# Light, Glass, and Bird–building Collisions in an Urban Park

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**Abstract**–Building collisions are a significant threat to birds in North America, and urban areas can be particularly hazardous to birds using city parks as stopover habitat. We examined the effects of light and glass on bird–building collisions in an urban park using New York City Audubon's collision-monitoring data from fall migration 2013 and photographic analysis of building facades. We found a significant positive relationship between the number of collisions and interior building light (*rho* = 1); however, the amount of light was strongly correlated with the amount of glass in building facades ($r^2 = 0.82$). Carcass persistence at the site was examined using tagged, dead birds. Only 37 percent of carcasses were found by our monitors, suggesting that our estimate of bird mortality due to collisions has been too conservative. The amount of glass on a building facade may have an equal or greater effect on bird–building collisions than the amount of light emitted from the facade. Mitigation of both light and glass are needed to reduce bird–building collisions in urban areas.

## Introduction

Collisions with structures in the built environment are a significant source of bird mortality in North America. Loss et al. (2014) conservatively estimated that between 365 and 988 million birds die per year in North America because of collisions with buildings. Building-collision mortality is second only to predation by *Felis catus* L. (Domestic Cat) (1.4–3.7 billion bird deaths each year) as a source of anthropogenic causes of avian mortality (Loss et al. 2013, 2014). As urbanized areas continue to expand, 2 major threats to birds are artificial light and glass.

Birds that migrate at night are attracted to the lights on structures such as communication towers and tall buildings, especially on nights with fog or low cloud-ceilings (Avery et al. 1976, Erickson et al. 2005, Kerlinger 2000, Larkin and Frase 1988, Manville 2000). Once attracted by lights, birds may become disoriented, and, once inside a lighted area, continue to fly in it as if trapped (Avery et al. 1976, Graber 1968, Larkin and Frase 1988). These "trapped" birds can collide with the lighted structures, may be at a higher risk of predation, or can drop to the ground from exhaustion (Avery et al. 1976, Erickson et al. 2005, Evans Ogden 1996, Graber 1968, Stoddard and Norris 1967).

Daytime collisions with buildings have killed individuals from 225 different species in North America, which is 25% of all North American species (Klem 2006). Glass can act as a mirror, and birds may fly into windows to reach perceived images reflected in the glass (Klem 2007, 2009). Once a bird collides with a window or building, death usually occurs from brain hemorrhage (Klem 1990a, 1990b;

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Veltri and Klem 2005), and stunned birds that do not die immediately are at risk of predation (Graham 1997, Klem 1990b, Klem et. al. 2004). The peak numbers of bird strikes in urban areas occur during the time of spring and fall migration, with significantly more deaths occurring in the fall than in the spring (Borden et al. 2010, Gelb and Delacretaz 2006).

Urban parks can provide stopover habitat for birds migrating through cities (Fowle and Kerlinger 2001, Seewagen and Slayton 2008, Seewagen et. al. 2010). Because they are attracted to the natural areas, birds are more likely to encounter windows and buildings that are adjacent to parks and open space, increasing the risks posed by light and glass in such areas, but only a handful of studies have examined the drivers of bird collisions in highly urbanized settings like New York City. Several authors have concluded that nighttime lighting is the driver of collisions in urban areas, but others have shown data to support that reflective glass is the major risk factor in bird collisions. Evans Ogden (2002) and Lights Out Columbus (2012) found significant correlations between bird collisions and nighttime lighting but not the size of the building or number of floors. However, neither of these studies took into account that the amount of nighttime light in a building may be a function of the amount of glass in the building facade, which might reduce the validity of their conclusions and point to glass as the main driver of bird collisions in urban areas. In NYC, bird–building collisions most often occur in the morning hours, as opposed to nightime (DeCandido 2005, Gelb and Delecretaz 2009), and the majority of collisions occur at reflective areas of buildings, particularly at windows (Klem 2009).

Since 1997, NYC Audubon has led Project Safe Flight (PSF), a citizen science collision-monitoring program that has recorded 6363 collisions from 114 species to date. During the 2013 fall migration (September 3 through November 4), we focused our monitoring efforts around Bryant Park, a city park in midtown Manhattan. The park is a prime example of combined collision-risk factors, with tree-lined streets that attract birds, bright stadium lighting, and tall, brightly lit buildings with many windows. In addition, Bryant Park is one of few patches of green space south of Central Park in Manhattan, and it is a recommended place to find migratory birds (NYC Audubon 2013).

