A REVIEW OF EXPERIMENTAL METHODS USED TO TEST THE EFFECTIVENESS OF BIRD-DETERRING GLASS

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1. INTRODUCTION

Conventional glass used in the construction of homes, commercial buildings, and roadside sound barriers is imperceptible to birds and believed to be one of the largest anthropogenic sources of bird mortality. Birds collide with glass when attempting to fly towards habitat or sky seen either through the glass, or reflected on its surface. All strategies to prevent or reduce bird collisions with glass have the ultimate goal of making glass recognizable to birds as a solid barrier. Strategies range from opaque markings added to the surface of, or imbedded within, conventional glass, to alternative glass materials that absorb and/or reflect ultraviolet (UV) light. The latter strategy stems from the unique ability of birds to see UV light, which humans cannot. In theory, glass that reflects and/or absorbs UV light should be more recognizable to birds as a solid barrier than conventional glass, while remaining generally translucent in appearance to humans.

Researchers in the US and Europe have in recent years attempted to measure the effectiveness of window retrofitting techniques and alternative glass types for reducing bird collisions. Experimental methods among studies share many similarities but also differ in a number of ways. This report summarizes the main methods used in experimental studies of bird collisions with glass and subsequently discusses their primary strengths and shortcomings.

2. METHOD SUMMARIES

2.1. Ley (2007)

- Flight tunnel with two side by side glass types positioned in escape path of bird
- Dichotomous choice experiment
- Tunnel operated indoors at Max Planck Institute for Ornithology
- Glass front- and back-lit
- Artificial front-lighting from inside tunnel; mix of artificial and natural back-lighting outside tunnel
- Mist net suspended in front of glass
- Locally captured wild passerines used as study subjects
- Multiple species used as study subjects
- Individuals tested only once
- Sample sizes ranged 18 -105 flights for each glass type tested
- Birds attempting to fly towards what is seen through the glass (as opposed to a reflection on the glass surface)
- Background/habitat beyond glass panels unknown

2.2. Ley and Fiedler (2010)

- Outdoor study of free-flying birds in a German field
- Natural lighting; glass back- and front-lit

- Separate analyses of data collected during sunny and cloudy weather conditions
- Dichotomous choice experiment
- Two panels of conventional glass and two panels of Ornilux positioned side by side between bird feeder in an open field and woodland edge habitat
- Mist net suspended in front of glass panels
- Multiple species observed
- Some individuals likely observed more than once
- Continuous observation throughout experiment; number of flights towards left side panels compared to right side panels
- Sample sizes ranged 68 – 89 flights per weather category
- Birds presumably attempting to fly from feeder towards woodland habitat seen through the glass (as opposed to a reflection of the field and the feeder on the glass surface)

2.3. Rössler et al. (2007)

- Flight tunnel with two glass types positioned in escape path of bird
- Dichotomous choice experiment
- Tunnel operated outdoors near ringing station in Austria
- Natural lighting; experiments conducted on days with various lighting conditions
- Dual mirrors used to reflect sunlight onto front of glass (i.e., side facing bird) so glass front- and back-lit
- Tunnel rotated to keep its position relative to the sun consistent over time
- Sensors used to record lighting characteristics around tunnel and reflectance levels of glass panels throughout experiments
- Mist net suspended in front of glass
- Locally captured wild passerines used as study subjects
- Multiple species used as study subjects
- Individuals tested only once
- Sample sizes ranged 72-90 flights per test
- Birds attempting to fly towards what is seen through the glass (as opposed to a reflection on the glass surface)
- Background a mixture of field edge vegetation and sky

2.4. Klem (2009)

Field experiments

- Outdoor field study of free-flying birds in Pennsylvania, USA
- Natural lighting; glass front- and back-lit
- 1.2 m x 0.9 m wood-framed windows placed along field edge bordering woodland

- Not dichotomous choice; 3-7 window types tested simultaneously and relative collision frequency compared
- Conventional, clear glass included among window types in each trial to serve as a control
- Feeders placed 10 m opposite windows in the open field
- Birds presumably attempting to fly from feeder towards woodland seen through glass (as opposed to a reflection of the field and the feeder on the glass surface)
- No mist net in front of windows
- The number of casualties found daily in trays beneath windows and evidence of collisions on window surfaces (e.g., feathers, smudges) used to tally total collisions with each window
- Multiple species represented
- N=85 total strikes per trial, on average (3-7 glass types/trial)

