**STUDYING VARIOUS SPACIAL PATTERNS OF BIRD'S EYE VIEW WINDOW FILM AS A MEANS TO DETER OR PREVENT BIRD-WINDOW COLLISIONS[1]**

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## ABSTRACT (SUMMARY)

A field experiment replicating reflective windows installed in commercial and residential dwellings is used to evaluate the ability of Bird's Eye View (BEV) film elements applied in varying numbers (1, 2, 4, and 6) to multi-pane insulated glass to deter bird-window collisions. The number of BEV film elements applied to a window reduced the likelihood of a bird strike (made the window more bird safe) by 32 to 86%. More bird protection occurred with more film elements, four (BEV-4, separated by 21-34 cm or 8-13 in) and six (BEV-6, separated by *circa* 20 cm or 8 in) films reduced the risk of a strike by 86 and 83%, respectively. Notwithstanding the six film elements (BEV-P6), the greatest risk of a strike (68% compared to the control) occurred at the simulated dark-tinted window. Direct observations of the behavior of focal animals further supported these findings. Experimental results document the uniform application of BEV film separated by 8.3 in (21 cm) in horizontal rows and 13.4 in (34 cm) in vertical columns on the inner surface of windows reduce the risk of a bird strike by 86%. However, of the 71 flight paths documented for individual birds flying from the bird feeders that hit the control and test windows, 40 (56%) left no observable evidence that a strike occurred. Based on the direct observation data, BEV film may have alerted tracked focal animals to the presence of the hazard, resulting in avoidance or collision impacts with reduced force. This interpretation may explain the lower number of fatalities and the relatively large number of impacts leaving no evidence at the site of the strike (56% compared to 25-50% in previous studies).

## INTRODUCTION

Fundamental and recent descriptive summaries (Klem 1989, 1990, 2009a, 2009b, 2010, 2015, Klem and Saenger 2013, Loss et al. 2014) provide published peer-reviewed scientific evidence that clear and reflective windows are invisible, indiscriminate, unintended, and unwanted fatal hazards and a major source of human-associated avian mortality for specific species and birds in general. The objective is to quantitatively evaluate and confirm the effectiveness of various applications of spatial placement of discrete square window film to mitigate or eliminate bird-window collisions using established and effective field experimental techniques. The film is placed on either the outside (surface#1 or inside surfaces (surfaces#4, #6) of multi-pane insulated windows. The film projects a spectral reflective signal visible to birds and humans. A novel spectral component is absorption of 410 nm wavelength and emission to the outside at 440 nm. The reflective component in the near ultraviolet (UV) is hypothesized to be a complementary or principal component to alert birds to the presence of windows as a barrier to be avoided. This study evaluates the level of protection various numbers of Bird's Eye View (BEV) Window Film provide free-flying wild birds from collisions with windows.

## METHODS

Our field experiment was conducted on a 2-ha open rural area of mowed pasture bordered by second growth deciduous forest and shrubs in Henningsville, Berks County, Pennsylvania, USA (40$^{o}$ 27’ 53” N, 075 $^{o}$ 40’ 07” W). The experimental design was reported previously (Klem 1989, 1990, 2009a, Klem and Saenger 2013). All windows were clear covering a matted black non-reflecting background simulating sheet glass covering a darkened room, and placed in the same habitat oriented in the same direction 1 m (3.3 ft) from a tree-shrub edge facing an open field (Figure 1). Each window measured 1.2 m (4.0 ft) wide by 0.9 m (3.0 ft) high and was mounted 1.2 m (4.0 ft) above ground. Plastic mesh trays were placed under each window to catch casualties. Six window units were used in the experiment, and were separated by 2.4 m (8.0 ft). A single platform feeder measuring 61.0 cm (24.0 in) on a side and 1.2 m (4.0 ft) above ground mounted on wooden-legs centered and placed 10 m (33.0 ft) in front of each window to simulate a feeding station at a rural commercial or residential building. Feed consisted of 1:1 mixture of black-oil sunflower seeds and white proso millet. All feeders were kept full throughout the experiment. No window type was positioned at the same location on consecutive days, and each window tested was randomly assigned and moved to a new location daily. Windows are checked and changed each day 30 min before last light, and checked again in the morning and at varying times throughout the day. Windows were covered with opaque tarps and not monitored during inclement weather such as high winds, rain, or snow.

