BIRD COLLISIONS WITH WINDOWS: AN ANNOTATED BIBLIOGRAPHY

First edition by

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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. 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 occur, and that offer practical solutions.

The bibliography deviates from traditional format in that most 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. Non-English language literature is not comprehensively covered.

ANNOTATIONS

Avery, M.L. 1979. Review of avian mortality due to collisions with man-made structures. U.S. Fish and Wildlife Service, 11 pp. Available for download at http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1001&context=icwdm birdcontrol.

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

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 a 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.

Birds and Buildings Forum, 2007. Chicago Bird Safe Design Guide.

Downloadable: http://www.birdsandbuildings.org/docs/ChicagoBirdSafeDesignGuide.pdf

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).

Brown, H., S. Caputo, 2008. Bird-Safe Building Guidelines, 2nd edition. New York City Audubon, New York, New York. Downloadable at: http://www.nycaudubon.org/home/BSBGuidelines.shtml

An overview of causes of collisions, examples of problem construction and suggested design solutions.

City of Toronto Green Development Standard, .2007. Bird-friendly development guidelines. City Planning, Toronto, Ontario, Canada. Downloadable at:

http://www.toronto.ca/lightsout/pdf/development_guidelines.pdf

Covers Guidelines for reducing risk from glass and lighting in construction, including illustrated examples.

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.

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

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

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

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

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

Dunn analyzed surveys of people across North America who regularly feed wild birds around their homes during the winter and also record incidences of window collisions. 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.

Erickson, W. P., G. D. Johnson, M.D. Strickland, D. P. Young Jr., K.J. Sernka and R.E. Good. 2001. Avian Collisions with Wind Turbines: A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States. A resource document of the National Wind Coordinating Committee, http://www.nationalwind.org/publications/wildlife/avian_collisions.pdf

The goal of this report is to put avian mortality from wind turbines into context with mortality from vehicles: 60-80 million, buildings and windows: 98-980 million, power lines: tens of thousands – 174 million, communication towers: 4-50 million, wind generation: 10,000-40,000. Differences in total mortality correlates directly with the magnitude of the structure ie 4 million miles of road, 15,000 wind turbines (in 2001). Windplant mortality data is expected to be more accurate than for other types of structure, as monitoring generally includes estimates for scavenging and considers observer detection biases.

Erickson, W. P., G. D. Johnson, D. P. Young Jr. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. USDA Forest Service Gen. Tech. Rep. PSW-GTR-191, pp.1029-1041. Downloadable: http://www.fs.fed.us/psw/publications/documents/psw_gtr191/Asilomar/pdfs/1029-1042.pdf

A comprehensive review of multiple forms of human-caused bird mortality, including a section on collisions with buildings and windows. The findings of Klem (1990a) and Dunn (1993) are summarized.

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 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.

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.

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

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

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

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

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

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

Hager, S.B., H. Trudell, K.J. McKay, S.M. Crandall, L. Mayer. 2008. Bird density and mortality at windows. Wilson Journal of Ornithology 120(3):550-564.

This is the first study to test the hypothesis that window collision frequency and species richness of killed birds at a given site are positively correlated with the abundance and richness of birds in the surrounding area. Hager et al. monitored bird collisions year- round at buildings on two college campuses in Illinois and conducted point-counts in nearby wooded areas during the same time period.

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

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

Hager, Stephen B., 2009. Human-Related Threats to Urban Raptors. J. Raptor Res. 43(3):210–226

The author reviews 86 publications for information on raptor mortality in cities. Twenty-eight Falconiformes and 14 Strigiformes species are divided by degree of urban useage and dominant urban activities (feeding, breeding). Road use is treated similarly. To quote the abstract: *Within the Falconiformes (28 urban species), vehicle collisions and electrocutions were reported for most species (73% and 48%, respectively), and vehicular and window strikes were the leading sources of mortality for 39% and 12% of species, respectively. For the Strigiformes (14 urban species), vehicular (63%) and window (47%) collisions affected most species, and the primary sources of mortality were from vehicles (32%) and electrocution (5%). Window-strike mortality was reported for 45% of urban raptors and represented the leading source of mortality for Sharp-shinned Hawks (Accipiter striatus), Cooper's Hawks (A. cooperii), Merlins (Falco columbarius), and Peregrine Falcons (F. peregrinus). Mortality by electrocutions was also observed for 45% of the species.* Vehicle collisions were reported for 60% of species and for half of those was the primary source of mortality. The impact of collisions on population structure has been studied for very few species and more such work is needed. An appendix provides notes for each of the sources used in the review.

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.

Johnson, R. E. and G. E. Hudson. 1976. Bird mortality at a glassed-in walkway in Washington State. Western Birds 7:99-107.

The authors recorded bird collisions with a four story glass walkway that connects two buildings on a rural college campus. The glass does not reflect images of nearby vegetation; rather, it is completely transparent and birds attempt to fly towards what is on the other side of the invisible barrier (trees and sky when approaching from the south and only sky when approaching from the north).

