BIRD COLLISIONS WITH GLASS: AN ANNOTATED BIBLIOGRAPHY

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INTRODUCTION

Searches of the Ornithological Worldwide Literature database, the Searchable Ornithological Research Archive, and Google Scholar were conducted to find peer-reviewed literature pertaining to bird collisions with glass for the first edition. Numerous reports of collisions occur in state ornithology journals as well as bird club magazines and newsletters, newspapers, and other types of popular and grey literature. Such observations are not exhaustively covered in the bibliography as most do not provide novel information or insight on the issue (a list of some of those not annotated is provided in the appendix). Instead, the bibliography focuses more on empirical studies that contribute to an understanding of when, how, why, and where most collisions (primarily window collisions) occur, and that offer practical solutions.

The bibliography deviates from traditional format in that some annotations are longer. Longer, detailed annotations are provided because many of the articles may be relatively difficult for some to acquire and do not contain abstracts. Papers available on-line, without charge, have minimal annotation beyond the abstract.

Bibliography

Adalsteinsson, Solny A., Jeffrey J. Buler , Jacob L. Bowman, Vincent D'Amico, Zachary S. Ladin and W. Gregory Shriver, 2018. Post-independence mortality of juveniles is driven by anthropogenic hazards for two passerines in an urban landscape. J Avian Biology 49(8) https://doi.org/10.1111/jav.01555
Urban environments impose novel selection pressures with varying impacts across species and life history stages. The post-fledging stage for migratory passerines, defined as the period of time from when hatch-year birds fledge until their first migration, is a poorly understood component of annual productivity that potentially limits population growth. We studied two migratory passerines with positive and negative population responses to urbanization, respectively: Gray Catbird (*Dumetella carolinensis*) and Wood Thrush (*Hylocichla mustelina*). Our goals were to estimate post-fledging survival rates for urban bird populations and determine which features of the urban landscape impact mortality risk during the post-fledging stage. From 2012–2014, we tracked 127 fledglings (60 Gray Catbirds and 67 Wood Thrushes). Over 55 days after fledging, cumulative survival of Gray Catbirds (0.32 [95% CI: 0.22–0.47]) was approximately half that of Wood Thrushes (0.63 [95% CI: 0.52–0.75]). Thus, survival rates during the post-fledging stage, taken in isolation, do not explain differential trajectories of Gray Catbird and Wood Thrush populations in urban environments. Most mortality (86%) for both species was due to predation. However, after reaching independence from parental care, 6 birds (9.4% of mortalities) died of anthropogenic causes (e.g. building, car strikes). Crossing roads significantly increased mortality risk, but increasing daily movement distance decreased mortality risk. Our results raise the question of whether anthropogenic sources of mortality are compensatory or additive to natural mortality; we emphasize the need to monitor fledgling survival beyond the parental-dependence stage in order to fully understand the impacts of anthropogenic hazards on juvenile birds.

Adams, Carrie Ann, Arden Blumenthal, Esteban Fernández-Juricic, Erin Bayne and Colleen Cassady St. Clair, 2019. Effect of anthropogenic light on bird movement, habitat selection, and distribution: a systematic map protocol. Environ Evid 2019, 8(Suppl 1):13 https://doi.org/10.1186/s13750-019-0155-5
The authors describe a detailed protocol for creating a comprehensive bibliography covering the

effects of anthropogenic lights on birds.

Agudelo-Álvarez, Laura, Johan Moreno-Velasquez & Natalia Ocampo- Peñuela, 2010. Colisiones De Aves Contra Ventanales En Un Campus Universitario De Bogotá, Colombia (Collisions of birds with windows on a university campus in Bogotá, Colombia). Ornitología Colombiana No. 10 (2010): 3-10.
Resumen La transformación y el crecimiento de las ciudades han llevado al surgimiento de problemáticasde conservación que han sido poco estudiadas en el trópico. Este es el caso de las colisiones de las aves contra diferentes estructuras urbanas, que se estima cobra miles de millones de víctimas año tras año alrededor del mundo. Entre abril de 2006 y noviembre de 2008 registramos 106 choques de 18 especies (11 migratorias boreales y 7 residentes) contra los ventanales de seis edificios del campus de la Pontificia Universidad Javeriana de Bogotá; 88% de las colisiones fueron fatales para las aves. Encontramos que los migratorios boreales chocaron con ventanales con mayor frecuencia que las especies residentes y que la época de más colisiones era la de la migración otoñal de estas aves. Determinamos que los ventanales a través de las cuales las aves podrían ver vegetación al otro lado fueron más peligrosos (73% de todas las colisiones) para las aves que los que simplemente reflejaban la vegetación o el cielo. Extrapolando nuestros resultados, calculamos que podrían ocurrir cerca de 271 colisiones anuales contra ventanales en todo el campus. Invitamos a otros observadores a extender estas observaciones y a coleccionar como especímenes científicos a las aves que mueren para que puedan ser fuentes de información sobre patrones de migración, ampliación de rangos de distribución y la potencial de amenaza nacional y global para algunas especies. Discutimos algunas posibles medidas de mitigación y sugerimos implementar y someter a prueba a algunas de las que han sido efectivasen otras latitudes.

Abstract: Land transformation and the accelerated rate at which cities are growing have generated new conservation problems that have not been studied thoroughly in the tropics. This is the case of bird collisions with human built structures, estimated to claim billions of victims every year around the world. Between April 2006 and November 2008, we recorded collisions of 106 individuals of 18 species, including 11 species of boreal migrants and 7 resident species, with windows of six buildings in the campus of the Pontificia Universidad Javeriana in Bogotá; 88% of all collisions were fatal to the birds. We found that windows through which birds could see vegetation beyond were more dangerous (73% of all collisions recorded) than those which simply reflected vegetation or the sky, and that the number of collisions peaked during the period of fall migration by boreal breeders.
Extrapolating our study of collisions at six buildings, we estimate that ca. 271 collisions could occur annually over the entire campus. We invite others to extend these observations and to collect as scientific specimens the casualties so they can serve as a source of information on patterns of migration, expansion of distribution ranges and potential national and global threat for some species. We review possible mitigation measures and encourage others to apply and evaluate those that have proved effective elsewhere.

American Bird Conservancy website collisions section
https://abcbirds.org/program/glass-collisions/
This site provides updates to the material presented in Bird-friendly Building Design (Sheppard, 2015). It is also intended to assist developers, architects, and building owners working with LEED Pilot Credit #55 – Reducing Bird Collisions; regulators and builders researching the application of voluntary guidelines or mandatory standards for buildings; or anyone simply looking for detailed information on the collisions issue and designing structures that minimize bird deaths. Also see birdsmartglass.org for information on

solutions and collisions.abcbirds.org.

Arnold, Todd W. and Robert M. Zink, 2011. Collision Mortality Has No Discernible Effect on Population Trends of North American Birds. PLoS One 6(9) e24708.

Because mortality from collisions with anthropogenic objects are widely dispersed, calculating their impact is difficult. The authors collected 243,103 records of building collisions reported by FLAP (Evans-Ogden, 1996) and communication tower collisions summarized by Shire et al in 2000 (http://www.abcbirds.org/newsandreports/special_reports/towerkillweb.PDF). They found differential mortality by species, with higher levels for night flying and long distance migrants than for diurnal migrants or residents. They found no correlations between mortality rates and species population trends. The authors state that their conclusion should not reduce efforts to reduce mortality from collisions. (this paper has generated much controversy and criticism – see Longcore et al 2012; Loss et al, 2012; Schaub et al, 2011).

Avery, M.L. 1979. Review of avian mortality due to collisions with man- made structures. U.S. Fish and Wildlife Service, 11 pp. Available for download at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context= icwdm birdcontrol.
A literature review that includes a brief section on bird collisions with glass. The findings of Klem (1979) are summarized.

Aymi, Raül,Yolanda González, Txiqui López & Oscar Gordo, 2017. Bird-window collisions in a city on the Iberian Mediterranean coast during autumn migration. Revista Catalana d'Ornitologia 33:17-28
Very few monitoring studies in Europe, with the exception of papers on collisions with highway noise barriers.
Abstract: Collision with buildings is a major threat to birds that provokes the death of millions of birds every year in built-up areas. Despite its magnitude, this phenomenon remains poorly studied in Europe. We studied bird-window collisions during postnuptial migration in the city of Tarragona (NE Spain). We surveyed a 15-m-high residential building in the city centre with a reflective façade for 189 days during postnuptial periods in 2012– 2015. We found 172 dead birds belonging to 15 species, most of them migratory. Blackcaps *Sylvia atricapilla*, Reed Warblers *Acrocephalus scirpaceus* and Pied Flycatchers *Ficedula hypoleuca* were the commonest casualties, representing 72% of all recovered bird corpses. Once the uneven sampling effort between days and years was corrected for, we estimated that the total number of fatalities during the study period was 350 birds (SE=22.2). However, this figure is probably an underestimate due to certain biases in sampling carcasses in a city including collection by pedestrians or removal by cleaning services and owners. Overall, there was a patent seasonal pattern to the collisions, with a peak around 1 October, probably reflecting the timing of migration in the species present at the site. There were no differences in either age, sex or biometrics between the birds found in Tarragona and those trapped on the same days at a ringing station in the Ebro Delta, 60 km to the south-west. This suggests that the probability of collision affected all migrants in a uniform fashion. Our study demonstrates for the first time that bird collisions with buildings are a serious threat to migrants in the Mediterranean, a key area for bird migration in Europe.

Belcher, Richard N.,Keren R. Sadanandan, Emmanuel R. Goh, Jie Yi Chan, Sacha Menz, Thomas Schroepfer (2019). Vegetation on and around large-scale

buildings positively influences native tropical bird abundance and bird species richness. Urban Ecosystems 22(2):213-225.
In response to habitat loss caused by urbanization in the tropics, planners and architects are creating networks of greenspaces, including green roofs, walls and gardens. This study in Singapore investigated whether these areas have a positive impact on native or introduced bird species. Roof gardens and green walls on large-scale buildings supported a higher richness of birds and abundance of urban native birds than control roofs and walls without vegetation. Ground gardens supported similar levels of native species as roof gardens but also a larger proportion of non-natives. No tropical forest habitat specialists were reported from any of these spaces. Specific heights and plant species supported different bird taxa. The authors suggest that these ecological requirements for different species groups are considered when designing a building's green space.

Banks, R. C. 1976. Reflective plate glass - a hazard to migrating birds. BioScience 26(6):414.

Banks notes that large-scale mortality caused by collisions with man-made structures such as lighthouses and communications towers has received great notice for over century, whereas smaller-scale and "less spectacular" deaths of individual birds from collisions with plate glass has received relatively little attention. He suspects the collective toll of the latter is significant and may in fact be greater than that caused by the more noted episodic mortality associated with towers and skyscrapers. This may be the first assertion of this in the scientific literature.

Banks notes that reflective plate glass is becoming a popular feature of office parks and similar structures constructed near vegetated areas. He expresses concern that the proliferation of such buildings will lead to increased migrant mortality.

Banks, R. C. 1979. Human related mortality of birds in the United States. Special Scientific Report 215, U.S. Fish and Wildlife Service, Washington D.C. 16pp.

The report contains a short section on window strike mortality. Banks uses an unexplained and arbitrary rate of one death per square mile per year to estimate a total annual mortality of 3.5 million birds in the U.S.

Barton CM, Riding CS, Loss SR (2017) Magnitude and correlates of bird collisions at glass bus shelters in an urban landscape. PLoS ONE 12(6): e0178667. https://doi.org/10.1371/journal.pone.0178667
Abstract Wildlife residing in urban landscapes face many human-related threats to their survival. For birds, collision with glass on manmade structures has been identified as a major hazard, causing hundreds of millions of avian fatalities in North America every year. Although research has investigated factors associated with bird-glass collision mortality at buildings, no prior studies have focused on bird fatalities at glass-walled bus shelters. Our objectives in this study were to describe the magnitude of bird-bus shelter collisions in the city of Stillwater, Oklahoma and assess potential predictors of collision risk, including characteristics of shelters (glass area) and surrounding land cover (e.g., vegetative features). We surveyed for bird carcasses and indirect collision evidence at 18 bus shelters over a five-month period. Linear regression and model selection results revealed that the amount of glass on shelters and the area of lawn within 50 m of shelters were both positively related to fatal bird collisions; glass area was also positively associated with observations of collision evidence on

glass surfaces. After accounting for scavenger removal of carcasses, we estimate that a minimum of 34 birds are killed each year between May and September by collision with the 36 bus shelters in the city of Stillwater. While our study provides an initial look at bird fatalities at bus shelters, additional research is needed to generate a large-scale estimate of collision mortality and to assess species composition of fatalities at a national scale. Designing new bus shelters to include less glass and retrofitting existing shelters to increase visibility of glass to birds will likely reduce fatal bird collisions at bus shelters and thus reduce the cumulative magnitude of anthropogenic impacts to birds in cities.

Bayne, Erin M., Corey A. Scobie and Michael Rawson, 2012. Factors influencing the annual risk of bird–window collisions at residential structures in Alberta, Canada. Wildlife Research - http://dx.doi.org/10.1071/WR11179

Estimates of mortality from building collisions, especially collisions with homes, are often challenged as being based on insufficient evidence. These authors hypothesize that the risk of bird–window collisions varies according to location (urban *v*. rural), home v. apartment, with or without feeders and age of neighbourhood.

The project was conducted by undergraduates as part of a biology class. On-line surveys from 1458 respondents gathered information on homes and yards, general demographic information about participants, and whether they had observed evidence of bird– window collisions at their home. 39% had seen a collision in the past year, totalling 2575, with a mean of 1.7 ± 4.6 (in the same range reported by Klem and Dunn); 0.7 ± 2.3 of these collisions (1044) were reported as deaths. Rural residences had more collisions than urban ones and residences with feeders had almost twice as many collisions as those without feeders. For urban dwellings, incidence of collisions increased with age of neighbourhood, associated with presence of mature trees. Frequency of collisions varied seasonally: 24% in fall, 35% summer, 25% spring 16% winter. Mortality patterns were similar: 26% fall, 31% summer, 26% spring, 17% winter. 48 species were reported; 'American robins (*Turdus migratorius*) suffered a slightly higher mortality than was expected on the basis of the frequency of collisions, whereas black-capped chickadees (*Poceile atricapillus*) suffered a slightly lower mortality.'

Benedikt Huggins, Sabine Schlacke (2019). Rechtliche Anforderungen und Gestaltungsmöglichkeiten [Protection of species from glass and light: Legal requirements and design options.] in German. Springer. ISBN 978-3-662-58257-2

This book examines legal obligations and design options for protecting against hazards to birds, bats and insects from glass and light.

Best, Joel, 2008. Birds -- Dead and Deadly: Why Numeracy Needs to Address Social Construction. Numeracy 1(1), article 6.
http://scholarcommons.usf.edu/cgi/viewcontent.cgi?article=1001&context=numeracy Best uses the way Klem's 1990 estimate of mortality from collisions and its derivation has morphed into certainty through 'social construction' in non-scientific contexts, especially by media or when used to justify taking action. It is important, when using statistics and other numbers, to understand where they came from originally. Another example is the threat of a possible epidemic avian flu in 2005.Blem, C.R.and B.A.Willis, 1998. Seasonal variation of human – caused mortality of birds in the Richmond area. Raven 69(1):3-8.

The authors examined museum specimens salvaged from collisions with motor vehicles and windows to determine what species are most commonly killed and how collision frequency varies seasonally. The two causes of mortality are not addressed individually throughout the paper, preventing readers from interpreting results solely in the context of window collisions. One must assume the trends observed in the study are equally attributable to both types of mortality.

In total, permanent resident birds were significantly more common in the data set than winter residents, migrants, or summer residents. However, analyses of individual months found that in September and October, mortality was highest among migrants and in November, mortality was highest among winter residents. The most commonly killed species in each season are listed. The paper demonstrates that museum collections can be useful for studying avian window strike mortality (see also Codoner 1995 and Klem 1989).

Bhagavatula P, Claudianos C, Ibbotson M, Srinivasan M (2009) Edge Detection in Landing Budgerigars (*Melopsittacus undulatus*). PLoS ONE 4(10): e7301. doi:10.1371/journal.pone.0007301

Abstract: While considerable scientific effort has been devoted to studying how birds navigate over long distances, relatively little is known about how targets are detected, obstacles are avoided and smooth landings are orchestrated. Here we examine how visual features in the environment, such as contrasting edges, determine where a bird will land. Landing in budgerigars (*Melopsittacus undulatus*) was investigated by training them to fly from a perch to a feeder, and video-filming their landings. The feeder was placed on a grey disc that produced a contrasting edge against a uniformly blue background. We found that the birds tended to land primarily at the edge of the disc and walk to the feeder, even though the feeder was in the middle of the disc. This suggests that the birds were using the visual contrast at the boundary of the disc to target their landings. When the grey level of the disc was varied systematically, whilst keeping the blue background constant, there was one intermediate grey level at which the budgerigar's preference for the disc boundary disappeared. The budgerigars then landed randomly all over the test surface. Even though this disc is (for humans) clearly distinguishable from the blue background, it offers very little contrast against the background, in the red and green regions of the spectrum. We conclude that budgerigars use visual edges to target and guide landings.
Calculations of photoreceptor excitation reveal that edge detection in landing budgerigars is performed by a color-blind luminance channel that sums the signals from the red and green photoreceptors, or, alternatively, receives input from the red double-cones. This finding has close parallels to vision in honeybees and primates, where edge detection and motion perception are also largely colorblind.

Bhagavatula, Partha S.C harles Claudianos, Michael R. Ibbotson, and Mandyam V. Srinivasan, 2011. Optical Flow Cues Guide Flight in Birds. Current Biology 21, 1794–1799. DOI 10.1016/j.cub.2011.09.009

Despite the significant literature on mechanisms involved in bird migration, much less is known about how they navigate local, complex environments. In this experiment, budgies were videotaped flying down a narrow passage with different visual patterns on the side walls. "The results demonstrate .... that birds negotiate narrow gaps safely by balancing the speeds of image motion that are experienced by the two eyes and that the speed of flight is regulated by monitoring the speed of image motion that is experienced by the two eyes."

Biagi, Nicole, 2019. Breeding season bird mortality from window collisions: Comparing species-specific abundance with mortality rates. MURAJ 1(1): 1-10 z.umn.edu/MURAJ

The author performed point counts and monitored collisions in downtown St. Paul, from June 1-

July 5, 2017, observing 1551 live birds and 17 collisions. A larger data set might confirm trends identified here, especially the low rate of collisions relative to observed abundance, of non-native species, including Rock Dove, House Sparrow, House Finch and European Starling.

Blackwell, Bradley F, Esteban Fernandez-Juricic, Thomas W. Seamans, and Tracy Dolan (2009). Avian visual system configuration and behavioural response to object approach. Animal Behaviour 77:673-684. doi:10.1016/j.anbehav.2008.11.017
This study shows that birds may not have enough time to avoid a threat after it is perceived.

Bocetti, C.I., 2011. Cruise ships as a source of avian mortality during fall migration. The Wilson Journal of Ornithology, 123(1):176-178. 2011.
Cruise ships are brilliantly lit through the night and may be an unrecognized source of collisions. The author reports 8 Yellow-throated Warblers killed in a single incident in 2003; cleaning staff acknowledged removal of additional collision victims. There were 2981 ship-nights in the Caribbean Sea alone in 2003, possibly killing over 700,000 birds. The author suggests both organized study of this source of mortality and working with ship-owning companies to develop improved lighting strategies.

Bolshakov, Casimir V., Michael V. Vorotkov, Alexandra Y. Sinelschikova, Victor N. Bulyuk and Martin Griffiths, 2010. Application of the Optical- Electronic Device for the study of specific aspects of nocturnal passerine migration. Avian Ecol. Behav. 18: 23-51.
The authors developed a protocol, the 'Optical-Electronic Device' to study nocturnal migration behaviors of songbirds. Inspired by the more limited techniques of moon watching and watching birds cross ceilometer beams, the Device uses searchlights to illuminate birds from the ground, while a recording unit documents. With this technique, they can study 1) ground- and airspeed; 2) compensation for wind drift on the basis of direct measurements of headings and track directions of individual birds; 3) wing-beat pattern and its variation depending on wind direction and velocity. In some cases, species can be identified.

Bolshakov, Casimir V., Victor N. Bulyuk, Alexandra Y. Sinelschikova and Michael V. Vorotkov, 2013. Influence of the vertical light beam on numbers and flight trajectories of night-migrating songbirds. Avian Ecol. Behav. 24: 35-49.
Using the device described in Bolshakov et al, 2010, the authors examined the effects of wind conditions on numbers of birds aloft, and flight trajectories of birds crossing the light beam from the apparatus. They determined that numbers of birds do differ with wind strength, but that birds may be attracted to the light beam under calm conditions. They also found that the light beam disturbs straight flight trajectories, especially in calm wind conditions. Regression models suggest that the probability of curved flight trajectories is greater for small birds, especially when there is little or no moon. Humidity also had an impact.

Borden, W.C., O.M. Lockhart, A.W. Jones and M.S. Lyonn, 2010. Seasonal, taxonomic and local habitat components of bird-window collisions on an urban campus in Cleveland, OH. Ohio J Sci 110(3):44-52.
Many studies of collision mortality monitor tall buildings. The authors monitored collisions at a complex of mostly low-rise (<30m) buildings over 12 months and conclude that these also pose a significant hazard to birds. Mortality peaked during fall migration, with a smaller peak in spring, accounting for 90% of collisions. More glass on a building façade

correlated with more collisions, as did reflections of trees in glass. Consistent with other monitoring reports, White-throated Sparrow was the most frequently killed species.

