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CHARACTERISTICS OF BIRD STRIKES AT ATLANTA'S COMMERCIAL BUILDINGS DURING LATE SUMMER AND FALL MIGRATION, 2005

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Introduction

Collisions with anthropogenic structures including communication towers, wind turbines, transmission lines, light houses, and windows in commercial and residential buildings have long been known to cause avian mortality (Erickson et al. 2005). While exact numbers are unknown, estimates for mortality from building collisions range from 365 to 988 million annually in the United States (Loss et al. 2014). Cities including New York (Gelb and Delacretaz 2006), Toronto (Ogden 1996), Milwaukee (Diehl, unpubl.), and Chicago (Stoltz, unpubl.) have documented significant numbers of bird strikes at commercial buildings, particularly when nighttime inclement weather occurs during peak migration season. These collisions have inspired "Lights-Out" programs in several cities to reduce the number of nocturnal collisions.

It appears that birds hit buildings for a variety of reasons. Klem (1990a, 1990b) argued that birds do not see glass as a barrier and fly into it either because they are confused by a reflection or they are attracted to suitable habitat they see through the glass itself. A number of factors likely contribute to window collisions including building height, reflectivity of glass, amount of glass, night lighting, weather, local bird densities, interior-facing (concave) glass corners, vegetation adjacent to building, and local bird feeding activity (either in vegetation or at bird feeders). Large scale nocturnal strike events tend to be associated with inclement weather when birds fly lower and appear disoriented by artificial lights, often circling lit structures until they collide with them or land exhausted (Klem 1990a). Diurnal bird strikes are often associated with either reflective glass that birds perceive as vegetation or sky, or situations when birds attempt to fly to habitat visible through the clear glass (Klem 1990a, 1990b).

Prior to this study, no systematic study of bird collisions at multiple buildings in Atlanta, Georgia had been published. Johnston (1955) documented 327 strikes involving 28 species at multiple television towers across the state during a single weather event. Later (1957), he reported other mortality events at several television towers, the Tybee Island lighthouse, and at an Atlanta ceilometer. Fink (1970, 1971) and Fink and French (1971) documented 58 species and over 500 bird fatalities at 2 newly constructed buildings in downtown Atlanta. The majority of deaths (444 birds) occurred during 2 nights associated with a September cold front.

Since these studies, Atlanta has grown significantly, with buildings taller than 12 stories increasing from 63, prior to 1980, to 227 buildings (http://www.emporis.com). Presumably avian mortality has increased with this nearly four-fold increase in the number of tall buildings in the past 35 years. This study measures avian mortality at multiple buildings in Atlanta and attempts to quantify the building characteristics and weather conditions that may contribute to this mortality. We also attempted to determine whether bird collisions were more common in the vicinity of the Chattahoochee River, a presumed migration corridor located in northwestern Atlanta.

Methods

To assess the extent and nature of bird collisions with commercial buildings in Atlanta, 45 commercial buildings were selected for monitoring in 4 areas of Atlanta: Downtown (15), Midtown (10), Buckhead (10), and Riveredge (10) (Fig 1). Volunteers at various locations in the city monitored an additional 8 buildings, bringing the total number monitored to 53. Buildings were selected based on known records of bird strikes or because they displayed at least one known "attractor" for birds, including reflective glass, trees and shrubs around the base, interior or exterior night lighting, or indoor plants that were visible from outside. Researchers also received access to the entire perimetereter of the building and cooperation of the building managers.

The Downtown area had the least natural vegetation of the 4 study sites, with 97% of the land cover developed (buildings, roads, or parking lots) and 3% as isolated trees planted along roadsides. The Midtown site was 93% developed and 7% isolated trees. Adjacent Piedmont Park provided a large (76 hectare) greenspace attractive to migrants. The Buckhead area is in closer proximity to wooded neighborhoods than either Downtown or Midtown and was 60% developed and 40% deciduous cover in neighborhoods. The Riveredge area was the least developed with 40% developed and 60% forest cover. Riveredge is located along the Chattahoochee National Recreation Area, which provides a large band of undeveloped forest along the Chattahoochee River, and is a well-documented migratory corridor for many birds.

