# Glass: A Deadly Conservation Issue for Birds

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Aside from habitat destruction that eliminates fundamental resources upon which life depends, it is my contention that clear and reflective sheet glass causes the deaths of more birds than any other human-related avian mortality factor. Although clear and irrefutable evidence to support this claim is currently not available, a vast amount of data and its interpretation overwhelmingly upholds this assertion. I have spent more than 30 years studying bird-glass collisions and human-related avian mortality in general, and this article presents an overview of the glass hazard for birds: its character, scale, and our current knowledge about how to mitigate, if not eliminate, this unintended killing of birds.

**A Descriptive Overview**

Glass in the form of windows has enriched and contributed to the aesthetic, cultural, economic, physiological, and psychological well-being of humans for at least 16 centuries (Klem 1979, 1989). Although glass in the form of window panes almost certainly has exacted an increasing toll on birds since its presence in the environment, at no time have I advocated the removal of windows from human structures, believing it is possible to protect birds and still retain the properties of glass that humans enjoy. No cost effective, universally accepted means of protecting birds from glass is yet known, although this is an active area of research, and several techniques to mitigate and eliminate lethal strikes already exist, and have proved acceptable at select locations. The amount of glass continues to increase in new and remodeled human dwellings, with new construction soaring worldwide. New, low-iron sheet glass is currently being manufactured with unprecedented clarity. All this portends an unrelenting and increasingly lethal hazard for common, as well as rare, threatened, and endangered species, and for bird populations in general (Figure 1).

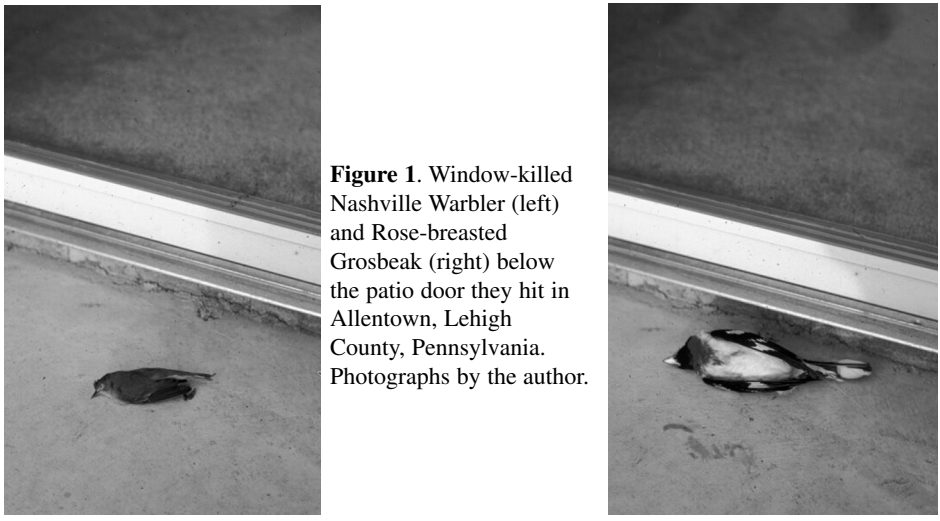

**Figure 1**. Window-killed Nashville Warbler (left) and Rose-breasted Grosbeak (right) below the patio door they hit in Allentown, Lehigh County, Pennsylvania. Photographs by the author.

