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# EFFECTS OF WINDOW ANGLING, FEEDER PLACEMENT, AND SCAVENGERS ON AVIAN MORTALITY AT PLATE GLASS

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ABSTRACT.—Extensive observations and experiments suggest that collisions with plate glass result in more avian mortalities than any other human-associated factor. We tested the effects of window angling and the distance of bird feeders from windows on bird-glass collisions. Strike frequency differed among windows oriented vertically (control) and those angled 20 and 40 degrees from vertical; as the angle of orientation increased, strikes and fatalities decreased. Strike frequency and fatalities at windows also increased as the distance between bird feeders and the glass surface increased. No fatalities were recorded when feeders were located within 1 m of a window, but a marked increase in mortality occurred when feeders were placed 5 and 10 m from the glass. Most glass-collision victims may go unnoticed, hidden by vegetation where they remain out of view or are removed by scavengers. We found that scavengers frequently removed baits from beneath windows at six buildings, but no baits were taken from a site without windows that served as a control. The importance of window strikes as an avian mortality factor, and the likelihood that it will increase over time, compel us to recommend a reevaluation of the Migratory Bird Treaty Act (MBTA). Angling panes in new and remodeled buildings and placing bird feeders closer to windows can potentially reduce avian mortality. *Received 3 September 2003, accepted 6 April 2004.*

Birds are vulnerable to collisions with windows—from small panes to walls of glass covering entire buildings (Klem 1989, 1991). Extensive observations and several experiments reveal that birds apparently cannot recognize clear or reflective panes of glass as barriers to be avoided (Klem 1990b). Conservative estimates of annual avian mortality from collisions with glass for the U.S. alone and for the entire North American continent range from approximately 100 million to 1 billion birds, respectively (Klem 1990b, 1991; Dunn 1993), representing from 0.5 to 5% of the fall bird population (American Ornithologists' Union 1975). Comparative figures for other human-associated bird mortalities (collisions with vehicles, communication towers, wind turbines, power lines, or nocturnal strikes at multistory buildings) are at least an order of magnitude less than those known to occur at glass (Banks 1979, Klem 1991, Shire et al. 2000, Erickson et al. 2001, Johnson et al. 2002). Only predation by domestic cats—estimated at 1 billion birds per year in North America—results in comparable mortality rates.

Glass as a mortality factor for specific species is generally unknown. One exception is the Swift Parrot (*Lathamus discolor*) of Tasmania—1.5% of the entire population (1,000 breeding pairs) is killed annually by colliding with windows (R. Brereton pers. comm.). Lethal collisions have been recorded whenever and wherever both birds and glass occur. Moreover, the fittest individuals of populations are known to be as vulnerable as any other (Klem 1990b).

Although bird-glass collisions occur in every season, the general impression is that most occur during fall and spring migration. In fact, systematic monitoring of houses suggests that most birds in North America are killed during winter, when many are attracted to bird feeders (Klem 1990b, Dunn 1993). During 2001, 54 million U.S. residents (25% of the population ≥16 years of age) participated in feeding birds and other wildlife (U.S. Department of Interior and U.S. Department of Commerce 2002). Exacerbating our understanding of the problem is the practice of planting vegetation

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around human dwellings, which often hides glass-strike casualties from human attention (Klem 1990a). Scavengers are known to remove dead birds (Klem 1981), and they are believed to kill and remove injured birds from window-collision sites. However, no experiments have specifically addressed the removal of dead or injured birds by scavengers as a possible explanation for why collision casualties are not discovered beneath windows more often.

Here, we examine the effects of window angling on bird-glass collisions, and attempt to determine where bird feeders should be placed to reduce or eliminate window hazards. Additionally, we present experimental results that indicate scavengers regularly patrol areas near windows and remove evidence that avian fatalities have occurred.

## METHODS

We conducted the window angling and bird feeder placement experiments at the 15-ha Muhlenberg College Raker field site south of Germansville, Lehigh County, Pennsylvania (40° 41′ N, 75° 42′ W). Land cover is 40% second-growth deciduous woodland, 35% fallow field, 15% wetland, 5% open water (Jordan Creek), and 5% man-made structures. The scavenger experiment was conducted at Muhlenberg College (40° 35′ N, 75° 30′ W) and Cedar Crest College (40° 35′ N, 75° 31′ W). The two campuses are adjacent to one another in suburban, west Allentown, Lehigh County, Pennsylvania.