The objective of this study was to test hypotheses about the effect of artificial light and the amount of window glass on bird collisions in an urban park in New York City. Based on the results from Evans Ogden (2002) and Lights Out Columbus (2012), we hypothesized that the number of bird collisions is positively correlated with the amount of artificial light emitted from the building at the collision site. Two alternate hypotheses are that (1) bird collisions are a function of the amount of glass in a building, regardless of the amount of light, and (2) bird collisions are a function of the amount of light emitted from the collision site, the amount of glass in the building at the collision sites, and an interaction between light and glass.

**Study Site**

Bryant Park is a 3-ha urban park located in the Midtown neighborhood of Manhattan, NY (Fig. 1). It is bordered by Fifth Avenue on the east, Sixth Avenue on the west, 40th Street to the south, and 42nd Street to the north (40°45'N, 73°58'W). The main branch of the New York Public Library is situated on the east side of the park. On the west side is a mowed lawn approximately 91 m in length by 66 m wide. The lawn is surrounded on 2 sides by mature ornamental non-native trees (predominately *Platinus* x *acerofolia* (Aiton) Willd. [London Plane]) and various ornamental non-native flowers. At night the park is brightly illuminated by twelve 2000-watt light bulbs from the top of 1095 Avenue of the Americas, a 40-story building on the northwest corner of the park.

## Methods

### Bird-collision surveys

During 45 observation days occurring between 10 September and 4 November 2013, PSF citizen science volunteers used standard protocols (Gelb and Delecretaz 2009) to monitor the Bryant Park area for dead and injured birds. The sidewalk across the street from each side of the park is referred to as a "site", for a total of 4 sites (Fig. 1). Each volunteer was assigned one day of the week (Monday through Friday) to monitor the site, taking between 45 to 60 minutes to complete the circuit. The sites were each monitored once daily between 7 a.m. and 10 a.m. Each bird carcass or injured bird found in front of a building (from the foot of the building at the sidewalk to the street) was recorded as a collision (Gelb and Delecretaz 2009,

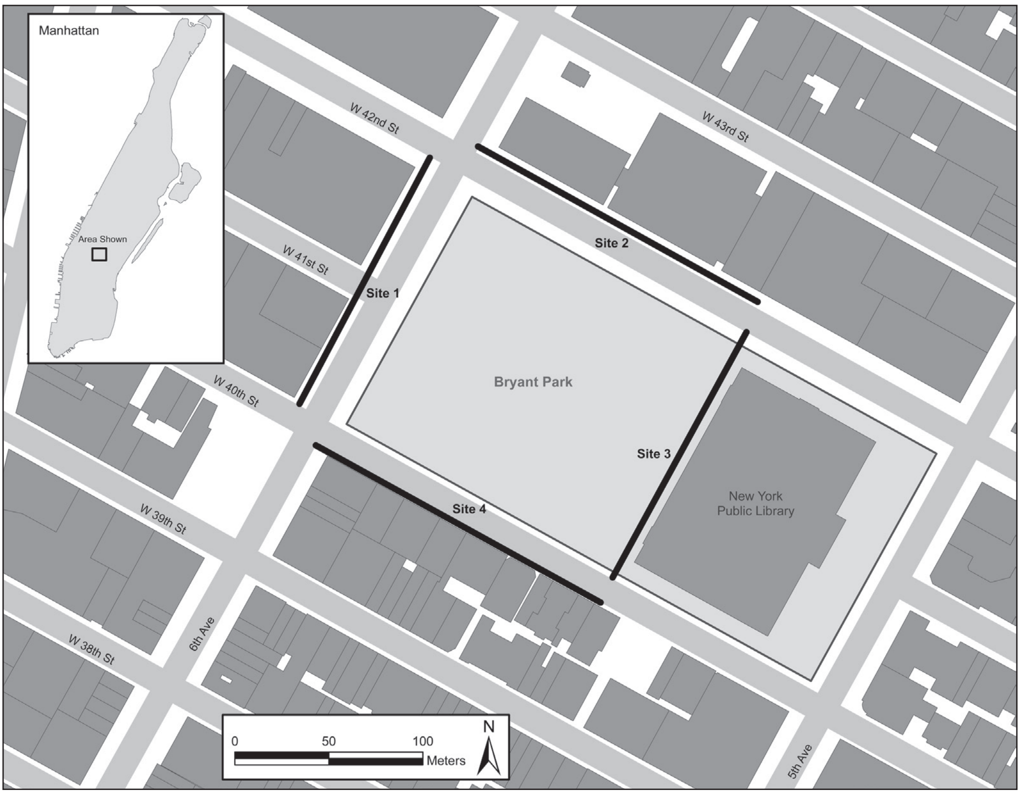


Figure 1. Project Safe Flight collision monitoring sites 1–4 at Bryant Park, New York, NY.

