highly skewed, and it was necessary to apply a log transformation to these response variables. We used the *logst* transformation in the R package *regr0* (8), which is equivalent to a $\log_{10}$ transformation for all but the smallest values, which are scaled such that the transformation yields all finite values. We chose this option because, unlike adding an arbitrary constant value to all observations, this method of scaling small values is determined by the distribution of the data. It only modifies the smallest observations, leaving all others unchanged. For models with log-transformed response variables, we express effect size as a multiplicative factor, found by exponentiating the coefficient.

In addition to testing for average differences in bird numbers between light and dark periods over the entire night, we looked at changes in peak concentrations between periods. We compared measurements made during periods of darkness (up to 30 minutes in duration) to those made during adjacent 30-minute illuminated periods. In each period, we found the maximum values of standardized peak density and total number of birds for both 0.5° and 1.5° sweeps. We constructed linear models as above, but without smooth terms because autocorrelation was not an issue. Again, we tested for the best of three possible models using AIC. We log-transformed response variables to satisfy model assumptions.

Figures were produced using the R packages *lattice* (9), *Hmisc* (10), *ggplot2* (11), and *cowplot* (12).

Simulations. We defined our simulations with the following assumptions. A bird in the migratory state could fly undisturbed in an average preferred migratory direction. Birds enter the disoriented state following a normal probability distribution *f* (see Fig. S8*A*) that decreases with distance (*d*) from the light.

$$f(d \mid a, \sigma) = a e^{-\frac{d^2}{2\sigma^2}} \tag{1}$$

Here, *a* is the model parameter specifying the maximum probability to disorient when a bird is within (or very near) the lights. The standard deviation (σ) specifies the characteristic distance from the light at which birds become disoriented. In the disoriented state, birds depart from their preferred migratory direction and draw their flight direction from circular normal distribution *g* (von Mises distribution, see Fig. S8*B*):

$$g(\alpha|\alpha_{\text{light}}, \kappa) = \frac{e^{\kappa \cos(\alpha - \alpha_{\text{light}})}}{2\pi I_0(\kappa)} \tag{2}$$

with α_{light} the angular direction of the lights at the position of the bird, I_0 the modified Bessel function of order 0, and κ the concentration parameter. When $\kappa = 0$ the function g is uniform, and birds' flight paths follow a random walk. When $\kappa > 0$ there is a preferential flight direction towards the lights, with larger κ implying a more directed flight towards the light source.

The simulation model thus has three main parameters

- *a*, the probability of disorientation
- κ, the concentration parameter for disoriented flight, determining the extent to which birds fly towards ALAN when disoriented
- σ, the characteristic distance from the lights within which ALAN affects bird behaviors

The simulation grid had a 5 x 5 km extent, with grid cells of 50 x 50 m. The simulation time step Δt = 10 s. In each simulation step, we determined the proportion of birds in that cell affected by ALAN using Equation (1). We propagated these disoriented birds over a distance Δt v_{bird} into directions given by the angular distribution of Equation (2). We propagated the remaining birds in the migratory state over an equal distance into the preferred migratory direction.

Model parameters were fit to the radar observations in years 2010, 2012, 2013, 2015 and 2016, when lights were manipulated. Simulations were performed on the basis of lights-on periods, in which we assumed the baseline migration density and speed to be constant. The baseline migration ground speed v_{bird} was calculated at the location of KOKX, using a vertical profile extraction following the methods of (13). The baseline migration density was calculated as the average bird density in the area 2-20 km distance from the installation, assuming a cross-section per bird of 8.1 cm^2. The peak density at the installation for each radar scan was calculated as the maximum density observed within 500 m of the installation. The frame of reference is rotated such that the birds' migratory directions were upward towards the lights, located in the center of the simulation grid. We excluded the first lights-on period after sunset, as bird densities change rapidly in this time window, and to not be affected by potentially different behavior during takeoff or when it is not fully dark. This gave 20 lights-on periods in total for the 5 years.

The model was fit by an exhaustive search in the model parameter space, considering a=0.25-0.98 (steps of 0.1), κ=0-0.8 (steps of 0.1), and σ=250-2000 m (steps of 250 m). All possible combinations of parameter values were tested in separate model runs coded in Wolfram Mathematica 11, requiring ≈12 days of CPU time on a