BIRD-WINDOW COLLISIONS: FIELD TESTING A POTENTIAL SOLUTION AND EVALUATING STAKEHOLDER PERCEPTIONS

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Title of Study: BIRD-WINDOW COLLISIONS: FIELD TESTING A POTENTIAL SOLUTION AND EVALUATING STAKEHOLDER PERCEPTIONS

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Abstract: Bird-window collisions are a major source of human-caused avian mortality for which there are multiple mitigation and prevention options available. Despite growing availability of products designed to reduce collisions, few replicated field tests have been conducted. Such tests are crucial to assessing effectiveness of products in real-world situations after installation on glass. The widespread adoption of available mitigation and prevention approaches, which is ultimately necessary to reduce bird-window collisions, also relies on understanding human perceptions. To address these research needs imperative to reducing this major source of avian mortality, we conducted two studies.

First, we conducted a well-replicated field study to evaluate the effectiveness of a commercially marketed product (Feather Friendly® markers) in reducing bird-window collisions at glass-walled bus shelters in Stillwater, Oklahoma, USA. This study included a before-after control-impact (BACI) analysis comparing numbers of collisions at 18 bus shelters in both pre-treatment (2016) and post-treatment (2020) periods, and an analysis comparing 18 treated and 18 untreated shelters during 2020. Both analyses found that the treatment was highly effective and together, these analyses provide a rigorous field test of the effectiveness of this treatment option in reducing bird-window collisions.

Second, we investigated stakeholder perceptions and priorities related to bird-window collision mitigation and prevention. Specifically, we used a strengths, weaknesses, opportunities, and threats (SWOT) – Analytic Hierarchy Process (AHP) framework to learn more about the most effective ways to engage the public in helping to reduce bird-window collisions. Our results demonstrate that respondents from two stakeholder groups, homeowners and conservation practitioners, have an overall positive perception toward reducing bird-window collisions and that they believe the benefits of implementing mitigation and prevention techniques outweigh obstacles that may impede such measures. Our results indicate that the public may be receptive to education on this issue and that targeted and active education may be successful in garnering public support for and participation in bird-window collision mitigation and prevention.

Together, these two studies help make substantial progress in mitigating and preventing bird-window collisions.

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CHAPTER I

TESTING THE EFFECTIVENESS OF WINDOW MARKERS IN DETERRING BIRD-WINDOW COLLISIONS: A BACI STUDY

Abstract

Bird-window collisions are a major source of human-caused avian mortality for which there are multiple mitigation and prevention options available. Despite growing availability of products designed to reduce collisions (e.g., glass with etched or inlaid patterns and markers and films adhered over existing glass), few replicated field tests have been conducted to assess their effectiveness after installation on glass. We conducted a well-replicated field study to evaluate the effectiveness of a commercially marketed product (Feather Friendly® markers) in reducing bird-window collisions at glass-walled bus shelters in Stillwater, Oklahoma, USA. This study included a before-after control-impact (BACI) analysis comparing numbers of collisions at 18 bus shelters in both pre-treatment (2016) and post-treatment (2020) periods, and an analysis comparing 18 treated and 18 untreated shelters during 2020. For the BACI analysis, collisions, were significantly reduced between 2016 and 2020 at shelters treated with the Feather Friendly® markers even though collisions increased at shelters that remained untreated. For the 2020 analysis, there were significantly fewer collisions at treated than untreated shelters. Relative to a baseline study in 2016, we estimated that treating half of

Stillwater's bus shelters resulted in a 64% reduction in total annual bird collisions. Together, these analyses provide a rigorous field test of the effectiveness of this treatment option in reducing bird-window collisions. Our research provides a model for similar studies at both bus shelters and buildings to evaluate and compare products designed to reduce bird-window collisions, and therefore, contribute to reducing this major mortality source affecting bird populations.

Introduction

As humans continue to alter landscapes, wildlife face increasing threats associated with human activities. These include indirect threats like habitat loss and climate change and numerous sources of direct mortality. For birds, collisions with manmade structures like power lines, communication towers, wind turbines, and buildings are a major source of direct, anthropogenic mortality (Erickson et al. 2005; Calvert et al. 2013; Loss et al. 2015). Bird collisions with buildings and their windows are a top source of avian mortality worldwide, with between 365 and 988 million annual deaths in the United States alone (Loss et al. 2014). Birds collide with glass due to their inability to perceive it as a barrier, which results from its reflective and transparent qualities (Klem 1989).

Many studies have identified temporal and spatial correlates of bird-window collisions that give insight into development of approaches to reduce collisions. For example, the amount of artificial light emitted from and near buildings at night has been found to correlate with numbers of collisions, due to light attracting and confusing nocturnally migrating birds (Evans Ogden 1996; Horton et al. 2019; Lao et al. 2020). This finding has informed recommendations to reduce lighting during key bird migration periods. Identification of temporal correlates of collisions, such as variation in weather and bird migration traffic rate (Loss et al. 2020; Elmore et al. 2021), allow targeting of collision management (e.g., lighting reduction) in time. Studies finding that collisions are influenced by vegetation around buildings (Klem et al. 2009; Cusa et al. 2015; Loss et al. 2019) have led to recommendations about managing the amount, presence, and height of nearby vegetation. Finally, the many studies showing that numbers of collisions increase with amounts of glass on structures (Hager et al. 2013; Kahle et al. 2016; Barton et al.

2017; Riding et al. 2020) have led to development of several technologies and products designed to break up large expanses of reflective and/or transparent glass to make it more visible to birds. These include glass with built-in features (e.g., etched patterns or UV light-reflecting strips), plus films, markers, decals, and other products that adhere to or cover glass to increase the likelihood that birds will perceive it as a barrier.

Researching the effectiveness of products designed to reduce glass reflectivity and transparency is a crucial step in reducing bird-window collisions. Such research can increase applicability and marketability of these products and determine if they require adjustments to be optimally effective. Collision-reducing products have primarily been studied in controlled settings outside of the context of buildings. One commonly used approach is tunnel testing, which uses a flight tunnel that gives birds a choice between flying toward a glass pane treated with the focal product and an untreated pane (birds are recaptured unharmed before reaching the glass; Rössler et al. 2015; Sheppard 2019). This approach tests a treatment's effectiveness in reducing glass transparency, but may not necessarily give an indication of how birds will respond with added reflectivity effects and building-related cues. Another approach involves field experiments using sheets of glass placed in open areas (Klem 1989; 1990; 2013), which captures transparency and reflectivity effects but without the context of a surrounding building. These approaches have many advantages, including use of standardized and controlled conditions, but they do not capture all of the complex and variable building- and environment-related cues that birds encounter when flying toward a building.

Despite the importance of field-testing such products when installed on buildings, only a few studies have done so, and most lacked replication. A study in Utah, USA, compared bird collisions before and after a commercial product (Feather Friendly® markers) was installed and found some evidence that collisions were reduced (Brown et al. 2019). A study at two buildings in São Paulo, Brazil tested effectiveness of bird-of-prey decals, finding a reduction in collisions, albeit a statistically non-significant one (Brisque et al. 2017). A study in California, USA recorded a significant reduction in collisions after using external shades to cover windows (Kahle et al. 2016). Finally, a study in Poland found that glass bus shelters obscured by graffiti and dust had significantly fewer collisions compared to clean shelters (Zyśk-Gorczyńska et al. 2020). These studies have provided important insights into collision mitigation approaches. However, studies with greater replication and that compare collisions at the same structures before and after treatment, as well as between treated and untreated structures during the same time period (i.e., a before-after control-impact (BACI) study design, Underwood 1992; Smith 2014), would greatly advance understanding about the effectiveness of products designed to reduce bird collisions.