Klem et. al. 2009). Monitors also recorded the date, time, weather information, site number, and condition and species of the bird found. Bird carcasses were removed from the site, placed in a plastic bag, labeled with name of the volunteer and the time and site it was collected, and brought to the NYC Audubon office to be stored in a freezer. We donated the dead birds to the New York State Museum, Albany, or the American Museum of Natural History, NYC. All dead- or live-bird handling was carried out under the required state and federal permits (New York Department of Conservation permit number 1466, USGS permit 21032).

**Bird-collision monitoring: Variance**

To assess variance in the collision-monitoring data, we conducted a persistence study. Twenty-four bird carcasses (12 *Molothrus ater* (Boddaert) [Brown-headed Cowbird] and 12 *Sturnus vulgaris* L. [European Starlings]) were tagged with unique individual identification numbers. Carcasses (hereafter referred to as "test birds") were thawed and placed along the monitoring patrol route at 11 pm. These species were used because of their standard size and color, as to not introduce further confounding variables. Locations for test-bird placement were chosen opportunistically within the 4 designated patrol sites surrounding Bryant Park (1 = 6th Avenue, 2 = West 42nd Street, 3 = West side of New York Public Library to 5th Avenue, 4 = West 40th Street). One bird was placed at each site per day. These steps were replicated on 6 test days between 17 September and 3 October, using 4 test birds per day.

If found during regular collision surveys, monitors returned test birds to the NYC Audubon office. If not found during a collision survey the morning after placement, one of the authors (E. Barnes) returned to the known placement locations 12 hours after placement to determine if test birds were missed by a monitor or had disappeared from the placement location. We used a chi-square test of independence to determine if the likelihood of carcass persistence differed between sites.

**Light analysis**

We performed light analysis using the method described by Lights Out Columbus (2012), adapted from Evans Ogden (2002). Using a Nikon d40 DSLR camera with an 18-mm lens, we took pictures of the buildings at each site on a weeknight at least 1 hour after sunset during the collision-monitoring period. We took the photographs from across the street at a height of 1.67 m in order to position the entire building in one frame. Each building was photographed on 3 or more nights, and the number of lit pixels was compared between photographs of the same building. For all buildings the number of lit pixels did not differ significantly between photographs (chi-square test: $P > 0.05$), so we chose one photo of each for analysis.

Photos were analyzed using Photoshop (CS6/13.0; Adobe, Inc.) and Image J (Version 1.47t; NIH 2009) image-processing programs. To determine nighttime lighting within the face of each building, we masked photos to include only the pixels from illuminated windows in the building (Fig. 2). Using this method, the pixels that made up the lit windows of a building were converted to black, while all other pixels in the photo were converted to white. We counted the number of lit window pixels. The same method was then used to mask and count the number of pixels within the entire face of the building, including windows. We calculated a percentage of illumination for each building by dividing the pixels within illuminated windows by the total pixels in the building, a light index for each building by multiplying the illumination percentage by the number of floors in the building (Evans Ogden 2002), and a light index for each site by averaging the light indices of all the buildings at the site. For the purposes of this paper, we are assigning the name "pixel units" to this measure. The terms pixel units and light index are used interchangeably To determine the percent of glass in each building, we masked all pixels representing clear or reflective plate glass in a building facade and divided this number by total pixels in the building.

We used descriptive statistics and non-parametric tests to explore the avian-collisions data. We ranked sites from 1 (lowest) to 4 (highest) by light index and by number of collisions, and employed a Spearman's rank-order correlation to determine the relationship between light index and number of bird collisions. To test the influence of overall percent of glass in a building facade on the light index of each of the buildings we used a linear-regression model (SYSTAT Systat Software, a subsidiary of Cranes Software International, Ltd.).

