The Wilson Journal of Ornithology

# Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-window Collisions

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Published by the
Wilson Ornithological Society

WILSON ORNITHOLOGICAL SOCIETY
1888

*The Wilson Journal of Ornithology* 125(2):406–411, 2013

# Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-window Collisions

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ABSTRACT.—Billions of birds are estimated to be killed striking clear and reflective windows worldwide, and conservation, ethical, and legal reasons justify preventing this unintended human-associated avian mortality. Field experiments reveal that to be effective, UV signals used to prevent bird-window collisions must minimally reflect 20–40% from 300–400 nm. Field experiments reveal 3.175 mm parachute cord hung in front of clear and reflective windows separated by 10.8 cm and 8.9 cm are effective bird-window collision preventive methods. The results of the parachute cord experiment and those of previous studies support the importance of applying collision prevention methods to the outside window surface reflecting the facing habitat and sky. Comparison of field and tunnel testing experimental protocols to evaluate bird-window colli-

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sion preventive methods suggest that tunnel testing is useful for initial assessment but not as a definitive measure of effectiveness. *Received 6 January 2012. Accepted 19 December 2012.*

Key words: collision prevention, testing, ultraviolet (UV) signals, visual information, windows.

Except for habitat destruction, the casualties attributable to bird-window collisions total in the billions worldwide and are estimated to be greater than any other human-associated source of avian mortality (Klem 1990, 2009a; Hager et al. 2008). More accurate estimates of birds killed striking windows and the implications of this and other human-caused avian mortality are currently under study for management of specific species and birds in general (Arnold and Zink 2011, Bayne et al. 2012, Loss et al. 2012). Minimally, preventing these unintended and unwanted deaths has ethical and moral value, and a legal international treaty obligation, implemented in the United States by The Migratory Bird Treaty Act (MBTA) of 1918 and the Endangered Species Act of 1973, as respectively amended (Bean 1983, Corcoran 1999).

Several review papers document extensive published evidence in the ornithological literature that birds behave as if clear and reflective windows are invisible to them (Erickson et al. 2001; Klem 2006, 2009a, 2010; Drewitt and Langston 2008). Visual patterns composed of uniformly spaced elements covering an entire pane are known to transform windows into obstacles that birds see and avoid (Klem 1990, 2009b). To retain the utility of unobstructed viewing, the seemingly most acceptable solution to protect birds from windows is to incorporate ultraviolet (UV) signals into visual patterns that birds see and humans do not (Klem 2009b).

We evaluated the strength and wavelength of UV signals necessary to prevent bird-window collisions using field experiments, and we compare these results to those evaluating the same signals using a flight tunnel. We also reexamine and evaluate the spacing of opaque elements making up a pattern uniformly covering a window to prevent collisions. Specifically, we tested: (1) a commercial window manufactured for new and remodeled construction named ORNILUX Mikado that offers a UV signal for the purpose of preventing bird-window collisions, and (2) two versions of a commercial window product named Acopian BirdSavers that uses vertically hung opaque parachute cords. We use our findings and previously published results to comment on the relative importance of using field experiments as a final test in evaluating bird-window collision prevention methods and the importance of applying preventive methods to the surface of a window facing the outside environment.

## METHODS

Our field experiments were conducted on a 2-ha area of mowed pasture bordered by second growth deciduous forest and shrubs in Henningsville, Berks County, Pennsylvania, USA (40° 27′ 53″ N, 075° 40′ 07″ W). The basic design of the two field experiments was the same as reported previously (Klem 1989, 1990, 2009b), consisting of wood-framed picture windows, simulating those in houses. All windows were placed in the same habitat facing the same direction along the edge of trees and open field (Klem 1989: fig. 1). Each window measured 1.2 m wide × 0.9 m high, and was mounted 1.2 m above ground. Plastic mesh trays were placed under each window to catch casualties. Three window units were used in the first experiment and four in the second; all windows in both experiments were separated by 2.4 m. Simulating a feeding station at a commercial building or residential home, a single platform feeder measuring 30.5 cm on a side and 1.2 m above ground mounted on crossed wooden-legs were centered and placed 10 m in front of each window. Feed consisted of a 1:1 mixture of black-oil sunflower and white proso millet. All feeders were kept full throughout each experiment. Controls and treatments were randomly assigned daily to a new position with the exception that no treatment or control was permitted in the same position on consecutive days. Windows were checked each day 30 min after first light and checked and changed daily 30 min before last light. In an attempt to observe active avoidance of treatments, all windows in the second experiment were monitored during multiple-hour continuous periods totaling 63.5 hrs over 16 days (22, 26 Feb, 18, 21, 22, 26, 27, 28, 29 Mar, and 4, 8, 9, 11, 15, 18, 22 Apr 2011). The observer was positioned 20 m from and in the middle of the window units in a camouflaged blind behind the platform feeders. The flights of individual birds moving from the tray feeders toward the windows were recorded and assessed as an active avoidance if a bird changed direction and passed around or over a window.

