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A study of White-tailed Eagle *Haliaeetus albicilla* movements and mortality at a wind farm in Norway

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The wind power plant on the island of Smøla, western Norway, is currently the largest in Norway; it has 68 turbines with nominal capacity of 2–2.3 MW each, hub height of 70 m and rotor blade radius of 38–41 m,. It was constructed in two phases between 2001 and 2005. Approximately 60 White-tailed Eagle *Haliaeetus albicilla* territories are found in the whole Smøla archipelago. Before construction there were 13 Eagle pairs holding territories in the wind farm area and within 500 m of it, whereas in 2009 this was reduced to only five. Since 1996, baseline data on the White-tailed Eagle population size and reproduction have been collected.

In a post-construction study, 50 fledglings were satellite-tagged during 2003–2009, of which 45 provided more than 80 000 GPS positions in total. In addition to the geographical location, data on altitude and flight speed were provided by the transmitters (Microwave Telemetry, Inc., Columbia, MD, USA). Juveniles of both sexes stayed within the Smøla archipelago during their first winter. Most individuals moved away from the area during spring in their second year (April–May). Females dispersed further than males, often more than 800 km during summer, generally to the north. There was a return movement to the natal area during the second autumn. The same pattern was repeated in the third and fourth years for females, while the males showed more philopatry (Bevanger *et al*., 2009).

From August 2005 to May 2010, four of the satellite-tagged birds were killed by collisions with turbines, of 36 White-tailed Eagles in total, involving 20 adults, nine immatures and seven juveniles. April and May are the months with the highest collision frequencies, with 13 (*c*. 36%) and nine (*c*. 25%) of the known fatalities.

Risk assessments were performed based on GPS positions during the different months of the year and the age of the birds. The transmitters were programmed to transmit their positions at different intervals. Long time intervals (up to 24 h) were used during winter, 3–6 h during spring and autumn, and 1–3 h during summer. An analysis of moves showed that the birds changed positions on average 15 times per day, using a 100-m difference between positions as an indicator of movement. Every change in position was considered to involve a collision risk when the birds were at Smøla and its archipelago. Moves when they were elsewhere were not considered. Monthly 95 and 50% utilization distributions (UDs) (Worton 1989) were produced using the positions from the Smøla archipelago only, with all birds in each month and age-class pooled. The expected number of moves by each bird was estimated by weighing the number of obtained positions by a factor equal to 15 divided by the pre-programmed number of positions taken for each transmitter and month. The total number of expected moves (M_e) was then obtained by summing over all birds for each calendar year and month. Kernel UD (95 and 50%) areas by calendar year and month (A_{k95} and A_{k50}) were produced via ArcView 3.3, by using cross-validation and the default smoothing factors. The total rotor-swept area (RSA) (A_{t95} and A_{t50}) of turbines that overlapped each kernel area was found by multiplying the number of turbines by the RSA (r^2, where r is the radius of the rotor-blades). The probability of each position being within an RSA was then calculated as A_{t95}/A_{k95} and A_{t50}/A_{k50} for each calendar year and month. The expected number of positions within an RSA was then calculated as M_e*0.95 A_t/A_k and M_e*0.5 A_t/A_k for the 95 and 50% kernel areas, respectively, for each calendar year and month.

Based on information from 34 birds for which the altitude was known (birds in their nests), a standard deviation of altitude of 7.8 m was found. This was considered sufficient to produce an estimate of the fraction of the flights within rotor height. Using only the data from positions when the birds were assumed to be flying (speed > 0), we found that on average 24% of the flights in the wind farm were within rotor height. Calculations with and without this figure as an adjustment factor were used. Figure 1 shows the expected number of positions within an RSA per calendar year and month based on 95 and 50% UDs, and the number of actual kills of tagged birds was registered.