We conducted a well-replicated study that included a BACI analysis of the effectiveness of a commercially available window application, Feather Friendly®, when installed on glass-walled bus shelters known to cause bird collisions (Barton et al. 2017). Glass-walled bus shelters provide an ideal setting for conducting this type of BACI field study; their small size makes them highly replicable because they are easy to monitor and less expensive to treat than larger buildings. Our study included two components: (1) a BACI analysis comparing numbers of bird collisions at 18 bus shelters monitored both pre-treatment in 2016, and in 2020 after half the shelters had been treated, and (2) a complementary analysis comparing collisions between 18 treated and 18 untreated bus shelters during the same time period in 2020. Our study design provides a model for similar studies evaluating effectiveness of products designed to reduce bird-window collisions. In particular, use of a BACI approach that assesses changes in numbers of collisions from pre- to post-treatment periods, comparing these changes between treated and untreated shelters, allows isolation of the effects of window products from other factors that cause temporal variation in collisions (e.g., weather, fluctuations in bird populations).

Methods

Study Area

We surveyed for evidence of and carcasses from bird collisions with glass-walled bus shelters in Stillwater, Oklahoma, USA. Stillwater is a small urban area with a human population of approximately 50,000 people (census.gov; 2018) that is located in the transitional ecoregion of the Cross Timbers, which contains a mixture of grasslands, shrublands, and deciduous woodlands and forests. We conducted surveys at all 36 bus shelters located throughout the city, 18 of which are located on the Oklahoma State University (OSU) campus and 18 of which are located throughout the rest of Stillwater (**Figure 1)**. All bus shelters are maintained and used by OSU's Transit Services, except two that are maintained by other entities (Payne County and a private apartment complex). Each shelter has an open front and three glass walls; 26 of the shelters have the same design consisting of four glass panes that collectively include approximately 10.5m^2 of glass (**Figure 1)**, while the remaining 10 shelters differ slightly from this design in the number and/or size of glass panes.

Study Design

For the “before” data in our BACI analysis, we used bird collision data collected in 2016 from a sub-set (n=18) of Stillwater’s 36 bus shelters (Barton et al. 2017). The “impact” we implemented and evaluated was treatment of the exterior of shelters (treatments implemented during summer 2019) with Feather Friendly® window markers in the 2” x 2” Symmetry style **(Figure 2)**. Of the 18 shelters monitored in 2016, the 9 with the most collisions observed in the baseline study were selected for treatment and the other 9 remained as untreated controls. We used this approach for selecting treatment shelters, as opposed to completely randomized selection, due to the relatively low number of bird collisions observed at bus shelters (Barton et al. 2017) and to increase the probability that any effects of the film in reducing collisions could be detected statistically. As described further under “Statistical Analyses,” this BACI design allowed us to assess the effectiveness of the window markers by evaluating differences in the before-after (2016 to 2020) comparison between impact (treated) and control (untreated) shelters.

In addition to these 18 shelters evaluated in 2016 and 2020 under the BACI framework, we also sought to compare a larger sample of treated and untreated shelters during the same time period. We therefore selected an additional 9 bus shelters for treatment from among the remaining 18 shelters that were not monitored in 2016. These 9 shelters were selected using a stratified random sampling approach, such that approximately half of treated shelters were in relatively urbanized/developed areas (i.e., on the OSU campus and in/near downtown Stillwater) and approximately half were in less urbanized/developed locations (i.e., low-density residential and exurban settings in and around Stillwater). Combined with the shelters described in the previous paragraph, these additional 18 shelters (9 treated, 9 untreated) resulted in a total sample of 18 treated and 18 untreated shelters for which we compared collisions during 2020, an analysis that was separate from the above-described BACI analysis. A map of all shelters included in these analyses, including which were treated and untreated and which were monitored in 2016 and/or 2020, is illustrated in **Figure 3**.

Data Collection

In the baseline study (Barton et al. 2017), the 18 shelters that we used for the BACI analysis were monitored for collisions twice weekly from 4 May to 30 September of 2016. In 2020, we used a similar schedule of twice-weekly surveys, but we expanded sampling to cover 1 April to 31 October, and to include all 36 bus shelters. The protocol was adapted from Hager and Cosentino's (2014) standardized bird-window collision monitoring protocol. This included an initial "clean sweep" in which we surveyed each shelter 24 hours before our first survey and removed any existing carcasses and collision evidence on glass to ensure that any carcasses or evidence found during surveys occurred within the previous 24-hour period. In 2020, the shelters were split into two 18-shelter routes, with each route including an approximately equal mix of treated and untreated shelters. We alternated which route was surveyed on successive days, such that each entire route was monitored twice weekly (e.g., route 1 surveyed on Monday and Thursday; route 2 surveyed on Tuesday and Friday). The order in which shelters were surveyed on a route was shifted by one on each successive monitoring day to account for time-of-day effects (e.g., when peak numbers of collisions occur) that could bias comparisons due to individual shelters always being monitored during the same period of the morning. Additionally, survey direction around each shelter was altered on each subsequent survey (clockwise during one visit followed by counterclockwise on the subsequent visit) to account for any biases associated with directional perception (e.g., shading and sunlight glare).

To conduct a survey, we walked slowly around the perimeter of each shelter looking for bird carcasses within two meters of the interior and exterior of the shelter. When a carcass was found, we recorded the species and information on its location relative to the shelter (i.e., whether it was found on the interior or exterior of shelter, and how many meters from glass it was found). Next, to facilitate identification of bird species and to prevent duplicated recordings of carcasses, we took photos of the carcass in the context of its surroundings as well as close-up photos of the dorsal, lateral, and ventral sides of the bird. Carcasses were then left in place for scavenger removal trials (described below). During surveys, each pane of glass on each shelter was carefully examined for evidence of collisions, which included feathers attached to glass or smudge marks clearly made from a bird (i.e., a smudge in the shape of a bird/wings or smudge accompanied by feathers). When such collision evidence was found, we recorded its description and location (interior or exterior of shelter) and took photos of it. Evidence was then removed with glass cleaner to avoid duplicated recording on future surveys. For both the 2016 (Barton et al. 2017) and 2020 data collection efforts, all bird carcasses were handled under Scientific Collector’s Permits obtained through the U.S. Fish and Wildlife Service (Permit #MB05120C-0) and Oklahoma Department of Wildlife Conservation (multiple permits over the course of the study). Our protocols were also approved by the Institutional Animal Care and Use Committee at Oklahoma State University (IACUC protocols #AG-14-8 and #AG-20-13).

Both humans and animal scavengers are known to remove bird carcasses resulting from window collisions, which can bias estimates and comparisons of bird fatalities if not accounted for (Hager et al. 2012; Riding and Loss 2018; Loss et al. 2019). To minimize human removal of carcasses we contacted the organizations responsible for bus shelter management (OSU Transit Services in both 2016 and 2020 and Payne County and the private apartment complex in 2020) to request that carcasses be left in place when found by maintenance personnel. In both years, we also conducted removal trials (fully described in Barton et al. 2017) to account for scavenger removal, as well as any removal of carcasses by humans that we were unable to prevent. These trials were designed to estimate the probability that carcasses persist between the collision event and the subsequent monitoring survey; data from trials thus allowed us to generate estimates of total collisions that account for carcass removal. For these removal trials, we left all carcasses found at shelters in place and monitored their presence during each subsequent survey until they were undetectable due to removal or decomposition.

