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Bird Strike Study

Research Report

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## **Introduction**

Structures like cars, cell towers, windmills, power lines, and buildings are among the many man-made obstacles birds collide with on a daily basis (Klem *et al.* 2004). However, buildings and windows are responsible for more avian deaths than any other factors associated with human activity, except habitat destruction (Klem 2009). In North America alone, anywhere from 100 million to 1 billion birds are killed after striking glass every year (Klem *et al.* 2004). There are many factors associated with the buildings that contribute to the frequency with which birds strike them, however, the likelihood of window strike occurrences are also dependent on a bird's maneuvering skills that allow it to avoid a collision. Comparing factors like wing morphology, flight velocity, and maneuverability from species to species may help us determine which birds face a greater risk of colliding with windows and other structures.

Birds' frequently collide with windows because they cannot perceive clear or reflective glass as obstacles (Klem 1989). Factors like vegetation and water sources surrounding buildings only increase the likelihood of bird-window collisions (Ocampo-Peñuela *et al.* 2016). Often a bird will become distracted while trying to land, perch, or hunt prey and instead collide with a window or building in the process (Klem 1990). While collisions occur at windows of all shapes and sizes (Klem 1989), buildings with a higher percentage of glass and larger windows produce more bird-window collisions (Ocampo-Peñuela *et al.* 2016).

In addition, the issue of bird-window collisions does not discriminate on the basis of species, age, sex, or size; all species are vulnerable (Klem 1990, 1989). However, that does not mean that all birds crash into buildings with the same frequency. A study done by Ocampo-Peñuela *et al.* (2016) calculated that 76% of collisions observed involved migratory birds. More specifically, passerines, such as warblers, thrushes, vireos, and sparrows, are more likely to be involved in window strikes (Evans Ogden 1999). Passerines' wing morphology, like wing loading, aspect ratio, and wing surface area may potentially drive their increased susceptibility. On Butler University's campus, Swainson's Thrushes have been found to collide with the campus buildings with a higher frequency than other species, so our study will pay special attention to this species.

Wing loading is a measure of the amount of weight a bird carries with their wings (Barnard, 2002), and is calculated by dividing the mass of a bird by its wing surface area (Bowlin 2007) (Fig. 1). As summarized by Chandler and Mulvihill (1992), birds with higher wing loading values fly at greater velocities because they have to flap their wings faster to keep their heavier bodies aloft. However, their ability to maneuver efficiently is compromised. Instead, excellent maneuvering skills tend to be associated with lower wing loadings that allow a bird to escape predators more easily, or in regards to this study, avoid colliding with a window (Chandler and Mulvihill 1992).

Aspect ratio is a measurement used to predict the aerodynamic efficiency of a bird's wings in regards to its lift to drag ratio (Aspect Ratio (aeronautics) 2017). This measurement is calculated by dividing a bird's squared wingspan by its wing surface area (Rayner *et al.* 2001) (Fig. 1). Birds with long, pointy wings have high aspect ratios, and those with wider wings and rounded wing tips have low aspect ratios (Tobalske 2007). Birds with high aspect ratios exhibit

more stability, less induced drag, and faster flight. However, these long wings don't allow for skillful maneuvering (Wing Aspect Ratio 2011).

In this study we sampled Swainson's Thrushes, Dark Eyed Juncos, and Indigo Buntings, all of which frequently strike buildings on Butler University's campus. Swainson's Thrushes, however, have been the most numerous fatalities leading us to believe their wing biomechanics could be contributing to their increased collision rates. We expected to find Swainson's Thrushes to have significantly higher wing loading and aspect ratios compared to the other bird species sampled in this study. These factors are associated with increased flight speeds and decreased maneuverability, which potentially increase the likelihood of striking windows hard enough to result in death. Since the ability to produce lift over a wide range of angles is associated with better maneuverability, we would also expect that they produce lift across a smaller range than other species.

## **Methods**

Three species were sampled for this study including Swainson's Thrushes (N=9), Dark Eyed Juncos (N=5), and Indigo Buntings (N=4). All birds were collected on Butler University's campus under a Special Salvage Permit #MB98877A-0 issued to Dr. Shelley Etnier.

