Bird Conservation International (2016) 26:256–261. © BirdLife International, 2014
doi:10.1017/S0959270914000471

Severe decline in Cantabrian Capercaillie *Tetrao urogallus cantabricus* habitat use after construction of a wind farm

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Summary

Tetrao urogallus cantabricus is the most endangered capercaillie subspecies and unlike the others it inhabits deciduous forests in the Cantabrian Mountains (north-west Spain). Its southernmost distribution occurs in Mediterranean forests outside conservation areas where wind farm construction is increasing. We surveyed Cantabrian Capercaillie presence in a wintering site one year before and four years after wind farm construction. Sign abundance greatly decreased after wind farm construction indicating a likely negative effect on Cantabrian Capercaillie habitat use. According to the precautionary principle, in order to conserve Cantabrian Capercaillie, all its range should be legally protected to avoid further wind farm construction and human disturbance.

Introduction

Western Capercaillie *Tetrao urogallus* is a forest grouse highly sensitive to habitat destruction and disturbance, which is declining throughout most of Europe (Storch 2007). Unlike the other subspecies, the Cantabrian Capercaillie *T. urogallus cantabricus* inhabits deciduous forests in the Cantabrian Mountains (north-west Spain). Cantabrian Capercaillie is restricted to less than 2,000 km^2 in north-west Spain (Figure 1a,b) and its population is estimated at 400 adult birds (Bañuelos and Quevedo 2008). Cantabrian Capercaillie is considered to be the most endangered subspecies according to the IUCN criteria, although reasons for the decline remain unknown and have not been studied (Quevedo *et al.* 2005).

Many causes have been proposed for Cantabrian Capercaillie decline, including low genetic variability, low reproductive success, resource competition with ungulates, forest fragmentation and climate change. However, a synergistic combination of several causes may be behind its decline (Quevedo *et al.* 2006).

Although over 90% of the Cantabrian Capercaillie range is included in the Natura 2000 network, the southernmost 10% of the range lies under no protection (authors' unpubl. data) and holds over 10% of the current population (González *et al.* 2010). In this area, the subspecies has adapted to a Mediterranean climate with an almost complete absence of bilberry *Vaccinium myrtillus* (< 0.5% of the forest ground cover) on which other populations rely, and therefore likely bears important genetic information. Further, this peripheral nucleus may be an expanding edge for the population if Pyrenean oak *Quercus pyrenaica* forests continue to spread southwards, and has already been found to be a genetic source for the northern core population of Cantabrian Capercaillie (Alda *et al.* 2013).

In this unprotected area, between 2009 and 2010, five wind farms have been constructed and 65 turbines have been erected with a potential negative impact on capercaillie numbers