Data Analyses

All statistical analyses were performed in R and the RStudio interface (R Core Team 2020; RStudio Team 2020). Values of response variables for the below statistical analyses were raw counts of total collisions (carcasses plus collision evidence) because we lacked replication of removal trials to generate adjusted fatality estimates for each bus shelter and year combination (Barton et al. 2017). However, as described below, we did use data from removal trials to generate total adjusted estimates of collisions across all bus shelters. Because response variables were counts and our data were over-dispersed, we used generalized linear models (GLMs) and first conducted a likelihood ratio test (LRT) to determine whether to use a Poisson or negative binomial distribution (Lewis et al. 2011). The LRT results were statistically significant for the BACI analysis ($X_2 = 7.82$; $p=0.005$), indicating the need to use a negative binomial model. For the analysis using only 2020 collision data at all 36 shelters, LRT results were non-significant ($X_2 = 2.07$; $p = 0.149$), so we used a Poisson model. The proportion of replicates with a value of zero was 38% and 52% for the BACI and 2020 analyses, respectively; therefore, we conducted a Vuong test to assess whether zero-inflated models were appropriate (Vuong 1989). For both the BACI and 2020 analyses, there was no support for using zero-inflated models (BACI analysis: Raw z-statistic = -0.52; AIC-corrected z-statistic = 0.06; BIC-corrected z-statistic = 0.52; all p-values ≥ 0.3; 2020 analysis: Raw z-statistic = 1.61; AIC-corrected z-statistic = 1.1; BIC-corrected z-statistic = 0.69; all p-values ≥ 0.05).

For the BACI analysis focused on the 18 bus shelters monitored in both 2016 and 2020, we tested for the effect of an interaction between time period (2016 vs. 2020) and whether the shelter was treated between 2016 and 2020 (i.e., treatment vs. control shelter). Because the length of the sampling period differed between 2016 and 2020 (4 May to 30 Sept in 2016; 1 Apr to 31 Oct in 2020), we also included an offset term for the number of collision surveys conducted at each shelter in each year. This analysis framework allowed us to test the hypothesis that the change in numbers of collisions between 2016 and 2020 was different between treated and untreated shelters. This approach allows separation of any treatment-related effect on collisions from other factors that could cause changes in collision numbers between the pre- and post-treatment period, and that would manifest in changes in numbers of collisions at control shelters (e.g., inter-annual fluctuations in weather, human disturbance, vegetation, or bird population sizes). For example, even if factors unrelated to glass treatment led to a reduction in collisions across all shelters, this approach would allow us to detect if there was a greater reduction in collisions at treated than untreated shelters. Likewise, if some external factor caused an increase in collisions at all shelters between 2016 and 2020, this approach would allow us to detect if there was a smaller increase, or even a decrease, in collisions at treated shelters. For the complementary analysis that considered all 36 shelters during 2020, we only assessed the effect of treatment to determine if collisions varied between the 18 treated and 18 untreated shelters during the same time period.

In addition to the above analyses, we used data from removal trials to generate estimates of total collisions, adjusted for removal bias, across all 36 monitored shelters in 2020. This analysis mirrors a similar analysis conducted by Barton et al. (2017) to estimate total collisions across the same 36 shelters during a period when none of them had been treated. Thus, comparing our adjusted fatality estimate to the one generated in the previous study allows an approximate assessment of the change in total collisions associated with treating half of the city’s bus shelters. To generate an adjusted fatality estimate, we used the R package “carcass” (Korner-Nievergelt et al. 2015) and the function “phuso” to implement a statistical estimator that has been widely used in studies of bird collisions with structures (Huso et al. 2011). While a newer and more generalized estimation approach can be implemented in the R package “GenEst” (Simonis et al. 2018), we used the above approach to maintain consistency with and allow more direct comparisons to the baseline study (Barton et al. 2017). We followed the same steps used by Barton et al. (2017), including implementation of the functions “persistence.prob” and “phuso”. The first function estimates carcass persistence probability based on data from removal trials; notably, we assumed constant persistence probability over time due to similarities in scavenger communities and climatic characteristics (e.g., temperature, humidity) across our study area as well as short search intervals and high searcher efficiency (Korner-Nievergelt et al. 2015, Riding and Loss 2018). The persistence estimates received from this function were then averaged across shelters, and the mean was used in “phuso” to generate fatality estimates adjusted for removal, assuming a searcher efficiency of 100% and a search interval of 3.5 days. We assumed a 100% searcher efficiency for the same reasons as in Barton et al. (2017), including the small carcass search areas around bus shelters (approximately 36–70m^2), the high visibility of carcasses with contrasting substrates like concrete and mowed grass, and few obscuring structures surrounding shelters. The search interval of 3.5 was obtained by averaging our search intervals of 3 and 4 days. We estimated the minimum number of birds killed in 2020 at all 36 bus shelters throughout Stillwater between the months of April and October by dividing the total number of carcasses found across all shelters by the obtained value of carcass persistence probability. We also generated a similar estimate for the total number of birds killed annually by calculating the total estimated number of birds killed per shelter per month and multiplying that value by the number of shelters (36) and months in the year (12); this extrapolation assumes a constant rate of mortality across all months in the year.

Results

Descriptive Results

From April to October of 2020, we found a total of 15 bird carcasses and 17 pieces of collision evidence that did not have an accompanying carcass (i.e., evidence that likely represented additional collisions independent from observed carcasses), resulting in a total of 32 collisions across the 36 monitored bus shelters. Six unique bird species collided, including 6 American Robins *(Turdus migratorius)*, 3 House Sparrows *(Passer domesticus)*, 2 Cedar Waxwings *(Bombycilla cedrorum)*, 2 Great-tailed Grackles *(Quiscalus mexicanus)*, 1 Northern Mockingbird *(Mimus polyglottos)*, and 1 Scissor-tailed Flycatcher *(Tyrannus forficatus)*. Of the 18 shelters monitored in 2016, the 9 treated shelters had a total of 13 bird carcasses and 19 pieces of collision evidence (32 total collisions) found during the before/pre-treatment period in 2016 (Barton et al. 2017), as compared to a total of 4 bird carcasses and one piece of collision evidence (5 total collisions) found during the after/post-treatment period in 2020. The 9 untreated shelters monitored in 2016 had 0 carcasses and 2 pieces of collision evidence (2 total collisions) found in 2016, as compared to 6 carcasses and 8 pieces of collision evidence (14 total collisions) in 2020.

BACI and 2020 Analyses

For the formal BACI analysis that tested for an interaction between year and treatment, we found a significant effect of this interaction term (p-value=3.31e-08; coefficient estimate ± standard error [SE] = 7.249 ± 1.31; df = 32). Assessment of the interaction plot **(Figure 4)** illustrated a slight increase in collisions between 2016 and

2020 at untreated shelters, and a substantial reduction in numbers of collisions between 2016 and 2020 at shelters treated in 2019 with the Feather Friendly® glass markers.

For the analysis comparing the 18 treated and 18 untreated shelters during 2020, we found 10 bird carcasses and 15 pieces of collision evidence (25 total collisions) at untreated shelters and 5 bird carcasses and 3 pieces of collision evidence (8 total collisions) at treated shelters. The formal analysis of the 2020 collision data illustrated that there were significantly fewer collisions at shelters treated with the Feather Friendly® markers compared to untreated shelters (p-value=0.005; coefficient estimate ± SE = 1.139 ± 0.406; df = 34; **Figure 5**).