### *Wing Morphology*

The species name, identification number, and weight, obtained on an electronic scale, were first recorded. Birds were then pinned to a dissection pan in a position that represents the natural flight position of wings (Fig. 2). The entire bird's body was then outlined onto a piece of copy paper. The wingspan was then cut out from the bird's outline and weighed. A conversion factor ( $0.06 \text{ m}^2 / 0.005 \text{ kg}$ ) was determined by weighing a comparable piece of copy paper with a known surface area of  $0.06 \text{ m}^2$ ; this was used to determine the surface area of the paper

wingspan. The bird's body mass was then divided by the surface area of the wings to find the wing loading (Fig.1). The aspect ratio was calculated by dividing the squared length of the wingspan by the wings' surface area (Fig. 1).

### *Dissection*

The birds' shoulder joint was located and with the use of surgical scissors all muscle and tendons attached to the shoulder joint were bisected allowing for disarticulation from the joint. The right wing was removed and then pinned onto the dissection pan in a spread out position, like a wing in flight. The wing was then dried for 2-3 days before lift was measured.

### *Lift Production*

Isolated wings were attached to a ring stand that rested on an electronic scale (Fig. 3). The resting mass of the wing and ring stand was recorded. The wings were then exposed to an average wind speed of 9.27 km/h produced by a Holmes box fan at its second speed. The fan's wind blew over the wing producing lift. The lift was measured by recording three final masses, and then by finding the difference between the initial mass and the average final mass. This difference represented the total lift produced by the wing and ring stand combined. This process was repeated 10 individual times with the wing at the following angles of attack relative to the horizon: -20°, -10°, 0°, 10°, 20°, 30°, 40°, 50°, 70°, and 90°. To find the lift produced solely by the wing, the lift generated by the ring stand was determined and subtracted from the total lift.

## **Results**

### *Wing Shape*

The Swainson's Thrushes differed significantly from both the Indigo Buntings and the Dark Eyed Juncos with regards to mass by species, however, the Dark Eyed Juncos and the Indigo Buntings did not differ from each other ( $F_{2,15} = 24.1693$ ,  $p = < 0.001$ ). The three species

sampled significantly different with regards to surface area by species ( $F_{2,15} = 164.5588$ ,  $p = <0.0001$ ).

### *Wing Biomechanics*

The three species studied were not significantly different with regards to wing loading by species ( $F_{2,15} = 3.9090$ ,  $p = 0.0430$ ). The Swainson's Thrushes and Dark Eyed Juncos differed significantly with regards to aspect ratio by species, while the Indigo Buntings did not differ with either the Swainson's Thrushes or Dark Eyed Juncos ( $F_{2,15} = 5.8511$ ,  $p = 0.0132$ ) (Table 1).

### *Lift Production*

The Swainson's Thrushes and Indigo Buntings were significantly different with regards to maximum lift by species, but the Dark Eyed Juncos did not vary from either the Swainson's Thrushes or Indigo Buntings ( $F_{2,15} = 8.6644$ ,  $p = 0.0032$ ). The three species sampled did not differ with regards to the angle at which maximum lift was achieved by species ( $F_{2,15} = 0.8642$ ,  $p = 0.4413$ ). Swainson's Thrushes and Indigo Buntings differed significantly with regards to maximum lift/mass by species, but the Dark Eyed Juncos did not significantly differ with either the Swainson's Thrushes or Indigo Buntings ( $F_{2,15} = 7.1404$ ,  $p = 0.0066$ ). In general they all were relatively small in size and they could all produce lift over a wider range of angles.

## **Discussion**

### *Mass and Surface Area*

In general, Swainson's Thrushes are bigger with significantly higher mass and significantly higher surface area when compared to the other birds sampled in this study. A consequence of this could simply mean that Swainson's Thrushes have more inertia when they fly, so they experience a harder impact when they collide with windows, leading to more fatal collisions than not.

### *Biomechanical Measurements*

The biomechanical variables measured in this study, including wing loading and aspect ratio, were independent of mass. We hypothesized Swainson's Thrushes would have significantly higher wing loading and aspect ratios since they experience higher collision rates than Dark Eyed Juncos and Indigo Buntings. However, the results show no difference in wing loadings between the species and they also exhibit similar aspect ratios, so perhaps these mechanical values are not driving the high collision numbers we have observed in Swainson's Thrushes. All three bird species have multiple fatalities due to window strikes, although the Swainson's Thrushes have the highest frequency collision rates on Butler's campus. Perhaps the lack of significant difference in wing loading and aspect ratio between the species suggests that their mechanical variables are indeed driving their increased susceptibility to window glass collisions. To answer this question it would be best to measure the biomechanical values in species that rarely strike windows and buildings.