Data potentially relevant to bird strikes were collected for each building. These included: building age and height (www.emporis.com), estimated percentage of glass, color and glass type (reflective or not), surrounding vegetation (calculated percent cover from 0 - 1, 1 - 5, 5 - 10, and 10 - 15 m from building), and index of night lighting per Ogden (2002). Presence of known “attractors” e.g., flowering plants beside buildings, number of flying insects on and around building at ground level, interior facing (concave) glass corners, reflected sky or vegetation in the glass, and indoor plants visible from outside, were also documented at each building. Weather data were collected daily including maximum and minimum temperatures, wind speed and direction, Beaufort index of cloud cover, and precipitation in inches (www.weather.gov).

Each building was visited every other day for 73 days (2 August - 13 October, 2005). Building staff and cleaning crews reported dead or injured birds found on days between visits. Monitoring occurred within 4 hours of sunrise. Each building perimeter was searched to a 5 m radius for both dead and injured birds and lower windows were observed for “detectable strikes”, which included feather-marks from a prior collision, blood, or feathers on glass. Bird species, age, and sex were determined where possible.

Simple Correlations, Principle Components Analysis (PCA), and Chi Square Goodness of Fit tests were used in data analysis. Analysis was completed with SPSS (2006) and Microsoft Excel programs. All tests were considered significant when $P < 0.05$.

Results

During the study period, 480 bird strikes were documented (Table 1) including 435 dead, 14 stunned, and 6 injured birds, as well as 25 "detectable strikes" with no carcasses recovered. In 81 strikes, the bird species were not identified because only blood, feathers, or heavily scavenged carcasses were present. Fifty-nine species from 22 families were identified, with wood warblers (*Parulidae*) and hummingbirds (*Trochilidae*) comprising 40% (N = 190) and 17% (N = 81) respectively of individuals recovered.

Ruby-throated Hummingbirds (*Archilochus colubris*), Tennessee Warblers (*Oreothlypis peregrina*), and Ovenbirds (*Seiurus aurocapilla*) comprised 40% of total strike mortality with 81, 61, and 45 strikes respectively. Other species were rarely encountered, with 66% (N = 40) documented less than 4 times. There was no significant difference between number of adults (111) and hatch year (132) birds, or between males (87) and females (85).

Bird strikes were documented on all but 9 days between 2 August and 13 October 2005. The number of strikes varied widely from day to day, with peaks on 8 September and 3 October (Fig 2). The first peak was influenced by an abundance of Ruby-throated Hummingbirds and the second peak was influenced by numbers of Tennessee Warblers. The count on 3 October represented the highest species diversity with 12 species documented. Most strikes occurred during clear or partly cloudy weather with no precipitation and north or east winds, but none of these relationships were statistically significant. There was only one significant weather frontal passage during the study period, occurring on 28 September. This day resulted in 21 strikes, the second highest one day count, and was within a 2 week period of elevated strike numbers that peaked with the 3 October count.

Strikes were documented at all 45 buildings surveyed by the authors and all but 3 of the 8 buildings monitored by volunteers. An average of 9 birds was found per building; but eight buildings had more than 20 strikes each, accounting for one-third of all recorded strikes. Buildings in the Riveredge area had the most strikes with 11.4 per building and Downtown had the least with 7.3 per building, but there was no significant difference among sites ($X^2 = 0.44$, $df = 3$, $P = 0.11$). At each of the 4 locations, 2 or 3 buildings accounted for 25 - 50% of all strikes.

Building height was not related to number of collisions. Birds were found on all sides of buildings with more on the north, northeast and northwest sides, and fewer on the southwest side, though these differences were not statistically significant.

Significant positive correlations between strikes and 5 building characteristics were found. Fifty-eight percent of strikes were at buildings with reflective glass ($X^2 = 226.1$, $df = 5$, $P = 0.001$). Buildings with higher percentages of glass had significantly more strikes ($r^2 = 0.18$, $P < 0.05$). Buildings with glass interior facing corners averaged nearly 4 times as many strikes than buildings without these features (25.2 and 6.8 respectively). This difference was significant ($X^2 = 5.76$, $df = 1$, $P < 0.05$). There was also a significant correlation between night-lighting index and bird strikes ($r^2 = 0.11$, $P < 0.05$). Finally, there was a significant positive relationship between estimates of insect abundance and number of strikes per building ($r^2 = 0.11$, $P < 0.05$).