Bracey, Matthew A. Etterson, Gerald J. Niemi, and Richard F. Green (*2016*) Variation in bird-window collision mortality and scavenging rates within an urban landscape. The Wilson Journal of Ornithology: June 2016, Vol. 128, No. 2, pp. 355- 367.
Window collision mortality was studies at 42 residential houses located within an urban landscape, along the shores of Lake Superior in Duluth MN in 2006–2009. 108 individuals of 40 species were recorded. Fatalities increased with distance from the city center, were higher at houses on the lake side of the study site, and on windows facing Lake Superior. Scavenging rates also increased with distance from the city center, with small carcasses being removed more quickly than large carcasses, and removal rates decreasing over time for all carcass sizes. Adjusted mortality rate of 11–16 birds per house during the study period was calculated. Houses with highest collision mortality also had the highest scavenging rates.

Brisque, Thaís, Lucas Andrei Campos-Silva and Augusto João Piratelli, 2017. Relationship between bird-of-prey decals and bird-window collisions on a Brazilian university campus ZOOLOGIA 34: e13729
http://zoobank.org/A127995A-5B57-4F7F-924F-E49E1AFA7028

ABSTRACT. Bird-window collisions are a dramatic cause of bird mortality globally. In Latin America, statistics are generally very scarce and/or inaccessible so the frequency of such incidents is still poorly understood. Nevertheless, civilians have applied preventive methods (e.g. adhesive bird-of-prey decals) sparsely but, to our knowledge, no study has evaluated their effectiveness in Brazil. Here, we estimated the mortality rate of bird-window collisions and tested the effectiveness of bird-of-prey decals at preventing such accidents. We undertook daily searches for bird carcasses, presumably resulting from window collisions, near all buildings on a university campus over seven months. Adhesive bird-of-prey decals were then applied to the two buildings with the highest mortality rates and surveys continued for over 12 more months. The mortality rates before and after the application of decals and between seasons were then compared using Friedman test. We recorded 36 collisions, 29 around the two buildings with the highest collision rates 19 prior and 10 after our intervention with associated collision rates of 0.08 and 0.04 collisions/day. Although mortality was reduced by almost half, this difference was not statistically significant. The Blue-black grassquit, *Volatinia jacarina* (Linnaeus, 1766), and Ruddy ground dove, *Columbina talpacoti* (Temminck, 1810) suffered the highest number of collisions, followed by the Rufous-collared sparrow, *Zonotrichia capensis* (P. L. Statius Müller, 1776). Our bird-of-prey decals and efforts were insufficient to prevent or dramatically reduce the number of bird-window collisions. Therefore, we recommend that different interventions be used and additional long-term studies undertaken on their efficacy.

Bulyuk, Victor N., Casimir V. Bolshakov, Alexandra Y. Sinelschikova and Michael V. Vorotkov, 2014. Does the reaction of nocturnally migrating songbirds to the local light source depend on backlighting of the sky? Avian Ecol. Behav. 25:21-26.
The authors used the device described in Bolshakov at al., 2010, to compare behaviors of night migrating passerines under natural nocturnal illumination (at the Courish Spit of the Baltic

Sea) with birds passing through an urban light environment (inside the city limits of St. Petersburgh). Songbirds were distinguished as 1. small passerines or 2. thrushes. The illuminated background caused a decrease in image quality. The shape of flight tracks was compared for the two groups and a larger proportion of small songbirds changed flight path while crossing the light. This could be explained by flight type or flight speed. The proportion of songbirds changing flight trajectory in the lighted condition was much smaller than under the dark condition. Very few thrushes showed curved tracks and non -broken tracks or circling.

Cabrera-Cruz, Sergio A., Jaclyn A. Smolinsky and Jeffrey J. Buler, 2018. Light pollution is greatest within migration passage areas for nocturnally-migrating birds around the world. Scientific Reports 8:3261 DOI:10.1038/s41598-018-21577-6

Abstract: Excessive or misdirected artificial light at night (ALAN) produces light pollution that influences several aspects of the biology and ecology of birds, including disruption of circadian rhythms and disorientation during flight. Many migrating birds traverse large expanses of land twice every year at night when ALAN illuminates the sky. Considering the extensive and increasing encroachment of light pollution around the world, we evaluated the association of the annual mean ALAN intensity over land within the geographic ranges of 298 nocturnally migrating bird species with five factors: phase of annual cycle, mean distance between breeding and non-breeding ranges, range size, global hemisphere of range, and IUCN category of conservation concern. Light pollution within geographic ranges was relatively greater during the migration season, for shorter-distance migrants, for species with smaller ranges, and for species in the western hemisphere. Our results suggest that migratory birds may be subject to the effects of light pollution particularly during migration, the most critical stage in their annual cycle. We hope these results will spur further research on how light pollution affects not only migrating birds, but also other highly mobile animals throughout their annual cycle.

Cabrera-Cruz, Sergio A., Jaclyn A. Smolinsky, Kyle P. McCarthy and Jeffrey J. Buler, (2019). Urban areas affect flight altitudes of nocturnally migrating birds. Journal of Animal Ecology. doi: 10.1111/1365-2656.13075

Abstract: Urban areas affect terrestrial ecological processes and local weather, but we know little about their effect on aerial ecological processes. Here, we identify urban from non-urban areas based on the intensity of artificial light at night (ALAN) in the landscape, and, along with weather covariates, evaluate the effect of urbanization on flight altitudes of nocturnally migrating birds. Birds are attracted to ALAN, hence we predicted that altitudes would be lower over urban than over non-urban areas [in fact, altitudes were higher over urban areas, possibly because of heat island effect].. However, other factors associated with urbanization may also affect flight altitudes. For example, surface temperature and terrain roughness are higher in urban areas, increasing air turbulence, height of the boundary layer, and affecting local winds. We used data from nine weather surveillance radars in the eastern US to estimate altitudes at five quantiles of the vertical distribution of birds migrating at night over urban and non-urban areas

Ciach, Micha and Arkadiusz Fröhlich, 2017. Habitat type, food resources, noise and light pollution explain the species composition, abundance and stability of a winter bird assemblage in an urban environment. Urban Ecosyst 20:547–559 DOI 10.1007/s11252-016-0613-6

Abstract At present, urban areas cover almost 3% of the Earth's terrestrial area, and this proportion is constantly increasing. Although urbanization leads to a decline in biodiversity, at the same time it creates extensive habitats that are exploited by an assemblage of organisms, including birds. The species composition and density of birds nesting in towns and

cities are determined by the types of buildings, the structure and maturity of urban greenery, and habitat diversity. In contrast, the habitat traits shaping the community of birds wintering in urban areas are not known. The aim of this work was to assess the influence of habitat structure, food resources and the urban effects (pollution, noise, artificial light) on an assemblage of birds overwintering in an urban area. It was carried out in 2014 and 2015 in the city of Kraków (southern Poland), on 56 randomly chosen sample plots, in which the composition, density and interseasonal similarity of bird assemblage were assessed with line transect method. A total of 64 bird species (mean = 17.7 ± 4.9 SD species/plot) was recorded. The mean density was 89.6 ind./km ±63.3 SD. The most numerous species were Great Tit *Parus major*, Magpie *Pica pica*, Blackbird *Turdus merula*, Blue Tit *Cyanistes caeruleus*, Rook *Corvus frugilegus*, Fieldfare *Turdus pilaris* and House Sparrow *Passer domesticus*. Noise adversely affected species numbers and density, but artificial light acted positively on the density of birds and their interseasonal stability. The species richness and density of birds were also determined by the number of food sources available (e.g. bird-feeders). In addition, the greater the proportion of open areas, the fewer species were recorded. In contrast, the more urban greenery there was, the greater the density of the entire bird assemblage. Urban infrastructure (buildings, roads, refuse tips) had a positive effect on the interseasonal stabilization of the species composition of wintering birds. The results of this work indicate that the urban effect, noise and light pollution, apart from purely habitat factors, provide a good explanation for the species richness, density and stability of bird assemblage wintering in urban areas.

City of Toronto, 2007. Green Development Standard, Bird-friendly development guidelines. City Planning, Toronto, Ontario, Canada. Downloadable at: http://www.toronto.ca/lightsout/pdf/development_guidelines.pdf

Toronto's guidelines for reducing risk from glass and lighting in construction, including illustrated examples. As of January, 2017, under revision.

City of Toronto, 2016. Bird-friendly Best Practices Glasshttp://www1.toronto.ca/City%20Of%20Toronto/City%20Planning/Environment/Files/pdf/B/BF%20Best%20Practices%20Glass_FinalAODA_Bookmarked.pdf

A companion document to Toronto's Bird-friendly Development Guidelines.

Codoner, N. A. 1995. Mortality of Connecticut birds on roads and at buildings. Connecticut Warbler 15(3):89-98.

Codoner used museum collection and rehabilitation center data to determine if vehicle and window collision rates have changed between 1962 and 1993. The most commonly killed species and monthly mortality totals are reported.

Records of window strike mortality rose continuously during the time period examined. Codoner attributes the increase in window strike mortality to increased residential development in the region. She acknowledges the data may be biased by the increased popularity of wildlife rehabilitation in recent years.

Surprisingly the Sharp-shinned Hawk was found to be the most common species among window collision records, whereas common feeder birds, the Blue Jay and Northern Cardinal, were noticeably absent. Window mortality was greatest during spring and autumn migrations. Mortality was also relatively high during the early summer months, unlike other studies (e.g., Klem 1989). Condoner speculates this may be due to increased foraging activity of adults to feed young during this time.

Collins, K. A. and D. J. Horn. 2008. published abstract. Bird-window collisions

and factors influencing their frequency at Millikin University in Decatur, Illinois. . Bird-window collisions and factors influencing their frequency at Millikin University in Decatur, Illinois 101(supplement):50. Bird collisions were monitored at 11 buildings on the Millikin campus, along with surface area and number of windows, presence of architectural features including alcoves and corridors, as well as landscape features. Most collisions were during migration periods and warblers most frequently killed. The authors estimate 8-11 birds killed/building/year. The total surface area of glass and total number of windows positively influenced the number of fatalities.

CSA, 2019. A460:19 Bird-Friendly Building Design. CSA Group, 43 pages SKU: 2426847. https://store.csagroup.org/ccrz__ProductDetails?viewState¼DetailView&cartID¼&portalUser¼&store¼&cclcl¼en_US&sku¼CSA%20A460%3A19.
Canadian model code for bird-friendly building design, available for purchase at link above. Must be individually adopted by provinces individually. Requires glass patterns on surface 1, to 90% of glass up to 6 meters above grade.

Cupul-Magaña, Fabio Germán, 2003. Nota sobre colisiones de aves en las ventanas de edificios universitarios en Puerto Vallarta, México HUITZIL (2003) 4: 17-21
Resumen: Esta nota presenta las observaciones de 15 colisiones de aves en ventanas de edificios de la Universidad de Guadalajara en Puerto Vallarta, Jalisco, México, a lo largo de 94 días de estudio (24 de enero al 27 de abril del 2003). *Columbina passerina* fue la especie que presentó el mayor número de fatalidades: ocho.
Abstract: Notes on bird collisions with windows of university buildings in Puerto Vallarta, Mexico Abstract: This note presents the observations of 15 birds collisions with windows of buildings of the University of Guadalajara in Puerto Vallarta, Jalisco, Mexico, throughout 94 days of study (January 24 to April 27 2003). *Columbina passerina* was the species that presented the greater number of fatalities: eight.

Cusa, Marine, Donald A. Jackson and Michael Mesure, 2015. Window collisions by migratory bird species: urban geographical patterns and habitat associations. Urban Ecosystems doi:10.1007/s11252-015-0459-3)
The authors analyzed collisions data collected from three areas in Toronto by FLAP in 2009 and 2010. They found that percentage of window cover and cover by built structures both correlated with numbers of collisions. Species that are typically found in forested habitats tended to collide with buildings surrounded by vegetation, while species colliding in more urbanized areas were more often species of open woodland/ground feeders.

Drewitt, Allan I. and R.H.W. Langston, 2008. Collision Effects of Wind-power Generators and Other Obstacles on Birds. Ann. N.Y. Acad Sci 1134: 233-266.

A comprehensive review of the literature on collisions with stationary man-made objects, including wind turbines, communication towers, buildings, glass, power lines and fences. The authors note that there are few longitudinal studies of collisions and that the pattern of fatalities follows that of observer effort. They report on changes of emphasis over time in the literature with wind turbines the current focus. They discuss risk factors contributing to each type of collision.

Because so many factors are involved in each type of collisions, mortality estimates are necessarily imprecise: Deaths from wind turbines have been reported ranging from 0 to 60 per turbine per year, although off-shore wind farms appear to have less impact; mortality at towers is estimated at 4-50 million/year in the US; powerlines have produced <3-489deaths/km (this is likely to be a low estimate as only 1/5 of bodies are found.) This translates to 130-174 million/year in the US; glass mortality estimates of 1- 10 birds/building/year, using 1986 building data gives 97-975 million/year. Fences erected to protect new forest growth from deer are less commonly studied, but have been shown to have serious impacts for some ground birds like grouse.

The impact of mortality on population sustainability is discussed but more work is needed to understand the implications, especially for rare or declining species. Measures to mitigate collision threats are enumerated. It is noted that large scale, consistent monitoring and standardized, comparable data formats are essential to providing information necessary to generate effective solutions. Experimentation is needed to devise methods of increasing the visibility of obstacles.

Dunn, E. H. 1993. Bird mortality from striking residential windows in winter. Journal of Field Ornithology 64(3):302-309.

Dunn analyzed surveys of people across North America who regularly feed wild birds around their homes during the winter and also record incidences of window collisions (Project Feeder Watch). Of the 5500 participants, 9.2% reported one or more instances of strike mortality. Window casualties were represented by 66 species, most of which are commonly associated with bird feeders. Dunn calculates a winter window strike mortality rate of 0.85 birds per home using the survey data. Accounting for the biases and assumptions behind this figure, she extrapolates to estimate total annual window mortality in North America at 0.65 to 7.70 window kills/home/year. Despite the extreme speculation behind the calculations, the estimate is similar to that of another study (Klem 1990a), adding validity to the result.

Dunn recommends screening windows and placing feeders where panic flights will lead birds away from windows as ways to reduce fatal collisions.

Engels, Svenja, Nils-Lasse Schneider, Nele Lefeldt, Christine Maira Hein, Manuela Zapka, Andreas Michalik,Dana Elbers, Achim Kittel, P. J. Hore4 & Henrik Mouritsen, 2014. Anthropogenic electromagnetic noise disrupts magnetic compass orientation in a migratory bird. Nature 509, 353–356. http://www.nature.com/nature/journal/v509/n7500/full/nature13290.htm l
Electromagnetic noise is emitted by electronic devices everywhere, with much debate over whether it has negative impacts on living organisms. This paper reports that migratory birds are unable to use their magnetic compass in the presence of urban electromagnetic noise.

Evans, A. M. 1976. Reflective glass. BioScience 26(10):596. In response to Banks (1976), Evans adds that birds frequently fly towards the windows of his home but impending collisions are interrupted by porch screening outside of the windows. After being stopped abruptly, the birds appear to fly away unharmed. Evans concludes that birds cannot see wire or nylon window screening and such screening may therefore be an effective and practical method of preventing bird collisions at residential and small commercial buildings.

Evans, WR, Y Akashi, NS Altman, AM Manville II, 2007. Response of night-migrating songbirds in cloud to colored and flashing light. North American Birds 60, 476 – 488.

Evans, W., 2011 Pers. comm. 'With regard to the red light results presented in the Evans, W.R., Y. Akashi, N.S. Altman, and A.M. Manville, II paper (that red light did not induce bird aggregation), I wanted to let you know we have since induced bird aggregation on low cloud migration nights with red light using double the quantity of light we used in our previous field work. Birds' rod cells (for night vision) are more sensitive to blue and green light than red light, so it makes sense on a visual basis that a red light source might need to be stronger to induce aggregation than blue or green.
Many interesting questions still to be answered, and as Al noted, more research and confirmation of research is needed all around.'

Evans-Ogden, L. P. 1996. Collision course: the hazards of lighted structures and windows to migrating birds. World Wildlife Fund Canada and the Fatal Light Awareness Program. 46 pp.

A lengthy overview of bird migration, size and distribution of North American cities, the attraction of nocturnal migrants to artificial light, and the overall hazards of tall illuminated buildings and reflective windows to birds in urban settings. Disorientation and night-time collisions with buildings caused by urban light pollution are the primary focus of the document, but a section on windows summarizes the previous research of D. Klem and acknowledges the additional significance of day-time collisions with glass.

Evans-Ogden, L.J., 2002. Summary Report on the Bird Friendly Building Program: Effect of Light Reduction on Collision of Migratory Birds. Special Report for the Fatal Light Awareness Program (FLAP) (available from FLAP). 29 pages.

An analysis of data on bird mortality, living birds recovered, weather and light emissions for 16 buildings, ranging from 8 to 72 stories, monitored during migration seasons in Toronto from 1997-spring 2001. Light emission was calculated from photographs taken on random nights, 8- 10 times per season and seasonal average calculated. The percentage of windows illuminated on the building overall was multiplied by the number of building stories to create a measure of light impact. In spring 2001, light emission for each building was calculated on five nights and correlated with numbers of birds collected the following morning

While there was some correlation between building height and number of birds collected, the effect of light impact was much greater.

Also included is an analysis of surveys conducted with managers of the monitored buildings. There was a net decrease in light emissions from the buildings overall, corresponding to savings on energy costs in many, but not all cases.

While the total number of nights of volunteer activity varies between seasons and between years, the search effort on each individual night was assumed to be constant (i.e.

fewer volunteers search for a longer time period, or many volunteers search for a shorter time period, with either scenario resulting in the maximum possible number of birds retrieved). This assumption allowed direct comparison of seasonal and annual values for average number of birds killed and found alive per night.

Fiedler, Wolfgang and Hans-Willy Ley, 2013. Ergebnisse von Flugtunnel-tests im Rahmen der Entwicklung von Glasscheiben mit UV-Signatur zur Vermeidung von Vogelschlag. Ber Vogelschutz 49/50:115-134.

Describes work at the Max Planck institute that led to the creation of Arnold's Ornilux glass.

Fink, L. C. and T. W. French. 1971. Birds in downtown Atlanta- Fall, 1970. Oriole 36(2):13-20.

Injured and dead birds found near two skyscrapers are listed. In addition to striking the upper floors of the buildings during night flights, birds also collide with the clear glass facing of the ground floor of one of the buildings during daytime. The authors presume birds that fly into the glass are attempting to reach the potted shrubbery in the lobby.

Fatal Light Awareness Program (FLAP) website http://flap.org/

Includes bird-friendly guidelines for commercial and residential buildings, links to other guidelines, ordinances and resources, as well as links to current issues like collisions related lawsuits.

FLAP Canada, 2018. An analysis of collision mitigation effectiveness pre- and post-installation of bird collision deterrents at four Toronto buildings. Unpublished report.

FLAP has been monitoring bird collisions in Toronto since 1993. This study analyzes data from four buildings with significant collisions, where there was both pre and post remediation monitoring. All remediation comprised versions of Feather Friendly (Convenience Group). One building had a striped type called 'Venetian'; the others had even dot patterns with 4mm grey or 5mm light grey dots. In some cases, more than one product was applied, at different times, to one structure. Reduction of collisions ranged from 87% to 94%. Please contact FLAP for more information.

Gaston, K.J. and T.M. Blackburn, 1997. How many birds are there? Biodiversity and Conservation 6: 615-625.

Measurements of global biodiversity have generally focused at the species level. The authors use 4 different methods to estimate the total global number of birds, calculating numbers that range from 200 to 400 billion individuals.

Gelb, Y. and N. Delacretaz. 2006. Avian window strike mortality at an urban office building. Kingbird 56(3):190-198.

The authors studied spring and fall window collisions at a six-story New York City office building. A small recreational park frequently used as a stopover site by migrating songbirds is opposite the building. Significantly more dead birds were found below windows that reflected vegetation than windows on another side of the building that did not. Ninety-two percent of salvaged birds were migratory species that only occur in the area during migration. A three-day period in October during which search frequency was increased from once per day to five times per day found most collisions occurred during the morning hours. Various methods of reducing bird collisions with glass are recommended.

Gelb, Y. and N. Delacretaz, 2009. Windows and Vegetation: Primary Factors in Manhattan Bird Collisions. Northeastern Naturalist 6(3):455–470.

Abstract - Bird collisions in Manhattan (New York City) were studied by analyzing collision data collected from 1997 to 2008 by Project Safe Flight (PSF) participants, representing one of the largest collision monitoring efforts in the nation. Over 5400 bird collisions were recorded during this period, two-thirds of which were fatal. Collisions involved 104 bird species, primarily from the warbler, sparrow, and thrush families, and mostly during spring and fall migration. Most collisions were documented to occur during the day at the lower levels of buildings where large glass exteriors reflected abundant vegetation, or where transparent windows exposed indoor vegetation. Most collisions in Manhattan likely occurred at a smaller number of high-collision sites where strike rates of well over 100 birds per year are considerably higher than previously reported rates. We suggest here that improving our understanding of the factors involved in collisions at such sites could greatly assist in reducing bird collisions.

Goller, Benjamin, Bradley F. Blackwell, Travis L. DeVault, Patrice E. Baumhardt and Esteban Fernández-Juricic (2018). Assessing bird avoidance of high-contrast lights using a choice test approach: implications for reducing human-induced avian mortality. PeerJ **DOI 10.7717/peerj.5404**

Note conclusion that steady burning red lights had least effect differs from results of Wiltschko and Wiltschko, and work on oil platform lighting.

Background: Avian collisions with man-made objects and vehicles (e.g., buildings, cars, airplanes, power lines) have increased recently. Lights have been proposed to alert birds and minimize the chances of collisions, but it is challenging to choose lights that are tuned to the avian eye and can also lead to avoidance given the differences between human and avian vision. We propose a choice test to address this problem by first identifying wavelengths of light that would over-stimulate the retina using species-specific perceptual models and by then assessing the avoidance/attraction responses of brown-headed cowbirds to these lights during daytime using a behavioral assay. Methods: We used perceptual models to estimate wavelength-specific light emitting diode (LED) lights with high chromatic contrast. The behavioral assay consisted of an arena where the bird moved in a single direction and was forced to make a choice (right/left) using a single-choice design (one side with the light on, the other with the light off) under diurnal light conditions.