The parameter (criterion) measured 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. The data are likely incomplete and conservative because a previous study where continuous monitoring occurred found that without continuous monitoring minimally 25% of strikes went undetected, leaving no evidence of a collision (Klem 2009a). Predators and scavengers also are known to remove the dead and injured collision victims (Klem et al. 2004, Hager et al. 2012), making specimens unavailable for detection and collection. The length of the experiment was determined by the number of recorded strikes required statistically to evaluate the differences between treatments. The experimental period occurred during non-breeding and migratory periods (some species), but previous studies indicate no seasonal differences in the ability of birds to avoid windows (Klem 1989).

Figure 1. Wooden-framed experimental structure with treatments (control and varying numbers of BEV film elements) in rural Henningsville, Berks County, Pennsylvania, USA); photographed Sunday 3 January 2016 by P. G. Saenger.

The experiment was conducted over 48 days from Sunday 3 January to Thursday 31 March 2016. The experiment tested five experimental treatments. Four treatments varied by the number of 4 x 4 inches (10.2 x 10.2 cm) BEV film elements that were applied to the inner surface (surface #4) of a two pane insulated window. A fifth treatment was modified by applying a darkened performance film that uniformly covered the interior (surface #4) of the pane to simulate a dark-tinted window with BEV film elements behind and also simulating being attached to the inner surface (surface #4). To the human eye, all windows (Control and five treatments) offered varying degrees of image quality throughout the day of facing habitat and sky, and treatment panes exhibited varying degrees of BEV film element visibility (see Figures 2, 3). The window treatments tested were the following.

1. Control - (C-R), Clear pane offering a reflective effect of facing habitat and sky simulating a view of a clear window covering a darkened interior space from a brighter outdoors (Figures 2a, 3a).

2. BEV-1, One Bird’s Eye View film element placed in the center of the window. (Figures 2b, 3b).

3. BEV-2, Two Bird’s Eye View film elements placed in the center of the window, separated by 14 inches (35 cm) (Figures 2c, 3c).

4. BEV-4, Four Bird’s Eye View film elements placed in the center of the window, separated by 8.3 inches (21 cm) vertically and 13.4 inches (34 cm) horizontally (Figures 2d, 3d).

5. BEV-6, Six Bird’s Eye View film elements placed in the center of the window, separated by 8.3 inches (21 cm) vertically and 8 inches (20 cm) horizontally (Figures 2e, 3e).

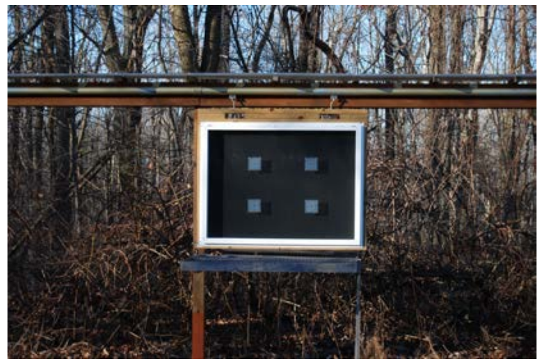
6. BEV-P6, Six Bird’s Eye View film elements placed in the center of the window and over a dark-tinted performance film, separated by 8.3 inches (21 cm) vertically and 8 inches (20 cm) horizontally (Figures 2f, 3f).