Notably, even though the Feather Friendly® product was applied only to the exterior surfaces of bus shelters, it appeared to reduce numbers of collisions on both exterior and interior surfaces. For the 9 shelters treated for the BACI analysis, numbers of interior collisions (including both carcasses and collision evidence) declined from 13 to 1 from 2016 to 2020 (exterior collisions declined from 19 to 4 from 2016 to 2020). Based on 2020 data at all 36 shelters, treated shelters had lower numbers of both interior and exterior collisions (1 and 7 collisions, respectively) compared to untreated shelters (9 and 15 collisions, respectively).

Scavenger Removal Trials and Adjusted Mortality Estimates

For carcass removal trials, which were based on bird carcasses that we found as collision casualties, left in place, and monitored on each successive survey (15 total trials in 2020, with 5 at treated shelters and 10 at untreated shelters), we estimated that the average length of time a carcass persisted until it was no longer detectable was 13.47

days. This corresponded to an estimated 0.857 daily probability of carcasses persisting (probability based on averaging across all bus shelters with carcasses observed). When this persistence probability was applied to raw carcass counts, and assuming constant mortality across all shelters, we estimated that there was a minimum of 17.4 total fatal bird collisions across all 36 shelters (18 treated; 18 untreated) from 1 April through 31 October of 2020. Using this value of 17.4 fatal collisions, we estimate that 30 total birds were killed throughout all of 2020, as compared to an estimate of 82.4 total birds killed throughout all of 2016 (Barton et al. 2017). In other words, we estimate that treating half of Stillwater's bus shelters in 2019 resulted in there being a 64% reduction in the number of total annual bird collisions.

Discussion

The multiple analyses we conducted all strongly point to the effectiveness of the Feather Friendly® markers in reducing bird-window collisions. These analyses included a replicated BACI analysis with before-after treatment data for both treated and control shelters, an analysis comparing treated and untreated shelters during the same time period, and our estimate of a substantial reduction in total bird collisions from 2016 to 2020 after treating half of Stillwater's bus shelters. As one of the first replicated tests of the effectiveness of a product designed to reduce bird-window collisions, and the first to include a replicated BACI analysis, these results have important implications and add valuable information to the body of knowledge about bird-window collisions. Results from the BACI analysis are especially compelling, as we showed that collisions decreased at treated bus shelters even with a longer collision monitoring season during the post-treatment period and with a slight increase in collisions observed during the same time period at untreated shelters.

This study builds on past research and adds further support for the effectiveness of the Feather Friendly® product we tested. Our results, along with previous studies conducted in Utah, USA (Brown et al. 2019; 2020), indicate that this product is effective in alerting birds that glass is a barrier. Specifically, Brown et al. (2019) tested the effectiveness of the same Feather Friendly® markers on a single façade of one university building during one winter season and found a 71% reduction in collisions after marker installation. A subsequent study (Brown et al. 2020) tested the same markers on the same building façade during one fall season and documented a similar reduction in collisions. While these studies highlight the effectiveness of this product in reducing bird collisions, their small sample size of one building façade and geographical setting limited generalizations about product effectiveness. One of the few other studies to monitor glass-walled bus shelters for collisions found that shelters obscured with graffiti and dust had the fewest collisions, lending broader support to the success of window treatments that function by breaking up glass transparency and reflectivity (Zyśk-Gorczyńska et al. 2020).

Bus shelters are structurally unique in that most only have three walls and are open on one side. This unique construction results in the transparent and/or reflective properties of the glass posing a collision threat to birds at both the interior and exterior surface of the glass. A window of $5m^2$ on a building presents a surface area of $5m^2$ over which birds can collide, but $5m^2$ of glass on a bus shelter is a $10m^2$-surface area of potential collision for birds. Our results suggest that the Feather Friendly® window markers installed on the exterior of bus shelters were not only effective at reducing total bird collisions, but also in reducing collisions on the interior, untreated sides of glass panes. Specifically, although we did not conduct statistical analyses to separately evaluate changes in numbers of interior and exterior collisions, our descriptive results suggest that markers reduced numbers of collisions occurring on the shelter interiors, presumably because the markers are visible to birds from both the exterior and interior sides of shelters. This finding is salient given the considerable risk of birds becoming entrapped inside of shelters and subsequently colliding (see also Zyśk-Gorczyńska et al. 2020), and given that 41% of total collisions were observed to occur on the interior of shelters in the baseline study (Barton et al. 2017). Thus, in the context of bus shelters, treating glass on only one side may reduce both interior and exterior collisions, although this may not necessarily be the case with all types of glass. For example, glass that is thicker or tinted/colored may reduce visibility of window markers from the other side, such that numbers of collisions on the untreated surface are not reduced.

Evaluating the applicability of the Feather Friendly® markers, as well as similar products, for reducing collisions at a wide variety of structure types requires consideration of how bus shelters differ from buildings in the context of bird collisions. Specifically, factors known to influence collisions, such as surrounding vegetation, structure size, and amount of artificial light emitted at night (Cusa et al. 2015; Hager et al. 2017; Horton et al. 2019), can vary between bus shelters and buildings. These differences can result in varying importance of the factors influencing collision rates. For example, there is generally less or no nighttime lighting emitted from bus shelters, which may reduce the importance of this factor compared to at buildings (Barton et al. 2017).

Variation in such collision correlates may also lead to differences between buildings and bus shelters in which bird species collide most frequently and which seasons experience peak collision rates. Collisions at building windows usually consist primarily of migratory bird species and tend to occur most frequently during migration periods (Arnold and Zink 2011; Loss et al. 2014). However, ours and the earlier baseline study (Barton et al. 2017) indicate that collisions at bus shelters consist mostly of non-migratory resident species and migrants during their summer residency period, with collisions occurring more evenly throughout spring, summer, and fall. Because of the above types of differences, the effectiveness of various mitigation techniques and products may also differ between bus shelters and buildings. Further well-replicated studies, including those that include a BACI component, are needed at buildings to test the effectiveness of this and other types of products designed to reduce bird-window collisions.

While our results show that glass-walled bus shelters provide a viable opportunity to test the effectiveness of marketed window treatments in reducing bird-window collisions, further research at both bus shelters and buildings is needed, including similarly designed BACI studies. For example, additional replicated field research could compare the effectiveness of different spacing distances for elements used in collision deterrent products (e.g., 2 in. x 2 in. spacing, such as used for the markers we tested, compared to the often-recommended 2 in. vertical x 4 in. horizontal spacing pattern; Klem 1990; 2009). This research will be important because certain patterns may be more or less likely to be purchased and installed due to factors such as aesthetic appearance and amount of natural light admitted into buildings. Well-replicated studies of various treatment types at diverse locations would also be valuable for determining product effectiveness in varying conditions and in relation to the above types of factors that vary between bus shelters and buildings (e.g., different collision correlates, species groups affected, and seasonal patterns of collisions). Comparing different products in the same study area or on different parts of the same building could allow for identification of the relative strengths or weaknesses of each treatment in different settings, including on different structure types, with different communities of affected bird species, and with varying levels of glass transparency and reflectivity, surrounding vegetation, and nighttime lighting. Additionally, evaluating combinations of mitigation approaches, such as films, markers, or decals along with management steps like altering vegetation or the amount of nighttime lighting, would clarify if and how multiple approaches interact to reduce collisions (e.g., a product could be more effective with less nearby vegetation to be reflected on the glass). Lastly, given benefits of controlled testing, such as tunnel tests and field experiments that facilitate replication and direct observation of interactions between birds and glass (Klem 2009; 2013; Sheppard 2019), research could evaluate the relationship between the effectiveness of products in controlled and real-world situations. This would facilitate predictions about product effectiveness based solely on results of controlled testing. Notably, the above types of studies of products installed on buildings may soon become more feasible as more entities (e.g., commercial businesses and universities) treat problem areas of building glass as a result of increased research, additional enactment of bird-friendly building guidelines and regulations, and increased public awareness of and support for addressing this issue.

