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Bird collisions at wind turbines in a mountainous area related to bird movement intensities measured by radar

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ABSTRACT

Bird collisions at wind turbines are perceived to be an important conservation issue. To determine mitigation actions such as temporary shutdown of wind turbines when bird movement intensities are high, knowledge of the relationship between the number of birds crossing an area and the number of collisions is essential. Our aim was to combine radar data on bird movement intensities with collision data from a systematic carcass search.

We used a dedicated bird radar, located near a wind farm in a mountainous area, to continuously record bird movement intensities from February to mid-November 2015. In addition, we searched the ground below three wind turbines (Enercon E-82) for carcasses on 85 dates and considered three established correction factors to extrapolate the number of collisions.

The extrapolated number of collisions was 20.7 birds/wind turbine (CI-95%: 14.3–29.6) for 8.5 months. Nocturnally migrating passerines, especially kinglets (*Regulus* sp.), represented 55% of the fatalities. 2.1% of the birds theoretically exposed to a collision (measured by radar at the height of the wind turbines) were effectively colliding.

Collisions mainly occurred during migration and affected primarily nocturnal migrants. It was not possible to assign the fatalities doubtlessly to events with strong migration. Fresh-looking carcasses were found after nights with both strong and weak bird movement intensities, indicating fatalities are not restricted to mass movement events (onshore). Rather, it is likely that an important factor influencing collision risk is limited visibility due to weather conditions. Local and regional visibility should be considered in future studies and when fine-tuning shutdown systems for wind turbines.

1. Introduction

Over the past 15 years, wind power installations have increased steadily across Europe (EWEA European Wind Energy Association, 2016). Due to the greenhouse gas reduction target 2020 (European Commission, 2010), this increasing trend will likely continue in coming years, as wind energy is renewable and CO_2-neutral. Negative impacts of conventional industrial wind turbines on avifauna are widely discussed and of global concern (Dai et al., 2015; Wang et al., 2015; Smith and Dwyer, 2016). The topic of bird collisions at wind turbines is considered to be of particular importance, as is the assessment of potential mitigation measures (Marques et al., 2014; May et al., 2015; Smith and Dwyer, 2016).

The temporary shutdown of wind turbines during high bird movement intensities might be an option to reduce the collision risk (Liechti et al., 2013). To define mitigation actions within the framework of approval processes for wind energy developments, the relationship between the number of birds crossing an area and the number of collisions must be known. Furthermore, knowledge about this relationship might improve siting of wind farms in general, which again decreases the number of necessary shut-down events. An investigation of the relationship between the number of birds crossing an area and the number of collisions requires continuous, quantitative data on diurnal and nocturnal bird movements within the height interval of the wind turbines as well as simultaneous monitoring of collision victims. Radar systems are suitable to record bird movement intensities continuously during day and night (Eastwood, 1967; Bruderer, 1997a, 1997b). However, estimates of absolute intensities require radar systems calibrated for bird detection, taking into account the bird-size specific detection probability and surveyed volume (Schmaljohann et al., 2008). In addition, it must be assured that small birds like warblers are detected and distinguished from similar sized large insects.

For determining the number of bird collisions, carcass searches have to be systematic and numbers must be corrected for the detection probability, which depends on search efficiency, persistence time of carcasses and the probability of a carcass lying within the searched area

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(Korner-Nievergelt et al., 2015). The accuracy of a carcass search study increases with increasing frequency of searches, narrow transects and a large surveyed area. Collection and analysis of this type of continuous data is extremely labour-intensive and time-consuming. Up to now, published studies of seasonal and altitudinal distributions of bird movement intensities in relation to wind farms (Bruderer and Liechti, 2004) or of carcass searches including small birds are rare (Johnson et al., 2002; Grodsky et al., 2013; Hull et al., 2013; Grünkorn et al., 2016). Likewise, studies combining radar data with carcass searches are uncommon. Krijgsveld et al. (2009) and Welcker et al. (2017) made an approach into this direction but used radar systems with limited bird detection abilities, during a limited number of days.

The present study investigates the relationship between the number of flying birds at risk and the number of bird collisions at a wind farm location in the Swiss Jura mountains. The first aim was to estimate theoretical collision risk by monitoring the intensity of diurnal and nocturnal bird movements within and above the height interval of three nearby located wind turbines. The second aim was to simultaneously conduct a systematic carcass search with a high detection probability to achieve a reliable estimate of the true number of fatal collisions. The correction factors search efficiency and persistence time were experimentally determined by placing test carcasses of wild birds in the field. The third aim was to link the number of birds theoretically at risk with the estimated absolute number of collisions to determine a collision rate and to infer an avoidance rate, respectively. The results of this study will provide information critical to the discussion of bird collisions at wind turbines and potential mitigation measures. Additionally, the aspect of wind turbines in mountainous areas is addressed.