Flight tunnel experiments

- Flight tunnel with one half of a bird's escape path obstructed by glass or deterrent objects tested, and the other half left as open air space
- Dichotomous choice experiment
- Tunnel operated outdoors in Pennsylvania, USA
- Natural lighting; experiments conducted on days with various lighting conditions
- Glass back-lit only
- No mist net
- 7 locally captured passerines held in captivity and used as study subjects; 5 of 7 individuals of the same species
- Individuals tested repeatedly (≥10 flights per individual per experiment)
- N=50-100 total flights per experiment

2.5. American Bird Conservancy / Powdermill Avian Research Center (in progress)

- Flight tunnel with two glass types positioned in escape path of bird
- Dichotomous choice experiment
- Tunnel operated outdoors at ringing station in Pennsylvania, USA
- Natural lighting; experiments conducted on days with various lighting conditions
- Dual mirrors used to reflect sunlight onto front of glass (i.e., side facing bird) so glass can be front- and back-lit
- Tunnel rotated to keep position relative to the sun constant over time
- Mist net suspended in front of glass
- Locally captured wild passerines used as study subjects

- Multiple species used as study subjects
- Individuals tested only once
- Birds attempting to fly towards what is seen through the glass (natural habitat in some tests, artificial background with various patterns in others)
- Some experiments conducted with glass only front-lit, others with glass front- and back-lit

2.6. Leiser (2010)

- Flight tunnel with two glass types positioned in escape path of bird
- Dichotomous choice experiment
- Tunnel operated outdoors at ringing station in Russia
- Natural lighting
- Non-rotating
- Glass back-lit only
- Mist net suspended in front of glass
- Locally captured wild passerines used as study subjects
- Multiple species used as study subjects
- Individuals tested only once
- Birds attempting to fly towards what is seen through the glass (natural background; habitat not described)

3. DISCUSSION

The greatest differences among experimental methods arise from the use of a flight tunnel or the placement of glass in open habitat of free-flying wild birds. Both approaches are valid and have advantages and disadvantages, and ultimately neither one is overwhelmingly superior to the other. There are also important differences among flight tunnel studies and among field studies that deserve consideration and are discussed below.

3.1. Study species

Countless bird species belonging to multiple Orders have been documented colliding with glass, and thus there appear to be no taxonomic differences in the inability of birds to recognize glass as a solid barrier. However, species differences in the effectiveness of various collision reduction methods could very well exist. For example, the effectiveness of opaque lines or other markings spaced across a window's surface could differ among bird species of different body size, as a given spacing interval would leave different sized openings relative to different sized birds. Different flying behaviors among species could also influence the effectiveness of opaque markings, as highly maneuverable species (e.g. swallows) might be more apt to attempt to fly between markings when others would swerve away from the area altogether. For such reasons it might be beneficial to include as many species in collision experiments as is feasible. The benefits of testing numerous species, however, must be weighed against the costs of having smaller sample sizes per species than studies involving only one or a few species.

Differences in the visual perception of UV light among taxonomic groups of birds (Osorio et al. 1999) could also result in species differences in the effectiveness of UV absorbing and/or reflecting materials. Among passerine species, however, UV perception is likely similar (Osario et al. 1999). Passerines comprise the largest Order of birds (Gill 1995) and appear to be the most common victims of window collisions (Dunn 1993, Klem 2009). Perhaps collision reduction efforts and evaluations of their effectiveness should therefore remain targeted towards passerines.

3.2. Sample size

Large sample sizes are important for robust statistical analyses of data. Flight tunnels operated near ringing stations (e.g. Rössler et al. 2007) provide the opportunity to obtain large sample sizes in less time than field studies, in which collision data are more opportunistically collected and constrained by the chance that free-flying birds will fly towards glass panels (e.g. Klem 2009, Ley and Fiedler 2010). Sample sizes obtained from flight tunnels can be large enough to separately examine relationships between glass type effectiveness and variables such as weather conditions, front and back lighting intensity and contrast, and species (e.g. Rössler et al. 2007). Smaller sample sizes obtained from field studies generally require data to be pooled, thereby prohibiting identification of potential covariates that could significantly influence the effectiveness of glass types. Prospective power analyses are worthwhile for determining in advance of any collision study the sample size that will be necessary to achieve a desirable effect size.

