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Using risk prediction models and species sensitivity maps for large-scale identification of infrastructure-related wildlife protection areas: The case of bird electrocution

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ABSTRACT

The use of systematic area-selection procedures to design protected areas can help optimize conservation actions. However, this process has rarely been used to identify high-risk mortality areas to protect wildlife from human impacts. Electrocution on power lines is one the most important human-related causes of bird mortality worldwide, especially for raptors. Identifying and correcting dangerous individual pylons can significantly reduce the number of electrocution victims, but applying this procedure at a large spatial scale is impractical. In this paper we describe a new selection process that allows for identification of high-risk mortality areas at large scales, combining spatial electrocution risk models with maps of species sensitivity to such an impact. We used the Valencia Region (eastern Spain) as our study system. The risk prediction map was built using bird electrocution records on 1 km × 1 km grids from 2000 to 2009 and the species sensitivity map was built using data on presence and use of four raptor species. The combination of both maps was compared to the distribution of Special Protected Areas and validated by local experts to identify prediction errors or gaps. The final proposal of high priority areas to protect birds from electrocution covered 16.3% of the Valencia Region. Our work supports the use of predictive models and sensitivity maps in the decision-making process to locate high priority infrastructure-related wildlife protection areas at a large scale.

1. Introduction

The use of protected areas can efficiently reduce diversity loss (Lovejoy, 2006), but identifying and establishing protected areas is a complex process (Vane-Wright et al., 1991). Systematic area-selection procedures to design protected areas can help optimize conservation actions in priority areas based on scientific criteria (Margules and Pressey, 2000; Possingham et al., 2001; Groves et al., 2002), which also reduces subjectivity and information biases (Wilson et al., 2006; Schmolke et al., 2010). For example, species distribution prediction models have been widely applied to optimize the design of protected aeas, e.g. marine reserves (Nur et al., 2011; Arcos et al., 2012; O'Brien et al., 2012), or to identify potential areas for protection in poorly-known terrestrial ecosystems (e.g. Raxworthy et al., 2003; Ortega-Huerta and Peterson, 2004). However, systematic area-selection processes have seldom been used to locate high-risk mortality areas to protect wildlife from human impacts, such as roads, wind farms, or bird electrocutions on power lines (e.g. Malo et al., 2004; Langen et al., 2009; Carrete et al., 2012; Santos et al., 2013). The implementation of systematic area-selection processes combining spatial risk models of wildlife mortality at a large spatial scale with data on presence or abundance of species sensitive to such an impact would help to optimize mitigation of widespread human infrastructure impacts, especially those affecting a large number of species.

Interaction with power lines is one the most important human-related causes of bird mortality worldwide (Bevanger, 1994, 1998; APLIC, 2006; Prinsen et al., 2011; Loss et al., 2014, 2015). Electrocution is especially problematic for threatened species, particularly raptors (Ferrer et al., 1991; Bayle, 1999; Janss, 2000; Lehman et al., 2007; Hernández-Matías et al., 2015). Work by researchers, managers,

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Abbreviations: AUC, area under the curve; ERM, Electrocution Risk Map; HPA, High Priority Areas; IIA, Insufficient Information Areas; PPA, Potential Priority Areas; ROC, receiver operating characteristic; SPA, Special Protected Area; SSM, Species Sensitivity Map; sSi, species sensitivity index

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and conservationists during the past few decades has led to an increased understanding of the factors that influence the risk of bird electrocution, such as bird size and behaviour, design and types of materials used in pylons, and the surrounding habitat (Olendorff et al., 1981; Janss and Ferrer, 1999, 2001; Mañosa, 2001; APLIC, 2006; Lehman et al., 2007; Tintó et al., 2010; Guil et al., 2011; Dwyer et al., 2014). Identifying and correcting the most dangerous pylons has been shown to reduce the number of electrocution victims (Tintó et al., 2010; López-López et al., 2011; Guil et al., 2011; Chevallier et al., 2015).

The process of identifying dangerous pylons generally follows a bird hazard assessment based on characterization of individual pylons by modelling technical characteristics and habitat variables, resulting in a pylon-based risk model (Izquierdo et al., 1997; Janss and Ferrer, 2001; Mañosa, 2001; Tintó et al., 2010; Guil et al., 2011; Dwyer et al., 2014). However, applying this selection procedure is impractical on a large spatial scale because of the time and economic resources needed to characterize and potentially modify all existing dangerous pylons. Moreover, electrocution risk is determined not only by hazards associated with individual pylons; the exposure to sensitive birds is also important. Thus, the likelihood of electrocution risk is higher when dangerous pylons are located in areas where electrocution-sensitive birds are present (Fernández-García, 1998; Mañosa, 2001; Tintó et al., 2010; Guil et al., 2011; Dwyer et al., 2014, 2016).

