Supporting Information

High-intensity urban light installation dramatically alters nocturnal bird migration

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SI Methods

Study Site. Tribute in Light consists of two ground-based installations of lights, each comprising 44 7,000-8,000-watt xenon bulbs pointing skyward, giving the appearance of two tall towers of light. The bulbs have a dichroic treatment as well as nickel rhodium reflectors that significantly reduce infrared and ultraviolet spectra and create an effect similar to daylight. Beam projection and visibility is highly dependent on weather conditions, but the columns of light can project vertically from thousands of meters to tens of kilometers and are visible from distances up to 100 km.

At the time that the agreement for shutting down the installation in the presence of birds was developed, there was no information available about the dynamics of how birds arrive and depart the tribute site, nor was there information about how the installation affected behaviors. The shutdown process takes several minutes to complete because each bulb of the two 44-bulb installations must be turned off individually. Once dark, lights remained off for 22 ± 6 SD minutes. A dark period of approximately 20 minutes represented the best consensus among all stakeholders to balance potentially conflicting interests to maintain the integrity and intent of the event and to remove the attractive stimulus to birds, allowing them to depart from the area of potential hazard.

Weather Data. Weather data included details of temperature, visibility, wind direction and speed, and general conditions (Table S3) as well as more detailed cloud ceiling and cover aloft (Table S4). Clear skies prevailed among the 77 hourly LCD observations, with 66 of 77 hours (85.7%) exhibiting conditions described as clear or mostly clear skies. Local visibility never dropped below 11 km on any of our monitoring nights, and visibility of 16 km or greater occurred in 66 of 77 samples (87.5%). Visibility was at maximum (18.5 km) for 71 of 77 hours, with the remaining six hours never dropping below 13.0 km. Additionally, cloud cover was less than 50% for all but eight hours, generally 12.5% or less, and never below 0.5 km above the ground, mostly 0.5-1.5 km above the ground (Table S4). Thus, we did not classify any of these nights as poor visibility conditions.

Weather Surveillance Radar. In addition to the methods presented in the main text, a number of methodologies were important for our calculations of metrics describing the influence of the installation. To quantify the total number of birds affected by the installation, we estimated the number of birds within 5 km of the installation up to a height of 4.5 km using data from the 0.5° elevation angle and applying the correction factors described in the main text (Fig. S10). We did this for all radar scans across all years. The correction factors allowed us to estimate the total number of birds present from altitudes of 0-4.5 km given the number of birds detected in the 0.5° sweep. For comparison, we calculated the average bird density between 10-20 km from the installation and found the expected number of birds within 5 km of the installation, assuming densities were the same as those 10-20 km away. The difference between the expected number and the directly measured number was our estimate of the number of birds influenced by the installation in that radar scan. When the density of birds near the installation was lower than baseline, we set the number of birds affected to zero for that scan. Because our simulations (see below) provide information on the actual turnover time, we arrived at a total estimate that avoids double-counting birds by subsampling our dataset by a factor equal to the median time between radar scans (9.5 minutes) divided by the stabilization time estimate. For example, if the average turnover time is 20 minutes and the median time between radar scans is 10 minutes, we would subsample by a factor of 10/20 = 0.5, summing on average every other radar scan. To quantify uncertainty in our estimate, we calculated 95% confidence intervals by subsampling 10,000 times and finding the 0.025 and 0.975 quantiles of the resulting values.

We also analyzed data from the radar sweep with an elevation angle of ≈1.5°. This sweep intersects the airspace above the installation at an altitude of approximately 3.2 km (50% power range 2.4-4.1 km), twice as high as the 0.5° sweep. These altitudes are at the upper limit of bird migration, particularly passerines, in this region (e.g. 1, 2). Using the approach described in the main text, we calculated the number of birds in a cylinder of radius 0.5 km along the ground and height 1.7 km. We did not apply an additional multiplier.