*Window angling experiment.*—We conducted the window angling experiment from 20 January to 17 May 1991. The basic design was the same as reported previously (Klem 1989, 1990b), consisting of six wood-framed picture windows, simulating those in houses; all were placed in the same habitat and faced the same direction along the edge of a mixed deciduous forest and open field (Klem 1989: Fig. 1). Three of the windows were tinted dark gray and three were clear. Tinted panes alternated with clear panes across the six positions, which were separated from one another by 43, 15, 24, 18, and 20 m. Distances between windows were selected to simulate the construction practice of building homes in rows, in this case adjacent to one another along a tree line facing a field. The vegetation cover in the field consisted of cut corn stalks and grasses, a uniform habitat with no obvious flight paths to attract birds to or away from the windows. Each window measured 1.4 m wide × 1.2 m high, and was mounted 1.2 m above ground. Wire-mesh trays were placed under each window to catch casualties. Tinted and clear windows were placed in each of three orientations: vertical (serving as the control), and angled downward from vertical at 20 and 40 degrees. Each window was constructed in such a way that it could be placed at all orientations. All panes remained in the same position throughout the experiment, and each day the three pane orientations were assigned randomly to the tinted and clear panes; panes were checked and changed 30 min before last light.

The parameter measured was the number of detectable bird strikes. A strike was registered when either a dead or injured bird was found beneath a window, or when fluid or a blood smear, feather, or body smudge was found on the glass. All window-killed casualties left evidence of a strike on the glass. Our data are likely to be incomplete and conservative because some strikes (e.g., a glancing blow) may not have left evidence of a collision. In addition, predators and scavengers may have removed some injured or dead birds that we did not detect.

*Feeder placement experiments.*—We conducted two feeder placement experiments, from 31 October to 17 December 1991 and from 24 January to 29 February 1992. The first experiment tested the effects of placing platform feeders 1, 5, and 10 m from conventional, vertically oriented panes. The second tested the effects of placing feeders 2, 3, and 4 m from windows. In the 1-, 5-, and 10-m experiment, we used the same six windows that were used in the angling experiment, but repositioned them so that they were 55 m apart. Each feeder placement was tested simultaneously at one clear and one tinted pane. Windows were positioned farther apart to reduce the possibility that birds attracted to one feeder placement might strike a window associated with another. In the 2-, 3-, and 4-m experiment, we replaced the tinted panes with clear panes because the quality of reflection from the tinted glass (salvaged) was not sharp, and we suspected that this effect contributed to the lower number of strikes at tinted panes in our angling experiment. Each feeder placement was tested simultaneously at two clear panes. Bird feeders were flat trays measuring 30.5 × 61.0 cm, and placed so that they were centered and level with the bottom of each windowpane. Feed consisted of a 1:1 mixture of black-oil sunflower seeds and either cracked corn or white millet. Each feeder was lightly covered with the same feed mixture 1 hr before sunrise each day. We recorded strike frequencies in the same manner as in the angling experiment.

*Scavenger experiment.*—The scavenger experiment was conducted from 25 January to 10 April 1992. Seven locations, distributed among four buildings on the campuses of Muhlenberg and Cedar Crest colleges, were selected as experimental sites. Six of these sites were below windows at which lethal bird strikes were known to have occurred. A building wall without windows—but which faced habitat and had human passage similar to that of the other sites—served as a control. Approximately 30 g of chicken breast meat was used to simulate a window-killed bird approximately the size of a Hermit Thrush (*Catharus guttatus*). At each location bait was placed out of sight from human passersby. From 25 January to 8 March, baits at each site were checked every 12 hr (10:00 and 22:00 EST), and then once every 24 hr (22:00) from 9 March to 10 April. Baits were replaced after 4 days if no disturbance occurred, or during bait checks if baits had been removed or moved from their original location. The ground areas on which baits were placed were finely raked so as to record the tracks of potential scavengers. The parameter measured was the number of baits taken or moved from their original locations by scavengers each day at each site.