Results: First, we identified lights with high saliency from the cowbird visual perspective: LED lights with peaks at 380 nm (ultraviolet), 470 nm (blue), 525 nm (green), 630 nm (red), and broad-spectrum (white) LED lights. Second, we found that cowbirds significantly avoided LED lights with peaks at 470 and 630 nm, but did not avoid or prefer LED lights with peaks at 380 and 525 nm or white lights.

Discussion: The two lights avoided had the highest chromatic contrast but relatively lower levels of achromatic contrast. Our approach can optimize limited resources to narrow down wavelengths of light with high visual saliency for a target species leading to avoidance. These lights can be used as candidates for visual deterrents to reduce collisions with man-made objects and vehicles.

Gómez-Moreno, Vannia del Carmen, José Rafael Herrera-Herrera, Santiago Niño-Maldonado, 2018. Colisión de aves en ventanas del Centro Universitario Victoria, Tamaulipas, México. Bird collisions in windows of Centro Universitario Victoria, Tamaulipas, México. Huitzil, Revista Mexicana de Ornitología 19(2).: 227-236 **https://doi.org/10.28947/hrmo.2018.19.2.347**

Resumen Las colisiones de las aves con diversas construcciones humanas (e.g., ventanales de cristal) son el segundo factor de mortalidad más importante en paisajes urbanos después de la depredación por gatos. Se ha estimado que alrededor de 988 millones de aves mueren anualmente solamente en los Estados Unidos y Canadá por estos factores. Entre agosto de 2015 y septiembre de 2016 evaluamos la frecuencia de colisiones aves-ventanas en el Centro Universitario Victoria de la Universidad Autónoma de Tamaulipas en el noreste de México. Para detectar aves muertas por colisiones realizamos recorridos en busca de cadáveres dentro de una franja perimetral (tres metros de ancho) alrededor de cuatro edificios durante dos sesiones diarias de muestreo (09:00-10:00 h y 16:0017:00 h). Identificamos 21 aves en el suelo de 16 especies, de éstas el 50% de las especies fueron residentes y del total de colisiones 16 fueron fatales. Las especies con mayor incidencia fueron la paloma ala blanca (Zenaida asiatica) con cuatro individuos y el colibrí pico ancho (Cynanthus latirostris) con tres. Durante el muestreo también detectamos cinco especies de aves residentes con conducta agonística contra su reflejo en las ventanas con vidrio reflejante de los edificios del campus universitario. Proponemos algunas medidas para mitigar el número de colisiones de aves en el cuv (e.g., colocación de bandas de colores en las ventanas). Las especies que colisionaron representaron el 5.2% de las especies descritas para el municipio de Victoria. Determinamos mayor frecuencia de colisión en los edificios con vidrios reflejantes. Es necesario seguir desarrollando más estudios de colisiones de aves usando metodologías sistemáticas, que incluyan puntos de conteo simultáneos para considerar la prevalencia de las especies en el sitio de estudio con el fin de documentar el impacto de la urbanización en las poblaciones y comunidades de aves en diferentes centros y paisajes urbanos de México. La determinación de los factores que más influyen en las tasas de colisión de aves-ventanas ayudará en el desarrollo de acciones efectivas de manejo para reducir las colisiones en diferentes escalas espaciales y temporales.

Abstract: Bird collisions in diverse man-made structures (e.g., glass windows) are the second most important mortality factor only after cat predation in urban landscapes in North America. Bird collisions have been estimated to cause approximately 988 million deaths annually in the Unites States and Canada alone for these factors. We assessed bird-windows collision frequency at the Centro Universitario Victoria (cuv) of the Universidad Autónoma de Tamaulipas in northeastern Mexico between August 2015 and September 2016. We used periodic walks in permanent transects searching for dead birds around the perimeter (3-m wide strip) of four buildings in two daily sessions (09:00-10:00 h y 16:00-17:00 h) at the cuv. We recorded 21 individual birds from 16 species hitting windows of the cuv Fifty percent of the recorded bird species were residents and 15 collisions out of the total were fatal. White-winged Dove (*Zenaida asiatica*) and Broad-billed Hummingbird (*Cynanthus latirostris*) were the species with the greatest incidence with four and three individuals respectively. We also detected five resident bird species showing agonistic behavior towards their reflection on window glasses in the campus facilities. We discuss some alternatives to mitigate (e.g., use of color strips attached to windows) the number of bird collisions. The 16 bird species that collided with the windows at the cuv represented the 5.2 % of the total bird species richness recorded for Victoria Municipality. We urge for more bird studies using systematic methodologies, including simultaneous point counts to account for species prevalence at the study site, to document the impact of urbanization on bird populations and communities in different urban centers and landscapes of Mexico. Determining what factors drive collision rates will aide in developing effective management actions in order to reduce collisions at different spatial and temporal scales.

Graham, D. L. 1997. Spider webs and windows as potentially important sources of hummingbird mortality. Journal of Field Ornithology 68(1):98- 101.

Graham observed daily collisions of birds with the windows of the La Selva Biological Station, Costa Rica. A detailed description of the windows is not given. Most collisions were non-lethal, but approximately 2-3 collisions per week resulted in death. Hummingbirds were the most commonly killed birds. Graham suspects the window mortality rate is great enough to significantly affect local hummingbird populations.

Grasso-Knight G. and M. Waddington. 2000. Bird collisions with windows on Swarthmore Campus. http://www.swarthmore.edu/NatSci/es/birdcollisions.html (accessed 20 August 2007).

Multiple campus buildings were surveyed for evidence of bird-window collisions during spring migration. The primary finding was bird mortality was unrelated to window size (see also Klem 1989). None of the study's results were robust, however, due to very small sample sizes.

Habberfield, Michael W. and Colleen Cassady St. Claire, 2016. Ultraviolet lights do not deter songbirds at feeders. J Ornithol (2016) 157:239–248. DOI 10.1007/s10336- 015-1272-8.
The authors tested the effect on bird proximity of a tubular (210x19mm) 1-W UV LED device emitting a pulsating wavelength of 390 nm [Spectral Impulse Anti-Collider, Y's Choice Investments, Ltd., Edmonton, Canada]. The device was designed for use in residential applications to deter birds from windows. Bird foraging behavior relative to the device was tested in four configurations to control for the presence of a novel object (i.e., the LED housing structure) at 8 residential sites with existing bird feeders. Video cameras were set to record one 10-s video using the high sensitivity setting, whenever motion-triggered by birds at the feeders. Number of feeder visits per day was the dependent variable in the analysis; 4569 feeder visits were recorded. Of multiple weather variables, only wind speed correlated with number of visits. No deterrent effect of the device was found.

Hager, S.B., H. Trudell, K.J. McKay, S.M. Crandall, L. Mayer. 2008. Bird density and mortality at windows. Wilson Journal of Ornithology 120(3):550-564.
This is the first study to test the hypothesis that window collision frequency and species richness of killed birds at a given site are positively correlated with the abundance and richness of birds in the surrounding area. Hager et al. monitored bird collisions year-round at buildings on two college campuses in Illinois and conducted point-counts in nearby wooded areas during the same time period.

The findings do not support the hypothesis that collision frequency is a function of local bird abundance. Rather, the authors conclude, window strike frequency is better explained by total window area, window height, surrounding habitat features, and behavioral differences among species (particularly between migrants and residents). Hence, birds in areas of relatively low abundance are not at decreased risk of collisions with windows and buildings in such areas should still take measures to reduce window strike potential.

The mortality rates of 55 and 24 birds/building/year observed during the study suggest the average mortality caused by commercial buildings in North America may be much greater than previously estimated (O'Connell 2001, Klem 1990).

Hager, Stephen B., 2009. Human-Related Threats to Urban Raptors. J. Raptor Res. 43(3):210–226
The author reviews 86 publications for information on raptor mortality in cities. Twenty-eight Falconiformes and 14 Strigiformes species are divided by degree of urban useage and dominant urban activities (feeding, breeding). Road use is treated similarly. To quote the abstract: *Within the Falconiformes (28 urban species), vehicle collisions and electrocutions were reported for most species (73% and 48%, respectively), and vehicular and window strikes were the leading sources of mortality for 39% and 12% of species, respectively. For the Strigiformes (14 urban species), vehicular (63%) and window (47%) collisions affected most species, and the primary sources of mortality were from vehicles (32%) and electrocution (5%). Window-strike mortality was*

reported for 45% of urban raptors and represented the leading source of mortality for Sharp-shinned Hawks (Accipiter striatus), Cooper's Hawks (A. cooperii), Merlins (Falco columbarius), and Peregrine Falcons (F. peregrinus). Mortality by electrocutions was also observed for 45% of the species. Vehicle collisions were reported for 60% of species and for half of those was the primary source of mortality. The impact of collisions on population structure has been studied for very few species and more such work is needed. An appendix provides notes for each of the sources used in the review.

Hager, Stephen B., Bradley J. Cosentino and Kelly J. McKay, 2012. Scavenging effects persistence of avian carcasses resulting from window collisions in an urban landscape. J. Field Ornithol. 83(2) 203-211.

Estimates of bird mortality at windows may be underestimated because of carcass scavenging. Scavenger activity was monitored at 20 buildings on the campus of Augustana College in suburban Illinois for one week in each season of the year, using motion triggered cameras. Carcass survival was greatest in winter, was related negatively window area and to the amount of cover within 50 meters, and was related positively to pavement cover.

The authors speculate that carcass survival time may be short in areas with habitat preferred by scavengers and where collisions create a predictable food source.

Hager SB, Cosentino BJ, McKay KJ, Monson C, Zuurdeeg W, and B. Blevins, 2013. Window Area and Development Drive Spatial Variation in Bird-Window Collisions in an Urban Landscape. PLoS ONE 8(1): e53371. doi:10.1371/journal.pone.0053371 Download link: http://people.hws.edu/cosentino/publications_files/PLoS%20ONE%202013%20Hager.pdf

Most collisions monitoring is non-random, buildings selected for convenience or perceived probability of collisions. Several papers have looked at differential collisions mortality at different types of building feature. Here, the authors examined collisions mortality at buildings selected randomly in an urban area of Illinois.

Hager SB, Cosentino BJ, McKay KJ, Monson C, Zuurdeeg W, et al. (2013) Window Area and Development Drive Spatial Variation in Bird-Window Collisions in an Urban Landscape. PLoS ONE 8(1): e53371. doi:10.1371/journal.pone.0053371

The 'results suggest that patchily distributed environmental resources and levels of window area in buildings create spatial variation in BWCs within and among urban areas. Current mortality estimates place little emphasis on spatial variation, which precludes a fundamental understanding of the issue. To focus conservation efforts, we illustrate how knowledge of the structural and environmental factors that influence bird-window collisions can be used to predict fatalities in the broader landscape.'

Hager, Stephen B and and Bradley J. Cosentino, 2014. Surveying for bird carcasses resulting from window collisions: a standardized protocol. https://peerj.com/preprints/406.pdf

Past studies on bird-window collisions have used a variety of survey protocols. Adoption of a standard protocol would improve the accuracy of mortality estimates at all scales. The authors present a standardized carcass survey protocol that they argue (a) is simple and inexpensive and (b) accounts for the removal of carcasses by scavengers and detection of carcasses by field workers. Addressed in the protocol are: 1. Preparing for

surveys, 2.
Supplies, 3. Frequency of surveys throughout the study, 4. When during the day to complete surveys, 5. Field worker behavior during surveys, 6. The pre-survey carcass 'clean-up', 7. How to conduct carcass surveys, 8. Carcass collection and containment, 9. Identifying species of bird carcasses, 10. Data collection and management, and 11. Duration of carcass surveys.

Hager SB, Craig ME. (2014) Bird-window collisions in the summer breeding season. PeerJ 2:e460
Download at https://dx.doi.org/10.7717/peerj.460

Most collisions monitoring takes place during migration, but collisions happen at any time of year. Hager and Craig examined window collisions during 4 breeding seasons in NW Illinois. The evaluated timing of collisions throughout the day as well as correlations among species, species abundance, age and number of collisions. Collision risk varies with bird age and migratory guild. Adult long- distant migrants collided more frequently early in the breeding season. Juveniles, in general, collided throughout the breeding season. The highest risk of collisions was for adults from least abundant species and juveniles from most abundant species.

Hager, Steven B. et al., 2017. Continent-wide analysis of how urbanization affects bird-window collision mortality in North America. Biological Conservation 212: 209-215
http://dx.doi.org/10.1016/j.biocon.2017.06.014
Abstract: Characteristics of buildings and land cover surrounding buildings influence the number of bird-window collisions, yet little is known about whether bird-window collisions are associated with urbanization at large spatial scales. We initiated a continent-wide study in North America to assess how bird-window collision mortality is influenced by building characteristics, landscaping around buildings, and regional urbanization. In autumn 2014, researchers at 40 sites (N =281 buildings) used standardized protocols to document collision mortality of birds, evaluate building characteristics, and measure local land cover and regional urbanization. Overall, 324 bird carcasses were observed (range =0–34 per site) representing 71 species. Consistent with previous studies, we found that building size had a strong positive effect on bird-window collision mortality, but the strength of the effect on mortality depended on regional urbanization. The positive relationship between collision mortality and building size was greatest at large buildings in regions of low urbanization, locally extensive lawns, and low density structures. Collision mortality was consistently low for small buildings, regardless of large-scale urbanization. The mechanisms shaping broad- scale variation in collision mortality during seasonal migration may be related to habitat selection at a hierarchy of scales and behavioral divergence between urban and rural bird populations. These results suggest that collision prevention measures should be prioritized at large buildings in regions of low urbanization throughout North America

Harden, J. 2002. An overview of anthropogenic causes of avian mortality. Journal of Wildlife Rehabilitation 25(1):4-11.
Numerous causes of injury to, and death of, birds admitted to a New Mexico wildlife rehabilitation center are discussed. Window collisions accounted for 8% of all human-caused injury and mortality.

Håstad, Olle and Anders Ödeen, 2014. A vision physiological estimation of ultraviolet window marking visibility to birds. PeerJ 2:e621; DOI10.7717/peerj.621 (available on line if you join Researchgate)

The authors used a physiological model of avian vision, using retinal data for the Blue Tit, as an example of Ultra Violet sensitive species (UVS), and the Indian Peafowl, as an example of Violet Sensitive (VS) species. They then collected photospectrometrical data to represent 4 scenarios encountered by birds, including reflections and habitat viewed through glass. They then modeled window markings as UV filters removing 25, 50 and 100% of UV wavelengths and calculated whether or not the markings would be detectable (not only visible, but different enough from the background to stand out) under the different conditions. They conclude that window markings absorbing (or reflecting) at least 50% of UV appear to be visible against a 'natural scene' to UVS species, including most passerines, but not for VS species like raptors, waterfowl and columbiforms. Interaction with glass reduces visibility to VS birds even farther.

Haupt, H. and U. Schillemeit, 2011. Skybeamer und Gebäudeanstrahlungen bringen Zugvögel vom Kurs ab: Neue Untersuchungen und eine rechtliche Bewertung dieser Lichtanlagen. NuL 43 (6), 2011, 165-170 [Search/spot Lights and Building Lighting Divert Migratory Birds Off Course: New investigations and a legal evaluation of these lighting systems]
The study describes and quantitatively examines the effects of upward-directed light sources on night-migrating passerines. More than 90 % of all birds flying through a light beam showed abnormal reactions such as circling, turnaround flights, change of direction, speed reduction, or undirected flights. Even after crossing the light beam, distracted birds often continued their flight in the changed direction. The authors suggest that these observations should lead to a ban on search lights, undirected building illuminations and other light sources directed upwards, at least during main bird migration. Legal provisions for regulatory activities definitely exist. Against this background the paper outlines relevant legal regulations for nature conservation and emission control.

Haupt, Heiko, 2009. Der Letzte macht das Licht an! – Zu den Auswirkungen leuchtender Hochhäuser auf den nächtlichen Vogelzug am Beispiel des „Post-Towers“ in Bonn (The last one turns the light on! The effects of lighted skyscrapers on nocturnal bird migration, using data from the "post-Towers" in Bonn.) Charadrius 45(1): 1-19
Abstract: From October 2006 to November 2007 the effects of illuminating the "Post Tower" in Bonn on birds were investigated. During this period, the nocturnal illumination attracted more than 1,000 birds from 29 species directly to the tower and its outbuildings. 200 birds were killed immediately, others were injured and presumably died later. They were either disoriented and collided with the glass panes or fell to the ground after flapping around the lights. Attraction and irritation effects were registered primarily during autumn migration between late July and early November, but in lower intensity also during spring migration between mid March and mid May. Firecrests and Robins were worst affected.

Hausberger M, Boigne A, Lesimple C, Belin L, Henry L, (2018) Wide-eyed glare scares raptors: From laboratory evidence to applied management. PLoS ONE 13(10): e0204802. https://doi.org/10.1371/journal.pone.0204802
Raptors are one of the most important causes of fatalities due to their collisions with aircrafts as well as being the main victims of collisions with constructions. They are difficult to deter because they are not influenced by other airspace users or ground predators. Because vision is the primary sensory mode of many diurnal raptors, we evaluated the reactions of captive raptors to a "superstimulus" (a "paradoxical effect whereby animals show greater responsiveness to an exaggerated stimulus than to the natural stimulus") that combined an "eye shape" stimulus (as many species have an aversion for this type of stimulus) and a looming movement (LE). This

looming stimulus mimics an impending collision and induces avoidance in a wide range of species. In captivity, raptors showed a clear aversion for this LE stimulus. We then tested it in a real life setting: at an airport where raptors are abundant. This study is the first to show the efficiency of a visual non-invasive repellent system developed on the basis of both captive and field studies. This system deterred birds of prey and corvids through aversion, and did not induce habituation. These findings suggest applications for human security as well as bird conservation, and further research on avian visual perception and sensitivity to signals.

Horton, Kyle G., Cecilia Nilsson, Benjamin M Van Doren, Frank A La Sorte, Adriaan M Dokter, and Andrew Farnsworth, 2019. Bright lights in the big cities: migratory birds' exposure to artificial light. Front Ecol Environ 2019; doi:10.1002/fee.2029
Excerpt: We conducted a quantitative assessment of continent- scale exposure of actively migrating birds to nighttime light pollution. The findings leverage recent advances in data access and machine learning to capture new and rich details in characterizing bird movements aloft in relation to radiance from human population centers. With considerations for urban areas and the numbers of migrants flying above them, we can now provide the data necessary to guide conservation actions to identify locations where ALAN- reducing programs may be most effective.

Johnson, R. E. and G. E. Hudson. 1976. Bird mortality at a glassed-in walkway in Washington State. Western Birds 7:99-107.
The authors recorded bird collisions with a four story glass walkway that connects two buildings on a rural college campus. The glass does not reflect images of nearby vegetation; rather, it is completely transparent and birds attempt to fly towards what is on the other side of the invisible barrier (trees and sky when approaching from the south and only sky when approaching from the north). Mortality was greatest during migration seasons, especially fall. Two years into the study, 6-12 raptor decals were placed on the glass. The authors observed an overall decrease in fatal strikes of 64%. A table is provided that shows the effect of decals on individual species.

Jones, J. and Francis, C.M., 2003. The effects of light characteristics on avian mortality at light houses. J. Avian Biol. 34:328-333.

Lighthouses are among the first structures reported to cause collision mortalities. The lighthouse at Long Point, Lake Erie, Ontario, Canada from 1960-1989 killed a mean number of 200 birds in spring and nearly twice that in fall, with up to 2000 birds killed in a single night. When the lighthouse was automated in 1989, with a narrower and less powerful beam, the mean mortality dropped to 18.5 in spring and 9.6 in autumn, for 1990-2002.

Kahle LQ, Flannery ME, Dumbacher JP (2016) Bird-Window Collisions at a West-Coast Urban Park Museum: Analyses of Bird Biology and Window Attributes from Golden Gate Park, San Francisco. PLoS ONE 11(1): e0144600. doi:10.1371/ journal.pone.0144600
A comprehensive study, including regular censuses of local bird populations along with monitoring of the building for five years. They noted that strikes occur throughout the day, but mitigation may be most effective in the morning and midday. Among other things, they also concluded that actively migrating birds may not be major contributors to collisions as has been found elsewhere and that males and young birds were both

significantly overrepresented relative to their abundance in the habitat surrounding the building.

Kenney, Devin T., 2015. Aesthetic Danger: How the Humane Need for Light and Spacious Views Kills Birds and What We Can (and Should) Do to Fix this Invisible Hazard. Journal of Animal and Natural Resource Law, Vol. 11 pp 137- 158.

Part I discusses the natural history of migratory birds and why they are particularly susceptible to collisions. Also, Part I discusses the historical and modern use of reflective and transparent glass in human architecture and its impact on birds. Part II discusses the various legal and ethical issues arising concerning avian mortality in window collisions and compares the existing approaches to the problem, in the United States, Canada, and the European Union, to determine the approach that is at once best for wildlife and most fair to the owners and builders of structures utilizing aesthetic glass. Part III discusses steps that might be taken both from a top-down regulatory approach as well as voluntary construction standards that might be explored to limit mortality in the future. Additionally, Part III considers the possibility of a negotiated international approach to resolution of this issue. Finally, Part IV concludes by calling for more research into the scope of the window collision problem and into the viability of proposed solutions to that problem.

https://www.animallaw.info/policy/journal-animal-and-natural-resource-law-vol-11

Klem, D., Jr. 1979. Biology of collisions between birds and windows. Ph.D. dissertation, Southern Illinois University, Carbondale, IL.
Klem examined various aspects of window collisions, including the species known to collide with windows, age and sex distributions of collision victims, seasonal variation in collision frequency, effects of window size and type on collision frequency, and effectiveness of some methods of preventing window strikes. Most of this research was later published in scientific journals (Klem 1989; 1990a,b; Klem et al. 2004).

Klem, D., Jr. 1989. Bird-window collisions. Wilson Bulletin 101(4):606-620.
Klem analyzed window collision data obtained from ornithological collections, volunteer monitoring of two homes, and field experiments. He concludes the likelihood of birds striking windows is generally unaffected by species, age, and sex, window height, size, and orientation, type of glass (i.e., clear or reflective), season, time of day, and weather conditions. The study demonstrates that window collisions occur simply because birds do not recognize glass as a barrier and all birds are vulnerable. This is contrary to popular beliefs that window collision victims are usually unhealthy or otherwise impaired.