## Results

### Bird collisions

Thirty-five birds of 16 different species were found and recorded as collision victims at Bryant Park. Four of these birds were injured, and 31 were dead. Some birds were recovered in semi-decayed, crushed, or otherwise degraded condition,

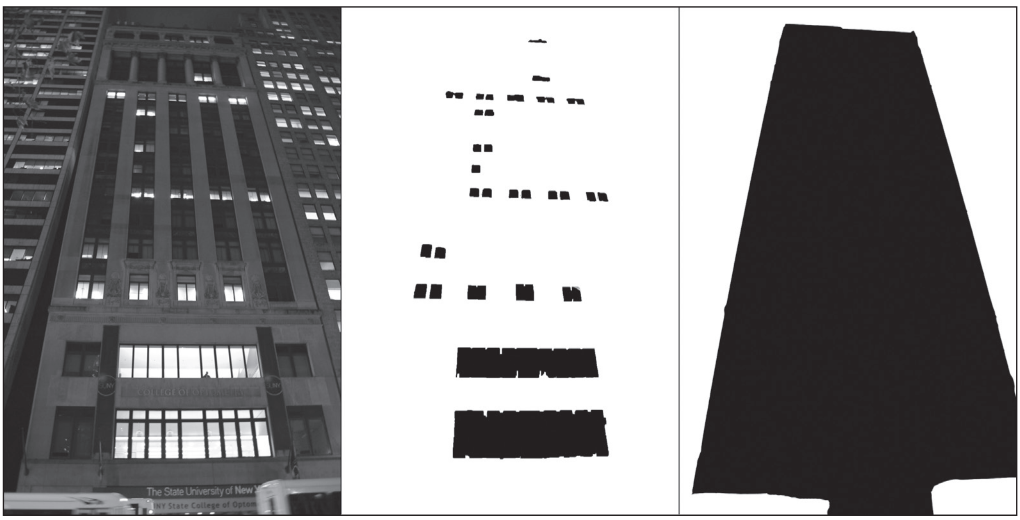


Figure 2. An example of a photo from the Project Safe Flight Bryant Park patrol before being modified for light analysis (left), after being masked to include only pixels from lit areas within the building (center), and after being masked to include only pixels from the building facade (right).

and could only be identified to the genus or family level. Of the 26 individuals identified to the species level, *Dendroica striata* (Blackpoll Warbler) and *Geothlypis trichas* (Common Yellowthroat) were most common (Table 1).

**Carcass Persistence**

Of the 24 carcasses placed at the sites, 15 were not found and reported after 12 hours. We calculated carcass persistence at the site to estimate the likelihood of finding a carcass that has collided and used it as a multiplier to improve the quality of our monitoring data. The mean persistence rate of carcasses was 0.38 (SD = 0.49, $n = 24$), with a 95% confidence interval of 0.17 to 0.58. We found no difference in persistence of carcasses between the sites ($\chi^2 = 1.22$, $P = 0.75$).

**Light analysis**

Light index values at Bryant Park ranged from 0.11 to 4.67. The sites with the most collisions (Site 1 and Site 2) had the highest light index values (2.49 and 4.67, respectively). We found a significant positive rank-order correlation between bird collisions and light index ($rho = 1.0$, one-tailed, $P < 0.05$).

The proportion of glass in building facades ranged from 2.02 to 55.98 percent. We found a significant positive correlation between glass and light index (linear regression: $r^2 = 0.82$, $P < 0.05$), with the percent of glass in the building facade explaining 82% of the variability in light index (Fig. 3).

Table 1. Number of individuals and locations of all bird species (AOU) recorded as building collision victims in Bryant Park, Manhattan, NY between 10 September and 4 November, 2013.

| Scientific name | Common name | Taxonomic group | Number | Location |
|---|---|---|---|---|
| *Pheucticus ludovicianus* (L.) | Rose-breasted Grosbeak | *Cardinalidae* | 1 | 4 |
| *Melospiza lincolnii* (Audubon) | Lincoln's Sparrow | *Emberizidae* | 1 | 1 |
| *Zonotrichia albicollis* (Gmelin) | White-throated Sparrow | *Emberizidae* | 2 | 1,2 |
| n/a | Sparrow sp. | *Emberizidae* | 2 | 2 |
| *Dumetella carolinensis* (L.) | Gray Catbird | *Mimidae* | 1 | 1 |
| *Setophaga ruticilla* (L.) | American Redstart | *Parulidae* | 1 | 1 |
| *Mniotilta varia* (L.) | Black-and-white Warbler | *Parulidae* | 1 | 4 |
| *S. caerulescens* (Gmelin) | Black-throated Blue Warbler | *Parulidae* | 1 | 1 |
| *S. fusca* (Müller) | Blackburnian Warbler | *Parulidae* | 1 | 2 |
| *S. striata* (Forster) | Blackpoll Warbler | *Parulidae* | 6 | 1, 2 |
| *S. pensylvanica* (L.) | Chestnut-sided Warbler | *Parulidae* | 1 | 2 |
| *Geothlypis trichas* (L.) | Common Yellowthroat | *Parulidea* | 4 | 1 |
| *S. Americana* (L.) | Northern Parula | *Parulidea* | 2 | 2 |
| *S. palmarum* (Gmelin) | Palm Warbler | *Parulidea* | 1 | 2 |
| n/a | Warbler sp. | *Parulidea* | 5 | 1, 2 |
| *Troglodytes aedon* (Vieillot) | House Wren | *Troglodytidae* | 1 | 1 |
| *Catharus ustulatus* (Nuttall) | Swainson's Thrush | *Turdidae* | 1 | 1 |
| *Hylocichla mustelina* (Gmelin) | Wood Thrush | *Turdidae* | 1 | 2 |
| n/a | Unknown | n/a | 2 | 1, 2 |