Although our study design was rigorous and our results valuable, it is crucial to acknowledge limitations of this study. For example, our estimates of total annual bird collisions across all bus shelters in Stillwater, Oklahoma, should be interpreted with caution as we only monitored for collisions over a period of 7 months (Apr–Oct) and assumed that monthly collision rates during this period were similar to the rest of the year. Bird abundance and species composition change throughout the year, and this typically results in most collisions occurring during spring, summer, and fall (and especially in spring and fall migration in many areas), with fewer in winter (Borden et al. 2010; Bayne et al. 2012; Hager et al. 2013; Nichols et al. 2018). Thus, estimates of total annual collisions were likely inflated in both the baseline and current studies. We also did not account for searcher detection bias and instead assumed 100% detection of collision events, a likely overestimation (Riding and Loss 2018). However, as we made the same assumption in the baseline study, any introduced bias should not have greatly affected collision comparisons between years. Another limitation is that the before and after periods for the BACI analysis each consisted of only one field season of collision monitoring. Likewise, the analysis comparing all treated and untreated shelters during 2020 was based on a single field season of data collection. Monitoring bus shelters across more years would have captured greater "background" variation in numbers of collisions (e.g., due to factors like variation in bird populations), and therefore, provided a better understanding of the product's effectiveness in reducing collisions. Despite this limitation, the major differences in collisions for both the BACI and 2020 analysis provide compelling evidence for the product's effectiveness in reducing collisions.

Finally, we note that the Stillwater bus system was not operational from approximately March through July of 2020 due to the SARS-CoV-2 pandemic. For the same reason, OSU classes were held online starting in March 2020 resulting in few students and staff being on campus throughout the summer. Anecdotally, bus use was lower than normal even after the restoration of transit services in July 2020. This substantial change in human activity in the study area, including near bus shelters, could have resulted in more birds being near shelters and thus partly contributed to the slight increase in collisions from 2016 to 2020 at untreated shelters **(Figure 4).** The difference in the length of the collision monitoring season (4 May–30 Sep in 2016 and 1 Apr–31 Oct in 2020) could also have contributed to this collision increase at untreated shelters. Regardless of whether altered transit services influenced bird collisions, the BACI study design allowed us to document that the treatment was highly effective even if there were confounding factors causing changes in numbers of collisions from 2016 to 2020.

Conclusions

Our well-replicated study of 36 glass-walled bus shelters, which included a before-after control-impact testing component at 18 of these shelters and a comparison between all treated and untreated shelters during 2020, provides strong evidence of the effectiveness of a commercially marketed product (Feather Friendly®) in reducing bird-glass collisions. Our results also illustrate an opportunity for cities, local municipalities, and other entities that manage public transit services, to engage in efforts to reduce bird-glass collisions at bus shelters, and thus contribute to addressing the many human-related threats affecting bird populations. Treating half of Stillwater's bus shelters resulted in an estimated 64% reduction in total bird collisions, and even greater reductions in numbers of collisions would be likely with treatment of all bus shelters. Our research also provides a model for designing similar studies at both bus shelters and buildings to evaluate and compare products designed to reduce bird-window collisions, and therefore, to facilitate expanded use of highly effective products across a wide variety of structure types. Additional replicated research is still needed to test the effectiveness of many types of collision-reducing products after being installed on buildings, including glass with built-in features designed to reduce collisions (e.g., etchings and UV-reflecting patterns), and films, markers, decals, and other products that cover or adhere to glass. Nonetheless, this study bodes well for the potential use of Feather Friendly® markers, as well as similar products, to contribute to substantially reducing the number of bird-window collisions and thus greatly benefitting bird populations.

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Tables and Figures

Figure 1.1. Example of a typical glass-walled bus shelter in Stillwater, Oklahoma, USA; 26 of the city’s 36 shelters had an identical or nearly identical design.

Figure 1.2. A close-up image of the Feather Friendly® 2” x 2” Symmetry style window markers that were installed on glass-walled bus shelters in Stillwater, Oklahoma, USA, and for which we evaluated effectiveness at reducing bird collisions at these shelters.