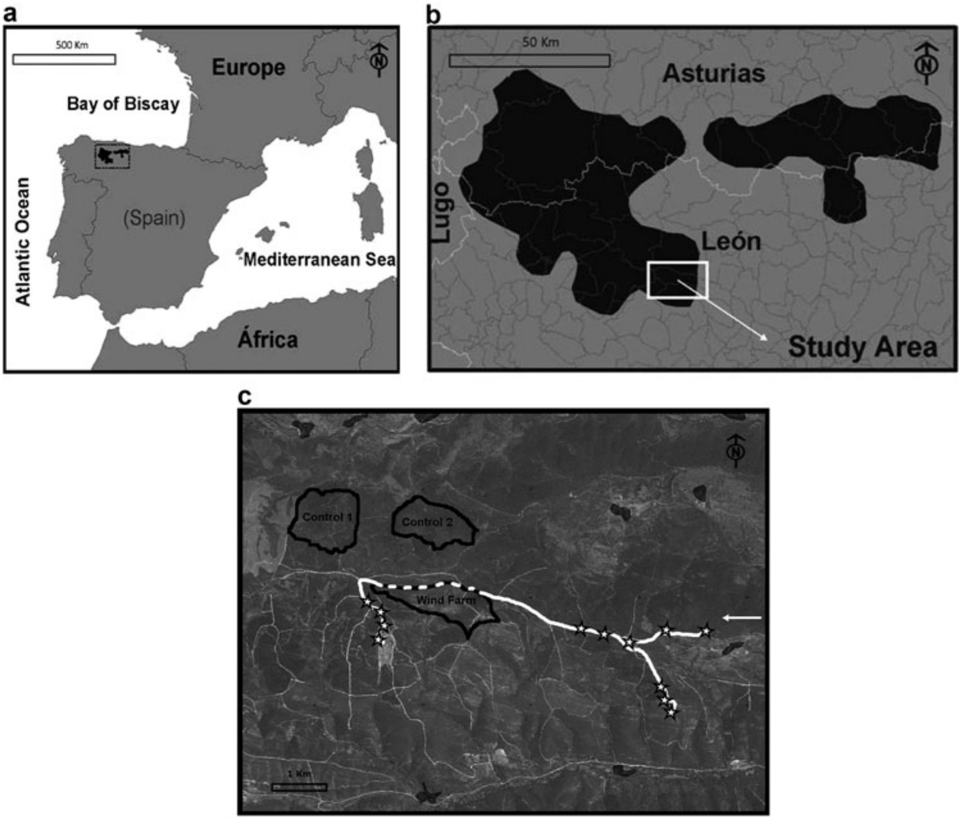

Figure 1. Maps illustrating (a) the distribution of the Cantabrian Capercaillie in Spain (black area), (b) the location of the study area (white rectangle), and (c) ortho-photo with the location of the three survey routes (black circuits), the wind farm turbines (stars), the maintenance track (thick white line), other pre-existing tracks (thin white lines) and the nearest human settlements (irregular black shadows). The white dashed line indicates the part of maintenance track shared with Wind Farm survey route and the white arrow the main access route.

(González and Ena 2011). Six additional wind farms are authorised for construction in the near future, which would mean a total of 11 wind farms and 127 wind turbines. Wind farm installation has been found to affect grouse populations, which either showed dramatic declines (*Tetrao tetrix*; Zeiler and Grünschachner-Berger 2009) or avoidance behaviour (*Tympanuchus* sp; Pruett *et al.* 2009). However, the effects of wind farms on capercaillie are beginning to be detected with evidence of two deaths by collision (http://www.tjaderobs.se/vindkraft.html) and probable habitat avoidance (González and Ena 2011). Since European energy policy is quickly increasing the number of wind farms in grouse habitats, their likely negative effects on capercaillie are expected to escalate (González and Ena 2011, Coppes 2013).

The aim of this study is to examine whether the occurrence of wintering Cantabrian Capercaillie changed at a site one year before and four years after the construction of a wind farm, and to compare these results with those of two close and similar wintering sites where wind farm construction did not take place. This study is a continuation of the survey carried out in the area by González and Ena (2011) one year before and one year after the wind farm construction.

https://doi.org/10.1017/S0959270914000471 Published online by Cambridge University Press

Methods

The study was carried out in a 50 km² area where three traditional wintering sites were known to occur (Figure 1). The climate is Mediterranean with average annual temperature 4–9°C and annual precipitation between 866 and 1,100 mm, with sporadic snowfall in winter and a severe two month long summer drought. The landscape is mountainous (800–1,700 m asl) and mainly covered by *Q. pyrenaica* forest intermingled with *Pinus sylvestris* plantations younger than 30 years old. The area is neither considered in the Cantabrian Capercaillie Recovery Plan (BOCYL 2009) nor in the Natura 2000 network.

Between 1 August and 15 December 2009, 12 wind turbines were erected over existing tracks in one of the wintering sites, hereafter referred as Wind Farm, and which extends for 6 km (Figure 1c). Turbines have been actively rotating since January 2011 after a delay of one year due to legal constraints (see González and Ena 2011). Five occupied leks occur in < 5 km radius around Wind Farm, three of them closer than 2 km (González *et al.* 2010).

