Appendix #2

Statistical analysis

Analysis of flight directions
Circular data analysis were done using the R package circular 0.4-93 (Agostinelli and Lund 2017). To display the central tendency of the raw data for flight directions, the circular median is preferable to the circular mean as it is less affected by outliers (Otieno and Anderson-Cook 2006). However, for statistical comparisons of changes in flight direction over the night for each of the 12 azimuthal points, we calculated the circular mean; the 95% confidence intervals (CI) of these means, each generated with 9999 bootstrap replicates using the parameter of a vonMises distribution. If the 95% CIs excluded 0°, we concluded we had evidence of a change of flight direction during the night (no change [Pewsey et al. 2013]). The tests were conducted for paired-samples only at locations with sufficient data for ≥ 5 nights.

Raw nightly observations of flight directions
The raw nightly observations of flight directions measured at 40 km range are also presented in circular plots separately for each radar and each season, at the four azimuthal points, to show the distribution and variation in flight patterns among nights.

Circular statistics summaries on flight directions
We computed the median and the mean deviation for the median, the skewness and the kurtosis along with their 95% bootstrap CIs using R code found in Pewsey et al. (2013; chapter 5), and compared them using the test of common medians (Fisher’s nonparametric test) and the test of common distributions (large-sample Mardia-Watson-Wheeler test) with the R code in Pewsey et al. (2013; chapter 7).

Comparing bird density between radars
We calculated the mean bird density η at each radar, night and time. We used LMM to model the natural log of the mean bird density for which we had minimally data in n ≥ 10 blocks at each radar, night and time, against the fixed effects of radar and time of night (factorial) with their two-way interaction, and the random effect of night as a random intercept. Nights were weighted by the inverse of the variance in bird density η among blocks within each radar following meta-analysis principles. We fitted the models using the nlme 3.1-139 (Pinheiro et al. 2019), with its function ‘lme’ and a fixed variance structure (‘varFixed’) and the argument ‘lmeControl(sigma = 1)’
The estimated marginal means were computed with the R package `emmeans` 1.3.5.1 (Lenth 2019) with statistical contrasts calculated: 1) between radars within time and 2) between times within radar.

**Comparison of bird density within groups of blocks**

We compared bird density among blocks within each group to test whether densities varied over relatively short distances in relation to factors such as coastlines. We used LMM or GLMM, fitted separately by season and by radar to model bird density $\eta$ against the fixed effects group, block nested within group and time with their two- and three-way interactions, and the random effects of night with time as a random slope. Following Zuur et al. (2010), we initially fitted linear mixed effects models (LMM) to the natural log of bird density $\eta$, but if the model did not fit well, based on analyses of residuals, we then modelled raw bird density $\eta$ with a log link using generalized mixed effects models (GLMM), assuming either Gaussian or Gamma residuals, using a likelihood ratio test to determine which model was the best fit (Bolker et al. 2009, Faraway 2016). We used maps to display graphically the estimated marginal means of bird densities $\eta$ from the valid models, for each season and time within groups of blocks. The LMM and GLMM were fitted using the R package `lme4` 1.1-21 (Bates et al. 2015) and the residuals were extracted using the R package `broom` 0.5.2 (Robinson and Hayes 2019). The estimated marginal means were computed with the R package `rcompanion` 2.2.1 (Mangiafico 2019) and `emmeans` 1.3.5.1 (Lenth 2019) with statistical contrasts calculated: 1) between blocks within time and 2) between times within block.

**Comparison of bird density between paired-groups**

To test whether bird density varied at medium scales (i.e., 50 to 100 km) we compared densities between pairs of groups that were symmetrically opposed at similar angles on each side of a centered flight direction on a particular night and time. The centered flight direction was the azimuth of nearest maximum negative or positive velocity measurement on VAD and was allowed to vary of $\pm 15^\circ$. For these comparisons, we only used nights and times when both groups had data for at least 3 blocks and when the total paired-sample size was $\geq 5$ within each time. Either LMM or GLMM were fitted for each season and radar separately, using the same protocol as explained in the sections above. Models included fixed effects of group id and time (if there were sufficient data for both times in a pair), and random effects of night with a random intercept, and time as a random slope, if needed. The estimated marginal means were computed with the R package `emmeans` 1.3.5.1 (Lenth 2019) with statistical contrasts calculated between groups within time.
We performed contrasts at $\alpha = 0.05$ with a Tukey adjustment method, and used R 3.6.0 (R Development Core Team 2019) for all statistical analysis.
Litterature cited


