is not evident. The results of the analysis of different environmental and socio-economic factors affecting bird electrocution rates are similar between ringed birds and traditional power line surveys. Our modelling suggests three common factors that influence mortality rates: number of hunted rabbits, tree coverage and length of the power line network. Thus, the use of alternative information sources to detect high mortality areas due to electrocution by power lines may be a useful tool to complement other methods.

1. Introduction

Since the late 19th century, negative interactions between lineal infrastructure and birds have been well documented (Coues, 1876), and represent in Europe one of the main causes of bird mortality (Haas et al., 2005). Power lines are a landscape element with which birds interact in different ways (Bevanger, 1998; Negro, 1999; Lehman et al., 2007). On the one hand, as a positive ecosystem element, electric infrastructure can provide nesting platforms and are used as perches for resting or searching for potential prey, thus benefitting many species (Steenhof et al., 1993), while at the same time increasing predation rates on some species (Lammers and Collopy, 2007). On the other hand, negative interactions appear to play a greater role in the relationship of birds and electric infrastructure. Power lines have a negative impact on bird survival due to direct mortality as a consequence of direct collision, entangling and electrocution (Bevanger, 1998; Lehman et al., 2007). They may also present negative effects derived from electromagnetic fields (Phernie et al., 2000). Although positive interactions are relevant for the conservation of many species (Tryjanowski et al., 2013), negative impacts of power lines have been the focus of most published works on this issue.

Spain has one of the most diverse avian communities in Europe, and is a stronghold of populations of threatened taxa potentially affected by power lines. Spain hosts almost the entire global population (97%) of Spanish Imperial Eagles (*Aquila adalberti*), 70% of the Bonelli's Eagle (*Aquila fasciata*), 67% of the Bearded Vulture (*Gypaetus barbatus*), 60% of the Great Bustard (*Otis tarda*) and 90% of the Little Bustard (*Tetrax tetrax*) population (BirdLife International, 2004; Deinet et al., 2013). One of the most important causes of mortality for Spanish avian species is interaction with power lines. According to the Red Book of Birds of Spain (Madroño et al., 2004), this interaction is one of the main threats for 24 bird species, impacting their global conservation status. It is the most important mortality factor for the Spanish Imperial Eagle, causing over 50% of non-natural deaths (González et al., 2007). It is also the leading cause of mortality in Bonelli's Eagle, representing as much as 50% of registered casualties (Real et al., 2001), and accounts for annual mortality rates of up to 25% in the endemic species population, including such species as the Houbara Bustard (*Chlamydotis undulata fuerteventurae*) (García del Rey and Rodríguez-Lorenzo, 2012).

In Spain, most attention has been paid to electrocution, mainly in raptors (Lehman et al., 2007). Thus, an important body of literature on the impact of electrocution is available (Ferrer et al., 1991; Janss and Ferrer, 2001; Mañosa, 2001; Tintó et al., 2010). There are several underlying, non-mutually exclusive factors prompting this research effort, apart from the high abundance and richness of soaring birds (such as storks, scavengers and large eagles; BirdLife International, 2004), including the presence of a well-developed overhead power grid in rural areas and a strong interest in biodiversity preservation. Thus, Spain provides a good case study for the assessment and development of methods enabling precise knowledge of electrocution rates in birds. Those methods can subsequently be implemented in other regions where similar conservation problems exist.

Most of the works concerning avian electrocution (Lehman et al., 2007; Loss et al., 2014) are based on the same methodology: surveying power lines by foot to find corpses and remains of killed birds, obtaining a mortality rate in relation to the length of power lines or number of pylons monitored (Guil et al., 2011). But this monitoring technique comes at a high cost in terms of time and economic resources, so the development of new, more economically efficient study methods may help to optimize economic and human resources invested in conservation efforts.

Here, we aim to develop a complementary and alternative methodology, to assess spatial and temporal avian mortality rates caused by electrocution. Taking Spain as a case study, we use two alternative information sources for this purpose: the recovery of ringed birds found dead by electrocution in comparison with the total number of ringed birds; and literature related to avian mortality based on direct observations during the survey of electric power lines. Ringed dead birds are used both in a spatial and temporal analysis, and literature analysis will assess time variations. We hypothesized that the general trend of mortality rates of birds and factors explaining these rates are similar between the proposed methodology and traditional survey methods.

2. Material and methods

2.1. Study scope

The study was carried out in Spain, including information obtained from the Iberian Peninsula, Canary and Balearic Islands, and Ceuta and Melilla in northern Africa. The target species were the 337 bird species breeding in Spain

(Martí and Del Moral, 2004), representing 61.05% of the total breeding species in the European Union (SEBI, 2007), with 26 of those species being diurnal raptors and eight being owls (Gutiérrez et al., 2012).

We used two complementary information sources. First, we considered recoveries of electrocuted ringed birds for both spatial and time analyses. The information concerning ringed birds (dead or alive) recovered with signs of electrocution between 1990 and 2010 was requested to the Migratory Species Office of the Spanish Ministry of Agriculture, Food and Environment. The data for the total number of ringed birds in Spain were obtained from http://www.anillamientoseo.org/. In both cases the data corresponded to birds ringed with ICONA—Ministry of the Environment rings. The second source was the compilation of official reports and scientific articles referring to bird electrocution in different Spanish regions during 1980–2010.

2.2. Time analysis

To determine the species most affected by electrocution, we used two complementary analyses. First, an initial exploratory analysis was implemented. At species level, using data from ringed birds, the variable "ringed electrocuted birds during the study period (20 years)" as compared to the total number of ringed birds during the same period was considered. As the probability of a ringed bird dying depends on its longevity, this number was corrected considering each ringed bird species rate that could possibly die through electrocution. For the estimation, we used a corrected coefficient dependent on the longevity of each species (see Supplementary data, Appendix A). The corrected coefficient was made accepting the uniform distribution of the age of the individuals. Because we do not know the age of all ringed individuals, we assumed a uniform distribution. Thus, the proportion of individuals expected to death annually was estimated by 1/longevity.

As a second approach for the time analysis we used the bibliographic compilation for the period 1980–2010. Three types of information were considered: general mortality rate of all birds, mortality rate of raptors (diurnal and nocturnal) and mortality rate of large eagles (e.g. Spanish Imperial Eagle, Bonelli's Eagle and Golden Eagle). We estimated mortality rate as the number of killed/injured birds per 100 pylons surveyed. When the work did not provide the number of surveyed pylons, we considered 1 pylon/100 m walked (Janss and Ferrer, 1999). The geographical areas (regions, provinces or areas) in with at least two papers or reports published were included. Only papers with at least a five year gap were analysed in order to avoid time autocorrelation between the two studies, thus comparing electrocution rates in the late 1980s and 1990s and since 2000. In the cases where survey starting date was not indicated, we considered the starting year as that previous to publication.