Klem, D., Jr. 1990a. Collisions between birds and windows: Mortality and prevention. Journal of Field Ornithology 61(1):120-128.
Houses and commercial buildings were monitored for window strikes during autumn and winter months. Based on the mortality observed at these sites, Klem reaches a conservative annual estimate of 1-10 birds killed per building per year. When multiplied by the number of buildings in the U.S., it is estimated that 97.6-975.6 million birds are killed by windows each year. Experiments found single hawk silhouettes and other objects placed on windows did not significantly reduce mortality. Mortality was only reduced when several items were spaced <10 cm apart and covered most of the glass surface.

Klem, D., Jr. 1990b. Bird injuries, cause of death, and recuperation from collisions with windows. (Heridas, Causas De Muerte Y Restablecimiento

De Aves Que Chocan Con Ventanas). Journal of Field Ornithology 61(1):115- 119.

Klem determines most collision victims die from intracranial hemorrhaging and subsequent brain damage; few suffer skeletal fractures.

Resumen: Sinopsis.-Trecientas fatalidades y 31 sobrevivientes, fueron estudiados para determinar el tipo de dafio, causa de muerte y restablecimiento de aves que chocan con el cristal de ventanas.
Las consecuencias de estas colisiones dependen del momentum del pajaro al instante del choque. El efecto de los choques vari6 desde ningin daiio visible hasta huesos fracturados y sangramiento superficial o interno. Las fracturas fueron rairas. Las aves muertas presentaron hemorragia intracraneal, lo que sugiere que la causa del deceso fue el resultado de la ruptura de vasos sanguineos y del dafio cerebral a causa del impacto. Los sobrevivientes tambien mostraron hemorragias intracraneales, y un individuo exhibio una paralisis que progreso con el pasar del tiempo. Otras aves que no murieron, parecieron no sufrir danio de inmediato, otras se recuperaron totalmente a lo largo de diferentes periodos de tiempo. Para aumentar la probabilidad de que un ave se recupere, debe colocarse el pajaro en un lugar aislado. El lugar debe mantenerse calido y se debe proveer al ave con alimento y agua.

Klem, D., Jr. 1991. Glass and bird kills: An overview and suggested planning and design methods of preventing a fatal hazard. Pp. 99-104 in L. W. Adams and D. Leedy (Eds.), Wildlife Conservation in Metropolitan Environments. Natl. Inst. Urban Wildl. Symp. Ser. 2, Columbia, MD.
Klem reviews existing knowledge and urges landscapers and architects to take measures to minimize window strike potential. Recommendations include feeder placement close to windows, covering of windows with netting or strips of translucent fabric, and window angling.

Klem, D. Jr., D. C. Keck, K. L. Marty, A. J. Miller Ball, E. E. Niciu, C. T. Platt. 2004. Effects of window angling, feeder placement, and scavengers on avian mortality at plate glass. Wilson Bulletin 116(1):69-73.
Experiments revealed that window strike mortality is inversely related to window angle and feeder distance, with the most angled windows and closest feeders causing the least mortality. Thus, angling windows slightly downwards and only placing feeders within 1 m of windows are recommended by the authors as practical solutions to reduce avian mortality at homes and commercial buildings.
The results of a carcass removal experiment suggest that scavengers can have a significant effect on detection probability (see also Young et al. 2003). Previously calculated strike rates that do not account for carcass removal are likely underestimates of true mortality. Future window strike studies should quantify scavenger removal in concert with bird mortality to ensure more precise mortality rate estimates.

Klem, D., Jr. 2006. Glass: A deadly conservation issue for birds. Bird Observer 34(2):73-81.
Klem provides an overview of his research on bird collisions with glass, followed by detailed explanations of potential solutions. Klem discusses past failures of the conservation community and building industry to recognize and respond to the issue. Klem notes a recent dramatic increase in awareness, particularly in the form of media attention.

Klem, D. Jr. 2009. Preventing Bird-Window Collisions. The Wilson Journal of Ornithology 121(2):314–321.

Klem conducted a series of aviary and field trials, testing commercial products a string of colored feathers (ineffective), Window Alert decals (effective when densely applied), CollidEscape (very effective), UV absorbing film (somewhat effective), fritted glass (effective) and films made with high UV reflecting/high UV absorbing materials arranged in different configurations (some very effective). The UV films were prototypes, promising but not commercially available at this time). Continuous monitoring showed that 25% of collisions left no marks on glass.

Klem, D. Jr., C. J. Farmer, N. Delacretaz, Y. Gelb and P.G. Saenger, 2009. Architectural and Landscape Risk Factors Associated with Bird-Glass Collisions in an Urban Environment. Wilson Journal of Ornithology 121(1): 126-134.
Using mortality data from monitoring of 73 building facades in Manhattan, the authors test the hypothesis that architectural and/or landscape variables can account for risk of death from collisions. Mortality increased with glass area and height of vegetation.

Klem, D. Jr. 2010. Avian mortality at windows: the second largest human source of bird mortality on earth. Proc. Fourth Int. Partners in Flight Conference: Tundra to Tropics. pp 244-251 An overview of Klem's findings concerning bird collisions with plastic and glass.

Klem, D. Jr., 2010. Sheet Glass as a Principal Human-Associated Avian Mortality Factor Chapter 20 in Majumdar, S.K., Master, T.L., Brittingham, M., Ross, R.M., Mulvihill, R. and J. Huffman. *Avian Ecology and Conservation: A Pennsylvania Focus with National Implications*.
Pennsylvania Academy of Science.
A review of factors and issues involved in collisions with glass. Quotes an AOU compilation of species reported by museums and individuals – the American Robin is the most frequent collision victim and the list is quite different from lists reported by urban monitoring programs. Klem also provides a table of Watchlist species that have been documented as collision casualties.
Klem, Daniel Jr. and Peter G. Saenger, 2013. Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-window Collisions. The Wilson Journal of Ornithology 125(2):406–41. Download at: http://www.muhlenberg.edu/main/academics/biology/faculty/klem/aco/Bird- window.html
Using the protocol described in earlier papers, the authors undertook 2 trials. The first compared the number of bird strikes caused by clear and mirrored glass controls and ORNILUX Mikado in a free-standing condition. 116 strikes were recorded and numbers of strikes did not differ significantly among treatments, with 32 (28%) at the clear glass control, 43 (37%) at the reflective glass control, and 41 (35%) at the Mikado. However, the number of fatal strikes differed significantly across all treatments with 2 (10%) at the clear glass control, 6 (32%) at the reflective glass control, and 11 (58%) at the Mikado. It is not clear why mortality rates differ but strike rates do not.
The second trial tested the clear glass control, an ORNILUX Mikado pane covering a recessed non-reflective black wooden board simulating a window that covered a darkened room, and two vertically striped spacing variations of preventive treatments known as Acopian BirdSavers: (1) a clear glass pane covered with 3.175 mm parachute cord spaced 10.8 cm from the center of one cord to the center of the next, and (2) a reflective (mirror) glass pane covered with 3.175 mm parachute cord spaced 8.9 cm from the center of one cord to the center of the next. In this case, the number of strikes differed among

treatments, with 69 (62%) at the clear glass control, 31 (28%) at ORNILUX over dark interior, 7 (6%) at parachute cords spaced 10.8 cm apart covering clear pane, and 5 (4%) at parachute cords spaced 8.9 cm apart covering reflective pane.

Klem, Daniel Jr. (2015) Bird–Window Collisions: A Critical Animal Welfare and Conservation Issue, Journal of Applied Animal Welfare Science, 18:sup1, S11- S17, DOI:10.1080/10888705.2015.1075832
'Avian window casualties are important for birds and people, and they have nonhuman animal welfare, biodiversity, sustainability, legal, and ethical and moral value justifying responsible human action. Preventing this unintended and unwanted lethal hazard for free- flying birds should be an obligation.'

Kummer, J. A., and E. M. Bayne. 2015. Bird feeders and their effects on bird-window collisions at residential houses. *Avian Conservation and Ecology* 10(2):6. http://dx.doi.org/10.5751/ACE-00787-100206

During the study there were 51 collisions when there was no bird feeder and 94 when the feeder was present. 26 of 55 windows in the study had zero collisions. The season when each trial was setup was the best individual predictor of bird-window collisions, with most during fall migration and least in winter. (it was not noted whether windows had screens).

Kummer, Justine A., Erin M. Bayne and Craig S. Machtans, 2016a. Use of citizen science to identify factors affecting bird–window collision risk at houses. The Condor, 118(3):624-639. DOI: http://dx.doi.org/10.1650/CONDOR-16-26.1 URL: http://www.bioone.org/doi/full/10.

Abstract: Bird–window collisions at houses have been identified as a significant source of mortality for North American birds, but which types of houses and windows are most problematic remains poorly understood. We assessed how neighborhood type, yard conditions, house attributes, and window type influenced collision rates. Data were collected from citizen scientists across Alberta, Canada, who surveyed their houses daily. In relation to the best-fitting model, the yard model explained 58.1% of the explained deviance, the neighborhood model 45.6%, and the house model 42.6%. The factors that had the largest effect for predicting collision risk included season and whether the house was in a rural or an urban area (rural areas in the fall had a 6.0× higher collision risk than urban areas in the winter), the height of vegetation in the front yard of the house (trees >2 stories high increased collision risk by 3.6× compared to houses with no trees), and the presence of a bird feeder (which increased collision risk by 1.7×). This suggests that multiple factors affect collision rates and that the suitability of a yard as bird habitat is likely a key driver. Given that few homeowners are likely to take an approach that reduces the number of birds in their yards, future focus needs to be given to bird-friendly urban design and developing the most effective window deterrents so that collisions can be reduced and birds enjoyed in urban environments

Kummer, J. A., E. M. Bayne, and C. S. Machtans, 2016b. Comparing the results of recall surveys and standardized searches in understanding bird window collisions at houses. *Avian Conservation and Ecology* 11(1):4. http://dx.doi.org/10.5751/ACE-00820-110104
Collision recall rates in this study (56.5%) were very similar those in a prior 2012 study, where 50.5% of participants remembered a bird colliding with a window at some time in

the past. Fatality estimates, however, were 1.4 times higher in the 2012 study than in the study based on standardized searches. Rural houses with a bird feeder consistently had the highest number of collisions. The authors found considerable differences in absolute values for collisions but similar rankings of collision rates between residence types.

Kummer, J. A., C. J. Nordell, T. M. Berry, C. V. Collins, C. R. L. Tse, and E. L. Bayne. 2016. Use of bird carcass removals by urban scavengers to adjust bird-window collision estimates. *Avian Conservation and Ecology* 11(2):12. http://www.ace-eco.org/vol11/iss2/art12/
http://dx.doi.org/10.5751/ACE-00927-110212
A bird carcass and time-lapse camera were placed at 44 houses in Edmonton, Alberta. In total, 166 7-day trials were conducted throughout 2015. 67.5% of carcasses were removed. The date the carcass was placed, the year the house was built, and the level of development within 50 m of the house were the covariates that had the largest effect on carcass removal. The factors affecting carcass survival time are similar to those factors we identified as having a large effect on bird–window collisions (Kummer et al. 2016*a*). This suggests that those homes that are experiencing a large number of collisions are probably experiencing a higher number of scavenging events that need to be corrected for when estimating collision rates.
Scavenging rates were different from those reported by Machtans and by Klem; determining local scavenging rates may be important in developing overall collisions mortality estimates.

La Sorte FA, Fink D, Buler JJ, Farnsworth A, Cabrera-Cruz SA. Seasonal associations with urban light pollution for nocturnally migrating bird populations. Glob Change Biol. 2017;23:4609–4619. https://doi.org/10.1111/gcb.13792

Abstract

The spatial extent and intensity of artificial light at night (ALAN) has increased worldwide through the growth of urban environments. There is evidence that nocturnally migrating birds are attracted to ALAN, and there is evidence that nocturnally migrating bird populations are more likely to occur in urban areas during migration, especially in the autumn. Here, we test if urban sources of ALAN are responsible, at least in part, for these observed urban associations. We use weekly estimates of diurnal occurrence and relative abundance for 40 nocturnally migrating bird species that breed in forested environments in North America to assess how associations with distance to urban areas and ALAN are defined across the annual cycle. Migratory bird populations presented stronger than expected associations with shorter distances to urban areas during migration, and stronger than expected association with higher levels of ALAN outside and especially within urban areas during migration. These patterns were more pronounced during autumn migration, especially within urban areas. Outside of the two migration periods, migratory bird populations presented stronger than expected associations with longer distances to urban areas, especially during the nonbreeding season, and weaker than expected associations with the highest levels of ALAN outside and especially within urban areas. These findings suggest that ALAN is associated with higher levels of diurnal abundance along the boundaries and within the interior of urban areas during migration, especially in the autumn when juveniles are undertaking their first migration journey. These findings support the conclusion that urban sources of ALAN can broadly effect migratory behavior, emphasizing the need to better understand the implications of ALAN for migratory bird populations.

Ley, H.W. 2006. Experimentelle Überprüfung der Wahrnehmbarkeit patentierter Vogelschutzgläser durch eine Stichprobe mitteleuropäischer Gartenvögel. Max Planck Institut für Ornithologie [available for download from http://www.wua-wien.at/publikationen]

Ley, H.W. 2006. Experimental examination of the perceptibility of patented bird- protecting glass to a sample of Central European perching birds. Max Planck Institute for Ornithology, unpublished report

Using an indoor flight tunnel, Ley tested the effectiveness of 17 European- patented glass types specifically designed to reduce bird collisions. The glass reflects and/or absorbs ultraviolet light, intending to make the surface visible to birds while not appearing different than conventional glass to humans. Only one of the 17 types tested was significantly effective when compared to ordinary glass or a section of open air space. This type consisted of a combination of ultraviolet reflecting and absorbing vertical stripes.

Descriptions of the 16 ineffective types are not provided. Ley cautions that the glass' effectiveness under more natural, outdoor conditions may differ from what was found during the indoor flight tunnel experiments. This work led to the first generation of Ornilux glass.

Lin H-T, Ros IG, BiewenerAA. 2014 Through the eyes of a bird:modelling visually guided obstacle flight.J. R. Soc. Interface 11: 20140239. http://dx.doi.org/10.1098/rsif.2014.0239

Various flight navigation strategies for birds have been identified at the large spatial scales of migratory and homing behaviours. However, relatively little is known about close-range obstacle negotiation through cluttered environments. To examine obstacle flight guidance, we tracked pigeons (*Columba livia*) flying through an artificial forest of vertical poles. Interestingly, pigeons adjusted their flight path only approximately 1.5 m from the forest entry, suggesting a reactive mode of path planning. Combining flight trajectories with obstacle pole positions, we reconstructed the visual experience of the pigeons throughout obstacle flights. Assuming proportional–derivative control with a constant delay, we searched the relevant parameter space of steering gains and visuomotor delays that best explained the observed steering. We found that a pigeon's steering resembles proportional control driven by the error angle between the flight direction and the desired opening, or gap, between obstacles. Using this pigeon steering controller, we simulated obstacle flights and showed that pigeons do not simply steer to the nearest opening in the direction of flight or destination. Pigeons bias their flight direction towards larger visual gaps when making fast steering decisions. The proposed behavioural modelling method converts the obstacle avoidance behavior into a (piecewise) target-aiming behaviour, which is better defined and understood. This study demonstrates how such an approach decomposes open-loop free-flight behaviours into components that can be independently evaluated.

Liu, Hui and Xu Yanchun, 2017. Bird Collision with Building Glass Outer Wall Caused by Landscape Structure: a Case Study; College of Wildlife Resources, Northeast Forestry University; Chinese Journal of Wildlife, 2014-02

Glass is extensively used for decorating outer walls(curtain walls) of buildings in cities around the world.Birds frequently collide with these glass walls during flight,resulting in massive death each year.This has become the second factor influencing bird populations after habitat degradation.The building of the College of Wildlife Resources,Northeast Forestry University,Harbin,China,was decorated with a blue glass wall measuring 33 ×13 m.Every migration season,collisions of dusky warbler *Phylloscopus fuscatus*, Arctic warbler *P.borealis* and other passerine species are reported and result in numerous bird deaths.From 2011 to 2013,we investigated the collision cases during migration seasons,and identified several landscape structural conditions that influence frequencies of bird collisions with this building,including:1)the large size of the glass wall;2) short distance(about 20 m) between the glass wall and the street-side trees in front of it;3) the presence of potted birch trees and needle juniper trees adjacent to the glass wall that cause the reflection of the street-side trees to appear as natural vegetation, encouraging birds to fly towards the reflected image; and 4)the presence of a small paved parking area adjacent to the building, passing which the birds accelerate and collide with the glass wail at high speed. The impact of this micro-landscape structure suggests prevention of bird collision with this glass wall should focus on removal of one or more of the above conditions to avoid the reflection of habitats birds naturally inhabit.

Longcore Travis, Catherine Rich, Pierre Mineau, Beau MacDonald, Daniel G. Bert, Lauren M. Sullivan, Erin Mutrie, Sidney A. Gauthreaux Jr, Michael L. Avery, Robert L. Crawford, Albert M. Manville II, Emilie R. Travis and David Drake, 2012. An estimate of avian mortality at communication towers in the United States and Canada.
http://www.plosone.org/article/info%3Adoi%2F10.1371%2Fjournal.pone.0034025
The authors compiled a database of communication towers in the continental United States and Canada and estimated avian mortality by tower with a regression relating avian mortality to tower height. This equation was derived from 38 tower studies for which mortality data were available and corrected for sampling effort, search efficiency, and scavenging where appropriate. Although most studies document mortality at guyed towers with steady-burning lights, they accounted for lower mortality at towers without guy wires or steady-burning lights by adjusting estimates based on published studies. The resulting estimate of mortality at towers is 6.8 million birds per year in the United States and Canada.

Longcore, Travis, Catherine Rich, Pierre Mineau, Beau MacDonald, Daniel G. Bert, Lauren M. Sullivan, Erin Mutrie, Sidney A. Gauthreaux Jr., Michael L. Avery, Robert L. Crawford, Albert M. Manville II, Emilie R. Travis, and David Drake, 2013. Avian mortality at communication towers in the United States and Canada: which species, how many, and where? Biological Conservation 158:410–419.
(Abbreviated abstract) The authors calculated mortality at lighted communication towers by species and by Bird Conservation Regions, and then calculated the mean proportion of each species killed at towers within aggregated Bird Conservation Regions. These were combined with mortality estimates previously calculated for those regions. Estimated bird mortality rates were compared to the estimated populations of species in the United States and Canada. Neotropical migrants suffer the greatest mortality; 97.4% of birds killed are passerines, mostly warblers (Parulidae, 58.4%), vireos (Vireonidae, 13.4%), thrushes (Turdidae, 7.7%), and sparrows (Emberizidae, 5.8%). Thirteen birds of conservation concern in the United States or Canada suffer annual mortality of 1–9% of their estimated total population. Of these, estimated annual mortality is >2% for Yellow Rail (*Coturnicops noveboracensis*), Swainson's Warbler (*Limnothlypis swainsonii*), Pied-billed Grebe (*Podilymbus podiceps*), Bay-breasted Warbler (*Setophaga castanea*), Golden-winged Warbler (*Vermivora chrysoptera*), Worm-eating Warbler (*Helmitheros vermivorum*), Prairie Warbler

(*Setophaga discolor*), and Ovenbird (*Seiurus aurocapilla*).

Longcore, T., and P. A. Smith. 2013. On avian mortality associated with human activities. Avian Conservation and Ecology 8 (2): 1. http://dx.doi.org/10.5751/ACE-00606-080201

The authors discuss why documentation of species level decline is much too coarse a benchmark to capture many serious impacts of human-caused bird mortality on ecosystems.

Loss, Scott R., **Tom Will and Peter P. Marra, 2012. Direct human-caused mortality of birds: improving quantification of magnitude and assessment of population impact. Frontiers in Ecology and the Environment, September, Vol. 10, No. 7: 357- 364**

There are many types of human caused bird-mortality, including cats, collisions with buildings, turbines, towers, roads and power lines, pesticide poisoning, oiling and more. Quantifying mortality levels and impacts on populations has been difficult, however, with few rigorous studies available. The authors outline methodology and techniques of analysis that would produce more consistently useful results. This is important, as this information is the basis for policies and legislation.

Loss, Scott R., Tom Will, Sara S. Loss and Peter P. Marra, 2014. Bird–building collisions in the United States: Estimates of annual mortality and species vulnerability. Condor 116:8-23. DOI: 10.1650/CONDOR-13- 090.1

The authors comprehensively acquired published and unpublished data sets on collisions with buildings. Data sets were variable and filtered using a variety of criteria to ensure they could be used in single analyses. The authors calculate a median value for mortality at homes at 253 million, 2.1 birds per structure. Urban residences without feeders account for 33% of this mortality cumulatively, as there are more such residences, even though residences with feeders produce more collisions individually.

Rural residences without feeders account for 31% of residential mortality, followed by urban residences with feeders (19%) and rural residences with feeders (17%). Median mortality at low rise buildings (4-11 stories), calculated from two data sets, was averaged as 339 million, 21.7 birds per building. High rises, although collectively causing least mortality (508,000) individually had the highest median rate of 24.3 birds per building. Combining all building classes produces a median estimate of 599 million birds killed annually in the U.S.

The authors also investigated relative species vulnerability. 35% of birds reported were White-throated Sparrow, Dark-eyed Junco and Song Sparrow, but these were also the species with largest populations. Accounting for this and other factors, some species exhibited a disproportionate tendency to collide with buildings, especially Ruby-throated Hummingbird, Brown Creeper, Ovenbird, Yellow-bellied Sapsucker, Gray Catbird and Black-and-White Warbler. Seven disproportionately vulnerable species are national Birds of Conservation Concern and ten are listed regionally.