## Discussion

### Collision monitoring and carcass persistence

Species diversity was high among the collision victims at the Bryant Park sites: 26 individuals representing 16 different species. Sixty-three percent ($n$ = 10) of the species belonged to the warbler family, which is consistent with previous studies that suggested the disproportionate vulnerability of this taxon (e.g., Hager et al. 2008, Loss et. al 2014). In addition, all of the identified species were passage migrants, whereas the most-common resident birds in the area—European Starling, *Passer domesticus* (L.) (House Sparrow), and *Columba livia* Gmelin (Rock Pigeon)—were notably not collision victims. While resident birds may be at high risk for collisions in locations with feeders (Dunn 1993, Klem 1989, Loss et al. 2014), our results support previous findings at locations without feeders that strike rates are higher in the spring and fall and are mainly the result of collisions by migrants (Evans Ogden 1996, Gelb and Delecretaz 2009, Loss 2014, O'Connell 2001).

The results of our persistence study suggest that collisions in NYC are under-reported. On average, sixty-three percent (CI =0.42–0.83) of all birds that are injured or die in collisions were never found by the volunteers and were not reported. NYC Audubon has extrapolated PSF data collected from 1997 through 2009 to estimate the average annual mortality in New York City from collisions is approximately 90,000 birds. Using our determined mean carcass persistence rate, we calculated a multiplier of 2.70 to adjust collision estimates (Gehring et al. 2011). Using this multiplier, the estimated number of collisions in NYC could be as high as 243,000 birds per year.

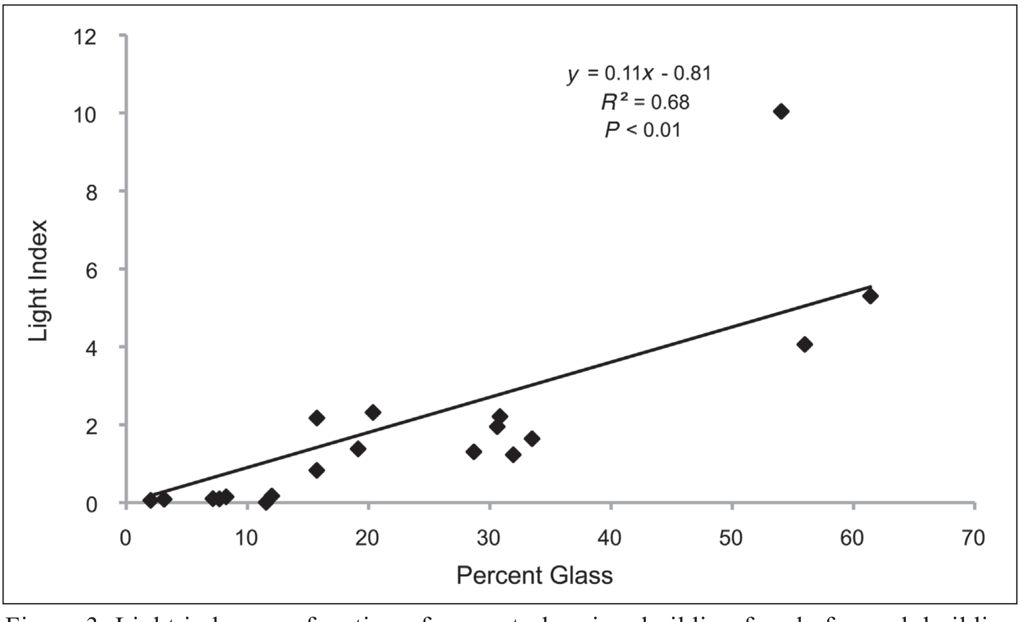


Figure 3. Light index as a function of percent glass in a building facade for each building at Bryant Park patrol sites during New York City Audubon's Project Safe Flight monitoring 10 September–4 November, 2013.