The relative spectral details of light intensity and sensitivity and their interpretation are from Artscape staff and associates and Professor of Chemistry Steven G. Mayer of the University of Portland (Figures 4 and 5). Artscape marketing statements describing these spectra are that “Bird’s Eye View film absorbs light peaking at 410 nm and reemits the light peaking at 450 nm. Bird vision extends well into the ultraviolet range and is near maximum sensitivity at 450 nm whereas; human vision is only about 7% of maximum sensitivity at 450 nm. To birds, the Bird’s Eye View film presents a bright blue glow spreading out in all directions across the window surface disrupting the reflection of habitat but to humans, it appears as a faint white pattern on the window surface.” (Figures 4 and 5).

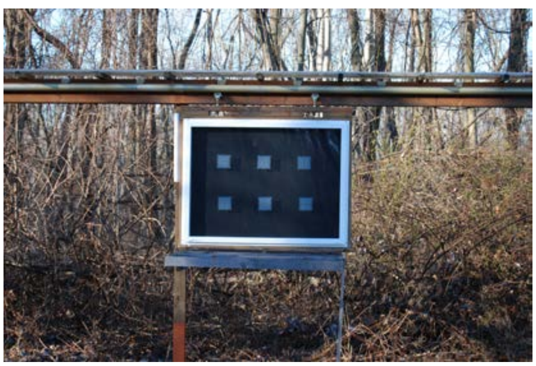
a. Control-(C-R)

b. Artscape BEV-1

c. Artscape BEV-2



d. Artscpae BEV-4



e. Artscape BEV-6

f. Artscape BEV-6P with uniform covering of dark-tinted performance film

Figure 2. Control and experimental treatments by number of Bird's Eye View (BEV) film elements applied to interior surface (surface#4) of window, photographed in early morning direct sunlight; one treatment (BEV-P6) also has a dark-tinted performance film uniformly applied to interior surface (surface#4) Photographs by P. G. Saenger.

a. Control-(C-R)

b. Artscape BEV-1

c. Artscape BEV-2

d. Artscpae BEV-4

e. Artscape BEV-6

f. Artscape BEV-6P with uniform covering of dark-tinted performance film

Figure 3. Control and experimental treatments by number of Bird's Eye View (BEV) film elements applied to interior surface (surface#4) of window, photographed in early evening indirect sunlight; one treatment (BEV-P6) also has a dark-tinted performance film uniformly applied to interior surface (Surface#4) Photographs by P. G. Saenger.

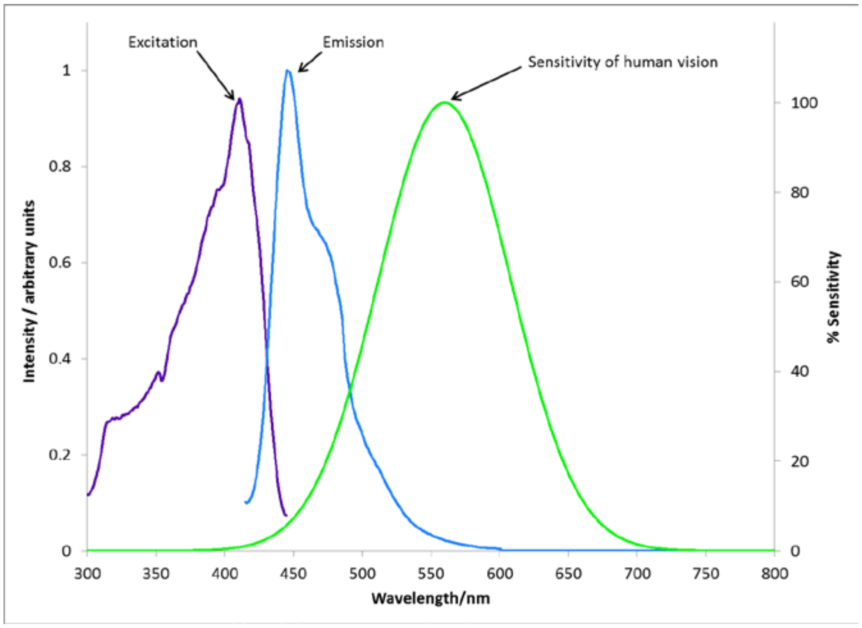



Figure 4. Spectroscopic data showing the range of light absorbed (excitation) and the light emitted (emission) by the Bird's Eye View film. The green curve shows the approximate spectral response of the human eye. Legend and graph by Steven G. Mayer, Professor of Chemistry, University of Portland, Portland, Oregon.

