Bird collisions with glass and the effects of artificial light on bird navigation, orientation, and mortality: 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. This bibliography also includes a section on artificial light at night as it pertains to collisions with windows, towers, and other human-made structures.

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.

The collisions section continues below; the light section begins on page 107.

Collisions

Abbott J. 2023. Navigating a path: Advocacy strategies of a migratory bird NGO. Geoforum 147:103885. https://doi.org/10.1016/j.geoforum.2023.103885

Abstract To achieve their goals, non-governmental organizations (NGOs) frequently interact with public and private stakeholders. Interactions can be generally characterized as falling within a continuum of collaborative to confrontational approaches, with each approach having advantages and disadvantages. A more collaborative approach may lead to opportunities to share data and access funding; however, an NGO may risk its goals becoming compromised. Similarly, a more confrontational approach can draw attention to NGO causes and effect change, but may limit opportunities for partnership. This paper considers how a NGO concerned with preventing bird-window collisions has balanced between collaboration and confrontation with municipal government and commercial properties. While this NGO's strategy has been largely collaborative, its experience also demonstrates that confrontational approaches, while less frequent and indirect, also have a role in attaining objectives.

Adalsteinsson, S.A., J.J. Buler, J.L. Bowman, V. D'Amico, Z.S. Ladin and W.G. 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

Abstract 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, C.A., A. Blumenthal, E. Fernández-Juricic, E. Bayne and C.C. 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, L., J. Moreno-Velasquez & N. 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.

Alaniz, A.J., K. Astudillo-Hinojosa, A.F. Soto, P.M. Vergara, M.A. Carvajal, and D. Moreira-Arce. 2022. Rapid behavioral recovery based on environmental enrichment of a white-throated toucan (Ramphastos tucanus: Ramphastidae) affected by collision trauma. Journal of Veterinary Behavior 57:1-5. https://doi.org/10.1016/j.jveb.2022.07.014

Abstract Captive animals that have experienced traumatic events require a high range of care prior to reintroducing them into their natural habitat; and this care should ensure their welfare in captivity. This report shows the ethological evolution of beneficial effects attributed to environmental enrichment. Specifically, the report focuses on the recovery of a white-throated toucan (*Ramphastos tucanus*: Ramphastidae) affected by a collision trauma resulting in a skull fracture, which received treatment and care in the Taricaya wildlife rescue center (Madre Selva, Peru). An environmental enrichment protocol was implemented for 30 days, recording all activities during this period. We performed generalized linear models to identify significant trends in the observed activities. We showed that inactive time and self-mutilation significantly decreased, while walking, eating, and washing activities increased during the study period. Temporal improvement in toucan welfare may be associated with higher energy (walking), better nutrition (eating), and decreased stress, as shown by reduced self-mutilation. Our report provides evidence on the favorable outcome of environmental enrichment in a toucan, raising its importance as a management tool for veterinary practitioners in wildlife rescue centers.

Altshuler, D.L. and M. Srinivasan. 2018. Comparison of Visually Guided Flight in Insects and Birds. Front. Neuroscience. 16 March, 2018. https://doi.org/10.3389/fnins.2018.00157

Abstract Over the last half century, work with flies, bees, and moths have revealed a number of visual guidance strategies for controlling different aspects of flight. Some algorithms, such as the use of pattern velocity in forward flight, are employed by all insects studied so far, and are used to control multiple flight tasks such as regulation of speed, measurement of distance, and positioning through narrow passages. Although much attention has been devoted to long-range navigation and homing in birds, until recently, very little was known about how birds control flight in a moment-to-moment fashion. A bird that flies rapidly through dense foliage to land on a branch—as birds often do—engages in a veritable three-dimensional slalom, in which it has to continually dodge branches and leaves, and find, and possibly even plan a collision-free path to the goal in real time. Each mode of flight from take-off to goal could potentially involve a different visual guidance algorithm. Here, we briefly review strategies for visual guidance of flight in insects, synthesize recent work from short-range visual guidance in birds, and offer a general comparison between the two groups of organisms.

American Bird Conservancy website collisions section https://abcbirds.org/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

Innovation Credit- Bird Deterrance; 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.

Anderson, A.W. 2018. Modeling Bird–Window Collisions in Core Urban Environments. A Thesis submitted to the faculty of the University of Minnesota.
https://conservancy.umn.edu/handle/11299/218668

Abstract Birds contribute to ecosystem function (Şekercioğlu 2006) and deliver valuable ecosystem services to human societies (Şekercioğlu et al. ed. 2016). Furthermore, experiencing human–nature relationships is part of a good life (sensu Chan et al. 2016), and for city-dwellers, that can include observing birds interact with the environment. However, global bird populations are threatened by multiple anthropogenic stressors. Climate change and habitat loss impoverish bird biodiversity through indirect pathways. Meanwhile, events that directly kill birds include depredation by cats, exposure to toxins, entrapment, and collisions with human-made structures. This two-chapter thesis focuses on bird collisions with glass, specifically within urban core environments in the Twin Cities, Minnesota. Chapters 1 and 2 explore complementary dimensions of bird–window collisions. Chapter 1 examines spatial patterns using 10 years of collision data collected by citizen scientists. Because those data are from migration seasons, the ecological context is birds locating and using stopover sites to refuel. My goal in Chapter 1 is to learn from key collision hotspots in order to inform bird-safe practices. To accomplish this, I test the hypothesis that more birds collide with skyways than buildings. Additionally, I re-test a model in which environmental factors—such as nearby vegetation and proximity to a river—explain collision risk because they attract birds to an area. In contrast, for Chapter 2 I directly observe how many birds are in an area and use that to learn about collision processes. Chapter 2's ecological context is the breeding season. I ask, given a local bird population of certain size, how many birds strike windows? Further, I ask if mortality rates vary among species groups. Lastly, I pose a novel hypothesis that bird body size plays a role in collision susceptibility. Bird–building collisions are part of a greater conversation on how people relate with nature, especially within human-dominated landscapes. Designing bird-safe environments that reduce preventable harm brings ethical as well as biodiversity benefits. This is especially relevant in our increasingly urbanized world where conservationists engage city dwellers to monitor, protect, and appreciate biodiversity.

Arnold, T.W., and R.M. Zink. 2011. Collision mortality has no discernible effect on population trends of North American birds. PLoS One 6(9):e24708.
https://doi.org/10.1371/journal.pone.0024708

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://abcbirds.org/wp-content/uploads/2015/05/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
https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context=icwdmbirdcontrol

A literature review that includes a brief section on bird collisions with glass. The findings of Klem (1979) are summarized.

Aymi, R., Y. González, T. López, and O. 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, apart from 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.

Bajagain, S., A.B. Joshi, and A. Pradhan. 2023. Urbanization and avian collisions: Baseline study on bird-building strikes in Nepal. Danphe: Bird Conservation Nepal 31(4). ResearchGate PDF link

The authors collected data on bird-building collisions across Nepal. 41 collisions were documented over two years. Collision data is summarized by species, time of day, and lethality.

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.

Barboza, Y.H. 2021. Relación entre paneles de vidrio y collision de aves silvestres contra ventanas en San Gerardo de Dota, San José. Costa Rica. Repertorio Cientifico 24(2). https://doi.org/10.22458/rc.v24i2.3162

Resumen La colisión de aves silvestres contra ventanas es un problema recurrente en las edificaciones de la comunidad de San Gerardo de Dota. Se Analizó la problemática de la colisión de las aves silvestres contra los ventanales de edificaciones de la comunidad de San Gerardo de Dota. Esta problemática fue descrita a partir de la observación directa de la infraestructura, identificación de especies de aves y la cuantificación del número de individuos que han sufrido colisiones contra paneles de vidrio. El estudio se realizó de febrero a mayo del 2018 en el Hotel Savegre, Hotel El Trogón, Hotel Sueños del Bosque, Centro de Investigación el Quetzal y una casa de habitación, donde funcionarios, habitantes, personal de estos sitios voluntariamente enviaron sus reportes sobre aves golpeadas contra ventanas, en el proceso se tomaron datos como fecha, hora y lugar del incidente que fueron enviados junto a una fotografía del ave para posteriormente poder ser identificada. Se registró un total de 13 familias reportadas, 24 especies y 40 individuos, entre los que se encuentran 9 especies endémicas de la región, 6 especies migratorias y 18 residentes. Se observó un aumento de colisiones conforme aumentaba el área de vidrio en los edificios. Las familias más afectadas fueron Trochilidae, Turdidae, Tyrannidae, Thraupidae y Passerellidae, se encontró especies con poblaciones decrecientes como el quetzal (Pharomachrus mocinno) y el tucancillo verde (Aulacorhynchus prasinus) y especies con poblaciones amenazadas como el loro Aliazufrado (Pyrrhura hoffmanni). El número de individuos que golpean contra cristales puede representar una amenaza para la estabilidad en las poblaciones de aves

Barton C.M., Riding C.S., Loss S.R. 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.

Basilio, L.G., D.J. Moreno & A.J. Piratelli. 2020. Main Causes of Bird-Window Collisions: A Review. An Acad Bras Cienc 92(1). https://doi.org/10.1590/0001-3765202020180745

Abstract Bird-window collisions are a major cause of bird mortality in the world; up to one billion birds die each year from collisions with glass panes in North America alone. However, relatively little attention had been given to this issue in the broad scientific literature, despite a recent increase in the number of papers. In this paper, the indexed literature on bird-window collisions was reviewed, specifically addressing the causal factors. The search retrieved 53 papers, mostly from North America. The factors linked to higher collision rates were large areas of continuous glass, the presence of nearby vegetation and feeders, bird migration, abundance, and behavior. Several factors were site-specific, preventing the global extrapolation of these findings. There is a lack of scientific knowledge regarding bird-window collisions in tropical countries. One of the challenges to mitigating this problem is the small amount of information and – frequently - the extrapolation of findings described for temperate regions to other areas. There is a need for a greater and urgent effort to fill this gap.

Bayne, E.M., C.A. Scobie, and M. Rawson. 2012. Factors influencing the annual risk of bird–window collisions at residential structures in Alberta, Canada. Wildlife Research 39:583–592. 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, totaling 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.'

Belcher, Richard N., Keren R. Sadanandan, Emmanuel R. Goh, Jie Yi Chan, Sacha Menz, and 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.

Best, J. 2008. Birds– dead and deadly: Why numeracy needs to address social construction. Numeracy 1(1):6. http://dx.doi.org/10.5038/1936-4660.1.1.6

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 action. It is important, when using statistics and other numbers, to understand where they came from originally. Another example used 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., C. Claudianos, M. Ibbotson, and M. Srinivasan. 2009. Edge Detection in Landing Budgerigars (Melopsittacus undulatus). PLoS ONE 4(10):e7301. https://doi.org/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, P.S., C. Claudianos, M.R. Ibbotson, and M.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, N. 2019. Breeding season bird mortality from window collisions: Comparing species-specific abundance with mortality rates. MURAJ 1(1):1-10. https://pubs.lib.umn.edu/index.php/muraj/article/view/1332/1137

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, B.F., E. Fernandez-Juricic, Seamans, W. Thomas, and T. Dolan. 2009. Avian visual system configuration and behavioral response to object approach. Animal Behavior 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.

Abstract Antipredator behaviour theory provides a framework to understand the mechanisms behind human–wildlife interactions; however, little is known about the role of visual systems in the responses to humans. We quantified responses of brown-headed cowbirds, Molothrus ater (Boddaert), and mourning doves, Zenaida macroura (Linnaeus), to object approach (a ground-based vehicle) and vehicle lighting regimen, and we examined two visual properties (visual acuity and visual fields) that could influence antipredator behaviour. Brown-headed cowbird groups exposed to vehicle approach and constant illumination of the vehicle-mounted lamp showed alert behaviour earlier than did groups exposed to pulsating treatments or no lamp. Interestingly, light treatments interacted with ambient light; cowbird alert response occurred sooner under sunny conditions and constant illumination of the lamp. Mourning doves were not affected by light treatments. Between species, mourning dove groups had a quicker alert response (and slower flight response) than brown-headed cowbirds. Visual acuity was higher and the visual field was wider in mourning doves than in brown-headed cowbirds. We speculate that brown-headed cowbirds might flush sooner to reduce predation risk costs associated with a relatively lower ability to visually track a given object. Our findings have theoretical and applied implications, as our model species belong to families that show different antipredator responses, and provide insight as to how object lighting might be used to reduce bird–structure/vehicle collisions, an increasing source of mortality in birds.

Blary C.L., O. Duriez, F. Bonadonna, M. Mitkus, S.P. Caro, A. Besnard, and S. Potier. 2023. Low achromatic contrast sensitivity in birds: a common attribute shared by many phylogenetic orders. Journal of Experimental Biology, jeb-246342. https://doi.org/10.1242/jeb.246342

Achromatic contrast related to birds' ability to perceive markers on glass that are meant to prevent collisions.

Abstract Vision is an important sensory modality in birds, often outperforming other vertebrates in some visual abilities. One of these abilities, sensitivity to achromatic contrasts – the ability to discern luminance difference between two objects or an object and its background – has been shown to be lower in birds compared to other vertebrates. We conducted a comparative study to evaluate the achromatic contrast sensitivity of 32 bird species from 12 orders using the optocollic

reflex technique. We then performed an analysis to test for potential variability in contrast sensitivity depending on the corneal diameter to the axial length ratio, a proxy of the retinal image brightness. To account for potential influences of evolutionary relatedness, we included phylogeny in our analyses. We found a low achromatic contrast sensitivity for all avian species studied compared to other vertebrates (except small mammals), with high variability between species. This variability is partly related to phylogeny, but appears to not be dependent upon image brightness.

Bocetti, C.I. 2011. Cruise ships as a source of avian mortality during fall migration. The Wilson Journal of Ornithology, 123(1):176-178. https://doi.org/10.1676/09-168.1

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, C.V., M.V. Vorotkov, A.Y. Sinelschikova, V.N. Bulyuk, and M. Griffiths. 2010. Application of the Optical- Electronic Device for the study of specific aspects of nocturnal passerine migration. Avian Ecol. Behav. 18:23-51. https://www.zin.ru/journals/aeb/pdf/Bolshakov_2010_18_AEB.pdf

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, C.V., V.N. Bulyuk, A.Y. Sinelschikova and M.V. Vorotkov. 2013. Influence of the vertical light beam on numbers and flight trajectories of night-migrating songbirds. Avian Ecol. Behav. 24:35-49. https://www.zin.ru/rybachy/sinelsh-pdf/2013.pdf

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. https://kb.osu.edu/handle/1811/52787

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.

Boycott T.J., S.M. Mullis, B.E. Jackson, and J.P. Swaddle. 2021. Field testing an "acoustic lighthouse": Combined acoustic and visual cues provide a multimodal solution that reduces avian collision risk with tall human-made structures. PLOS ONE 16(4):e0249826. https://doi.org/10.1371/journal.pone.0249826

Abstract Billions of birds fatally collide with human-made structures each year. These mortalities have consequences for population viability and conservation of endangered species. This source of human-wildlife conflict also places constraints on various industries. Furthermore, with continued increases in urbanization, the incidence of collisions continues to increase. Efforts to reduce collisions have largely focused on making structures more visible to birds through visual stimuli but have shown limited success. We investigated the efficacy of a multimodal combination of acoustic signals with visual cues to reduce avian collisions with tall structures in open airspace. Previous work has demonstrated that a combination of acoustic and visual cues can decrease collision risk of birds in captive flight trials. Extending to field tests, we predicted that novel acoustic signals would combine with the visual cues of tall communication towers to reduce collision risk for birds. We broadcast two audible frequency ranges (4 to 6 and 6 to 8 kHz) in front of tall communication towers at locations in the Atlantic migratory flyway of Virginia during annual migration and observed birds' flight trajectories around the towers. We recorded an overall 12–16% lower rate of general bird activity surrounding towers during sound treatment conditions, compared with control (no broadcast sound) conditions. Furthermore, in 145 tracked "at-risk" flights, birds reduced flight velocity and deflected flight trajectories to a greater extent when exposed to the acoustic stimuli near the towers. In particular, the 4 to 6 kHz stimulus produced the greater effect sizes, with birds altering flight direction earlier in their trajectories and at larger distances from the towers, perhaps indicating that frequency range is more clearly audible to flying birds. This "acoustic lighthouse" concept reduces the risk of collision for birds in the field and could be applied to reduce collision risk associated with many human-made structures, such as wind turbines and tall buildings.

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 128(2):355- 367. https://doi.org/10.1676/wils-128-02-355-367.1

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.

Brown B.B., Kusakabe E., Antonopoulos A., Siddoway S., Thompson L. 2019. Winter bird-window collisions: Mitigation success, risk factors, and implementation challenges. PeerJ 7:e7620. http://doi.org/10.7717/peerj.7620

Abstract Millions of birds die in bird-window collisions in the United States each year. In specialized test settings, researchers have developed methods to alter window designs to mitigate collisions. However, few published studies provide pretest and posttest evaluations of mitigation treatment areas and untreated control areas on existing buildings. We initially monitored bird-

window collisions at a single building on the University of Utah campus in Salt Lake City, Utah, USA, during winter 1 (November 9, 2017–January 2, 2018). We found 15 bird-window collisions, most under a portion of the building with a mirrored facade. To test a mitigation treatment, we installed Feather Friendly® bird deterrent film on part of the mirrored facade after winter 1. The unmitigated areas of the same building served as a control area. We continued monitoring during the following winter 2 (November 15, 2018–January 12, 2019). The treated area collisions declined from seven before mitigation to two after mitigation, a 71% reduction. The control area had eight collisions at both times. Results of a generalized estimating equation yielded a significant area by season interaction effect ($p = 0.03$) and fewer collisions in the mitigated area than the control area at winter 2 ($p = 0.03$), supporting efficacy of the mitigation. In winter 2, we also expanded monitoring to eight total buildings to evaluate the risks of mirrored windows and proximity to fruiting pear trees (Prunus calleryana) and the benefits of bird-friendly glass. Bird-friendly glass, found on two buildings, included windows with permanent fritted dots or embedded ultraviolet patterns. We counted 22 collisions across the eight buildings. Mirrored windows and proximity to fruiting pear trees related to higher odds of bird-window collisions, based on separate generalized estimating equations. The best fit model included mirrored windows and pear trees. The two buildings with bird-friendly glass had only one collision, suggesting that these designs deter collisions, although the difference was not statistically significant. To publicize the study and to receive reports of additional bird collisions or fatalities on campus, we created a citizen science project on iNaturalist and engaged in additional outreach efforts that yielded 22 ad hoc reports. Many previous studies have documented Cedar Waxwing (Bombycilla cedrorum) collisions, but at relatively low numbers. Cedar Waxwings accounted for 31 of 34 identifiable collisions from the monitoring study and 4 of 21 identifiable collisions or fatalities from ad hoc reports.

Brown B.B., L. Hunter, and S. Santos. 2020. Bird-window collisions: different fall and winter risk and protective factors. PeerJ 8:e9401 https://doi.org/10.7717/peerj.9401

Background To reduce bird fatalities from millions of window collisions each year in North America, it is important to understand how design and landscape elements relate to collision risk. The current study extends prior research that found that buildings near ornamental pear trees (Prunus calleryana) and buildings with mirrored windows significantly increased odds of collisions among eight buildings on the University of Utah campus in winter. The previous study found bird-friendly glass was not related to collision risk, although only one fatality occurred at two buildings with ORNILUX® ultraviolet (UV) or fritted windows. We reasoned that extending data collection to include fall might provide a better test of efficacy. We tested the following three hypotheses: (1) Buildings with mirrored windows would experience more collisions, replicating the original study; (2) the addition of fall migration data would reveal fewer collisions at the buildings with bird-friendly windows; (3) the danger of pear tree proximity would be heightened in winter, when fruit is ripe enough to appeal to frugivores, especially the Cedar Waxwings (Bombycilla cedrorum) that frequent these trees.

Discussion This research provides the first peer-reviewed evidence found for the efficacy of bird-friendly fritted windows and ORNILUX ® UV windows in buildings. In addition, it replicated a study that established the dangers of mirrored windows and fruiting pear trees near buildings. These risks were especially dangerous to Cedar Waxwings, who constituted 62.2% of the identifiable window collision victims. This research highlights how building risks depend on window design, landscape choices, species, and season. If replicated, analyses of risk factors can help identify buildings that require mitigation to make existing windows less deadly. Results also support the installation of bird-friendly glass in new or renovated buildings to reduce fatalities.

Brown BB, S. Santos, and N. Ocampo-Peñuela. 2021. Bird-window collisions: Mitigation efficacy and risk factors across two years. PeerJ 9:e11867. https://doi.org/10.7717/peerj.11867

Background Research on bird-window collision mitigation is needed to prevent up to a billion bird fatalities yearly in the U.S. At the University of Utah campus (Salt Lake City, Utah, USA), past research documented collisions, especially for Cedar Waxwings (Bombycilla cedrorum) drawn to fruiting ornamental pears in winter. Mirrored windows, which have a metallic coating that turns window exteriors into mirrors, had frequent collisions, which were mitigated when Feather Friendly®bird deterrent markers were applied. Bird-friendly windows–ORNILUX®ultraviolet (UV) and fritted windows–also reduced collisions when data were collected across fall and winter. Extending this prior research, we evaluated additional mitigation and tested the replicability of effects for pear trees, mirrored windows, and bird-friendly windows across two years.

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 (Curitiba), 34. 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.

Bruderer, Bruno, Dieter Peter and Thomas Steuri. 1999. Behaviour of migrating birds exposed to X-band radar and a bright light beam. Journal of Experimental Biology 202(9): 1015–1022. https://doi.org/10.1242/jeb.202.9.1015

Radar studies on bird migration assume that the transmitted electromagnetic pulses do not alter the behaviour of the birds, in spite of some worrying reports of observed disturbance. This paper shows that, in the case of the X-band radar 'Superfledermaus', no relevant changes in flight behaviour occurred, while a strong light beam provoked important changes. Large sets of routine recordings of nocturnal bird migrants obtained using an X-band tracking radar provided no indication of differing flight behaviour between birds flying at low levels towards the radar, away from it or passing it sideways. Switching the radar transmission on and off, while continuing to track selected bird targets using a passive infrared camera during the switch-off phases of the radar, showed no difference in the birds' behaviour with and without incident radar waves. Tracking single nocturnal migrants while switching on and off a strong searchlight mounted parallel to the radar antenna, however, induced pronounced reactions by the birds: (1) a wide variation of directional shifts averaging 8 ° in the first and 15 ° in the third 10 s interval after switchon; (2) a mean reduction in flight speed of 2–3 m s−1 (15–30 % of normal air speed); and (3)

a slight increase in climbing rate. A calculated index of change declined with distance from the source, suggesting zero reaction beyond approximately 1 km. These results revive existing ideas of using light beams on aircraft to prevent bird strikes and provide arguments against the increasing use of light beams for advertising purposes.

Bullock H.E., C.T. Panter, and T.A. Miller. 2024. Conservation Letter: Raptor collisions in built environments. Journal of Raptor Research 58(3):396-406. https://doi.org/10.3356/jrr248

An overview of the impacts of collisions on raptors worldwide, including window collisions.

Excerpt from Window Collisions. More studies exist on bird–building collisions than perhaps any other collision source. Birds collide with windows because they do not perceive glass as humans do. Instead, birds perceive clear glass as an open passageway and mirrored glass as a continuation of habitat (Fig. 1E; Klem 1979). Though most bird–building collision studies focus on songbirds, numerous studies from rehabilitation and veterinary clinics around the world report raptor–building collisions as a top cause of admissions (Neese et al. 2010, Thompson et al. 2013, Smith et al. 2018, Panter et al. 2022) with numerous raptors documented, including various falcon (n = 6), hawk (n = 13), and owl (n = 15) species. Klem (1979) reported Accipitridae (hawks, eagles, and kites) among the top ten bird families most prone to window collisions in the USA and Canada. Because buildings with glass windows are present nearly everywhere humans live, this indiscriminate source of death poses a threat to raptors globally, though some species are more vulnerable to window collisions than others.

Bulyuk, V.N., C.V. Bolshakov, A.Y. Sinelschikova, and M.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. https://www.old-aj.cz/publicFiles/110_2009-VETMED.pdf

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.

Bumbálek, R., T. Zoubek, R. Stehlík, R. Kuneš, J.E. De Dieu, and M. Ufitikirezi. 2024. Design and development of software to detect bird collisions with glass obstacles. Technoforum 2024: New Trends in Machinery and Technologies for Biosystems.

Abstract The paper is focused on the problem of image processing. Its output is software for the identification of bird collision with a glass obstacle using the detection of changes in the image with implemented basic algorithms in this area, which is created in MATLAB programming language. The first part, oriented to the theoretical introduction to the topic, is divided into image segmentation focusing on edge detection. The second part of the paper contains an introduction to software development, including its flowchart and examples of selected parts of the pseudocode of the applied algorithms, with a short description. Subsequently, the functionality of the developed system is verified on test video frames and the implemented methods and settings are compared based on data processing speed and reliability of image change detection.