2.3. Space analysis

To determine factors influencing the mortality rate of ringed birds due to electrocution we considered as response variable the number of dead ringed animals due to electrocution by province during 1990–2010. As explanatory variables we used those relevant according to previous studies of bird electrocution rates on power lines (Mañosa, 2001; Lehman et al., 2007; Guil et al., 2011), all considered at provincial level: Q2

- Power line length by province (1:25,000 scale, National Cartographic Base). This cartographic resource detects only transport power lines (>66 kV). This network scarcely causes bird electrocution but as its length is highly related to the overall distribution power grid, we considered it as a surrogate of the total power line grid.
- Number of hunted rabbits (2004 Agriculture Statistics Annual Directory). Due to the lack of standardized population indexes for this keystone species (Delibes-Mateos et al., 2007) at a global scale we considered the number of hunted rabbits as a surrogate of the food availability for medium and large sized raptors.
- Surface of Important Bird Areas in the province (IBA; Spanish Natural Heritage and Biodiversity Inventory).
- Number of UTM 10 × 10 grids with raptor reproduction detected (Spanish Natural Heritage and Biodiversity Inventory) by province, considering all raptor species.
- Province surface (1:25,000 scale, National Cartographic Base).
- Rural path length in the province (1:25,000 scale, National Cartographic Base).
- Province inhabitants (National Statistical Office, on January 1st 2011). The data obtained this year are considered representative for the entire study period, as no significant changes have occurred.
- Number of ornithologists (members of the national BirdLife organization [SEO/BirdLife], on February 1st 2013). Q3
- Ornithologist ratio (number of the national BirdLife organization [SEO/BirdLife] members per 10 000 inhabitants, as of February 1st 2013).
- Surface of Natura 2000 network (Spanish Natural Heritage and Biodiversity Inventory).
- Average cover of trees / province (1:50,000 scale, Spanish Natural Heritage and Biodiversity Inventory).
- Average cover of bush / province (1:50,000 scale, Spanish Natural Heritage and Biodiversity Inventory).
- Presence of specific regional regulations concerning birds and power lines.

Please cite this article in press as: Guil, F., et al., Space–time trends in Spanish bird electrocution rates from alternative information sources. Global Ecology and Conservation (2015), http://dx.doi.org/10.1016/j.gecco.2015.01.005

2.4. Statistical analyses

Three different statistical analyses were implemented. First of all, a descriptive analysis was used for the identification of those species with a higher mortality risk by electrocution and trends of dead birds during the 20 studied years. We also performed a linear regression by estimating the annual trend of electrocuted birds (increase/decrease).

A second analysis was used for the time analysis. As the target of the study was to determine the temporal trend in electrocution rates, the Wilcoxon paired data test was used for observed differences in mortality rate obtained from the literature, using a unilateral test.

The third statistical treatment was related to space analysis. The objective was the study of the explicative variables affecting electrocution numbers. We used General Lineal Models (GLM) with a log-link function and a Poisson function for error structure. We implemented three different models: one for birds in general, including all species (hereafter "*Birds*"); one specific for birds of prey, including diurnal and nocturnal birds (hereafter "*Raptors*"); and a third for "*Large Eagles*" (including Spanish Imperial, Bonelli's and Golden eagles). The presence of regulations was used as a categorical variable and the rest were continuous co-variables. This analysis allowed for the determination of the influence of the described factors in electrocution numbers for *Birds*, *Raptors* and *Large Eagles*, with these acting as response variables. Because the explanatory variables are not independent (i.e., there is co-linearity between some variables), multicollinearity was limited in all models and statistical inferences were valid as variance inflation factors were consistently less than five (Fox and Weisberg, 2011). All statistical analyses were performed using R 2.10.1. (R Development Core Team, 2014).

3. Results

3.1. Time analysis

During 1990–2010, a total of 979 corpses of 35 different species of ringed birds were found. The most recorded species was the White Stork *Ciconia ciconia*, with 670 corpses found which was also one of the most commonly ringed species (51,270 records). As shown in Fig. 1, species with the highest mortality rate (deaths/total individuals of the same species ringed), corrected for longevity, are the Spanish Imperial Eagle (6.04%), the Osprey *Pandion haliaetus* (3.65%), the Bonelli's Eagle (3.09%) and the Golden Eagle *Aquila chrysaetos* (2.55%). Griffon Vulture *Gyps fulvus* with 1.96% and the White Stork with 1.94% also showed important percentages. As shown in Fig. 2, between 1995–2005 there was an increasing trend in electrocutions ($R^2 = 0.873$), with an average annual increase of 5%. We observed a change in this trend as of 2005, and the descending line shows an annual decrease in the percentage of electrocuted birds of 15.8 ($R^2 = 0.946$).

The literature review comprised 11 Spanish provinces (EU NUTS 3 level) or more definite areas, providing information for two different time periods with a time gap of at least five years (Table 1). Considering those areas, our results showed that electrocution rates/100 surveyed pylons generally decreased except for Doñana (southern Spain), central Cáceres (western Spain) and Navarra (northern Spain) for *Large Eagles* and Navarra for *Raptors*. For the *Birds* category, the decrease was significant ($n = 7, V = 28, p = 0.016$) as was the case for *Raptors* ($n = 11, V = 54, p = 0.008$). On the contrary, the decrease observed in *Large Eagles* ($n = 10, V = 30, p = 0.107$) was not statistically significant, while the number of surveyed pylons in each study increased ($n = 11, V = 3, p = 0.005$).

3.2. Space analysis

According to our model (Table 2), nine variables influenced the number of electrocuted *Birds* explaining 52.1% of data variability while for *Raptors* eight variables explained the 56.2%. For *Large Eagles* only three explicative variables explained 72.8% of variability. Three variables with a strong influence are consistent among the three models: number of hunted rabbits, average tree coverage in the province, and power line length. *Raptors* is a subset of *Birds* group, and *Large Eagles* is also a subset from *Raptors*, so there is a growing homogeneity of characteristics within subsets of the considered species. So the increasing explained variability seems consistent with the decrease in the number of species included in each studied group (Birds > Raptors > Large Eagles).

4. Discussion

4.1. Observed electrocution rates

The lowest mortality rate for ringed dead birds with respect to the total number of ringed birds was detected in the Lesser Kestrel *Falco naumanni*. In this case, though a high number of birds were ringed (42,887 between 1990 and 2010) only two electrocuted individuals were found. Conversely, in species such as the Spanish Imperial Eagle over 6% of ringed birds were found electrocuted (Frías et al., 2009). Our results suggest a differential susceptibility of birds to electrocution; which may be a consequence of their morphologic traits, feeding habits and behaviour (Janss, 2000). However, these results may be influenced by two complementary facts. First of all, there are species with additional survey approaches, in addition to conventional ringing (e.g. radio-transmitters, GPS-transmitters). So, increasing monitoring efforts entails

Please cite this article in press as: Guil, F., et al., Space–time trends in Spanish bird electrocution rates from alternative information sources. Global Ecology and Conservation (2015), http://dx.doi.org/10.1016/j.gecco.2015.01.005