### *Lift Production*

Overall, the three sampled species produced lift over a wide range of angles suggesting they all have similar levels of maneuverability (Fig. 4). The maximum lift/mass by species suggests Indigo Buntings produced more lift for their body size compared to the Swainson's Thrushes, meaning while these three species have similarly shaped wings, functionally the Swainson's Thrushes' wings did not produce as much lift. As a consequence Swainson's Thrushes must flap their wings faster to keep their weight aloft possibly increasing their flight velocity.

### *Limitations*

The species used in this study were chosen largely because there were enough to allow a larger sample size. Birds with single collisions are problematic with regards to statistical analysis. However, we can compare our values to previously reported data. Using biomechanical measurements from Michalski's study (2010), the wing loading of an Indigo Bunting (11.8 g) can be compared to the wing loading of another species of comparable mass, like a Red Breasted Nuthatch (11.5 g). Indigo Buntings had a recorded mean wing loading of  $17.0800 \text{ N/m}^2$ , while Red Breasted Nuthatches had an average wing loading of  $15.239 \text{ N/m}^2$ . While not empirically confirmed, the Indigo Bunting's higher wing loading suggests it would have to fly faster and potentially be more likely to have a fatal collision than the Red Breasted Nuthatch, as observed.

### *Future Studies*

Although the Swainson's Thrushes' biomechanical variables did not differ as predicted, Swainson's Thrushes, none-the less, are hitting campus windows more frequently than the Dark Eyed Juncos and Indigo buntings. If mechanical values are not driving this difference then perhaps it has more to do with the building parameters or the species' behavior. Future studies could compare biomechanical variables with birds that do not strike buildings as frequently. Perhaps by analyzing species with a distinct size difference statistical testing will show more dramatic and conclusive results. Further research might also focus on Swainson's Thrushes' behavioral factors. For example, Swainson's Thrushes are nocturnal migrants, so researchers might want to characterize the illumination and duration artificial lights are used at locations on campus where Swainson's Thrushes strike glass the most, such as the north side of Holcomb, the west side of Gallahue, and the skywalks (Albers 2017). Previous research suggests that lighting

may influence night flying birds, so future research might want to focus on the different types of artificial lighting and the effects they have on nocturnal species.



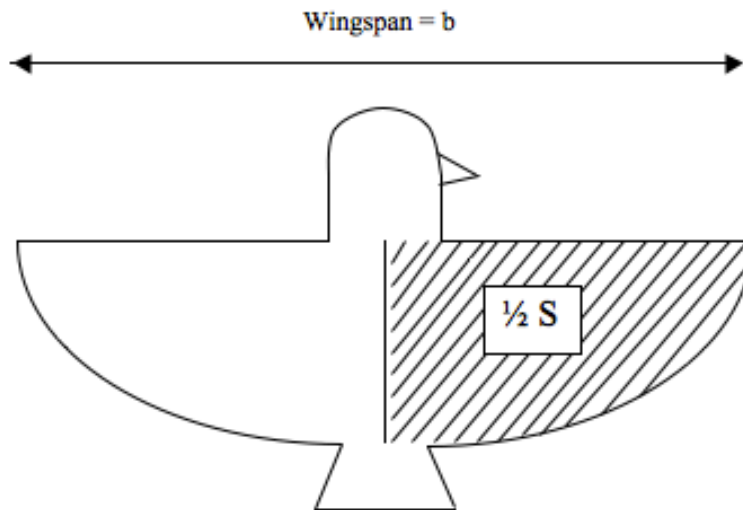
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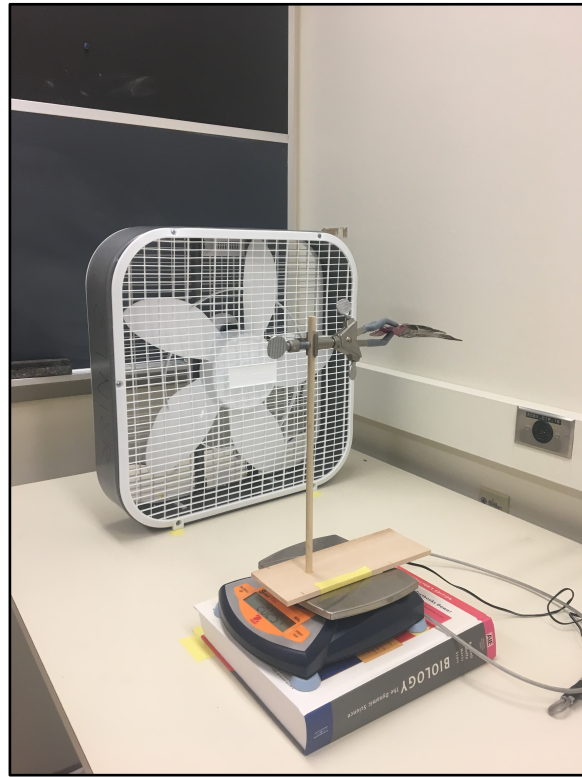