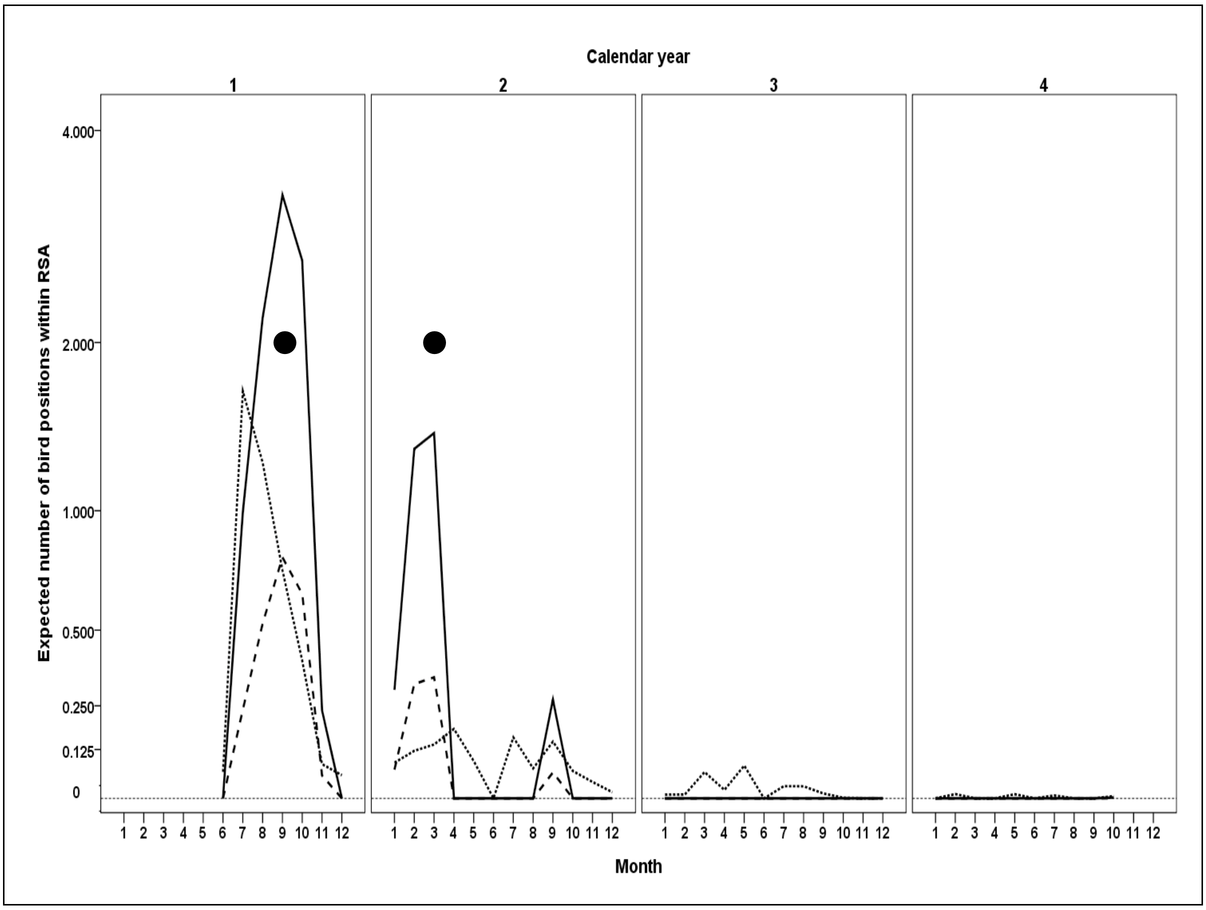

Figure 1. The expected number of positions of satellite-tagged young White-tailed Eagles within the rotor-swept area at Smøla wind farm by calendar year and month. Calculations were based on 50% kernel UDs (unadjusted for altitude = solid line, adjusted = open dashed line) and 95% kernel UDs adjusted for altitude (= densely dashed line). Actual recorded kills of tagged birds are shown as black dots. Note that the number of birds with working tags is decreasing with age, so the graph does not indicate individual risk rate over time.