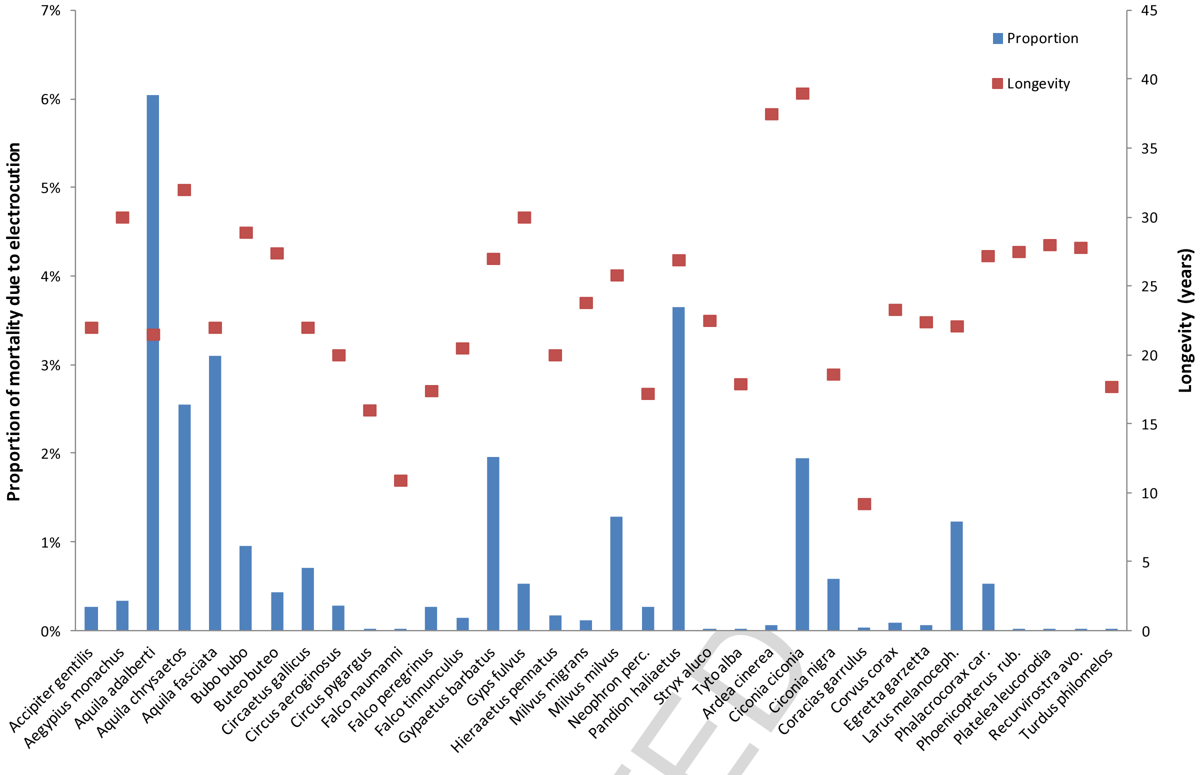

Fig. 1. Percentage variation in the corrected proportion of mortality due to electrocution of avian ringed species (column) in relation to their recovery rate and their longevity (red squares) as a correction factor. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
Trends in the electrocution rate of Birds (every bird species), Raptors (birds of prey) and Large Eagles (Spanish Imperial, Bonelli's and Golden eagles), expressed as the number of corpses per 100 surveyed pylons. Year indicates when the fieldwork of each referenced work began. *N* indicates the number of surveyed pylons. Data with a decrease in the electrocution index between periods is shown in bold.

Area	Year	Birds	Raptors	Large Eagles	*N*	Reference
Navarra (North Iberian Peninsula)	–	**11.80**	6.85	0	1796	Asociación Landazuria-CODA, 1994.
	–	**11.23**	7.40	0.36	3608	Fernández and Azkona, 2002.
Fuerteventura (Canary Islands)	1993	**1.92**	**1.20**	0	417	Lorenzo et al., 1997.
	2005	**0.76**	**0.17**	0	2384	Lorenzo and Ginovés, 2007.
Campo de Montiel and Sierra Morena (Central Iberian Pen.)	1989	16.94	**16.82**	**3.32**	1629	Guzmán and Castaño, 1998.
	2003	–	**15.10**	**2.51**	6304	Guil et al., 2011.
Doñana N.P. (Southwestern Iberian Pen.)	1982	–	**8.07**	0.18	1127	Ferrer et al. 1990
	1990	10.37	**6.17**	0.40	5053	Janss and Ferrer, 2001.
Central Toledo (Central Iberian Pen.)	1992	**39.88**	**37.69**	**5.65**	2229	Calvo, 1999.
	2009	**11.05**	**9.92**	**0.59**	1194	Unpublished own data
Lanzarote (Canary Islands)	1994	**0.35**	0	0	574	Lorenzo et al., 1997.
	2005	**0.05**	0	0	2037	Lorenzo and Ginovés, 2007.
Granada (South Iberian Pen.)	–	–	**5.94**	**1.63**	673	Bautista et al., 1999.
	1998	–	**0.80**	**0.27**	3384	Moleón et al., 2007.
W Madrid (Central Iberian Pen.)	1988	**77.5**	**75.94**	**3.75**	320	Múgica, 1989
	2005	**2.21**	**2.21**	**0.22**	452	Unpublished own data
Huelva (Southwestern Iberian Pen.)	1997	–	**6.96**	**0.83**	848	Moleón et al., 2007.
	2002	10.62	**5.25**	**0.39**	1525	Garrido, 2003.
Central Cáceres (Western Iberian Pen.)	2004	**13.05**	**8.09**	0.26	383	Unpublished own data
	2009	**6.43**	**5.19**	0.62	482	Zalba, 2009.
Sierra de Escalona (Eastern Iberian Pen.)	1996	**71.54**	**45.77**		182	Izquierdo et al., 1997
	2009	**9.46**	**6.83**	0.35	571	Pérez-García, 2014

greater opportunities for detection (González et al., 2007). Greater effort in a given survey on threatened and flagship species (i.e., Spanish Imperial Eagle, Bonelli's Eagle) may conversely increase the finding rate of electrocuted animals as compared to other species (Fernández et al., 2009; Hernández-Matías et al., 2013; Margalida et al., 2013). The second hypothesis is based