The parameter measured in the experiments was the number of detectable bird strikes. A strike was recorded when either dead or injured birds were found beneath a window, or when fluid or a blood smear, feather, or body smudge was found on the glass. As in previous studies of similar design (Klem 1989, 1990, 2009b; Klem et al. 2004), the data are likely to be incomplete and conservative because some strikes may not have left evidence of a collision. Additionally, predators and scavengers are known to remove some injured or dead birds (Klem 1981, 2009b; Klem et al. 2004; Hager et al. 2012).

Our field design can accommodate a maximum of four window units; two experiments were required to test the effectiveness of the preventive methods studied. The first experiment was conducted over 75 days from 3 October–18 December 2010, and compared clear (see-through) and reflective (mirrored) glass controls and an ORNILUX Mikado window offering UV signals as a see-through pane simulating installation in a corridor between buildings, as a noise barrier along roadways, or as glass walls around zoo enclosures or building atria.

The second experiment was conducted over 68 days from 9 February–22 April 2011, and tested the clear glass control, 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.

CPFilms, Solutia, Inc. measured reflected UV strength and wavelength for a sample of ORNILUX Mikado and for the conventional clear and reflective float glass controls using a Cary 5000 Spectrophotometer. ORNILUX Mikado reflected 7% UV from 300–380 nm, and 7–22% from 380–400 nm. The clear and reflected glass controls uniformly reflected 13% UV or less over 300–400 nm. The parachute cord reflected 8% UV or less over 300–400 nm; it was olive green and non-reflective to the human eye.

Our experimental protocol was approved by our Institutional Animal Care and Use Committee (IACUC), and birds killed during the study were salvaged under state and federal permits. Chi-square goodness-of-fit was used to compare the frequency of strikes among treatments in the two experiments, and test results were considered statistically significant when $P < 0.05$ (Siegel 1956). We used SPSS (SPSS 2010) for all statistical analyses of the experiments.

## RESULTS

A total of 116 strikes were recorded in the first experiment; 19 (16%) were fatal. The number of strikes did not differ significantly across all treatments with 32 (28%) at the clear glass control, 43 (37%) at the reflective glass control, and 41 (35%) at the ORNILUX Mikado ($\chi^2 = 1.776$, df $= 2$, $P = 0.41$). 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 ORNILUX Mikado ($\chi^2 = 6.421$, df $= 2$, $P = 0.040$). Species numbers and treatment at which fatalities occurred were: two Dark-eyed Juncos (*Junco hyemalis*) at the clear glass control, two Black-capped Chickadees (*Poecile atricapillus*), three Northern Cardinals (*Cardinalis cardinalis*), and one House Finch (*Carpodacus mexicanus*) at the reflective glass control, and two Black-capped Chickadees, one Ruby-crowned Kinglet (*Regulus calendula*), one Hermit Thrush (*Catharus guttatus*), one Gray Catbird (*Dumetella carolinensis*), three Northern Cardinals, two Dark-eyed Juncos, and one American Goldfinch (*Spinus tristis*) at the ORNILUX Mikado.

One hundred and twelve strikes were recorded in the second experiment; 22 (27%) were fatal. The total number of strikes differed significantly across all windows, 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 ($\chi^2 = 95.00$, df $= 3$, $P < 0.001$). The number of fatal strikes differed significantly across all treatments with 1 (5%) fatality of Northern Cardinal at the clear pane covered by parachute cords spaced 10.8 cm apart, and all 21 (95%) other fatalities at the clear glass control that included: one Mourning Dove (*Zenaida macroura*), one Black-capped Chickadee, three Northern Cardinals, one Purple Finch (*Carpodacus purpureus*), one White-throated Sparrow (*Zonotrichia albicollis*), and 14 Dark-eyed Juncos ($\chi^2 = 58.364$, df $= 3$, $P < 0.001$).