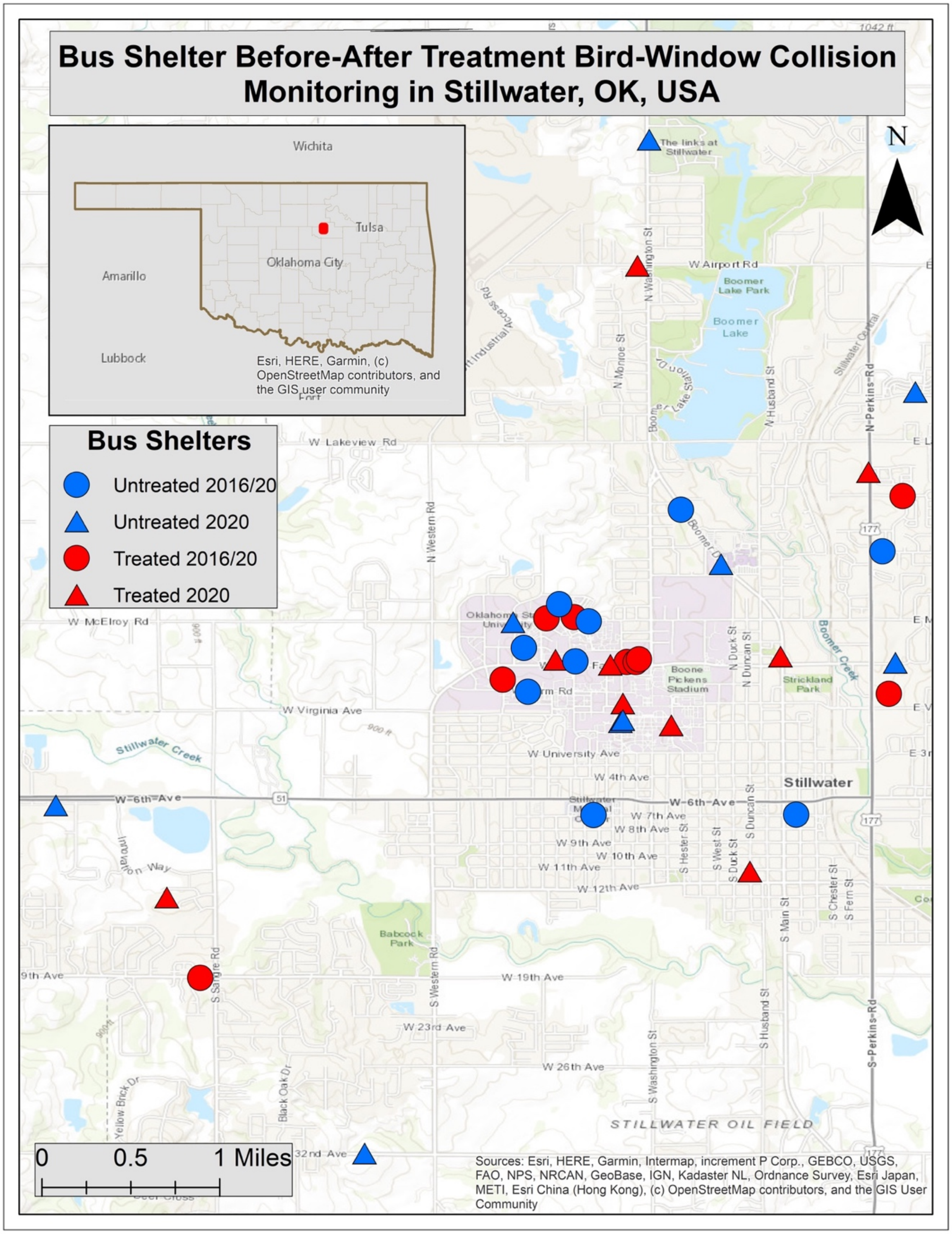

Figure 1.3. Map of locations for 36 glass-walled bus shelters included in a study evaluating the effectiveness of Feather Friendly® 2” x 2” Symmetry style window

markers at reducing bird collisions in Stillwater, OK, USA. Effectiveness was evaluated based on: (1) a before-after control-impact analysis at 18 bus shelters monitored in both 2016 and 2020, half of which had markers installed in 2019 (represented by red circles) and half that remained untreated (blue circles); and (2) an analysis of 36 bus shelters monitored in 2020, half of which were treated with the markers and half that were untreated (all red and blue symbols, respectively); also, half of these 36 shelters were those included in the BACI analysis (blue and red circles) and half were only monitored in 2020 (blue and red triangles).

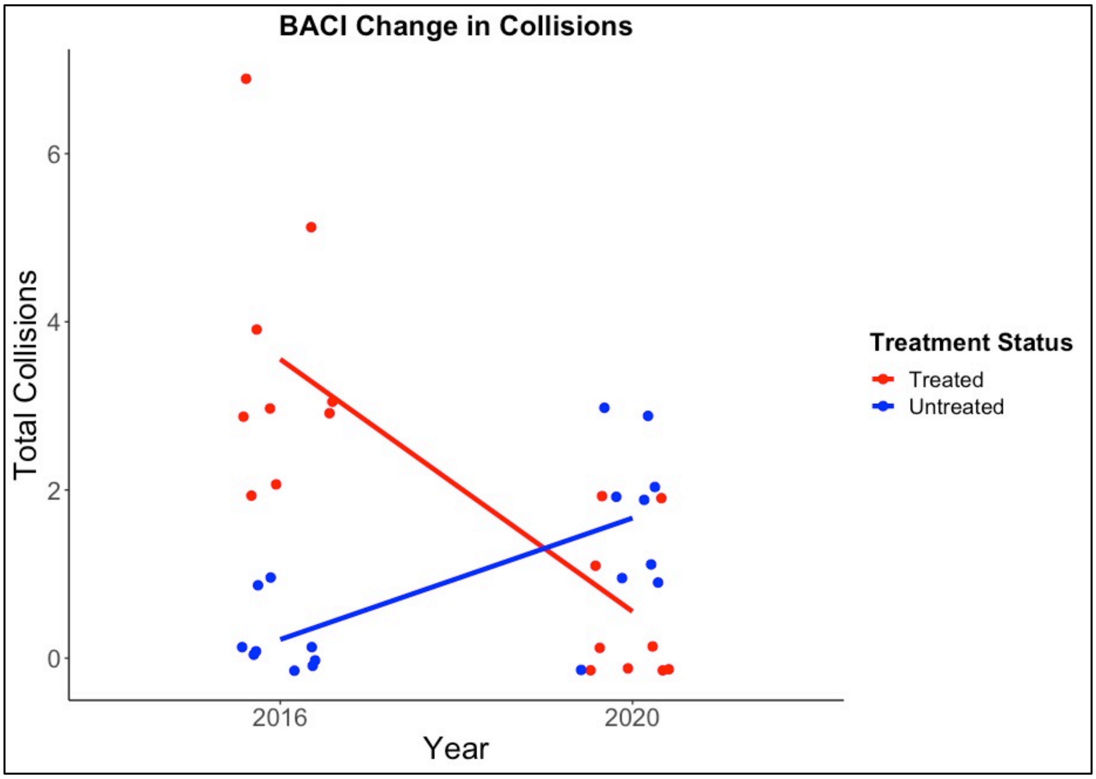

Figure 1.4. Interaction plot between year and treatment status of bus shelters displaying results of the before-after control impact (BACI) analysis of the effectiveness of Feather Friendly® 2” x 2” Symmetry style window markers based on monitoring at 18 shelters in

both 2016 and 2020 in Stillwater, OK, USA, with half of shelters treated in 2019 and half remaining untreated.

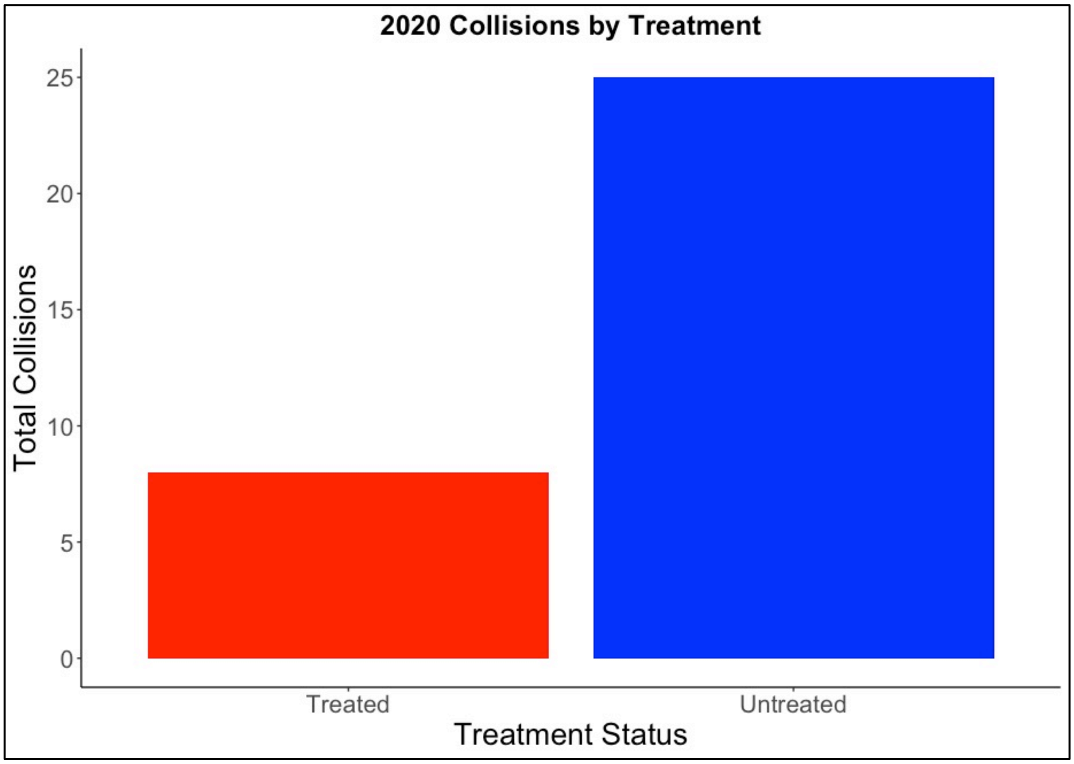

Figure 1.5. Plot displaying results of the analysis of bird-window collision data that compared 18 treated and 18 untreated shelters during 2020 to assess effectiveness of Feather Friendly® 2” x 2” Symmetry style window markers in Stillwater, OK, USA.