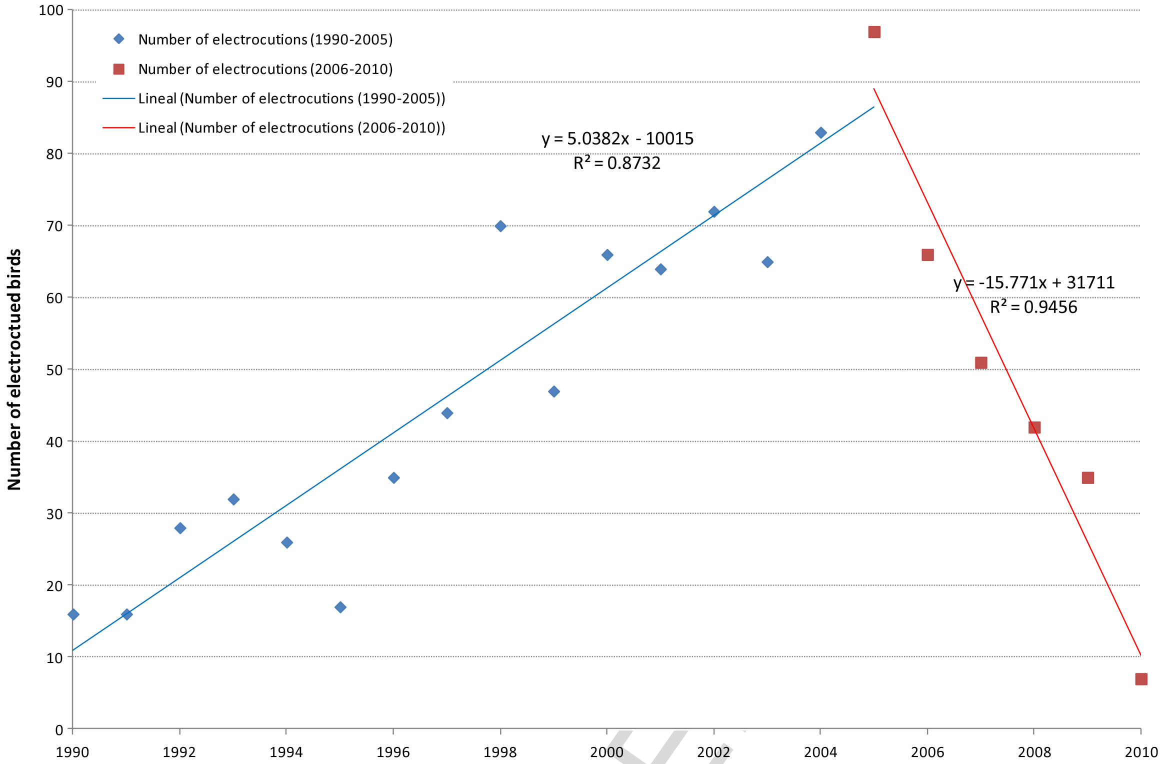

Fig. 2. Regression of the annual mortality index of Spanish ringed species between 1990–2010. Blue line indicates the trend between 1990–2005 and the red line indicates the trend between 2006–2010. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2
Statistically significant results from the GLM analysis performed to assess the influence of several explanation variables on electrocution rate (number of electrocuted birds per number of ringed birds and corrected for bird species longevity). Results are shown for all found birds (Bird), birds of prey (Raptors) and Large Eagles depending on the considered explanatory variables. In all cases, the relationship between variables is positive.

Explanatory variables	Birds		Raptors		Large Eagles	
	Estimate value	*p*-value	Estimate value	*p*-value	Estimate value	*p*-value
Province length of rural paths	−9.684e−02	0.008	−1.897e−07	0.026		
Number of hunted rabbits	−9.684e−02	<0.001	1.392e−06	0.008	4.681e−06	<0.001
Average cover of trees	2.402e−02	<0.001	−4.111e−02	0.002	−1.512e−01	0.006
Surface by province of Important Bird Areas	−2.439e−04	<0.001				
Presence of specific regional regulations	7.116e−01	<0.001	9.099e−01	<0.001		
Province inhabitants	−7.703e−08	0.012	1.636e−07	0.001		
Ornithologist ratio	−1.927e−01	<0.001	−1.725e−01	0.001		
Protected Natura 2000 surface	5.203e−04	<0.001	3.685e−04	<0.001		
Power line length	6.654e−07	<0.001	1.871e−07	0.049	1.233e−06	0.001
Null deviance:	1293.72		438.96		180.718	
Residual deviance:	619.33		192.16		49.909	
Deviance, D^2	52.12%		56.22%		72.35%	

on species' size. Large species exhibit higher electrocution rates due to their greater biomass and a subsequent increase in the detection probabilities of their carcasses (Ponce et al., 2010).

Our results identified a regressive trend in the rate of electrocutions from 2005. The literature review confirms this substantial decrease: from an average of 29.12 birds/100 pylons in the studies carried out during 1980–90 to 6.47 birds/100 pylons obtained in the most recent studies. Differences could be traced back to four possible direct causes: (1) less effort devoted to power line surveys; (2) lower mortality due to implemented retrofitting activities; (3) increase in predator numbers causing a greater carcass consumption thus masking detection probability (Ponce et al., 2010; Herruzo and Martínez-Jáuregui, 2013) or (4) a "finding" effect (see below).

As the standardized index allows us to make comparisons over time (electrocutions/100 pylons), the first hypothesis can be discarded despite evidence of a lower number of amateur and professional observers in the natural environment (Pergams and Zaradic, 2008) due to the economic crisis (i.e., less investment in survey programs). Because only three of the eleven studies were implemented after 2005, and the economic crisis in Spain began in 2008, we do not consider this explanation as valid. Nevertheless, to avoid the first possibility, statistics on the surveying effort are desirable, and in the best-case scenario would include the number GPS location and characteristics of reviewed pylons by region and province. A national coordinated strategy to assess bird mortality and to reduce electrocution/collision impact in power lines might be a helpful tool to achieve this target.

Regarding the second hypothesis, power line retrofitting substantially increased as of 2006, partially due to specific economic resources provided by official authorities, which during 2006–2010 involved an investment of more than 7.3 M € (in the case of the Spanish Ministry of the Environment, MMA, 2011), in addition to funding from regional governments, the European Commission through LIFE, EAFRD and EFRD funds, electric companies and compensatory measures from infrastructure development (Abellán et al., 2012; Barrientos et al., 2012). Reduction of electrocution due to power line retrofitting has been suggested as a crucial factor in this declining trend (MMA, 2001; López-López et al., 2011) despite not all technical modifications entail equal effectiveness or duration (Tintó et al., 2010). New surveys are therefore necessary to assess the effectiveness of measures already applied mainly in power line isolation (Guil et al., 2011) and in the regions where mortality indexes (Table 1) showed fewer differences.

Concerning the third hypothesis, the possible influence of a greater abundance of scavenger species cannot be rejected, since the decreasing trend in electrocution has coincided with the closure of vulture restaurants following the implementation of sanitary regulations reducing livestock carcass availability for scavenger species (Donázar et al., 2009; Margalida et al., 2010). This caused behavioural changes (Zuberogoitia et al., 2010; Margalida et al., 2011, 2014) and dietary shifts (Donázar et al., 2010) in avian scavengers, with better abilities to exploit unusual food resources. In this sense, food shortages probably enhanced opportunism in facultative scavengers (birds and mammals) (Margalida and Colomer, 2012), with a subsequent decrease in corpse detection in surroundings of the power lines.

The last hypothesis, the finding effect, might be an important source of bias. There are three complementary main sources of bias concerning this hypothesis. First, some people (rangers, naturalists, etc.) might survey particular pylons causing high bird mortality rates and pick-up the corpses, thus avoiding them to be found in subsequent standardized studies. Data centralization in recovery centres could be a helpful tool to avoid this bias (Molina-López et al., 2011). Second, the differential scavenging rates, both between areas and species, might hide real mortality rates (Ponce et al., 2010). Thus, scavenging rates can influence the number of found bodies within the same time lapse. We tried to minimize this source of bias by considering only studies with a lapse of at least 5 years, but only specific studies determining scavenging rates might eliminate this source of bias. And finally, the degree of experience of the searchers might influence the finding rate (Schutgens et al., 2014).