A principle components analysis (PCA) of building height, building age, percent glass, vegetation categories, and night lighting index resulted in a significant regression on the second component ($t = 7.02$, $P < 0.05$). The most important variable in this component were percent vegetation within 0 - 5 m of the building (accounting for 20% of variance). There were no other significant relationships with any other building variables.

Discussion

This study documented fewer bird strikes than previously reported in Atlanta. Fink and French (1971) documented 461 bird strikes at 2 Atlanta buildings during a single cold front with fog on 28 - 29 September 1970. Extreme mortality events tend to be linked to very specific weather conditions, and the lower number of strikes documented in this study may simply be a result of the lack of foggy weather associated with a frontal system during our survey period. A more disheartening possibility is that there are fewer migrants passing through Atlanta than there were 40 years ago. Several studies (Butcher and Niven 2007, North American Bird Conservation Initiative 2014) estimate that many eastern birds have declined by between 20 - 40% since 1965.

This study also reported fewer strikes than have been reported during similar studies in other cities such as Toronto, Chicago, and New York. Ogden (1996) reported that in a Toronto-based study monitoring 53 buildings, an average of 970 strikes occurred during the fall survey period, more than twice the strikes we documented. Stolz (unpubl.) reported an average of 1219 birds killed annually at a single building in Chicago. Gelb (unpubl.) reported that a New York City-based survey of 28 buildings documented an average of 563 strikes. These cities may have greater potential for bird strikes than Atlanta based on their positions on the Mississippi and Atlantic flyways. It is also possible that the positions of these three cities along major bodies of water lead more regularly to local weather conditions (such as fog) that create extremely hazardous conditions for migratory birds.

In comparison to other collision studies, the abundance of Ruby-throated Hummingbird strikes we documented is noteworthy. Fink and French (1971) reported no hummingbirds in their Atlanta study, but the majority of their reported strikes were nocturnal migrants during a single cold front and hummingbirds would not have been affected because most would have already migrated through the area. Ruby-throated Hummingbirds were not in the top 50 species found at Chicago's "most deadly" building from 1978 to 2004 (Stoltz unpubl.), and represented less than 1% of strikes (19 out of 4847) in Toronto (Ogden 1996). Only one building in this study had a hummingbird feeder within the 5 m survey area, and presence of flowers near buildings was not correlated to higher numbers of strikes. Based on Atlanta's geographic position within the breeding range of Ruby-throated Hummingbirds, Atlanta may simply experience more migrating hummingbirds than the northern cities with extensive bird strike studies.

The prevalence of Tennessee Warblers and Ovenbirds in this study matches the findings of many other studies. Tennessee Warblers are regularly among the top 10 species documented in both building and communication tower collision studies (Johnston 1955, Longcore et al. 2005, Stoltz unpubl.). The high numbers of Tennessee Warblers may simply correspond to their abundance, as they are estimated to be the fifth most abundant eastern wood warbler (Partners in Flight 2012, 2013) with 70 million individuals. Ovenbirds are routinely the second or third most abundant species documented in collision studies of both buildings and towers (Fink and French 1971, Taylor 1972, Klem 1989, Ogden 1996, Ogden 2002, Longcore et al. 2005, Gelb and Delacretaz 2006). While Ovenbirds are also a numerous species (estimated 22 million individuals) they appear to be more vulnerable to strikes than other more numerous birds.

We recorded only 30 urban resident bird strikes, suggesting that they may adjust to the concrete and glass environs and have fewer collisions. Alternately, since most are year-round residents, they are not migrating at night when they could be affected by inclement weather or confused by lights.

This study provides evidence for both nocturnal and diurnal strikes. The correlation of night lighting index with bird strikes suggests that many strikes were nocturnal migrants, while the number of Ruby-throated Hummingbirds, a well-known diurnal migrant (Robinson et al. 1996), suggests day-time collisions. The PCA results suggesting that vegetation at ground level was the strongest predictor of strikes, also suggests daytime collisions may be associated with foraging. It is likely that some birds collided with buildings at night when disoriented by artificial lights, while others collided during the day when reflective glass gave the illusion of a potential flight path.