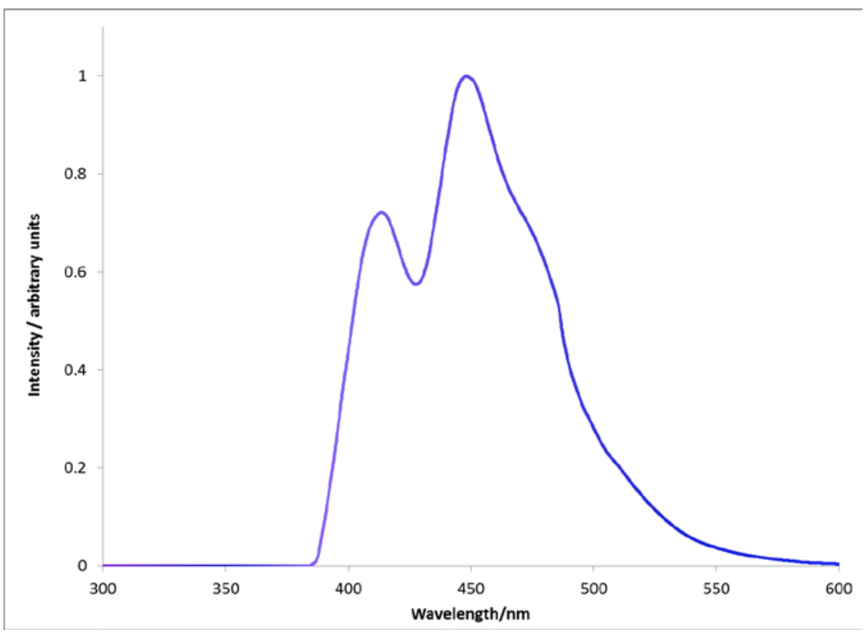



Figure 5. The spectrum that results from 410 nm light striking glass with Bird's Eye View film affixed to the back. The peak at 410 nm is the result of incident light reflecting off the surface of the glass and the peak at 450 nm is the result of light being emitted by the Bird's Eye View film. Legend and graph by Steven G. Mayer, Professor of Chemistry, University of Portland, Portland, Oregon.

Additionally, a total of 50 hours of separate periods of four to six hours each of continuous observation from a blind (hide) were conducted over seven days from Monday 1 February to Thursday 31 March 2016 to record individual flight paths exhibiting avoidance or non-avoidance behavior associated with each window type (control and BEV film treatments).

The experimental protocol was approved by Muhlenberg College Institutional Animal Care and Use Committee (IACUIC); Institutional Animal Research Form (IARF) approval number 1201. Birds killed during the study were salvaged under state (Wildlife Collecting permit number 21168, Pennsylvania Game Commission) and federal (Scientific Collecting permit number MB737465-0, U.S. Fish and Wildlife Service, Migratory Bird Permit Office – Region 5) permits, and deposited in the bird museum, Acopian Center for Ornithology, Department of Biology, Muhlenberg College. I used SPSS (SPSS Inc. 2012) for the statistical analysis. Chi-square ($\chi^2$) goodness-of-fit was used to compare the frequency of strikes among treatments (number of strikes per window type compared to a uniform distribution across all window types), and the test result was considered statistically significant when $P < 0.05$ (Siegel 1956).