Surveys of bird strike records from individuals and museums reveal that approximately 25 percent or 225 species in the United States and Canada, and 6 percent or 556 species of the world's birds have been documented striking windows. The species not recorded as window-kills are those that typically do not occur near human dwellings. The species recorded most often in order of documented frequency for North America are: American Robin, Dark-eyed Junco, Cedar Waxwing, Ovenbird, Swainson's Thrush, Northern Flicker, Hermit Thrush, Yellow-rumped Warbler, Northern Cardinal,and Evening Grosbeak. Half a hemisphere away, a globally endangered species, the Swift Parrot (*Lathamus discolor*) of Australia, is a prominently documented window-kill. According to Raymond Brereton, Manager of the Swift Parrot Recovery Program for the Parks and Wildlife Service of the State of Tasmania, 1.5 percent of the entire population of 1000 breeding pairs are annually killed striking windows. The vulnerability of this species to glass is especially noteworthy and troubling because it documents a specific human-related mortality factor as a threat to the overall health of a specific population. How many other species the world over are or will be affected by attrition resulting from glass strikes is yet to be determined.

Birds behave as if clear and reflective glass is invisible to them (Klem 1989, 1990b, O'Connell 2001). Primarily, they strike clear panes while attempting to reach habitat and sky seen through corridors, windows positioned opposite each other in a room, or where glass walls meet in corners. They also strike reflective panes of all colors, attempting to reach habitat and sky mirrored in the glass surface. The sex, age, or resident status of a bird in any locale has little influence on its vulnerability. Glass casualties have been recorded the world over at windows of all sizes, from tiny garage panes in residential homes to the glass walls of multistory buildings. Repeated observations and experiments reveal that lethal collisions are possible wherever birds and glass mutually occur, but landscape features such as lighting, internal and external vegetation, and flight paths created by the arrangement of structures can help explain the toll exacted at any one site. Given the nature of the hazard for birds, the best predictor of strike rate at any one site is the density of birds in the vicinity of glass. There are no times of the day, seasons of the year, or weather conditions during which birds are immune from glass. At the latitude of New England, strikes are more frequent during winter — when birds are attracted to feeders in large numbers —than at any other time of the year, including the spring and fall migratory periods when collision casualties typically attract the most human attention because they are often more visible on sidewalks and around workplaces. Writing in *Bird Observer,* Wiggin (1974) described noteworthy seasonal kills, many associated with glass strikes, at the Prudential Center in Boston. Glass victims are so consistently available at some sites that raptors and shrikes are known to regularly frequent the areas near windows to collect these vulnerable prey (Klem 1981).

A related but different phenomenon is when a bird interprets its reflection as a rival and repeatedly attacks a pane attempting to defend its territory from itself. These types of collisions are not the subject of my studies, however. I have no records of a bird being harmed in this practice; bloody and disheveled yes, but not otherwise harmed.

Dead and dying victims of glass collisions are most often hidden from view in vegetation surrounding human dwellings. Further, whether they are killed outright, or merely injured or stunned, they are quickly taken by scavengers and predators (Klem et al. 2004). Continuous monitoring at single homes, along with other field experiments, reveals that one out of every two strikes results in a fatality (Klem 1990a). The actual cause of death of strike victims is head trauma, intracranial pressure and blood in the brain, and not the often-cited and almost universally inaccurate "broken neck" explanation; in a fresh specimen, the special articulating surfaces of the avian cervical vertebrae effect a highly flexible neck that is easily thought to be broken (Klem 1990a, Veltri and Klem 2005).

In the late 1970s I used available U.S. Census data to estimate that approximately 100 million to 1 billion birds were killed annually by striking windows in the U.S., based on the assumption that 1 to 10 birds are killed at one building each year (Klem 1990b). An independent study of North American window-kills at homes where winter bird feeding was monitored supported and judged this range of annual mortality to be reasonable (Dunn 1993). Given what we currently know about the glass threat to birds, common sense suggests that even the upper range, 1 billion U.S. death toll estimate may be highly conservative.

Comparable annual U.S. bird deaths from other human-related sources include: 120 million from hunting, 60 million from vehicular collisions, 10,000 to 40,000 at wind power turbines, and as many as a billion by domesticated cats (American Ornithologists' Union 1975, Banks 1979, Klem 1990b, Klem 1991, Erickson et al. 2001). Even considering the remarkable number attributable to cats, this figure is more than likely to be far less than the annual kill at glass. Further, cats are active predators that most often capture vulnerable prey, while sheet glass is an indiscriminate killer that takes the strong as well as the weak and is astronomically more abundant than cats in the environment.