Flight paths of 44 individual birds flying from bird feeders toward the experimental windows were recorded to determine avoidance performance. Of six individuals flying toward the clear glass control, four (67%) moved to avoid and two (33%) hit the window. Of 16 individuals flying toward the ONILUX over dark interior, 12 (75%) moved to avoid and four (25%) hit the window. Of 12 individuals flying toward the parachute cords spaced 10.8 cm apart covering the clear pane, 11 (92%) moved to avoid and one (8%) hit the window. Of 10 individuals flying toward the parachute cords spaced 8.9 cm apart covering the reflective pane, all 10 (100%) moved to avoid the window.

## DISCUSSION

Several studies document evidence that birds perceive UV wavelengths from approximately 300–400 nm (Burkhardt 1982, Bennett and Cuthill 1994, Vitala et al. 1995, Bennett et al. 1996, Hunt et al. 1998), and although Martin (2011) questioned static UV signals as a collision deterrent, external films consisting of contrasting UV-absorbing and UV-reflecting patterns applied to sheet glass have been effective in deterring bird-window collisions (Klem 2009b). The use of UV signals to deter bird-window collisions is arguably the most practical solution because they preserve the properties that humans expect and enjoy from sheet glass while seemingly transforming clear and reflective panes into obstacles that birds see and avoid. External films can be used to retrofit existing panes to render them bird-safe, but uniquely manufactured sheet glass with UV coating (glazing) patterns to be used in new and remodeled construction will be required for a long-term solution to protect birds from the harmful effects of window strikes worldwide. ORNILUX Mikado is a uniquely prepared and commercially available sheet glass for new and remodeled construction that claims to use UV signals to prevent bird strikes. Our first field experiment revealed that an ORNILUX Mikado pane installed in see-through settings was more lethal to birds than conventional clear or reflective panes. We suggest these results can be explained by the quality of the UV signal offered by ORNILUX Mikado to birds. The UV signal from ORNILUX Mikado reflected a maximum 7–22% UV from 300–400 nm, reaching above 20% reflection only at 397 nm. By contrast, previous tests using the same field experimental design found external films with a UV-reflecting component of 20–40% over 300–400 nm to effectively deter bird-window collisions (Klem 2009b). We suggest that the inability of ORNILUX Mikado installed in a see-through setting to deter bird strikes is explained by the lower level of reflected UV that is available for bird perception, and to offer an effective collision deterrence the UV-reflecting component of the signal minimally must be 20–40% and be adjacent to contrasting areas of UV-absorption to further highlight the UV signal overall.

In our second experiment, ORNILUX Mikado covering a darkened interior exhibited a 55% reduced number of strikes compared to the clear glass control, and this compares to the 58% and 66% deterrence reported for ORNILUX Mikado in a see-through setting using tunnel testing experiments (American Bird Conservancy 2011). Tunnel testing experiments consist of releasing birds at one end of an enclosure where they are attracted to fly to a brighter lighted opposite end at which they choose one of two flight paths though an unobstructed side serving as a control, and the alternative side containing the collision prevention treatment being tested (Rossler and Zuna-Kratky 2004, American Bird Conservancy 2011). Why the ORNILUX Mikado window was more effective in deterring bird strikes when covering a darkened interior is not known, and may or may not be associated with the UV signal offered by the pane.

The frequency of bird strikes at clear and reflective panes covered by the two spacing versions of vertically hung parachute cord provide additional evidence, further validating previous studies that vertical stripes separated by 10 cm or less are effective bird-window collision preventive methods (Klem 1990, 2009b; Rossler and Zuna-Kratky 2004; American Bird Conservancy 2011).

The observations documenting flight paths of individual birds toward the window treatments in the second field experiment further supports the level of deterrence recorded for ORNILUX Mikado covering a darkened interior and the two vertically hanging parachute cord patterns.

The discrepancy in the test results that occurred using our field experiment compared to tunnel testing experiments conducted by the American Bird Conservancy (2011) suggests caution in relying on tunnel testing as a final assessment of effectiveness of any bird-window collision prevention method. When comparing the protocol of field and tunnel testing experiments, tunnel experiments are markedly not as accurate in simulating hazardous clear and reflective windows installed in human structures. Components of tunnel experiments that limit a more accurate simulation of installed windows include: (1) the stress of captured individuals of several different species released to fly within restricted space to alternative decision areas, (2) controlling illumination to simulate clear and reflective panes, (3) netting placed in front of test panes that subjects can potentially see and thereby influence their choice, and (4) not being able to control for variable weather conditions during test periods. By contrast, our field experimental design far more accurately simulates installed windows in commercial and residential buildings, and each preventive treatment and control are monitored under the same conditions. Moreover, field experiments can control for bias of installation location by randomly moving treatments and control daily over the experimental period. The ability to conduct experiments by randomly moving treatments and controls at existing structures is extremely difficult and most often impractical.