We used SPSS (SPSS, Inc. 2002) for all statistical analyses. Chi-square goodness-of-fit was used to evaluate experimental results except for one dichotomous comparison in which a 2-tailed binomial test was more appropriate. We considered test results to be statistically significant when $P < 0.05$.

## RESULTS

*Window angling experiment.*—We recorded 53 strikes, of which 12 (23%) were fatal (Table 1). Dead birds included: Black-capped Chickadee (*Poecile atricapillus*), Northern Cardinal (*Cardinalis cardinalis*), White-throated Sparrow (*Zonotrichia albicollis*), Song Sparrow (*Melospiza melodia*), and Dark-eyed Junco (*Junco hyemalis*). Total number of strikes differed significantly across window angle, with 57% at the vertical control, 28% at the 20-degree angle, and 15% at the 40-degree angle ($\chi^2 = 14.3$, df = 2, $P = 0.001$). Similar strike differences occurred across window angle for both the clear panes ($\chi^2 = 10.5$, df = 2, $P = 0.005$) and tinted panes ($\chi^2 = 4.4$, df = 2, $P = 0.11$). Irrespective of window angle, strike frequency differed between clear (36) and tinted (17) panes (Binomial test, $Z = -2.47$, 2-tailed, $P = 0.013$).

TABLE 1. The number of bird strikes (fatalities) decreases with increased window angling. Data are from field experiments at Germansville, Lehigh County, Pennsylvania, 1991.

| Glass type | Angle of tilt (orientation): Vertical | 20 degrees | 40 degrees | Total |
|---|---|---|---|---|
| Tinted | 9 (0) | 6 (0) | 2 (0) | 17 (0) |
| Clear | 21 (7) | 9 (4) | 6 (1) | 36 (12) |
| Total | 30 (7) | 15 (4) | 8 (1) | 53 (12) |

*Feeder placement experiments.*—During the 1-, 5-, and 10-m experiment we recorded 105 strikes, 50% of which were fatal. Dead birds were: Blue Jay (*Cyanocitta cristata*), Black-capped Chickadee, Tufted Titmouse (*Baeolophus bicolor*), White-breasted Nuthatch (*Sitta carolinensis*), American Robin (*Turdus migratorius*), Common Yellowthroat (*Geothlypis trichas*), Northern Cardinal, White-throated Sparrow, Dark-eyed Junco, House Finch (*Carpodacus mexicanus*), and American Goldfinch (*Carduelis tristis*). Total number of strikes differed significantly across placements, with 25 (24%) at 1 m, 29 (28%) at 5 m, and 51 (48%) at 10 m ($\chi^2 = 11.2$, df = 2, $P = 0.004$). Fatal strikes also differed significantly across feeder placement, with 0 (0%) at 1 m, 17 (33%) at 5 m, and 35 (67%) at 10 m ($\chi^2 = 33.0$, df = 2, $P < 0.001$); all but four fatalities occurred at clear panes.

During the 2-, 3-, and 4-m experiment we recorded 197 strikes, 21 (11%) of which were fatal. Dead birds were: Tufted Titmouse, Northern Cardinal, Chipping Sparrow (*Spizel-*

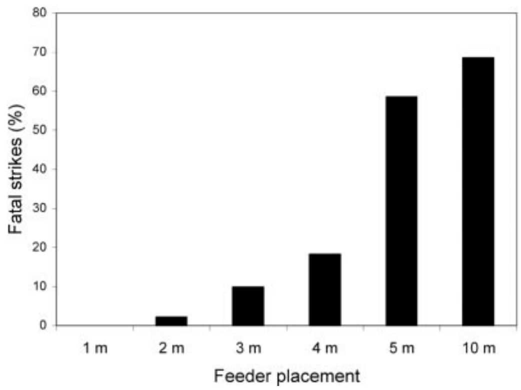


FIG. 1. The proportion of bird fatalities (%) at windows increases as bird feeders are placed farther from the glass surface. Data are from field experiments at Germansville, Lehigh County, Pennsylvania, 1991–1992.