**Raising Awareness**

Only recently, within the last few years, has the glass threat to birds been acknowledged as a serious avian conservation issue by more than a few. For several decades prior to the spring of 2003, only a relatively meager collection of individuals took window-kills seriously or even acknowledged them.

When my doctoral adviser, William G. George at Southern Illinois University at Carbondale, recommended I look into bird kills at windows, I was struck almost immediately by the potential magnitude of loss from such a ubiquitous, invisible threat, installed in virtually every human structure. After a time, I adopted "sound bite" tactics to draw attention to the scale of the problem. One such attention-getter was: "if you accept my lowest attrition figure of 100 million annual kills at glass in the U.S. you would need 333 Exxon Valdez oil spills each year to match the carnage." It is ironic that the 100,000 to 300,000 marine birds estimated to have been killed by the 1989 Exxon Valdez oil spill in Alaska is still often cited by various media sources as a prime example of a world-class environmental disaster while the far greater toll exacted by glass every year largely goes unnoticed.

Since the 1980s, after I completed my doctoral work (Klem 1979), I have tried to enlist the aid of two principal constituencies, the building industry and the conservation community, in my efforts to save birds from glass collisions. It was my expectation that architects, in particular, were likely to offer creative solutions to the problem. Unfortunately, glass manufacturers, architects, developers, and landscape planners tended to view the issue as uncomplimentary, one that associated their work or product with death and destruction, and for many years I was unable to generate serious interest.

Within the conservation community, I was, and continue to be disappointed that federal, state, and regional governments charged with, or at least party to, protecting birds, respond to the issue of glass collisions with only mild interest, preferring to focus on other higher profile avian mortality causes such as domestic cats, power lines, communication towers, and wind turbines.

Interest in bird kills at glass seemed to change overnight, however, following a recent, two-year spate of prominent media coverage of the issue and my work. This included features in the *Philadelphia Inquirer* (Yakutchik 2003), and *Audubon Magazine* (Malakoff 2004), an article by AP reporter Joann Loviglio, that appeared in hundreds of newspapers and web media pages, and most recently, a spot on the National Public Radio (NPR) news program *Morning Edition* (Nielsen 2006). On the heels of this coverage, I began at last to make the sorts of contacts that had eluded me for decades: architects interested in helping birds, glass and glass-related product manufacturers willing to try to help me address key experimental questions by offering technical expertise and products. Local, national, and international conservation organizations also seemed willing now to address the topic.

Ten thousand birds killed on one foggy night at a communication tower is a horrific but rare event; while more than that number are almost certainly killed daily at residential and commercial buildings in North America alone, and tens of thousands more are likely killed each day elsewhere around the world. Addressing this carnage, in the face of the growing use of glass in a growing construction industry, is imperative to protect our current and future bird populations.

**Seeking Solutions**

Enforcement of the Migratory Bird Treaty Act (MBTA) of 1918, as amended, and the Endangered Species Act (ESA) of 1973 to protect the unintended killing of birds at glass is seen as impractical, even though this legislation has been used to address other unintended avian mortality, such as that associated with pesticides and power lines (Corcoran 1999). While no reasonable person would advocate prosecuting homeowners for birds killed by their windows, we *should* expect responsible government agencies to address those sites where hundreds of birds are killed by glass, in some cases, in a single day. These kills are substantial, foreseeable, and avoidable, and I believe that at such sites, birds do merit protection from glass under the purview of the MBTA and ESA. Minimally, we should expect the MBTA and ESA to be consistently enforced, no matter what the source of unintended mortality.