Byron, S. 2024. Crash course conservation: Evaluating the effectiveness of Feather Friendly® markers and bird-safe murals in reducing bird-window collisions. UBC Social Ecological Economic Development Studies (SEEDS) Student Report, University of British Columbia, Vancouver, BC, Canada. (undergraduate research) https://open.library.ubc.ca/soa/clRcle/collections/undergraduateresearch/18861/items/1.0444884

Abstract Human-wildlife conflicts arise out of incompatibilities between the needs, goals, or activities of humans and wildlife, which result in real or perceived threats to either party. Such conflicts encompass not only direct confrontations between humans and wildlife, but also indirect consequences resulting from their impacts on the shared environment. Bird window strikes, or mid-flight collisions between birds and glass window features, are an example of such consequences. Estimated to upwards of 1.3 billion birds each year in North America alone, bird-window collisions are one of the largest anthropomorphic threats to avian populations. With many bird species experiencing a widespread decline in abundance, diversity, and biomass, there is an urgent need to confront the sources of human caused mortalities in birds. The objective of this study was to identify which facades at IRSHDC, CIRS, and MTM may be considered high risk for window collisions, and to evaluate the effectiveness of existing Feather Friendly® window applications and bird safe murals on facades at IRSHDC and CIRS respectively. The results of our study revealed an 84.6% decrease in collisions at IRSHDC facade 1 following the application of Feather Friendly® Markers. We advocate for the application of Feather Friendly® Markers to other high risk facades on UBC campus, and for the continued monitoring of IRSHDC and MTM to better understand the long term effects of such prevention strategies. Future research should analyze the large-scale impacts of collision prevention strategies, and address knowledge gaps in order to target areas of high mortalities and meet conservation goals.

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, S.A., J.A. Smolinsky, K.P. McCarthy, and J.J. Buler. 2019. Urban areas affect flight altitudes of nocturnally migrating birds. Journal of Animal Ecology. https://doi.org/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.

Cabrera-Cruz, S.A., E.B. Cohen, J.A. Smolinsky, and J.J. Butler. 2020. Artificial light at night is related to broad-scale stopover distributions of nocturnally migrating landbirds along the Yucatan Peninsula, Mexico. Remote Sensing 12(3):395. https://doi.org/10.3390/rs12030395

Abstract The distributions of birds during migratory stopovers are influenced by a hierarchy of factors. For example, in temperate regions, migrants are concentrated near areas of bright artificial light at night (ALAN) and also the coastlines of large water bodies at broad spatial scales. However, less is known about what drives broad-scale stopover distributions in the tropics. We quantified seasonal densities of nocturnally migrating landbirds during spring and fall of 2011–2015, using two weather radars on the Yucatan peninsula, Mexico (Sabancuy and Cancun). We tested the influence of environmental predictors in explaining broad-scale bird stopover densities. We predicted higher densities in areas (1) closer to the coast in the fall and farther away in spring and (2) closer to bright ALAN and with lower ALAN intensity in both seasons. We found that birds were more concentrated near the coastline in the fall and away from it in spring around Cancun but not Sabancuy. Counter to our expectations, we detected increased bird densities with increased distance from lights in spring around Sabancuy, and in both seasons around Cancun, suggesting avoidance of bright areas during those seasons. This is the first evidence of broad-scale bird avoidance of bright areas during stopover.

Caves, E.M., E. Fernández-Juricic, and L.A. Kelley. 2023. Ecological and morphological correlates of visual acuity in birds. Journal of Experimental Biology jeb-246063. https://doi.org/10.1242/jeb.246063

Abstract Birds use their visual systems for important tasks such as foraging and predator detection that require them to resolve an image. However, visual acuity, the ability to perceive spatial detail, varies by two orders of magnitude across birds. Prior studies indicate that eye size and aspects of a species' ecology may drive variation in acuity, but these studies have been restricted to small numbers of species. We used a literature review to gather data on acuity measured either behaviorally or anatomically for 94 species from 38 families. We then examined how acuity varies in relation to eye size, habitat spatial complexity, habitat light level, diet composition, prey mobility, and foraging mode. A phylogenetically controlled model including all of the above factors as predictors indicated that eye size and foraging mode are significant predictors of acuity. Examining each ecological variable in turn revealed that acuity is higher in species whose diet comprises vertebrates or scavenged food and whose foraging modes require resolving prey from farther away. Additionally, species that live in spatially complex vegetative habitats have lower acuity than expected for their eye sizes. Together, our results suggest that the need to detect important objects from far away, such as predators for species that live in open habitats and food items for species that forage on vertebrate and scavenged prey, has likely been

a key driver of higher acuity in some species, helping to elucidate how visual capabilities may be adapted to an animal's visual needs.

Chang-Min Kim, Ju-Hee Kim and Seung-Hoon Yoo. 2022. Economic benefits of preventing bird collisions in South Korea: findings from a choice experiment survey. Environmental Science and Pollution Research. https://doi.org/10.1007/s11356-022-22343-y

Abstract Bird deaths due to collisions with artificial structures, such as glass windows of buildings and transparent noise barriers, are continuing to occur in South Korea. The government is trying to prevent bird collisions by increasing the attachment of specially designed tapes to help birds avoid windows. This article estimates the economic benefits arising from the prevention of collisions by applying a choice experiment (CE). For this purpose, a CE survey of 1000 South Korean interviewees was conducted. The four attributes to be attached with the tapes for the CE application were a transparent soundproof wall window on an expressway, a transparent soundproof wall window on a general road, a glass window in a public building, and a glass window in a private building. The unit was the percentage of each structure with the tapes attached to the window. The marginal values of a one-unit (1%p) increase in each attribute were computed to be KRW 534 (USD 0.46), KRW 233 (USD 0.20), KRW 1,318 (USD 1.13), and KRW 12,930 (USD 11.05), respectively. This quantitative information will be an important reference for implementing the prevention policy. For example, based on the collision prevention of 1000 birds per structure, the priority for attaching tapes can be placed in the order of expressways, public buildings, private buildings, and general roads

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.

Chen, K., S.M. Kross, K. Parkins, C. Seewagen, A. Farnsworth, and B.M. Van Doren. 2024. Heavy migration traffic and bad weather are a dangerous combination: Bird collisions in New York City. Journal of Applied Ecology 61(4):784-796. https://doi.org/10.1111/1365-2664.14590

Abstract Bird–building collisions account for 365–988 million bird fatalities every year in the United States alone. Understanding conditions that heighten collision risk is critical to developing effective strategies for reducing this source of anthropogenic bird mortality. Meteorological factors and regional migration traffic may increase collision rates but also may be difficult to disentangle from other effects. 2. We used 5 years of bird collision counts in New York City to examine the influence of nocturnal weather conditions and bird migration traffic rates on collisions with buildings during spring and fall. 3. We found that seasonally unfavorable winds and conditions that impede visibility are important factors that increase the rates of bird–building collisions during both seasons. Specifically, northerly and westerly winds and low visibility in the spring and southerly and westerly winds and low cloud ceiling height in the fall are associated with higher collision risks. 4. Generally, these weather variables associated most strongly with increased collisions when nocturnal bird migration traffic was high, with the exception of low visibility in spring, which was predicted to triple collision rates compared to high visibility, independent of bird migration traffic. 5. Synthesis and applications: Although legislation to turn off unnecessary nocturnal lighting for the entirety of the migration seasons may be an ultimate goal, a proximate goal invaluable for reducing collisions will be predicting which nights will be of highest risk and using this information to determine when mitigation efforts could be most effective.

City of Toronto, 2016. Bird-friendly Best Practices Glass https://www.toronto.ca/wp-content/uploads/2017/08/8d1c-Bird-Friendly-Best-Practices-Glass.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.

Colbaugh, J. 2023. A Meta-Analysis of bird-window collision solutions. Master's Thesis, Auburn University, Auburn, Alabama, USA. https://etd.auburn.edu//handle/10415/9016

Abstract North American bird populations are declining and bird-window collisions are a leading cause, resulting in 365 - 988 million bird deaths each year in the U.S. alone. One approach aimed at reducing these collisions is treating windows to reduce reflectiveness. To address the lack of comparisons between window treatments, my goal was to use a meta-analytic approach to

evaluate window treatments. Specifically, the objective was to account for the variation between studies and quantify an overall effect of applied treatments, effect and rank of individual treatments, and effect and rank of treatment characteristics. I reviewed the literature following PRISMA guidelines and used meta-analysis to evaluate data across studies. I used rate ratios to compare collision rates of treated windows to clear glass for an overall estimate of effectiveness, as well as estimate for individual treatments and treatments grouped by characteristics. Overall, all treatments included in the study resulted in ~80% reduction in rate of collisions compared to clear glass. Individual treatments that performed best were complete coverage of the window with a UV absorbing and reflecting pattern (CPFilms, Fieldale, Virginia, USA) and complete coverage with white CollidEscape (Janesville, Wisconsin, USA). Assessment of treatment characteristics suggests extensive patterning and contrast are important for bird-window collision solutions to be extremely effective. Application of treatments to existing windows provide a benefit to birds and feasible solutions are available for homes and businesses.

Colling, O.M. 2019. Differential Vulnerability to Window Collision Mortality Among Migratory Songbird Species. Thesis, University of Western Ontario. Electronic Thesis and Dissertation Repository. 6410. https://ir.lib.uwo.ca/etd/6410/

Abstract Millions of birds die annually in North America by colliding with windows. I investigated differential vulnerability to window collision among migratory songbird species using long-term citizen science datasets from two bird banding stations and the fatal light awareness program. I used negative binomial regressions to model species-specific catch ratios, a mixed-effects negative binomial regression to model trophic guild-specific catch ratios and mixed-effects logistic regressions to model the odds of catching different age classes. Species-specific vulnerability varied significantly. Blue-headed Vireos, Yellow-rumped Warblers and Ruby-crowned Kinglets were least vulnerable, while Ovenbirds, Common Yellowthroats, Fox Sparrows and Bay-breasted Warblers were most vulnerable. Foraging height influenced vulnerability with ground foragers being most vulnerable. The effect of age varied across species, with only some species showing significant effects. This study contributes to the growing foundation that is required for future studies to investigate why these factors influence vulnerability and how to minimize future collision mortality.

Colling, O.M., C.G. Guglielmo, S.J. Bonner, and Y.E. Morbey. 2022. Migratory songbirds and urban window collision mortality: vulnerability depends on species, diel timing of migration, and age class. Avian Conservation and Ecology 17(1):22. https://doi.org/10.5751/ACE-02107-170122

Abstract Hundreds of millions of birds are estimated to die annually in North America by colliding with windows, and understanding the species-level correlates of collision mortality is an important step towards mitigation. We used a 16-year window collision dataset for 35 migratory songbird species from Toronto's (Canada) Fatal Light Awareness Program (FLAP) to quantify species differences in vulnerability to urban window collision mortality and potential correlates during the autumn period by applying generalized linear models. To control for annual abundance, we used migration monitoring data from two stations. Our index of vulnerability was the catch ratio, defined as the ratio of annual catch-per-unit effort in each station's mist net program to annual catch-per-unit effort in FLAP. Catch ratios varied among species with Ovenbird (*Seiurus aurocapilla*), Common Yellowthroat (*Geothlypis trichas*), and Lincoln's Sparrow (*Melospiza lincolnii*) being most vulnerable to window collision mortality and Blue-headed Vireo (*Vireo solitarius*), Yellow-rumped Warbler (*Setophaga coronata*), and Ruby-crowned Kinglet (*Regulus calendula*) being least vulnerable. Foraging guild had a minor effect on the catch ratio, but species with a propensity for nocturnal migration had lower catch ratios (greater vulnerability) than those that did not. Based on a subset of species (n = 4) and years (n = 2), hatch-year birds were overrepresented relative to

after-hatch-year birds in FLAP compared to the nearby migration monitoring station in 3 of 4 species. This study provides the first ranked list of species vulnerability to urban window collision mortality for songbirds migrating through downtown Toronto, provides evidence that juveniles are more vulnerable to window collision mortality than adults in some species, and highlights the need for more comparative studies of migratory movement behavior to investigate why some species are more vulnerable to urban window collision mortality than others.

Collins, K.A. and D. J. Horn. 2008. Bird-window collisions and factors influencing their frequency at Millikin University in Decatur, Illinois. Published Abstract. Transactions of the Illinois State Academy of Science 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.

Coolidge, Mary, David Helzer and Jade Ujcic-Ashcroft, 2021. A Successful Mitigation and Monitoring Project to Address Bird Window Collisions at the City of Portland's Columbia Building. Presentation at Urban Ecology Research Consortium 2021 Annual Symposium. https://archives.pdx.edu/ds/psu/35488

Abstract Avian window collisions kill an estimated 365-988 million birds each year in North America. This places collisions among the top three anthropogenic sources of mortality for wild bird populations, after habitat destruction and free roaming cats. A 2019 study indicates a nearly 30% decline in North American bird populations since 1970. Community science monitoring from 2009-2011 documented 69 species of warblers, thrushes, sparrows, hummingbirds, flycatchers, woodpeckers, and hawks that collided with buildings in Portland. Nationwide research shows that over half of all collisions occur at low rise commercial buildings, and that most collisions occur within the first 40-60 feet of a building where birds are most active, and vegetation is reflected in unmarked glass. In phase one, we initiated a yearlong effort to investigate the scope and scale of a known window collision issue at the City of Portland's single-story glass-walled Columbia Building. We conducted twice weekly surveys and recorded collisions observed by building occupants. Phase one collision monitoring indicated a rate of 125-150 strikes per year and an estimated range of 65-115 mortalities per year. Collisions involved at least thirteen avian species and there was no clear seasonal pattern. In 2017, the building was retrofitted with a full-coverage window film featuring a horizontal line pattern. In phase two, we repeated our survey methods for another year, and documented a 94% reduction in window collisions on treated windows, with a post-retrofit estimated range of 7.5-9 strikes per year and an estimated range of 4-7 mortalities per year.

Crews C. Reducing bird-window collisions at a botanical garden: The effect of bird-friendly artwork and dirty windows. Undergraduate research paper. University of British Columbia. Available at http://hdl.handle.net/2429/83003

Abstract With up to 42 million dying each year due to window strikes, evaluating the effectiveness of mitigation strategies is a must to protect vulnerable bird species. One of the most effective strategies is the application of decals to the outside surface of a window. Commercial products, such as Feather Friendly® bird deterrent film, use a grid pattern of small dots that helps reduce visual obstruction for humans. However, bird-friendly artwork has been suggested as a strategy that combines effectiveness and aesthetic appeal, but has not been critically evaluated. Dirty windows too, are suggested as being effective, but little research exists to support these claims. This study performed bird collision monitoring at the UBC Botanical Garden before and after the

application of bird-friendly artwork to the Pavilion, and during a time where dirt was allowed to accumulate on the windows at the Garden Centre. Monitoring was performed 4 times a week for 8 weeks during February and March. Building facades were searched for collision evidence, such as carcasses, feather piles, and feather smears. The reduction in collisions was dramatic; collisions decreased from 11 to 0 at the Pavilion, and from 84 to 3 at the Garden Centre. The results of this study support the use of bird-friendly artwork and dirty windows as management strategies for bird collisions, but also support student engagement in identifying collision hotspots and informing mitigation. Continued monitoring of the garden is suggested. Future research is needed to quantify the level of dirt on a window and how that effects collision risk, as well as research into public perception of dirty windows. Overall, the results of this study are promising for the future of birds at the UBC Botanical Garden.

CSA, 2019. A460:19 Bird-Friendly Building Design. CSA Group, 43 pages SKU: 2426847. https://www.csagroup.org/store/product/CSA%20A460:19/

Canadian model code for bird-friendly building design, available for purchase at link above. Must be 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. This note presents the observations of 15 bird 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 greatest 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 18(4):1427-46. https://doi.org/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.

De Groot, Krista L., Porter Alison N., Norris Andrea R., Huang Andrew C., Joy Ruth. 2021. Year-round monitoring at a Pacific coastal campus reveals similar winter and spring collision mortality and high vulnerability of the Varied Thrush, Ornithological Applications 123(3):duab027. https://doi.org/10.1093/ornithapp/duab027

Abstract Bird–window collisions are a leading cause of direct anthropogenic avian mortality, yet our state of knowledge regarding this threat relies heavily on eastern North American studies. Seasonal patterns of collision mortality may differ along the Pacific coast, and western North American species remain understudied. We therefore surveyed a stratified random sample of 8

buildings for collisions at the University of British Columbia, Vancouver, Canada over 45-day periods during 2 winters, 1 spring, 1 summer, and 1 fall season between January 22, 2015 and March 15, 2017. After accounting for the rate of scavenging and efficiency of observers in finding carcasses, we estimated that 360 collision fatalities (95% CI: 281–486) occurred over 225 days of collision monitoring. Collision mortality was highest in fall, but in contrast to most published research, collision mortality was intermediate in both winter and spring and was lowest in summer. In winter 2017, we performed point-count surveys to assess whether individual species are disproportionately vulnerable to collisions when accounting for population size and found that the Varied Thrush (Ixoreus naevius) was 76.9 times more likely to collide with buildings, relative to average species vulnerability in winter. To our knowledge, this is the first study to report the Varied Thrush as a species that is disproportionately vulnerable to collisions. Further studies are needed to assess the vulnerability of Western North American species and subspecies, and to determine whether similar patterns of seasonal collision mortality are found elsewhere.

De Groot Krista L., Amy G. Wilson, René McKibbin, Sarah A. Hudson, Kimberly M. Dohms, Andrea R. Norris, Andrew C. Huang, Ivy B. J. Whitehorne, Kevin T. Fort, Christian Roy, Julie Bourque and Scott Wilson. 2022. Bird protection treatments reduce bird-window collision risk at low-rise buildings within a Pacific coastal protected area. DOI 10.7717/peerj.13142

Background In North America, up to one billion birds are estimated to die annually due to collisions with glass. The transparent and reflective properties of glass present the illusion of a clear flight passage or continuous habitat. Approaches to reducing collision risk involve installing visual cues on glass that enable birds to perceive glass as a solid hazard at a sufficient distance to avoid it.

Methods We monitored for bird-window collisions between 2013 and 2018 to measure response to bird protection window treatments at two low-rise buildings at the Alaksen National Wildlife Area in Delta, British Columbia, Canada. After 2 years of collision monitoring in an untreated state, we retrofitted one building with Feather Friendly circular adhesive markers applied in a grid pattern across all windows, enabling a field-based assessment of the relative reduction in collisions in the 2 years of monitoring following treatment. An adjacent building that had been constructed with a bird protective UV-treated glass called ORNILUX Mikado, was monitored throughout the two study periods. Carcass persistence trials were conducted to evaluate the likelihood that carcasses were missed due to carcass removal between scheduled searches. Results and Conclusions: After accounting for differences in area of glass between the two buildings, year, and observer effects, our best-fit model for explaining collision risk included the building's treatment group, when compared to models that included building and season only. We found that the Feather Friendly markers reduced collision risk at the retrofitted building by 95%. Collision incidence was also lower at the two monitored façades of the building with ORNILUX glass compared to the building with untreated glass. Although more research is needed on the effectiveness of bird-protection products across a range of conditions, our results highlight the benefit of these products for reducing avian mortality due to collisions with glass.

de Wilde, P., and C.B. de Souza. 2022. Interactions between buildings, building stakeholders and animals: A scoping review. Journal of Cleaner Production 133055. https://doi.org/10.1016/j.jclepro.2022.133055

Abstract The preservation of biodiversity is a rising global concern and will have a major impact on the design and management of buildings and their immediate surroundings. Thus far, the majority of work on biodiversity and the built environment appears to focus on urban planning, project development, and the niche area of designing buildings with living walls and green roofs. Knowledge on the specific interaction between individual buildings and animals is fragmented, preventing holistic efforts to better manage these interactions. This paper presents the findings from a scoping study which captures the state-of-the-art about relationships between individual

buildings, building stakeholders, and animals. It reviews the current body of knowledge and points out three areas of interest that are crucial for future work on this area of study: (1) different stakeholder perspectives of building stakeholders on animals in and around buildings (2) positive and negative interactions between individual buildings and their immediate surroundings with animals and (3) management of interactions between animals in and around buildings. Findings show that literature in relation to these three aspects is fragmented and contains multiple gaps in relation to which species need to be considered and how, including a total absence of mathematical models able to represent animal-building interactions. It calls for better engagement between built environment researchers and their counterparts in biological sciences to collect appropriate data and extract relevant information from it, enhancing knowledge on complex biological processes towards producing shared understanding and developing integrated actions.

Diaz, Lizzy, Jonathan Kacvinsky, Sam Pensiero and Landon Tafo. 2021. Bird Strike Mitigation. Powerpoint Presentation. Available at https://openscholarship.wustl.edu/cgi/viewcontent.cgi?article=1012&context=sustainabilityexchange

Bird collisions and remediation on the campus of Washington University in St. Louis

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.

Elmore, J.A., Hager, S.B., Cosentino, B.J., O'Connell, T.J., Riding, C.S., Anderson, M.L., Bakermans, M.H., Boves, T.J., Brandes, D., Butler, E.M. and Butler, M.W. 2021. Correlates of bird collisions with buildings across three North American countries Conservation Biology 35: 654-665. https://doi.org/10.1111/cobi.13569

Abstract Collisions with buildings cause up to 1 billion bird fatalities annually in the United States and Canada. However, efforts to reduce collisions would benefit from studies conducted at large spatial scales across multiple study sites with standardized methods and consideration of species- and life-history-related variation and correlates of collisions. We addressed these research needs through coordinated collection of data on bird collisions with buildings at sites in the United States (35), Canada (3), and Mexico (2). We collected all carcasses and identified species. After removing records for unidentified carcasses, species lacking distribution-wide population estimates, and species with distributions overlapping fewer than 10 sites, we retained 269 carcasses of 64 species for analysis. We estimated collision vulnerability for 40 bird species with ≥2 fatalities based on their North American population abundance, distribution overlap in study sites, and sampling effort. Of 10 species we identified as most vulnerable to collisions, some have been identified previously (e.g., Black-throated Blue Warbler [*Setophaga caerulescens*]), whereas others emerged for the first time (e.g., White-breasted Nuthatch [*Sitta carolinensis*]), possibly

because we used a more standardized sampling approach than past studies. Building size and glass area were positively associated with number of collisions for 5 of 8 species with enough observations to analyze independently. Vegetation around buildings influenced collisions for only 1 of those 8 species (Swainson's Thrush [*Catharus ustulatus*]). Life history predicted collisions; numbers of collisions were greatest for migratory, insectivorous, and woodland-inhabiting species. Our results provide new insight into the species most vulnerable to building collisions, making them potentially in greatest need of conservation attention to reduce collisions and into species- and life-history-related variation and correlates of building collisions, information that can help refine collision management.

Elmore, J.A., C.S. Riding, K.G. Horton, T.J. O'Connell, A. Farnsworth, and S.R. Loss. 2021. Predicting bird-window collisions with weather radar. Journal of Applied Ecology 58: 1593–1601. https://doi.org/10.1111/1365-2664.13832

Up to 1 billion birds die annually in the U.S. from window collisions; most of these casualties represent migratory native species. Because this major mortality source likely contributes to the decline of the North American avifauna, mitigation tools are needed that accurately predict real-time collision risk, allowing hazards to be minimized before fatalities occur. We assessed the potential use of weather surveillance radar, an emerging tool increasingly used to study and to predict bird migration, as an early warning system to reduce numbers of bird-window collisions. Based on bird-window collision monitoring in Oklahoma, USA, we show that radar-derived migration variables are associated with nightly numbers of collisions. Across the entire night, numbers of collisions increased with higher migration traffic rate (i.e. numbers of birds crossing a fixed line perpendicular to migration direction), and migration variables for specific periods within the night were also related to nightly collisions. Our study suggests that radar can be an invaluable tool to predict bird-window collisions and help refine mitigation efforts that reduce collisions such as reducing nighttime lighting emitted from and near buildings.

Emerson, L. C., R. G. Thady, B. A. Robertson, and J. P. Swaddle. 2022. Do lighting conditions influence bird–window collisions? Avian Conservation and Ecology 17(2):3. https://doi.org/10.5751/ACE-02167-170203

Abstract Bird–window collisions account for approximately one billion bird deaths annually in North America. Highly reflective or mirrored glass is associated with increased collision risk, but little is known about whether the reflection caused by differential lighting of otherwise clear glass influences the risk of window collisions. We aimed to determine whether reflection from a clear window influences daytime collision risk by manipulating the lighting conditions on exterior and interior window surfaces. In a flight tunnel, we flew domesticated Zebra Finches (Taeniopygia guttata) toward windows manipulated to be of higher or lower reflection and recorded collision risk and flight velocity using three-dimensional videography. We predicted that the risk of collision would be greater when windows were manipulated to be more reflective. We found no support for this prediction. In contrast, we found that collision risk decreased in the presence of a stronger reflection during bright, midday exterior-lighting conditions. We suggest that the influence of window reflection on daytime window collisions is more complex than often assumed and might involve previously unaccounted properties of light, such as the polarity of light. Lastly, we recommend directions for future collision research and non-invasive mitigation strategies which involve the manipulation of interior lighting throughout the day.