Three circuits 4-km long were located in wintering sites along dirt tracks and perpendicular footpaths: one in Wind Farm and two more (Controls 1 and 2) in a < 2 km radius. Circuits were surveyed five times every year on a weekly basis from mid-January to the end of February before (2009) and after (from 2010 to 2013) wind farm construction. Besides the turbines, the maintenance track that connects them was considered a source of disturbance for capercaillie due to heavy traffic (lorries, 4WD) during and after wind farm construction. Control circuits were placed at least 0.6 km apart from disturbance sources, while 86% of the Wind Farm survey route lay at a shorter distance, and 42% of its length followed the maintenance track (Figure 1c). Control circuits were placed in a habitat as similar as possible to that of Wind Farm according to the most recent national forest inventory (MARM 2009) using ARCGIS 9.3 (ESRI 2010). They were validated using the most recent geo-referenced aerial photographs at 0.25 m pixel resolution (PNOA 2008) and with field observations at the time of the study. Capercaillie presence was searched for i) by direct sighting at any distance and ii) by finding droppings, footprints and feathers on the track surface and on a vegetated strip 2 m wide on each side of the survey route. Survey circuits were performed along tracks with similar substrates and homogeneous surface to increase sign detectability and to avoid bias between them (Table S1 in the online supplementary material). All capercaillie signs were collected or erased to avoid considering them again in the next survey. Since the data obtained on direct sightings, footprints and feathers were too sparse, only the number of droppings found on surveys 2 to 5 was considered in the analyses. Droppings found each year in the first survey were excluded from the analyses since they had accumulated for a longer and undefined period of time.

We used a generalised linear mixed model (GLMM) to assess how wind farm presence affected the number of Cantabrian Capercaillie droppings found per survey. Data were modelled using a negative binomial error distribution with a log link between the response (number of droppings) and the explanatory variables: factors 'site' (three levels: Wind Farm/Control 1/Control 2), 'time period' (two levels: before/after wind farm construction) and their interaction. A random term accounted for the hierarchical sampling design and was defined by factor 'survey' (four levels) nested within factor 'year' (five levels). The significant interaction (see below) was explored with a post-hoc analysis to test the simple effects of 'time period' at each level of factor 'site'. P-values for multiple comparisons were adjusted using Holm procedure. Analyses were carried out with libraries *lme4* and *phia* of the R statistical package (R Development Core Team 2013).

Results

The analysis found that the number of droppings in Wind Farm significantly differed between time periods ($t = -6.60$, $P < 0.0001$) and that this rate of change was distinct from those of control routes (Control 1: $t = 5.21$, $P < 0.0001$; Control 2: $t = 4.54$, $P < 0.0001$; Table 1). The post-hoc analysis showed that the number of droppings in control routes did not significantly differ before and after wind farm construction (Control 1: $\chi^2 = 0.23$, $P\text{-}adj = 1$; Control 2: $\chi^2 = 0.38$, $P\text{-}adj = 1$). The number of droppings found per survey in Wind Farm decreased from an average of 34.8 (± 4.5 SE) before turbine erection to 1.0 (± 1.0) or lower in the following years. Mean number of droppings per survey fluctuated over time between 4.0 (± 2.3) and 16.3 (± 1.9) in Control 1 and between 8.5 (± 4.9) and 16.3 (± 1.9) in Control 2, but never attained the low values found in Wind Farm (Figure 2). Although the mean number of droppings per survey decreased along time in Control 2, the overlapping standard errors between years rendered this pattern not significant.

Discussion

These results indicate a sharp decrease in the abundance of capercaillie signs after wind farm construction compared to the other two wintering sites, likely implying a reduction in habitat use. In our study, pre-existing tracks were used for wind farm construction so the only impact on habitat structure was turbine erection. However, the heavy traffic on the maintenance track during and after construction may have displaced birds to quieter areas and, together with turbine noise, prevented them returning afterwards to an otherwise suitable habitat. The possible accompanying negative effects of displacement of birds are discussed below, but even if this was not the case, the probable increase in their stress levels due to constant human disturbance should be considered and assessed (Thiel *et al.* 2011 and references therein).