Although the issue went underappreciated and largely ignored for decades, there have been a select and distinguished number of individuals and organizations committed to, and advancing the cause of saving birds from glass collisions. As early as 1976, a Trent University undergraduate student, Michael Butler, began documenting and collecting window-kills in the downtown financial district of Toronto. Independently, some years later, in that same city a group of dedicated conservationists founded an organization in 1993 to address migratory bird kills associated with lighted buildings. They called themselves the Fatal Light Awareness Program (FLAP, <http://www.flap.org>) and they documented 10,000 annual deaths in the metropolitan area they surveyed. Partnering with the World Wildlife Fund of Canada, FLAP published a detailed account of their findings and interpretations in an attempt to draw attention to the collision killing that they believed was occurring in other urban centers worldwide (Ogden 1996).

Thanks to the efforts of FLAP and its collaborators, on January 31, 2006, the City of Toronto adopted formal guidelines to prevent bird collisions with buildings, making it the first city in the world to implement a migratory bird protection policy.

Following the example of FLAP, other organized efforts are now underway to address the connection of urban lighting and collision kills during migratory periods in New York City and Chicago. Rebekah Creshkoff, an amateur birder and activist, convinced the New York City Audubon Society of the importance of this issue for her city, and in turn they have been the leading force in establishing a Bird Safe Glass Working Group (BSGWG) composed of architects, ornithologists, artists with expertise in glass design, government officials committed to bird protection, legal council, and groups concerned with animal care such as the Humane Society of the United States. The BSGWG is committed to making glass and human structures in general safe for birds worldwide. Rebekah was also responsible for getting the building managers of the former World Trade Center to put up netting to help prevent bird-glass kills at their structures. She was also the originator of "Project Safe Flight," a program that enlists volunteers to collect collision victims during migratory periods in New York City.

Randi Doeker of the Chicago Ornithological Society, in cooperation with Mayor Richard Daley and the City of Chicago, the College of Architecture at the Illinois Institute of Technology (IIT), Robbie Hunsinger and her volunteer organization, The Chicago Bird Collision Monitors, and Libby Hill and the Evanston North Shore Bird Club, brought together architects, conservationists, and scientists to address the bird-glass issue in the first ever *Birds and Buildings Conference*, in Chicago in March of 2005. Since then, Ms. Doeker has established a website <www.birdsandbuildings.org> to inform and guide building professionals, especially on what can be done at existing structures. The architects at IIT describe this now as a cutting edge research topic in architecture.

**Swarthmore College Project**

After helping a student with a window-kill study on the campus of Swarthmore College in Philadelphia, I was invited by Dr. E. Carr Everbach, Professor of

Engineering and Chair of their Green Team, to advise them on how to make the glass in a proposed new science building safe for birds. They wanted their new facility to meet the criteria of the U.S. Green Building Council (USGBC) and serve as a model for environmentally responsible structures elsewhere. Based on my research, Swarthmore chose a patterned glass called "Ceramic Frit," manufactured by Goldray, Inc. of Calgary, Alberta, Canada (www.goldrayinc.com). The fritted glass is etched with a pattern of dots, but was acceptable in terms of aesthetics and clarity. My experiments have shown this glass to be an effective collision deterrent.

The USGBC consists of architects and other building professionals who have established a rating system called Leadership in Energy and Environmental Design (LEED). The LEED rating system is a voluntary set of national standards for evaluating how "green" a building is, and it includes assessments of the amount of recycled construction materials used, accommodation for natural lighting, attention to water runoff and erosion, and several other considerations addressing how a structure is likely to impact the specific environment in which it is set. While I could not be more supportive of this responsible approach to new or remodeled construction, I cannot think of any building as "green" if birds are routinely killed flying into its clear or reflective low-E (energy) glass, no matter how many other environmentally responsible features have been incorporated into the structure.