Engels, Svenja, Nils-Lasse Schneider, Nele Lefeldt, Christine Maira Hein, Manuela Zapka, Andreas Michalik, Dana Elbers, Achim Kittel, P. J. Hore & 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.html

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, W.R., Y. Akashi, N.S. Altman, and A.M. Manville II. 2007. Response of night- migrating songbirds in cloud to colored and flashing light. North American Birds 60:476-488.
https://www.researchgate.net/publication/303170066_Response_of_night-migrating_songbirds_in_cloud_to_colored_and_flashing_light

Abstract Night-migrating birds often accumulate near bright man-made light on nights with low cloud cover or rain. Mass avian mortality events associated with this phenomenon have been documented for more than 150 years. Understanding the mechanism that induces the aggregation of migrants in lighted airspace could lead to a reduction in such mortality . Toward this end, we subjected nightmigrating birds flying in dense cloud cover to alternating short periods of different artificial light characteristics. Bird aggregation occurred during periods of white, blue, and green light but not in red light or flashing white light. We discuss these results with respect to visual and magnetoreception-based aggregation theories and the phenomenon of light-induced bird mortality at tall television towers in North America.

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 pp.

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.

Fallas-Abarca, Noelia. 2021. Factores que influyen en las colisiones de colibríes contra ventanas: métodos preventivos en Costa Rica. [Factors influencing hummingbird collisions against windows: preventive methods in Costa Rica.] Zeledonia 25:2.

Resumen La colisión contra ventanas es una causa importante de mortalidad para los colibríes En este artículo, analizo factores estructurales y ambientales que influyen en las colisiones de colibríes contra ventanas y propongo métodos para prevenirlas El estudio se realizó en Costa Rica de enero a mayo del 2021 Se solicitaron reportes de colisiones de colibríes en grupos de Facebook relacionados con aves, y que incluyeran la ubicación geográfica y fotografías para la identificación de especies Se realizó un análisis cuantitativo de la infraestructura de cinco hoteles en Bahía Ballena, Puntarenas, para proponer el uso de métodos preventivos para proteger a los colibríes y evaluar la percepción de los administradores En la encuesta participaron 132 personas que reportaron 302 colisiones y 22 especies en cinco de las seis zonas biogeográficas del país La presencia de vegetación y comederos artificiales afectaron el número de colisiones Se obtuvo una alta aceptación por parte de los administradores de los hotels de métodos para prevenir colisiones, los cuales fueron efectivos pues no se reportaron colisiones en las ventanas en las que fueron colocados durante el periodo de estudio La mortalidad fue afectada por factores ambientales y estructurales que pueden ser controlados y modificados por los dueños y administradores de los edificios para prevenir las colisiones Palabras claves: mortalidad, colisión de aves, ciencia ciudadana.

Abstract Window collisions are a major cause of mortality for hummingbirds. In this article, I analyze structural and environmental factors influencing the collisions of hummingbirds against windows and propose methods to prevent them. The study was carried out in Costa Rica from January to May 2021. Reports of hummingbird collisions were requested through Facebook groups related to birds and included the geographical location and photographs for the identification of the species. A quantitative analysis of the infrastructure of five hotels in Bahía Ballena, Puntarenas, was carried out to propose preventive methods to protect hummingbirds and evaluate the perception of administrators. The analysis included 132 surveys reporting 302 collisions and 22 species in five of the six biogeographic areas of the country. The presence of vegetation and artificial feeders affected the number of collisions. Methods to prevent collisions were highly accepted by hotel administrators and were effective since no collisions were reported in the windows in which they were placed during the study period. Mortality was affected by

environmental and structural factors that can be controlled and modified by owners and managers to prevent collisions.

Farnsworth, A., K.G. Horton, and P.P. Marra. 2024. To mitigate bird collisions, enforce the Migratory Bird Treaty Act. Proceedings of the National Academy of Sciences 121(9), p.e2320411121. https://doi.org/10.1073/pnas.232041112

The authors discuss the significant threat posed to migratory birds by collisions with glass in buildings, which kill an estimated 388–965 million birds annually in the U.S. The authors emphasize the need for bird-safe building materials and designs, such as treated glass and reduced lighting, to mitigate bird fatalities. Legislation, like the Federal Bird Safe Buildings Act, has been proposed but has not yet passed. The authors highlight a recent event in Chicago, where nearly 1,000 birds were killed at McCormick Place due to high-intensity migration, poor visibility, and abundant reflective glass. While Chicago has some voluntary programs, the authors argue that stronger enforcement is necessary.

The authors then propose that one potential solution is utilizing the Migratory Bird Treaty Act (MBTA) of 1918, which protects migratory birds from harm. The authors suggest that the law should be adapted to address modern threats, including glass collisions, and that the U.S. Fish and Wildlife Service (USFWS) should enforce the prohibition of "incidental take," where birds die as an unintended result of human activities. The authors call for stronger enforcement of the MBTA to incentivize building operators to adopt bird-friendly designs and for more cities to adopt mandatory bird-safe standards.

Fischer, Silas and Kamal Islam. 2020. Identifying bird-window collisions on a university campus during spring and fall migration. Proceedings of the Indiana Academy of Science 129(1):47–55.

Abstract Birds in flight have difficulty detecting glass and often collide with windows because of glass reflectivity. Based on estimates, window collisions may account for up to one billion avian mortalities in the U.S. each year. Research has shown that bird-window collisions occur on university campuses and kill a diverse array of bird species. During a 16-month period, student volunteers surveyed bird mortality from window collisions at twelve buildings on the Ball State University campus in Muncie, Indiana. We compared migration phenology, identified species and families, and determined the most problematic buildings for bird mortality from window collisions. From August 2014-May 2016, 158 carcasses representing 46 species from 18 families were collected. The greatest number of deaths occurred in the families Parulidae (n = 40), Turdidae (n = 38), and Passerellidae (n = 26). Long-and short-distant migrants made up the bulk of bird-window collisions (85%) compared to resident species (15%). Overall, collisions were highest during fall migration, but the greatest number of deaths occurred in May 2016. There were three ''hotspots'' on campus with the highest number of collisions: Worthen Arena (n = 39), Bracken Library (n = 38), and the Architecture Building (n = 38). Studies of bird-window collisions on university campuses present hands-on learning opportunities for students with a real-world conservation problem and a leadership opportunity for universities to implement measures to become a more environmentally sustainable and bird safe campus.

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.

Fontoura, G.D., D.E. Sousa, I.L. Macêdo, L.Q. Hirano, and M.B. Castro. 2023. Fatal traumatic injuries in free-living wild Passeriformes and Psittaciformes birds in Central Brazil, 2006-2018. Pesquisa Veterinária Brasileira 43:e07275. https://doi.org/10.1590/1678-5150-PVB-7275

Resumo As lesões traumáticas são uma causa significativa de morte nas aves em todo o mundo, pois apresentam um risco maior de colisões e outras lesões devido aos ambientes degradados e criados pelo homem. Este estudo examinou a frequência e as características morfológicas das lesões traumáticas fatais em Passeriformes e Psittaciformes endêmicos e migratórios do Bioma Cerrado, uma área com rica biodiversidade, mas ameaçada no Brasil. Os resultados demostraram que as lesões traumáticas fatais foram observadas em 21,8% das aves (285/1305), principalmente na primavera e verão, durante a época reprodutiva das aves. O periquito-do-encontro-amarelo (Brotogeris chiriri) e Passeriformes da família Thraupidae foram as aves mais frequentemente acometidas. Por volta de 70% das lesões fatais observadas foram nos membros torácicos e pélvicos, e crânio, e os tipos de fraturas e ossos afetados foram minuciosamente avaliados. Os traumas contudentes foram as principais causas das lesões. As injúrias que afetaram o esqueleto apendicular e a cabeça representaram as mais importantes causas de morte traumática para Passeriformes e Psittaciformes. A frequência dessas lesões fatais vem aumentando nos últimos anos, o que pode estar relacionado às mudanças ambientais marcantes no Bioma Cerrado e colocar em risco a sobrevivência de muitas espécies de aves.

Abstract Traumatic injuries are a significant cause of death for birds worldwide, as they are at an increased risk of collisions and other injuries due to man-made environments. This study examined the frequency and morphological characteristics of fatal traumatic injuries in endemic and migratory Passeriformes and Psittaciformes from the Cerrado Biome, a biodiverse but threatened area in Brazil. Results showed that fatal traumatic injuries were found in 21.8% of birds (285/1305), mainly in spring and summer, during the birds' reproductive period. The yellow-chevroned parakeet (Brotogeris chiriri) and Passeriformes from the Thraupidae family were the most affected. Nearly 70% of the fatal injuries observed were to the thoracic, pelvic limbs, and skull, and types of fractures and affected bones were thoroughly evaluated. Blunt traumas were one of the most frequent causes of injuries. Injuries affecting the appendicular skeleton and head represented significant causes of traumatic death for Passeriformes and Psittaciformes. The frequency of

these fatal injuries has been increasing in recent years, which may be related to the remarkable environmental changes in the Cerrado Biome and jeopardize the survival of many bird species.

Fornazari, Gabrielle Adad, André Saldanha, Rogerio Ribas Lange, Tilde Froes, Daniel Klem Jr, Bret A. Moore, and Fabiano Montiani-Ferreira. 2021. Window collisions by birds in Brazil: Epidemiologic factors and radiographic and necropsy assessments. Journal of Avian Medicine and Surgery 35(3):313-324. https://doi.org/10.1647/20-00009

Abstract Birds are among the most visually proficient group of animals on the planet; however, their inability to visualize and discriminate translucent glass structures results in an extreme number of deaths worldwide from high-speed collisions. Despite reports of avian glass collisions in North America, only a few studies have been developed to understand this problem in South America, and none evaluated radiographic and postmortem findings. One hundred cadavers were examined radiographically and postmortem, and data from 186 collision reports were analyzed for seasonality (website and manual reports and cadavers). A total of 34 different species of birds within 22 families were evaluated for this study, with the rufous-bellied thrush (*Turdus rufiventris*; n = 12), eared dove (*Zenaida auriculata*; n = 12), and ruddy ground dove (*Columbina talpacoti*; n = 10) being the most common species. Only 6 (27.7%) migratory species were reported: Sick's swift (*Chaetura meridionalis*), small-billed elaenia (*Elaenia parvirostris*), Black Jacobin (*Florisuga fusca*), Great kiskadee (*Pitangus sulphuratus*), Double-collared seedeater (*Sporophila caerulescens*), and Creamy-bellied thrush (*Turdus amaurochalinus*). Males (51) were more frequently reported than females (5), and 50.1% of the males had active gonads. Sex was unable to be determined in 44 birds. The most common radiographic lesion, noted in 16 of 82 (19.5%) animals, was loss of coelomic definition, suggestive of hemorrhage. Prevalent postmortem findings included skull hemorrhages (58/75, 77.3%) and encephalic contusions (47/73, 64.4%), followed by coelomic hemorrhages (33/81, 40.7%). Most of the window collisions (61/186, 32.8%) occurred during spring, the most common breeding season of avian species in Brazil. Cranioencephalic trauma was identified as the primary cause of mortality associated with birds flying into glass windows. Migration does not appear to be the main predisposing factor for window collisions by birds in Brazil. Increased activity and aggression related to breeding season, especially in males, may be a more important predisposing factor for window collision accidents.

Gámiz, Elisabet Pérez. 2021. La prevención de accidentes de la avifauna por colisión contra cristales en ambientes urbanos. Papel del Centro de Conservación Zoo de Córdoba. [Prevention of birdlife accidents due to collision with glass in urban environments. Role of the Córdoba Zoo Conservation Center.] https://zoo.cordoba.es/wp-content/uploads/2022/05/TFG-Prevencion-de-accidentes-avifauna.pdf

Resumen En este trabajo se aborda el problema de las colisiones de avifauna contra cristales, que representa la segunda causa de muerte de las aves en entornos urbanos y que tiene un origen en las actuaciones arquitectónicas antrópicas. La aplicación de la metodología de búsqueda bibliográfica en la literatura científica, nos ha permitido dar a conocer que las principales fuentes de peligro son la transparencia y reflexión de los cristales, el mal uso de la luz en horas nocturnas y los depredadores oportunistas del entorno. Las limitaciones para percibir el entorno afectan de distinta manera ente especies y las colisiones presentan una estacionalidad marcada. Dentro de las zonas urbanas más vulnerables encontramos las instalaciones de los parques zoológicos, los jardines públicos que cuenten con edificaciones a su alrededor, las barreras antirruido de carreteras, edificaciones de los Campus Universitarios y estructuras y edificaciones de polideportivos. Para eludir tal problema en la avifauna se establecen soluciones al alcance de todos para evitar las principales fuentes de peligro, así como recomendaciones para el día a día del ciudadano. La normativa existente a nivel europeo y a nivel nacional para la conservación de avifauna, incluye algunas medidas de prevención de los accidentes de las aves por colisión con

tendidos eléctricos, pero no existe una normativa concisa frente a colisiones de la avifauna contra cristales en zonas urbanas. Los programas educativos que se desarrollan en el Centro de Conservación Zoo de Córdoba incluyen contenidos de conservación y protección de las especies. En estetrabajo proponemos incluir en los programas formativos de este centro contenidos específicos sobre los accidentes que sufren las aves por las colisiones contra cristales en el entorno urbano, a desarrollar a través de una serie de actividades educativas con el objeto de dar a conocer, sensibilizar y crear concienciar social frente del problema

Abstract This paper addresses the problem of bird collisions with glass, which represents the second cause of death of birds in urban environments and which has its origin in anthropic architectural actions. The application of the bibliographic search methodology in the scientific literature has allowed us to discover that the main sources of danger are the transparency and reflection of glass, the misuse of light at night and opportunistic predators in the environment. Limitations in perception of the environment affect different species in different ways and collisions have a marked seasonality. Among the most vulnerable urban areas are zoo facilities, public gardens with surrounding buildings, road noise barriers, university campus buildings and sports centre structures and buildings. In order to avoid this problem for birdlife, solutions within everyone's reach are established to avoid the main sources of danger, as well as recommendations for the day-to-day life of citizens. The existing European and national regulations for the conservation of birdlife include some measures for the prevention of bird accidents due to collisions with power lines, but there are no concise regulations for bird collisions with glass in urban areas. The educational programmes developed at the Cordoba Zoo Conservation Centre include content on the conservation and protection of species. In this work we propose to include in the educational programmes of this centre specific content on the accidents suffered by birds due to collisions with glass in the urban environment, to be developed through a series of educational activities with the aim of raising awareness and creating social awareness of the problem.

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. https://nybirds.org/KBsearch/y2006v56n3/y2006v56n3p190-198gelb.pdf

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. https://doi.org/10.1656/045.016.n312

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, B., B.F. Blackwell, T.L. DeVault, P.E. Baumhardt and E. Fernández-Juricic. 2018. Assessing bird avoidance of high-contrast lights using a choice test approach: implications for reducing human-induced avian mortality. PeerJ 6:e5404. https://doi.org/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.

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, M.W., and C.C. St. Claire. 2016. Ultraviolet lights do not deter songbirds at feeders. J Ornithol 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, and L. Mayer. 2008. Bird density and mortality at windows. Wilson Journal of Ornithology 120(3):550-564. https://doi.org/10.1676/07-075.1

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, S.B. 2009. Human-Related Threats to Urban Raptors. J. Raptor Res. 43(3):210–226. https://doi.org/10.3356/JRR-08-63.1

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 usage 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. https://doi.org/10.1111/j.1557-9263.2012.00370.x

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 S.B., B.J. Cosentino, K.J. McKay, C. Monson, W. Zuurdeeg, and B. Blevins. 2013. Window area and development drive spatial variation in bird-window collisions in an urban landscape. PLoS ONE 8(1): e53371. https://doi.org/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, S.B, and B.J. Cosentino. 2014. Surveying for bird carcasses resulting from window collisions: a standardized protocol. https://peerj.com/preprints/406/

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. 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, S.B., Cosentino, B.J., Aguilar-Gómez, M.A., Anderson, M.L., Bakermans, M., Boves, T.J., Brandes, D., Butler, M.W., Butler, E.M., Cagle, N.L. and Calderón-Parra, R. 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.

Hariyanto, A., G. Rajeshkumar, J. Tasto, and V. Bennett. Through the Bird's Eye View. In Bakermans, Marja, Mickaela Gunnison, and William San Martín (Eds.). Extinction Stories: licensed under a Creative Commons Attribution-NonCommercial 4.0 International License, except where otherwise noted. https://pressbooks.pub/extinctionstories/

Abstract Approximately 1 billion bird collisions happen in North America yearly, and Chicago is the city where most incidents happen. Consequently, Chicago has solutions to reduce bird collisions, and our goal is to explore both Lights Out Chicago and bird-friendly window designs as viable solutions. Our findings conclude that the two programs have an impact on bird collision fatalities in the city, making both solutions viable and beneficial for bird collision reduction. This chapter discusses several possible improvements for the solutions including the reporting of the solution's status on a city-wide scale, providing more incentives, and increasing public awareness

Håstad, O., and A. Ödeen. 2014. A vision physiological estimation of ultraviolet window marking visibility to birds. PeerJ 2:e621. https://doi.org/10.7717/peerj.621

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 Columbiformes. 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. [Search/spotlights and building lighting divert migratory birds off course: New investigations and a legal evaluation of these lighting systems] NuL 43(6):165-170.

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. https://www.wua-wien.at/images/stories/naturschutz_stadtoekologie/heiko-haupt-post-tower-bonn.pdf

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.

Heide, K.T., L.E. Friesen, V.E. Martin, E.D. Cheskey, M.D. Cadman, and D.R. Norris. 2023. Before-and-after evidence that urbanization contributes to the decline of a migratory songbird. Avian Conservation and Ecology 18(1). https://doi.org/10.5751/ACE-02366-180115

Abstract Although urbanization is widely believed to be an increasing threat to biodiversity, drawing strong inferences about its effects on wildlife has been challenging because the state of a population prior to development is rarely known. The Wood Thrush (*Hylocichla mustelina*) is a steeply declining migratory songbird that breeds in North American temperate deciduous forests and winters in Central America. From 1987 to 2001, Wood Thrush abundance and daily nest survival were measured in 72 forest fragments across Waterloo Region, Ontario, Canada. Some of these fragments have since been surrounded by urbanization while others have remained rural. In 2020 and 2021, we reassessed Wood Thrush abundance and daily nest survival in these same fragments by replicating point count and nest monitoring protocols. Our results suggest that Wood Thrush have declined most steeply in fragments with development built within 1 km during the intervening 20-year period (-79% vs. only -57% elsewhere), although experiencing no decline in daily nest survival over the same time period, regardless of development. Our findings provide rare before-and-after evidence that urbanization near breeding habitat is contributing to a pronounced localized decline of a migratory songbird, likely by mechanisms unrelated to nest survival.

Heister, C. 2021. Geospatial and Temporal Drivers of kererū (Hemiphaga novaeseelandiae) Bird-Window Collisions in Dunedin, New Zealand. (Thesis, Master of Science). University of Otago. Retrieved from http://hdl.handle.net/10523/12188

The authors of this study "aimed to determine the most reliable field-based way to sex kererū and understand geospatial, temporal, sex class, age class, seasonal, monthly, and decade trends amongst kererū [a large, monomorphic pigeon species endemic to New Zealand] BWCs [bird-window collisions] in Dunedin." The authors sexed 100 dead kererū from Otago Museum, Komiti Taoka Tuku Iho, and the Wildlife Hospital, using morphometric measurements and DNA sexing and found that DNA sexing is the most reliable method for sexing kererū. The authors also analyzed a dataset of kererū deaths and injuries collected since 1968 and did not detect temporal, sex, or age class trends among kererū collisions in Dunedin. They did find a significant correlation between kererū BWCs and areas containing dense residential properties and commercial buildings. The authors also discuss mitigation of kererū BWCs.

Hiemstra, Maaike A, Erin K Dlabola and Erin L O'Brien. 2020. Factors Influencing Bird-Window Collisions. Northwestern Naturalist 101:27–33 https://doi.org/10.1898/1051-1733-101.1.27

Abstract Bird-window collisions occur across North America and are estimated to kill hundreds of millions of birds annually. Previous studies show that collisions occur non-randomly and can be influenced by building characteristics, time-of-year, and species-specific physiology and behavior. Much of the available research is based in northeastern North America, though different species and habitats in the West may be affected differently. We collected strike data from 2 buildings in Victoria, British Columbia, from June to October 2018. We found that window width was positively related to the probability of a strike occurring, whereas vegetation distance to window, window aspect, and the building at which it occurred did not predict strike probability. A substantial increase in strikes occurred in September and October, which coincides with peak migration on Vancouver Island, and suggests that migration influences collision risk to bird species.

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 17(4):209-14. https://doi.org/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.

Hsieh, C.H., G.C. Hsu, and L.M. Wang. 2024. Preprint. Can social media serve as a potential citizen science source for bird-window collision (BWC) data? A study using a decadal data set in Taiwan. bioRxiv, pp.2024-03. https://doi.org/10.1101/2024.03.29.587372

Abstract Citizen science is increasingly used in bird-window collision (BWC) research to collect data. However, few studies have collected BWC data from social media, and it remains unknown whether the data quality is comparable to that of reported on dedicated platforms. To evaluate the potential of social media as a citizen science data source for BWC, we collected BWC data on social media Facebook as well as Taiwan Roadkill Observation Network (TaiRON), the main dedicated citizen science platform for reporting wildlife mortalities in Taiwan. We compared a decade of BWC data (2012–2022) from the two platforms by examining the nationwide geographical coverage and the species compositions of the BWC observations. Overall, we recorded 2,583 BWC cases involving 153 BWC species from Facebook, and 1,000 BWC cases involving 104 BWC species from TaiRON. More than half of the BWC individuals from Facebook were not found dead when observed, whereas all records on TaiRON were dead individuals. The nationwide geographical coverage and the species compositions of the top 80% cumulative BWC individuals were generally similar between the two platforms. Moreover, the sampling completeness of the two platforms both exceeded 95% (Facebook: 98.0%; TaiRON: 96.0%). To our knowledge, this study is among the first to collect BWC data through social media posts, and our results show that the quantity and quality of Facebook data can be comparable to that of the well-developed citizen science platform TaiRON. Taken together, social media Facebook may not only serve as a promising tool for collecting BWC data, but also provide a platform for public education, which can benefit bird conservation. Finally, integrating data from different citizen science sources helps paint a more complete picture of BWC patterns, especially in understudied areas such as Asia.

Huggins, Benedikt and 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.

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 provided table 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. https://doi.org/10.1111/j.0908-8857.2003.03183.x

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, and 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.

Karmaker, Debajyoti, Julia Groening, Michael Wilson, Ingo Schiffner and Mandyam V. Srinivasan. 2020. Budgerigars adopt robust, but idiosyncratic flight paths. Scientific Reports 10:2535. https://doi.org/10.1038/s41598-020-59013-3

Abstract We have investigated the paths taken by Budgerigars while flying in a tunnel. The flight trajectories of nine Budgerigars (Melopsittacus undulatus) were reconstructed in 3D from high speed stereo videography of their flights in an obstacle-free tunnel. Individual birds displayed highly idiosyncratic flight trajectories that were consistent from flight to flight over the course of several months. We then investigated the robustness of each bird's trajectory by interposing a disk-shaped obstacle in its preferred flight path. We found that each bird continued to fly along its preferred trajectory up to a point very close to the obstacle before veering over the obstacle rapidly, making a minimal deviation to avoid a collision, and subsequently returning to its original path. Thus, Budgerigars show a high propensity to stick to their individual, preferred flight paths even when confronted with a clearly visible obstacle, and do not adopt a substantially different, unobstructed route. The robust preference for idiosyncratic flight paths, and the tendency to pass obstacles by flying above them, provide new insights into the strategies that underpin obstacle avoidance in birds. We believe that this is the first carefully controlled study of the behavior of birds in response to a newly introduced obstacle in their flight path. The insights from the study could also have implications for conservation efforts to mitigate collisions of birds with man-made obstacles.

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 11:137- 158. https://www.animallaw.info/policy/journal-animal-and-natural-resource-law-vol-11

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 US, 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 collisions problem and into the viability of proposed solutions to that problem.

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. https://www.jstor.org/stable/4162790

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. https://www.jstor.org/stable/4513512

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. https://www.jstor.org/stable/4513511

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

Resumen 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 presen-taron 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, and C. T. Platt. 2004. Effects of window angling, feeder placement, and scavengers on avian mortality at plate glass. Wilson Bulletin 116(1):69-73. https://doi.org/10.1676/0043-5643(2004)116[0069:EOWAFP]2.0.CO;2

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. https://doi.org/10.1676/08-118.1

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. https://doi.org/10.1676/08-068.1

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.
https://www.muhlenberg.edu/media/contentassets/images/academics/biology/biology/faculty/klem/aco/documents/Klem_PIF09-Final-rec-1-XII-09.pdf

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, D. 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.
https://doi.org/10.1676/12-106.1

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, D. Jr. 2015. Bird–window collisions: A critical animal welfare and conservation issue. Journal of Applied Animal Welfare Science, 18(sup1):S11-7.
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.

Klem, D. Jr. Solid Air. Invisible Killer: Saving Billions of Birds from Windows. 2021. Hancock House Publishers. Blaine, Washington, USA.

