High-intensity urban light installation dramatically alters nocturnal bird migration

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Edited by James A. Estes, University of California, Santa Cruz, CA, and approved August 31, 2017 (received for review May 29, 2017)

Billions of nocturnally migrating birds move through increasingly photopolluted skies, relying on cues for navigation and orientation that artificial light at night (ALAN) can impair. However, no studies have quantified avian responses to powerful ground-based light sources in urban areas. We studied effects of ALAN on migrating birds by monitoring the beams of the National September 11 Memorial & Museum's "Tribute in Light" in New York, quantifying behavioral responses with radar and acoustic sensors and modeling disorientation and attraction with simulations. This single light source induced significant behavioral alterations in birds, even in good visibility conditions, in this heavily photopolluted environment, and to altitudes up to 4 km. We estimate that the installation influenced ≈1.1 million birds during our study period of 7 d over 7 y. When the installation was illuminated, birds aggregated in high densities, decreased flight speeds, followed circular flight paths, and vocalized frequently. Simulations revealed a high probability of disorientation and subsequent attraction for nearby birds, and bird densities near the installation exceeded magnitudes 20 times greater than surrounding baseline densities during each year's observations. However, behavioral disruptions disappeared when lights were extinguished, suggesting that selective removal of light during nights with substantial bird migration is a viable strategy for minimizing potentially fatal interactions among ALAN, structures, and birds. Our results also highlight the value of additional studies describing behavioral patterns of nocturnally migrating birds in powerful lights in urban areas as well as conservation implications for such lighting installations.

artificial light | nocturnal migration | remote sensing | radar ornithology | flight calls

The extent of artificial light at night (ALAN) at regional and global scales has increased 5–10% annually in portions of North America and Europe and exponentially in some other regions (1), resulting in sky glow that is often significantly brighter than luminance of the natural sky. ALAN may affect a diverse array of nocturnally active animals, and recent studies have highlighted the need for primary research into these potential impacts (2, 3). The biological effects of anthropogenic light pollution may be especially significant for nocturnally migrating birds (2–6).

Birds engage in seasonal migrations that are often global in distribution and span a broad range of spatial and temporal scales (7, 8). Avian migratory movements are often thought of as feats of endurance; some species undertake days-long, nonstop, transhemispheric flights, while others embark on complex, months-long journeys (9). Failed migration may have detrimental effects at individual and population scales (10, 11). Despite birds' primarily diurnal activity for the majority of the annual cycle, most migratory movements are nocturnal (7, 8), and the numbers of birds that migrate at night are enormous (12, 13). Numerous studies have offered perspectives on factors that govern nocturnal movements (14–18) and insights into adaptations necessary to orient and navigate at night (19, 20).

Visual cues are essential for navigation during migration (21), and ALAN may alter birds' abilities to orient and navigate (22, 23). The avian geomagnetic sense, which provides songbirds with a compass to inform their spatial maps (19, 20, 24), may function with a dependency on frequencies of light, and ALAN may interfere with this dependency (25–28). Impediments to orientation and navigation senses may prove costly for avian migrants, creating new hazards during an already challenging and dynamic period of the annual cycle (29). Additionally, ALAN can alter the ways birds communicate (30) and avoid predation (31).

Accounts of birds' responses to light are numerous in literary and historical anecdotes, peer-reviewed journal articles, and popular media. Mortality at lighted structures has been documented across a wide geographic area and a broad range of species (4, 6, 32–44). It is likely that hundreds of millions of birds die annually from nocturnal collisions with buildings (29), representing a diverse array of migrant species (32, 33). Understanding the causes of these events is paramount; proposed explanations include that birds exhibit phototaxis and experience light-induced disorientation.

Generally, negative impacts of ALAN for birds in flight have been associated with conditions that are already poor for navigation and orientation, such as low cloud ceiling, fog, and stalled or weak frontal boundaries between air masses (34–39, 43, 45–48). Experimental field studies are generally rare (22, 26, 49–51) and offer limited evidence of the extent and intensity of ALAN's effects on nocturnally migrating birds, particularly with respect to

Significance

Artificial light at night is a novel stimulus in the evolutionary history of nocturnal animals. Light pollution can significantly alter these organisms' behaviors, from migration to foraging to vocal communication. Nocturnally migrating birds are particularly susceptible to artificial light because of adaptations and requirements for navigating and orienting in darkness. However, light's effects on in-flight behaviors have not been well quantified, especially in urbanized environments. Here we report that an iconic urban light installation dramatically altered multiple behaviors of nocturnally migrating birds—but these effects disappeared when lights were extinguished. We recommend selective removal of light pollution during nights with substantial bird migration to mitigate negative effects on birds, in particular collisions with lighted structures.

Author contributions: A.F. developed the study, collected visual observations and weather data, and wrote the paper; B.M.V.D. shaped the study, performed statistical analyses, and contributed to writing the paper; K.G.H. analyzed radar data and contributed to writing the paper; B.M.V.D. and K.G.H. generated figures and animations; A.M.D. developed simulations and produced associated figures and text; H.K. performed acoustic energy analysis; H.K. and A.F. analyzed acoustic data; S.B.E. provided bird mortality data, provided coordination, support, and access to the study site.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Data deposition: All visual counts made at Tribute in Light are archived in the eBird database at ebird.org/ebird/hotspot/L1744278.

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This article contains supporting information online at www.pnas.org/lookup/suppl/doi:10.1073/pnas.1708574114/-/DCSupplemental.