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Review

Bird collisions with power lines: State of the art and priority areas for research

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ABSTRACT

Transmission and distribution electricity grids are expanding rapidly worldwide, with significant negative impacts on biodiversity and, in particular, on birds. We performed a systematic review of the literature available on bird collisions with power lines to: (i) assess overall trends in scientific research in recent decades; (ii) review the existing knowledge of species-specific factors (e.g. vision, morphology), site-specific factors (e.g. topography, light and weather conditions, and anthropogenic disturbance), and power line-specific factors (e.g. number of wire levels, wire height and diameter) known to contribute to increased bird collision risk; and (iii) evaluate existing mitigation measures (e.g. power line routing, underground cabling, power line configuration, wire marking), as well as their effectiveness in reducing collision risk. Our literature review showed (i) there is comparatively little scientific evidence available for power line-specific factors, (ii) there is a scarcity of studies in Asia, Africa and South America, and (iii) several recommendations of good practice are still not supported by scientific evidence. Based on knowledge gaps identified through this review, we outline suggestions for future research and possible innovative approaches in three main areas: bird behaviour (e.g. further use of loggers and sensors), impact assessment (e.g. understanding the drivers of mortality hotspots, assess population-level impacts, develop methods for automatic detection of collisions) and mitigation measures (e.g. further need of BACI approaches to compare the effectiveness of different wire marking devices). The complex and region-specific interactions between collision drivers and bird ecology continue to limit our ability to predict impacts and the success of mitigation measures.

1. Introduction

Global energy demand is expected to grow 30% between 2016 and 2040, particularly in parts of Asia (where more than half the increase is expected), Africa, Latin America, and the Middle East (IEA, 2016). Bringing this energy to end users (people and industries) will require a 7.2–8.1 trillion USD investment in the global electricity grid (IEA, 2016), which is growing at a rate of about 5% annually (Jenkins et al., 2010). This expansion will require the construction of thousands of kilometres of new overhead power lines (Gellings, 2015), which can be divided in two main types: "transmission lines" carry electricity at high voltages from generating facilities to substations (where voltage is reduced) and "distribution lines" deliver electricity to individual consumers at lower voltages (IEA, 2016). The voltage threshold between these power line types usually varies between 60 kV and 132 kV, depending on the country or region (CIGRE, 2017).

Overhead power lines and associated infrastructure entail various impacts on biodiversity. One of the most well-known is bird mortality

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due to collision and electrocution, which represents a major source of anthropogenic mortality and kills hundreds of thousands to millions of birds every year (Erickson et al., 2005; Loss et al., 2014, 2015; Rioux et al., 2013). This paper is focused on collision as the most widespread interaction of these infrastructures with birds in the sense that virtually any aerial wire can pose an obstacle to flying birds, and it is thus associated with both distribution and transmission power lines (e.g. Bevanger, 1994).

Several studies suggest that power line collision mortality can have significant population-level impacts (Loss et al., 2012; Schaub et al., 2010; Schaub and Pradel, 2004), and red-listed and economically important species are commonly documented casualties (Bevanger, 1995a, 1998; Hobbs, 1987; Janss, 2000). In some cases, there is evidence that power line collision mortality can even lead to changes in migratory patterns and flyways (Palacín et al., 2017). Thus, it is important to continuously improve impact assessment methods and to design appropriate mitigation measures to be applied when new power lines are designed and constructed, as well as when existing lines are retrofitted. This would assist companies and authorities in ensuring that infrastructure is developed in the most environmentally friendly way.

Scientific understanding of the links between power lines and bird collisions, and effectiveness of mitigation measures, has steadily advanced over the past 20–30 years (e.g. Barrientos et al., 2011, 2012; Bevanger, 1990, 1994; Jenkins et al., 2010; Loss et al., 2015; Smith and Dwyer, 2016). The first peer-reviewed publications summarising available information on drivers of bird collision, as well as mitigation measures, were published by Bevanger (1994, 1998). Since then, there has been no peer-reviewed update of scientific evidence, with the exception of Jenkins et al. (2010) which focussed specifically on South Africa. Furthermore, there are still significant knowledge gaps that need to be identified (e.g. Richardson et al., 2017) as, for example, some widely accepted principles have never been tested, species-specific differences in collision risk are not well understood, and the evaluation of effectiveness of mitigation measures to date yields widely differing results (e.g. Barrientos et al., 2011; Jenkins et al., 2010).