Dr. Daniel Klem, Jr., describes and summarizes the challenges and solutions to this important conservation issue for birds and people that can be used by, among others, architects and developers, legislators, legal professionals, urban planners, and homeowners alike.

Klem, D. Jr., P.G. Saenger, and B.P. Brogle. 2024. Evidence, consequences, and angle of strike of bird–window collisions. The Wilson Journal of Ornithology 136(1):113-119. https://doi.org/10.1676/23-00045

Abstract We used direct observation to record what, if any, evidence was measurable when a bird hit the outside surface of plate glass during 18 field experiments to evaluate several products to deter window strikes. A total of 1,356 strikes were witnessed over 508 d and 1,202 h of observation; 678 (50%) left no evidence of a collision, and 190 (14%) resulted in an immediate fatality. For 10 experiments, 1,261 detailed individual flightpaths were drawn over 235 d and 799 h of observation; 916 (73%) were strikes and 22 (2%) of these resulted in an immediate fatality. We recorded 822 (90%) flightpaths that hit perpendicular or within 40° on either side of perpendicular to the glass surface; 94 (10%) hit with a glancing blow of greater than 40° on either side of perpendicular. Perpendicular strikes resulted in 689 (84%) of individuals flying off immediately with no sign of impairment, 113 (14%) stunned, and 20 (2%) fatalities. Glancing blow strikes resulted in 81 (86%) flying off with no sign of impairment, 11 (12%) stunned, and 2 (2%) fatalities. Considering that 50% of bird–window collisions leave no measurable evidence of a strike, and as much as 70% of stunned victims likely succumb from a collision, annual mortality may be minimally 1.28 billion–3.46 billion or as high as 1.92 billion–5.19 billion in the United States, with potentially billions more worldwide.

Korner-Nievergelt, Fränzi, Oliver Behr, Robert Brinkmann, Matthew A. Etterson, Manuela M. P. Huso, Dan Dalthorp, Pius Korner-Nievergelt, Tobias Roth and Ivo Niermann. 2015. Mortality estimation from carcass searches using the R-package carcass—A tutorial. Wildl. Biol. 21:30–43. https://doi.org/10.2981/wlb.00094

This article is a tutorial for the R-package carcass. It starts with a short overview of common methods used to estimate mortality based on carcass searches. Then, it guides step by step through a simple example. First, the proportion of animals that fall into the search area is estimated. Second, carcass persistence time is estimated based on experimental data. Third, searcher efficiency is estimated. Fourth, these three estimated parameters are combined to obtain the probability that an animal killed is found by an observer. Finally, this probability is used together with the observed number of carcasses found to obtain an estimate for the total number of killed animals together with a credible interval.

Korner, P., von Maravic, I. and Haupt, H. Birds and the 'Post Tower' in Bonn: a case study of light pollution. J Ornithol 163, 827–841 (2022). https://doi.org/10.1007/s10336-022-01985-2

Abstract During six consecutive autumn seasons we registered birds that were attracted to an illuminated 41-storey building in Bonn, Germany, the so-called 'Post Tower'. Casualties on the ground were disoriented by the light and in most cases collided with the building. All-night observations with numbers of casualties, efective light sources, moon, and weather parameters registered hourly allowed for analyses of the role of these factors for the attraction and disorientation of numerous migratory birds. As expected, the conspicuous façade illumination was responsible for many casualties (fatal or non-fatal). Additionally, the illuminated roof logos and even faint light sources like the emergency lights were attractive and led to casualties. Moon and rain were negatively correlated with casualties, but there was no clear correlation with other weather parameters. Turning of lights was key, but efects of other ex post mitigation measures were limited: shutters were not originally intended for the attenuation of light emissions, control technology was insufcient, and there was a lack of willingness of the building owner to reduce light emissions consistently, even during core bird migration periods. Conservation recommendations are derived from this case study.

Kornreich, A., D. Partridge, M. Youngblood, and K. Parkins. 2024. Rehabilitation outcomes of bird-building collision victims in the Northeastern United States. PLOS ONE 19(8):e0306362. https://doi.org/10.1371/journal.pone.0306362

Abstract Building collisions are a leading threat to wild birds; however, only those that are found dead or fatally wounded are included in current mortality estimates, with injured or stunned birds largely assumed to survive long-term. Avian building collision victims are often brought to wildlife rehabilitators for care, with the hopes they can be released and resume their natural lives. We examined the wildlife rehabilitation records of over 3,100 building collisions with 152 different avian species collected across multiple seasons to identify patterns of survival and release among patients. The number of admissions varied by season; fall migration had the highest number of cases and winter had the least number of cases, and summer having the lowest release proportion and winter having the highest. The most common reported injury was head trauma and concussion. Our logistic and Poisson models found that mass had a strong positive effect on release probability, and the season of summer had a strong negative effect on release probability. Mass and winter had a strong positive effect on treatment time, and age and the seasons of fall and winter had a strong negative effect on treatment time in these models. Ultimately, about 60% of patients died in care, either by succumbing to their injuries or by euthanasia. Patients that were released remained in care for longer than patients that died. This study reports different data than carcass studies and views bird-building collisions from the perspective of surviving victims to explore longer-term effects of these collisions on mortality. Increased communication and collaboration between wildlife rehabilitators and conservation researchers is recommended to better understand building collisions and how to respond to this leading threat to wild birds. These findings, along with our estimate of delayed mortality, suggest that overall collision mortality estimates based on carcass collection far exceed one billion birds in the U.S. each year.

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. http://dx.doi.org/10.1650/CONDOR-16-26.1

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. Bayne. 2016. Use of bird carcass removals by urban scavengers to adjust bird-window collision estimates. Avian Conservation and Ecology 11(2):12. 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. 2016a). 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, and Cabrera-Cruz SA. 2017. Seasonal associations with urban light pollution for nocturnally migrating bird populations. Glob Change Biol. 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.

La Sorte, Frank A. and Kyle G. Horton, 2021. Seasonal variation in the effects of artificial light at night on the occurrence of nocturnally migrating birds in urban areas. Environmental Pollution 270:116085 https://doi.org/10.1016/j.envpol.2020.116085

Highlights Cities contained the most nocturnally migratory bird species during spring. Light pollution reduced species numbers during the winter and summer. Light pollution enhanced species numbers during spring and autumn migration. Tree canopy cover enhanced species numbers during spring migration and the summer.

Abstract Urban areas often contain large numbers of migratory bird species during seasonal migration, many of which are nocturnal migrants. How artificial light at night (ALAN) and urban landcover are associated with the diurnal occurrence of nocturnal migrants within urban areas across seasons has not been explored. Here, we use eBird bird occurrence information to estimate the seasonal species richness of nocturnally migrating passerines (NMP) within 333 well surveyed urban areas within the contiguous USA. We model the relationship between seasonal NMP species richness and ALAN, proportion of tree canopy cover, and proportion of impervious surface. NMP species richness reached its highest levels during spring and autumn migration and lowest during the winter and summer. Greater tree canopy cover was associated with higher NMP species richness during spring and autumn migration and the summer. A 10% increase in the proportion of tree canopy cover was associated with a 2.0% increase in NMP species richness during spring migration, a 1.8% increase during autumn migration, and a 0.9% increase during the summer. More impervious surface was associated with higher NMP species richness during the winter. A 10% increase in the proportion of impervious surface was associated with a 6.1–9.8% increase in NMP species richness. Higher ALAN was associated with lower NMP species richness during the winter and summer, and higher NMP species richness during spring and autumn migration. A 50% increase in ALAN was associated with a 3.0–3.6% decrease in NMP species richness during the winter, a 1.7% increase during spring migration, a 2.1% decrease during the summer, and a 5.0% increase during autumn migration. These findings highlight the variable effects of ALAN and urban landcover on the seasonal occurrence of NMP species in urban areas, the value of tree canopy cover during migration and the breeding season, and the importance of reducing ALAN during migration.

La Sorte, Frank, A., Alison Johnston, Amanda D. Rodewald, Daniel Fink, Andrew Farnsworth, Benjamin M. Van Doren, Tom Auer and Matthew Strimas-Mackey. 2022. The role of artificial light at night and road density in predicting the seasonal occurrence of nocturnally migrating birds. Diversity and Distributions 28(5):992-1009. https://doi.org/10.1111/ddi.13499

Aim Artificial light at night (ALAN) and roads are known threats to nocturnally migrating birds. How associations with ALAN and roads are defined in combination for these species at the population level across the full annual cycle has not been explored. Location: Western Hemisphere. Methods: We estimated range-wide exposure, predictor importance and the prevalence of positive associations with ALAN and roads at a weekly temporal resolution for 166 nocturnally migrating bird species in three orders: Passeriformes (n = 104), Anseriformes (n = 27) and Charadriiformes (n = 35). We clustered Passeriformes based on the prevalence of positive associations.

Results Positive associations with ALAN and roads were more prevalent for Passeriformes during migration when exposure and importance were highest. Positive associations with ALAN and roads were more prevalent for Anseriformes and Charadriiformes during the breeding season when exposure was lowest. Importance was uniform for Anseriformes and highest during migration for Charadriiformes. Our cluster analysis identified three groups of Passeriformes, each having similar associations with ALAN and roads. The first occurred in eastern North America during migration where exposure, prevalence, and importance were highest. The second wintered in Mexico and Central America where exposure, prevalence and importance were highest. The third occurred throughout North America where prevalence was low, and exposure and importance were uniform. The first and second were comprised of dense habitat specialists and long-distance migrants. The third was comprised of open habitat specialists and short distance migrants. Main conclusions: Our findings suggest ALAN and roads pose the greatest risk during migration for Passeriformes and during the breeding season for Anseriformes and Charadriiformes. Our results emphasise the close relationship between ALAN and roads, the diversity of associations dictated by taxonomy, exposure, migration strategy and habitat and the need for more informed and comprehensive mitigation strategies where ALAN and roads are treated as interconnected threats.

Main conclusions Our findings suggest ALAN and roads pose the greatest risk during migration for Passeriformes and during the breeding season for Anseriformes and Charadriiformes. Our results emphasise the close relationship between ALAN and roads, the diversity of associations dictated by taxonomy, exposure, migration strategy and habitat and the need for more informed and comprehensive mitigation strategies where ALAN and roads are treated as interconnected threats.

Länderarbeitsgemeinschaft der Vogelschutzwarten (LAGVSW). 2017. Der mögliche Umfang von Vogelschlag an Glasflächen in Deutschland – eine Hochrechnung Länderarbeitsgemeinschaft der Vogelschutzwarten. [The possible dimension of bird collision with glass in Germany – an extrapolation by the state working group of bird sanctuaries.] Berichte zum Vogelschutz 53/54: 63–67.

Abstract

Collision with glass constitutes a significant human-induced mortality cause for birds. It is estimated that in the USA several hundreds of millions of birds collide with glass every year. Here we try, with appropriate caution, to transfer these figures to Germany. Our rough estimate is that there are 30-35 million bird-glass strikes at residential detached, semi-detached and terrace houses, 70-80 million strikes at multi-story residential buildings, non-residential buildings, hospitals, schools and universities, and 60,000 at high-rise buildings. This results in an estimated total of 100-115 million birds colliding with glass annually in Germany. As bus shelters, noise protection walls and other translucent structures are not included in this estimate, the number of

birds colliding with glass might be even higher. For reasons of simplicity, we assume that the number of bird collisions is identical with the number of deaths. While there are huge differences in the collision rate between bird species, it is assumed that the mortality rate through collision with glass is somewhere in the range of 5-10% of the birds that occur in Germany throughout the year.

Lao, Sirena, Robertson Bruce A., Andersen Abigail W., Blair Robert B., Eckles Joanna W., Turner Reed J., and Loss Scott R. 2020. The influence of artificial light at night and polarized light on bird-building collisions. Biological Conservation 241:108358.
https://doi.org/10.1016/j.biocon.2019.108358

Abstract Collisions with buildings annually kill up to 1 billion birds in the United States. Bird-building collisions primarily occur at glass surfaces: birds often fail to perceive glass as a barrier and appear to be attracted to artificial light emitted from windows. However, some aspects of avian vision are poorly understood, including how bird responses to different types of light influence building collisions. Some evidence suggests birds can detect polarized light, which may serve as a cue to assist with migration orientation and/or detect water bodies. Dark, reflective surfaces, including glass, reflect high degrees of polarized light, causing polarized light pollution (PLP). However, no studies have analyzed the relationship between bird collisions and PLP reflected from buildings. Additionally, while artificial light at night (ALAN) is frequently implicated as a major factor influencing bird-building collisions, few studies have analyzed this relationship. We investigated both types of light pollution—PLP and ALAN—and their association with bird collisions at 48 façades of 13 buildings in Minneapolis, Minnesota, USA. We found that the area of glass emitting ALAN was the most important factor influencing collisions, and that this effect of ALAN was independent of overall glass area; this result provides strong support for turning off lights at night to reduce bird-building collisions. Although we found no relationship between PLP and collisions, additional research is needed to better understand bird responses to polarized light. Fully understanding how different aspects of light influence bird-building collisions can inform conservation efforts to reduce this major threat to birds.

Lao, S., Anderson, A.W., Blair, R.B., Eckles, J.W., Turner, R.J. and Loss, S.R. 2022. Bird–building collisions increase with weather conditions that favor nocturnal migration and with inclement and changing weather. Ornithological Applications.
https://doi.org/10.1093/ornithapp/duac045

Abstract Collisions with building windows are a top bird mortality source, but few studies have evaluated how bird–window collisions are influenced by weather. By monitoring collisions daily at 21 buildings in Minneapolis, Minnesota, over 4 migration seasons, we show that weather influences numbers of window collisions of nocturnal migrants in spring and fall, indicating that collisions may be forecastable based on weather conditions. Collisions increased with weather favoring migration, such as consecutive nights of south wind in spring and even short periods of north wind in fall. We also found evidence that spring and fall collisions increase with weather changes that impede migration, such as changes from fair conditions and tailwinds early in the night to headwinds near sunrise. Our study suggests complex weather effects never before considered in the context of bird collisions, including possible time lag effects of conditions 2–3 nights before collisions occur, effects of multi-day sequences of conditions, and interactions between conditions at different times of night. More research is needed to determine if accuracy of weather-based collision prediction systems improves by integrating such nuances and to clarify mechanisms through which these complex effects operate, such as influences of weather on migration intensity and collision avoidance behavior. Weather-based forecasts may allow refinement of collision mitigation approaches (e.g., reducing building lighting on certain nights or using temporary glass coverings or treatments). However, because challenges remain to

communicating such temporally targeted actions and implementing them in a timely manner, other bird-friendly practices (e.g., season-long lighting reduction and permanent glass treatments) should continue to be prioritized.

Lee, S.J., F.N. Matos, C.R.R. Gonzaga, M.A. de Medeiros, S.D.F.S. Leandro, R.H.F. Teixeira, A.L.M. da Costa, and A.J. Piratelli. 2024. Post-mortem analysis of birds that collided with glass panes reveals multiple injuries and fractures. Ornithology Research 32(4):399-403.
https://doi.org/10.1007/s43388-024-00201-4

Abstract Collisions between wild birds and anthropogenic structures, such as window panes, pose a significant threat, resulting in an alarming number of bird deaths annually. Despite being a global concern, scientific research in Latin America remains incipient, highlighting the need for more research into the impacts on birdlife. In this study, we collected and examined 46 carcasses of 23 bird species that collided with glass structures on a university campus in Sorocaba, SP, Brazil, from March 2017 to June 2023, as part of regular local monitoring of bird collisions and windows. The carcasses were analyzed using necropsy procedures and x-rays, to understand the physical damage caused by these accidents. The species with the largest number of samples were Columbina talpacoti (9 individuals) and Turdus leucomelas (5 individuals). The findings revealed fractures in several bones, bruises and cranial hemorrhages as the main injuries of these collisions. This preliminary assessment not only contributes to the limited existing knowledge, but also highlights the urgency of addressing bird-window collisions to mitigate their detrimental effects on birds.

Lessin, L.M. 2021. Factors related to bird collisions with buildings along the coast of Lake Erie. Thesis: Presented in Partial Fulfillment of the Requirements for the Degree Master of Science in the Graduate School of The Ohio State University.
http://rave.ohiolink.edu/etdc/view?acc_num=osu1641474194012681

Abstract In North America, the replacement of greenspaces with human-made structures causes hundreds of millions, if not billions, of avian fatalities every year. Through the continuous increase in urbanization, threats to avian wildlife are exacerbated by a multitude of related factors such as habitat loss, fragmentation, and pollution. Bird collisions with buildings are an integral component of these threats because they directly cause avian mortality, and they are expected to increase as human populations continue to grow in urban areas. Bird collisions with buildings represent the largest source of collision mortalities, ahead of collisions with windmills, power lines, and vehicles. Cities serve as physical impediments for numerous bird species, as many urbanized landscapes are located along migratory routes. Birds play an important role in the proper functioning of ecosystems, and they also play an important role within human societies. Therefore, it is important to explore determinants of bird collisions with buildings to identify effective mitigation strategies that aim to counter the rapid decline of bird populations. Previous studies have identified that numerous factors correlate with bird collisions with buildings. These factors include species' life-history traits, artificial lighting at night, building characteristics, and atmospheric conditions. There are likely a multitude of other factors influencing bird collisions with buildings at any point in time, and this further increases the complexities behind collision dynamics.

I evaluated previously identified factors related to bird collisions with buildings to test their influence on bird collisions in Cleveland, Cuyahoga County, Ohio, during fall of 2017. I identified that life-history strategies related to migration distance and foraging height, along with family groupings, differentiated collision frequencies. For example, long-distance migrant and warbler (Family *Parulidae*) species were overrepresented in their collision frequencies when compared to their local relative abundances. Next, I explored patterns of collision over time and found a

complex interaction of variables related to bird collisions with buildings. Variables included in the final model included atmospheric pressure, peak wind speeds, temperature, relative abundance, date, and flying altitude. I also found that time lags were important when exploring determinants of collision. For example, atmospheric conditions (i.e., peak wind speeds) one day before collision events were critical in capturing changing weather conditions over time. This study also found an important multiplicative interaction between Julian date and maximum dry bulb temperature when predicting collision numbers, and this highlights the need to include complex variable interactions when modeling and predicting collision risk. Every year, there are large numbers of bird collisions with buildings, so when exploring and creating efficient mitigation efforts, it is crucial to consider changing atmospheric conditions and avian movement patterns both during and before actual collision events.

Ley, H.W. 2006. Experimentelle Überprüfung der Wahrnehmbarkeit patentierter Vogelschutzgläser durch eine Stichprobe mitteleuropäischer Gartenvögel. Max Planck Institut für Ornithologie.

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. [available for download from http://www.wua-wien.at/publikationen]

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, and Biewener AA. 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

Abstract Various flight navigation strategies for birds have been identified at the large spatial scales of migratory and homing behaviors. 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 behavioral modelling method converts the obstacle avoidance behavior into a (piecewise) target-aiming behavior, which is better defined and understood. This study demonstrates how such an approach decomposes open-loop free-flight behaviors into components that can be independently evaluated.

Lind O, Mitkus M, Olsson P, Kelber A. 2014 Ultraviolet vision in birds: the importance of transparent eye media. Proc. R. Soc. B 281:20132209.
http://dx.doi.org/10.1098/rspb.2013.2209

Abstract Ultraviolet (UV)-sensitive visual pigments are widespread in the animal kingdom but many animals, for example primates, block UV light from reaching their retina by pigmented lenses. Birds have UV-sensitive (UVS) visual pigments with sensitivity maxima around 360–373 nm (UVS) or 402–426 nm (violet-sensitive, VS). We describe how these pigments are matched by the ocular media transmittance in 38 bird species. Birds with UVS pigments have ocular media that transmit more UV light (wavelength of 50% transmittance, IT0.5, 323 nm) than birds with VS pigments (IT0.5, 358 nm). Yet, visual models predict that colour discrimination in bright light is mostly dependent on the visual pigment (UVS or VS) and little on the ocular media. We hypothesize that the precise spectral tuning of the ocular media is mostly relevant for detecting weak UV signals, e.g. in dim hollow-nests of passerines and parrots. The correlation between eye size and UV transparency of the ocular media suggests little or no lens pigmentation. Therefore, only small birds gain the full advantage from shifting pigment sensitivity from VS to UVS. On the other hand, some birds with VS pigments have unexpectedly low UV transmission of the ocular media, probably because of UV blocking lens pigmentation

Liu, Hui and Xu Yanchun. 2014. Bird collision with building glass outer wall caused by landscape structure: A case study. Chinese Journal of Wildlife 35(2): 216-219.

Abstract 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. PLoS one 7(4):e34025.
https://doi.org/10.1371/journal.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. https://doi.org/10.1016/j.biocon.2012.09.019

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*). Avian mortality from anthropogenic sources is almost always reported in the aggregate ("number of birds killed"), which cannot detect the species-level effects necessary to make conservation assessments. Our approach to per species estimates could be undertaken for other sources of chronic anthropogenic mortality.

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.

Longcore, Travis and Rich, Catherine. November 2016. Ecological and Organismic Effects of Light Pollution. eLS 2016:1-8. https://doi.org/10.1002/9780470015902.a0026328.

Since the invention of the electric light bulb in 1879, a significant portion of the planet has been transformed from experiencing a natural pattern of light and dark determined by the sun, moon, stars and occasional other transient lights to being subjected to intermittent and perpetual illumination from human civilization that is unprecedented in the history of Earth. The pervasiveness of this phenomenon and its exponential growth has measurable and significant consequences for living organisms. The results of recent research have extended knowledge about the geographic scope and specific impacts of artificial night lighting on animal behaviour, physiological processes and ecological interactions across a range of taxa and its broader ecosystem effects

Lopes, A.C., G.O.C. Rocha, M.F. de Oliveira Passos, L. Barçante, and C.S. de Azevedo. 2024. The influence of building surroundings and glass cover in bird collisions. Birds 5(4):703-711. https://doi.org/10.3390/birds5040048

Abstract The characteristics of building surroundings can influence the number of bird deaths caused by collisions with glass structures. Thus, this study investigated whether the number of

trees, the distance to the nearest tree, the number of fruit trees, and the glass area influenced the number of bird collisions on a university campus in Brazil from March 2017 (breeding and non-breeding seasons) to January 2018 (breeding season). Twenty-four birds died due to collisions with the windows in the one-year sampling. Among the factors evaluated, the number of trees and the area of the glass predicted the number of deaths from collisions. The greater the number of trees and the glass area, the greater the number of bird collisions. This suggests that the more vegetation there is near windows, the more birds are attracted, and the less visible the glass barrier becomes, possibly due to the appearance of trees in reflections or scenes viewed through the glass, making it difficult for birds to distinguish the real landscape from the reflected environment. If large expanses of glass are placed on buildings near vegetation, including trees, more bird collisions will occur. Thus, to reduce bird collisions, building designs should reduce the amount of glass used on building exteriors near vegetation and ensure the glass is treated with visual markers.

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 10(7): 357- 364. https://doi.org/10.1890/110251

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. https://doi.org/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., and Marra. P.P. 2014. Best practices for data collection in studies of bird-window collisions. Available online https://abcbirds.org/glass-collisions/resources/

The authors outline best practices for collecting and standardizing data on bird-window collisions to improve understanding and mitigation of bird fatalities. Recommendations include randomizing building samples, recording all surveys (including zero-counts), noting search effort, categorizing birds' outcomes, distinguishing incidental findings, detailing building characteristics, and including diverse building types. Accurate documentation facilitates broader-scale analysis and more effective conservation strategies.

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. https://doi.org/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.

Loss SR, Lao S, Eckles JW, Anderson AW, Blair RB, and Turner RJ. 2019. Factors influencing bird-building collisions in the downtown area of a major North American city. PLoS ONE 14(11): e0224164. https://doi.org/10.1371/journal.pone.0224164

Abstract Bird-building collisions are the largest source of avian collision mortality in North America. Despite a growing literature on bird-building collisions, little research has been conducted in downtown areas of major cities, and no studies have included stadiums, which can be extremely large, often have extensive glass surfaces and lighting, and therefore may cause many bird collisions. Further, few studies have assessed the role of nighttime lighting in increasing collisions, despite the often-cited importance of this factor, or considered collision correlates for different seasons and bird species. We conducted bird collision monitoring over four migration seasons at 21 buildings, including a large multi-use stadium, in downtown Minneapolis, Minnesota, USA. We used a rigorous survey methodology to quantify among-building variation in collisions and assess how building features (e.g., glass area, lighting, vegetation) influence total collision fatalities, fatalities for separate seasons and species, and numbers of species colliding. Four buildings, including the stadium, caused a high proportion of all collisions and drove positive effects of glass area and amount of surrounding vegetation on most collision variables. Excluding these buildings from analyses resulted in slightly different collision predictors, suggesting that factors leading some buildings to cause high numbers of collisions are not the exact same factors causing variation among more typical buildings. We also found variation in collision correlates between spring and fall migration and among bird species, that factors influencing collision fatalities also influence numbers of species colliding, and that the proportion, and potentially area, of glass lighted at night are associated with collisions. Thus, reducing bird collisions at large buildings, including stadiums, should be achievable by reducing glass area (or treating existing glass), reducing light emission at night, and prioritizing mitigation efforts for glass surfaces near vegetated areas and/or avoiding use of vegetation near glass.