CHAPTER II

STAKEHOLDER PERCEPTIONS OF BIRD-WINDOW COLLISIONS

Abstract

Bird-window collisions are a major source of human-caused avian mortality for which there are multiple mitigation and prevention options available. However, minimal research has been conducted to understand human perspectives related to this issue. This information gap limits understanding about the most effective ways to engage the public in helping to reduce bird-window collisions. We investigated stakeholder perceptions and priorities of bird-window collision mitigation and prevention using a strengths, weaknesses, opportunities, and threats (SWOT) – Analytic Hierarchy Process (AHP) framework. Our results demonstrate that respondents from two stakeholder groups, homeowners and conservation practitioners, have an overall positive perception toward reducing bird-window collisions and that they believe the benefits of implementing mitigation and prevention techniques outweigh obstacles that may impede such measures. However, policy and financial-related obstacles (e.g., a lack of policy/guidelines to require or guide mitigation activities, and the cost of implement such activities) were perceived as potential roadblocks to reducing bird-window collisions. Our results indicate that the general public may be receptive to education on this issue and that targeted and active education may be successful in garnering public support for and participation in

bird-window collision mitigation and prevention.

Introduction

As earth's human population continues to grow (United Nations 2019), human actions and ways of life increasingly affect wildlife and their habitats, and the many sources of unintended, direct wildlife mortality are a major component of these human impacts (Calvert et al. 2013; Loss et al. 2015; Nyhus 2016). Among direct sources of avian mortality, collisions of birds with buildings and their windows are a top global threat. Window collisions cause between 365 and 988 million bird deaths annually in the United States alone (Loss et al. 2014) and are also a top threat to birds in other countries (e.g., Canada, Mexico, Brazil, Spain, Singapore, South Korea; Kim et al. 2013; Machtans et al. 2013; Aymí et al. 2017; David et al. 2017; Santos et al. 2017; Gómez-Martínez et al. 2019). Birds collide with glass because they are unable to perceive it as a barrier due to its reflective and transparent qualities (Klem 1989), and because artificial light at night confuses and draws migrating birds near buildings, elevating collision risk (Winger et al. 2019; Lao et al. 2020). Bird collisions occur at a wide variety of building types; tall buildings such as skyscrapers have higher per-building collision rates, but smaller and far more abundant residential buildings account for higher cumulative mortality despite lower per building collision rates (Machtans et al. 2013; Loss et al. 2014).

Many studies have identified factors that lead to spatiotemporal variation in bird-building collisions. Temporal factors include weather, bird abundance, seasonality, and migration phenology (Kahle et al. 2016; Nichols et al. 2018; Loss et al. 2019). Spatial factors include building-related features like amount of glass, building shape, and nearby vegetation (Klem et al. 2009; Hager et al. 2013; Riding et al. 2020), and broader landscape features like surrounding greenspace and urbanization intensity (Hager et al.

2017). Research into correlates of bird-window collisions has led to development of recommendations and management approaches that can be used to reduce collisions. Technologies and commercially available products that reduce glass reflection and transparency have been developed, tested, and marketed, and guidelines to make newly constructed buildings bird-friendly (e.g., by reducing amount of glass or using opaque, fritted, or colored glass) have also been summarized (Klem 2009; Sheppard et al. 2011; Sheppard 2019). Municipal, state, and federal policy guidelines and regulations to implement such bird-friendly approaches have also been adopted or are under consideration. These include, for example, *Standards for Bird-Safe Buildings* in San Francisco, California, U.S.A (San Francisco Planning 2021), *Buildings, Benchmarks, and Beyond* in Minnesota, U.S.A. (Regents of the University of Minnesota 2017), *Best Practices for Bird-friendly Glass* and *Best Practices for Effective Lighting* in Toronto, Canada (City of Toronto 2021), and the *Bird-Safe Buildings Act of 2019* currently under consideration by the U.S. federal government (U.S. Congress 2019).

Bird-window collisions occur at places with human infrastructure, and humans regularly encounter the bird carcasses that result. However, while significant resources have gone into designing and testing mitigation approaches to reduce bird-window collisions, and into developing and implementing bird-friendly policies and guidelines, little research has evaluated human perceptions and priorities related to these practices. In fact, there is a general lack of human dimensions research for nearly all sources of direct, human-caused bird mortality, including other kinds of bird collisions (e.g., with wind turbines, communication towers, and vehicles) (but see studies of wildlife predation by domestic cats; Wald et al. 2013; Gramza et al. 2016). The only study that has evaluated human perspectives on bird-window collisions was a graduate thesis examining the Canadian public's willingness to pay (WTP) to reduce collisions at their homes (Warren et al. 2013). This study found that WTP by homeowners was positively associated with age, income, and interest in birds, among other factors. Learning more about what people think about and how they might prioritize bird-window collision mitigation and prevention techniques would give researchers and conservation practitioners more insight into the public's acceptance of these practices. Understanding broader public perception is crucial because achieving significant reductions in bird-window collisions will require multiple stakeholder groups (e.g., residential homeowners, owners/managers of commercial and industrial buildings, building architects, policymakers) to be willing to implement recommended practices.

We began to address this major research gap by evaluating perceptions and priorities related to bird-window collisions among a diverse pool of respondents in North America. The specific objectives of this study were to: (1) evaluate how stakeholders perceive and prioritize potential benefits and obstacles of bird-window collision mitigation and prevention measures; and (2) assess whether and how these perceptions and priorities vary between two important stakeholder groups (owners of individual residences, i.e., "homeowners," and conservation practitioners in state, federal, and non-government conservation organizations). To address these objectives, we applied two commonly used frameworks in human dimensions analysis. These included the strengths, weaknesses, opportunities, and threats (SWOT) and the Analytical Hierarchy Process (AHP) analyses. A paired SWOT-AHP approach allows quantitative assessment of the perceptions and priorities of stakeholders regarding an issue.

Methods

Study Design

We used a combined SWOT-AHP perception analysis approach (i.e., a strengths, weaknesses, opportunities, and threats analysis linked with an analytic hierarchy process analysis). This method is often used to survey, analyze, and compare perceptions of diverse stakeholder groups regarding conservation issues (Dwivedi and Alavalapati 2009; Darshini et al. 2013; Joshi et al. 2018; Starr et al. 2019). We used the SWOT approach to ask surveyed stakeholders to prioritize strengths, weaknesses, opportunities, and threats related to bird-window collision mitigation and prevention. Strengths and weaknesses are factors internal to the issue, or in other words, direct outcomes of programs or decisions (Kurttila et al. 2000). Opportunities and threats are indirect implications or byproducts of decisions (Kurttila et al. 2000). The ultimate goal of a SWOT analysis is to determine perceptions of stakeholders to help develop a strategy that optimizes the tradeoff between strengths and weaknesses of various options, while considering both internal and external factors (Kurttila et al. 2000). When used alone, SWOT cannot rank attributes based on relative priorities (Kurttila et al. 2000). However, when paired with AHP, a generalized method to rank decision problems assuming independence among options, these methods allow quantitative comparisons of different SWOT options, which helps determine relative importance of a decision (Saaty 2004).