To address the challenges outlined above, Dwyer et al. (2016) proposed the use of a regional prediction model using power pole density as a surrogate of bird electrocution, combined with a foraging map of a sensitive species, to locate priority areas for mitigating avian electrocution. Although this proposed procedure is promising for identifying priority areas, some limitations include the assumption of homogeneity in power pole design and the linear relationship between power pole density and avian electrocution mortality. Furthermore, a procedure to reduce avian electrocutions on power lines ideally should allow for not only prioritization of existing high risk powerlines for mitigation, but also should identify areas that should be prioritized for protection in the future.

In this study we describe a systematic selection process to identify high priority areas for protection of birds from power lines at a regional scale. This process is composed of two parts. The first is a general procedure combining spatial electrocution risk models of bird mortality with occupancy data on birds sensitive to such an impact. The second part of our process involves the integration of data inherent to our particular study system (national and regional infrastructure composition and environmental regulations) with other independent sources of information including mortality records and expert knowledge to validate the models. Incorporating expert knowledge is accepted as a suitable method to complement reserve selection processes based on mathematical models (Store and Kangas, 2001; Cowling et al., 2003; Elbroch et al., 2011). Our systematic selection process could improve the design of protected areas and also help managers and power line companies prioritize mitigation and corrective actions, saving time and money.

We used the Valencia Region in eastern Spain as our model study area. This region has experienced the highest bird mortality rate from electrocution in the Iberian Peninsula (Izquierdo et al., 1997; Pérez-García, 2009), and detailed information on the presence of threatened birds and environmental variables is available. Our specific objectives were to i) analyze the relationship between bird electrocution and landscape configuration; ii) build a large-scale electrocution risk map and sensitivity map for a set of species of interest according to their conservation status, and iii) according to the Spanish national policies concerning protection against bird electrocution, identify a network of high priority areas for bird electrocution protection.

2. Material and methods

2.1. Study area

The Valencian Autonomous Community (hereafter Valencia Region) covers 23,655 km^2 and lies in the eastern Iberian Peninsula. It is a relatively mountainous region; mean elevation is 396 m asl, and maximum elevation is 1839 m asl. The climate across most of the study area is typically Mediterranean. Mean annual precipitation is between 20 and 85 cm. Natural overstory vegetation is predominantly *Pinus halepensis* and *P. sylvestris*, interspersed with Mediterranean scrub.

The Valencia Region has experienced a high bird mortality rate from electrocution on power lines (Izquierdo et al., 1997; Pérez-García, 2009). Until 2008, no mitigation strategy existed on a regional scale and only local mitigation actions had been conducted (Pérez-García, 2009). In 2008 a national law (RD 1432/2008) regarding the protection of birds against electrocution and collision on power lines was adopted in Spain. This regulation designated priority areas for mitigating power line infrastructure and included two categories: existing protected areas and specific areas to be identified by a regional manager. Existing protected areas included Spatial Protected Areas (SPAs) and areas used for implementation of action plans for threatened species. Specific areas to be designated by a regional manager included important areas for breeding, feeding, dispersal and concentration of species included in the catalogue of endangered species. Such areas could be delimited following a systematic selection process to target resources available for retrofitting power poles and to optimize the effectiveness of the regulation, and in our current study have been designated as High Priority Areas (HPA).

2.2. Modelling methodology

To identify High Priority Areas (HPA) for bird protection against electrocution, we employed a two-part process (a conceptual graphic of this is shown in Fig. 1). In the first, we constructed a map of Potential Priority Areas (PPA) for bird electrocution by combining two spatial models: 1) an Electrocution Risk Map (ERM) that related observed bird mortality with environmental variables, and 2) a Species Sensitivity Map (SSM) that identified the presence of sensitive birds based on the potential risk of electrocution and conservation status (Pérez-García et al., 2016), as determined by species-specific traits.

In the second part of the process, HPA were further identified by integrating into the PPA the specific features related to power line wildlife-impact regulations and a model validation. To adapt the PPA to specific national regulations (in this case RD 1432/2008), areas specifically included in the regulation, and therefore targets for corrective actions, were excluded. Subsequently, to validate the PPA located outside specific regulation areas and detect gaps or errors, a validation was performed using expert knowledge and supplementary mortality information not used for modelling the ERM. This evaluation identified two PPA groups: areas that were confirmed as HPA for bird protection against electrocution, which were directly incorporated into the final HPA proposal, and a second group that was designated as Insufficient Information Areas (IIA). For the latter, field sampling was conducted to determine if each IIA should be included in the HPA proposal (Fig. 1). Aditionally, experts could propose some areas that, despite not being identified within the PPA, were known for high mortality of birds by electrocution.

2.3. Bird electrocution and environmental variables

We collected all bird electrocution fatalities recorded by wildlife recovery centres and principal electric distribution companies between January 2000 and July 2009 in the study area. After we filtered and eliminated duplicate records among information sources, a total of 1098 records of electrocutions from 51 bird species was collected.

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