4.2. Electrocution: relevant factors

In the models implemented for the three groups (*Birds, Raptors, Large Eagles*) and regarding electrocution mortality for ringed birds, there are three outstanding factors: the number of hunted wild rabbits (Guil et al., 2011), the average tree coverage by province (Tintó et al., 2010; Pérez-García et al., 2011; Pérez-García, 2014), and the power line length. These results are consistent with those obtained from traditional survey methods of power lines (i.e., direct searching for corpses around the base of pylons, Lorenzo et al., 1997; Guzmán and Castaño, 1998 and Mañosa, 2001). Thus, our methodology can be considered an objective and useful tool in this regard.

Wild Rabbit is a keystone species in Mediterranean ecosystems (Delibes-Mateos et al., 2007), and are one of the most important prey in the diet of several raptor species (Delibes-Mateos et al., 2008a). Thus, the relationship between raptors' electrocution and prey abundance seems clear and has been previously documented (Lehman et al., 2007; Guil et al., 2011). High quality areas can act as ecological traps because they attract more individuals, both breeders and non-breeders, increasing the probability of mortality combined with the more likely of use of pylons and lines as perching sites. But there might be a complementary explanation, as most of the corpses were from non-raptor species. Rabbit abundance is higher in traditional agro-ecosystems with a high diversity of natural habitats (Delibes-Mateos et al., 2009a). Those are also well preserved areas which, in summary, could attract several other species than raptors, acting also as ecological traps for them.

Average province tree cover is an important factor, and can be considered to act inversely to mortality rates. We found a direct explanation when considering that trees are natural perches for birds. Thus, the absence of trees would favour perching on power lines (Pérez-García et al., 2011), with the consequent increasing risk of electrocution (Tintó et al., 2010). Moreover, we might consider forest as a low quality habitat for the Wild Rabbit (Rollán and Real, 2011) then acting as areas with low prey availability for raptors. Forests are the main habitat for wild ungulates, which compete with (e.g. Red Deer *Cervus elaphus*; Soriguer, 1987) or directly prey on rabbits (such as the Wild Boar *Sus scrofa*; Cabezas-Díaz et al., 2010). Recently, it has been stated that high ungulate densities negatively affect Wild Rabbit population viability (Carpio et al., 2014).

Power line length is the last of the most affecting factors. Following a likelihood rationale, where the number of pylons increases, perching in those elements is more likely, so the probability of electrocution also increases. It also can be due to the fact of an increasing number of power lines comprises an increasing probability of dangerous pylons (Guil et al., 2011).

There are other significant factors common to *Birds* and *Raptors*, related to electrocution rates: length of rural paths, number of inhabitants, ornithologist ratio, surface of Natura 2000 network, and presence of specific regional regulations concerning birds and power lines. With respect to the length of rural paths and human population, those variables are related

Please cite this article in press as: Guil, F., et al., Space–time trends in Spanish bird electrocution rates from alternative information sources. Global Ecology and Conservation (2015), http://dx.doi.org/10.1016/j.gecco.2015.01.005

to a greater activity in rural areas. This may be caused by a higher electrocution rate in more inhabited areas as suggested previously (Guil et al., 2011). A secondary explanation is that there are electrocution-prone species which are more common in semi-urban habitats (Dwyer and Mannan, 2007; Palomino and Carrascal, 2007). The third explanation involves an aspect already treated. As the highest rabbit abundance occurs in transformed and inhabited areas, e.g. traditional dry farming agro-ecosystems (Delibes-Mateos et al., 2008b), those might be the most-electrocution prone for many species. Where Natura 2000 protected areas are present, bird detections become easier, especially when power line survey programs are established (as described in Cerezo et al., 2010). However, sampling in the surroundings becomes necessary, as these areas generally have more agriculture and human presence, and thus higher rabbit populations provoking higher electrocution rates (Delibes-Mateos et al., 2009b; Pérez-García et al., 2011). A complementary explanation is that Natura 2000 areas act as sources for birds, in a sink-source dynamics. In Spain Natura 2000 comprises wilder and more forested areas than the rest of the territory, more adequate as breeding areas for even all of the electrocution-prone species (Abellán et al., 2011, but see Palomino and Carrascal, 2007). And the surroundings to those protected areas tend to have higher rabbit densities and more agricultural landscapes. Probably also Natura 2000 have a lower degree of the power network development, due to higher regulation standards, lesser population density and lower intensity use (Pozo-Rivera et al., 2013). The higher ornithologist ratio is consistent with the fact that a larger percentage of members of bird preservation entities has a positive impact on corpses detection. The presence of specific regional regulations concerning birds and power lines is a significant factor for both *Birds* and *Raptors*. Electrocution rates are greater where there are regional regulations. This may occur because regulations tend to address a pre-existing problem, such as high electrocution rates. So the presence of a regulation can be, in some cases, subsequent to electrocution data and public awareness.

5. Conclusions

Our results show how the use of alternative information sources allows the identification of broad areas where avian electrocution concentrates. This methodology implies lower costs but depends on efforts carried out on other programs/studies. The main bias of the method could be related to a low standardization between methods of field surveys and differences in susceptibility to mortality among species, areas or periods.

We show that there is an apparent decreasing trend in the electrocution rate in the second part of 2000 decade, as evidenced by a reduction in the mortality index, although it remained high for certain threatened species. Regulation enactment implemented in areas with the highest electrocution rates has had an important effect in monitoring the impact of this threat as well as in retrofitting the most dangerous power lines.

From the data obtained through recovered ringed birds, we conclude that avian mortality by electrocution in Spain is a common phenomenon as the result of a large power line distribution network. This seems more acutely in the Mediterranean region, in contrast with Atlantic and Macaronesian areas (Mañosa, 2001; Lorenzo and Ginovés, 2007; Pérez-García, 2014). This pattern is emphasized in *Raptors*. Explanatory hypotheses to be analysed in forthcoming works, might include the higher diversity – abundance of *Birds* and *Raptors* –, the presence of migration corridors and the agro-exploitation of the landscape, thus requiring electricity (mainly due to irrigation typology, etc.) around the Mediterranean Basin.

Raptors appear to be prone to electrocution over wide areas, where population and Natura 2000 areas also occur. The *Large Eagle*'s favourable conservation status will be enhanced through the correction of dangerous power line in open habitats with high rabbit abundance (Guil et al., 2011).

Acknowledgements

We wish to express our gratitude to Dra. Eva Banda and Oficina de Especies Migratorias staff for providing ringed bird data. We also recognize Beatriz Sánchez and Fernando Guerrero, from SEO/BirdLife, for forwarding information on members. A.M. was supported by a Ramón y Cajal research contract from the Ministerio de Economía y Competitividad (RYC-2012-11867). Rosa Jiménez, Carlos Soria, F. Javier Sánchez, Manuel Martín and J. Arcadio Calvo helped on the fieldwork in Cáceres, Madrid and Toledo provinces. Three anonymous reviewers provided interesting comments to improve the manuscript. Mar Celada and Sarah Young helped with the translation of the original MS.