Most mortality data come from urban monitoring programs focused on spring and fall migration, although studies show that there is significant mortality throughout the year. The authors suggest that, based on year-round data, collisions mortality may exceed one billion annually.

Loss, S.R., Loss, S.S., Will, T., Marra, P.P. 2014. Best practices for data collection in studies of bird-window collisions. Available online: https://abcbirds.org/program/glass-collisions/learn-more/

Loss, Scott R., Tom Will and Peter P. Marra, 2015. Direct Mortality of Birds from Anthropogenic Causes. Annual Review of Ecology, Evolution and Systematics 46:99-120. doi: https://www.annualreviews.org/doi/pdf/10.1146/annurev-ecolsys-112414-054133
Abstract: Understanding and reversing the widespread population declines of birds require estimating the magnitude of all mortality sources. Numerous anthropogenic mortality sources directly kill birds. Cause-specific annual mortality in the United States varies from billions (cat predation) to hundreds of millions (building and automobile collisions), tens of millions (powerline collisions), millions (powerline electrocutions, communication tower collisions), and hundreds of thousands (wind turbine collisions). However, great uncertainty exists about the independent and cumulative impacts of this mortality on avian populations. To facilitate this understanding, additional research is needed to estimate mortality for individual bird species and affected populations, to sample mortality throughout the annual cycle to inform full life-cycle population models, and to develop models that clarify the degree to which multiple mortality sources are additive or compensatory. We review sources of direct anthropogenic mortality in relation to the fundamental ecological objective of disentangling how mortality sources affect animal populations.

Machtans, Craig S., Christopher H. R. Wedeles and Erin M. Bayne, 2013. A First Estimate for Canada of the Number of Birds Killed by Colliding with Building Windows. Avian Conservation and Ecology 8(2): 6. http://dx.doi.org/10.5751/ACE-00568-080206
(abbreviated abstract) The authors estimated the number of birds killed by collisions with glass in Canada, making distinct models for houses, low-rise commercial and institutional buildings, and tall buildings. They estimate that about 25 million (range 16–42 M) birds are killed by colliding with windows in Canada annually, with 90% of building-related mortalities caused by houses, low-rise buildings slightly less than 10%, and tall buildings approximately 1%. The disproportionate contribution of mortality caused by houses is a function of their relative number compared to the two other classes of buildings. Warblers and sparrows were the most commonly killed birds at low-rise and tall buildings, and insufficient information exists on species deaths at houses to determine proportions. Targeted mitigation for certain tall buildings and a segment of the low-rise building types could significantly reduce the total mortality for both these building types.

Machtans, Craig S. and Wayne E. Thogmartin, 2014. Understanding the value of imperfect science from national estimates of bird mortality from window collisions. Condor 116:3-7.
The authors consider efforts to estimate the magnitude of bird mortality from collisions. Available data is necessarily patchy, making precise calculations impossible. However, there are many benefits, including development of new strategies to improve calculations and stimulating responses to the information.

Mahjoub, Ghazi , Mark K. Hinders and John P. Swaddle, 2015. Using a "sonic net" to deter pest bird species: Excluding European starlings from food sources by disrupting their acoustic communication. Wildlife Society Bulletin 39(2):326–333; 2015; DOI: 10.1002/wsb.529
Abstract Pest avian wildlife is responsible for substantial economic damage every year in the United States. Previous technologies used to deter starlings have generally failed because birds quickly habituate to startle regimes. In this study, conducted from May to July 2013, we focused

on altering the foraging behavior of the European starling (Sturnus vulgaris), a pest bird that is responsible for crop losses and also poses notable risk for bird–aircraft strikes. The goal of our project was to develop an effective system to limit starlings' use of a food patch. Using nonlinear ultrasonic parametric arrays, we broadcast a directional sound that overlapped in frequency with starling vocalizations and was contained in a specific area, creating a "net." We hypothesized that the "sonic net" would disturb acoustic communication for starlings, causing them to leave and feed elsewhere. Using wild-caught starlings in a large aviary, we deployed the sonic net over one food patch while leaving another food patch unaltered, and assessed their presence and feeding for three consecutive days. The sonic treatment decreased starlings' presence at the treated food patch, on average by 46%. Additionally, we assessed whether the sonic net disrupted the birds' response to an alarm call. When under the sonic net, starlings did not respond to the alarm call, suggesting that the sonic net disrupted acoustic communication. The sonic net is a promising new method of decreasing foraging activity by pest bird species.

Martin, G.R. 2011. Understanding bird collisions with man-madobjects: a sensory ecology approach. Ibis 153:239-54.
To understand why birds collide with man-made objects it is important to knowing how birds see. This paper identifies aspects of bird vision and visual behavior that probably contribute to collisions – for example, in flight, at times, some birds may actually be blind in the direction of travel. Frontal vision may be tuned for direction of movement, not for detection of spatial detail. Birds in flight may predict that the environment ahead is open, because they have no template for recognizing wind turbines, buildings or power lines.

Martin, Graham R. 2012. Through birds' eyes: insights into avian sensory ecology. Journal of Ornithology, August 2012, Volume 153, Issue 1 Supplement, pp 23-48. This paper is well worth reading in its entirety.
Sensory ecology describes 'the information that underlies an animal's interactions with its environment' – the information that animals have available to them. The paper reviews Martin's own work in the field, for example how owls, kiwi, oilbirds and penguins differently solve problems related to nocturnal activity. He also uses a sensory ecology approach to examine why birds collide with man-made objects like power lines and wind turbines that to humans appear very obvious. Fundamental to avian sensory ecology is understanding important differences between the way birds and humans see their environment. Humans, with forward facing eyes, have significant three-dimensional vision but a relatively restricted field of view compared to most birds, with eyes at the side of the head, restricted three-dimensional vision and a field of view that in a few cases is actually 360 degrees. Other, equally major differences mean that human vision cannot be used to model avian vision.

Martin's conclusions concerning collisions include:

1. Some birds may be blind ahead of themselves in flight
2. Vision in the direction of travel is not high resolution vision and may be tuned for movement, not spatial detail
3. Birds use lateral vision for detection of food, predators etc and this may be why they look downwards during flight
4. Birds in flight may predict that the environment ahead is not cluttered

Marquenie, J.; Donners, M.; Poot, H.; Steckel, W.; de Wit, B., "Bird- Friendly Light Sources: Adapting the Spectral Composition of Artificial Lighting," *Industry Applications Magazine, IEEE* , vol.19, no.2, pp.56,62, March-April 2013

http://ieeexplore.ieee.org/stamp/stamp.jsp?tp=&arnumber=6401220&isnumber=6461508.

May *et al.* Do birds in flight respond to (ultra)violet lighting? *Avian Res (2017) 8:33*
https://doi.org/10.1186/s40657-017-0092-3
Abstract Concerns for bird collisions with wind turbines affect the deployment of onshore and offshore windpower plants. To avoid delays in consenting processes and to streamline the construction and operation phase, functional mitigation measures are required which efficiently reduces bird mortality. Vision is the primary sensory system in birds, which for a number of species also includes the ultraviolet spectrum. Many bird species that are known to collide with offshore wind turbines are sensitive in the violet or ultraviolet spectrum. For species that are mainly active at lower ambient light levels, lighting may deter birds from the lit area. Utilizing (ultra)violet lights may in addition not disturb humans. However, we do not know whether UV- sensitive birds in flight actually respond behaviourally to UV lights. We therefore tested the efficacy of two types of lights within the violet (400 nm) and ultraviolet (365 nm) spectrum to deter birds from the lit area. These lights were placed vertically and monitored continuously between dusk and dawn using an avian radar system. Relative to control nights, bird flight activity (abundance) was 27% lower when the ultraviolet light was on. Violet light resulted in a 12% decrease in overall abundance, and in addition, a vertical displacement was seen, increasing the average flight altitude.

McLaren, J. D., Buler, J. J., Schreckengost, T., Smolinsky, J. A., Boone, M., Emiel van Loon, E., Dawson, D. K. and Walters, E. L. (2018), Artificial light at night confounds broad-scale habitat use by migrating birds. Ecol Lett. doi:10.1111/ele.12902
Abstract With many of the world's migratory bird populations in alarming decline, broad-scale assessments of responses to migratory hazards may prove crucial to successful conservation efforts. Most birds migrate at night through increasingly light-polluted skies. Bright light sources can attract airborne migrants and lead to collisions with structures, but might also influence selection of migratory stopover habitat and thereby acquisition of food resources. We demonstrate, using multi-year weather radar measurements of nocturnal migrants across the northeastern U.S., that autumnal migrant stopover density increased at regional scales with proximity to the brightest areas, but decreased within a few kilometers of brightly-lit sources. This finding implies broad-scale attraction to artificial light while airborne, impeding selection for extensive forest habitat. Given that high-quality stopover habitat is critical to successful migration, and hindrances during migration can decrease fitness, artificial lights present a potentially heightened conservation concern for migratory bird populations.

Menacho-Odio, Rose Marie, 2015. Colisión de aves contra ventanas en Costa Rica: conociendo el problema a partir de datos de museos, ciencia ciudadana y el aporte de biólogos. Zeledonia 19(1) 10-21. Spanish and English abstracts below. Full text available at http://www.zeledonia.com/uploads/7/0/1/0/70104897/19-1.pdf
Resumen: El presente estudio consistió en el registro de especies de aves que han presentado colisiones contra ventanas o puertas de vidrio en Costa Rica. Los datos se obtuvieron a partir de una revisión de especímenes del Museo Nacional de Costa Rica y del Museo de Zoología de la Universidad de Costa Rica, además, datos de colectas realizadas por biólogos y de información enviada por científicos ciudadanos del grupo de redes sociales de la Asociación Ornitológica de Costa Rica. Como resultado se compiló un

listado de 131 especies de aves que han presentado colisiones contra ventanas en Costa Rica. Entre ellas se encuentran aves con poblaciones reducidas como el pájaro campana Procnias tricarunculatus (n=4) y el loro cabecipardo Pyrilia haematoti. También se encontró que individuos de especies con poblaciones decrecientes como la de los jilgueros Myadestes melanops y el quetzal Pharomachrus mocinno (n=1) han presentado colisiones contra ventanas. Entre las 74 especies residentes encontradas, se hallaron especies típicas de bosques tropicales, como el jacamar, tucanes, carpinteros y trepatroncos. Algunas de las familias con mayor número de especies que presentan colisiones es la de los colibríes (Trochilidae), zorzales, (Turdidae) y saltarines (Pipridae). Por otra parte, se encontró a 24 especies migratorias y a ocho especies residentes con algún grado de endemismo. Los resultados son preliminares, ya que la forma de obtener los datos implica un sesgo pues algunos lugares de Costa Rica, como Monteverde, la Estación La Selva de Sarapiquí, y San Vito de Coto Brus, son favorecidos por la presenciade biólogos o naturalistas en zonas que facilitan mayor cantidad de información que otras zonas del país.

Abstract: This study consisted of documenting bird species that have collided against windows or doors of glass in Costa Rica. The data were obtained from a review ofspecimens from the National Museum of Costa Rica and the Museum of Zoology of the University of Costa Rica in addition to data collections carried out by biologists and information sent by the citizen science network of the Costa Rica Ornithological Association. The result was a list of 131 species of birds that have collided with windows in Costa Rica. Among these are birds with small populations like the Three-wattled Bellbird, *Procnias tricarunculatus* (n= 4) and the Brown-headed Parrot, *Pyrilia haematoti*. Also found were individuals of species with decreasing populations such as Black-faced Solitaire, *Myadestes melanop,s* and the Resplendent Quetzal *Pharomachrus mocinno* (n = 1). Among the 74 resident species found were those typical of rainforests, as jacamar, toucans, woodpeckers and woodcreeper. Some of the families with the largest number of species documented were hummingbirds (Trochilidae), thrushes (Turdidae) and manakins (Pipridae). In addition, 24 migratory species and eight residents with some degree of endemism were found. These results arepreliminary, since the data are biased, with some places, like Monteverde, Sarapiquí, and San Vito of Coto Brus, providing more information than other areas in Costa Rica, because of the number of biologists or naturalists working the

Menacho-Odio, R. Local perceptions, attitudes, beliefs, and practices toward bird-window collisions in Monteverde, Costa Rica. Cuadernos de Investigación UNED 10 (1): 33-40. http://investiga.uned.ac.cr/revistas/index.php/cuadernos/article/view/2038/2323

ABSTRACT: Bird-window collisions are an important cause of bird mortality worldwide. Reducing collisions requires understanding of the costs and benefits perceived by stakeholders. I consulted two focus groups, conducted 18-semi-strcutured interviews and applied surveys to 58 residents of Monteverde, Costa Rica, to understand their perception of the problem. Many reported collisions in their houses but there is a lack of information about the magnitude of the situation. Black silhouettes are the most frequent method of prevention, even though they are mostly ineffective. The main factors for selecting methods include unblocked views, aesthetics, effectiveness, ease of installation and removal, and ease of maintenance. The preferred effective method was cords (Acopian Bird Savers), and painted dots was the least liked. I recommend education about effective methods for Monteverde and similar communities.

RESUMEN: Percepciones locales, actitudes, creencias y prácticas sobre colisiones de aves en ventanas en Monteverde, Costa Rica. Las colisiones de aves con ventanas son una causa importante de mortalidad de aves en todo el mundo. La reducción de colisiones requiere la comprensión de los costos y beneficios percibidos por los tomadores de decisiones. Consulté dos grupos focales, realicé 18 entrevistas semi-estructuradas y apliqué encuestas a 58 residentes de Monteverde, Costa Rica, para comprender su percepción del problema. Muchos reportaron colisiones en sus casas, pero hay una falta de información sobre la magnitud de la situación. Las siluetas oscuras de aves son el método más frecuente de prevención, aunque en su mayoría son ineficaces. Los factores principales para seleccionar métodos incluyen que no bloqueen la vista, estética, efectividad, facilidad de instalación y eliminación, y facilidad de mantenimiento. El método preferido son las cuerdas colgantes (Acopian Bird Savers), y los puntos pintados eran los menos apreciados. Recomiendo educación sobre métodos efectivos para Monteverde y comunidades similares.

Menacho-Odio, Rose Marie, 2018. Colisión de aves con ventanas: problema, prevención, mitigación y tendencias de investigación [Bird-window collisions: problem, prevention, mitigation and research directions]. Zeledonia 22:1.
Resumen: La colisión de aves con ventanas es un problema antropogénico de índole global. Provoca la muerte de millones de aves, afecta especies migratorias, residentes, comunes, raras y amenazadas. En este artículo se explica el por qué las aves colisionan con ventanas, por qué mueren y qué hacer para auxiliarlas. Se señalan métodos cuya efectividad ha sido probada y otros que no son recomendables para prevenir las colisiones. Finalmente, se describe algunas medidas para manejar el problema como educación, legislación y recomendaciones para la investigación del mismo. Palabras claves: conservación, estrategias, mitigación, mortalidad
Abstract: Bird-window collisions is an anthropogenic problem of a global nature. It causes the death of millions of birds, affects migratory species, residents, common, rare, and threatened. This article explains why birds collide with windows, why they die, and what to do to help them. Methods are indicated whose effectiveness has been proven and others that are not recommended to prevent collisions. Finally, it describes aspects of the management of this problem such as education and legislation on the subject, and recommendations for future research.

Menacho-Odio, R. M., Garro-Cruz, M., & Arévalo, J. E. (2019). Ecology, endemism, and conservation status of birds that collide with glass windows in Monteverde, Costa Rica. Revista de Biología Tropical, 67(2) Suplemento, S326-S345.
Abstract: Worldwide, billions of birds die annually due to window collisions. Nevertheless, few accounts document bird-window collisions in the Neotropics. In this study, we document species that collided with windows in Monteverde, Costa Rica, and describe their ecological and conservation status. We gathered information from different sources, including data from museum records and accounts by Monteverde residents who participated as “citizen scientists” between May 2014 and December 2017. We conducted carcass searches between March 2015 and February 2016. We classified window-strike species by migratory, forest dependence, trophic guild, weight, abundance, conservation, and endemism status. We registered 103 species striking windows in Monteverde, which includes 98 of 267 species known to occur in three life zones in Monteverde and five not registered in the area. Window strike casualties' frequencies differed by species, trophic guild and migratory status. Most window victims were residents, small, insectivorous, considered common or fairly common, with declining population trends. The families with the most species represented were Parulidae (14 spp.), Trochilidae (13 spp.), Turdidae (10 spp.), and Tyrannidae (9 spp.). Most species were passerines (Order Passeriformes) (71 spp.). No hawks or vultures were found colliding with buildings. The three species most commonly killed by windows were frugivores: Swainson's Thrush (*Catharus ustulatus*), Northern Emerald-Toucanet (*Aulacorhynchus prasinus*), and Black-faced Solitaire

(*Myadestes melanops*). Among window-kills were five species whose status on the IUCN Red List are Near Threatened and one Vulnerable, including the Resplendent Quetzal (*Pharomachrus mocinno*) and the Three-wattled Bellbird (*Procnias tricarunculatus*). Six species are listed as in danger of extinction and four are listed as species with reduced populations by the National System of Conservation Areas for Costa Rica (SINAC). 12 endemic species are strike casualties. The premontane wet forest is the life zone where more species were found (n=64 spp.), followed by the premontane moist forest (n = 49 spp.) and the lower montane wet forest (n = 31 spp.). These findings demonstrate the urgent need for conservation measures to mitigate bird mortality due to window collisions. Promoting use of methods to protect birds from windows should be an important goal for this IBA and the rest of Costa Rica. We also recommend collecting data in order to increase understanding about bird window collisions.

Merkel, Flemming Ravn and Kasper Lambert Johansen, 2011. Light induced bird- strikes on vessels in South West Greenland. Marine Pollution Bulletin 62: 2330- 2336. Also available as a report at: www.natur.gl

Forty-one bird mortality incidents reported by boats using searchlights to navigate in dark seas off SW Greenland. Up to 88 birds were killed with larger numbers happening in conditions of poor visibility because of snow. 95% of casualties were Common Eiders.

Mitrus, Cezary and Adam Zbyryt, 2017. Reducing avian mortality from noise barrier collisions along an urban roadway. Urban Ecosystems https://doi.org/10.1007/s11252-017-0717-7

Anthropogenic changes, including road network, have strongly influenced biodiversity of Europe. For the past 100 years, road networks have become a conspicuous part of European landscape and strongly affected environment and human well-being, including effect by noise. To reduce impact of noise the special barriers (mainly transparent) are installed along a road. Annually thousands of birds die in collision with glass and acrylic screens, and these are important causes of avian mortality. Here we report about and describe how to prevent the lethal hazards that clear and acrylic (plastic) noise barriers along an urban road in eastern Poland pose to birds. A total of 114 fatal strikes representing 26 species were documented along transparent noise barriers. In unmodified sections in both study periods (2012/2013 and 2013/2014) we observed differences in number of fatalities between the seasons, the dead birds were found mostly in the summer, less in the spring and autumn and fewest in winter, but no differences were found between study periods (2012/2013 v. 2013/2014). These result we treat as base line or control data and compare them to experimental modification of the same barriers. After applying a film consisting of horizontal black thick stripes the number of fatal strikes decreased significantly. The average number of fatalities decreased from 1.02 to 0.06 ind./km for all panels of all sections combined and the number of species killed decreased from 19 in unmodified to 4 in modified sections. We highly recommend this effective and inexpensive application as a responsible public utility measure to protect bird life found near roads.

Monge-Nájera, Julián & Zaidett Barrientos Llosa (2018). A new, cheap method to reduce bird mortality from window collisions. UNED Research Journal (ISSN: 1659-441X) Vol. 10(1): 83-84, June, 2018.

A building in cattle pasture did not cause a notable number of collisions until secondary vegetation grew up in the surrounding area. Collisions went from seldom to weekly to daily. The authors put a 30cm (12”) tall photo of a cat in one window and collisions ceased; the same photo was placed in the other seven windows of the building. One year later, the authors report one fatality and five collisions in which the birds were able to fly away.

Nichols KS, Homayoun T, Eckles J, Blair RB (2018) Bird-building collision risk: An assessment of the collision risk of birds with buildings by phylogeny and behavior using two citizen-science datasets. PLoS ONE 13(8): e0201558.https://doi.org/10.1371/journal. pone.0201558

Exerpts: As expected, our top model shows that an increase in abundance is associated with an **increase** in collisions–if there are more individuals of a species around, more birds of that species will hit buildings. Nighttime and other migrants are more likely to collide with buildings than diurnal migrants. These findings suggest that there is a behavioral or physiological difference in daytime migrants that affords them a greater ability to avoid building collisions. Nighttime migrants experience sleep deprivation, and while major declines in cognitive function have not been found under laboratory conditions, these birds may be less adept at interpreting the visual cues indicative of building glass. This sleep deprivation has been shown to alter the diurnal foraging behavior to include micro-naps in Swainson's Thrushes (*Catharus ustulatus*); perhaps sleep deprivation causes other behavioral changes in nighttime migrants that makes these birds more likely to hit buildings.

It is important to note that while nighttime migrants appear more susceptible to collisions, we have no evidence that these collisions are occurring at night. In fact, previous research shows that collision frequency peaks in early morning when considering all species in aggregate and this is also consistent with volunteer observations along BirdSafe routes in Minneapolis and Saint Paul. If nighttime migrant collisions also peak in early morning, this would support the hypothesis that nighttime migrants are hitting buildings when they are physically and mentally depleted after a night of migration and are searching for food and/ or roosting sites rather than hitting buildings during migration flights. Additionally, as nighttime migrants are selecting stopover habitat under low light conditions, they are less able to visually assess habitat and thus avoid areas with high densities of buildings compared to daytime migrants. Furthermore, nighttime migrants may be attracted to urban areas because of light pollution by buildings and are therefore selectively choosing stopover habitat in closer proximity to buildings than diurnal migrants.