3.3. Background

It is likely that the degree of contrast between collision deterrents and the background largely determines their effectiveness, whether they are opaque markings or UV absorbing/reflecting materials. The background behind test panes is therefore an important variable to consider in experiments. Most experiments have used natural backgrounds, including woodland vegetation, open field, and a mix of vegetation and sky. Perhaps more important than what habitat type is used as a background, or whether a natural or artificial background is used, is that some form of consistency is maintained among future studies. Use of different background types weakens the comparability of results and replicability of studies.

3.4. Representation of real world conditions: See-through vs. reflection

A potentially large weakness of the studies conducted to date is their inability to create conditions in which birds are attempting to fly towards habitat reflected on the surface of glass, instead of what is seen beyond the glass. Scenarios in which birds attempt to fly towards habitat or sky on the other side of glass are largely limited to roadside sound barriers. Collisions with building windows are most often the result of birds attempting to fly towards habitat reflected on the glass surface. Yet, no experiment has directly tested the effectiveness of deterrents and alternative materials for preventing birds from flying towards reflections on the glass surface. Experiments conducted to date are therefore most representative of sound barrier collisions, and how well their results translate to prevention of collisions with traditional windows is uncertain.

Reflecting sunlight on to the surface of glass panels in flight tunnel studies (e.g., Rössler et al. 2007, ABC/PARC) at least allows markings to receive strong front lighting and partially compensates for the lack of a habitat reflection. Tunnel studies in which glass is only back-lit (e.g. Klem 2009) are discouraged, as they present conditions that are farthest from real world window collision scenarios. Rarely are bird collisions with windows the result of birds attempting to fly inside a house or building.

Field studies of free-flying birds (e.g. Ley and Fiedler 2010) have presented conditions in which glass is front and back-lit to varying degrees of contrast by natural lighting. It is unclear how often the glass panes in these studies are strongly reflecting habitat versus appearing translucent. Lighting from both sides likely reduces the reflectance of the glass and presumably most collisions in these studies are the result of birds attempting to fly towards habitat seen through the glass, as opposed to habitat reflected on the surface. This scenario is again more representative of sound barriers than building windows.

Studies in which birds fly towards glass that reflects opposing habitat would provide the most realistic tests of the effectiveness of Ornilux and related UV reflecting/absorbing glass intended for homes and buildings. This could be achieved by pairing Ornilux and other alternative glass types with conventional glass on the same building, but the feasibility of this may be low. Moreover, sample sizes would be small, as collision data would have to be opportunistically collected and would be constrained by the chance that free-flying birds fly towards the windows of interest. Flight tunnels with sunlight-reflecting mirrors that provide strong front lighting offer perhaps the next closest representation of real world scenarios in which birds fly towards window reflections of habitat and sky, while also providing large sample sizes. Comparisons of flight tunnel results to real buildings that feature both conventional glass windows and windows with collision deterrents could provide interesting and informative ground-truthing of tunnel experiments.

3.5. Individual differences among flight tunnel study subjects

Most flight tunnels have been operated in association with local ringing stations (e.g. Rössler et al. 2007, Leiser 2010, ABC/PARC). In such studies, birds captured at the ringing station are put through the flight tunnel once and then released. This provides data from numerous individuals and multiple species. In contrast to these studies, Klem (2009) used a small group of captive birds for flight tunnel experiments. Seven individuals representing three species were tested repeatedly over the course of several weeks. The disadvantage of this approach is that such a small sample of individuals may not be sufficiently representative of the species as a whole. It is possible that different individuals, even of the same species, respond differently to the same flight tunnel tests. These individual differences are actually quite apparent in Klem's (2009) results. Among only five Dark-eyed Juncos, the same patterns significantly deterred some individuals while hardly deterring others. As such, studies using captive birds will require much larger populations to properly account for behavioral differences that can exist among individuals.