Although our study suggests a low rate of carcass recovery on New York City streets surrounding Bryant Park, we can only speculate as to the source and timing of carcass removal. Predator removal is a common concern at collision locations (Klem et. al. 2004), and the most common predators in NYC are feral cats and rats. However, in highly urbanized areas such as Bryant Park, carcasses may also be removed by sidewalk sweepers and building maintenance crews. Also, the times of day with the highest strike rates are 6:45 am to 9:00 am, which coincide with pedestrian rush hour (Gelb and Delecretaz 2009), and carcasses may be kicked or trampled beyond recognition before being found by monitors. Additional study is needed to determine when and how carcasses are being removed. In the spring of 2014, we will begin to address the question about carcass persistence by engaging sidewalk sweepers to help monitor for collisions.

**Light and glass**

While some studies suggest that nighttime lighting is the driving cause of bird collisions in highly urbanized areas (Evans Ogden 2002, Lights Out Columbus 2012), the results of our photographic light analysis suggest that the percent of glass in a building facade may have an equal or greater effect on bird–building collision. Because glass can act as a mirror, birds may fly into windows to reach perceived images reflected in the glass (Klem 2007, 2009). The amount of vegetation reflected in or present behind glass windows has an effect on the number of avian collisions at a location, and landscaping that causes the reflection of vegetation in glass can increase the risk of collision deaths (Borden et al. 2010; Gelb and Delacretaz 2006, 2009; Klem et al. 2009). The buildings surrounding Bryant Park are landscaped using flowers and shrubs, and the entire area is lined in trees, many of which are reflected in many of the glass windows and building facades. The sites with the highest number of collisions (sites 1 and 2) are the locations of 1100 Avenue of the Americas, 1095 Avenue of the Americas, and 1114 Avenue of the Americas. These buildings are all between 17 and 50 stories with expansive reflective glass exteriors.

The City Planning Commission in NYC requires tall buildings to have set-backs (City Planning Commission 1961), rendering collisions that occur at night and above ground level to go undetected. In an unpublished study, S.B. Elbin found two *Sphyrapicus varius* (L.) (Yellow-bellied Sapsuckers) on the 42$^{nd}$-floor balcony of a high-rise in lower Manhattan that collided over night. On the other hand, Gelb and Delecretaz (2009) and DeCandido (2005) found that few collisions occur during the nighttime in Manhattan, further supporting the role of glass in bird–building collisions as compared to the direct effect from light at night. Based on the low number of collisions detected that occur at night and the strong correlation between the amount of glass and light index of a given building (82% of the variability in light index can be explained by thepercent of glass), we suggest that most collisions are occurring during the daylight hours and are not directly caused by lighted windows. We are not completely discrediting the role of light in bird collisions, but our data do not support a cause-and-effect relationship.

Artificial light plays another role that needs to be addressed. There are other types of light not examined in this study, including street lighting, upward-facing building lights, and stadium lighting. This type of lighting may affect birds, making them more vulnerable to collisions with reflective glass. Artificial light alters bird behavior, causing birds to change the direction they are flying (J.A. Clark, Fordham University, Bronx, NY, unpubl. Data; A. Farnsworth, Cornell University, Ithaca, NY, unpubl. data). Migrating birds are attracted to lighted structures (Avery et. al. 1976, Kerlinger 2000, Larkin and Frase 1988, Manville 2000), and NYC is known for its iconic skyline at night (http://www.iesnyc.org/nightseeing.aspx). Bryant Park is brightly lit at night with stadium lights, which may attract or disorient birds during the spring and fall migration. The morning after flying into the park at night, these birds are surrounded by vegetation reflected in the glass buildings surrounding the park. In this way, the park and its surrounding building essentially act as a trap for migrating birds.

This study combines an analysis of bird–building collisions with respect to the local presence of live birds, the amount of light emitted from surrounding building facades, the percent of glass on surrounding buildings, and provides a measure of variance in the monitoring data. Our findings highlight the need for multi-variate approaches to investigate the impact of light (quality and quantity), reflective glass, and habitat on birds during migration. Mitigation of both light and glass are needed to reduce bird collisions in urban areas.

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