*Figure 1.* The bird's wingspan,  $b$ , is found by measuring the distance from wingtip to wingtip.

The bird's wing surface area includes the middle portion of the bird's body. These measurements are used to calculate aspect ratio ( $AR = b^2/S$ ) and wing loading ( $WL = \text{weight}/S$ ) (Michalski 2010).



*Figure 2.* All birds sampled were pinned to a dissection pan in a position that represents the natural flight position of their wings. The bird's body was outlined onto a piece of copy paper to later find the wing loading and aspect ratio.



*Figure 3.* Each wing was attached the ring stand shown above and rotated to vary the angle of attack. This wing is shown at  $-10^\circ$ . The angles of attack were measure as the angle between the horizon and the flat line along the bottom of the wing.

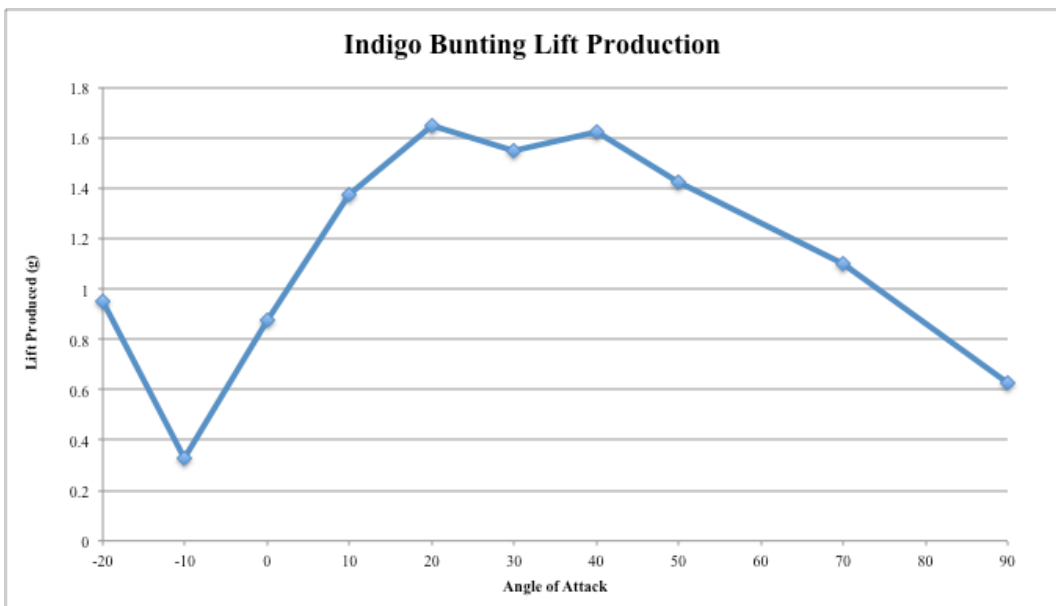
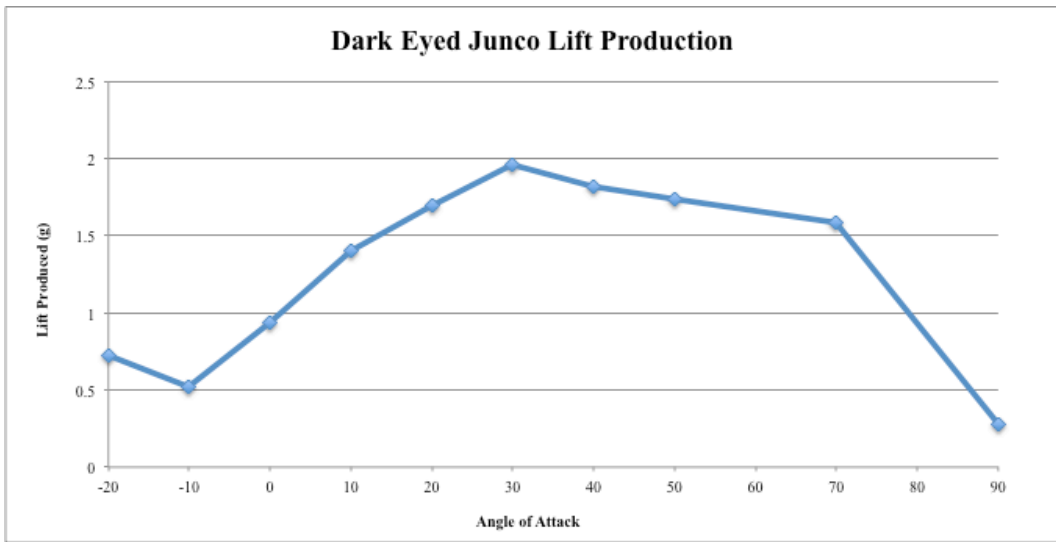
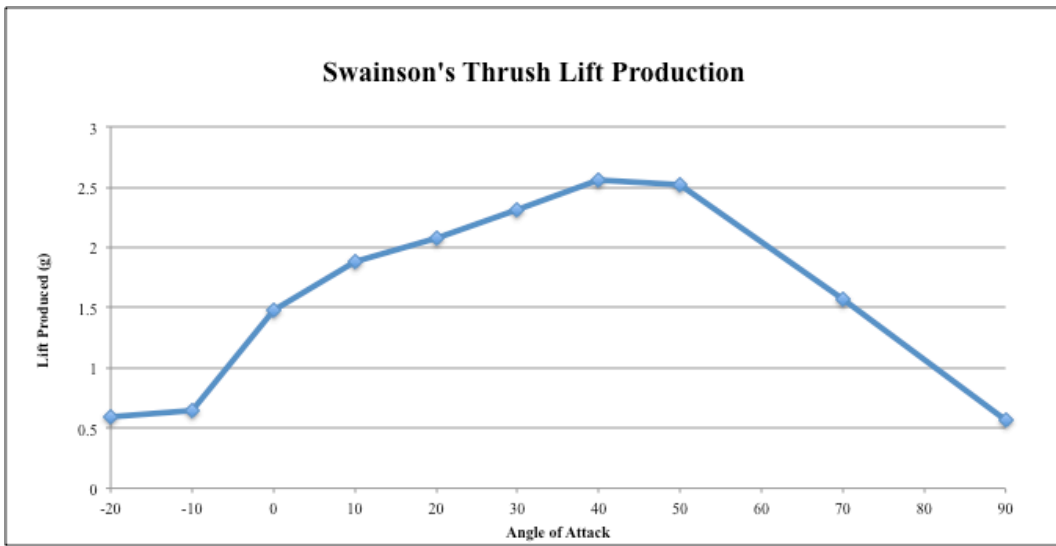