Loss, S.R., B.V. Li, L.C. Horn, M.R. Mesure, L. Zhu, T.G. Brys, A.M. Dokter, J.A. Elmore, R.E. Gibbons, T.Z. Homayoun, K.G. Horton, P. Inglet, B.J. Jones, T. Keys, S. Lao, S.S. Loss, K.L. Parkins, H.L. Prestridge, G.J. Riggs, C.S. Riding, K.R.I. Sweezey, A.C. Vallery, B.M. Van Doren, J. Wang, Zuzula C, and A. Farnsworth. 2023. Citizen science to address the global issue of bird–window collisions. Frontiers in Ecology and the Environment 21(9): 418-427. https://doi.org/10.1002/fee.2614

Abstract Bird–window collisions (BWCs) are a major threat to avian populations, annually causing up to one billion bird deaths in the US alone and untold numbers of fatalities worldwide. Until recently, there has been limited institutional and governmental recognition of this issue and few coordinated, national-level efforts to address it. To fill this need, citizen-science campaigns have stepped in to generate scientific information about BWCs, raise public awareness, and advocate for policy and actions to reduce collisions. We review the BWC issue and showcase how citizen-science programs in multiple countries have achieved these outcomes. Additional citizen-driven successes in addressing BWCs are possible if key constraints are overcome, including funding limitations and challenges of proactively engaging stakeholders who can reduce BWCs at scale. Addressing this global conservation issue will also require building upon the recent increase in attention to BWCs by government agencies, nongovernmental organizations, commercial entities, and professional scientists.

Machtans, C.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, C.S. and W.E. Thogmartin. 2014. Understanding the value of imperfect science from national estimates of bird mortality from window collisions. Condor 116:3-7. https://doi.org/10.1650/CONDOR-13-134.1

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, G, M.K. Hinders and J.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. https://doi.org/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.

Marler, S.C. 2024. Bird-Window Strike Trends and Mitigation. Master's thesis, University of Saint Joseph, West Hartford, Connecticut.
https://www.proquest.com/openview/fa60c6585c7108eb6068f3148c0d9d82/1?pq-origsite=gscholar&cbl=18750&diss=y

Abstract Collisions with windows pose a significant threat to birds, as they often fail to perceive clear or reflective glass as a barrier. This is due to the combination of reflection and transparency, which creates the illusion of open airspace, despite the presence of a deadly obstacle. A study conducted between May 2022 and August 2023 in Connecticut tracked bird-window collisions and evaluated various products designed to reduce the risk. A total of 571 collisions were recorded, with the highest frequency occurring in September and October. The majority of collisions were fatal, and most victims were adult birds, particularly New World Warblers and New World Sparrows. The study found that exterior window screens were the most effective treatment to reduce both transparency and reflectance, making them the best option for mitigating bird strikes.

Martin, G.R. 2011. Understanding bird collisions with man-made objects: A sensory ecology approach. Ibis 153:239-54. https://doi.org/10.1111/j.1474-919X.2011.01117.x

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 153(Suppl. 1):23-48. https://doi.org/10.1007/s10336-011-0771-5

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., and de Wit, B. 2013.Bird- Friendly Light Sources: Adapting the Spectral Composition of Artificial Lighting. Industry Applications Magazine 19(2):56-62. https://ieeexplore.ieee.org/document/6401220

Abstract Over 60 million birds, of many species, cross the North Sea twice each year. Light has a significant impact on migratory birds at sea as it can attract and trap birds at large illuminated structures such as offshore platforms. In this article, we study the behavior of birds around offshore platforms and test the effect of the presence of lighting, the intensity and type of lights, and the light color on bird behavior. We developed a bird-friendly light spectrum that can be applied offshore to provide safe lighting for both humans and birds. We present the results of a field demonstration test involving the exchange of lights to the new color on a gas production platform. We also demonstrate our systems compliance with explosion safety requirements. It is expected that the bird-friendly lighting will become the new standard for any installation situated in areas 56 with bird migration.

Matt CL, Di Girolamo N, Hallman RM, Bailey KL, O'Connell TJ, Brandão J. 2022. Diagnostic accuracy of seven radiographic views, alone and in combination, for diagnosis of pectoral girdle fractures in wild passerines after window collisions. Journal of the American Veterinary Medical Association 260(6):628-33. https://doi.org/10.2460/javma.20.11.0642

Objective To determine the prevalence of pectoral girdle fractures in wild passerines found dead following presumed window collision and evaluate the diagnostic accuracy of various radiographic views for diagnosis of pectoral girdle fractures. Sample Cadavers of 103 wild passerines that presumptively died as a result of window collisions. Procedures Seven radiographic projections (ventrodorsal, dorsoventral, lateral, and 4 oblique views) were obtained for each cadaver. A necropsy was then performed, and each bone of the pectoral girdle (coracoid, clavicle, and scapula) was evaluated for fractures. Radiographs were evaluated in a randomized order by a blinded observer, and results were compared with results of necropsy. Results Fifty-six of the 103 (54%) cadavers had ≥ 1 pectoral girdle fracture. Overall accuracy of using individual radiographic projections to diagnose pectoral girdle fractures ranged from 63.1% to 72.8%, sensitivity ranged from 21.3% to 51.1%, and specificity ranged from 85.7% to 100.0%. The sensitivity of using various combinations of radiographic projections to diagnose pectoral girdle fractures ranged from 51.1% to 66.0%; specificity ranged from 76.8% to 96.4%. Clinical Relevance Radiography alone appeared to have limited accuracy for diagnosing fractures of the bones of the pectoral girdle in wild passerines after collision with a window. Both individual radiographic projections and combinations of projections resulted in numerous false negative but few false positive results.

May, R., Åström, J., Hamre, Ø., & Dahl, E. L. 2017. Do birds in flight respond to (ultra)violet lighting? Avian Research 8(1):1-10. https://doi.org/10.1186/s40657-017-0092-3

Abstract Concerns for bird collisions with wind turbines affect the deployment of onshore and offshore wind power 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 behaviorally 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. 21(3):356-364. 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.

McRae, C. 2022. Window Collisions in Contemporary American Poetry. Pages 181-195 in Danette DiMarco and Timothy Ruppert (*Eds.*) Avian Aesthetics in Literature and Culture: Birds and Humans in the Popular Imagination. Lexington Books, Lanham, Maryland, USA.

Menacho-Odio, R.M. 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 of specimens 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 melanops 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 are preliminary, 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.M. 2018a. Local perceptions, attitudes, beliefs, and practices toward bird-window collisions in Monteverde, Costa Rica. Cuadernos de Investigación UNED 10 (1): 33-40. https://revistas.uned.ac.cr/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, R.M. 2018b. Colisión de aves con ventanas: problema, prevención, mitigación y tendencias de investigación [Bird-window collisions: problem, prevention, mitigation and research directions]. Zeledonia 22:1.
https://www.zeledonia.com/uploads/7/0/1/0/70104897/zel22-1-june-2018-complete.pdf#page=61

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., M. Garro-Cruz, and J.E. Arévalo. 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.

Mitrus, C., and A. Zbyryt. 2017. Reducing avian mortality from noise barrier collisions along an urban roadway. Urban Ecosystems 21(2):351-6. https://doi.org/10.1007/s11252-017-0717-7

Abstract 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, J. and Z.B. 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.

Mora, J.M, and R. Vargas. 2022. Migratory raptor's (*Buteo platypterus*) opportunistic capture of birds injured in window collisions. Spizaetus 33:13-17. https://assets.peregrinefund.org/docs/newsletters/spizaetus-33-english-2022-06-16_113857.pdf#page=13

Observations of a Broad-winged Hawk taking several species of bird after they collided with windows, including Summer Tanager (*Piranga rubra*), Silver-throated Tanager (*Tangara icterocephala*), Wood Thrush (*Hylocichla mustelina*), White-eyed Vireo (*Vireo griseus*), White-ruffed Manakin (*Corapipo altera*), Chestnut-sided Warbler (*Setophaga pensylvanica*), White-tipped Sicklebill (*Eutoxeres aquila*), and White-tipped Dove (*Leptotila verreauxi*) at Soltis Center, located in San Isidro de Peñas Blancas, San Ramón, Costa Rica.

Mouchet, S.R., Wauters, R., Haye, E., Lucas, S. and Deparis, O., 2023. Bioinspired coating for bird-safe glazing optimised for avian and human vision. In 13th International Conference on Metamaterials, Photonic Crystals and Plasmonics, META 2023 (p. 1118).

Abstract Bird-window collisions often lead to the death of the bird and damage to the window. However, many animals, including birds, can perceive UV light. Many species have hence developed visual communication in this wavelength range, for instance, thanks to photonic structures. Such structures allowed us to design a new UV-reflecting multilayered coating for bird-safe glazing, through a bioinspiration approach. This coating was optimised for bird and human visual perception.

Mouton JA. 2022. Collisions on Campus: Species-specific susceptibility of resident and migrant birds to window strikes at Louisiana State University. Undergraduate Honors Thesis. https://repository.lsu.edu/cgi/viewcontent.cgi?article=2052&context=honors_etd

Abstract Collisions with windows are the second leading cause of bird mortality worldwide. Since its identification as a major threat to avian biodiversity, bird-window collisions (BWCs) have been the focus of numerous studies attempting to determine what factors contribute to the susceptibility of birds to collisions. Migratory status, ecological niche, and local abundance have all emerged as possible contributors to species-specific collision risk. Our study models the relationship between species-specific local abundance and collision vulnerability from standardized collision surveys and eBird records. Collision surveys were conducted over approximately 3 years (30 Sept. 2018 - 23 Dec. 2021), covering 21 target buildings on the Louisiana State University main campus. A total of 3,118 surveys yielded 363 collisions, with the 5 most represented target buildings having a collision rate per survey of at least 10%. The collision dataset included 76 total species from 28 families, with passerines representing 80.17% of all collisions and Common Yellowthroats (Geothlypis trichas) being the top collider overall. We generated a hierarchical generalized additive model (HGAM) relating collision probability to local abundance for 21 species based on the fall 2020 and spring 2021 collision data and local eBird records. Our eBird dataset was particularly thorough, and included 34,484 unique observations from 1,358 checklists, accounting for 301 total species. Results of the modelling reveal four broad categories of species based on how their collision susceptibility relates to their local abundance, including species whose collisions appear dependent on their local abundance (e.g. Yellow-rumped Warbler, Setophaga coronata), those whose risk is independent of abundance (Common Yellowthroat and Ruby-throated Hummingbird, Archilochus colubris), those that are secretive yet highly vulnerable (e.g. Ovenbird, Seiurus aurocapilla), and those that are collision-avoidant (most residents). Our results also indicate that local abundance is overall a poor predictor of collision vulnerability and confirm previous studies' conclusions identifying migrant species as more susceptible than residents, as well as the importance of localized assessments of collision vulnerability for determining collision risk factors and effective mitigation strategies on a local scale.

Nemes C, Cabrera-Cruz SA, Anderson M, DeGroote LW, DeSimone JG, Massa M, Cohen EB. 2023. More than mortality: Consequences of human activity on migrating birds extend beyond direct mortality. Ornithological Applications 125:duad021. https://doi.org/10.1093/ornithapp/duad020

Abstract Birds must contend with an array of anthropogenic threats during their migratory journeys. Many migrants are killed due to encounters with artificial light, introduced species, pollutants, and other anthropogenic hazards, while survivors of these encounters can suffer longer-lasting negative effects. The nonlethal effects of anthropogenic threats on migrating birds are less well understood than direct mortality, yet both potentially contribute to population declines. For example, building collisions frequently kill migrating birds, but the numbers of migrants that survive with an impaired ability to fly, refuel, or navigate to their destination on time

is not well understood. Though not immediately fatal, such injuries can lead to delayed mortality and, ultimately, reduced lifetime reproductive success. Furthermore, migrants are likely to encounter multiple threats on their journeys, which can interact synergistically to further reduce fitness. For instance, light pollution attracts and disorients migrants, increasing the likelihood of window strikes, and surviving birds may be more vulnerable to predation from introduced predators. While considerable attention has focused on the lethal effects of anthropogenic threats, here, we review nonlethal effects of 8 types of threats during migration, their interactions, and the pathways through which they can exert fitness costs. In doing so, we identify knowledge gaps and suggest areas for future research. In the absence of more information, we propose that the greatest reduction in the cumulative lethal and nonlethal impacts of anthropogenic hazards will be achieved by addressing threat types, like artificial light at night, that interact with and compound the impact of additional threats. Direct mortality from anthropogenic sources is recognized as a key driver of population declines, but a full understanding of the impacts of human activity on migrating birds must include the cumulative and interacting effects that extend beyond immediate mortality en route to influence overall migration success and lifetime fitness.

Nichols KS, Homayoun T, Eckles J, and 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

Abstract Bird collisions with buildings are the second largest anthropogenic source of direct mortality for birds (365–988 million birds killed annually in the United States). Recent research suggests that this mortality occurs disproportionately across species. However, previous work had relied on regional and annual measures of relative species abundance. Our research identifies which species experience higher or lower collision rates than expected from local abundances using two sets of citizen science data: Minnesota Project BirdSafe and the Mississippi River Twin Cities Important Bird Area Landbird Monitoring Program. Our analysis used a measure of relative species abundance that spatially overlaps the area monitored for building collisions and was measured weekly, allowing for a temporally and spatially more specific analysis than most previous analyses. Abundance and collision data were used to model phylogenetic and behavioral traits associated with increased collision risk. Behavioral traits included diurnal/nocturnal migration timing, length of migration, and foraging strategies. Our analysis shows that birds that predominately migrate during the day have a decreased risk of building collisions despite peak collision numbers occurring during early morning; this result suggests that more nuanced behavioral or physiological differences between diurnal and nocturnal migrants could contribute to bird-building collision risk. Additionally, for many species, local abundance is the predominant determining factor for collision risk. However, for ~20% of species studied, the family, genus, and/or species of a bird may affect the collision risk.

Netzley, R., H.C. Partridge, and S.A. Gagné. 2024. Shadow-boxing: Major gaps to knock out in bird–window interaction research. Ornithological Applications p.duae054.
https://doi.org/10.1093/ornithapp/duae054

Abstract Bird–window collisions are a leading source of bird mortality worldwide, estimated to kill as many as 1 billion birds annually in the U.S. alone. Though researchers have examined the factors contributing to general bird–window collisions, shadow-boxing, a nonfatal but potentially ecologically significant bird–window interaction, has primarily been excluded from the conversation. Shadow-boxing occurs when birds attack their reflection in human-made surfaces believing the reflection to be another individual intruding on their territory. Current bird–window interaction research often does not consider the unique drivers, impacts, and mitigation strategies associated with shadow-boxing. In this paper, we identify 5 major knowledge gaps: (1) building

and environmental characteristics that lead to shadow-boxing; (2) the impacts on individual birds, (3) populations, and (4) people; and (5) the effectiveness of existing mitigation strategies for shadow-boxing. For each knowledge gap, we list research questions that will further our understanding of the scale and significance of shadow-boxing.

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. https://doi.org/10.1111/j.1469-7998.1999.tb01190.x

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.

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."

Ocampo-Peñuela N, Winton RS, Wu CJ, Zambello E, Wittig TW, and 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. https://www.researchgate.net/publication/258870238_Avian_window_strike_mortality_at_a_suburban_office_park

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 13(36):1-10. https://doi.org/10.1186/1471-2148-13-36

Background Color 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 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 acids residues UV sensitivity are foung 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 were 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 the 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 share that avian color vision shifted between VS and UVS at least 14 times. Single Nucelotide substitutions can explain all these shifts. The common ancestor of birds most likely had a VS phenotype. However, the ancestral state of the avian SWS1 opsin's spectral tuning sites cannot be resolved, since the Paleognathae are F86, C90 while the Neoghnathae are ancestrally S86, S90. The phylogenetic distribution of UVS and VS color vision in birds is so complex that inferences of spectral sensitivities from closely related taxa should be used with caution.

Oglęcki, P., & Żabicka, J.M. 2023. Mortality of birds as a result of collisions with glazing on the example of building structures in Warsaw. Scientific Papers of the Main School of Fire Service 85:43-58. https://bibliotekanauki.pl/articles/24202695.pdf

Abstract Collisions between birds and buildings are a common phenomenon given the increasing anthropogenisation of the environment and the emergence of human settlements along traveling routes of species' migration. Glass surfaces, which are increasingly frequently used in modern construction engineering, appear to be particularly dangerous in this aspect, as birds may not recognise them as obstacles even during the day. In this paper, the results of a study of collisions between birds and different types of buildings in the urban zones with low, medium and high proportions of green areas in buildings were analysed. The highest number of collisions was observed for buildings located near enclaves of vegetation, characterised by high biological diversity. The presence of distractors on the glazing had a significant impact on reducing the number of collisions.

Oh, J. The Kestrel Drone: Reimagining Bird's Eye View with Biomimetic AI-drone for Bird Strike Prevention. 2023. Proceedings of the ACM on Computer Graphics and Interactive Techniques. 6(2):1-0. https://doi.org/10.1145/359762

Abstract Artificial intelligence (AI) is redefining roads and skyways with advanced mobility technologies such as autonomous driving and Urban Air Mobility (UAM), suggesting a new paradigm for human mobility. This project sheds new light on drone mobility technology in terms of environmental aesthetics, focusing on global ecological issues. The Kestrel Drone is proposed based on a speculative scenario where "birds" become front-line users of drone technology and share their air routes with drones. At the exhibition hall, five Kestrel Drones were equipped with bird-mimicking wings and an AI tracker. The drones simulated a guiding bird for resident birds in a city. This project aims to evolve AI into a technology that has various parallel values that can coexist with non-human values, thus expanding the possibilities of technology.

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 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.

Pilla, L., and J. G. Nagidi. 2021. Save Birdlife: A Novel Deep Learning method for Detecting and Automatically Diversifying Birds from the Window Glass. Pages 339-342 In 2021 International Conference on Advance Computing and Innovative Technologies in Engineering (ICACITE). doi: 10.1109/ICACITE51222.2021.9404610

Abstract According to a BBC news report: Window strikes are among the top three human-related causes of bird deaths, along with cats and habitat destruction. Nearly one billion birds die each year in the United States due to collisions with windows, and research reports on this case show

that 54-76 percent of window collisions are mortal. Because Sometimes, birds do not perceive windows as a barrier. Instead, reflections in glass look to them as open areas, so they fly directly into the glass-window. The absence of depth perception may contribute to birds" false belief that the reflection they have seen is a bird belonging to their habitat. So, it is our responsibility to save birds. We came up with a creative project by which we can reduce the death rate of birds. We are proposing a deep learning method by using an object detection technique. We came up with a new solution using which we can divert the birds through wooden curtains(blind). They operate according to the instructions that are passed from the Arduino. When the model detects the bird that is coming close towards the window glass, the window blind will automatically shut down and even if the bird hits, it won't collide instantly as the momentum will decrease gradually. The window blind will automatically open when there is no bird. It is a useful technique by which we can divert the birds. This technique has multiple credits like we are saving birds with a practical and cost-efficient approach.

Powell, J.K., and D.S. Powell. 2024. Construction, confusion, and collision: Avian interactions with the built environment. Florida Bar Journal 98(5). Available at https://www.floridabar.org/

Abstract The article delves into the confusion with the interpretations and enforcement of the Migratory Bird Treaty Act (MBTA) regarding avian interactions with the built environment, particularly the intentional taking or killing of protected bird species. Topics discussed include sustainable development and voluntary initiatives for the protection of plants and animal species, provisions of the Lacey Act and MBTA on wildlife protection, and building modifications to prevent bird collisions.

Powers KE, LA Burroughs, NI Harris III, and RC Harris. 2021. Biases in bird-window collisions: A focus on scavengers and detection rates by observers. Southeastern Naturalist 20(2):293-307. https://doi.org/10.1656/058.020.0207

Abstract Bird–window collisions (BWCs) represent a source of mortality for both resident and migratory birds that researchers aim to quantify. Factors that limit carcass detection, including removal of carcasses by scavengers and inherent error in observer detection, can complicate these efforts. We combined 2 studies to examine what proportion of carcasses were scavenged and removed and how successful observers were at detecting bird decoys of multiple types. In fall 2019 and spring 2020, we deployed 40 bird carcasses at Radford University campus buildings and monitored visitation events with game cameras for up to 4 nights/5 days. Scavengers visited 31 of the carcasses and scavenged (disturbed but not removed) 14/31. Scavengers included Felis catus (Domestic Cat, n = 6 events), Mephitis mephitis (Striped Skunk, n = 3), and Procyon lotor (Raccoon, n = 3). All mammalian scavenging events were nocturnal. Cats visited carcasses without disturbing them (n = 22 events), whereas Raccoons (3/3 events) and Striped Skunks (3/4) scavenged carcasses on discovery. Mammals scavenged or removed 3 carcasses in the first night after deployment (e.g., in the first 14 h), suggesting that scavenging can cause daily surveyors to miss ~7.5% of carcasses. Across spring and fall 2020, we deployed 60 decoys of 4 unique types (varying in color or shape), partially obscuring them under shrubs and along landscaped herbaceous vegetation. We found that observers detected 48% of the decoys on their first attempts (min–max: 8.7–100%). Decoy type did not affect observer detection. By our estimates, 2 observers per day could have collectively missed 27% of carcasses. Although BWC projects typically complete surveys once or twice daily, we suggest twice-daily surveys when monitoring BWC during migratory seasons and once-daily surveys at other times to minimize carcass loss due to scavenging.

Powers, KE, DM Clore, GM Davidson, and RC Harris. Bird's-eye view: Novel use of drone images to quantify differences in altitudinal reflections in bird-window collision studies. American Midland Naturalist 187:51–61. https://doi.org/10.1674/0003-0031-187.1.51

Abstract Bird-window collisions (BWCs) constitute a significant source of mortality for both resident and migratory birds. Because windows reflect surrounding landscape components, such as vegetation or sky, birds do not always perceive glass as a barrier. Here we demonstrate a novel technique to classify and quantify reflections in windows on the Radford University campus in southwest Virginia, U.S.A. We deployed a consumer-grade Unmanned Aerial Vehicle, i.e., drone, to photograph 14 contiguous or near-contiguous window columns across five campus buildings in August 2020. For each study aspect, the drone (equipped with an RGB camera) captured images at ca. 5 m altitudinal increments from the ground floor to the roof of each building (three to six images/vertical column). We then manually classified each image in ImageJ to calculate approximate proportions of reflected: (1) vegetation, (2) sky, (3) and artificial structures or impervious surfaces, plus (4) nonreflective glass. We used a generalized linear model to determine how proportional reflections of vegetation, sky, buildings, and nonreflective glass varied across vertical increments. We found the proportion of sky significantly decreased with increasing photo heights, whereas proportion of nonreflective glass significantly increased with increasing heights. This supports previous findings that because birds are drawn to sky reflections, they may collide at relatively lower positions on buildings. Inconsistency in landscape design and building positioning on the campus precluded trends in vegetative or building reflections by height. Our pilot study demonstrates the applicability of a consumer-grade drone for investigating visual characteristics of reflections that influence BWCs from variable observation angles. We suggest the expanded use of drone images as a straightforward technique to measure changes in reflection characteristics from varying degrees of observation. They are a novel method in developing a BWC risk assessment as well as potential mitigation strategies in a suburban or campus environment with buildings of intermediate heights.

Rawlings, Cynthia M. and David Joseph Horn. 2010. Scavenging rates highest at windowed compared to windowless sites at Millikin University in Decatur, Illinois. Illinois State Academy of Science 103(3-4):153-8. https://ilacadofsci.com/wp-content/uploads/2013/03/103-19MS2908-print.pdf

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. ISBN: 9781559631297

Book Description While certain ecological problems associated with artificial night lighting are widely known-for instance, the disorientation of sea turtle hatchlings by beachfront lighting-the vast range of influences on all types of animals and plants is only beginning to be recognized. From nest choice and breeding success of birds to behavioral and physiological changes in salamanders, many organisms are seriously affected by human alterations in natural patterns of light and dark. *Ecological Consequences of Artificial Night Lighting* is the first book to consider the environmental effects of the intentional illumination of the night. It brings together leading scientists from around the world to review the state of knowledge on the subject and to describe specific effects that have been observed across a full range of taxonomic groups, including mammals, birds, reptiles and amphibians, fishes, invertebrates, and plants. *Ecological*

Consequences of Artificial Night Lighting provides a scientific basis to begin addressing the challenge of conserving the nighttime environment. It cogently demonstrates the vital importance of this until-now neglected topic and is an essential new work for conservation planners, researchers, and anyone concerned with human impacts on the natural world.

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 233:220–227. https://doi.org/10.1016/j.biocon.2019.02.029

Abstract 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 color (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.