Tunnel experiments are most useful in evaluating several potential preventive options to deter birds from striking see-through windows. Most results from tunnel tests are similar to field tests (Rossler and Zuna-Kratky 2004, American Bird Conservancy 2011), but we suggest that the limitations of tunnel experiments to accurately simulate windows in actual buildings precludes this protocol from serving as a definitive tool in evaluating bird-window collision prevention methods. We further suggest that the field experiment protocol described here provides accurate results to serve as a definitive assessment of evaluating bird-window collision prevention methods, because the effectiveness of treatments are compared in an environment like that of windows installed in actual buildings. Moreover, given the limitations of tunnel testing to simulate windows installed in human structures, we recommend field experiments with the protocol we report here be used to verify tunnel testing results to qualify for Pilot Credit 55 Bird Collision Deterrence used by the United States Green Building Council (2011) in their Leadership in Energy and Environmental Design (LEED) used to promote the construction of environmentally friendly structures.

The effectiveness of vertically hung parachute cords to deter bird collisions is attributable to the critical spacing between cords, and also as important is the placement of the cords over the surface facing the outside. Architects and other building professionals number the surface of windows from the outside inward such that surface number one is that surface facing the outside environment. Unlike the parachute cords, glass manufactures that produced the ORNILUX Mikado using UV signals and other patterns such as ceramic frit that uses dots, stripes or other more creative shapes that are also visible to the human eye are applied to interior surfaces of multi-pane windows as a means of protecting the collision deterring pattern from the weathering effects of the environment. The physical properties of light absorption, refraction, reflection, and transmission influence how humans, and almost certainly birds, perceive patterns applied to interior window surfaces (Knight 2013). Whenever interior lighting is equal to or of greater intensity to that of the outside environment, patterns applied to surfaces other than surface one will be visible to birds and humans looking at the window from the outside. Clear windows on either side of a corridor (link way) or where glass walls meet in the corners permit patterns on interior surfaces of windows to be visible when viewed from the outside. But when windows cover darkened interiors such that interior light is of less intensity than outside, surface one reflects the facing habitat and sky masking any patterns on interior window surfaces and rendering them ineffective in preventing bird strikes. Thus, like the parachute cords, methods used to prevent bird-window collisions at windows reflecting the facing habitat and sky that are applied to surface one will be most effective. Additional support of the importance of placing bird-window collision prevention methods on surface one are results of previously reported studies in which all external films applied to surface one, no matter what their visual appearance, reduced the risk of bird-window strikes by 59% or more (Klem 2009b).

## ACKNOWLEDGMENTS

We thank CPFilms, Solutia, Inc. and T. Port and B. Lawless-Coale specifically for measuring the UV signal from ORNILUX Mikado and the parachute cord, and discovering and reporting the error in UV signal measurement from the external films previously published (Klem 2009b, UV-reflection strength reported as 80% should read 20–40%). We thank C. Mathers and M. K. Erdman for collecting the individual flight path behavior, and J. D. Flood and M. Jacob for technical help interpreting the properties of sheet glass. We are especially grateful to Arnold Glas and Jeff Acopian for financial support and supplying samples of ORNILUX Mikado and Acopian BirdSavers for our experiments, respectively. We thank the anonymous reviewers and the Editors for extensive suggested modifications that markedly improved the manuscript. D. Klem, Jr. holds a patent (US 8,114,503 B2) on the critical spacing between elements forming a pattern to transform windows into barriers that birds will avoid. The authors and the Acopian Center for Ornithology at Muhlenberg College have no conflict of interest and have not and do not expect to receive any financial benefit from products described in this study.

## LITERATURE CITED

American Bird Conservancy. 2011. Tabular summary of tunnel testing results of bird-window collision deterrence. www.usgbc.orgShowFile.aspx?DocumentID=10649 (accessed 11 Jun 2012).

Arnold, T. W. and R. M. Zink. 2011. Collision mortality has no discernible effect on population trends of North American birds. PLoS ONE 6:e24708.