Figure 4. Lift production capabilities of sampled species varies over angle of attack. The lift production capabilities of the three species studied are summarized in this figure. The average lift production at each angle is shown.

	Swainson's Thrush (N=9)	Dark Eyed Junco (N=5)	Indigo Bunting (N=4)
Mass (g)	<u>30.18±1.59</u> -----	<u>17.97±2.13</u>	<u>11.78±2.38</u> -----
Surface Area (m <sup>2</sup> )	<u>0.01±0.00</u>	<u>0.01±0.00</u>	<u>0.01±0.00</u>
Wing Loading (N/m <sup>2</sup> )	22.18±1.17	18.01±1.57	17.08±1.76
Aspect Ratio	<u>5.31±0.08</u>	<u>4.89±0.08</u>	<u>5.02±1.76</u>
Maximum Lift (g)	<u>2.83±0.13</u>	2.32±0.17	<u>1.90±0.19</u>
Angle of Maximum Lift	37.78±4.35	34.00±5.83	27.50±6.52
Maximum Lift / Mass	<u>0.10±0.01</u>	0.11±0.01	<u>0.17±0.02</u>

*Table 1.* Table summarizes the biomechanical measurements investigated in the study. The means and standard deviations of the different variables are shown. Values underlined with the same patterned line were found to be significantly different from each other.