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Reduced breeding success in white-tailed eagles at Smøla windfarm, western Norway, is caused by mortality and displacement

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ABSTRACT

Climate change scenarios and efforts to reduce CO_2 emissions have increased the focus on wind power and other renewable energy sources. Despite producing "clean" electricity, windfarms do have impacts on the environment. We studied the impact from a coastal windfarm on the breeding success of white-tailed eagles (*Haliaeetus albicilla*) at Smøla, western Norway by means of a BACI (before–after–control–impact) approach. The objective was to compare pre- and post-construction breeding success. A 10 year dataset from 47 eagle territories were analyzed using a generalized linear mixed model. Successful breeding was used as a response variable, while distance to turbines, distance to roads and before/after turbine construction were used as predictors. There was a significant effect of the interaction between time period and distance to turbines, showing that territories within 500 m from the turbines in the post-construction period experienced significantly lower breeding success than the same territories before construction. We found that this effect was most likely due to territories being vacated. The results emphasize the importance of using a BACI approach when assessing possible effects from wind-power production on breeding birds, especially for species breeding at low densities. It also emphasizes the importance of conducting thorough pre-construction studies on vulnerable bird species.

1. Introduction

Climate change and global warming scenarios (e.g. IPCC, 2007) together with increased energy demands (IEA, 2009) have made renewable energy production a key issue worldwide to reach the international targets on reducing CO_2 emissions. The potential for wind power as a source for electricity is substantial in most countries (Hoogwijk et al., 2004; IEA, 2009; Lu et al., 2009) including Norway (NVE, 2009).

Like all energy generation, wind-power plants may have adverse environmental effects on wildlife. A particular concern is the potential effects on birds (Drewitt and Langston, 2006, 2008), especially on large birds of prey (Carrete et al., 2009). Research on impacts of windfarms on wildlife has so far mainly focused on mortality from bird collisions with turbines and with collision risk assessment, as this is thought to be the most severe problem from wind power generation (Hunt, 2000; Kingsley and Whittam, 2005; Smallwood and Thelander, 2008). Large soaring birds such as raptors are particularly vulnerable to collisions (Barrios and Rodriguez, 2004; Bevanger et al., 2009; Hunt, 2002). However, so far results are inconsistent and the numbers of casualties recorded differ widely between wind-power plants and species (Kuvlesky et al., 2007). Considering the high number of turbines in some power plants, even low mortality rates per turbine could have severe population impacts for some bird species, especially those with low reproductive rates (Orloff, 1992; Percival, 2003; Thelander and Rugge, 2000). Other possible negative impacts are loss of, or reduced, habitat quality and disturbance leading to displacement. Pearce-Higgins et al. (2009) found that seven out of 12 bird species occurred at lower densities close to wind turbines compared to more distant areas. Although these effects have received less attention, they could potentially be of equal importance to collision mortality (Kingsley and Whittam, 2005; Langston and Pullan, 2003). Increased human activity can influence the use of nest sites, foraging sites and flight paths in birds (Drewitt and Langston, 2008) as well as displace birds into suboptimal habitats reducing their chances of survival and reproduction (Drewitt and Langston, 2006; Frid and Dill, 2002). Unfortunately, few conclusive studies have been carried out on the relevance of such factors, which is mostly due to lack of BACI (before–after–control–impact, (Krebs, 1999) assessments (Drewitt and Langston, 2006). The fact that raptors in general occur at low breeding densities (Newton, 1979),

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together with a lack of studies with a BACI-approach, has led to very few displacement studies of breeding raptors (Madders and Whitfield, 2006).

From October 2005 to December 2009, 28 dead white-tailed eagles (*Haliaeetus albicilla*) were recorded as collision victims within Norway's first large-scale windfarm on Smøla island, Central Norway (Bevanger et al., 2009). In 2010, 11 additional eagles were found killed by turbines (own unpubl. data). Smøla holds a large and dense breeding population of white-tailed eagles, estimated at more than 50 breeding pairs (Bevanger et al., 2009). Follestad et al. (2007) investigated the spatial distribution of eagle territories on Smøla using Kernel densities (Worton, 1989), showing that the pre-construction breeding density was highest within the windfarm area. Several of the former territories within the windfarm area are now vacant, and the "high-density" area of occupied territories has shifted to an area west of the windfarm (Bevanger et al., 2009). Bird species that mature late, lay few eggs and have a long life span, have demographic characteristics making their population growth rate especially sensitive to changes in adult mortality (Sæther and Bakke, 2000). Eagles fall into this category, and are therefore vulnerable to increased adult mortality caused by windfarms.