## RESULTS

A total of 224 strikes were recorded in the experiment; nine (4%) were fatal. The Control (C-R) and all experimental panes (BEV-1 to BEV-P6) were uniformly represented at each unit location (position) to ensure and account for no unit location (position) bias ($\chi^2 = 8.821$, df = 5, $P < 0.116$). The number of strikes differed significantly across all treatments with 77 (34%) at C-R (Control-1), 33 (15%) at BEV-1, 38 (17%) at BEV-2, 11 (5%) at BEV-4, 13 (6%) at BEV-6, and 52 (23%) at BEV-P6 ($\chi^2 = 82.857$, df = 5, $P < 0.001$; Figure 6). Of the nine fatal strikes: 3 (33%) occurred at C-R (Control), 2 (22%) at BEV-1, 3 (33%) at BEV-2, and 3 (33%) at BEV-P6. Species numbers and treatment at which fatalities occurred were: three Dark-eyed Junco (*Junco hyemalis*) at C-R, two Dark-eyed Junco at BEV-1, two Dark-eyed Junco and one House Sparrow (*Passer domesticus*) at BEV-2, and one Brown-headed Cowbird (*Molothrus ater*) at BEV-P6 (Figure 6).

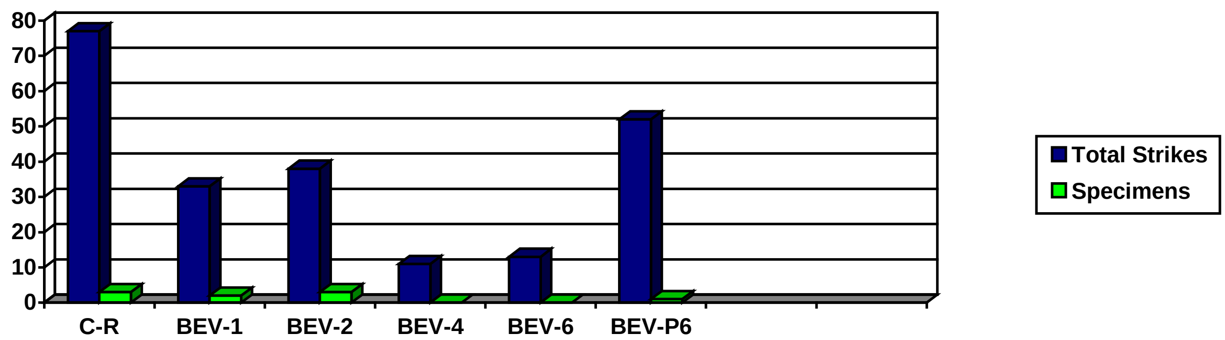



Figure 6. . Bar graph of the number of total bird collisions at each window treatment (see text for detail).

A total of 178 flight paths were documented for individual birds flying from the bird feeders to the experimental windows. A total of 30 flight paths were recorded for C-R (Control) and of these 20 (67%) resulted in a strike and 10 (33%) were seen to actively avoid striking the window. Results from the other test panes are: for BEV-1 of 20 flight paths recorded 10 (50%) were strikes and 10 (50%) were avoidances; for BEV-2 of 28 flight paths recorded 9 (32%) were strikes and 19 (68%) were avoidances, for BEV-4 of 27 flight paths recorded 2 (7%) were strikes and 25 (93%) were avoidances, for BEV-6 of 32 flight paths recorded 8 (25%) were strikes and 24 (75%) were avoidances, and for BEV-P6 of 41 flight paths recorded 22 (54%) were strikes and 19 (46%) were avoidances (Figure 7).