2. Methods

2.1. Study area

This study was conducted in the Jura Mountains of northwest Switzerland, in a region near the French border known as “Franches Montagnes”. The wind farm was erected in 2010 at “Le Peuchapatte” (47°12′N, 6°57′E) and consists of three wind turbines of the type Enercon E-82 E2/2.3 MW (Fig. 1) placed at altitudes between 1125 and 1180 m above sea level (asl, tower feet). The wind turbines are 600–700 m apart, placed along the axis of the main bird migration direction (about 230°, Bruderer and Liechti, 1990). The turbines have a rotor diameter of 80 m and a hub height of 108 m, resulting in a total height of nearly 150 m (including rotor blades). They are illuminated by a permanent red light at middle height of the tower and by a flashing red light on the hub. For 95% of the study duration, the turbines were rotating with at least 5 rounds per minute which is a rotor tip speed of at least 77 km/h. The landscape is hilly with a mosaic of forest and agricultural land (mainly grassland and pastures).

2.2. Radar investigation

2.2.1. Radar measurements, analysis and bird movement intensity

The radar system was located close to the farm “Le Roselet”, at 1050 m asl (47°13′28″N, 7°00′24″E), about 3.5 km northeast of the wind farm site, along the axis of the main bird migration direction. The radar location is about 100 m lower in elevation compared to the wind farm. This ensured that radar measurements were not significantly contaminated with ground clutter and were fully covering the height interval of the wind turbines. Based on a radar study conducted in the region 2010/2011 (mean values published in Liechti et al., 2013), we are confident that the bird movement intensity measured at “Le Roselet” corresponds to the general bird movement intensity of the region (broad front migration). Bird movements were recorded automatically and continuously between 26 February 2015 and 17 November 2015 (265 days) with a fixed-beam radar of the type BirdScanMT1 (Bruderer et al., 2012). General details on fixed-beam radar measurements are given in Komenda-Zehnder et al. (2010) and details specific to the study in the online Appendix A1.

Radar data were processed by tailor-made software. Extracted targets were classified automatically as birds or non-birds based on the maximum reflectivity and the temporal pattern of the reflectivity (echo signature). In the case of single flying birds the echo signature corresponds to wing-beat pattern (Zaugg et al., 2008; Bruderer et al., 2010). After separating birds from non-birds (mainly insects), hourly bird movement intensities per km (birds $* \mathrm{km}^{-1} * \mathrm{h}^{-1}$) were calculated for height intervals of 50 m up to a height of 2550 m above ground level (agl). Bird movement intensities are equivalent to migration traffic rates according to Schmaljohann et al. (2008), but additionally including non-migratory bird movements. They are defined as the number of birds crossing a virtual line of 1 km length per hour. For the calculation of bird movement intensities we took into account a size-class-specific detection probability and surveyed volume of the radar device (Schmaljohann et al., 2008). From the altitudinal distributions, we extracted the number of birds flying within the height range of the wind turbines. During the day, birds often aggregate in flocks, which are represented as a single echo in radar data. Therefore, the diurnal bird movement intensity values should be considered as the minimum number of birds flying at a given time (Bruderer, 1997a). The time of civil twilight was used to distinguish between diurnal and nocturnal bird movement intensities.

2.2.2. Theoretical number of birds exposed to collisions

To calculate the theoretical number of birds exposed to collisions, we first estimated the number of birds flying across a virtual window 200 m in height and 1 km in width (Fig. 2), situated within the altitudinal range of the wind turbines (1150 to 1350 m asl). We then calculated the proportion of this area covered by one wind turbine, which included the surface area of the three rotor blades (not the swept area) plus the part of the tower protruding above the trees. Together, this constituted an area of roughly 500 m^2 and corresponded to 0.25% of the total area of the virtual window. Assuming that birds crossed this virtual window area randomly distributed, did not show any avoidance behaviour and were able to pass through the space between the rotor blades unoffended, 0.25% of the birds would theoretically be exposed to collisions. We expect this to be the minimum theoretical number of birds exposed to a collision risk; mainly because diurnal bird numbers are minimum numbers (see Section 2.2.1).

2.2.3. Carcass search, ground cover and X-ray analysis

We searched the ground below all three wind turbines for carcasses on 85 days between March 1, 2015 and November 15, 2015. On average a search was done every 2.8 days with search intervals of 2–7 days (online appendix A2). For carcass searches, it is recommended (Gauthreaux, 1996; Hull and Muir, 2010) and common (Johnson et al., 2002; Krijgsveld et al., 2009; Grodsky et al., 2013) to consider an area within a radius that is roughly equivalent to the total height of a wind turbine (in our case 140 m). When searching the entire recommended area is not possible due to not searchable ground cover (e.g. forest, shrubs) or financial constraints, collision calculations need to be corrected for the area not searched by considering the probability of a carcass lying within the searched area. Our searches covered a radius of 100 m (69 dates) or of 50 m (16 dates, online Appendix A2).and so the area not included in the search (up to 140 m), was considered afterwards in the analysis to calculate the correction factor “probability of a carcass lying within the searched area” (see Section 2.2.4). All searches were conducted by the same two observers, each on alternate days. For each search, one observer walked along parallel transects spaced 5 m apart below all three wind turbines during one day. The length of the transects underneath all three wind turbines summed up to a distance of about 15 km (100 m radius) and about 4.8 km (50 m radius), respectively.

80% of the searched area (radius 100 m) was grassland. The