Mortality was greatest during migration seasons, especially fall. Two years into the study, 6-12 raptor decals were placed on the glass. The authors observed an overall decrease in fatal strikes of 64%. A table is provided that shows the effect of decals on individual species.

Klem, D., Jr. 1979. Biology of collisions between birds and windows. Ph.D. dissertation, Southern Illinois University, Carbondale, IL.

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

Klem, D., Jr. 1989. Bird-window collisions. Wilson Bulletin 101(4):606-620.

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

Klem, D., Jr. 1990a. Collisions between birds and windows: Mortality and prevention. Journal of Field Ornithology 61(1):120-128.

Houses and commercial buildings were monitored for window strikes during autumn and winter months. Based on the mortality observed at these sites, Klem reaches a conservative annual estimate of 1-10 birds killed per building per year. When multiplied by the number of buildings in the U.S., it is estimated that 97.6-975.6 million birds are killed by windows each year.

Experiments found single hawk silhouettes and other objects placed on windows did not significantly reduce mortality. Mortality was only reduced when several items were spaced <10 cm apart and covered most of the glass surface.

Klem, D., Jr. 1990b. Bird injuries, cause of death, and recuperation from collisions with windows. Journal of Field Ornithology 61(1):115-119.

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

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. L. Leedy (Eds.),

Wildlife Conservation in Metropolitan Environments. Natl. Inst. Urban Wildl. Symp. Ser. 2, Columbia, MD.

Klem reviews existing knowledge and urges landscapers and architects to take measures to minimize window strike potential. Recommendations include feeder placement close to windows, covering of windows with netting or strips of translucent fabric, and window angling.

Klem, D. Jr., D. C. Keck, K. L. Marty, A. J. Miller Ball, E. E. Niciu, C. T. Platt. 2004. Effects of window angling, feeder placement, and scavengers on avian mortality at plate glass. Wilson Bulletin 116(1):69-73.

Experiments revealed that window strike mortality is inversely related to window angle and feeder distance, with the most angled windows and closest feeders causing the least mortality. Thus, angling windows slightly downwards and only placing feeders within 1 m of windows are recommended by the authors as practical solutions to reduce avian mortality at homes and commercial buildings.

The results of a carcass removal experiment suggest that scavengers can have a significant effect on detection probability (see also Young et al. 2003). Previously calculated strike rates that do not account for carcass removal are likely underestimates of true mortality. Future window strike studies should quantify scavenger removal in concert with bird mortality to ensure more precise mortality rate estimates.

Klem, D., Jr. 2006. Glass: A deadly conservation issue for birds. Bird Observer 34(2):73-81.

Klem provides an overview of his research on bird collisions with glass, followed by detailed explanations of potential solutions. Klem discusses past failures of the conservation community and building industry to recognize and respond to the issue. Klem notes a recent dramatic increase in awareness, particularly in the form of media attention.

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

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

Klem, D. Jr., C. J. Farmer, N. Delacretaz, Y. Gelb and P.G. Saenger, 2009. Architectural and Landscape Risk Factors Associated with Bird-Glass Collisions in an Urban Environment. Wilson Journal of Ornithology 121(1): 126-134.

Using mortality data from monitoring of 73 building facades in Manhattan, the authors test the hypothesis that architectural and/or landscape variables can account for risk of death from collisions. Mortality increased with glass area and height of vegetation.

Ley, H.W. 2006. Experimentelle Überprüfung der Wahrnehmbarkeit patentierter Vogelschutzgläser durch eine Stichprobe mitteleuropäischer Gartenvögel. Max Planck Institut für Ornithologie [available for download from www.windowcollisions.info].

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 [English translation available from ABC].

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 ineffectivetypes 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

Newton, I., I. Wyllie, and L. Dale. 1999. Trends in the numbers and mortality patterns of Sparrowhawks (*Accipiter nisus*) and Kestrels (*Falco tinnunculus*) in Britain, as revealed by carcass analyses. Journal of Zoology 248:139-147.

The causes of death of 1,797 Sparrowhawks and 1,483 Kestrels found in Britain between 1963 and 1997 were determined. Window casualties accounted for 28.6% of Sparrowhawks and 0.5% of Kestrels. Differences in hunting methods of the two species make Sparrowhawks more vulnerable to window collisions. Numbers of Sparrowhawks killed by windows increased over the 35 years, likely a result of increased use of large plate glass in houses over the same period. The Kestrel showed little seasonal variation in window mortality, whereas Sparrowhawk window mortality increased greatly in August. Juveniles accounted for 93% of August Sparrowhawk collisions.

O'Connell, T. J. 2001. Avian window strike mortality at a suburban office park. Raven 72(2):141-149.

O'Connell monitored window strike mortality at four glass buildings in a Richmond, VA office park. Mortality was highest during migration seasons, and significantly more migrants were salvaged than resident or "feeder birds". This is inconsistent with the findings of some previous studies (Klem 1990a, Dunn 1993) and is likely because O'Connell surveyed buildings that do not attract birds with feeders.