Appendix A. Supplementary data

Supplementary material related to this article can be found online at http://dx.doi.org/10.1016/j.gecco.2015.01.005.

References

Abellán, M.D., Aledo, E., Cerezo, E., Manso, A., Escarabajal, J.M., 2012. Corrección de tendidos eléctricos en la Región de Murcia. Resultados alentadores en la corrección, el control y el seguimiento de los puntos negros. Quercus 321, 34–41.
Abellán, M.D., Martínez, J.E., Palazón, J.A., Esteve, M.A., Calvo, J.F., 2011. Efficiency of a protected-area network in a Mediterranean region: a multispecies assessment with raptors. Environ. Manage. 47, 983–991. http://dx.doi.org/10.1007/s00267-011-9640-5.
Asociación Landazuria-CODA, 1994. Tendidos eléctricos en Navarra: afecciones sobre la avifauna. In: CODA, (Ed.), El Impacto de los Tendidos Eléctricos en la Avifauna. CODA, Madrid, pp. 36–46.

Barrientos, R., Ponce, C., Palacín, C., Martín, C.A., Martín, B., Alonso, J.C., 2012. Wire marking results in a small but significant reduction in avian mortality at power lines: a BACI designed study. PLoS One 7 (3), e32569. http://dx.doi.org/10.1371/journal.pone.0032569.
Bautista, J., Calvo, R., Otero, M., Martín, J., Gil, J.M., 1999. Águilas perdiceras mueren en los tendidos del suroreste de Granada mientras se dispersan. Quercus 165, 49.
Bevanger, K., 1998. Biological and conservation aspects of bird mortality caused by electricity power lines: a review. Biol. Conserv. 86, 67–76. http://dx.doi.org/10.1016/S0006-3207(97)00176-6.
BirdLife International, 2004. Birds in the European Union: A Status Assessment. BirdLife International, Wageningen.
Cabezas-Díaz, S., Virgós, E., Mangas, J.G., Lozano, J., 2010. The presence of a ''competitor pit effect'' compromises wild rabbit (*Orcytolagus cuniculus*) conservation. Anim. Biol. 61, 319–334. http://dx.doi.org/10.1163/157075511X584254.
Calvo, J.A., 1999. En seis años murieron más de 800 rapaces electrocutadas en Toledo. Quercus 157, 54–55.
Carpio, A.J., Guerrero-Casado, J., Ruiz-Aizpurua, L., Vicente, J., Tortosa, F.S., 2014. The high abundance of wild ungulates in a Mediterranean region: is this compatible with the European rabbit? Wildl. Biol. 20, 161–166. http://dx.doi.org/10.2981/wlb.13113.
Cerezo, E., Aledo, E., Manso, A., 2010. Patrimonio Natural y Líneas Eléctricas en la Región de Murcia. Dirección General de Patrimonio Natural y Biodiversidad. Consejería de Agricultura y Agua, Región de Murcia, Murcia, [online] http://www.murcianatural.carm.es/europa/life00214/pdf/documentacion/Manual_tendidos.pdf (accessed 8 November, 2014).
Coues, E., 1876. The destruction of birds by telegraph wire. Am. Nat. 10, 734–736.
Deinet, S., Ieronymidou, C., McRae, L., Burfield, I.J., Foppen, R.P., Collen, B., Böhm, M., 2013. Wildlife Comeback in Europe: The Recovery of Selected Mammal and Bird Species. Zoological Society of London, [online] http://rewildingeurope.com/wp-content/uploads/2013/11/Wildlife-Comeback-in-Europe-the-recovery-of-selected-mammal-and-bird-species.pdf (accessed 8 November, 2014).
Delibes-Mateos, M., Delibes, M., Ferreras, P., Villafuerte, R., 2008a. Key role of European rabbits in the conservation of the Western Mediterranean basin hotspot. Conserv. Biol. 22, 1106–1117. http://dx.doi.org/10.1111/j.1523-1739.2008.00993.x.
Delibes-Mateos, M., Ferreras, P., Villafuerte, R., 2008b. Rabbit populations and game management: the situation after 15 years of rabbit haemorrhagic disease in central-southern Spain. Biodivers. Conserv. 17, 559–574. http://dx.doi.org/10.1007/s10531-007-9272-5.
Delibes-Mateos, M., Ferreras, P., Villafuerte, R., 2009a. European rabbit population trends and associated factors: a review of the situation in the Iberian Peninsula. Mammal Rev. 39, 124–140. http://dx.doi.org/10.1111/j.1365-2907.2009.00140.x.
Delibes-Mateos, M., Ferreras, P., Villafuerte, R., 2009b. Rabbit (*Oryctolagus cuniculus*) abundance and protected areas in central-southern Spain: why they do not match? Eur. J. Wildl. Res. 55, 65–69. http://dx.doi.org/10.1007/s10344-008-0216-5.
Delibes-Mateos, M., Redpath, S.M., Angulo, E., Ferreras, P., Villafuerte, R., 2007. Rabbits as a keystone species in southern Europe. Biol. Conserv. 137, 149–156. http://dx.doi.org/10.1016/j.biocon.2007.01.024.
Donázar, J.A., Cortés-Avizanda, A., Carrete, M., 2010. Dietary shifts in two vultures after the demise of supplementary feeding stations: consequences of the EU sanitary legislation. Eur. J. Wildl. Res. 56, 613–621. http://dx.doi.org/10.1007/s10344-009-0358-0.
Donázar, J.A., Margalida, A., Carrete, M., Sánchez-Zapata, J.A., 2009. Too sanitary for vultures. Science 326, 664. http://dx.doi.org/10.1126/science.326_664a.
Dwyer, J.F., Mannan, W.R., 2007. Preventing raptor electrocutions in an urban environment. J. Raptor Res. 41, 259–267. http://dx.doi.org/10.3356/0892-1016(2007)41[259:PREIAU]2.0.CO2.
Fernández, C., Azkona, P., 2002. Tendidos Eléctricos y Medio Ambiente en Navarra. Gobierno de Navarra, Pamplona.
Fernández, M., Oria, J., Sánchez, R., González, L.M., Margalida, A., 2009. Space use of adult Spanish imperial eagles *Aquila adalberti*. Acta Ornithol. 44, 17–26. http://dx.doi.org/10.3161/000164509X464849.