There currently is no specific LEED evaluation point for preventing bird kills at glass in new or remodeled structures. The fritted glass used in Swarthmore's new science center contributed to its LEED certification under a rating category addressing innovative design. This was the first time bird-glass collisions were factored into an LEED evaluation, and the hope is that the latest LEED 3.0 or future versions will include a formal rating item addressing the degree to which a structure is designed to prevent bird strikes at glass.

**Available Solutions**

Homeowners and managers of commercial and other buildings can mitigate or eliminate bird-glass collisions in a number of ways (Klem 1990b, Klem et al. 2004). Window screens designed specifically for this purpose are available (www.windowscreen.com), but other physical barriers, such as garden netting or insect screening can work to equal effect.

Decals of any shape and size work to eliminate bird strikes when applied to uniformly cover the glass surface, separated by 5-10 cm (2-4 in). (Decals must be applied on the outside surface of reflective glass.) The falcon silhouette, a popular window-kill preventive decal, is no more effective than any other shape. In one of my first field experiments I found that a single falcon silhouette applied to a window resulted in nine deaths over a 54-day period compared with 12 deaths at an unaltered control window. The window with the falcon silhouette decal killed fewer birds, but it was not a significant reduction. The more decals, the fewer strikes and the fewer deaths. Include enough decals on a pane to uniformly cover the entire surface such that they are separated by the 5-10 cm (2-4 in) distance and you eliminate strikes altogether. Mylar strips, feathers on monofilament line, maple leafs that have a

translucent appearance and reflect UV are all effective if applied in an amount that uniformly covers the glass surface, and spaced 10 cm. (4 in.) apart when oriented vertically, and 5 cm. (2 in.) apart when oriented horizontally. Why a smaller horizontal spacing is required is not clear, but it may be that birds are more apt to give wider clearance flying around vertical tree trunks than over and under more closely spaced horizontal branches.

A simple but effective way to reduce window-kills around bird feeders is to move the feeder to within 1 m (a bit more than 3 ft.) from the glass surface (Klem et al. 2004). Birds come and go from feeders; only rarely will they pass by at full speed to strike glass. The results of feeder placement experiments conducted by my research group has prompted many conservation organizations to adopt feeder placement as recommended method for preventing millions of bird fatalities at glass (Figure 2).

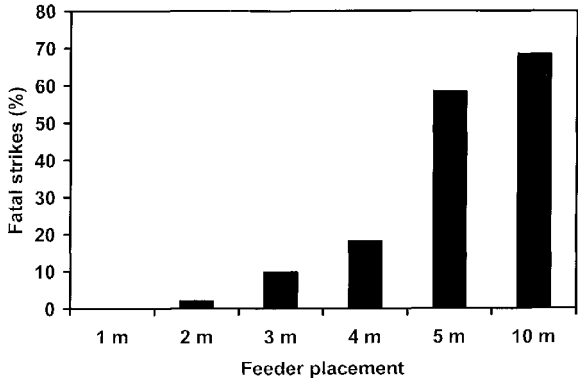


**Figure 2**. The proportion of bird fatalities (%) at windows increases as bird feeders are placed farther from the glass surface. Data are from field experiments at Germansville, Lehigh County, Pennsylvania, 1991-1992 (Published as FIG. 1 in Klem et al 2004 and reprinted here with permission from The Wilson Journal of Ornithology).

Ideally, we need plate glass manufactured and installed that retains all the qualities of existing panes but which flying birds can see and avoid. Such a glass currently does not exist. For some time now I have advocated the manufacture of a "one-way" type pane which, when viewed from the inside, appears the same as conventional glass, but from the outside shows visible patterns that birds will avoid. Perhaps the optimal solution would be to apply patterns to glass that either reflects or absorbs ultraviolet (UV-A) wavelengths (ranging from 300-400 nanometers), a range of wavelengths that birds see but we do not. Of the relatively few but diverse bird species tested so far, it is hypothesized that just about all birds see UV light (perhaps nocturnal species are exceptions). The question of UV light serving as a signal to alert birds to the danger of glass is currently an active area of my research; however, as I write this, existing literature on the topic and my preliminary results are not encouraging (Graham 1997).