Winter is a critical period for capercaillie when the bird survives with low food availability and harsh weather conditions (Storch 1993 and references therein). Although the Mediterranean climate in this area may convey milder winters, human disturbance may force Capercaillie to displace to habitats of lower quality, increasing their energetic expenditure and stress levels. While this did not affect the number of birds in nearby leks during the study period (authors' unpubl. data), it may have had negative consequences on their breeding success and fitness, which may in turn reduce the population in the short and medium terms (Thiel *et al.* 2011 and references therein).

In the Cantabrian context, it is urgent to understand the local problems faced by capercaillie, while developing precise conservation measures and preserving the natural systems (Quevedo *et al.* 2005). Further studies on conservation threats and appropriate surveys must be carried out in order to ascertain the real causes of the decline. Until then, habitat conservation is currently the only available measure for the *in situ* conservation of Cantabrian Capercaillie (Quevedo *et al.* 2005, Storch *et al.* 2006). The increase in wind farm construction and the heavy anthropogenic disturbance it brings are thus incompatible with the conservation and recovery of a subspecies catalogued as endangered. In our view, according to the precautionary principle, any area occupied by Cantabrian Capercaillie should be within the Natura 2000 Network. This measure would ensure that key areas of conservation importance are protected not only from the location of wind farms but from further human disturbance.

Table 1. Generalised linear mixed model results of the effect of 'site' (Wind Farm/Control 1/Control 2), 'time period' (before/after wind farm construction) and their interaction on dropping abundance. Results obtained using treatment contrasts, which compare each parameter with the Intercept (Wind Farm before turbine erection).

Parameters	Estimate (mean ± SE)	*t* value	*P* value
(Intercept)	3.55 ± 0.47	7.53	**<0.0001**
Control 1	−1.50 ± 0.68	−2.19	**0.0282**
Control 2	−0.78 ± 0.67	−1.15	0.2487
After construction	−4.02 ± 0.61	−6.60	**<0.0001**
Control 1 : After construction [a]	4.29 ± 0.82	5.21	**<0.0001**
Control 2 : After construction [a]	3.69 ± 0.81	4.54	**<0.0001**

[a]Interaction terms compare the rate of change in the number of droppings occurred along time in Controls 1 and 2 with that found in Wind Farm. Significant *P* values are indicated in bold.

https://doi.org/10.1017/S0959270914000471 Published online by Cambridge University Press

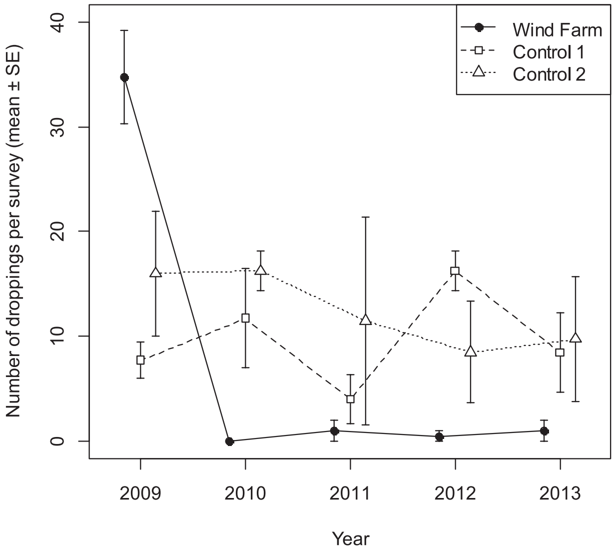

Figure 2. Mean number (± SE) of Cantabrian Capercaillie droppings found per survey at each site before the wind farm construction (2009) and after completion (2010–2013). Only data from surveys 2 to 5 were included in the graph.

Supplementary Material

The supplementary materials for this article can be found at journals.cambridge.org/bci

Acknowledgements

Alejandro Santos and Alicia Gil-Pastor helped with ARCGIS and useful comments. Ramón Balaguer and Luis Robles collaborated in field surveys. Two anonymous reviewers greatly improved the manuscript quality with their suggestions. Special thanks to Vicente Ena and Francisco J. Purroy for their constant support. This study was funded by University of León within the research project ULE AG-185.

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Received 21 December 2013; revision accepted 16 November 2014;
Published online 20 January 2015