The strikes documented in this study are clearly an underestimate of the actual number of birds killed. Scavengers and predators are known to consume dead and injured birds located around buildings. Some birds were likely undetected, especially where vegetation around the building made searching more difficult. Some of the buildings also had high ledges and balconies that may have prevented birds from falling to the ground, rendering them undetectable during the ground surveys. This study ended in early October, missing the end of songbird migration, particularly for southbound sparrows such as White-throated Sparrow (*Zonotrichia albicollis*) that are commonly detected strike mortalities in similar studies.

While the number of strikes documented was not as many as was found in other studies, it must be remembered that a very small subset of Atlanta's buildings were monitored, and every building had some level of mortality. A similar study during a fall migration season with more fog may produce much higher numbers.

Reducing bird strikes in an urban environment is clearly a great challenge. Other large cities have been able to mobilize birding groups to monitor strikes, rehabilitate injured birds, and advocate for bird friendly construction and building management. This study provides some useful information to begin such an effort. Based on the number of attractants associated with bird strikes, and the evidence of both diurnal and nocturnal strikes, there will not be a single solution to ending building strikes (Brown et al. 2007). The evidence collected during this study however, suggests that a small subset of buildings are likely to cause the majority of bird mortalities, and the presence of certain attractants (i.e., highly reflective glass, vegetation within 5 m of the base, extensive lighting at night, and interior facing glass corners) could be used to predict which are likely to be the most dangerous. Plans can then be developed to minimize risk to migrating birds at these buildings or in designing future building projects.

To reduce diurnal collisions, stickers or other techniques to make glass visible could be applied just to the level of adjacent vegetation (Rössler et al. 2007) or on interior-facing glass corners (Klem 1991). A reduction of night lighting, as proposed by a number of "Lights Out" programs, would almost certainly reduce the number of nocturnal building strikes. Even a partial "Lights Out" program that targets periods of inclement weather may provide significant benefits to migrating birds. Any such efforts should be tracked carefully to determine the relative cost and effectiveness of each conservation measure. Ideally this would be conducted in an adaptive management framework where conservation actions, followed by monitoring, could be used to form future efforts.

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Table 1. Complete list of documented bird collisions at 53 Atlanta metropolitan-area buildings between 2 August and 13 October, 2005.

Family (total #)	**Species**	**Scientific name**	**Number**
Ardeidae (1)	Green Heron	*Butorides virescens*	1
Rallidae (2)	Sora	*Porzana carolina*	2
Columbidae (7)	Rock Dove	*Columba livia*	1
	Mourning Dove	*Zenaida macroura*	6
Cuculidae (7)	Yellow-billed Cuckoo	*Coccyzus americanus*	7
Caprimulgidae (2)	Common Nighthawk	*Chordeiles minor*	1
	Whip-poor-will	*Caprimulgus vociferus*	1
Trochilidae (81)	Ruby-throated Hummingbird	*Archilochus colubris*	81
Picidae (2)	Yellow-bellied Sapsucker	*Sphyrapicus varius*	1
	Hairy Woodpecker	*Picoides villosus*	1
Tyrannidae (3)	Eastern Wood Peewee	*Contopus virens*	1
	Acadian Flycatcher	*Empidonax virescens*	2
Vireonidae (4)	White-eyed Vireo	*Vireo griseus*	1
	Blue-headed Vireo	*Vireo solitarius*	1
	Red-eyed Vireo	*Vireo olivaceus*	2
Sittidae (2)	Brown-headed Nuthatch	*Sitta pusilla*	2
Troglodytidae (3)	House Wren	*Troglodytes aedon*	1
	Winter Wren	*Troglodytes hiemalis*	1
	Sedge Wren	*Cistothorus platensis*	1
Polioptilidae (1)	Blue-gray Gnatcatcher	*Polioptila caerulea*	1
Turdidae (33)	Veery	*Catharus fuscesens*	2
	Gray-cheeked Thrush	*Catharus minimus*	3
	Swainson's Thrush	*Catharus ustulatus*	21
	Wood Thrush	*Hylocichla mustelina*	2
	American Robin	*Turdus migratorius*	5
Mimidae (17)	Gray Catbird	*Dumetella carolinensis*	12
	Brown Thrasher	*Toxostoma rufum*	2
	Northern Mockingbird	*Mimus polyglottos*	3
Sturnidea (1)	European Starling	*Sturnus vulgaris*	1
Parulidae (190)	Ovenbird	*Seiurus aurocapilla*	45
	Northern Waterthrush	*Parkesia noveboracensis*	4
	Golden-winged Warbler	*Vermivora chrysoptera*	1
	Blue-winged Warbler	*Vermivora cyanoptera*	1