While over 80% of species considered in the model are neither more nor less likely to collide with windows than expected after accounting for timing of migration and local abundance, this estimate is a conservative one that will overlook particularly rare species which will have very large shrinkage estimates that exclude them from being considered supercolliders or superavoiders. For example, the Golden-winged Warbler (*Vermivora chrysoptera*) is a Near Threatened species on the IUCN red list [50], and had a risk level of -0.499±0.924 (random effect estimate ±shrinkage estimate); the large shrinkage estimate for the species–in part due to the small sample size (n = 7)–made it impossible to classify this species as a superavoider, despite a trend towards avoidance (S2 Fig). While acknowledging the conservativeness of our classification of superavoiders and supercolliders, the relatively few obvious supercolliders and superavoiders may explain why early work on susceptibility to collisions, which relied on more limited datasets, found no differential susceptibility to collisions by species. Were our analysis to be replicated in other locations across North America, particularly in locations in the Western part of the continent, where avian communities are different from the Upper Midwest, we would expect some differences in the particular species that are classified as superavoiders or supercolliders.

North American Bird Conservation Initiative Canada. 2012. *The State of Canada's Birds, 2012*. Environment Canada, Ottawa, Canada. 36 pages. http://www.stateofcanadasbirds.org/ "This report summarizes the status of Canada's bird populations, both nationally and individually, for each of eight major regions of the country (see the chapter "Measuring the State of Canada's Birds" for details on methods).

The results point to the strong influences of human activity on birds, both positive and negative. This report also identifies threats to birds and offers solutions to keep common birds common and restore threatened species."

Newton, I., I. Wyllie, and L. Dale. 1999. Trends in the numbers and mortality patterns of Sparrowhawks (*Accipiter nisus*) and Kestrels (*Falco tinnunculus*) in Britain, as revealed by carcass analyses. Journal of Zoology 248:139-147.
The causes of death of 1,797 Sparrowhawks and 1,483 Kestrels found in Britain between 1963 and 1997 were determined. Window casualties accounted for 28.6% of Sparrowhawks and 0.5% of Kestrels. Differences in hunting methods of the two species make Sparrowhawks more vulnerable to window collisions. Numbers of Sparrowhawks killed by windows increased over the 35 years, likely a result of increased use of large plate glass in houses over the same period. The Kestrel showed little seasonal variation in window mortality, whereas Sparrowhawk window mortality increased greatly in August. Juveniles accounted for 93% of August Sparrowhawk collisions.

Ocampo-Peñuela N, Winton RS, Wu CJ, Zambello E, Wittig TW, Cagle NL. (2016) Patterns of bird-window collisions inform mitigation on a university campus. PeerJ 4:e1652 https://doi.org/10.7717/peerj.1652
A monitoring study of six buildings on the Duke University campus in Durham, NC. Building size, window area and surrounding habitat were quantified. The building with the most window area caused the most collisions. A resolution to remediate this building, supported by the student government resulted in application of a Feather Friendly product. Another building, almost entirely glass, caused only 2 collisions. 30% of the glass on this building has a bird-friendly frit. It would be interesting to know if other factors are involved, as well.

O'Connell, T. J. 2001. Avian window strike mortality at a suburban office park. Raven 72(2):141-149.
O'Connell monitored window strike mortality at four glass buildings in a Richmond, VA office park. Mortality was highest during migration seasons, and significantly more migrants were salvaged than resident or "feeder birds". This is inconsistent with the findings of some previous studies (Klem 1990a, Dunn 1993) and is likely because O'Connell surveyed buildings that do not attract birds with feeders. The observed mortality rate was far greater than the estimates of Klem (1990a) and Dunn (1993), although inconsistencies in methodology among studies weaken comparisons. O'Connell recommends standardizing protocols for studies of window strike mortality to allow for better comparisons of results.Because of the high mortality of migrants relative to resident species that are attracted to feeders, O'Connell concludes that bird mortality at office parks is more similar to that caused by skyscrapers or other tall structures than homes.

Ödeen, Anders and Olle Håstad, 2013. The phylogenetic distribution of ultra violet vision in birds. BMC Evolutionary Biology 2013, 13:36
http://www.biomedcentral.com/1471-2148/13/36

Background: Colour vision in birds can be categorized into two classes, the ultraviolet (UVS) and violet sensitive (VS). Their phylogenetic distributions have traditionally been regarded as highly conserved. However, the complicated nature of acquiring spectral sensitivities from cone photoreceptors meant that until recently, only a few species had actually been studied. Whether birds are UVS or VS can nowadays be inferred from a wide range of species via genomic sequencing of the UV/violet SWS1 cone opsin gene.

Results: We present genomic sequencing results of the SWS1 gene from 21 avian orders. Amino acid residues signifying UV sensitivity are found in the two most important spectral tuning sites 86 and 90 of Pteroclidiformes and Coraciiformes, in addition to the major clades, Palaeognathae, Charadriiformes, Trogoniformes, Psittaciformes and Passeriformes, where they where previously known to occur. We confirm that the presumed UVS-conferring amino acid combination F86, C90 and M93 is common to Palaeognathae and unique to this clade, despite available spectrometric evidence showing the ostrich retina to be VS.

Conclusions: By mapping our results together with data from previous studies on a molecular phylogeny we sh that avian colour vision shifted between VS and UVS at least 14 times. Single nucleotide substitutions can explair all these shifts. The common ancestor of birds most likely had a VS phenotype. However, the ancestral state of th avian SWS1 opsin's spectral tuning sites cannot be resolved, since the Palaeognathae are F86, C90 while the

Neognathae are ancestrally S86, S90. The phylogenetic distribution of UVS and VS colour vision in birds is so complex that inferences of spectral sensitivities from closely related taxa should be used with caution.

Oviedo, Stephanie y Rose Marie Menacho-Odio, 2015. Actitud en la preferencia de métodos para evitar el choque de aves contra puertas y ventanas de vidrio en Costa Rica. Zeledonia 19(1) 22-31 Spanish and English abstracts below. Full text available at http://www.zeledonia.com/uploads/7/0/1/0/70104897/19-1.pdf

Resumen: El objetivo general del estudio fue analizar la preferencia de los costarricenses en relación a los métodos para evitar el choque de aves contra las puertas y ventanas de vidrios. Durante la investigación se utilizaron métodos que incluyeron las observaciones, y la aplicación de entrevistas y encuestas. Las entrevistas y encuestas fueron aplicadas durante los meses de marzo y abril del año 2014, en seis de las siete provincias de Costa Rica. Como resultado, se obtuvo la participación de 77 personas, algunos implementan métodos por la recomendación de otras personas, por la versatilidad de los métodos o por la inversión monetaria que representan. Además, la selección de los métodos estuvo relacionada con la estética de la ventana, ya que es importante para los participantes mantener esta estética debido al costo económico del diseño, construcción, comodidad, luz y vista del paisaje. Hubo otras personas en que la estética no la consideraron tan importante, al punto de colgar bromelias secas, implementar cañas de bambú delgadas, entre otros métodos.

Abstract: The overall objective of the study was to examine the preference of Costa Rican citizens for methods to avoid collisions of birds against glass doors and windows. Observations, interviews and surveys were used for the investigation. The interviews and surveys took place during the months of March and April, 2014, in six of the seven provinces of Costa Rica. 77 people participated. Methods were used because they were recommended by others, because of the versatility of the methods or the monetary investment they represent. Another consideration for some participants was the aesthetics of the window, to maintain an attractive appearance, illumination and view of the landscape in spite of the cost of the solution. For some other people aesthetics were less important, and they used methods like hanging dry bromeliads or thin bamboo rods.

Parkins, Kaitlyn L, Susan B. Elbin and Elle Barnes, 2015. Light, Glass, and Bird–building Collisions in an Urban Park. Northeastern Naturalist 22(1): 84- 94.
http://dx.doi.org/10.1656/045.022.0113
The authors examined the impact of both glass and light on collisions at buildings near NYC's Bryant Park. They found a positive correlation between number of collisions and building light at night, but also a correlation between the amount of glass and the amount of light. Only 37% of tagged carcasses were found by monitors, so their estimates of total mortality may be low.

Pelley, Janet, 2014. Campus windows save birds, energy. *Frontiers in Ecology and the Environment* 12: 372–375. http://dx.doi.org/10.1890/1540- 9295-12.7.372 Atlantic Cape Community College (ACCC) installed CollidEscape, successfully reducing bird collisions and lowering energy costs.

Rawlings, Cynthia M.and Horn, David Joseph 2010. Scavenging rates highest at windowed compared to windowless sites at Millikin University in Decatur, Illinois. Illinois State Academy of Science 103(3-4)
This study compared scavenging rates at windowed sites compared to windowless walls at Millikin University in Decatur, Illinois from Fall 2007 to Fall 2008. Twenty gram pieces of raw chicken were placed at 0 or 10 meters from windowed or windowless walls, with a total of 16 sites. Scavenging rates were fastest at sites 0 meters from windowed walls. Overall, scavenging rates were highest in spring and summer and did not reflect the frequency of collisions, highest during spring and fall migration. Among scavengers observed included domestic cats, squirrels and insects. Rich, Catherine and Travis Longcore eds, 2006. Ecological Consequences of Artificial Night Lighting. Island Press, Washington. 459 pages.

Rebke, Maren, Volker Dierschke, Christiane N. Weiner, Ralf Aumüller, Katrin Hill, and Reinhold Hill, 2019. Attraction of nocturnally migrating birds to artificial light: The influence of colour, intensity and blinking mode under different cloud cover conditions. Biological Conservation 233 (2019) 220–227.
A growing number of offshore wind farms have led to a tremendous increase in artificial lighting in the marine environment. This study disentangles the connection of light characteristics, which potentially influence the reaction of nocturnally migrating passerines to artificial illumination under different cloud cover conditions. In a spotlight experiment on a North Sea island, birds were exposed to combinations of light colour (red, yellow, green, blue, white), intensity (half, full) and blinking mode (intermittent, continuous) while measuring their number close to the light source with thermal imaging cameras. We found that no light variant was constantly avoided by nocturnally migrating passerines crossing the sea. The number of birds did neither differ between observation periods with blinking light of different colours nor compared to darkness. While intensity did not influence the number attracted, birds were drawn more towards continuous than towards blinking illumination, when stars were not visible. Red continuous light was the only exception that did not differ from the blinking counterpart. Continuous green, blue and white light attracted significantly more birds than continuous red light in overcast situations. Our results suggest that light sources offshore should be restricted to a minimum, but if lighting is needed, blinking light is to be preferred over continuous light, and if continuous light is required, red light should be applied.

Riding, Corey S. and Scott R. Loss, 2018. Factors influencing experimental estimation of scavenger removal and observer detection in bird–window

collision surveys. Ecological Applications 28(8): 2119-2129
https://doi.org/10.1002/eap.1800

Wildlife collisions with human-built structures are a major source of direct anthropogenic mortality. Understanding and mitigating the impact of anthropogenic collisions on wildlife populations require unbiased mortality estimates. However, counts of collision fatalities are underestimated due to several bias sources, including scavenger removal of carcasses between fatality surveys and imperfect detection of carcasses present during surveys. These biases remain particularly understudied for bird–window collisions, the largest source of avian collision mortality. In Stillwater, Oklahoma, USA, we used bird carcasses collected during window collision monitoring to experimentally assess factors influencing scavenging and observer detection, and we employed trail cameras to characterize the scavenger community and timing of scavenging. We recorded nine scavenger species, but the domestic cat and Virginia opossum were responsible for 73% of known-species scavenging events. The most frequent scavenger species were primarily nocturnal, and 68% of scavenging events occurred at night. Scavenger species best predicted time to first scavenging event, season best predicted carcass persistence time, and both season and carcass size predicted whether any carcass remains persisted after scavenging. Our results also suggest that observer detection was influenced by substrate, with greater detection of carcasses on artificial substrates. Our findings related to scavenging timing have important implications for the unbiased estimation of collision mortality because the timing of peak scavenging relative to timing of peak mortality can substantially influence accuracy of adjusted mortality estimates. Further, the differences in correlates for time to first scavenging and time to carcass removal (i.e., persistence time) illustrate the importance of explicitly measuring these often-independent events that are frequently conflated in the anthropogenic mortality literature.

Ronconi, Robert A., Karel A. Allard and Philip D. Taylor, 2015. Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. Journal of Environmental Management 147: 34-45.

This literature review identified 24 studies and reports of bird-platform interactions, most qualitative and half peer-reviewed.

The most frequently observed effect, for seabirds and landbirds, is attraction and sometimes collisions associated with lights and flares; episodic events have caused the deaths of hundreds or even thousands of birds. Though typically unpredictable, anecdotally, it is known that poor weather, such as fog, precipitation and low cloud cover, can exacerbate the effect of nocturnal attraction to lights, especially when coincidental with bird migrations.

Other effects include provision of foraging and roosting opportunities, increased exposure to oil and hazardous environments, increased exposure to predators, or repulsion from feeding sites. Current approaches to monitoring birds at offshore platforms have focused on observer-based methods which can offer species level bird identification, quantify seasonal patterns of relative abundance and distribution, and document avian mortality events and underlying factors.

Observer-based monitoring is time-intensive, limited in spatial and temporal coverage, and suffers without clear protocols and when not conducted by trained, independent observers. These difficulties are exacerbated because deleterious bird-platform interaction is episodic and likely requires the coincidence of multiple factors (e.g., darkness, cloud, fog, rain conditions, occurrence of birds in vicinity).

Rodríguez, Airam, Peter Dann and André Chiaradia, 2017. Reducing light-induced mortality of seabirds: High pressure sodium lights decrease the fatal attraction of shearwaters. Journal for Nature Conservation 39 (2017) 68–72. The authors note that more birds were attracted by metal halide lights and LEDs than high pressure sodium lights. They relate this to the information on seabird retinas, which are particularly sensitive to wavelengths between 406 and 566 nm or light in the blue range. High pressure sodium lights produce more 'warm' wavelengths and this may be less visible to the birds. This study used light fixtures generally used to light parking lots, stadiums etc, so there is no way to know exactly how the three kinds of light differ in the perception of the birds. The authors point out that this result is the opposite of results found in studies of songbirds, which may be more attracted by red and white light.

Ros IG, Bhagavatula PS, LinH-T, Biewener AA. 2017 Rules to fly by: pigeons navigating horizontal obstacles limit steering by selecting gaps most aligned to their flight direction. Interface Focus 7:20160093. http://dx.doi.org/10.1098/rsfs.2016.0093
This bears on design, especially spacing, of bird collision deterrents

Flying animals must successfully contend with obstacles in their natural environments. Inspired by the robust manoeuvring abilities of flying animals, unmanned aerial systems are being developed and tested to improve flight control through cluttered environments. We previously examined steering strategies that pigeons adopt to fly through an array of vertical obstacles (VOs). Modelling VO flight guidance revealed that pigeons steer towards larger visual gaps when making fast steering decisions. In the present experiments, we recorded three-dimensional flight kinematics of pigeons as they flew through randomized arrays of horizontal obstacles (HOs). We found that pigeons still decelerated upon approach but flew faster through a denser array of HOs compared with the VO array previously tested. Pigeons exhibited limited steering and chose gaps between obstacles most aligned to their immediate flight direction, in contrast to VO navigation that favoured widest gap steering. In addition, pigeons navigated past the HOs with more variable and decreased wing stroke span and adjusted their wing stroke plane to reduce contact with the obstacles. Variability in wing extension, stroke plane and wing stroke path was greater during HO flight. Pigeons also exhibited pronounced head movements when negotiating HOs, which potentially serve a visual function. These head-bobbing-like movements were most pronounced in the horizontal (flight direction) and vertical directions, consistent with engaging motion vision mechanisms for obstacle detection. These results show that pigeons exhibit a keen kinesthetic sense of their body and wings in relation to obstacles. Together with aerodynamic flapping flight mechanics that favours vertical manoeuvring, pigeons are able to navigate HOs using simple rules, with remarkable success.

Rössler, M. and T. Zuna-Kratky. 2004. Vermeidung von Vogelanprall an Glasflächen. Experimentelle Versuche zur Wirksamkeit verschiedener Glas-Markierungen bei Wildvögeln. Bilogische Station Hohenau- Ringelsdorf [available for download from http://www.wua-wien.at/publikationeno].

Rössler, M. and T. Zuna-Kratky. 2004. Avoidance of bird impacts on glass: Experimental investigation, with wild birds, of the effectiveness of different patterns applied to glass. Hohenau-Ringelsdorf Biological Station, unpublished report. (English translation available from ABC). An outdoor flight tunnel was constructed to test the effectiveness of different marking patterns at reducing bird collisions with glass. The opening at the end of the tunnel through which birds would attempt to escape was partitioned so two pattern types could be tested simultaneously and directly compared. Tests were also conducted in which one pane was patterned and the other was plain. A mist net was suspended in front of the glass to prevent lethal collisions. Test patterns included vertical white strips of adhesive tape of varying widths and spacing, one horizontal stripe pattern, a non- geometric branch pattern, and a grid. All patterns except the grid significantly reduced collisions when compared to plain glass. Among the effective patterns, the branch and vertical stripe patterns were significantly more effective than the horizontal pattern. During paired comparisons of patterns, 2cm wide vertical stripes with 10cm spacing was found to be most effective at reducing collisions. Results did not differ among groups of species associated with four different habitat types. The influence of bird body size on effectiveness was not investigated.

Rössler, M. 2005 Vermeidung von Vogelanprall an Glasflächen. Weitere Experimente mit 9 Markierungstypen im unbeleuchteten Versuchstunnel. Wiener Umweltanwaltschaft. Bilogische Station Hohenau- Ringelsdorf [available for download from http://www.wua-wien.at/publikationen].

Rössler, M. 2005. Avoidance of bird impact at glass areas: Further experiments with nine marking types in the unlighted tunnel. Hohenau-Ringelsdorf Biological Station, unpublished report. (English translation available from ABC).

Using the same methods as Rössler and Zuna-Kratky (2004), this study examined the effectiveness of eight additional patterns at reducing bird collisions. New patterns included: large circles, small circles, large squares, small squares, grid (wider stripes and larger cell sizes than Rössler and Zuna-Kratky [2004]), vertical stripes of irregular width, and thin, black, horizontal lines imbedded inside plexi-glass. All patterns were white except the last. All white patterns were created with adhesive tape except the small square pattern which was created by silk screening. Each pattern significantly reduced collision frequency when compared to plain glass. Of these, the small square pattern was least effective. Rössler hypothesizes this may be due to the higher transparency of silk screening than adhesive tape. Small circles and irregular vertical stripes were 100% effective. The grid pattern containing vertical and horizontal stripes was no more effective than vertical stripes alone. The thin black horizontal stripes were effective despite having the lowest total coverage area of all patterns (6.7%). The patterns with the lowest coverage area (and therefore presumed by Rössler to be most aesthetically-acceptable to the public) and greatest effectiveness were thin black horizontal stripes, 2cm wide vertical white stripes with 10cm spacing, large circles, large squares, and the branch pattern previously studied (Rössler and Zuna- Kratky 2004).

Rössler, M., W. Laube, and P. Weihs. 2007. Vermeidung von Vogelanprall an lasflächen. Experimentelle Untersuchungen zur Wirksamkeit von lasmarkierungen unter natürlichen Lichtbedingungen im Flugtunnel II. Bilogische Station Hohenau-Ringelsdorf [available for download from http://www.wua-wien.at/publikationen].

Rössler, M., W. Laube, and P. Weihs. 2007. Investigations of the effectiveness of patterns on glass, on avoidance of bird strikes, under natural light conditions in Flight Tunnel II. Hohenau-Ringelsdorf Biological Station, unpublished report. English translation available for download from http://www.wua-wien.at/publikationen.

A new flight tunnel capable of rotating to maintain a constant orientation to the sun was constructed. It also allows light to fall in front as well as behind test panels. Using this tunnel, Rössler examined the effectiveness of new patterns and re-examined some patterns studied previously (2004, 2005). New patterns included: dots of 9mm radius, white vertical stripes 0.5cm wide with 10cm spacing, black vertical stripes 0.5cm wide with 10cm spacing, and black and white side-by-side vertical stripes of 2cm total width and 10cm spacing. Rössler also tested plain glass paired with an empty frame (i.e., free air space) to determine if plain glass is an appropriate control for use in experiments of pattern effectiveness. The distribution of collisions with plain glass and open air did not differ, suggesting plain glass is a suitable control in pattern testing experiments. In general, low background light levels seemed to reduce the effectiveness of all pattern types, but sample sizes were insufficient for statistical analyses of individual patterns under different light conditions. Each pattern significantly reduced collision frequency when compared to plain glass. Black and white vertical stripes did not significantly differ from each other, indicating pattern color may not be important. As during previous experiments (Rössler and Zuna-Kratsky 2004, Rössler 2005), white horizontal stripes 2cm wide with 10cm spacing were least effective at reducing collisions. Similar to Rössler (2005), thin, black, horizontal stripes imbedded in the glass were most effective despite the low coverage area, the reasons for which remain unclear. The high effectiveness and low coverage area gives promise to the development of an effective, yet aesthetically-acceptable design.

Rössler, M. and W. Laube. 2008. Vermeidung von Vogelanprall an Glasflächen. Farben, Glasdekorfolie, getöntes Plexiglas: 12 weitere Experimente im Flugtunnel II. Bilogische Station Hohenau-Ringelsdorf **[available for download from http://www.wua-wien.at/publikationen]. English summary at http://wua-wien.at/images/stories/publikationen/avoiding-bird- collisions-glass-surfaces-2008.pdf**
Rössler, M. and W. Laube. 2008. Avoidance of bird impacts on glass. Colors, decorative window-film, and noise-damping plexiglass: Twelve further experiments in flight tunnel II.
Hohenau-Ringelsdorf Biological Station, unpublished report. (English translation available from ABC) Using the same tunnel and protocol as Rössler et al. (2007), Rössler and Laube (2008) test bird collisions with tinted plexiglass, new pattern types, new colors, and a new adhesive material in addition to re-testing the “10v” pattern (20mm wide vertical white stripes with 10cm spacing) from prior studies. Glass with thin, black, horizontal stripes placed on the outside of glass was tested for comparison to the plexiglass with embedded, black, horizontal lines foundto be highly effective by Rössler (2005) and Rössler et al. (2007). Tests conducted under low and high light conditions were compared, to determine how lighting influences pattern effectiveness. A faux window frosting film was highly effective at reducing collisions, but this was likely due to the extreme coverage area of the patterns created with this material (25 and 50%). A version of the 10v pattern, with interrupted lines was highly effective when placed on both sides of the glass (over 90% effective). The glass with outer black, horizontal lines and the plexiglass with embedded, black, horizontal lines did not differ significantly in effectiveness under higher intensity light conditions. Under lower intensity lighting, the plexiglass with embedded lines was more effective than the glass with similar stripes placed on the outer surface. All patterns, except the black horizontal lines, performed better under low light conditions than under bright conditions. The 10v pattern using orange lines instead of the traditional white lines, was highly effective under both lighting conditions and among the most effective of all patterns and colors tested.