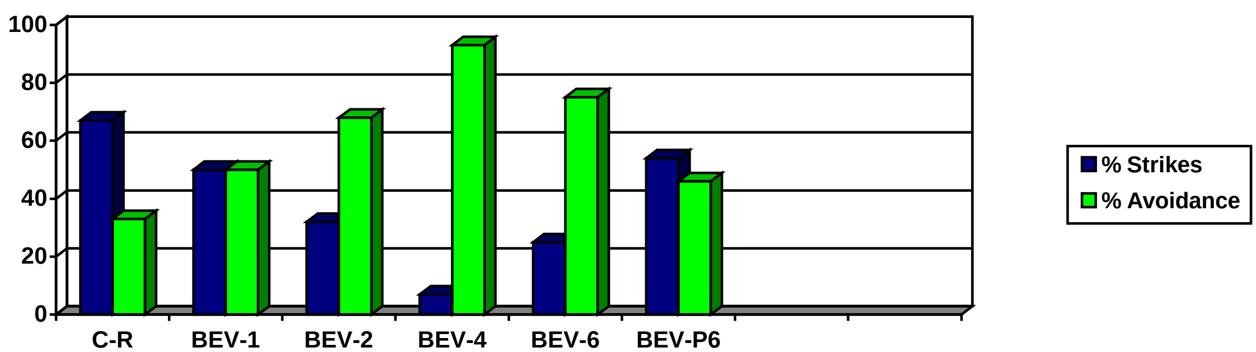



Figure 7. Bar graph of percentage (%) of strikes and avoidances of 178 flight paths documented for individual birds flying from bird feeders to each window type (see text for detail).

a. Bird strike body smudge remnant on BEV-1 in indirect evening sunlight.

b. Bird strike body smudge remnant on BEV-2 in indirect evening sunlight.

c. Bird strike body smudge remnant on BEV-P6 in direct morning sunlight.

Figure 7. Bird strikes adjacent to (a, b) and between (c) Bird's Eye View (BEV) film elements.

Of the 71 flight paths documented for individual birds flying from the bird feeders that hit the control and test windows, 40 (56%) left no observable evidence that a strike occurred.

## DISCUSSION

As expected, most strikes occurred at the clear glass control offering an unobstructed reflective image of the facing field habitat and sky. In comparison to the control, the reduced risk to birds having the varying number of BEV films are: (1) 57% for BEV-1, (2) 51% for BEV-2, (3) 86% for BEV-4, (4) 83% for BEV-6, and (5) 32% for BEV-P6. Stated another way, the number of BEV film elements applied to a window 0.9 x 1.2 m (3 x 4 ft) reduced the likelihood of a bird strike (made the window more bird safe) by 32 to 86%. More bird protection occurred with more film elements, four (BEV-4, separated by 21-34 cm or 8-13 in) and six (BEV-6, separated by *circa* 20 cm or 8 in) films reduced the risk of a strike by 86 and 83%, respectively. The treatment (BEV-P6) simulating a dark-tinted window offered the greatest threat by modestly reducing the risk of a strike by 32 % compared to the control. The direct observation of focal animals further validated these results. Based on previous studies and the evidence of strikes immediately adjacent to film elements in this experiment, applications of BEV films that uniformly cover a window such that they are separated by 5 cm (2 inches) if oriented horizontally and 10 cm (4 inches) if oriented vertically will eliminate collisions entirely (Klem 1990, 2009a). Additionally, there is strong experimental evidence in this study that uniform application of BEV film separated by 8.3 in (21 cm) in horizontal rows and 13.4 in (34 cm) in vertical columns on the inner surface of windows reduce the risk of a bird strike by 86%. Although this experiment cannot confirm or reveal the direct detailed affect (influence) on avian perception and behavioral response, the results document significant deterrence indirectly by avoidance response that may be directly attributable to the unique spectral signature in the near UV (absorbing light peaking at 410 nm and reemitting at 450 nm). The documented deterrence is especially impressive because the results indicate birds are perceiving and reacting to BEV film placed on the inner surface of the treatment windows. Applications on surface #1 are expected to offer even greater deterrence because of expected increased visibility, markedly increasing the deterrence effect for the simulated dark-tinted window treatment (BEV-P6) where the film would be visually distinct and not masked by surface #1 reflection documented in these results. Based on the direct observation data, BEV film may have alerted tracked focal animals to the presence of the hazard, resulting in avoidance or collision impacts with reduced force. This interpretation may explain the low number of fatal strikes and the relatively large number of impacts leaving no evidence at the site of the strike (56% compared to 25-50% in previous studies).

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