In this study we focus on possible impacts of the wind power plant on the breeding success of white-tailed eagles on Smøla. The objective was to test if the proportion of successful breeding events changed over time by comparing the breeding success before and after windfarm construction, controlling for the distance to the wind turbines.

2. Methods

2.1. Study species

The white-tailed eagle is a monotypic species currently distributed throughout northern and central Eurasia, west Iceland and southwest Greenland (del Hoyo and Elliott, 1994). The European population is estimated at 5000–6600 pairs and comprises more than 50% of the global population. As a result of a population increase the species has been downlisted to "Least Concern" on the IUCN Red List (IUCN, 2009). Norway is a stronghold of the white-tailed eagle and has ca. 40% of the European population (BirdLife International, 2002). In 2000 the Norwegian population was estimated at approximately 2200 territorial pairs (Folkestad, 2003), and has probably increased since.

The white-tailed eagle is territorial, monogamous and pairs up to establish territories at an age of about 5 years. Adult pairs are sedentary throughout the year, holding onto specific territories for their lifetime (Cramp, 1980; Fischer, 1982).

2.2. Study area

Data were collected in the Smøla archipelago on the outermost coast of Møre & Romsdal county, Norway (63°24′N, 8°00′E) (Fig. 1). The archipelago consists of a large main island surrounded by more than 5500 smaller islands, islets and skerries. The total land area is 274 km^2, and the coastline length of the archipelago is 1913 km. The landscape on the main island is characterized by heather moors with some extensive blanket bogs and a few rocky outcrops. The main island is flat, the highest peak being 64 m, and there are only small patches of trees, mainly introduced Sitka spruce (*Picea sitchens*). Most white-tailed eagle nests in the archipelago are placed on flat ground or small outcrops, a few in trees. The human population of the island is about 2000, and most of the inhabited areas are close to the sea.

The archipelago supports a white-tailed eagle population breeding at a very high density (Follestad et al., 1999), an important reason for the island's status as an Important Bird Area, IBA (Heath and Evans, 2000). In 2002, the largest Norwegian energy company (Statkraft) began construction of a large-scale wind power plant on Smøla. The power plant consists of 68 turbines covering a formerly undisturbed area of 18.1 km^2, and was constructed in two stages. The first stage had 20 turbines, with an installed capacity of 40 MW, and was operating from September 2002. The second stage, an additional 48 turbines with an installed capacity of 110 MW, was in operation from August 2005, making the total installed capacity 150 MW. The power plant has a yearly average power production of 450 GWh. In addition to the turbines themselves, the power plant holds an extensive infrastructure with a power station, 14.7 km of power lines and 28 km of roads connecting the turbines (Statkraft, 2008).

2.3. Data collection

During 1997–2009 all known white-tailed eagle territories in the Smøla archipelago were monitored. A nesting territory was defined as an area that contained one or more nests within the home range of a pair of mated birds (Steenhof and Newton, 2007). An occupied territory was defined based on observations such as the presence of adult pairs and nests in use or newly fledged chicks (Oehme, 2003). There was considerable variation in the number of nest sites used within the territories of eagle pairs during the study period. Some pairs used only one single nest while other pairs used up to five different nest sites during the 13-year period. A nest was defined as used when it contained fresh twigs, fresh grass, eggshells, eggs or ultimately chicks. Breeding was categorized as either successful or unsuccessful. A successful breeding was recorded when one or more large nestlings were observed at the nest.

Each territory and every nest site were visited at least once a year between hatching and fledging, and all territories were checked late in the breeding season to determine breeding outcome. In addition, new territories and nest sites were actively searched for. Activity in the territories, ranging from no activity to young in the nest, was recorded. The distances from all nest sites to the nearest wind turbine, as well as to the nearest road, were determined using the function Near in ArcGIS- ArcInfo (version 9.3, ESRI, USA). The distance to roads was used as an indicator of human disturbance in addition to the wind turbines (Martinez-Abrain et al., 2010).

The spatial distribution of eagle territories on Smøla is complex, and a number of pairs breed in the archipelago surrounding the main island. These pairs are likely to be more influenced by other factors, such as other human traffic (boats), and less from distance from the wind turbines and the distance to roads. They are therefore excluded from the analyses to minimize effects of environmental variables not related to the main objectives of the study. Thus, only pairs breeding on the main island were included in the analyses (Fig. 1).

2.4. Statistical analyses

Two separate datasets were analyzed; one including territories from the year they were confirmed established until they were confirmed deserted (i.e. only occupied territories). In the second dataset, territories were included from the year they were established and onwards throughout the study period, regardless of whether or when they later were deserted or not. This separation was done to investigate if any possible effect was due to a change in breeding success among occupied territories or due to territories being vacated.