## References


American Ornithologists' Union. 1975. Report of the ad hoc Committee on Scientific Educational Use of Wild Birds. *Auk* 92 (Suppl.): 1A-27A.

Banks, R.C. 1979. *Human Related Mortality of Birds in the United States*. U.S. Fish and Wildlife Service Special Report 215: 1-16.

Corcoran, L.M. 1999. Migratory Bird Treaty Act: strict criminal liability for non-hunting caused bird deaths. *Denver University Law Review* 77: 315-58.

Dunn, E.H. 1993. Bird Mortality from Striking Residential Windows in Winter. *Journal of Field Ornithology* 64 (3): 302-09.

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.* National Wind Coordinating Committee, Washington, D. C.

Graham, D.L. 1997. Spider Webs and Windows as Potentially Important Sources of Hummingbird Mortality. *Journal of Field Ornithology* 68 (1): 98-101.

Klem, D. Jr. 1979. *Biology of Collisions Between Birds and Windows*. Ph.D. Dissertation, Southern Illinois University at Carbondale, 256 pp.

Klem, D. Jr. 1981. Avian Predators Hunting Birds Near Windows. *Proceedings of the Pennsylvania Academy of Science* 55: 90-92.

Klem, D. Jr. 1989. Bird-Window Collisions. *Wilson Bulletin* 101 (4): 606-20.

Klem, D. Jr. 1990a. Bird Injuries, Cause of Death, and Recuperation from Collisions with Windows. *Journal of Field Ornithology* 61 (1): 115-19.

Klem, D. Jr. 1990b. Collisions Between Birds and Windows: Mortality and Prevention. *Journal of Field Ornithology* 61 (1): 120-28.

Klem, D. Jr. 1991. Glass and Bird Kills: An Overview and Suggested Planning and Design Methods of Preventing a Fatal Hazard. In *Wildlife Conservation in Metropolitan Environments NIUW Symposium Series 2*, L. W. Adams and D. L. Leedy, eds., National Institute for Urban Wildlife, MD, 99-104.

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.

Loviglio, J. 2004. *Glass windows an 'Indiscriminate' Bird Killer* (www.cnn.com/2004/TECH/science/02/03/birds.clear.danger.ap/)

Malakoff, D. 2004. Clear & Present Danger. *Audubon* 106 (1): 65-68.

Nielsen, J. 2006. Windows: A Clear Danger to Birds. *Morning Edition*, National Public Radio, 3 January (Available online at http://www.npr.org/templates/story/story.php?storyId=5076012.)

O'Connell, T.J. 2001. Avian Window Strike Mortality at a Suburban Office Park. *The Raven* 72 (2): 141-49.

Ogden, L.J.E. 1996. *Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds*. World Wildlife Fund Canada and the Fatal Light Awareness Program.

Veltri, C.J. and D. Klem, Jr. 2005. Comparison of fatal bird injuries from collisions with towers and windows. *Journal of Field Ornithology* 76 (2): 127-33.

Wiggin, H.T. 1974. Birding at the Prudential Center. *Bird Observer* 2 (5): 136-40.

Yakutchik, M. 2003. *Philadelphia Inquirer Magazine* (11 May): 12-17.



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*and overall environmental ethic among the citizenry of this developing nation, and former Soviet Republic, through the appreciation and study of birds, and to inform western cultures about ornithology in a part of the world where, until recently, little was made available. Among other accomplishments, the project resulted in the publication of three books co-authored by M. S. Adamian and D. Klem, Jr.:* A Field Guide to Birds of Armenia *(1997 English and 2003 Armenian editions), and a comprehensive ornithological monograph* Handbook of the Birds of Armenia *(1999).*

Impression of bird (likely a Mourning Dove) left on window after a collision; photograph © 2003 by Janie Johns.