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Differential recovery of habitat use by birds after wind farm installation: A multi-year comparison

M.A. Farfán [a,b,*], J. Duarte [b,c], R. Real [b], A.R. Muñoz [b,d], J.E. Fa [e], J.M. Vargas [b]

[a] Biogea Consultores, Calle Navarro Ledesma 243, Portal 4, 3° C, 29010, Málaga, Spain
[b] Departamento de Biología Animal, Facultad de Ciencias, Universidad de Málaga, Campus de Teatinos, 29071, Málaga, Spain
[c] Ofitecma, Calle Colombia 5, 29400 Ronda, Málaga, Spain
[d] Departamento de Botànica, Facultad de Farmacia, Universidad de Valencia, Avda. Vicente Andrés Estellés s/n, Burjassot, Valencia, Spain
[e] Division of Biology and Conservation Ecology, School of Science and the Environment, Manchester Metropolitan University, Manchester M1 5GD, UK

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ABSTRACT

Onshore wind farms remain one of the most widely used technologies for the production of renewable energy. These are known to affect birds through disturbance or collision. Most research focus on the impact of wind farms on raptors or other large bird species, especially those of conservation concern. However, limited information exists on the effect of wind farms on small birds. Recovery of large *versus* small bird populations impacted by wind farms is also largely unstudied. A reason for this is the lack of long-term datasets based on standardized, systematic assessments. We monitored birds in the vicinity of a wind farm in an upland habitat in southern Spain (Malaga province), immediately after installation and 6.5 years post-construction. During both study periods, we observed 11 raptor and 38 non-raptor species (including 30 passerines). We found differences in recovery rates between raptors and non-raptors. Raptors showed an upturn in numbers but non-raptor abundance fell significantly.

Greater attention should be paid to the recovery of wildlife after initial impact assessments than at present. This study confirms that regulatory authorities and developers should consider the likely impacts of wind farms on small bird populations. Mitigation measures focused particularly on non-raptor species should be considered and implemented as a means to reduce these negative effects.

1. Introduction

Wind energy has gained prominence among renewable resources and has become an increasingly important sector of the energy industry. Wind farms have thus grown rapidly throughout the world, and are expected to continue to increase in future years (Ledec et al., 2011). Spain is among the five largest markets for wind power worldwide alongside China, USA, Germany, and India (WWEA, 2015). By the end of 2015, Spain had an installed capacity of 22,988 MW distributed among 1077 wind farms (AEE, 2016).

Adverse impacts of wind energy facilities on wildlife, particularly on individual birds and bats have been well documented, especially direct mortality caused by collisions (Barrios and Rodriguez, 2004; Thelander and Smallwood, 2007; Drewitt and Langston, 2008; De Lucas et al., 2012). Although low collision rates are typical in most wind farms, high mortality rates have been recorded in some installations (Erickson et al., 2001; De Lucas et al., 2008). Wind farms also cause displacements or exclusion of individual birds, including the modification of their territories (Larsen and Guillemette, 2007). Habitat loss or damage from the construction of wind turbines and associated infrastructure is likewise possible (Langston and Pullan, 2003).

The potential for biologically significant impacts continue to be a source of concern. Bird populations overlapping with wind energy facilities may experience long-term declines owing to habitat loss and fragmentation, but may also increase mortality from numerous anthropogenic activities (Drewitt and Langston, 2008). However, long-term studies that focus on the impact of wind farms on wildlife populations based on continuous, standardized, and systematic assessments are less common, though fundamental. In the European Union, wind farms are subject to environmental impact assessments (EIAs) before installation (Article 2, Directive 85/337/EEC). However, the absence of agreed fixed baseline surveys has meant that only a few studies have been undertaken comparing pre-construction mortality predictions with post-construction actual mortality data (but see Ferrer et al., 2012) or population changes over time.

Most wind farm impact studies have focused on raptors or other large bird species, especially those of conservation concern (*e.g.* Larsen and Guillemette, 2007; Hill et al., 2011; Mammen et al., 2011; Muñoz et al.,

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* Correspondence author at: Biogea Consultores, Calle Navarro Ledesma 243, Portal 4, 3° C, 29010, Málaga, Spain.

E-mail addresses: mafarfanaguilar@hotmail.com (M.A. Farfán), jddofitecma@gmail.com (J. Duarte), roman@uma.es (A.R. Muñoz), jfa949@gmail.com (J.E. Fa).

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2011; Martínez-Abraín et al., 2012; Reid et al., 2015). There is thus limited information on collision rates or disturbances caused by wind farms on small birds (but see Bastos et al., 2016; García et al., 2015). This is arguably due to a combination of lower detection rates of the smaller birds, rapid scavenger removal (Lekuona and Ursúa, 2007; Ponce et al., 2010), or less interest on these species compared to the more charismatic taxa.

In this paper, we examine long-term effects of a wind farm on a bird community. We separately analyse the impact of disturbance and mortality on raptors, passerines and non-passerines. By taking advantage of already existing information (Farfán et al., 2009) we compare changes in total abundances and flight behaviour of the three bird groups around the wind farm during its placement, and six and half years after installation. We discuss management implications for large and small birds in the light of our observations.