Rebolo-Ifrán, Natalia, Agustina di Virgilio & Sergio A. Lambertucci. 2019. Drivers of bird-window collisions in southern South America: an assessment applying citizen science. Scientific Reports 9:18148. https://doi.org/10.1038/s41598-019-54351-3

Abstract Bird-window collisions are one of the main causes of avian mortality worldwide, with estimations reaching up to almost one billion of dead individuals annually due to this cause in Canada and the USA alone. Although this is a growing conservation problem, most of the studies come from North America, evidencing the lack of knowledge and concern in countries with high biodiversity and growing population development. Our objectives were: (1) to estimate the current situation of bird-window collisions in Argentina, a country with around 10% of the world's avian biodiversity, and, (2) to identify drivers of bird-window collisions at a national and local scale, focusing on a city surrounded by a protected area. We used a citizen science project called "Bird-Window Collisions in Argentina" that consisted of an online survey that collected data on collision metrics and risk factors. We found that more than half of participants reported at least one collision during the last year, suggesting this issue is common and widespread. In addition, our data show that the number of windows and the presence of vegetation reflected in windows are factors that strongly influence the risk of collision at national scale. On the other hand, the environment surrounding buildings affects the rate of bird-window collisions at local scale, being greater in buildings surrounded by tall vegetation than in buildings surrounded by a greater proportion of urbanization (human-made structures). We call for attention on a topic that has been poorly evaluated in South America. We also encourage future scientific studies to evaluate additional risk factors and mitigation strategies accordingly, to provide a better understanding of collisions, particularly in a highly biodiverse region as South America.

Rebolo-Ifrán, Natalia, Lucía Zamora-Nasca, and Sergio A. Lambertucci. 2021. Cat and dog predation on birds: The importance of indirect predation after bird-window collisions. Perspectives in Ecology and Conservation 19(3):293-299. https://doi.org/10.1016/j.pecon.2021.05.003

Abstract Predation of free-living birds by cats (Felis silvestris catus) and dogs (Canis lupus familiaris) is one of the main urbanization impacts on avifauna worldwide. In addition to direct predation, these pets capture birds after window collisions, an unexplored human cause of avian mortality. In this study we (1) estimated the number of cats and dogs in Argentina, (2) calculated the metrics of direct bird predation by cats and dogs, (3) analyzed factors that influence the probability of pets capturing birds, and (4) estimated annual bird mortality due to pet predation following bird-window collision events. To this end, we conducted an online survey to collect information on bird predation by cats and dogs in Argentina, both direct and indirect after bird-window collisions. We found that more than 68% of participants had at least one dog or cat, and of these, 45.3% reported having observed at least one case of bird predation by cats or dogs in their household. We estimated that the rough annual bird mortality rate due to predation following bird-window collisions could reach approximately 6 million birds in Argentina (range = 1–11 million birds). Our results show that direct bird predation by pets but also indirect predation after bird-window collisions represents a considerable source of avian mortality, which requires further attention in pursuit of solutions.

Rhodes EM, Borden JA, McCreadie J. 2022. Quantification of physiological aging criteria utilizing window strike data. Journal of Field Ornithology 93(4):12. https://doi.org/10.5751/JFO-00220-930412

Abstract Recent studies have been interested in the effects of age on window strike vulnerability in avian species. To accurately assess age-dependent patterns in avian populations, proper aging criteria should be used to allow for comparisons across studies. Recent window strike studies rely heavily on skull ossification, and we were interested in the accuracy of this method compared to other physiological-based age determinations in passerines and non-passerine landbirds. In this study, we quantitatively analyzed three potential aging criteria that can be used for aging specimens: presence/absence of the bursa of Fabricius, skull ossification, and gonadal maturity. To our knowledge, this is the first quantitative comparison of these criteria. While one study did qualitatively compare the number of agreements versus disagreements between these methods, our study expands on this research by implementing a statistical approach. Skull, bursa, and gonad measurements all were significantly and positively correlated with each other. Nevertheless, we did find disagreement between the methods when further exploring their relationships using Generalized Linear Models. For example, when we compared the number of adult females with immature females to test for window strike vulnerability using a Chi-square test, all three aging criteria produced similar results. Adult females showed a statistically higher rate of window strikes than immature females. However, we still suggest caution using only one criterion to age specimens. In summary, while we did find these three aging characters to be highly correlated, disagreement does exist between these characters.

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

Abstract 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.

Riding Corey S., O'Connell Timothy J., Loss Scott R. 2020. Building façade-level correlates of bird–window collisions in a small urban area. The Condor 122(1):duz065.
https://doi.org/10.1093/condor/duz065

Abstract Urbanization increasingly exposes birds to multiple sources of direct anthropogenic mortality. Collisions with buildings, and windows in particular, are a top bird mortality source, annually causing 365–988 million fatalities in the United States. Correlates of window collision rates have been studied at the scale of entire buildings and in relation to the surrounding landscape, and most studies have only assessed correlates for all birds combined without considering season- and species-specific risk factors. In Stillwater, Oklahoma, USA, we conducted bird collision surveys at 16 buildings to assess building structural-, vegetation-, and land cover-related collision correlates. Unlike past studies, we focused at the scale of individual building façades, and in addition to considering correlates for total collisions, we assessed correlates for different seasons and separately for 8 collision-prone species. Several façade-related features, including proportional glass coverage, façade length, and façade height, were positively associated with total collisions and collisions for most separate seasons and species. Total collisions were also greater at alcove-shaped façades than flat, curved, and portico-shaped façades. We found that collision correlates varied among seasons (e.g., surrounding lawn cover important in summer and fall, but not spring) and among species (e.g., surrounding impervious cover positively and negatively related to collisions of Painted Bunting [*Passerina ciris]* and American Robin [*Turdus migratorius*], respectively). Given the importance of glass proportion, collision reduction efforts should continue to focus on minimizing and/or treating glass surfaces on new and existing buildings. Our species- and season-specific assessments indicate that management of some collision risk factors may not be equally effective for all seasons and species. Future research, policy, and management that integrates information about collision risk for all bird species and seasons, and at multiple scales from building façades to the surrounding landscape, will be most effective at reducing total mortality from bird–window collisions.

Riding, C.S., O'Connell, T.J. & Loss, S.R., 2021. Multi-scale temporal variation in bird-window collisions in the central United States. Scientific Reports 11(1):1-12.
https://doi.org/10.1038/s41598-021-89875-0

Abstract Expansion of urbanization and infrastructure associated with human activities has numerous impacts on wildlife including causing wildlife-structure collisions. Collisions with building windows represent a top bird mortality source, but a lack of research into timing of these

collisions hampers efforts to predict them and mitigate effects on avian populations. In Stillwater, Oklahoma, USA, we investigated patterns of bird-window collisions at multiple temporal scales, from within-day to monthly and seasonal variation. We found that collisions peaked during overnight and early morning hours, a pattern that was consistent across seasons. Further, temporal variation in fatal collisions was explained by an interaction between season and avian residency status. This interaction illustrated the expected pattern that more migrant individuals than residents collided in fall, but we also documented unexpected patterns. For example, the highest monthly total of collisions occurred in spring migration during May. We also found similarly high numbers of resident and migrant collisions in spring, and a roughly similar amount of migrant mortality in spring and fall migration. These findings, which provide unprecedented quantitative information regarding temporal variation in bird-window collisions, have important implications for understanding mechanisms by which birds collide and improving timing of measures to reduce this major bird mortality source.

Riggs GJ, Joshi O, and Loss SR. 2022. Stakeholder perceptions of bird-window collisions. PLoS ONE 17(2): e0263447. https://doi.org/10.1371/journal.pone.0263447

Bird-window collisions are a major source of human-caused avian mortality for which many mitigation and prevention options are available. However, because very little research has characterized human perspectives related to this issue, there is limited understanding about the most effective ways to engage the public in collision reduction efforts. To address this research need, we: (1) evaluated how two stakeholder groups, homeowners and conservation practitioners, prioritize potential benefits and obstacles related to bird-window collision management, (2) compared priorities between these groups, and (3) evaluated potential conflicts and collective strength of opinions within groups. We addressed these objectives by merging the strengths, weaknesses, opportunities, and threats (SWOT) and analytic hierarchy process (AHP) survey approaches. Specifically, survey respondents made pairwise comparisons between strengths and weaknesses (respectively, direct outcomes and barriers related to management, such as fewer collisions and increased costs) and opportunities and threats (indirect outcomes and barriers, such as increased bird populations and fewer resources for other building-related expenses). Both homeowners and conservation practitioners ranked strengths and opportunities higher than weaknesses and threats, indicating they have an overall positive perception toward reducing bird-window collisions. However, key obstacles that were identified included costs of management and a lack of policy and guidelines to require or guide management. These results suggest that substantial advances can be made to reduce bird-window collisions because both homeowners and conservation practitioners had positive views, suggesting their receptivity toward collision management measures. However, because of more neutral views and conflicting responses within the homeowner group, results also highlight the importance of targeting homeowners with education materials that provide information about bird-window collisions and solutions that reduce them. Because bird-window collisions are a human-caused phenomenon, such information about human perspectives and priorities will be crucial to addressing this threat and thus benefitting bird populations.

Riggs, G.J., Barton, C.M., Riding, C.S., O'Connell, T.J. & Loss, S.R. 2022. Field-testing effectiveness of window markers in reducing bird-window collisions. Urban Ecosystems 1-11. https://doi.org/10.1007/s11252-022-01304-w

Abstract Bird-window collisions are a major source of human-caused mortality for which there are multiple mitigation and prevention options available. Despite growing availability of products designed to reduce collisions (e.g., glass with etched patterns or markers and films adhered over existing glass), few replicated field tests have been conducted to assess their effectiveness after installation on glass. We conducted a field study to evaluate the effectiveness of a commercially

marketed product (Feather Friendly® markers) in reducing bird-window collisions at glass-walled bus shelters in Stillwater, Oklahoma, USA. This study included a before-after control-impact (BACI) analysis comparing numbers of collisions at 18 bus shelters in both pre-treatment (2016) and post-treatment (2020) periods, and an analysis comparing 18 treated and 18 untreated shelters during 2020. For the BACI analysis, collisions were significantly reduced between 2016 and 2020 at shelters treated with the Feather Friendly® markers even though collisions increased at shelters that remained untreated. For the 2020 analysis, there were significantly fewer collisions at treated than untreated shelters. Relative to a baseline study in 2016, we estimated that treating half of Stillwater's bus shelters resulted in a 64% reduction in total annual bird collisions. Together, these analyses provide a rigorous field test of the effectiveness of this treatment option in reducing bird-window collisions. Our research provides a model for similar studies at both bus shelters and buildings to evaluate and compare products designed to reduce bird-window collisions, and therefore, contribute to reducing this major mortality source affecting bird populations.

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 39:68–72. https://doi.org/10.1016/j.jnc.2017.07.001

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.

Ronconi, R.A., Allard, K.A. and Taylor, P.D. 2015. Bird interactions with offshore oil and gas platforms: Review of impacts and monitoring techniques. Journal of Environmental Management 147:34-45. https://doi.org/10.1016/j.jenvman.2014.07.031

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 land birds, is attraction and sometimes collisions associated with lights and flares; episodic events have caused the deaths of hundred or 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, rain conditions, fog, occurrence of birds in the vicinity).

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.

Abstract Flying animals must successfully contend with obstacles in their natural environments. Inspired by the robust maneuvering 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 favors vertical maneuvering, pigeons are able to navigate HOs using simple rules, with remarkable success.

Ros IG and Biewener AA. 2017. Pigeons (C. livia) follow their head during turning flight: Head stabilization underlies the visual control of flight. Frontiers in Neuroscience 11:655. doi: 10.3389/fnins.2017.00655

Abstract Similar flight control principles operate across insect and vertebrate fliers. These principles indicate that robust solutions have evolved to meet complex behavioral challenges. Following from studies of visual and cervical feedback control of flight in insects, we investigate the role of head stabilization in providing feedback cues for controlling turning flight in pigeons. Based on previous observations that the eyes of pigeons remain at relatively fixed orientations within the head during flight, we test potential sensory control inputs derived from head and body movements during 90◦ aerial turns. We observe that periods of angular head stabilization alternate with rapid head repositioning movements (head saccades), and confirm that control of head motion is decoupled from aerodynamic and inertial forces acting on the bird's continuously rotating body during turning flapping flight. Visual cues inferred from head saccades correlate with changes in flight trajectory; whereas the magnitude of neck bending predicts angular changes in body position. The control of head motion to stabilize a pigeon's gaze may therefore facilitate extraction of important motion cues, in addition to offering mechanisms for controlling body and wing movements. Strong similarities between the sensory flight control of birds and insects may also inspire novel designs of robust controllers for human-engineered autonomous aerial vehicles.

Rosenberg, Kenneth V., Adriaan M. Dokter, Peter J. Blancher, John R. Sauer, Adam C. Smith, Paul A. Smith, Jessica C. Stanton, Arvind Panjabi, Laura Helft, Michael Parr and Peter P. Marra. 2019. Decline of the North American Avifauna. Science 04: 120-124. https://science.org/doi/10.1126/science.aaw1313

Abstract Species extinctions have defined the global biodiversity crisis, but extinction begins with loss in abundance of individuals that can result in compositional and functional changes of ecosystems. Using multiple and independent monitoring networks, we report population losses across much of the North American avifauna over 48 years, including once-common species and from most biomes. Integration of range-wide population trajectories and size estimates indicates a net loss approaching 3 billion birds, or 29% of 1970 abundance. A continent-wide weather radar network also reveals a similarly steep decline in biomass passage of migrating birds over a recent 10-year period. This loss of bird abundance signals an urgent need to address threats to avert future avifaunal collapse and associated loss of ecosystem integrity, function, and services.

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. In German (1.2-MB-PDF)

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).

Note: All glass testing tunnel reports by Martin Rössler are available for download at https://wua-wien.at/publikationen under the heading "Studien zur Verhinderung von Vogelanprall an Glasflächen." Direct links provided where possible.

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. In German (466-KB-PDF)

Rössler, M. 2005. Avoiding bird collisions with glass surfaces. Test of 9 markings in the unlit flight tunnel. Hohenau- Ringelsdorf Biological Station, unpublished report. In English (400-KB-PDF)

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 Glasflächen. Experimentelle Untersuchungen zur Wirksamkeit von lasmarkierungen unter natürlichen Lichtbedingungen im Flugtunnel II. Bilogische Station Hohenau-Ringelsdorf. In German (1.3-MB-PDF)

Rössler, M., W. Laube, and P. Weihs. 2007. Avoiding bird collisions with glass surfaces Experimental investigations of the efficacy of markings on glass panes under natural light conditions in Flight Tunnel II. Hohenau-Ringelsdorf Biological Station. (In English 2.7-MB-PDF)

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 give 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. In German (250-KB-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. In English (400-KB-PDF)

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 found to 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 (1.1-MB-PDF)

Rössler, Martin. 2012. Bird collisions with glass surfaces – test report Ornilux Mikado Test in the flight tunnel II at the Biological Station Hohenau-Ringelsdorf (Austria). In English (850-KB-PDF)

Zusammenfassung Ornilux Mikado, vom Hersteller als „Vogelschutzglas“ bezeichnet, wurde in drei standardisierten Versuchsreihen untersucht. Es sollte die Frage geklärt werden, ob Vögel in der Lage sind, die laut Hersteller mit UV-wirksamen Beschichtungen versehene Scheibe in ausreichendem Ausmaß als Hindernis zu erkennen und ob das Spezialglas in der Lage ist, Vogelanprall wirksam zu reduzieren. Die Scheibe wurde auf drei Arten geprüft: Zusätzlich zu dem in Österreich durch die Technische Regel ONR 191040 geregelten Prüfverfahren wurde in zwei weiteren experimentellen Schritten untersucht, welchen Einfluss Spiegelungen auf den Scheiben haben können. Begleitend zur Ornilux-Untersuchung wurden Referenzuntersuchungen mit einer gut untersuchten und als hoch wirksam eingestuften sichtbaren Markierung durchgeführt. Auf Basis der vorliegenden Untersuchungen kann nicht nachvollzogen werden, wodurch das Prädikat „Vogelschutzglas“ zu rechtfertigen ist. Ornilux Mikado ist nach den vorliegenden Ergebnissen unter Ausschaltung von Spiegelungen vor natürlichem Hintergrund schwach wirksam, allerdings reicht das Ergebnis nicht entfernt an jenes hoch wirksamer Markierungen heran. Werden Spiegelungen von Himmel und Vegetation in den Versuch integriert, kann keine Wirksamkeit mehr erkannt werden: Vögel unterscheiden die Ornilux-Scheibe nicht von unmarkiertem Fensterglas.

English summary courtesy of City of Vienna, Office of Environmental Protection

Summary Ornilux Mikado, referred to by the manufacturer as "bird protection glass", was examined in three standardized test series. The question was to be clarified as to whether birds are able to recognize the pane, which according to the manufacturer has UV-effective coatings, as an obstacle to a sufficient extent and whether the special glass is able to effectively reduce bird collisions. The pane was tested in three ways: In addition to the test procedure regulated in Austria by Technical Rule ONR 191040, two further experimental steps were carried out to investigate the influence reflections on the panes can have. Accompanying the Ornilux study, reference studies were carried out with a well-studied visible marking classified as highly effective. On the basis of the available investigations, it cannot be understood how the title "bird protection glass" can be justified. According to the available results, Ornilux Mikado is weakly effective with the elimination of reflections against a natural background, but the result does not come close to that of highly effective markings. If reflections from the sky and vegetation are integrated into the test, the effectiveness can no longer be recognized: birds cannot distinguish the Ornilux pane from unmarked window glass.

Rössler, Martin. 2013. Verminderung von Vogelanprall an Glasflächen - ABC Bird Tape Tesa® 4593", Prüfung im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf nach ONR 191040 und unter Einbeziehung von Spiegelungen bei dunklem Hintergrun (WIN-Versuch). In German (475-KB-PDF)

Rössler, Martin. 2013. Test report ABC Bird Tape and Tesa® 4593. Test in the flight tunnel II at the Biological Station Hohenau-Ringelsdorf (Austria) according to ONR 191040 and in a test setup for checking the effect of reflections (WIN-test). English Abstract (300-KB-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 Glasflächen - Prüfbericht Birdpen®", Prüfung nach ONR 191040 und WIN-Versuch im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, In German (934-KB-PDF)

Rössler, Martin. 2015. Bird collisions with glass surfaces – Test report birdpen®. Test according to ONR 191040 and WIN-Test in the flight tunnel II of the Biological Station Hohenau-Ringelsdorf. In English (670-KB-PDF)

English **Abstract**, provided by Ombuds Office for Environmental Protection of the City of Vienna, Austria

Abstract 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 and 400nm. 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 and Alexander Bruckner. 2015. Glass pane markings to prevent bird-window collisions: Less can be more. Biologia 70(4):535—541.
https://doi.org/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.

Rössler, Martin, Dl. 2018. "Vogelanprall an Glasflächen - Prüfbericht Dr. Kolbe Birdsticker®", Prüfung unter Einbezug von Spiegelungen im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, im Auftrag der Schweizerischen Vogelwarte Sempach, February 2018. In German (400-KB-PDF)

Rössler, Martin, Dl. 2018. "Bird collisions on glass surfaces - Dr. Kolbe Birdsticker® test report", test including reflections in Flight Tunnel II of the Hohenau-Ringelsdorf Biological Station, on behalf of the Swiss Ornithological Institute in Sempach, February 2018.

Zusammenfassung Im Auftrag der Schweizerischen Vogelwarte Sempach hat die Biologische Station Hohenau-Ringelsdorf, Österreich, durchsichtige und laut Hersteller UV-wirksame Aufkleber auf ihre Wirkung zur Vermeidung von Vogelanprall an Glasscheiben geprüft. Es wurden sowohl die im Handel erhältlichen Greifvogel- silhouetten-förmigen Dr. Kolbe birdsticker® geprüft als auch vom Hersteller zur Verfügung gestellte identische Folie, die in vertikalen Streifen aufgebracht wurde. Die Untersuchung fand im Flugtunnel der Biologischen Station Hohenau bei natürlichem Licht und unter Einbezug von Spiegelungen statt (WIN-Test). Weder bei den birdstickers® noch bei der Folie in Streifenform konnten positive Effekte festgestellt werden. Die Wirkungslosigkeit des Produktes reiht sich in die ebenfalls unbefriedigenden Ergebnisse vorangehender Untersuchungen mit UV-wirksamen ("unsichtbaren") Glas-Markierungenein.

Summary On behalf of the Swiss Ornithological Institute in Sempach, the Biological Station Hohenau-Ringelsdorf, Austria, tested transparent and, according to the manufacturer, [https://www.drkolbe.de/birdsticker.html?L=en] UV-effective stickers for their effectiveness in preventing birds from colliding with glass panes. Both the commercially available raptor silhouette-

shaped Dr. Kolbe birdsticker® was tested as well as the same material provided by the manufacturer, applied in vertical stripes. The investigation took place in the flight tunnel of the Hohenau Biological Station in natural light and including reflections (WIN test). No positive effects could be determined either with the birdstickers® or with the film in strip form. The product's ineffectiveness is in line with the equally unsatisfactory results of previous tests with UV-effective (“invisible”) glass markings.

Rössler, Martin, DI. 2019. "Vogelanprall an Glasflächen - Prüfbericht Punktraster Anthrazit 3 mm, Prüfung unter Einbezug von Spiegelungen im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, DI Martin Rössler im Auftrag Wiener Umweltanwaltschaft, März 2019. (97-KB-PDF)

Rössler, Martin DI. 2019. Bird collisions on glass surfaces - test report point grid anthracite 3 mm, test including reflections in flight tunnel II of the biological station Hohenau-Ringelsdorf, DI Martin Rössler on behalf of the Vienna Environmental Ombudsman's Office, March 2019.

Zusammenfassung Im Rahmen einer Versuchsserie zur Wirksamkeit von Punktrastern als Vogelanprall verhindernde Glas- scheibenmarkierungen wurde im Auftrag der Wiener Umweltanwaltschaft (WUA) ein Punktraster im Flugtunnel der Biologischen Station Hohenau-Ringelsdorf (collabs) bei natürlichem Licht und unter Einbezug von Spiegelungen (WIN-Versuch) geprüft. Die Prüfmarkierung setzte sich aus anthrazitfarbenen Punkten mit einem Durchmesser von 3 mm in Mittelpunktabständen von 14 mm (Deckungsgrad 3,6 %) zusam- men. Das geprüfte Punktraster hat sich als wirkungslos erwiesen.

Summary As part of a series of tests on the effectiveness of dot grids on glass on deterring bird collisions, the Vienna Environmental Ombudsman's Office (WUA) commissioned a test by the flight tunnel at the Biological Station Hohenau-Ringelsdorf. The test with natural light and with inclusion checked by reflections (WIN attempt). The test marking consisted of dark-colored dots with a diameter of 3 mm at a center distance of 14 mm (degree of coverage 3.6 %). The tested point grid proved to be ineffective.

Rössler, Martin, DI. 2020. "Test Report "Reduction of Bird - Window Strikes SEEN glass elements, Reflective and semi-reflective 9 mm dots", Tests im Flight Tunnel II at Biologische Station Hohenau-Ringelsdorf, Austria, DI Martin Rössler im Auftrag von SEEN GmbH, Februar 2020. (250-KB-PDF)

Task And Test Method In commission of SEEN GmbH, Waldstatt, Switzerland, two prototypes of glass applied with a novel marking technique of aluminum coated elements were examined to assess their efficacy in reducing bird-window collisions. To this end, dichotomous choice experiments were conducted using wild birds in a flight tunnel. Both prototypes consisted of a double-glazed unit of 2 x 4mm low iron glass laminated with a PVB interlayer where the bird deterring elements were situated. The reference pane was an unmarked 4mm thick float glass. The test panes were exposed to natural sunlight.

Rössler, Martin, DI. 2020. "Vogelanprall an Glasflächen - Prüfbericht Punktraster Anthrazit 9 mm, Quadrate Raster Anthrazit 12 mm", Prüfung unter Einbezug von Spiegelungen, Tests im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, im Auftrag von SEDAK GmbH, März 2020 (300-KB-PDF)

Rössler, Martin, DI, 2020. "Bird impact on glass surfaces - test report point grid anthracite 9 mm, square grid anthracite 12 mm", test including reflections, tests in flight tunnel II of the biological station Hohenau-Ringelsdorf, DI Martin Rössler on behalf of SEDAK GmbH, March 2020.

Zusammenfassung In den Jahren 2018 und 2019 wurden im Auftrag der Sedak GesmbH zwei Siebdruckmuster der Farbe Anthrazit, aufgebracht auf Position 1 auf VSG, im Flugtunnel der Biologischen Station Hohenau-Ringelsdorf auf ihre Eignung zur wirksamen Vermeidung von Vogelanprall geprüft. Die Prüfung erfolgte nach der Methode „WIN-Test“ unter Einbezug von Spiegelungen. Referenzscheibe war jeweils 4mm starkes unmarkiertes Floatglas. Beide Kandidaten können wegen ihrer hohen geprüften Wirksamkeit zur Anwendung empfohlen werden. Die aus regelmäßig im Mittelpunktabstand von 90mm (Kantenabstand 78mm) angeordneten schwarzen Quadrate mit einer Seitenlänge von 12mm bestehende Markierung „Quadrate 12 mm“ wurde im Wahlversuch von zehn Prozent der Testvögel angeflogen. Die aus regelmäßig im Mittelpunktabstand von 90mm angeordneten schwarzen Punkte (Kreise) mit einem Durchmesser von 9mm bestehende Markierung„P unkte 9 mm“ wurde im Wahlversuch von 14 Prozent der Testvögel angeflogen.

