Avian collision risk at an offshore wind farm

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We have been the first to investigate whether long-lived geese and ducks can detect and avoid a large offshore wind farm by tracking their diurnal migration patterns with radar. We found that the percentage of flocks entering the wind farm area decreased significantly (by a factor 4.5) from pre-construction to initial operation. At night, migrating flocks were more prone to enter the wind farm but counteracted the higher risk of collision in the dark by increasing their distance from individual turbines and flying in the corridors between turbines. Overall, less than 1% of the ducks and geese migrated close enough to the turbines to be at any risk of collision.

Keywords: migration; radar; wind turbines; avoidance; collision; waterbirds

1. INTRODUCTION

Since the early 1990s marine wind farms have become a reality (Larsson 1994), and no fewer than 13 000 offshore wind turbines are currently proposed in European waters. At present, two large offshore wind farms operate in Denmark, one of which was the focus of the present radar study. Here, hundreds of thousands of waterbirds migrate annually between breeding and wintering grounds, and there is great public concern about the risk of bird–turbine collisions. The assessments to date of wind turbine collision risk for birds have mostly been conducted on land (Garthe & Hüppop 2004), and offshore investigations are expensive. However, the risk of collision at sea needs to be investigated as well, not in the least because long-lived waterbird populations are especially sensitive to additional mortality (Sether & Bakke 2000). To help address this, we have investigated the avian avoidance response to offshore wind turbines in order to assess the risk of collisions.

2. MATERIAL AND METHODS

This study was conducted at the Nysted offshore wind farm (160 MW) situated in the western part of the Baltic Sea, offshore from southern Denmark. The 72 turbines (each 2.3 MW; blade length: 41 m; hub height: 69 m; red lights or red flashing lights on edge turbines) mounted on the nacelle top) are placed in eight rows of 12 turbines, each 480 m apart. The flight trajectories of migrating waterbirds were mapped by the use of a surveillance radar (Furuno FR2125, peak power 25 kW, variable pulse length/volume 0.3–1.2 μs, pulse repeat frequency 9410±30 MHz, vertical beam width 20°, monitor resolution 1280×1024 pixels where each pixel represents a square of 23×23 m) mounted at an 8 m high observation tower situated 5.6 km northeast of the wind farm. Radar range was set to 11 km. There was a shading at an 8 m high observation tower situated 5.6 km northeast of pixels where each pixel represents a square of 23 × 23 m.

The assessments to date of wind turbine collision risk have been shown to be consistent irrespective of various crosswind conditions (Kahlert et al. 2004). The proportion of flocks entering the wind farm if they crossed either transect C, between transect B, C or D (see below) were included (transects A–D are depicted in figure 3 in the Electronic Appendix). Flocks were defined as entering the wind farm if they crossed transect B, situated along the eastern edge of turbines. Flocks defined as not encountering the wind farm if they crossed either transect C, between the northern corner of the wind farm and the radar platform, or transect D, between the southeastern corner of the wind farm and the northern end of transect A. The avoidance response has previously been shown to be a small but significant difference between geese and common eiders in their ability to migrate along straight lines. In order to compare situations with good and poor visibility only, the data collected during daylight were excluded from the analysis. Night was defined as the period from 2 h after sunset to 2 h before sunrise, and day as the period from sunrise to sunset. During daylight the birds were most probably responding to the turbines themselves, and at night to the red warning lights. For the proportion analysis, only flocks passing both transect A (11 km long, oriented parallel to the eastern row of turbines and 5.3 km from these) due south of the radar platform and either transect B, C or D (see below) were included (transects A–D are depicted in figure 3 in the Electronic Appendix). Flocks were defined as entering the wind farm if they crossed transect B, situated along the eastern row of turbines. Flocks were defined as not encountering the wind farm if they crossed either transect C, between the north-eastern corner of the wind farm and the radar platform, or transect D, between the southeastern corner of the wind farm and the southern end of transect A. The avoidance response has previously been shown to be a small but significant difference between geese and common eiders in their ability to migrate along straight lines.