Rössler, Martin, 2012. Ornilux Mikado. Prüfung im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf; Wiener Umweltanwaltschaft. In

German. Download at: http://www.wua-wien.at/publikationen English summary at http://wuawien.at/images/stories/publikationen/avoiding-bird- collisions-glass- surfaces-2012.pdf

Rössler, Martin, 2013. VERMINDERUNG VON VOGELANPRALL AN GLASFLÄCHEN PRÜFBERICHTABC BIRD TAPE, TESA ® 4593. Prüfung im **Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf nach ONR 191040 und unter Einbeziehung von Spiegelungen bei dunklem Hintergrund (WIN-Versuch). In German. Download at http://wuawien.at/images/stories/publikationen/vogelanprall-bird-tape-tesa.pdf English summary courtesy of City of Vienna, Office of Environmental Protection** Two kinds of transparent adhesive tapes have been tested –ABC Bird Tape and Tesa® 4593.

Four test series -three with ABC Bird Tape, one with Tesa® 4593 – have been conducted. ABC Bird Tape got tested according to ONR 191040 (Austrian Standard for Bird Protection Glass) in two different arrangements: as single stripes with an interspace of 10cm and two tapes placed with an interspace of 0.5cm. These „double-stripes " had an interspace of 10cm to the next„double-stripe". The share of covered space in these two versions were 15.2% and 22.8%and are comparable to the markings with semitransparent foil tested 2007. In the test setup for checking the effect of reflections („WIN-test") ABC Bird Tape single stripes and Tesa® 4593 got tested. ONR Test ABC Bird Tape „ABC Bird Tape single stripes " with a coverage of 15.2%has been approached by 18.5%of the birds. Thus it is classified as a limited suitable marking. The results correlate with those from the similar semitransparent glass decor foil called ORACAL Etches ® tested in 2007 (Study published 2008). ABC Bird Tape double stripes "with a coverage of 22.8% has been approached by 10.2%of the birds and therefore misses category A (highly efficient).

Thus it appears that a higher share of covered space is necessary for ABC Bird Tape to work extremely efficient. This was the result of the tests of semitransparent foil in 2007 too. There were no disparities in different light situations. WIN-Test „ABC Bird Tape single stripes "and „ Tesa®". So far there are just a few comparative values available for this experimental arrangement. A number of less than 20% of the birds approaching the marked pane has only been achieved by a black-orange marking with high contrast. Numbers close to 20% have often been achieved by markings of category A (highly efficient) and B (limited suitable). „ABC Bird Tape single stripes" and „Tesa®" were approached by 21.8% and 22.3%and thus do not differ in their efficacy. There were no disparities in different light situation in this experiment, too. © Ombuds Office for Environmental Protection of the City of Vienna (Austria) www.wua-wien.at Conclusion In consideration of efficacy in terms of reducing bird collisions on glass panes ABC Bird Tape is comparable to the semitransparent foil which was tested in 2007. The adhesive tape reduces the risk of a collision even though category A is only achievable with a high share of covered surface. The ONR-experiment shows that single stripes with an interspace of 10cm are not enough for high efficacy. A doubling of the covered surface with parallel "twin lines" is favorable according to the ONR-experiment. In the WIN-experiment „ABC Bird Tape single stripes" turned out to work pretty good. This seems to be due to richness in contrast between the bright tape and the dark background of interior rooms. In another WIN-test setup in 2012 which cannot be further discussed because of a non-disclosure agreement with the purchaser, 21.5% of birds approached a pane with thin horizontal black stripes. These stripes meet the marking standard for glass panes according to ONR 191040. This means that single Bird Tape stripes are equal in efficacy to the black stripes often suggested by us. That applies to Tesa® 4593 too.

Hitherto only black- orange-dotted markings performed better in the WIN-test setup.

Rössler, Martin, 2015. VOGELANPRALL AN GLASFLÄCHENPRÜFBERICHTBIRDPEN® Prüfung nach ONR 191040 und WIN-Versuch im Flugtunnel II der Biologischen Station Hohenau- Ringelsdorf. In German. Download at http://wua-wien.at/images/stories/publikationen/pruefbericht-birdpen-2015.pdf English abstract, provided by Ombuds Office for Environmental Protection of the City of Vienna, Austria By order of the Wiener Umweltanwaltschaft (Ombuds Office for Environmental Protection of the City of Vienna, Austria) a birdpen®-marked float glass pane has been tested in the Flight Tunnel II of the Biological Station Hohenau-Ringelsdorf according to the Austrian Standard ONR 191040 (transparency without reflection) from August9th to September 2ndin 2013 and including specular reflections ("WINtest", reflections according to windowpanes) from August 1st to September 15th in 2014. The ONR-test did not lead to a positive result. The birds did not recognize the marked pane and did not approach it less than an unmarked reference glass in an at least significant extent. Three series of tests including reflections showed numbers of approach, which stand for notable but very low efficacy (WIN 2014, reference test mirror versus floatglass pane, reference test birdpen® versus unmarked floatglass pane). Although the manufacturer promises recognizability, because birds are UV- sensitive organisms, the product is not easier to recognize in ultraviolet light than in visible light. Optical measurements revealed very weak contrasts in UV between 350 and400nm.
Because the contrasts are minimal in the spectrum visible for humans, birdpen® is –as indicated by the manufacturer-more or less invisible. Due to the results there is no cause of expecting a reduction of bird collisions in a desirable extent. Thus there are no reasons for recommending the product.

Rössler, Martin, Erwin Nemeth & Alexander Bruckner, 2015. Glass pane markings to prevent bird-window collisions: less can be more. Biologia 70/4: 535—541. DOI: 10.1515/biolog-2015-0057
An analysis and thoughtful discussion of Rössler's results from his first generation flight tunnel. Rössler's goal was to identify maximally effective patterns with minimal intrusiveness to human perception. He shows 'efficacy of a deterring pattern does not necessarily depend on the size of the surface area of the marking but on orientation, spacing and dimension of the marking elements.' This interaction among different elements comprising a pattern is fundamental to evaluation of materials that may deter collisions and this paper helps support the fact that the '2x4 rule' must be qualified, to include more than simply spacing.

Roth, T. C. II, S. L. Lima, W. E. Vetter. 2005. Survival and causes of mortality in wintering Sharp-shinned Hawks and Cooper's Hawks. Wilson Bulletin 117(3):237-244. Roth et al. radio-tracked a total of 67 Sharp-shinned and Cooper's Hawks over five winters in rural and urban areas. Two birds were killed by window collisions. The authors observed several non-lethal window collisions where hawks contacted the glass feet-first, presumably in reaction to a perception of their own reflection as another bird.

Sabo, Ann M., Natasha D.G. Hagemayer, Ally S Lahey and Eric L. Walters, 2016, Local avian density influences risk of mortality from window strikes. PeerJ 4:e2170; DOI 10.7717/peerj.2170 The authors compared mist netting data (representing the population of birds in the park) to window strike data at the Virginia Zoo, during the autumns of 2013 and 2014. Migrants were considerably more likely to hit glass than resident species. Thrushes (Turdidae), primarily American Robins, were the most numerous avian family and represented 44.9% (N = 314) of birds sampled using mist nets and 14.8% (N = 27) of fatal window strikes.

Wood-warblers, primarily Yellow-rumped Warblers, were the second-most numerous avian family captured (23.3%, N = 314), and comprised a significantly higher proportion of fatal window strikes (55.6%, N = 27). Mimidae, Cardinalidae, and Emberezidae struck windows proportionally to their relative abundances in mist nets; other taxa were omitted from the analysis because of small numbers. Juveniles were represented in similar proportions in both samples.

Sagers, Rachel, Brinnlie Harward, Landon Keller and Haley Schmid with Dr. Kim Sullivan (2018). Physical Features that Increase Risk for Collision. Poster, Utah State University, Department of Biology.
Overall, we identified several variables that influence the distribution and frequency of window collisions, including: ➢ Season and temperature ➢ Surface area of glass ➢ Proximity to trees and shrubs ➢ Presence of human disruption (e.g., construction) ➢ Species type ➢ Migration season ➢ Hunting by predatory birds ➢ Reflectivity of windows ➢ Types of trees (fruit bearing or. Not

Schaub, Michael, Marc Kèry , Pius Korner and Fränzi Korner-Nievergelt, 2011. A critique of 'Collision Mortality Has No Discernible Effect on Population Trends of North American Birds'. http://www.plosone.org/annotation/listThread.action;jsessionid=729FAA9E574223617 40ADB1E3BE3851B?root=9659 The authors contest the assumption that lack of correlation between estimated collision risk and estimated population trend can be used to conclude that collision mortality produces no effect. They discuss several scenarios and note that local population level effects may be far more important than continent wide trends. Also, this sort of analysis is unlikely to be useful for rare species with small populations, where a single collision could be of significance, but would be unlikely to be recorded.

Schiffner, Ingo, Hong D Vo, Partha S Bhagavatula and Mandyam V Srinivasan, 2014. Mind the Gap. Frontiers in Zoology 11:64 http://www.frontiersinzoology.com/content/11/1/64
Understanding what cues prompt changes in bird flight paths is basic to developing strategies to stop collisions. However, we know much less about how birds navigate local environments than we do about long distance migration. How insects use visual information to avoid collisions, estimate speed, distance and other factors is now relatively well known, but there is little comparable understanding for birds. This study, using 3D video to record budgies flying in a 'tunnel', with stripe patterns projected on the walls is one of the first to tackle this problem.
This paper bears directly on the derivation of the 2x4 or handprint rule.
From their summary: Budgies were trained to fly in a 'tunnel', through a vertically oriented gap of variable width, to investigate their ability to perform evasive manoeuvres during passage. When the gap was wider than their wingspan, the birds passed through it without interrupting their flight. When traversing narrower gaps, however, the birds interrupted their normal flight by raising their wings or tucking them against the body, to prevent contact with the flanking panels. The results suggest that the birds are capable of estimating the width of the gap in relation to their wingspan with high precision: a mere 6% reduction in gap width causes a complete transition from normal flight to interrupted flight. Furthermore, birds with shorter wingspans display this transition at narrower gap widths.

Schiffner, Ingo and Mandyam V. Srinivasan, 2015. Direct Evidence for Vision-based Control of Flight Speed in Budgerigars Sci Rep. 2015; 5: 10992.Published online 2015 Jun 5. doi: 10.1038/srep10992.
Abstract: We have investigated whether, and, if so, how birds use vision to regulate the speed

of their flight. Budgerigars, *Melopsittacus undulatus*, were filmed in 3-D using high-speed video cameras as they flew along a 25 m tunnel in which stationary or moving vertically oriented black and white stripes were projected on the side walls. We found that the birds increased their flight speed when the stripes were moved in the birds' flight direction, but decreased it only marginally when the stripes were moved in the opposite direction. The results provide the first direct evidence that Budgerigars use cues based on optic flow, to regulate their flight speed.
However, unlike the situation in flying insects, it appears that the control of flight speed in Budgerigars is direction-specific. It does not rely solely on cues derived from optic flow, but may also be determined by energy constraints.

Schleidt, Wolfgang, Michael D. Shalter and Humberto Moura-Neto, 2011. The Hawk/Goose Story: The Classical Ethological Experiments of Lorenz and Tinbergen, Revisited. Journal of Comparative Psychology, 125(2) 121– 133. DOI: 10.1037/a0022068
The idea that a decal depicting a raptor silhouette can keep birds away from glass persists, even though it has been proven conclusively false, goes back to the 1937 'hawk/goose' experiments of Lorenz and Tinbergen. The work itself involves 'flying' 2 dimensional models of different shapes, over pens of turkeys and ducks. The paper provides the history of that work, how it was interpreted and how some misinformation was perpetuated. They also describe later experiments intended to support or refute its conclusions, along with some interesting insights into how science works.

Schramm, I, Jacqueline Fiala, Therese Noe, Paul Sweet, Annette Prince and Caleb Gordon, 2007. Calls, captures and collisions: Triangulating three census methiods to better understand nightly passage of songbird migrants through the Chicago region during May. Meadowlark 16(4): 122-129.
Three different methods of characterizing the passage of migrating passerines through the Chicago area in May 2006-7 are compared: mist-net captures, nocturnal flight call recordings and window collisions rescues/collections. Combined data included 1432 identified and 2520 unidentified flight calls, 3040 mist-net captures and 1060 window collisions. The authors conclude that a combination of mist-netting and nocturnal flight call recording provides the most comprehensive picture on songbird migration, especially if combined with other information, including weather radar images and standardized daytime bird observations.

Schmid, H., W. Doppler, D. Heynen & M. Rössler (2012): Vogelfreundliches Bauen mit Glas und Licht. 2., überarbeitete Auflage. Schweizerische Vogelwarte Sempach http://www.vogelglas.info/public/voegel_glas_licht_2012.pdf [Bird-friendly Buildings with Glass and Light, 2nd edition. Chapters include Forward; Introduction; Glass as Danger to Birds; Bird-friendly Solutions; Case Studies; Current Research; Light as a Trap for Birds and Insects; Lighting Solutions; Summary; Bibliography, Products and Other Information. Also available in French and Italian at http://www.vogelglas.info/f/merkblatt.html]

Schneider RM, Barton CM, Zirkle KW, Greene CF, Newman KB. (2018) Year-round monitoring reveals prevalence of fatal bird-window collisions at the Virginia Tech Corporate Research Center. PeerJ 6:e4562 https://doi.org/10.7717/peerj.4562 pdf of the paper is available for download
Abstract Collisions with glass are a serious threat to avian life and are estimated to kill hundreds of millions of birds per year in the United States. We monitored 22 buildings at the

Virginia Tech Corporate Research Center (VTCRC) in Blacksburg, Virginia, for collision fatalities from October 2013 through May 2015 and explored possible effects exerted by glass area and surrounding land cover on avian mortality. We documented 240 individuals representing 55 identifiable species that died due to collisions with windows at the VTCRC. The relative risk of fatal collisions at all buildings over the study period were estimated using a Bayesian hierarchical zero-inflated Poisson model adjusting for percentage of tree and lawn cover within 50 m of buildings, as well as for glass area. We found significant relationships between fatalities and surrounding lawn area (relative risk: 0.96, 95% credible interval: 0.93, 0.98) as well as glass area on buildings (RR: 1.30, 95% CI [1.05–1.65]). The model also found a moderately significant relationship between fatal collisions and the percent land cover of ornamental trees surrounding buildings (RR = 1.02, 95% CI [1.00–1.05]). Every building surveyed had at least one recorded collision death. Our findings indicate that birds collide with VTCRC windows during the summer breeding season in addition to spring and fall migration. The Ruby-throated Hummingbird (Archilochus colubris) was the most common window collision species and accounted for 10% of deaths. Though research has identified various correlates with fatal bird-window collisions, such studies rarely culminate in mitigation. We hope our study brings attention, and ultimately action, to address this significant threat to birds at the VTCRC and elsewhere.

Sealy, S. G. 1985. Analysis of a sample of Tennessee Warblers window-killed during spring migration in Manitoba. North American Bird Bander 10(4):121-124. Approximately 150 passerines struck a glass arboretum connecting two apartment buildings in Winnipeg in one afternoon. A detailed description of the structure is not provided. Seventy-one of the birds were Tennessee Warblers. All birds possessed some subcutaneous fat. There were significantly more males than females in the sample (51 males, 20 females). A nearby bird banding station operating at the same time, however, captured more females than males. Sealy does not conclude that males are more vulnerable to window strikes than females and offers no explanation of the contradictory results.

Seewagen, Chad, 2011. A review of experimental methods used to test the effectiveness of bird-deterring glass. Unpublished report, American Bird Conservancy.
The author reviews methodologies from Ley/Fiedler (Max Planck Institute), Klem (Muhlenberg College), Rössler (Hohenau), Sheppard (American Bird Conservancy) and Leiser (Chornomorskyi), including study species, sample size, representation of realworld conditions, free vs forced flights and migrant vs resident subjects. Available from American Bird Conservancy.

Sheppard, Christine, 2011. Bird-friendly Building Design. American Bird Conservancy, The Plains, VA 20198. 60 pages. http://abcbirds.org/wp-content/uploads/2015/04/Bird-friendly_Building_Guide_WEB.pdf Bird-friendly Building Design, published in 2011, explains in straightforward terms why birds hit glass, what features make certain buildings more prone to bird collisions, and the science behind the collision phenomenon. Most importantly, the book provides cost- neutral solutions for new building construction and reasonable ways that existing buildings can be retrofitted to make them bird- friendly. See seconds edition below: Sheppard and Phillips, 2015.

Sheppard, Christine, 2019. Evaluating the relative effectiveness of patterns on glass as deterrents of bird collisions with glass. Global Ecology and Conservation 20 (2019) e00795. https://doi.org/10.1016/j.gecco.2019.e00795

Studies documenting bird mortality from collisions with glass on buildings estimate hundreds of millions of birds die each year in North America from this cause alone. To reduce this mortality, it is essential to provide an objective assessment of the relative collision threat posed by glass and other materials incorporating patterns intended to deter collisions, similar to ratings for insulation value and breaking strength, for use by building professionals such as architects, engineers, planners, and other decision makers. We wanted to determine whether we could use a non-injurious binomial choice test developed in Austria, with local bird taxa in Pennsylvania, to provide objective collision threat ratings. Preliminary work in 2010-11 tested three patterns tested in Austria in 2004-6 and produced virtually identical scores leading to the conclusion that the test should apply generally to passerines. Additional trials indicated that variables including dimensions of pattern elements, spacing and orientation may interact in producing tunnel scores. The tunnel test has the potential to: a) determine how size, orientation and spacing of pattern elements impact collision-reduction effectiveness, b) rate commercially available glass, and c) evaluate new bird-friendly technologies.

Sheppard, Christine and Glenn Phillips, 2015. *Bird-Friendly Building Design,* 2nd Ed. (The Plains, VA: American Bird Conservancy, 2015). Free download at: http://abcbirds.org/wp-content/uploads/2015/05/Bird-friendly- Building-Guide_2015.pdf. To purchase hardcopies, contact American Bird Conservancy

Sloan, Allison, 2007. Migratory bird mortality at the World Trade Center and World Financial Center, 1997-2001: A deadly mix of lights and glass. Transactions of the Linnaean Society of NY 10:183-204. http://linnaeannewyork.org/Transactions%20X.pdf
Volunteers monitored bird mortality at the two World Trade Center towers and four other buildings in that complex, plus the nearby World Financial Center, starting in 1997. There were no mass kill events but carcasses were found consistently during migration periods. The project was adopted by New York City Audubon in 2000, as Project Safe Flight. Monitoring took place daily; dead birds were collected, frozen, photographed and shipped to the Patuxent Wildlife Research Center. Injured birds were caught when possible and either released in a park or taken to a rehabilitator. 2352 birds of at least 83 species were found; 68% were dead. Monitoring took place near dawn; maintenance, security and office workers reported that birds continued to collide throughout the day. Some carcasses were observed to be taken by gulls or raptors, others were swept up by maintenance workers. It was not possible to monitor rooftops, ledges, setbacks etc, so actual mortality numbers were certainly higher. Weather and architectural factors involved in daily variations of collisions are discussed and an update covering 2001-2006 is included.

Smith, Kathryn A., G. Douglas Campbell, David L. Pearl, Claire M. Jardine, Fernando Salgado-Bierman, and Nicole M. Nemeth, 2018. A Retrospective Summary of Raptor Mortality In Ontario, Canada (1991–2014), Including The Effects Of West Nile Virus. Journal of Wildlife Diseases, 54(2): 1-11.Wildlife Disease Association. DOI: 10.7589/2017-07-157
Glass collisions was a primary cause of deaths.
ABSTRACT: The causes of mortality of free-ranging raptors range from anthropogenic (e.g., trauma) to dynamic environmental conditions that may affect habitat suitability and prey availability. The province of Ontario, Canada, is vulnerable to anthropogenic and environmental changes because of its northern latitudes and expanding human populations,

both of which may impact wildlife. We retrospectively evaluated diagnostic data from raptors submitted to the Ontario-Nunavut node of the Canadian Wildlife Health Cooperative (CWHC) from 1991 to 2014 (n¼41,448). Submissions encompassed 29 species, most commonly the Red-tailed Hawk (*Buteo jamaicensis*; n¼4308) and Great Horned Owl (*Bubo virginianus*; n¼4237). Trauma (n¼4716) accounted for the majority of deaths among all species, followed by emaciation (n¼4241).
Traumatic deaths were most commonly attributed to collisions with stationary objects, and the odds of a diagnosis of trauma were significantly higher in adult versus immature raptors. The odds of being diagnosed with emaciation were significantly higher in males than in females but not in any age class or season. Mortality was less commonly attributed to infectious diseases (n¼4214), for which West Nile virus (WNV) was the most common etiology, making up 53.1% of infectious diagnoses after its 2001 arrival in Ontario. The odds of a raptor being diagnosed with an infectious disease were significantly greater in summer and fall versus spring. Immature Red-tailed Hawks had significantly greater odds of being diagnosed with WNV compared to adults. These results reveal that human- and potentially environmentally associated deaths (e.g., trauma and emaciation, respectively) are commonly diagnosed among Ontario raptors submitted to the CWHC. Infectious diseases are less commonly diagnosed, but WNV may have underlying, ongoing impacts on the health of some raptor species.

