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

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GRAPHICAL ABSTRACT

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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

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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