The observed mortality rate was far greater than the estimates of Klem (1990a) and Dunn (1993), although inconsistencies in methodology among studies weaken comparisons. O'Connell recommends standardizing protocols for studies of window strike mortality to allow for better comparisons of results.

Because of the high mortality of migrants relative to resident species that are attracted to feeders, O'Connell concludes that bird mortality at office parks is more similar to that caused by skyscrapers or other tall structures than homes.

Roessler, M. and T. Zuna-Kratky. 2004. Vermeidung von Vogelanprall an Glasflächen. Experimentelle Versuche zur Wirksamkeit verschiedener Glas- Markierungen bei Wildvögeln. Bilogische Station Hohenau-Ringelsdorf [available for download from www.windowcollisions.info].

Roessler, M. and T. Zuna-Kratky. 2004. Avoidance of bird impacts on glass: Experimental investigation, with wild birds, of the effectiveness of different patterns applied to glass. Hohenau-Ringelsdorf Biological Station, unpublished report. (English translation available from ABC).

An outdoor flight tunnel was constructed to test the effectiveness of different marking patterns at reducing bird collisions with glass. The opening at the end of the tunnel through which birds would attempt to escape was partitioned so two pattern types could be tested simultaneously and directly compared. Tests were also conducted in which one pane was patterned and the other was plain. A mist net was suspended in front of the glass to prevent lethal collisions. Test patterns included vertical white strips of adhesive tape of varying widths and spacing, one horizontal stripe pattern, a non- geometric branch pattern, and a grid.

All patterns except the grid significantly reduced collisions when compared to plain glass. Among the effective patterns, the branch and vertical stripe patterns were significantly more effective than the horizontal pattern. During paired comparisons of patterns, 2cm wide vertical stripes with 10cm spacing was found to be most effective at reducing collisions. Results did not differ among groups of species associated with four different habitat types. The influence of bird body size on effectiveness was not investigated.

Roessler, M. 2005 Vermeidung von Vogelanprall an Glasflächen. Weitere Experimente mit 9 Markierungstypen im unbeleuchteten Versuchstunnel. Wiener Umweltanwaltschaft. Bilogische Station Hohenau-Ringelsdorf [available for download from www.windowcollisions.info].

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

Using the same methods as Roessler 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 Roessler 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. Roessler 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 Roessler 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 (Roessler and Zuna- Kratky 2004).

Roessler, M., W. Laube, and P. Weihs. 2007. Vermeidung von Vogelanprall an lasflächen. Experimentelle Untersuchungen zur Wirksamkeit von lasmarkierungen unter natürlichen Lichtbedingungen im Flugtunnel II. Bilogische Station Hohenau-Ringelsdorf [available for download from www.windowcollisions.info].

Roessler, M., W. Laube, and P. Weihs. 2007. Investigations of the effectiveness of patterns on glass, on avoidance of bird strikes, under natural light conditions in Flight Tunnel II. Hohenau-Ringelsdorf Biological Station, unpublished report. English translation available for download from www.windowcollisions.info.

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, Roessler 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. Roessler 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 (Roessler and Zuna-Kratsky 2004, Roessler 2005), white horizontal stripes 2cm wide with 10cm spacing were least effective at reducing collisions. Similar to Roessler (2005), thin, black, horizontal stripes imbedded in the glass were most effective despite the low coverage area, the reasons for which remain unclear. The high effectiveness and low coverage area gives promise to the development of an effective, yet aesthetically-acceptable design.

Roessler, M. and W. Laube. 2008. Vermeidung von Vogelanprall an Glasflächen. Farben, Glasdekorfolie, getöntes Plexiglas: 12 weitere Experimente im Flugtunnel II. Bilogische Station Hohenau-Ringelsdorf [available for download from www.windowcollisions.info].

Roessler, M. and W. Laube. 2008. Avoidance of bird impacts on glass. Colors, decorative window-film, and noise-damping plexiglass: Twelve further experiments in flight tunnel II. Hohenau-Ringelsdorf Biological Station, unpublished report. (English translation available from ABC)

Using the same tunnel and protocol as Roessler et al. (2007), Roessler 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 Roessler (2005) and Roessler 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.

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

Roth et al. radio-tracked a total of 67 Sharp-shinned and Cooper's Hawks over five winters in rural and urban areas. Two birds were killed by window collisions. The authors observed several non-lethal window collisions where hawks contacted the glass feet-first, presumably in reaction to a perception of their own reflection as another bird.

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.

Snyder, L. L. 1946. "Tunnel fliers" and window fatalities. Condor 48(6):278.

Snyder surveyed accession records of the Royal Ontario Museum from the early 1940's to learn which species were most commonly salvaged from window strikes. He notes most of the commonly represented species are "tunnel fliers" that frequently fly through small spaces in dense understory habitats. This habit makes them more susceptible to window strikes (also asserted by Ross 1946, below).

Stedman, S. J. and Stedman, B. H. 1986. Preventing window strikes by birds. Migrant 57:18.

A brief recommendation to hang ¾ inch mesh nylon or plastic screening in front of windows to prevent lethal collisions.

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.

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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.