*la passerina*), Field Sparrow (*S. pusilla*), White-throated Sparrow, Dark-eyed Junco, and House Finch. Total number of strikes differed significantly across placements, with 46 (23%) at 2 m, 91 (46%) at 3 m, and 60 (31%) at 4 m ($\chi^2 = 16.2$, df = 2, $P = 0.001$). The number of fatal strikes also differed significantly across feeder placement, with 1 (5%) at 2 m, 9 (43%) at 3 m, and 11 (52%) at 4 m ($\chi^2 = 8.0$, df = 2, $P = 0.018$). The combined results of both feeder placement experiments revealed a marked increase in the proportion of fatal strikes as distance between feeder and window increased (Fig. 1).

*Scavenger experiment.*—During 77 days, scavengers found and disturbed 69 (13%) of 539 baits. At the six sites below windows, the number of disturbed baits was 17, 12, 12, 8, 9, and 11, respectively. Tracks revealed that the following scavengers found bait: 15 (22%) squirrel, 31 (45%) cat, 3 (4%) dog, 4 (6%) bird spp., and 16 (23%) unidentified. Baits were found by the same type of scavenger at the same site on 6 (cat), 8 (cat), and 2 (squirrel and dog) consecutive days, suggesting that the same individuals may have returned to a location where food was found previously. At the control-site building with no windows there was no evidence that any scavenger discovered bait during the entire experimental period.

## DISCUSSION

Preliminary observations had indicated that window angling might protect birds by reflecting the ground instead of the surrounding habitat and sky (Klem 1990b). Our experiments revealed that window-strike fatalities can be reduced significantly if panes are angled downward 20° and 40° from the vertical. Angled glass also may reduce the force with which birds in horizontal flight strike panes. Although glass orientation does not eliminate the lethal hazard of windows, it is an effective bird-strike deterrent and should be considered by architects and others involved in planning new structures or in remodeling existing ones. The effectiveness of window angling is substantial and is likely to become practical in one-story structures or at ground level in multistory buildings.

Results of the angled window and feeder placement experiments in which tinted glass was used indicate that tinting may afford some protection for birds. Although fewer strikes were recorded at tinted panes, the numbers of strikes at tinted and clear windows had similar trends in the angling experiment. We believe that the lower number of strikes at our tinted panes is explained best by the relatively poor reflective quality of the salvaged glass we used. In a previous experiment, clear and tinted panes were equally lethal to birds (Klem 1989). However, the hazards of varying types of clear and tinted glass need further study to determine their specific risks.

Results of previous experiments have documented the effectiveness of two other methods in eliminating window kills, but these techniques are often unacceptable to home owners and managers of commercial buildings because they are costly, impractical, or aesthetically unpleasing (Klem 1990b, 1991). One method is to place a physical barrier (netting, awning) in front of glass to prevent bird strikes. Screens for this purpose are now commercially available. Another method is to apply opaque or translucent objects (hawk silhouettes, geometric shapes, other creative patterns), separated by 5–10 cm, to the outside surfaces of windowpanes (Klem 1990b). Objects of any shape that visibly contrast with glass allow birds to recognize and avoid windows. The use of ultraviolet (UV) patterns to deter bird-glass collisions is currently under study in our laboratory. The expected principal advantage of UV deterrents is that they will be invisible to humans. Another potential long-term solution is the manufacture of a novel type of sheet glass, especially for multistory, glass-covered buildings (Klem 1991); this glass would provide an unobstructed view from the inside, but, when viewed from the outside, creative designs (dots, lines, variously shaped objects separated by 5–10 cm) would be visible to birds and direct them away from the hazard.

U.S. courts have established strict liability for unintentional avian mortality associated with pesticides and power lines pursuant to the Migratory Bird Treaty Act of 1918 (MBTA), as amended, or the Endangered Species Act (ESA) of 1973 (Corcoran 1999); however, the courts have not established strict liability for fatalities associated with vehicle, tower, or glass collisions. Our results suggest that bird kills at glass are substantial, foreseeable, and avoidable (Klem 1989, 1990b, 1991; Corcoran 1999) and we suggest that birds merit consideration for protection from glass collision under the purview of the MBTA and ESA.

Avian injury and mortality from collisions with glass can be reduced worldwide by those who feed birds. Our results showed an increase in window fatalities when bird feeders are placed 2–10 m from a glass surface, with marked increases at 5 and 10 m. Feeders placed within 1 m of a pane led to no fatalities and offer the most protection for birds, especially at residential buildings and visitor centers of local, state, and federal parks and other recreational facilities.

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