Summary In 2018 and 2019, on behalf of Sedak GesmbH, two screen print samples in anthracite, applied to position 1 on laminated safety glass, were tested in the flight tunnel of the Hohenau-Ringelsdorf biological station for their suitability for effectively preventing bird collisions. The test was carried out using the "WIN-Test" method, including reflections. The reference pane was 4mm thick unmarked float glass. Both candidates can be recommended for use because of their high proven effectiveness. Ten percent of the test birds flew to the “squares 12 mm” marking, which consists of black squares with a side length of 12 mm arranged regularly at a center distance of 90 mm (edge distance 78 mm). The “Points 9 mm” marking, which consists of black dots (circles) with a diameter of 9 mm, arranged regularly at a center distance of 90 mm, was flown to by 14 percent of the test birds in the selection test.

Rössler, Martin, DI, 2021. "Vogelanprall an Glasflächen - Zoolex Astmuster", Prüfung nach ONR 191040 (Durchsicht) und WIN-Versuch (Einbezug von Spiegelungen), Tests im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, im Auftrag der Wiener Umweltanwaltschaft und Glas Gasperlmeier GesmbH, Februar 2021. (360-KB-PDF)

Rössler, Martin, DI, 2021. "Bird impact on glass surfaces - Zoolex branch pattern", test according to ONR 191040 (view) and WIN test (inclusion of reflections), tests in flight tunnel II of the Biological Station Hohenau-Ringelsdorf, on behalf of the Vienna Environmental Ombudsman and Glas Gasperlmeier GesmbH, February 2021.

Zusammenfassung Im Auftrag der Wiener Umweltanwaltschaft (WUA) und der Glas Gasperlmeier Ges.m.b.H. wurde ein von M. Fiby (ZooLex Zoo Design, Vienna) entworfenes und auf Glas appliziertes Astmuster nach zwei Methoden untersucht, um die Eignung dieser Applikation als Markierung zur Verhinderung von Vogelanprall zu prüfen: 1) ONR-Test - Durchsicht bei hellem Hintergrund; Anwendungsfall zB Lärmschutzwand, 2) WIN-Versuch- Einbezug von Spiegelungen bei lichtschwachem Hintergrund; Anwendungsfall zB Fenster und Fassaden. Bei der Markierung handelt es sich um eine leicht transluzente Folie (ONR-Versuch, 2019) bzw. um opaken Digitaldruck auf Position 1 (WIN Test, 2020) in gelboliv (RAL 6014). Bei beiden Prüfmethoden handelt es sich um standardisierte Wahlversuche unter natürlichen Lichtverhältnissen mit tageslichtadaptierten Wildvögeln im Flugtunnel der Biologischen Station Hohenau – Ringelsdorf, Österreich. Die Prüfung basiert auf 94 bzw. 101 gültigen Testflügen im Zeitraum 19.07. bis 12.08.2019 (ONR-) und 11.07. bis 07.08.2020 (WIN Test). Sowohl im ONR-Durchsichtversuch als auch im WIN-Versuch mit Lichtverhältnissen im Hintergrund, die Innenräumen entsprechen, war das Ergebnis ausgezeichnet. Im ONR Versuch flogen 2% der Versuchsvögel zur Prüfscheibe und 98 % zur Referenzscheibe, im WIN-Versuch 4 % zur

Summary Transparency with a light background; Use case eg noise protection wall, 2) WIN test - inclusion of reflections with a low-light background; Application eg windows and facades. The marking is a slightly translucent foil (ONR test, 2019) or an opaque digital print on position 1 (WIN test, 2020) in olive yellow (RAL 6014). Both test methods are standardized selection tests under

natural lighting conditions with daylight-adapted wild birds in the flight tunnel of the Biological Station Hohenau - Ringelsdorf, Austria. The test is based on 94 or 101 valid test flights in the period 07/19. to 12.08.2019 (ONR-) and 11.07. until 07.08.2020 (WIN test). The result was excellent both in the ONR see-through test and in the WIN test with background lighting conditions corresponding to indoor rooms. In the ONR test 2% of the test birds flew to the test target and 98% to the reference target, in the WIN test 4% to the test target and 96% to the reference target. The examined marking is highly effective in terms of the Hohenauer evaluation scheme both with a bright and with a weak background. In the ranking of the tested markings, the marking is in first place in both test arrangements.

Rössler Martin, DI. 2021. Vogelanprall an Glasflächen - Prüfbericht Liniendesign vertikal 5/95 - Decochrome und Punktraster "Dart" 9/90 - Decochrome" WIN-Versuch (Anwendungsfall Fenster, Fassaden), Tests im Flugtunnel II der Biologischen Station Hohenau-Ringelsdorf, im Auftrag von Arnold Glas Kirchberg, Deutschland, Februar 2021 (400-KB-PDF)

Rössler Martin, DI, 2021. "Bird impact on glass surfaces - test report for Arnold Glas (Kirchberg, Germany) of vertical Decochrome line design 5/95 - and Decochrome point grid "Dart" 9/90 - WIN test (application case windows, facades), tests in flight tunnel II of the biological station Hohenau-Ringelsdorf. Germany, February 2021

Zusammenfassung Im Auftrag von Arnold Glas, Kirchberg, Deutschland, wurden zwei als Vogelschutzmarkierungen konzipierte chrom-metallische Beschichtungen (Decochrome) auf ihre Vogelanprall vermeidende Wirkung hin untersucht. Es handelte sich um ein vertikales Streifenmuster („Liniendesign vertikal 5/95“) bzw. um in einem Raster angeordnete kokardenartig unterbrochene Punkte („Punktraster Dart 9/90“) auf Position 1 von VSG 66.2. Die Markierungen wurden nach der WIN-Methode geprüft, welche bei lichtschwachem Hintergrund den Einbezug von Spiegelungen auf den Scheiben ermöglicht und daher für den Anwendungsfall Fenster und Fassade gilt. Die Ergebnisse gelten nicht für Anwendungen bei hellem Hintergrund wie Lärmschutzwände und Glasbrüstungen. Beim Prüfverfahren handelt es sich um standardisierte Wahlversuche. Die Untersuchungsmethode zielt auf einen Vergleich unterschiedlicher Kandidaten ab. Es können keine quantitativen Vorhersagen über Zahl oder einen Prozentwert im Anwendungsfall geretteter Vögel gemacht werden. Die Wahlversuche finden unter natürlichen Lichtverhältnissen mit tageslichtadaptierten Wildvögeln im Flugtunnel von collabs//Biologische Station Hohenau– Ringelsdorf, Österreich, statt. Die vorliegende Prüfung basiert auf 101 bzw. 102 gültigen Testflügen im Zeitraum 07.08. bis 13.09. 2020. Die Markierung „Liniendesign vertikal 5/95“ – Decochrome mit vertikalen chrom-metallischen Streifen von 5mm Breite im Kantenabstand von 9,5cm ergab im Wahlversuch 8% Anflüge zur Prüfscheibe und 92% zur Referenzscheibe und wird als hoch wirksame Markierung empfohlen (Kategorie A, hoch wirksam). Der Punktraster durchbrochener, konkardenartiger Punkte (Punktraster „Dart“ 9/90 – Decochrome) mit Durchmessern von 9mm und Mittelpunktabständen von 9cm ergab im Wahlversuch 16% Anflüge zur Prüfscheibe und 84% zur Referenzscheibe. Diese Markierung ist wirksam, unterscheidet sich aber signifikant von hoch wirksamen Markierungen (Kategorie B, bedingt geeignet).

Summary On behalf of Arnold Glas, Kirchberg, Germany, two chrome-metallic coatings (Decochrome) designed as bird protection markings were examined for their bird-preventing effect. Tested were a vertical stripe pattern (“Line design vertical 5/95” [5mm wide vertical lines spaced 95 mm apart]) or points arranged in a grid like a cockade (“point grid Dart 9/90”) on position 1 of VSG 66.2 [laminated safety glass]. The markings were tested using the WIN method, which allows reflections on the panes to be included in the case of a low-light background and therefore applies to windows and facades. Results do not apply to light background applications such as noise barriers and glass balustrades. The test procedure involves standardized selection tests. The research method aims to compare different candidates. No quantitative predictions can be made as to the number or percentage in use of rescued birds. The selection experiments take place under natural lighting conditions with daylight-adapted wild birds in the flight tunnel of

collabs//Biologische Station Hohenau- Ringelsdorf, Austria. This test is based on 101 or 102 valid test flights in the period 07.08. until 13.09. 2020. The marking "Line design vertical 5/95" - Decochrome with vertical chrome-metallic stripes of 5mm A width of 9.5 cm at the edge distance resulted in 8% approaches to the test pane and 92% to the reference pane and is recommended as a highly effective marking (category A, highly effective). The dot grid of broken, concard-like dots (dot grid "Dart" 9/90 - Decochrome) with a diameter of 9mm and center distances of 9cm resulted in 16% approaches to the test disc and 84% to the reference disc in the selection test. This marker is effective, but differs significantly from highly effective markers (category B, conditionally suitable).

Rössler, Martin, Dl. 2024. Vogelanprall an Glasflächen - Prüfbericht Birdshades ®, Win Versuch, in der Prüfanlage der Biologischen Station Hohenau-Ringelsdorf, Martin Rössler, Theresa Böckle collabs//Biologische Station Hohenau-Ringelsdorf im Auftrag der Wiener Umweltanwaltschaft und der Schweizerischen Vogelwarte Sempach. März 2024 (500-KB-PDF)

Bird impact on glass surfaces - Test report Birdshades ®, Win experiment, in the testing facility of the Biological Station Hohenau-Ringelsdorf, Martin Rössler, Theresa Böckle collabs//Biological Station Hohenau-Ringelsdorf on behalf of the Vienna Environmental Advocate and the Swiss Bird Observatory Sempach. March 2024.

Zusammenfassung Im Auftrag der Wiener Umweltanwaltschaft und der Schweizerischen Vogelwarte Sempach wurde aktuell verfügbare BirdShades®-Fensterfolie auf ihre Eignung zur Reduktion von Vogelanprallrisiken an Glasflächen untersucht. Im Zeitraum zwischen 13. August und 15. September 2023 wurde eine Prüfscheibe in einem WIN-Wahlversuch (2-fach-Isolierglasscheibe mit BirdShades®-Folienapplikation vs. unmarkierte Floatglasscheibe) unter Einbeziehung von Spiegelungen (entsprechend Fenstern und Fassaden) mit Tageslicht-adaptierten Wildvögeln getestet. Die Prüfscheibe wurde von BirdShades GmbH zur Verfügung gestellt. Sie wurde mit einer Stichprobe von n=81, (17 Tests bei diffusem Licht, 64 Tests bei direkter Sonnenstrahlung) geprüft. 36% der Anflüge waren zur Prüfscheibe gerichtet, 64% zur Referenzscheibe. Nach Hohenauer Bewertungsschema fällt die Markierung in Kategorie C (wenig wirksam). Unter mit identischem Versuchsaufbau geprüften Markierungen nimmt BirdShades® Rang 43 von 57 ein. Das Resultat liegt im Bereich anderer in Hohenau geprüfter UV-Markierungen.

Summary On behalf of the Vienna Environmental Protection Agency and the Swiss Bird Observatory in Sempach, the currently available BirdShades® window film was examined for its suitability for reducing the risk of birds striking glass surfaces. In the period between August 13th and September 15th, 2023, a test pane was tested in a WIN choice test (double insulating glass pane with BirdShades® film application vs. unmarked float glass pane) including reflections (corresponding to windows and facades) with daylight-adapted wild birds tested. The test disk was provided by BirdShades GmbH. It was tested with a sample of n=81 (17 tests in diffuse light, 64 tests in direct sunlight). 36% of the approaches were directed towards the test target, 64% towards the reference target. According to Hohenauer's evaluation scheme, the marking falls into category C (not very effective). Among markings tested with an identical test setup, BirdShades® ranks 43rd out of 57. The result is in the range of other UV markings tested in Hohenau.

Roth, T. C. II, S. L. Lima, and W. E. Vetter. 2005. Survival and causes of mortality in wintering Sharp-shinned Hawks and Cooper's Hawks. Wilson Bulletin 117(3):237-244. https://doi.org/10.1676/04-103.1

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.

Russ GM, Zink RM. 2020. Biases obscure whether sexes and ages of window-killed fall migrants die in proportion to their frequency in the migrating population. The Wilson Journal of Ornithology 132(2):421-8. https://doi.org/10.1676/1559-4491-132.2.421

Abstract The timing of migratory passage for sexes and ages of birds is difficult to document because migration is spread out over time and space. We compared sex and age ratios from 10 species of birds that were banded in Wisconsin during fall migration to a sample of autumn window-killed birds from Chicago, Illinois. We assumed that these specimens were a random sample of the migrating population because dates of passage in Wisconsin either predate or were coincident with specimens recovered in Chicago. More juveniles than adults collided with windows, which is expected because of the higher number of juveniles in the fall migratory population. For Connecticut Warbler (*Oporornis agilis*), Dark-eyed Junco (*Junco hyemalis*), Ovenbird (*Seiurus aurocapilla*), and White-throated Sparrow (*Zonotrichia albicollis),* statistically fewer adults collided with windows than expected. It is possible that adults of these species, who have made at least 2 prior successful migratory journeys, might have experienced some degree of learning to avoid windows. For specimen data, ratios of males to females were approximately equal, except for Swamp Sparrow (*Melospiza georgiana*; 1:0.82). However, banders were unable to determine sex for a high percentage of each species, ranging from 98.5% undetermined sex for Hermit Thrush (*Catharus guttatus*) to 48% for Common Yellowthroat (*Geothlypis trichas*). Taken at face value, banding records for Common Yellowthroat, Dark-eyed Junco, and White-throated Sparrow indicated a much higher percentage of males, whereas for Song Sparrow (*Melospiza melodia*), females were much more common; 6 species showed no apparent difference in sex ratio between the banding and window samples. In species for which banders declined to identify an individual's sex for a high percentage of birds, we questioned whether the identification of sex in the remaining small percentage

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, R., B. Harward, L. Keller H. Schmid, and K. Sullivan. 2018. Patterns of bird window strikes on USU campus and physical features that increase risk for collision. Poster, Utah State University, Department of Biology. Available at https://digitalcommons.usu.edu/researchweek/ResearchWeek2018/All2018/242/

Conclusions 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).

Samuels B, Fenton B, Fernández-Juricic E, & MacDougall-Shackleton SA. 2022. Opening the black box of bird-window collisions: passive video recordings in a residential backyard. PeerJ 10:e14604 https://doi.org/10.7717/peerj.14604

Abstract Collisions with windows on buildings are a major source of bird mortality. The current understanding of daytime collisions is limited by a lack of empirical data on how collisions occur in the real world because most data are collected by recording evidence of mortality rather than pre-collision behaviour. Based on published literature suggesting a causal relationship between bird collision risk and the appearance of reflections on glass, the fact that reflections vary in appearance depending on viewing angle, and general principles of object collision kinematics, we hypothesized that the risk and lethality of window collisions may be related to the angle and velocity of birds' flight. We deployed a home security camera system to passively record interactions between common North American bird species and residential windows in a backyard setting over spring, summer and fall seasons over 2 years. We captured 38 events including 29 collisions and nine near-misses in which birds approached the glass but avoided impact. Only two of the collisions resulted in immediate fatality, while 23 birds flew away immediately following impact. Birds approached the glass at variable flight speeds and from a wide range of angles, suggesting that the dynamic appearance of reflections on glass at different times of day may play a causal role in collision risk. Birds that approached the window at higher velocity were more likely to be immediately killed or stunned. Most collisions were not detected by the building occupants and, given that most birds flew away immediately, carcass surveys would only document a small fraction of window collisions. We discuss the implications of characterizing pre-collision behaviour for designing effective collision prevention methods.

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'. https://journals.plos.org/plosone/article/comment?id=info:doi/10.1371/annotation/68b2f3ba-a22b-499c-ae55-4aaf7013e6b1

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: In-flight body awareness in birds. Frontiers in Zoology 11:64. https://doi.org/10.1186/s12983-014-0064-y

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 maneuvers 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 Scientific Reports 5: 10992. https://doi.org/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. https://doi.org/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.

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.456220

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.

Schramm, l., J. Fiala, T. Noe, P. Sweet, A. Prince and C. Gordon. 2007. Calls, captures and collisions: Triangulating three census methods 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.

Scott KM, Danko A, Plant P, Dakin R. 2023. What causes bird-building collision risk? Seasonal dynamics and weather drivers. Ecology and Evolution 13(4):e9974.

Abstract Bird-building collisions are a major source of wild bird mortality, with hundreds of millions of fatalities each year in the United States and Canada alone. Here, we use two decades of daily citizen science monitoring to characterize day-to-day variation in building collisions and determine the factors that predict the highest risk times in two North American cities. We use these analyses to evaluate three potential causes of increased collision risk: heightened migration traffic during benign weather, increased navigational and flight errors during inclement weather, and increased errors in response to highly directional sunlight that enhances reflected images. The seasonal phenology of collisions was consistent across sites and years, with daily collision rates approximately twofold higher in autumn as compared to spring. During both migration seasons, collision risk was best predicted by the weather conditions at dawn. In spring, peak collision risk occurs on days with warm temperatures, south winds, and a lack of precipitation at dawn. In autumn, peak collision occurs on days with cool temperatures, north winds, high atmospheric pressure, a lack of precipitation, and clear conditions with high visibility. Based on these results, we hypothesize that collisions are influenced by two main weather-driven mechanisms. First, benign weather at dawn and winds that are favorable for migration cause an increase in migration traffic in both spring and autumn, creating greater opportunity for collisions to occur. Second, for autumnal migrants, cold clear conditions may cause an additional increase in collision risk. We propose that these conditions may be particularly hazardous in autumn because of the high abundance of naïve and diurnal migrants at that time of year. Our analysis also establishes that a relatively small proportion of days (15%) are responsible for 50% of the total collision mortality within a season, highlighting the importance of targeting mitigation strategies to the most hazardous times.

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. Available for download on ABC website

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 real world conditions, free vs forced flights and migrant vs resident subjects. Available from American Bird Conservancy.

Sheng, G.Q., S.N. Ingabo, and Y.C. Chan. 2024. Evaluating the impact of bird collision prevention glazing patterns on window views. Building and Environment 259:111657. https://doi.org/10.1016/j.buildenv.2019.111657

Abstract Optimal design of bird collisions prevention glazing patterns is pivotal in the protection of avian ecology and provision of quality window views for building occupants. However, a research gap currently exists regarding the impact of different pattern designs on the quality of window views. Therefore, this study evaluates the influence of various bird collision prevention pattern designs on window view clarity. A total of 18 patterns, including dot matrix, vertical stripes, and horizontal stripes, were designed and evaluated. The patterns had varying combinations of coverage rates and spacing ratios. Sixty participants were recruited to participate in an experimental survey using virtual reality (VR) technology. They were asked to rate the level of clarity of window views observed through different glazing pattern designs. The results indicated that the bird collision prevention glazing pattern designs significantly influenced occupants' perception of visual clarity. Designs featuring horizontal and vertical stripes attained higher visual clarity ratings compared to the dot matrix pattern. Additionally, visual clarity significantly decreased with increasing coverage rates and designs with larger spacing ratios were associated with higher clarity than smaller spacing ratios. Most participants were willing to sacrifice window view quality in order to minimize bird fatalities. These findings can guide the development of window view evaluation criteria in existing green building standards, by accounting for the trade-off between avian conservation and window view clarity.

Sheppard, Christine. 2011. Bird-friendly Building Design. American Bird Conservancy, The Plains, VA 20198. 60 pages.

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: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: https://abcbirds.org/wp-content/uploads/2020/09/Bird-Friendly-Building-Design.pdf

To purchase hardcopies, contact American Bird Conservancy

Simmons, Danica B. 2021. A Survey of bird-building collisions and building characteristics at the University Of New Mexico. NMOS Bulletin 49(2). Available at nmbirds.org

Abstract Billions of birds in the United States are annually killed by human influence (Loss et al. 2014, 2015), notably from predation by house cats and collisions with buildings, vehicles, or powerlines (Loss et al. 2015). While certain species of birds are more vulnerable to collisions, particularly migratory birds (Loss et al. 2014), the result is declining avian populations. Buildings across the U.S. are unfortunate examples of the lack of building and landscape planning concerning birds, resulting in frequent deaths (Loss et al. 2014, 2015; Hager et al. 2017). To combat this issue, researchers have investigated aspects of buildings that make them at risk for collision. Common features that contribute to bird-window collisions are glass area (Klem 2009, Klem et al. 2009, Nichols et al. 2018), surrounding vegetation (Hager et al. 2013, Klem et al. 2009), and building size (Hager et al. 2017). Research has established that birds are unable to see the clear, reflective glass and plastic common in many windows (Klem 2009). The birds are subsequently killed from rupturing bloodvessels and impact damage in their brains from colliding with windows (Klem 1990). Researchers across the globe have conducted studies to inform future planning and amending buildings to be more bird-friendly by surveying collisions (Klem et al. 2009, Ocampo-Peñuela et al. 2016, Hager et al. 2017, Low et al. 2017, Nichols et al. 2018). The University of New Mexico (UNM) is no stranger to human-caused avian fatalities. While the topic is more commonly studied in other parts of the U.S., there is no similar study in the Southwestern U.S. assessing bird-building collisions. In this study, the UNM central campus was surveyed for bird-building collisions by quantifying the number of bird casualties and identifying building characteristics that are known to be correlated with such collisions: building size and glass area. It was hypothesized that larger buildings, buildings with more glass area, and buildings with higher reflectivity increase collision risks and yield more casualties than those with lower risk characteristics.

史丹阳, 廖书跃, 朱磊, 李彬彬 (2022) 鸟撞建筑现象概述及系统性调查案例分析. 生物多样性30:21321.

Shi DY, Liao SY, Zhu L, and Li BV. 2022. Review on bird-building collisions and the case study of a systematic survey in China. Biodiversity Science, 30, 21321. doi: 10.17520/biods.2021321

Abstract Background: With urbanization, collision with man-made objects, such as buildings and windows, has become a major threat for birds. Because of the transparency and reflection of the glass, birds may not be able to recognize and avoid the glass, which leads them to collide with the buildings or windows. The outcomes of bird-building collisions are often fatal. This phenomenon is relatively well-researched in North America. In the United States alone, bird-building collision is estimated to cause between 300 million to 1 billion birds to die annually, making it one of the most significant direct anthropogenic causes of bird mortality. Despite being recognized as a major bird conservation issue in North America, bird-building collision has received limited attention in China. Progress: In this paper, we reviewed and summarized the factors influencing bird-building collisions, including seasonality, weather, building characteristics, the surrounding environment, and bird ecology. In addition, we introduced the current progress in mitigating bird-building collision and methods of conducting bird-building collision research. Finally, we presented the first systemic bird-building collision study in China. Prospects: Based on the existing studies, we proposed several suggestions for future research. This includes generating an overall assessment of the bird-building collision phenomenon in China, establishing standards for systematic bird collision survey and data collection, studying the mechanism of bird-building collisions, promoting public awareness, and advocating for eco-friendly urban planning and architectural innovation.

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. https://www.biodiversitylibrary.org/itemdetails/203394

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): 261-271. https://doi.org/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 (n¼1,448). Submissions

encompassed 29 species, most commonly the Red-tailed Hawk (Buteo jamaicensis; n¼308) and Great Horned Owl (Bubo virginianus; n¼237). Trauma (n¼716) accounted for the majority of deaths among all species, followed by emaciation (n¼241). 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 (n¼214), 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.

Smith, Reyd A., Maryse Gagne and Kevin C. Fraser. 2021. Pre-migration artificial light at night advances the spring migration timing of a trans-hemispheric migratory songbird. Environmental Pollution 269:116136. https://doi.org/10.1016/j.envpol.2020.116136

Abstract Artificial light at night (ALAN) is increasing at a high rate across the globe and can cause shifts in animal phenology due to the alteration of perceived photoperiod. Birds in particular may be highly impacted due to their use of extra-retinal photoreceptors, as well as the use of photoperiodic cues to time life events such as reproduction, moult, and migration. For the first time, we used light-logging geolocators to determine the amount of ALAN experienced by long-distance migratory songbirds (purple martin; Progne subis) while at their overwintering sites in South America to measure its potential relationship with spring migration timing. Almost a third of birds (48/155; 31%) were subjected to at least one night with ALAN over 30 days prior to spring migration. Birds that experienced the highest number of nights (10þ) with artificial light departed for spring migration on average 8 days earlier and arrived 8 days earlier at their breeding sites compared to those that experienced no artificial light. Early spring migration timing due to pre-migration ALAN experienced at overwintering sites could lead to mistiming with environmental conditions and insect abundance on the migratory route and at breeding sites, potentially impacting survival and/or reproductive success. Such effects would be particularly detrimental to species already exhibiting steep population declines such as purple martins and other migratory aerial insectivores

Snep, R.P., Kooijmans, J.L., Kwak, R.G., Foppen, R.P., Parsons, H., Awasthy, M., Sierdsema, H.L., Marzluff, J.M., Fernandez-Juricic, E., De Laet, J. and van Heezik, Y.M. 2016. Urban bird conservation: presenting stakeholder-specific arguments for the development of bird-friendly cities. Urban Ecosystems 19(4):1535-1550. https://doi.org/10.1007/s11252-015-0442-z

Abstract Following the call from the United Nations Convention on Biological Diversity “Cities & Biodiversity Outlook” project to better preserve urban biodiversity, this paper presents stakeholder-specific statements for bird conservation in city environments. Based upon the current urban bird literature we focus upon habitat fragmentation, 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. https://digitalcommons.usf.edu/cgi/viewcontent.cgi?article=7514&context=condor

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. https://doi.org/10.1016/j.tree.2015.06.009

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.