In this review, we aim to evaluate the current science and practice of understanding and mitigating bird collisions with power lines, and seek to identify major knowledge gaps that should be the focus of subsequent research. For that purpose, we have structured this paper into four major components:

a) We first present results of a systematic literature review undertaken to assess the overall trends in scientific research on bird collisions with power lines in recent decades, as well as the more commonly studied topics;
b) We then review factors known to contribute to increased collision risk, including species-specific factors (vision, morphology and ecology), site-specific factors (topography, landscape context, light and weather conditions, and anthropogenic disturbance) and power line-specific factors (number and spacing of wire levels, wire height and diameter);
c) Thirdly, we summarise the existing strategies for reducing collision risk, namely power line routeing, underground cabling, power line configuration, wire marking, and habitat management, as well as understanding their effectiveness;
d) We conclude by identifying knowledge gaps and suggesting future research avenues to answer persisting questions.

2. Methods

To review the literature, we compiled studies, both peer-reviewed and non-peer-reviewed (such as journal papers, books and book chapters, conference proceedings and technical reports) focusing on bird collision with power lines. We started with a systematic literature review, through the compilation of data from the search engines ISI Web of Knowledge and Google Scholar. The search was carried out in December 2016, using the term “power lines” combined with the following specific terms: “bird collision”; “bird collision mitigation”; “bird mortality”; “bird avoidance”; and “bird collision guidelines”. Based on the recommendations of Haddaway et al. (2015) the Google Scholar search focused on the first 300 results. All results from the ISI Web of Knowledge were checked and only documents assessing bird collision with power lines were included in the analysis (e.g. documents only reporting bird electrocutions or bird collisions with other man-made structures were excluded). Each document was assigned to one or more of the main topics of the manuscript (see Appendix, Table A1).

The systematic literature review had some limitations, as it was restricted to documents publicly available, accessible online, and written in English. Thus, whenever relevant to fulfil the objectives, we also reviewed key documents referenced by those identified through our systematic literature review, or included in our personal bibliographic collections (see Appendix, Table A2).

3. Overall trends in research topics

Overall, the systematic literature review resulted in 208 documents focusing on bird collision with power lines, of which 17 could not be accessed and were therefore excluded from the review. The first studies were carried out in the early 1970s and scientific evidence has been accumulating ever since, with the number of studies more than doubling over the last decade (Fig. 1).

The majority of studies (60.2%), especially those published earlier, focused on quantifying bird fatalities from collisions (Fig. 2). Collision risk factors were also frequently addressed, namely species-specific factors (51.3%), followed by site-specific (34.0%) and power line-specific factors (11.0%). Studies on strategies to mitigate bird collision events with power lines were also relatively frequent (46.6%).

Only a subset of 132 studies (69.1%) presented first-hand data on bird collisions with power lines (Fig. 3). These studies were conducted mainly in Europe and North America (43.2% and 34.8%, respectively), which are currently the regions with the largest extent of power lines (Wildemann et al., 2013). Transmission power lines were by far the most studied type, with 91 studies (68.9%), compared to 49 (37.1%) on distribution lines, even though distribution networks are significantly larger (CIGRE, 2017). However, some studies focused on both types, and surprisingly, a quarter of the studies (25.8%) did not provide information about power-line type.

4. Bird collision risk factors

A wide range of factors can influence avian collision risk with power lines. For simplicity, we have divided these into three main groups: species-specific, site-specific and power-line specific factors, although they are frequently interconnected.

4.1. Species-specific factors

Species-specific physiology, morphology and ecology are key to understanding collision risk. In this section, we summarise the current knowledge of how these factors may affect collision risk.

4.1.1. Sensory perception

The morphology and physiology of the avian eye, and therefore how information from the eye is processed, likely influences collision risk and the effectiveness of collision mitigation. Avian vision shares common principles with other terrestrial vertebrates (Martin, 1985, 1990; Martin and Osorio, 2008; Sillman, 1973). There are however, important differences that may limit our ability to understand how power lines and mitigation, such as wire markers, are perceived by birds.

Birds with eyes located laterally have broad visual coverage of the surrounding world (Martin, 1985, 1990, 2011), facilitating detection of