Ferrer, M., de la Riva, J., Castroviejo, J., 1991. Electrocution of raptors on power lines in Southwestern Spain. J. Field Ornithol. 62, 181–190.
Fox, J., Weisberg, H.S., 2011. An R Companion to Applied Regression. SAGE Publications, Inc., Thousand Oaks, California.
Frías, O., Serradilla, A.I., Escudero, E., 2009. Informe de actividades de la Central de Anillamiento de Aves ''ICONA'': año 2007. Ecología 22, 137–229. [online] http://www.magrama.gob.es/ministerio/pags/Biblioteca/Revistas/pdf_REPN%2FECO_2008_22_137_229.pdf (accessed 8 November, 2014).
García del Rey, E., Rodríguez-Lorenzo, J.A., 2012. Avian mortality due to power lines in the Canary Islands with special reference to the steppe-land birds. J. Nat. Hist. 45, 2159–2169. http://dx.doi.org/10.1080/00222933.2011.589916.
Garrido, J.R., 2003. Plan de Actuación para la Aplicación de Medidas Correctoras en Tendidos Eléctricos de Baja y Media Tensión para la Avifauna. Huelva. Tragsa, Huelva, [online] https://www.academia.edu/1629641/Plan_de_actuaci%C3%B3n_para_la_aplicaci%C3%B3n_de_medidas_correctoras_en_tendidos_el%C3%A9ctricos_de_baja_y_media_tensi%C3%B3n_para_la_avifauna._Huelva (accessed 8 November, 2014).
González, L.M., Margalida, A., Mañosa, S., Sanchez, R., Oria, J., Molina, J.I., Caldera, J., Aranda, A., Prada, L., 2007. Causes and spatio-temporal variations of non-natural mortality in the Vulnerable Spanish imperial eagle *Aquila adalberti* during a recovery period. Oryx 41, 495–502. http://dx.doi.org/10.1017/S0030605307414119.
Guil, F., Fernández-Olalla, M., Moreno-Opo, R., Mosqueda, I., García, M.E., Aranda, A., Arredondo, A., Guzmán, J., Oria, J., Margalida, A., González, L.M., 2011. Minimising mortality in endangered raptors due to power lines: the importance of spatial aggregation to optimize application of mitigation measures. PLoS One 6, e28212. http://dx.doi.org/10.1371/journal.pone.0028212.
Gutiérrez, R., de Juana, E., Lorenzo, J.A., 2012. Lista de las aves de España. SEO/BirdLife, [online] http://www.seo.org/wp-content/uploads/2012/10/Lista_-Aves_Espana_2012.pdf (accessed 8 November, 2014).
Guzmán, J., Castaño, J.P., 1998. Electrocución de rapaces en líneas eléctricas de distribución en Sierra Morena Oriental y Campo de Montiel. Ardeola 45, 161–169. [online] http://www.ardeola.org/volume/45(2)/article/161-169/383?lang=es (accessed 8 November, 2014).
Haas, D., Nipkow, M., Fiedler, G., Schneider, R., Haas, W., Schürenberg, B., 2005. Protecting Birds from Powerlines. Council of Europe Publishing, Strasbourg, [online] http://www.coe.int/t/dg4/cultureheritage/nature/bern/documents/072011_IKB/Protecting_birds_from_powerlines.pdf (accessed 8 November, 2014).
Hernández-Matías, A., Real, J., Moleón, M., Palma, L., Sánchez-Zapata, J.A., Pradel, R., Carrete, M., Gil-Sánchez, J.M., Beja, P., Balbontín, J., Vincent-Martin, N., Ravayrol, A., Benítez, J.R., Arroyo, B., Fernández, C., Ferreiro, E., García, J., 2013. From local monitoring to a broad-scale viability assessment: a case study for the Bonelli's Eagle in western Europe. Ecol. Monogr. 83, 239–261. http://dx.doi.org/10.1890/12-1248.1.
Herruzo, C., Martínez-Jáuregui, M., 2013. Trends in hunters, hunting grounds and big game harvest in Spain. For. Syst. 22, 114–122. http://dx.doi.org/10.5424/fs/2013221-03371.
Izquierdo, A., Martín, C., Rico, L., 1997. Factores técnicos y ambientales implicados en la electrocución de aves en los tendidos eléctricos. Inf. Constr. 49 (451), 49–56. http://dx.doi.org/10.3989/ic.1997.v49.i451.937.
Janss, G.F.E., 2000. Avian mortality from power lines: a morphologic approach of a species-specific mortality. Biol. Conserv. 95, 353–359. http://dx.doi.org/10.1016/S0006-3207(00)00021-5.
Janss, G.F.E., Ferrer, M., 1999. Avian electrocution on power poles: European experiences. In: Ferrer, M., Janss, G.F.E. (Eds.), Birds and Power Lines. Collision, Electrocution and Breeding. Quercus Editores, Madrid, pp. 145–164.
Janss, G.F.E., Ferrer, M., 2001. Avian electrocution mortality in relation to pole design and adjacent habitat in Spain. Bird Conserv. Int. 11, 3–12. http://dx.doi.org/10.1017/S0959270901001022.
Lammers, W.M., Collopy, M.W., 2007. Effectiveness of avian predator perch deterrents on electric transmission lines. J. Wildl. Manage. 71, 2752–2758. http://dx.doi.org/10.2193/2005-752.
Lehman, R.N., Kennedy, P.L., Savidge, S.A., 2007. The state of the art in raptor electrocution research: a global review. Biol. Conserv. 136, 159–174. http://dx.doi.org/10.1016/j.biocon.2006.09.015.
López-López, P., Ferrer, M., Madero, A., Casado, E., McGrady, M., 2011. Solving man-induced large-scale conservation problems: the Spanish imperial eagle and power lines. PLoS One 6, e17196. http://dx.doi.org/10.1371/journal.pone.0017196.
Lorenzo, J.A., Ginovés, J., 2007. Mortalidad de aves en los Tendidos Eléctricos de los Ambientes Esteparios de Lanzarote y Fuerteventura, con Especial Referencia a la Avutarda Hubara. SEO/BirdLife, La Laguna, Tenerife, [online] http://www.seo.org/lifehubara/Document/informe_tendidos.pdf (accessed 8 November, 2014).