2. Material and methods

2.1. Study area and wind farm facility

This study was undertaken at the “Sierra de Aguas” wind farm, located on a SW-NE oriented mountain ridge in southern Spain (Malaga province) (Fig. 1). The climate is typically Mediterranean, with a mean annual rainfall ranging from 400 to 659 mm and annual temperatures between 9.7 and 24.7 °C. The area is covered by scrub, with some rocky areas and small patches of young holm oaks (*Quercus rotundifolia*) and Aleppo pines (*Pinus halepensis*). The community of birds in the area is dominated by open-habitat Mediterranean species, at relatively low densities probably due to the predominant vegetation type. Although the wind farm is roughly 100 km from the Strait of Gibraltar, a major flyway for migratory birds (Bildstein and Zalles, 2000), the area is not a concentration point for migratory species.

The wind farm started operation in March 2005, at first consisting of 16 wind turbines (850 KW). Turbines were arranged along two continuous rows separated by a 400-m corridor (the lower row 1800 m long, and the upper one 1600 m), 815–940 m above sea level. During mid-2009, two extra turbines, similar to those originally fitted, were installed at a lower altitude, thus raising the total output to 15.3 MW. Each turbine was separated from each other by a 90-m corridor (see Fig. 1). The composition and structure of the vegetation around the wind farm was left relatively unmodified after construction.

2.2. Data collection and analysis

The study period stretched from November 2000 to August 2011 and covered 5 separate time phases: a) Period 1 (November 2000–October 2001): one year of observation prior to the construction of the wind farm; b) Period 2 (March 2005–February 2007): two years of observation immediately after start of operation; and c) Period 3 (September 2009 to August 2011): two years of observation six and a half years after installation.

Data from Period 1 were taken from an unpublished report on raptor abundance, allowing us to study this bird group for the 11-year period. However, for the other two groups we were only able to gather data for Periods 2 and 3. The following information was collected for all bird groups during Periods 2 and 3.

2.2.1. Bird abundances, flight behaviour and collision risk

Abundance and flight behaviour of birds were recorded by two observers along a pre-established area around the wind farm (Farfán et al., 2009). Observations were made from two fixed points located along the upper row of the wind farm. Bird movements were monitored during a total of 555 h (Period 1: 153 h; Period 2: 209 h; Period 3: 193 h).

Following Farfán et al. (2009), for each month, we calculated the total number of observations/hour as well as the total birds abundance/hour. Number of observation was calculated using each individual or group of birds observed in the wind farm, whereas total bird abundance employed the total number of birds registered during each bird observation. We applied a Kruskal-Wallis test to examine annual differences (Sokal and Rohlf, 1981).

We examined bird flight behaviour in the wind farm according to the following parameters: a) Height: a - under the blades; b - same height as the blades; c - above the blades; b) Flight direction: p - parallel or t - transversal to the wind turbine rows and c) Combined height and flight direction. We used a χ^2 (chi-square) test to determine whether there were significant differences in flight behaviours (Sokal and Rohlf, 1981).

We used the Specific Risk Index (SRI) described by Lekuona and Ursúa (2007) to determine the collision risk of all bird species in our study. In this way we took into account the relationship between the total number of individuals of each species detected in the area and the number of birds exposed to collision, *i.e.* the number of birds in the transversal direction to the blades, at the same height, and within the blade radius. For each

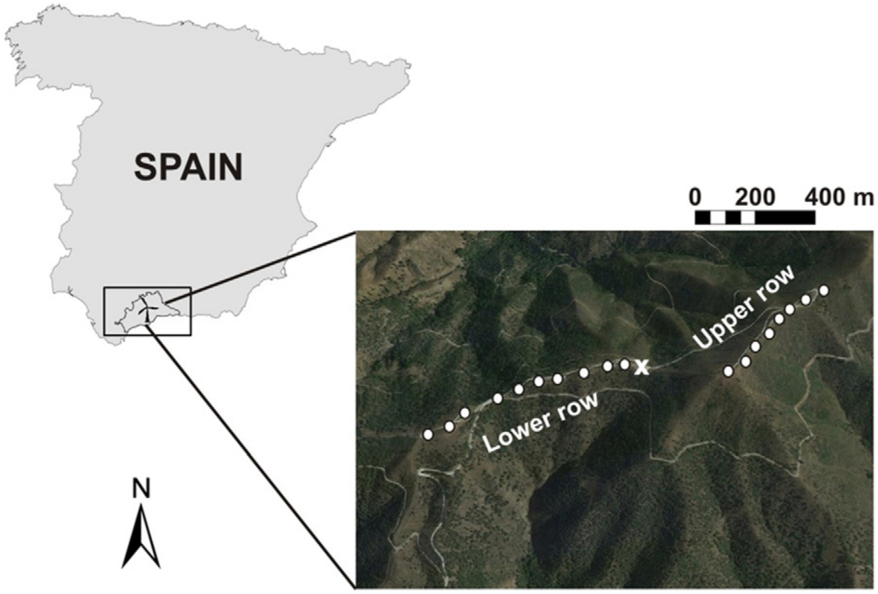

Fig. 1. Location of the study area. O: wind turbine; X: geographic reference (36° 51′ 18″N; 4° 46′ 43″W).