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Ecological impacts of wind farms on birds: Questions, hypotheses, and research needs

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ABSTRACT

Wind power is increasingly being used worldwide as an important contribution to renewable energy, due to its low greenhouse gas emissions compared to fossil fuels. However, it has been suggested that the development of wind power has caused an adverse impacts on birds. We summarise current evidence of bird fatalities resulting from wind power, outline the reasons why and how birds are killed by wind power developments, and identify research needs to better inform researchers, decision makers, developers and other stakeholders, to help mitigate any adverse impacts of wind power developments on birds.

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1. Introduction

The dual challenges of climate change and energy security mean that renewable energy technologies are likely to become ever more important in the future. Wind power is an important source of renewable energy, and has been used commercially to produce energy services in the United States of America (USA) since the early 1980s, and may help to satisfy a growing worldwide demand for electricity [1,2]. Generating electricity from wind energy reduces the consumption of fossil fuel, leading to greenhouse gas emission savings ranging from 330 to 590 t CO_2 per GWh (Gigawatt hours) [3]. Wind energy has been growing worldwide and there are now over two hundred

Abbreviations: AWEA, American Wind Energy Association; EWEA, European Wind Energy Association; FWS, US Fish and Wildlife Service; GOA, US Government Accountability Office; GWEC, Global Wind Energy Council; MAPR, Multiple Antenna Profiler Radar; NWCC, National Wind Coordinating Committee; WWEA, World Wind Energy Association

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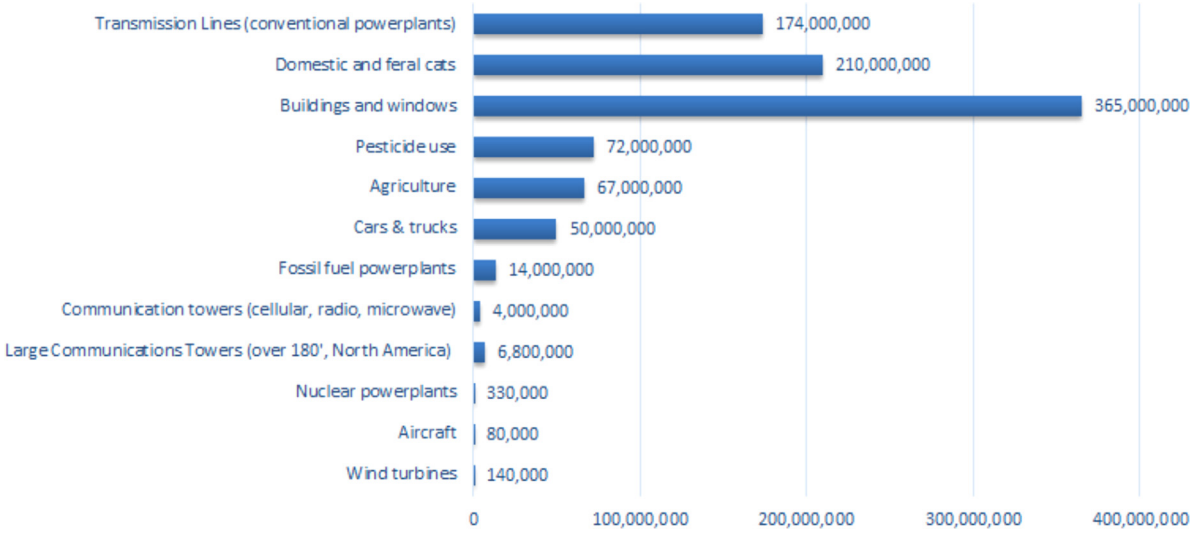

Fig. 1. Annual avian mortality in the USA [8–11]. Numbers show the lowest values when a range of estimates is given.

thousand wind turbines operating, with a total capacity of 318.1 Gigawatts (GW) at the end of 2013 [4].

However, although wind energy can contribute to growing energy demands and provide lower greenhouse gas emissions than fossil fuel, development of wind power can lead to bird fatalities [5,6], especially from growing developments in Europe, USA, Australia, China, and India [7]. Though bird mortality from wind turbines is far smaller than from many other forms of energy infrastructure and other human structures (see Fig. 1), it is a concern that bird fatalities could become a serious issue if wind power is deployed over large areas, potentially resulting in a reduction in biodiversity.

Studies to date reported that the avian mortalities are very dependent on the season, weather, specific site (for example, mountain ridge or migration route), topography, species (large and medium versus small, and migratory versus resident), type of bird activity (for example, nocturnal migrations and movements from and to feeding areas), layout of the wind farm and type of wind technology [9,12,13]. Among them, landscape topography, direction and strength of local winds, turbine design characteristics, and the specific spatial distribution of turbines within the wind farm are the main factors [12,13]. However, it is still unclear how these factors impact avian mortalities from wind power. Understanding how and why birds are killed can contribute to the mitigation of the bird fatalities. Studies related to this can be found in Winkelman [14], Richardson [15], Erickson et al. [16], Larsen and Clausen [17], Langston and Pullan [18], and recently in Drewitt and Langston [19], among others. However, the information revealed by these studies is sparse and unsystematic, so here we present a comprehensive and updated review. In this paper, we systematically collate information for use in analysing how and why birds are being killed by turbines, and further identify research needs to reduce/mitigate the adverse impacts of wind power on birds, to fill in this gap.

2. Wind energy development

The global annual installed wind capacity has increased greatly between 1996 and 2013, especially during the period 2006–2012 (Fig. 2). The average annual growth in new installations is 27.6% between 2005 and 2010 [20]. In 2013, the global annual installed wind capacity reached 35.3 GW and the global cumulative capacity was up to 318.1 GW [4]. Asia had the biggest annual installed capacity in 2013, followed by Europe, North America, Latin America and Pacific region, while Africa & Middle East had the smallest annual installed capacity in the same year [4]. In 2013, the top 10 countries with cumulative installed wind capacity were China, USA, Germany, Spain, India, United Kingdom (UK), Italy, France, Canada and Denmark, and these 10 countries together have a total cumulative installed wind capacity of 269.8 GW, accounting for 84.8% of world total (Table 1). Between them, China and USA have a 47.9% share of world total cumulative installed wind capacity (Table 1). Based on the current growth rates, World Wind Energy Association (WWEA) [21] projects the global cumulative installed wind capacity of 1900 GW by the end of the year 2020. Wind power market penetration is expected to reach 8% by 2018 [22].

3. Monitoring methods for bird fatality

The typical method used to estimate the bird fatality is based on carcass searches around wind turbines. In this method, a plot, normally ranging between 40 and 120 m around the turbine, is first defined. Then the trained searchers walk along parallel transects of the plot to look for carcasses and record the number of carcasses. Depending on the purpose of the study, for example the investigation of the temporal pattern of carcasses, such inspection will be repeated over time at regular or irregular intervals. The advantage of this method is its simplicity and does not need expensive instruments. However, the limitation of this method is that the number of carcasses found during the searches does not correspond to the real number of birds killed by the wind turbines, due to the possible removal of carcass by, e.g., scavengers, and therefore the value must be adjusted through taking into account carcass removal and searcher efficiency rates.

Recent developments in monitoring methods include the introduction of remote sensing technologies into the monitoring experiments. Radar is one remote sensing technology to have been extensively employed in monitoring experiments. Radar is an active microwave sensor which transmits a microwave signal (pulse of electromagnetic radiation) and then receives its reflection as the basis for forming an image of an object. Radar has the advantage of that it allows continuous and simultaneous sampling of bird movements over a large area without the limitation of time and visibility condition. A combination of horizontal and vertical Radar can even provide information on bird flight direction and