Swaddle JP, Emerson LC, Thady RG, Boycott TJ. 2020. Ultraviolet-reflective film applied to windows reduces the likelihood of collisions for two species of songbird. PeerJ 8:e9926. https://doi.org/10.7717/peerj.9926

Abstract Perhaps a billion birds die annually from colliding with residential and commercial windows. Therefore, there is a societal need to develop technologies that reduce window collisions by birds. Many current window films that are applied to the external surface of windows have human-visible patterns that are not esthetically preferable. BirdShades have developed a short wavelength (ultraviolet) reflective film that appears as a slight tint to the human eye but should be highly visible to many bird species that see in this spectral range. We performed flight tunnel tests of whether the BirdShades external window film reduced the likelihood that two species of song bird (zebra finch, *Taeniopygia guttata* and brown-headed cowbird, *Molothrus ater*) collide with windows during daylight. We paid particular attention to simulate the lighting conditions that birds will experience while flying during the day. Our results indicate a 75–90% reduction in the likelihood of collision with BirdShades-treated compared with control windows, in

forced choice trials. In more ecologically relevant comparison between trials where all windows were either treated or control windows, the estimated reduction in probability of collision was 30–50%. Further, both bird species slow their flight by approximately 25% when approaching windows treated with the BirdShades film, thereby reducing the force of collisions if they were to happen. Therefore, we conclude that the BirdShades external window film will be effective in reducing the risk of and damage caused to populations and property by birds' collision with windows. As this ultraviolet-reflective film has no human-visible patterning to it, the product might be an esthetically more acceptable low cost solution to reducing bird-window collisions. Further, we call for testing of other mitigation technologies in lighting and ecological conditions that are more similar to what birds experience in real human-built environments and make suggestions for testing standards to assess collision-reducing technologies.

Swaddle JP, Brewster B, Schuyler M, & Su A. 2023. Window films increase avoidance of collisions by birds but only when applied to external compared with internal surfaces of windows. PeerJ 11:e14676. https://doi.org/10.7717/peerj.14676

Abstract Window collisions are one of the largest human-caused causes of avian mortality in built environments and, therefore, cause population declines that can be a significant conservation issue. Applications of visibly noticeable films, patterns, and decals on the external surfaces of windows have been associated with reductions in both window collisions and avian mortality. It is often logistically difficult and economically prohibitive to apply these films and decals to external surfaces, especially if the windows are above the first floor of a building. Therefore, there is interest and incentive to apply the products to internal surfaces that are much easier to reach and maintain. However, there is debate as to whether application to the internal surface of windows renders any collision-reduction benefit, as the patterns on the films and decals may not be sufficiently visible to birds. To address this knowledge gap, we performed the first experimental study to compare the effectiveness of two distinct window films when applied to either the internal or external surface of double-glazed windows. Specifically, we assessed whether Haverkamp and BirdShades window film products were effective in promoting the avoidance of window collisions (and by inference, a reduction of collisions) by zebra finches through controlled aviary flight trials employing a repeated-measures design that allowed us to isolate the effect of the window treatments on avoidance flight behaviors. We chose these two products because they engage with different wavelengths of light (and by inference, colors) visible to many songbirds: the BirdShades film is visible in the ultraviolet (shorter wavelength) range, while the Haverkamp film includes signals in the orange (longer wavelength) range. We found consistent evidence that, when applied to the external surface of windows, the BirdShades product resulted in reduced likelihood of collision and there was marginal evidence of this effect with the Haverkamp film. Specifically, in our collision avoidance trials, BirdShades increased window avoidance by 47% and the Haverkamp increased avoidance by 39%. However, neither product was effective when the films were applied to the internal surface of windows. Hence, it is imperative that installers apply these products to exterior surfaces of windows to render their protective benefits and reduce the risk of daytime window collision.

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.

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.

Tan DJ, Freymueller N, Teo KM, Symes WS, Lum SK, Rheindt FE. 2023. Disentangling the biotic and abiotic drivers of bird-building collisions in a tropical Asian city using ecological niche modelling. bioRxiv. https://doi.org/10.1101/2023.06.27.546782

Bird-building collisions are responsible for a large number of bird deaths in cities around the world, yet they remain poorly studied outside of North America. This study presents one of the first city-wide fine-scale and landscape-scale analyses of bird-building collisions from Asia and represents a novel application of maximum entropy modeling (as commonly applied to species distribution modeling) to assess the drivers of bird-building collisions in the tropical city-state of Singapore. Our results show that the drivers of bird-building collisions often vary among taxa, with several migratory taxa having a higher relative collision risk linked to areas with high building densities and high levels of nocturnal blue light pollution. In contrast, non-migratory taxa had a higher collision risk in areas proximate to woodland cover. Projecting these models onto high-fidelity long-term government land-use plans, we demonstrate that our approach can be applied to predict future changes in bird-building collision risk stemming from future increases in blue light pollution and encroachment of buildings into forested areas. Our results suggest that bird-building collision mitigation measures need to account for the differential drivers of collision across both resident and migratory species, and show that combining community science and ecological modeling can be a powerful approach for analyzing bird-building collision data.

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.

Thady, Robin. Evaluating the use of acoustic warning signals to reduce avian collision risk. 2021. Masters Thesis. https://vsgc.odu.edu/wp-content/uploads/2021/11/Thady.pdf

Abstract Bird populations have declined sharply in recent years. Collisions with humanmade structures are responsible for a significant portion of this avian mortality, threatening potential ecological consequences and financial burdens to a variety of industries. Acoustic warning signals can be used to alert birds to obstacles in their flight paths in order to mitigate collisions, but these signals should be tailored to the sensory ecology of birds in flight. I evaluated the ability of four different sound signals to elicit collision-avoidant flight behavior from birds released into a corridor containing a physical obstacle. I selected these signals to test multiple frequency levels (4-6 kHz and 6-8 kHz) and temporal modulation patterns (broadband and oscillating) to determine which combination of sound attributes is the most detectable to a bird in flight. I found that sound treatments in general cause birds to maintain a greater distance from potential hazards and to adjust their flight trajectories before coming close to obstacles, with statistically non-significant trends in the data suggesting that the 4-6 kHz oscillating signal does this most effectively. These

findings can be used to refine acoustic warning signals and to demonstrate the value in using behavioral data to assess collision risk.

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. Effectiveness 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.

Ushine, Nana, Aki Tanaka, Tatsuo Sato, Masaki Nonagase, Shin-ichi Hayama, 2021. Internal and external features of wild birds after collisions without apparent trauma in Japan. PREPRINT https://doi.org/10.1101/2021.05.25.445584

Abstract Wild birds often require rehabilitation after collisions, even with no apparent injury. Information about aftermath of collisions is still scarce. Here, we investigated external characteristics and clinical features of the internal organs of wild birds that experienced collision and compared them with birds admitted to rehabilitation center for other reasons. Necropsy was performed on 55 bird carcasses from Passeriformes and Coraciiform. Five external characteristics were recorded before necropsy including; cause of admission, keel score, life stage, fat score, and number of days before death. The median survival time was calculated by Kaplan-Meier estimates. Data on external and internal features were compared using univariate and multivariate multinomial regressions. There was no significant difference in the median survival time among the causes of admission: 1 day for collision, 2 days for trauma, and 2 days for malnutrition. Kidney discoloration was more significantly associated with collision than with other trauma ($p = 0.01$). Although no apparent kidney abnormality (including enlargement) was observed, anterior lobe was significantly larger than posterior lobe with collision compared with malnutrition ($p = 0.045$). Birds that experienced collision exhibited a higher fat score than malnourished birds ($p = 0.03$). Our results suggested that wild birds with abundant fat were more likely to be admitted due to collision. The gross characteristics of collision included kidney discoloration and anterior lobe extension, which was possibly due to rupture of renal blood vessels by blunt external force. From these findings, it was considered that collision caused major axis of anterior lobe significantly larger than posterior lobe, even though no abnormal finding in renal size such as hypertrophy was recognized. This was the first study to evaluate the cause of admission, necropsy results, and external characteristics in wild birds admitted to rehabilitation centers. Absolute cage rest should be adhered to restore renal function for those birds admitted due to collision, and handling and treatment should be minimized to avoid excess movement of the birds.

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. https://doi.org/10.1073/pnas.170857411

Abstract 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.

Van Doren, Benjamin M., David E. Willard, Mary Hennen, Kyle G. Horton, Erica F. Stuber, Daniel Sheldon, Ashwin H. Sivakumar, Julia Wang, Andrew Farnsworth, and Benjamin M. Winger, 2021. Drivers of fatal bird collisions in an urban center. PNAS 118(24):e2101666118. https://doi.org/10.1073/pnas.2101666118

Abstract Millions of nocturnally migrating birds die each year from collisions with built structures, especially brightly illuminated buildings and communication towers. Reducing this source of mortality requires knowledge of important behavioral, meteorological, and anthropogenic factors, yet we lack an understanding of the interacting roles of migration, artificial lighting, and weather conditions in causing fatal bird collisions. Using two decades of collision surveys and concurrent weather and migration measures, we model numbers of collisions occurring at a large urban building in Chicago. We find that the magnitude of nocturnal bird migration, building light output, and wind conditions are the most important predictors of fatal collisions. The greatest mortality occurred when the building was brightly lit during large nocturnal migration events and when winds concentrated birds along the Chicago lakeshore. We estimate that halving lighted window area decreases collision counts by 11× in spring and 6× in fall. Bird mortality could be reduced by ~60% at this site by decreasing lighted window area to minimum levels historically recorded. Our study provides strong support for a relationship between nocturnal migration magnitude and urban bird mortality, mediated by light pollution and local atmospheric conditions. Although our research focuses on a single site, our findings have global implications for reducing or eliminating a critically important cause of bird mortality.

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. https://doi.org/10.1648/0273-8570-76.2.127

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.

Villon, E., 2024. How dangerous is glass? Understanding collisions and bird mortality in Finland. Master's Thesis, University of Helsinki, Helsinki, Finland. https://helda.helsinki.fi/server/api/core/bitstreams/71777fff-8cd6-4ff8-8e8c-82084d2ed3e5/content

Abstract Flight collisions with buildings are a significant cause of human-related bird mortality worldwide, yet the global scope of this issue remains understudied, especially concerning

European bird populations' vulnerability to such collisions. This study investigates the impact of bird-window collisions (BWCs) on bird populations in Finland by analyzing long-term bird ringing data and conducting an on-site survey in an urban area. Over the past 50 years, spatiotemporal and ecological patterns of collisions were identified, with a decrease in collision detection over time and seasonal peaks during spring and fall. Urban areas were found to experience the highest collision rates, with densities decreasing as urbanization levels rose. The White-backed Woodpecker, an endangered species in Finland, was notably the most vulnerable to collisions. Additionally, first-year birds were found to be more prone to collisions than adults, and the species' habitat preferences and foraging strata played significant roles in collision risks. Specifically, species preferring open or aquatic habitats had lower collision rates, while those favoring urban or forested areas collided more often. In a Helsinki case study, 42 collisions were recorded in 21 days, with the House Sparrow being the most common victim. The study also found a positive correlation between collision rates and glass area, while vegetation cover did not significantly affect collision occurrences. The research highlights critical species and urban factors influencing BWCs in Finland, proposing a standardized survey method to better assess and mitigate the impact of glass on bird populations.

Vo, Hong D., Ingo Schiffner and Mandyam V. Srinivasan. 2016. Anticipatory manoeuvres in bird flight. Scientific Reports 6:27591 https://doi.org/10.1038/srep27591

Abstract 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 maneuvers 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 analyzed 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.

Weisshaupt, N., Leskinen, M., Moisseev, D.N. and Koistinen, J. 2022. Anthropogenic Illumination as Guiding Light for Nocturnal Bird Migrants Identified by Remote Sensing. Remote Sensing 14(7):1616. https://doi.org/10.3390/rs14071616

Abstract Migrant birds rely on environmental and celestial cues for navigation and orientation during their journeys. Adverse weather, such as heavy rain or fog, but also thick layers of low-level clouds, affect visibility and can challenge birds' ability to orientate. Therefore, birds typically favour certain meteorological conditions for migration. Photopollution from artificial lights outdoors and radiated from buildings is known to negatively affect nocturnal migrants' flight behaviour and trajectories, which may lead to collisions with human infrastructure. Positive effects of artificial light have been identified in some stationary birds, e.g., for extended foraging hours, though not during migration. In the present study, we show the effect of artificial light on the concentration and flight directions of migrating birds during overcast conditions in the peri-urban woodland in Southern Finland. Overcast conditions, by low-level clouds, prompted birds to migrate at low

altitudes. Instead of spatially homogenous large-scale migration patterns, birds were observed to adapt their flight directions, in accordance with the artificial lights of the urbanized area. By using dual- and single-polarisation weather radar data we were able to study small-scale patterns of bird movements under the influence of low-level cloud layers. These cases show the remarkable capability of the existing weather radar networks to study bird migration.

Williams, C. David and Andrew A. Biewener. 2015. Pigeons trade efficiency for stability in response to level of challenge during confined flight. Proceedings of the National Academy of Sciences 112(11):3392–3396. https://doi.org/10.1073/pnas.1407298112

Significance The real world is a cluttered environment and animals traversing it are faced with innumerable obstacles in their normal locomotion. During normal flight, birds have to avoid hitting trees, lampposts, and other members of flocks. To investigate flight strategies used in these circumstances, we presented pigeons with a simplified challenge, a series of vertical gaps with variable spacings. The pigeons used two discrete postures. One posture granted them greater flight efficiency but was more disrupted when they collided with obstacles, and was used for traversing larger gaps. An alternate flight posture was less efficient but more stable when slight collisions occurred, and was used for traversing smaller gaps. To our knowledge, this is the first time we have seen flight strategies tuned during use in cluttered environments.

Abstract Individuals traversing challenging obstacles are faced with a decision: they can adopt traversal strategies that minimally disrupt their normal locomotion patterns or they can adopt strategies that substantially alter their gait, conferring new advantages and disadvantages. We flew pigeons (Columba livia) through an array of vertical obstacles in a flight arena, presenting them with this choice. The pigeons selected either a strategy involving only a slight pause in the normal wing beat cycle, or a wings-folded posture granting reduced efficiency but greater stability should a misjudgment lead to collision. The more stable but less efficient flight strategy was not used to traverse easy obstacles with wide gaps for passage but came to dominate the postures used as obstacle challenge increased with narrower gaps and there was a greater chance of a collision. These results indicate that birds weigh potential obstacle negotiation strategies and estimate task difficulty during locomotor pattern selection.

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. Proceedings of the Royal Society B 286(1900):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 McCormick 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, and 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 https://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.

Witting, 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

Abstract 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.

Yang H, Huang X, Thompson JR, Flower RJ. 2021. Bird-friendly buildings for China's cities. Science. 374(6565). https://doi.org/10.1126/science.abm3221

China's rapid urbanization has resulted in the proliferation of glass buildings, as has been the case elsewhere in the world. Bird collisions with glass buildings are now an important global factor in bird mortality (1). To prevent bird deaths in a country that hosts numerous vulnerable species, China should invest in research on bird-friendly building design and update building codes and regulations accordingly.

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.

Zhu, Xiongbin, Dong Bo and Xiaoqiao Chen. 2022. Preprint: Urban and Rural Environmental Management Strategy Based on the Cause of Bird Death Investigation: The Context of Wumeng Mountainous Area http://dx.doi.org/10.21203/rs.3.rs-1403149/v1

Abstract With the continuous deterioration of the ecological environment in the Wumeng mountain area, the number of birds has gradually decreased in recent years. To find out the cause of bird death, the author teamed up with many bird lovers and zoologists to collect bird corpses in the Wumeng mountain area with large topographic changes and rich geomorphic types from 2018 to 2020 in this area. With anatomical analysis and pathogen detection, the main findings include (1) The number of bird deaths has not increased due to the extreme high temperature in 2020 in Wumeng mountainous area. (2) The main causes of bird deaths are pesticide, rodenticide and birds-building collision. (3) Most birds died in summer and winter, which are mainly poisoned by insecticide in summer and killed by glass impact and rodenticide in winter. (4) The dead birds are mainly local dominant species(sparrows, white babblers, great tits and Northern Redstart).

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.

Żmihorski, Michał, Dorota Kotowska, and Ewa Zyśk-Gorczyńska. 2022. Using citizen science to identify environmental correlates of bird-window collisions in Poland. Science of the Total Environment 811:152358.

Abstract Bird collisions with windows are among the highest sources of human caused mortality to this group of animals. However, environmental correlates of spatial patterns in collision risk are poorly understood, thus making mitigation measures difficult to implement. We took advantage of Covid-19 lockdown in the spring of 2020, when people were obligated to stay mainly at home, and performed a memory-recall questionnaire survey concerning bird-window collisions in Poland. We received information on bird-window collisions with 1800 buildings across the whole country accompanied by characteristics of each building, its vicinity and resident's behavior (time spent home, window cleaning). We supplemented these data with landscape description and performed statistical models to estimate importance of 13 explanatory variables as predictors of number of bird-window collisions. Reported number of collisions increased with the share of forests and arable land within 2 km of the building, and with proximity to rivers. Number of collisions also increased when single trees were close to buildings. More collisions were reported for houses than for flats and for new buildings than for old ones. Reported number of collisions increased with window cleaning which might suggest that cleaning reduces glass visibility for birds. As bird-window collision risk is highly variable among buildings but can be reduced with several measures improving glass visibility for birds, we recommend to use predictive models to identify collision hotspots for applying these measures. New houses located near rivers, in forests or agricultural landscapes have highest collision risk, and trees near buildings, often planted to benefit birds, can additionally elevate collision rate, thus potentially creating ecological traps. In such collision hotspots, reduction of window cleaning frequency can be considered as a mitigation measure unless the visual markers improving glass visibility for birds are installed on the panels.

Zulian, V., A. R. Norris, K. L. Cockle, A. N. Porter, L. G. Do, and K. L. De Groot. 2023. Seasonal variation in drivers of bird-window collisions on the west coast of British Columbia, Canada. Avian Conservation and Ecology 18(2):15. https://doi.org/10.5751/ACE-02482-180215

Abstract We examined the effects of façade-level building and vegetation features on bird-window collision risk, and how these effects varied across seasons at a Pacific coastal campus with mild winters, abundant evergreen vegetation, and seasonally varied bird communities. We searched for bird carcasses at 57 façades of 8 buildings at the University of British Columbia (UBC) over 155 days between January 2015 and March 2017 (total: 8835 façade surveys). Collision monitoring occurred across five equal sampling periods that represented stages of the annual cycle of the bird community, including the fall and spring migratory periods, the breeding season, and the long overwintering period. For each season, we compared logistic regression models predicting the odds of a collision from different sets of façade and vegetation characteristics expected to influence collisions: façade area, area of glass, porous surface cover (ground and shrub vegetation, soil, leaf litter), tree cover, and the number of building stories reflecting vegetation. Consistent with other studies, area of glass had a positive influence on collision probability in all seasons; however, the effect was strongest during the fall migratory period, when daily collision mortality rates peaked at UBC. The number of stories reflecting vegetation also increased collision probability, but only in the fall, indicating that the vertical extent of vegetation and reflective glass may affect collision risk differently as bird communities change across seasons. Façade area increased collision probability only in the winter (a long and lethal period for bird collisions at UBC), reflecting different risk factors associated with the species most vulnerable to collisions during this life cycle stage. Our results highlight the need to measure building and vegetation effects across the longest and most lethal stages of the annual cycle of birds, both to predict the impact of proposed buildings and to prioritize mitigation strategies that will result in the greatest conservation benefits.

Zyśk-Gorczyńska, Ewa, Skórkaa Piotr and Żmihorskic Michał. 2020. Graffiti saves birds: A year-round pattern of bird collisions with glass bus shelters. Landscape and Urban Planning 193:103680. https://doi.org/10.1016/j.landurbplan.2019.103680

Abstract The increase in the human population is bringing with it a concomitant rise in the number of novel man-made structures appearing in different environments, which may affect wildlife. Glass shelters at bus stops create surfaces invisible to many animals like birds and may increase their mortality; evidence for this is rare, however. The main aim of the study was to analyze the temporal variation and frequency of the risk of birds colliding with small, man-made, glass structures. A year-round survey investigating the frequency of bird collisions with 81 glass bus shelters was performed in south-western Poland. A total of 2467 visits to these bus stops yielded evidence of 155 collisions at 40 of them (mean: 1.9 per shelter, range 0–18). The bird carcasses most often found were of passerines, principally blackbirds *Turdus merula*. The traces left on the glass included feather remains (70%) and whole bird contours (30%). The probability of finding, during a single visit to a bus stop, that a bird had collided with the glass shelter tended to be higher in rural than in urban areas. Both dust and graffiti covering the glass panels of a bus shelter reduced the likelihood of collision. The occurrence of collisions was the highest in July-August and the lowest from November to February. Our study is the first in Europe and the first year-round study worldwide to demonstrate that such small man-made objects can cause death and injuries to birds. We suggest covering such shelters with non-transparent objects, e.g. city maps, paintings or other forms of artwork, in order to reduce the negative impact of these structures on local birds.

Zyśk-Gorczyńska E, Sztwiertnia H, Pietkiewicz M, Kolanek A, Bojarska K, Żmihorski M. Local bird densities and habitats are poor predictors of bird collision with glass bus shelters. Landscape and Urban Planning 217:104285. https://doi.org/10.1016/j.landurbplan.2021.104285

Abstract Bird collisions with glass are a major source of avian mortality, killing billions of birds each year worldwide. Likely, the crucial step to prevent bird-glass collisions is understanding spatial and temporal bird-glass collision patterns. As more and more glass-made constructions appear in public spaces, it becomes essential to identify main drivers of bird collisions with these novel objects. In this study, we perform an attempt to identify local characteristics that may influence the risk of bird collisions with glass bus shelters. We monitored 58 bus shelters from March to July 2018 in urban and rural habitats of south-western Poland. We visited the shelters searching for bird carcasses and traces of collisions but also surveyed birds near shelters, considering the two scales (20 and 100 m of the shelter), and bird behavior (flying vs non-flying). We found 52 evidence of bird collisions and number of collisions per bus shelter ranged from 0 to 7 which substantially deviated from random distribution. Bird abundances recorded near bus shelters, recorded at both 20 m and 100 m scales, were poor predictors of bird-glass collisions and did not improve parsimony of models explaining collision risk. This refers to all recorded birds as well as to the subsets of flying individuals and species being collision victims. Similarly, habitat composition near bus shelters hardly predicted variation in bird-glass collision risk. As we did not manage to identify any important drivers explaining collision risk, we conclude that before we learn how to predict areas with high number of bird-glass collisions, we suggest that developers, urban planners and architects should be advised to design all public transportation shelters using nontransparent materials.

Zyśk-Gorczyńska, E., and Żmihorski, M. 2022. Ultraviolet film reduces bird–glass collision risk. Ornis Fennica 99(2-3). https://doi.org/10.51812/of.115995

Abstract It is estimated that millions of birds globally die due to collisions with glass surfaces. In order to reduce this mortality, it is essential to provide an objective assessment of the effectiveness of bird-friendly preventive methods. Several types of opaque films and stickers are

available nowadays and can be highly effective in protecting birds from fatal collisions. However, by being visible to the human eye, they can affect the users’ quality of view from within protected spaces. Products that take advantage of the birds' ability to see ultraviolet light seem to offset these impediments. This study determines if UV-reflective BirdShades film prevents birds from collisions with glass in natural environmental conditions. We monitored eight glass bus stops, where we had previously recorded high numbers of birds collisions. On four of them, we applied UV film, and the other four bus stops were used as control. A generalized additive mixed model showed a significant interaction between time (before vs. after) and film UV treatment (control vs. treated). Before the treatment, the number of collisions tended to be higher at treated bus shelters than control. However, this significantly changed after the treatment, suggesting that UV film reduces bird glass collision rate over 5-fold. Our study is the first worldwide that tested UV film on glass shelters and supports a conclusion that the UV film efficiently reduces the risk of bird collision.

Impact of lighting on bird navigation, orientation and mortality

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- (yellow) filter reduced brightness of lights by 75% (for shearwaters) but still bright enough for human purposes

Chapter 4: Attraction of Hawaiian seabirds to lights: conservation efforts and effects of moon phase

Chapter 5: Extending the Dartnall nomogram to long wavelengths as illustrated by behavioral scotopic sensitivity functions for three tern species

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