Snep, R.P., Kooijmans, J.L., Kwak, R.G. et al. Urban bird conservation: presenting stakeholder-specific arguments for the development of bird- friendly cities. Urban Ecosyst (2016) 19: 1535. doi:10.1007/s11252-015-0442-z Abstract: …this paper presents stakeholder-specific statements for bird conservation in city environments. Based upon the current urban bird literature we focus upon habitat fragmen tation, limited habitat availability, lack of the native vegetation and vegetation structure as the most important challenges facing bird conservation in cities. We follow with an overview of the stakeholders in cities, and identify six main groups having the greatest potential to improve bird survival in cities: i) urban planners, urban designers and (landscape) architects, ii) urban developers and engineers, iii) homeowners and tenants, iv) companies and industries, v) landscaping and gardening firms, vi) education professionals. Given that motivation to act positively for urban birds is linked to stakeholder-specific advice, we present ten statements for bird-friendly cities that are guided by an action perspective and argument for each stakeholder group. We conclude with a discussion on how the use of stakeholder-specific arguments can enhance and rapidly advance urban bird conservation action.

Snyder, L. L. 1946. "Tunnel fliers" and window fatalities. Condor 48(6):278. Snyder surveyed accession records of the Royal Ontario Museum from the early 1940's to learn which species were most commonly salvaged from window strikes. He notes most of the commonly represented species are "tunnel fliers" that frequently fly through small spaces in dense understory habitats. This habit makes them more susceptible to window strikes (also asserted by Ross 1946, below). Stedman, S. J. and Stedman, B. H. 1986. Preventing window strikes by birds. Migrant 57:18. A brief recommendation to hang ¾ inch mesh nylon or plastic screening in front of windows to prevent lethal collisions.

Swaddle, John P., Clinton D. Francis, Jesse R. Barber, Caren B. Cooper, Christopher C.M. Kyba, Davide M. Dominoni, Graeme Shannon, Erik Aschehoug, Sarah E. Goodwin, Akito Y. Kawahara, David Luther, Kamiel Spoelstra, Margaret Voss, and Travis Longcore, 2015. A framework to assess evolutionary responses to anthropogenic light and sound. Trends in Ecology and Evolution 30(9):550-560. Abstract: Human activities have caused a near-ubiquitous and evolutionarily-unprecedented

increase in environmental sound levels and artificial night lighting. These stimuli reorganize communities by interfering with species-specific perception of time-cues, habitat features, and auditory and visual signals. Rapid evolutionary changes could occur in response to light and noise, given their magnitude, geographical extent, and degree to which they represent unprecedented environmental conditions. We present a framework for investigating anthropogenic light and noise as agents of selection, and as drivers of other evolutionary processes, to influence a range of behavioral and physiological traits such as phenological characters and sensory and signaling systems. In this context, opportunities abound for understanding contemporary and rapid evolution in response to human-caused environmental change.
https://doi.org/10.1016/j.tree.2015.06.009

Switala Elmhurst, Katherine and Kathleen Grady, 2017. Fauna Protection in a Sustainable University Campus: Bird-Window Collision Mitigation Strategies at Temple University. Pp 69-82 in Handbook of Theory and Practice of Sustainable Development in Higher Education, Volume 1. W. Leal Filho, L. Brandli and P. Castro and J. Newman, eds, Springer International, 451 pages. Available at https://sustainability.temple.edu/birds
Abstract: Philadelphia resides along the Atlantic Flyway bird migration route, and each spring and fall thousands of birds pass through Temple University. Campus buildings, especially those with highly reflective or transparent window glass, are prone to bird collisions. Birds do not see glass as a solid object, rather a reflection of their habitat or nothing at all. Birds collide with the windows and either die from impact or are injured and become easy prey. Utilizing student problem- and project-based learning (PPBL) opportunities, Temple University identified collision hotspots and implemented mitigation strategies, such as decorative window film, to reduce campus bird strikes. Temple also created awareness about its efforts to reduce bird deaths through collaborative projects, art installations, presentations and media coverage. This paper provides a case study of one urban university's efforts to address bird-window collisions through independent research, curriculum infusion projects and campus awareness campaigns. The paper also provides recommendations for future research and work.

Tan, Dereck, 2018. Birdstrike deterrent through community-based application of oil-paint markers on glass. Biodiversity Research Center, Beaty Biodiversity Museum University of British Columbia.
The Beaty Biodiversity Centre maintains a database of bird strikes on the building, which includes noting their time, date, and location (https://biodiversity.ubc.ca/resources/bird-strikedatabase). A series of ground-floor full-height windows was identified as a problem area in fall of 2017. The windows are adjacent to the landscaped courtyard and may have reflected the trees and shrubs in the garden. A quick response to the issue was sought out by the Biodiversity Research Centre's Director, Loren Rieseberg, and the Building Administrator, Katie Beall, as a trial. A drawing existed commemorating the research subjects and organisms studied by the Centre, created by the Digital Media Specialist of the Beaty Biodiversity Museum, Derek Tan. A vector version of the drawing was adapted to the format of the east series of windows and was drawn on the windows by Derek and a group of Biodiversity Research Centre volunteers in fall of 2017. Paper was applied to the inside of the windows and the design was projected from the interior. Volunteers then traced the design on the outside using white oil-based paint pens to disrupt the reflection. The tracing was done on a cloudy day in September, and visibility of the projection given the ambient light was an issue. The working area required shading by a Coroplast (corrugated plastic) screen to see the design, which limited the number of people who could work at any one time. An area of 177 square feet (16.44 square metres) was covered by four

to five volunteers in approximately four hours.

Tellez-Colmenares, Nicolás N. and N. Bonilla- Sánchez, 2016.. Poster presented at the Colombian Ornithological Congress, courtesy of the authors. Pdf of the poster is available; contact csheppard@abcbirds.org.
Resumen: Los choques contra las construcciones son una de las mayores causas de mortalidad de aves en el mundo y casi en su totalidad causados por la presencia de vidrio, (6% de las especies se hallan muertas). Pocos estudios se han realizado en Colombia, así que no se conocen los alcances de este problema, ni las especies afectadas. El tamaño extenso de los ventanales, el alto porcentaje de vidrio presente en la estructura, la alta densidad de avifauna y cercanía a plantas frutales incrementan considerablemente el riesgo de colisión. El Jardín Botánico de Bogotá José Celestino Mutis (JBB) reúne las características que permiten estos incidentes, y se reportan (por parte de visitantes y trabajadores) numerosos choques de aves. Se recolectaron datos de aves muertas o heridas durante dos periodos–agosto a diciembre de 2015, febrero a mayo de 2016–mediante la implementación de formatos para la comunidad, uso de redes sociales (WhatsApp) y recorridos al interior del jardín entre 14:00 y 16:00 h tres veces por semana. Se realizó identificación taxonómica, registrando las características de los edificios donde chocaron los individuos (área planta, altura edificio, volumen, superficie total de ventanas). Se reportaron 25 colisiones y según los resultados del ANOVA multifactorial ninguna característica evaluada de las edificaciones tiene influencia significativa en el número de colisiones. Durante 2016-I no ocurrió ninguna de las colisiones, por lo tanto el pico de choques parece presentarse anualmente, se espera realizar monitoreo en 2016-II y 2017-I para verificar esta hipótesis.

Abstract: Collisions with buildings are one of the major causes of mortality of birds in the world, almost entirely caused by the presence of glass, (6% of bird species have been reported dead). Few studies have been conducted in Colombia, so the scope of this problem, nor the affected species are not known. Windows with large areas, a high percentage of glass in a structure overall, high density of avifauna and proximity to fruiting plants considerably increase the risk of collisions. The José Celestino Mutis Botanical Gardens de Bogotá brings together these features and numerous bird collisions are reported by visitors and employees. Data was collected from birds killed or injured during two periods–August to December 2015, February to May of 2016 – using community surveys, social networks (WhatsApp) and monitoring inside of the garden between 14:00 and 16:00 h three times a week. We recorded species names, along with features of the buildings where individual birds collided (planted area, height of building, surface area of windows). 25 collisions were reported and according to the results of a multifactorial ANOVA analysis, no recorded characteristic of the buildings had a significant influence on the number of collisions. During 2016-I, no collisions occurred, therefore the peak of collisions may be seasonal; monitoring in 2016-II and 2017-I will test this hypothesis.

Trybus, T. 2003. Wirksamkeit von Greifvogelsilhouetten zur Verhinderung von Kleinvogelanprall an Glasfronten. Die These des Masters, der Universität Wien [published in German with English abstract provided: **Trybus, T. 2003. Ef fectiveness of raptor silhouettes at preventing small bird collisions with glass.** Master's thesis, University of Vienna, Vienna, Austria.]
Raptor decals are shown to be ineffective at reducing bird collisions with large glass sound barriers in Vienna, Austria

Van Doren, Benjamin M., Kyle G. Horton, Adriaan M. Dokter, Holger Klinck, Susan B. Elbin and Andrew Farnsworth, 2017. High-intensity urban light installation dramatically alters nocturnal bird migration. Proc Nat Acad Sci:

114 (42) 11175–11180, doi: 10.1073/pnas.1708574114
Billions of nocturnally migrating birds move through increasingly photo polluted 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 photo polluted 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.

Veltri, C.J. and D. Klem Jr., 2005. Comparison of fatal bird injuries from collisions with towers and windows. J. Field Ornithol 76(2):127-133.
247 tower kills and 255 window kills were examined to determine type and extent of injuries and actual cause of death. Impact of bird age and weight was considered. Injuries caused by towers and windows were similar but subdermal injuries were more severe in tower kills. Subadults experienced more severe subdermal injuries than adults in either category. 98-99% of collision victims had subdermal intracranial hemorrhage; few had evidence of skeletal fracture. Bleeding in and around the brain is the probable cause of most deaths. Early treatment to reduce brain edema is recommended for birds that survive a collision.

Windowcollisions.info (available in English, German, Spanish and Italian)
Includes review of problem and solutions and includes a good bibliography of literature in French, Spanish, German and Italian.

Vo, H. D. *et al.* Anticipatory Manoeuvres in Bird Flight. *Sci. Rep.* 6, 27591; doi: 10.1038/srep27591 (2016).
Relevant to spacing/design of bird collision deterrents
It is essential for birds to be agile and aware of their immediate environment, especially when flying through dense foliage. To investigate the type of visual signals and strategies used by birds while negotiating cluttered environments, we presented budgerigars with vertically oriented apertures of different widths. We find that, when flying through narrow apertures, birds execute their maneuvers in an anticipatory fashion, with wing closures, if necessary, occurring well in advance of the aperture. When passing through an aperture that is narrower than the wingspan, the birds close their wings at a specific, constant distance before the aperture, which is independent of aperture width. In these cases, the birds also fly significantly higher, possibly pre-compensating for the drop in altitude. The speed of approach is largely constant, and independent of the width of the aperture. The constancy of the approach speed suggests a simple means by which optic flow can be used to gauge the distance and width of the aperture, and guide wing closure.

Vo, Hong D., Ingo Schiffner & Mandyam V. Srinivasan, 2016. Anticipatory Manoeuvres in Bird Flight. Nature: Scientific Reports 6:27591 DOI: 10.1038/srep27591

It is essential for birds to be agile and aware of their immediate environment, especially when flying through dense foliage. To investigate the type of visual signals and strategies used by birds while negotiating cluttered environments, we presented budgerigars with vertically oriented apertures of different widths. We find that, when flying through narrow apertures, birds execute their maneuvers in an anticipatory fashion, with wing closures, if necessary, occurring well in advance of the aperture. When passing through an aperture that is narrower than the wingspan, the birds close their wings at a specific, constant distance before the aperture, which is independent of aperture width. In these cases, the birds also fly significantly higher, possibly pre-compensating for the drop in altitude. The speed of approach is largely constant, and independent of the width of the aperture. The constancy of the approach speed suggests a simple means by which optic flow can be used to gauge the distance and width of the aperture, and guide wing closure. While considerable effort has been devoted to understanding how birds navigate over long distances, we know relatively little about how they guide their flight through cluttered environments. Flight through dense foliage, for example, requires the ability to avoid collisions with obstacles, to choose quickly between alternative routes, and to ensure safe flight through narrow passages. There is evidence to suggest that budgerigars steer through the middle of a corridor by balancing the magnitude of optic flow (the speed of image motion) experienced by the two eyes. Furthermore, budgerigars seem to be exquisitely 'body aware': when preparing to fly through a narrow

aperture, they close their wings only when the width of the aperture is smaller than their wingspan, demonstrating an ability to gauge aperture width in relation to wingspan with a precision of about 1 cm2. Similarly, pigeons, when flying through narrow apertures, adopt two different postures, depending upon the width of the aperture. When the aperture is relatively wide, they pass through with the wings held in the vertical position; when it is narrow, they fold their wings right back. The execution of such intricate manoeuvres requires selection of the appropriate motor action, as well as execution of these actions at the correct point in time or space. Gannets plunging into the ocean to catch fish fold their wings back in preparation for entry into the water at a fixed time prior to contacting the water surface. Hawks landing on a perch extend their talons at a fixed time prior to touchdown. How do birds orchestrate their flights when they fly through a narrow aperture? Here we film budgerigars as they take off from a perch, fly through an aperture of variable width, and land on a perch on the other side. The video data is analysed to measure the speed at which the bird approaches the aperture, and to determine the position and time at which it closes its wings. The analysis should enable us to understand how birds estimate the width of the aperture in relation to their wingspan and to determine whether wing closure is necessary or not,

and if so, when (or where) it should occur in relation to the aperture. In the aperture can be obtained through stereo vision (if extant). Straightforward geometrical considerations reveal that the width of the aperture can be estimated by combining this distance information with the visual angle subtended by the aperture. In addition, the time to reach the aperture can be estimated from either (a) the rate of change of the distance, or (b) the rate of change of the visual angle, combined with information about the instantaneous distance (from stereo), or (c) the ratio between the visual angle of the aperture and the rate of change of this angle. However, it is believed that most non-predatory birds lack frontal stereo vision, even if there is an overlap between the visual fields of the two eyes. Therefore, birds such as budgerigars are likely to rely upon cues based on optic flow to extract these variables. Here we seek to identify the cues that play a critical role in determining whether wing closure is necessary, and in controlling its timing.

Watson, Matthew J., David R. Wilson and Daniel J. Mennill, 2016. Anthropogenic light is associated with increased vocal activity by nocturnally migrating birds. Condor 118: 338–344. DOI: 10.1650/CONDOR-15-136.1

Abstract: Anthropogenic modifications to the natural environment have profound effects on wild animals, through structural changes to natural ecosystems as well as anthropogenic disturbances such as light and noise. For animals that migrate nocturnally, anthropogenic light can interfere with migration routes, flight altitudes, and social activities that accompany migration, such as acoustic communication. We investigated the effect of anthropogenic light on nocturnal migration of birds through the Great Lakes ecosystem. Specifically, we recorded the vocal activity of migrating birds and compared the number of nocturnal flight calls produced above rural areas with ground-level artificial lights compared to nearby areas without lights. We show that more nocturnal flight calls are detected over artificially lit areas. The median number of nocturnal flight calls recorded at sites with artificial lights (31 per night, interquartile range: 15–135) was 3 times higher than at nearby sites without artificial lights (11 per night, interquartile range: 4–39). By contrast, the number of species detected at lit and unlit sites did not differ significantly (artificially lit sites: 6.5 per night, interquartile range: 5.0–8.8; unlit sites: 4.5 per night, interquartile range: 2.0–7.0). We conclude that artificial lighting changes the behavior of nocturnally migrating birds. The increased detections could be a result of ground-level light sources altering bird behavior during migration. For example, birds might have changed their migratory route to pass over lit areas, flown at lower altitudes over lit areas, increased their calling rate over lit areas, or remained longer over lit areas. Our results for ground-level lights correspond to previous findings demonstrating that migratory birds are influenced by lights on tall structures.

Wiese, Francis K., W. A. Montevecchi, G. K. Davoren, F. Huettmann, A. W. Diamond and J. Linke, 2001. Seabirds at Risk around Offshore Oil Platforms in the North-west Atlantic. Marine Pollution Bulletin 42(12):1285-1290. Download at: http://play.psych.mun.ca/~mont/pubs.html This paper presents a literature review relating to seabird attraction to off-shore drilling platforms, recommends research to monitor and quantify attraction and mortality and develop mitigation. Seabirds aggregate at platforms, attracted by lights at night and associated food concentrations and mortality has been documented from collisions with the structure, oiling and flares. As drilling in the North Atlantic increases, this could become a serious source of mortality for seabirds, including migratory species.

Winger, Benjamin A., Brian C. Weeks, Andrew Farnsworth, Andrew W. Jones, Mary Hennen and David E. Willard, 2019. Nocturnal flight calling behavior predicts vulnerability to artificial light in migratory birds. Proc. R. Soc. B 286: 20190364. https://doi.org/10/1098/rspb.2019.0364.
The authors used 40 years of data collected on collisions in Chicago, as well as a smaller dataset collected in Cleveland, to test the hypothesis that night migrating bird species that use flight calls collide at a higher rate than would be predicted by their relative abundance. **This hypothesis was confirmed. Additional analysis, using data from the McCormic Convention Center, suggests that these species may have a strong response to artificial light, possibly related to habitat where they are resident.**

Winton RS, Ocampo-Peñuela N, Cagle N. (2018) Geo-referencing bird-window collisions for targeted mitigation. PeerJ 6:e4215 https://doi.org/10.7717/peerj.4215

Abstract Bird collisions with windows are an important conservation concern. Efficient mitigation efforts should prioritize retrofitting sections of glass exhibiting the highest mortality of birds. Most collision studies, however, record location meta-data at a spatial scale too coarse (i.e., compass direction of facing façade) to be useful for large buildings with complex geometries. Through spatial analysis of three seasons of survey data at a large building at a university campus, we found that GPS data were able to identify collision hotspots while compass directions could not. To demonstrate the broad applicability and utility of this georeferencing approach, we identified collision hotspots at two additional urban areas in North America. The data for this latter exercise were collected via the citizen science database, iNaturalist, which we review for its potential to generate the georeferenced data necessary for directing building retrofits and mitigating a major source of anthropogenic bird mortality.

Witting, Thomas, 2016. New Perspectives On Bird-Window Collision: The Effects Of Species Traits And Local Abundance On Collision Susceptibility. **Duke University** Master's Thesis. Complete text available at: http://dukespace.lib.duke.edu/dspace/handle/10161/11898 At each of three sites in the Triangle Region of N. Carolina, standardized surveys were conducted at six buildings to determine what species were colliding and how often. Data were then classified based on taxonomic family and order, feeding guild, feeding location, migration and breeding status, and synanthropic status, the degree to which a species otherwise benefits from human development. Collision frequencies among these classification groups were analyzed for indication of relative vulnerability. A second analysis, using data collected on the Duke University campus, looked at whether indications of collision vulnerability persisted when local abundance was considered. The Duke campus study revealed that local abundance does often mask actual levels of vulnerability among species.

Wittig, Thomas W., Nicolette L. Cagle, Natalia Ocampo-Peñuela, Robert Winton, Erika Zambello and Zane Lichtneger, 2017. Species traits and local abundance affect bird-window collision frequency. Avian Conservation and Ecology 12(1). https://doi.org/10.3929/ethz-b-000178648.
Studies on bird-window collisions have generally drawn inferences about species' differential vulnerability from collision tallies. However, this common methodology is potentially biased because the number of collision may simply reflect prevalence of species at the study site, rather than species-specific vulnerability. Building on recent studies of abundance and collision rates, we offered a complementary methodology based on point count data that could be widely applied alongside carcass surveys. Additionally, we broadened our analysis beyond previously applied taxonomic and migratory classifications to include functional classifications of feeding guild, breeding status and synanthropy. Our null hypothesis was that collisions frequencies reflect a species' or classification group's prevalence at study sites. To test this possibility, we used collision data collected at three sites in the Research Triangle Area of North Carolina, U.S. At one of these sites, Duke U Main Campus, we also gathered relative abundances from the local bird community to develop a case study assessment of how background prevalence compared to number of collisions. Using the larger, three-site dataset, we developed an initial picture of collision susceptibility based solely on frequency, the standard practice. Then, by bootstrapping our Duke abundance data, we generated confidence intervals that simulated collision based on chance versus prevalence. We identified several instances where collision tallies produced misleading perception of species-specific vulnerability. In the most extreme case, frequencies from our Triangle Area dataset indicated locally breeding species were highly vulnerable to collisions while our abundance-based case study suggested this same group was actually adept at

avoiding collisions. Through our case study, we also found that foliage gleaning was linked to increased risk and omnivory and ground foraging were associated with decreased risk. Although our results are based on a limited sample, we argue that abundance needs to be incorporated into future studies and recommend point our results are based on a limited sample, we argue that abundance needs.

Young, D. P. Jr., W. P. Erickson, M. D. Strickland, R. E. Good, K. J. Sernka. 2003. Comparison of avian responses to UV-light-reflective paint on wind turbines.
Subcontract Report 500-32840, National Renewable Energy Laboratory, Golden, CO. 38pp. Although this study focuses exclusively on bird collisions with wind turbines, the results of its carcass removal and searcher efficiency trials have important implications for observational studies of bird-glass collisions. Carcass removal trials found that the time carcasses remained in the study site prior to removal varied with bird body size and season.
Searcher efficiency did not differ among seasons, but varied dramatically with bird size. Only 59% of small birds were detected compared to 87% and 92% detection of medium and large birds, respectively. Differences among species in scavenger and searcher detection probabilities may bias studies of avian window strike mortality that do not control for these variables.

Zink, R.M. and J. Eckles, 2010. Twin Cities Bird-Building Collisions: A Status Update on "Project Birdsafe". The Loon 82(1):34-37. A summary of the Minnesota Project Birdsafe collisions monitoring program in Minneapolis and St. Paul, initiated in spring of 2007. The monitoring routes include a random sampling of buildings to help discriminate the effect of building design on collisions rate – most collisions occur at a few of the buildings monitored. The most common collision victims are listed, along with the least common. Collision peaks coincide with migration peaks.