Lorenzo, J.A., Linares, J., Abreu, J.N., 1997. Mortalidad de aves por tendidos eléctricos en la isla de Lanzarote, Islas Canarias. Vieraea 26, 1–10. [online] http://www.azoresbioportal.angra.uac.pt/files/publicacoes_Vieraea_26_1997-98_1.pdf (accessed 8 November, 2014).
Loss, S.R., Will, T., Marra, P.P., 2014. Refining estimates of bird collision and electrocution mortality at power lines in the United States. PLoS One 9, e101565. http://dx.doi.org/10.1371/journal.pone.0101565.
Madroño, A., González, C., Atienza, J.C., 2004. Libro Rojo de las Aves de España. Dirección General para la Biodiversidad-SEO/BirdLife, Madrid.
Mañosa, S., 2001. Strategies to identify dangerous electricity pylons for birds. Biodivers. Conserv. 10, 1997–2012. http://dx.doi.org/10.1023/A:1013129709701.
Margalida, A., Campión, D., Donázar, J.A., 2011. European vultures' altered behaviour. Nature 480, 457. http://dx.doi.org/10.1038/480457b.
Margalida, A., Campión, D., Donázar, J.A., 2014. Vultures vs livestock: conservation relationships in an emergent human-wildlife conflict. Oryx 48, 172–176. http://dx.doi.org/10.1017/S0030605312000889.
Margalida, A., Carrete, M., Hegglin, D., Serrano, D., Arenas, R., Donázar, J.A., 2013. Uneven large-scale movement patterns in wild and reintroduced pre-adult bearded vultures: conservation implications. PLoS One 8, e65857. http://dx.doi.org/10.1371/journal.pone.0065857.
Margalida, A., Colomer, M.À., 2012. Modelling the effects of sanitary policies on European vulture conservation. Sci. Rep. 2, 753. http://dx.doi.org/10.1038/srep00753.
Margalida, A., Donazar, J.A., Carrete, M., Sánchez-Zapata, J.A., 2010. Sanitary versus environmental policies: fitting together two pieces of the puzzle of European vulture conservation. J. Appl. Ecol. 47, 931–935. http://dx.doi.org/10.1111/j.1365-2664.2010.01835.x.
Martí, R., Del Moral, J.C., 2004. Atlas de las aves Reproductoras de España. SEO/BirdLife-Ministerio de Medio Ambiente, Madrid.
MMA, 2001. Estrategia Nacional para la Conservación del Águila Imperial ibérica. Ministerio de Medio Ambiente, Madrid, [online] http://www.magrama.gob.es/es/biodiversidad/temas/conservacion-de-especies/especies-proteccion-especial/ce-proteccion-estr-aguila.aspx (accessed 8 November, 2014).
MMA, 2011. Informe sobre inversión económica en modificación de tendidos eléctricos peligrosos para la avifauna. Inedit Report. Ministerio de Medio Ambiente y Medio Rural y Marino.
Moleón, M., Bautista, J., Garrido, J.R., Martín-Jaramillo, J., Ávila, E., Madero, A., 2007. La corrección de tendidos eléctricos en áreas de dispersión de águila-azor perdicera: efectos potenciales positivos sobre la comunidad de aves rapaces. Ardeola 54, 319–325.
Molina-López, R.A., Casal, J., Darwich, L., 2011. Causes of morbidity in wild raptor populations admitted at a wildlife rehabilitation centre in Spain from 1995–2007. A long-term retrospective study. PLoS One 6, e24603. http://dx.doi.org/10.1371/journal.pone.0024603.
Múgica, A., 1989. Aves electrocutadas en la Comunidad de Madrid. Quercus 39, 29.
Negro, J.J., 1999. Past and future research on wildlife interactions with power lines. In: Ferrer, M., Janss, G.F.E. (Eds.), Birds and Power Lines. Collision, Electrocution and Breeding. Quercus Editores, Madrid, pp. 21–29.
Palomino, D., Carrascal, L.M., 2007. Habitat associations of a raptor community in a mosaic landscape of Central Spain under urban development. Landsc. Urban Plann. 83, 268–274. http://dx.doi.org/10.1016/j.landurbplan.2007.04.011.
Pérez-García, J.M., 2014. Modelos predictivos aplicados a la corrección del impacto de la electrocución de aves en tendidos eléctricos (Ph.D. dissertation), Miguel Hernández University, [online] http://dspace.umh.es/bitstream/11000/1550/1/Tesis%20Doctoral%20JM%20Perez-Garcia%202014.pdf (accessed 8 November, 2014).
Pérez-García, J.M., Botella, F., Sánchez-Zapata, J.A., Moleón, M., 2011. Conserving outside protected areas: edge effects and avian electrocutions on the periphery of Special Protection Areas. Bird Conserv. Int. 21, 296–302. http://dx.doi.org/10.1017/S0959270911000062.
Pergams, O.R.W., Zaradic, P.A., 2008. Evidence for a fundamental and pervasive shift away from nature-based recreation. Proc. Natl. Acad. Sci. 105, 2295–2300. http://dx.doi.org/10.1073/pnas.0709893105.
Phernie, K., Bird, D.M., Dawson, R.D., Lague, P.C., 2000. Effects of electromagnetic fields on the reproductive success of American kestrels. Physiol. Biochem. Zool. 73, 60–65. http://dx.doi.org/10.1086/316726.
Ponce, C., Alonso, J.C., Argandoña, G., Garcia Fernandez, A., Carrasco, M., 2010. Carcass removal by scavengers and search accuracy affect bird mortality estimates at power lines. Anim. Conserv. 13, 603–612. http://dx.doi.org/10.1111/j.1469-1795.2010.00387.x.
Pozo-Rivera, E., Gutiérrez-Puebla, J., Rodríguez-Moya, J., Ramírez-García, S., GómezCerdá, G., García Palomares, J.C., 2013. Caracterización Socioeconómica de la Red Natura 2000 en España. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, [online] http://www.magrama.gob.es/es/ministerio/servicios/publicaciones/H108493_tcm7-329113.pdf (accessed 1 January, 2015).
R Development Core Team, 2014. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna.
Real, J., Grande, J.M., Mañosa, S., Sánchez-Zapata, J.A., 2001. Causes of death in different areas for Bonelli's Eagle *Hieraaetus fasciatus* in Spain. Bird Study 48, 221–228. http://dx.doi.org/10.1080/00063650109461221.
Rollán, À., Real, J., 2011. Effect of wildfires and post-fire forest treatments on rabbit abundance. Eur. J. Wildl. Res. 57, 201–209. http://dx.doi.org/10.1007/s10344-010-0412-y.
Schutgens, M., Shaw, J.M., Ryan, P.G., 2014. Estimating scavenger and search bias for collision fatality surveys of large birds on power lines in the Karoo, South Africa. Ostrich 85, 39–45. http://dx.doi.org/10.2989/00306525.2014.888691.
SEBI, 2007. Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. Technical Report Nº11/2007. European Environment Agency, Copenhagen, [online] http://www.eea.europa.eu/publications/technical_report_2007_11 (accessed 8 November, 2014).
Soriguer, R.C., 1987. Alimentación del conejo (*Oryctolagus cuniculus* L. 1758) en Doñana, SO, España. Doñana Acta Vertebrat. 15, 141–150.
Steenhof, K., Kochert, M.N., Roppe, J.A., 1993. Nesting by raptors and common ravens on electrical transmission line towers. J. Wildl. Manage. 57 (2), 271–281.
Tintó, A., Real, J., Mañosa, S., 2010. Predicting and correcting electrocution of birds in Mediterranean areas. J. Wildl. Manage. 74, 1852–1862. http://dx.doi.org/10.2193/2009-521.
Tryjanowski, P., Sparks, T.H., Jerzak, L., Rosin, Z.M., Skórka, P., 2013. A paradox for conservation: electricity pylons may benefit avian diversity in intensive farmland. Conserv. Lett. 7 (1), 34–40. http://dx.doi.org/10.1111/conl.12022.
Zalba, F.J., 2009. Catalogación de las líneas eléctricas peligrosas para las aves del P.N. Tajo Internacional y P.N. Monfragüe. Inedit Report. Junta de Extremadura, Mérida, [online] http://extremambiente.gobex.es/files/interreg/faunatrans/estudios_mejoras/catalogacion%20lineas%20electricas%20tajo%20y%20monfrague.pdf (accessed 1 January, 2015).
Zuberogoitia, I., Martínez, J.E., Margalida, A., Gómez, I., Azkona, A., Martínez, J.A., 2010. Reduced food availability induces behavioural changes in Griffon Vulture *Gyps fulvus*. Ornis Fenn. 87, 52–60.