Family (total #)	**Species**	**Scientific name**	**Number**
	Black-and-white Warbler	*Mniotilta varia*	16
	Tennessee Warbler	*Oreothlypis peregrina*	61
	Common Yellowthroat	*Geothlypis trichas*	7
	Hooded Warbler	*Setophaga citrine*	3
	American Redstart	*Setophaga ruticilla*	8
	Northern Parula	*Setophaga americana*	3
	Magnolia Warbler	*Setophaga magnolia*	15
	Blackburnian Warbler	*Setophaga fusca*	1
	Chestnut-sided Warbler	*Setophaga pensylvanica*	5
	Palm Warbler	*Setophaga palmarum*	3
	Yellow-rumped Warbler	*Setophaga coronata*	1
	Yellow-throated Warbler	*Setophaga dominica*	3
	Canada Warbler	*Cardellina canadensis*	1
	Wilson's Warbler	*Cardellina pusilla*	1
	Yellow-breasted Chat	*Icteria virens*	11
Emberizidae (2)	Eastern Towhee	*Pipilo erythrophthalmus*	2
Cardinalidae (27)	Summer Tanager	*Piranga rubra*	2
	Scarlet Tanager	*Piranga olivacea*	7
	Northern Cardinal	*Cardinalis cardinalis*	3
	Rose-breasted Grosbeak	*Pheucticus ludovicianus*	12
	Indigo Bunting	*Passerina cyanea*	3
Icteridae (1)	Common Grackle	*Quiscalus quiscula*	1
Fringillidae (9)	House Finch	*Haemorhous mexicanus*	7
	Purple Finch	*Haemorhous purpureus*	1
	American Goldfinch	*Spinus tristis*	1
Passeridae (4)	House Sparrow	*Passer domesticus*	4
Identified birds			399
Unidentified birds			81
Total Strikes			480

Figure 1. Study areas within the greater Atlanta metropolitan area with building locations monitored for bird strike mortalities, 2 August – 13 October 2005.

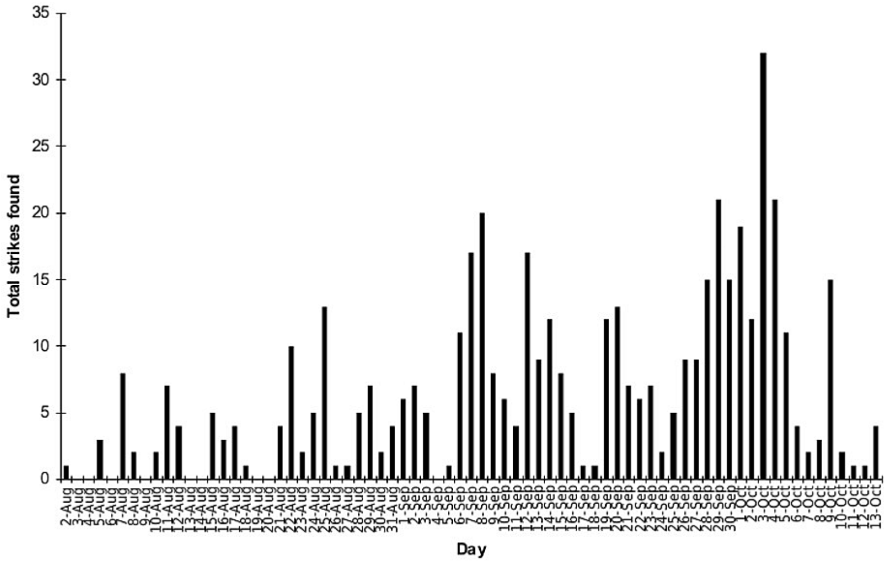

Figure 2: Total documented bird strikes per day from all Atlanta metropolitan-area buildings monitored from 2 August – 13 October 2005.