3.6. Migrants vs. residents

Most birds tested in flight tunnel studies at ringing stations are migrating birds, whereas outdoor studies of free-flying birds that rely on feeders to draw birds into the study area primarily involve year-round residents. However, there is no reason to expect migratory and resident birds to inherently differ in their perception of glass and collision deterrents, as both types of birds are common victims of collisions (Klem 1989, Dunn 1993, Blem and Willis 1998).

3.7. Decreases in local bird abundance during lethal field studies

Klem (2009) placed multiple glass types, including conventional glass, in a field and compared the relative number of birds that collided with each. No mist net was used and windows were not continuously observed in most experiments; daily collections of dead birds beneath windows and window smudges were used to tally collisions. Experiments were sometimes conducted over several months and killed up to 20 birds. In addition, some birds may have experienced non-lethal collisions and learned to avoid approaching the windows again (effectively removing them from the local population). As the absolute number of collisions in this type of study is likely a function of the abundance of birds in the surrounding area, one might argue that reductions in the number of birds in the surrounding area throughout the study resulting from the lethal methodology and avoidance learning would bias comparisons of collision totals across days and weeks. However, the small number of birds killed in each experiment (2 - 20) likely had a negligible effect on the abundance of birds inhabiting the surrounding area. Moreover, the protocol included conventional glass among the array of glass types tested every day. This allowed absolute numbers of collisions with alternative glass types on any given day to be interpreted *relative* to the collisions with conventional glass on the same day. As such, any gradual decreases in the abundance of birds surrounding the study area caused by the lethal collisions or learning effects would not affect comparisons of results across a multiple week study period.

3.8. Free vs. forced flights

An advantage of flight tunnels is they allow researchers to obtain large sample sizes by forcing birds to fly towards glass. In field studies of free-flying birds, researchers attempt to draw birds to the study area with feeders, but sample sizes are still constrained by the need for birds to fly on their own free will towards test glass. Supporters of field studies might argue that the high stress level of a bird in a flight tunnel impairs its visual perception of objects and biases its flight direction towards the tunnel exit. Yet, there is no basis to expect that birds flying under duress and away from a threat have a reduced ability to discriminate solid objects from open air space. Moreover, many collisions with windows occur when panicked birds flee from predators (Klem 1981, Dunn 1993). Thus, flights of birds through tunnels might be quite representative of the “panic flights” (*sensu* Dunn 1993) that so commonly lead to fatal window collisions in the real world.

4. CONCLUSION

Each of the experimental methods employed to date have many features in common while also having unique strengths and weaknesses. Each is valid and no one method can be said to be clearly superior to the others. However, as researchers undertake studies of their own collision solutions or commercial products such as Ornilux, a large degree of consistency among studies will be necessary for researchers to make meaningful comparisons of results. Rarely in science is there one universally approved and adopted method for a given type of research, and every method has proponents and critics. Tests of bird collision deterrents are likely no different. Yet, adoption of a standard testing method would allow for the most rapid progress towards a solution to the important problem of bird collisions with glass. The *relative* efficiency of different collision deterrents is what is most important to initially determine. It is the writer’s opinion that flight tunnels with the ability to illuminate glass from the front with natural light provide the greatest opportunity for consistent and replicable studies of the relative efficiency of different bird-safe glass designs. The designs identified by such studies to be the most effective can then be applied to buildings on a small scale to ground-truth flight tunnel results in a real word setting.

It should be noted that neither flight tunnels nor any other methodology put forward so far have been able to fully mimic habitat reflection scenarios which are likely the cause of most window collisions in the real world. Observational studies of buildings featuring different glass types would be severely constrained by small sample sizes and an inability to hold other important variables constant, such as lighting/weather conditions, type of habitat reflected, and abundance of birds in the surrounding area. Flight tunnels that direct natural sunlight onto the surface of test glass are unable to present reflections of habitat to birds, but they at least create conditions with strong front-lighting. Although such studies cannot fully imitate natural conditions, they provide the data necessary to narrow down numerous deterrent types to just the most relatively efficient ones which can then be more feasibly ground-truthed on real houses or buildings.

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