The method seems to be able to correctly identify the periods of the year and age-classes associated with the greatest hazard rate, judged from the recorded casualties. Calculations based on the unadjusted 50% UDs seemed to be the best predictor. It is worth noting that no avoidance rate was assumed, and that no adults were included.

The widely used Band method for collision risk assessment (Band *et al.* 2007) is often used in conjunction with an avoidance factor based on observations and recorded kills. We did not attempt to calculate an avoidance rate, as sufficient observational data from the field were not available. Furthermore, the number of moves per day was based on estimations, and any movement may involve a combination of circling and directional flight at different altitudes, and could involve risks connected with several of the 68 turbines. One should also bear in mind that the studied birds had an affinity to the area, being their natal place. Thus, our findings are probably only typical to juvenile White-tailed Eagles relatively close to their natal area; nevertheless, they are relevant for large parts of the Norwegian coast. Displacement was probably negligible or small in our case, as all birds were born within or close to the wind farm. On this basis, we suggest that the proposed avoidance rate proposed for Golden Eagles *Aquila chrysaetos* (*c.* 99%) at other wind farms (Whitfield 2009) is not applicable to White-tailed Eagles in connection with wind farms close to their breeding-sites. We are currently developing other risk assessment methods based on GPS position data using the method of 'Brownian bridges' (May and Nygård, 2009) and by using ground-truthed bird radar tracks.

Studies on Smøla have shown that White-tailed Eagles seem to use the air space inside and outside the wind farm area similarly (Hoel, 2009). Several observers have noted that White-tailed Eagles at Smøla often circle close to and around turbines, possibly induced by the extra wind energy created by the turbulence. The satellite-tagged victims were either killed in the first autumn (two in September) or in the following spring (two in April). The first autumn incidents may be influenced by lack of agility and experience, their naivety making them more prone to collisions. The incidents during spring in their second calendar year coincide with an overall greater turbine-related mortality rate during spring of all age-classes, possibly caused by increased territorial activity and good thermal conditions.

A Kaplan–Meier survival analysis showed that the additional mortality caused by the wind farm at Smøla was *c.* 10%, reducing the cumulative survival through their third year of life from 0.84 to 0.74. A full population model including adults is now under way, involving the use of DNA analysis of moulted feathers from nesting pairs to estimate adult turnover rates.

References

Band, W., Madders, M. & Whitfield, D.P. 2007. Developing field and analytical methods to assess avian collision risk at wind farms. In: de Lucas, M., Janss, G.F.E. & Ferrer, M. (eds) *Birds and Wind Farms. Risk Assessment and Mitigation:* 259–275. Madrid: Servicios Informativos Ambientales/Quercus.

Bevanger, K., Berntsen, F., Clausen, S., Dahl, E.L., Flagstad, Ø., Follestad, A., Halley, D., Hanssen, F., Hoel, P.L., Johnsen, L., Kvaløy, P., May, R., Nygård, T., Pedersen, H.C., Reitan, O., Steinheim, Y. & Vang, R. 2009. Pre- and post-construction studies of conflicts between birds and wind turbines in coastal Norway (BirdWind). Progress Report 2009. In *NINA Report.* 505. Trondheim: Norsk institutt for naturforskning.

Hoel, P.L. 2009. *Do wind power developments affect the behaviour of White Tailed Sea Eagles on Smøla?* Master of science thesis, Department of Biotechnology, Norwegian University of Science and Technology, Trondheim.

May, R. & Nygård, T. 2009. Spatial assessment of white-tailed sea eagle collision risk at the onshore wind-power plant on the island of Smøla. In: *2nd European Congress of Conservation Biology. Conservation biology and beyond: from science to practice.* Czech University of Life Sciences, Prague. http://www.eccb2009.org/uploads/book_of_abstracts_errata.pdf

Whitfield, D.P. 2009. *Collision avoidance of Golden Eagles at wind farms under the 'Band' collision risk model.* Banchory, UK: Natural Research, Ltd.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. *Ecology* 70: 164–168.

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