Bayne, E. M., C. A. Scobie, and M. Rawson-Clark. 2012. Factors influencing the annual risk of bird-window collisions at residential structures in Alberta, Canada. Wildlife Research. dx.doi.org/10.1071/WR11179 (accessed 24 Oct 2012).

Bean, M. J. 1983. The evolution of national wildlife law. Praeger, New York, USA.

Bennett, A. T. D. and I. C. Cuthill. 1994. Ultraviolet vision in birds: what is its function? Vision Research 34:1471–1478.

Bennett, A. T., I. C. Cuthill, J. C. Partidge, and E. J. Maier. 1996. Ultraviolet vision and mate choice in Zebra Finches. Nature 380:433–435.

Burkhardt, D. 1982. Birds, berries and UV. Naturwissenschaften 69:153–157.

Corcoran, L. M. 1999. Migratory Bird Treaty Act: strict criminal liability for non-hunting caused bird deaths. Denver University Law Review 77:315–358.

Drewitt, A. L. and R. H. W. Langston. 2008. Collision effects of wind-power generators and other obstacles on birds. Annals New York Academy of Sciences 1134:233–266.

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., USA.

Hager, S. B., B. J. Cosentino, and K. J. McKay. 2012. Scavenging affects persistence of avian carcasses resulting from window collisions in an urban landscape. Journal of Field Ornithology 83:203–211.

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 120:550–564.

Hunt, S., A. T. D. Bennett, I. C. Cuthill, and R. Griffith. 1998. Blue Tits are ultraviolet tits. Proceedings of Royal Society of London, Series B 265:451–455.

Klem Jr., D. 1981. Avian predators hunting birds near windows. Proceedings of the Pennsylvania Academy of Science 55:53–55.

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

Klem Jr., D. 1990. Collisions between birds and windows: mortality and prevention. Journal of Field Ornithology 61:120–128.

Klem Jr., D. 2006. Glass: a deadly conservation issue for birds. Bird Observer 34:73–81.

Klem Jr., D. 2009a. Avian mortality at windows: the second largest human source of bird mortality on earth. Pages 244–254 *in* Tundra to tropics: connecting birds, habitats and people, Proceedings of the Fourth International Partners in Flight Conference 2008 (T. D. Rich, C. Arizmendi, D. Demarest and C. Thompson, Editors). Partners in Flight, McAllen, Texas, USA.

Klem Jr., D. 2009b. Preventing bird-window collisions. Wilson Journal of Ornithology 121:314–321.

Klem Jr., D. 2010. Sheet glass as a principal human-associated avian mortality factor. Chapter 20 *in* Avian ecology and conservation: a Pennsylvania focus with national implications (S. K. Majumdar, T. L. Master, M. Brittingham, R. M. Ross. R. Mulvihill, and J. Huffman, Editors). Pennsylvania Academy of Science, Easton, USA.

Klem Jr., D., D. C. Keck, 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 116:69–73.

Knight, R. D. 2013. Physics for scientists and engineers: a strategic approach, 3rd Edition. Pearson, Glenview, Illinois USA.

Loss, S. R., T. Will, and P. M. Mara. 2012. Direct human-caused mortality of birds: improving quantification of magnitude and assessment of population impact. Frontiers in Ecology and the Environment 10:357–364.

Martin, G. R. 2011 Understanding bird collisions with man-made objects: a sensory ecology approach. Ibis 153:239–254.

Rossler, M. and T. Zuna-Kratky. 2004. Vermeidung von Vogelanprall an Glasflachen. Experimentelle Versuche zur Wirksamkeit verschiedener Glas-Markierungen bei Wildvogeln. Bilogische Station Hohenau-Ringelsdorf. www.windowcollisions.info (accessed 11 Jun 2012).

Siegel, S. 1956. Nonparametric statistics for the behavioral sciences. McGraw-Hill, New York, USA.

SPSS. 2010. SPSS for Windows, Version 19.0. SPSS, Chicago, Illinois, USA.

United States Green Building Council. 2011. Pilot Credit 55: bird collision deterrence. www.usgbc.org/ShowFile.aspx?DocumentID=10402 (accessed 11 Jun 2012).

Vitala, J., E. Korpimaki, P. Palokangas, and M. Koivula. 1995. Attraction of Kestrels to vole scent marks in ultraviolet light. Nature 373:425–427.