3. RESULTS

By tracking the spatial migration pattern of waterbirds by radar (figure 1) we found that the diurnal percentage of flocks entering the wind farm area decreased significantly (by a factor 4.5) from pre-construction to initial operation. At night, 13.8% of flocks entered the area of the initially operating turbines, but only 6.5% of those flew closer than 50 m to turbines. During the day, over the same period, these figures were 4.5 and 12.3%, respectively. This means, ceteris paribus, that only 0.9% of the night migrants and 0.6% of the day migrants flew close enough to the turbines to be at risk of colliding with the turbines.

The proportion of flocks (P_{day & night}) entering the wind farm (Kahlert et al. 2004) decreased significantly from 40.4% (n = 1406) during pre-construction (2000–2002) to 8.9% (n = 779) during initial operation (2003; χ^2 = 239.9, p < 0.001). P_{night} was significantly higher compared with P_{day} (13.8%; n = 289 and 4.5%; n = 378, respectively; χ^2 = 17.1, p < 0.001).
The cumulated frequency distribution, $F_N(x)$, of the distances between bird flocks and the nearest turbine when passing the north–south oriented rows of turbines was significantly different from an evenly distributed migration pattern both during day- and night-time (figure 2; Kolmogorov–Smirnov one-sample test; $D=0.0846$, $n=260$, $p<0.05$ and $D=0.1775$, $n=400$, $p<0.01$ for day and night, respectively). Finally, birds migrated significantly closer to individual turbines during the daytime than at night (Kolmogorov–Smirnov two-sample two-tailed test, $D=0.1273$, $n_{\text{day}}=260$, $n_{\text{night}}=400$, d.f.$=2$, $p<0.05$; figure 1). Mean flock sizes (95% confidence intervals) on log-transformed data of common eider and geese for autumn 2003 were 14.6 (13.3–16.2) and 7.7 (5.8–10.4), respectively. As the species-specific distributions of flock sizes differed markedly from normal distributions, log-transformation of data was undertaken when calculating the mean flock size and the 95% confidence intervals. This approach is generally less sensitive to extreme observations of very large flocks, which may occur at a very low frequency, compared to calculation of simple averages.

4. DISCUSSION

To date, 14 marine wind farms (in total 213 turbines) are in operation around the world (five in Denmark, three in Sweden, two in the Dutch IJsselmeer and two in the UK). However, few have provided adequate case studies upon which to base the current advice relating to the impacts of offshore wind farms on birds. The present radar study documents a substantial avoidance response by migrating waterbirds to a large offshore wind farm. A larger proportion of the birds fly within the wind farm at night- compared with daytime, but counteract this higher risk of colliding with the turbines in the dark by remaining at a greater distance from the individual turbines. Overall, less than 1% of the ducks and geese fly close enough to the turbines to be at any risk of collision. To date, the avian avoidance factor has never been implemented in models for estimating the number of bird-turbine collisions. Our findings stress the importance of
applying the avoidance factor when dealing with wind farm-related mortality.

These estimates of potential collision risk are over-inflated since those bird flocks migrating within the horizontal reach of the turbine blades may actually fly below or above, or fly unharmed through the turbine’s sweep area (Tucker 1996). Quantification of these altitude options will be addressed in subsequent research. Caution should be taken, though, since this study covers one year of initial operation only and has focused on waterbirds (mainly geese and common eiders). During the initial operation, frequent visits of maintenance vessels may have influenced the avian avoidance response to the sweeping turbines in an uncertain way. Before solid conclusions can be reached, complementary studies at other sites are needed to confirm these findings, to include possible habituation behaviour over the years to come, and to cover other focal species such as divers (Gavia sp.) and common scoter (Melanitta nigra).

These findings also stress that the agenda for future environmental impact assessments should change. Rather than focus only on possible local catastrophe, efforts should also be made to assess the cumulative impacts of small-scale local effects on the different geographically defined avian populations. Such an approach necessitates collaboration among scientists, reflecting that the preservation of migrating birds is, by its nature, an international effort.

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