Stakeholder Groups and Strategy to Distribute Survey Questionnaire

Initially, we sought to investigate priorities of four stakeholder groups: architects, homeowners, and conservation practitioners in both government agencies and nongovernmental organizations (NGOs). Each of these groups can play a key role in managing bird-window collisions. Architects can help reduce collisions by working from the top down to incorporate mitigation and prevention measures, within policy parameters, into design and construction of new buildings (Klem 2015; Snep et al. 2016). Homeowners act from the bottom-up as consumers by expressing their values and desires, buying and living in houses, and deciding whether to manage their properties in ways that benefit birds (e.g., feeding birds or applying films/decals to windows to reduce collisions) (Kummer and Bayne 2015; Snep et al. 2016). Government and NGO conservation practitioners are both knowledgeable about and advocate for wildlife, but these two groups enact change in different ways. Government (federal and state/provincial) practitioners help inform policy development with research and management, and while NGOs can also help inform policy, they typically have public involvement with activities such as education campaigns, volunteering, and public funding (Klem 2015; Snep et al. 2016).

To recruit respondents from all stakeholder groups (architects, homeowners, government and NGO conservation practitioners), and from as broad of a geographic area as possible, we used a nonprobability sampling method called snowball sampling, which uses gateway respondents to recruit more respondents (Bernard 2017). Gateway respondents in this case were members of each stakeholder group that the authors knew personally; most of these gateway respondents lived and worked in the United States (18 U.S. states represented), but Canada was also represented in our sample. We asked that our gateway respondents not only take the survey but also forward the request for participation to others they knew in the stakeholder groups. We also used multiple other materials for stakeholder recruitment including emails and social media platforms (Facebook 2021; Twitter 2021; YouTube 2021). Recruitment emails were tailored to each stakeholder group and contained a brief overview of the project, a request for participation, a link to sign up to take the survey, a link to our recruitment video, and a request that participants share recruitment materials with colleagues. Recruitment via social media platforms included brief posts containing information about the project, the recruitment video, a call for participation, and a request to share recruitment materials. The recruitment video contained a brief overview about the issue of bird-window collisions and this research project, as well as requests for participation and to forward the recruitment materials.

To broaden participation and increase replication of responses from members of the homeowner stakeholder group, we used another nonprobability sampling method called purposive sampling in which respondents are recruited to serve a specific purpose (Bernard 2017). We decided to use this approach prior to collecting any data because we expected it to be difficult to recruit homeowners. Specifically, we reached out to multiple neighborhood homeowner's associations (HOA) in Stillwater, Oklahoma, USA, the location of the authors' home institution (Oklahoma State University). Recruitment materials were sent to publicly available email addresses of HOA board member contacts; again, we requested participation in the survey and dissemination of recruitment materials to other HOA board members and neighborhood residents. For all stakeholder groups and sampling approaches, periodic reminders were sent during survey periods to increase numbers of responses. Sampling dates for Survey 1 ranged from 6/1/20 to 6/30/20 and sampling dates for Survey 2 were from 7/13/20 to 8/12/20.

Survey Questionnaire Details

To use SWOT-AHP, a survey must be developed that contains a list of top strengths, weaknesses, opportunities, and threats regarding the issue at hand. SWOT lists are often developed with assistance of experts on the issue (Starr et al. 2019). We created a comprehensive list of potential SWOT items related to bird-window collision mitigation and prevention and asked three external bird-window collision experts to rank items by importance. We used these rankings to create a final SWOT list with the top four items in each category **(Table 1).**

Following the methodology used by similar SWOT studies, stakeholder opinions were solicited in two rounds of surveys, each containing pairwise comparisons between SWOT factors using a scale of one to nine (Dwivedi and Alavalapati 2009; Catron et al. 2013; Starr et al. 2019). For Survey 1, all possible pairwise comparisons were made between individual factors *within* (but not between) SWOT categories. For example, respondents were asked to compare perceived importance between the two strengths *Fewer collisions* and *Fewer bird carcasses to clean up* (see **Figure 1** for range of possible numerical responses). Upon completion of Survey 1 by all respondents, we analyzed response data and calculated relative weights of each pairwise comparison, consistency ratios of responses for each stakeholder group, and the relative importance of each SWOT category (Starr et al. 2019).

We used the above calculations to create Survey 2 based on top priorities for each SWOT category from Survey 1. Survey 2 was tailored to each stakeholder group dependent on respondent answers to Survey 1; it asked respondents to make pairwise comparisons between top-ranking options *between* SWOT categories. For example, within the homeowner stakeholder group, the factor *Fewer collisions* ranked as the top Strength category and *No federal/state policy in many areas* ranked as the top Threat, so Survey 2 asked respondents to compare the importance of these two factors, along with all other top factors.

All surveys were conducted using the online platform Qualtrics (Qualtrics 2021), and both surveys had the same general format. They both contained multiple sections, including an introductory page displaying information about the study, for example, the study's purpose, what to expect, risks associated with participating, and confidentiality. Next, the survey asked for respondents to select their respective stakeholder group. The following section contained a brief introduction to the issue of bird-window collisions (to give respondents introductory background or to reorient them to the issue), as well as a table containing all of the SWOT factors. This study and the surveys were approved by and comply with the Oklahoma State University Institutional Review Board's (IRB) standards and regulations (approved IRB protocol # IRB-20-202).

Data Analysis

Analyses of survey response data followed methods of other SWOT-AHP studies (e.g., Starr et al. 2019; Joshi et al. 2020) that adapted their analyses from Saaty (1977). The same general procedures were used to analyze results from Survey 1 (comparisons within SWOT categories) to determine priorities for Survey 2, and to analyze results from Survey 2 (comparisons between SWOT categories). First, we collated response data for each pairwise comparison and calculated the weighted geometric mean for each factor in each category and stakeholder group (Krejčí and Stoklasa 2018). Each weighted geometric mean was entered into a standard reciprocal matrix, and values were then normalized and placed into a weighted reciprocal pairwise matrix. The weighted reciprocal pairwise matrix was used to calculate factor priority values for each factor in each SWOT category and stakeholder group; these values were used to evaluate relative importance of factors within each SWOT category (all factor priority values within a category sum to one). Factor priorities within each SWOT category were also added together to obtain group priorities, which represent the priority of the SWOT category as a whole. The standard reciprocal matrix and factor priority values for each category were also used to calculate a consistency index (CI), which when used with a random index (RI), determines the consistency ratio (CR), a metric indicating the consistency of responses among respondents in a stakeholder group (Saaty 2004; Joshi et al. 2020). Pairwise comparisons were determined to be internally consistent if the CR was less than 10%; however, CR values up to 20% are considered acceptable (Saaty 1977; Catron et al. 2013; Joshi et al. 2018; Joshi et al. 2020). When we conducted preliminary analyses of survey responses, we calculated unacceptably high consistency ratios for architect and NGO practitioner groups, which was most likely attributable to small sample sizes due to limited recruitment. We therefore could not further consider architects, and we combined government and NGO practitioners in a single group (conservation practitioners). Thus, our final analysis included two stakeholder groups, homeowners and conservation practitioners. The last step in the SWOT-AHP analysis was to calculate global priority values that rank individual SWOT factors among all categories for each stakeholder group. These global priority values allow for comparison among stakeholders' perceptions and priorities, as well as evaluation of SWOT factor (priority) rankings against each other (Dwivedi and Alavalapati 2009; Catron et al. 2013; Starr et al. 2019).

In addition to the SWOT-AHP analysis, we followed previous literature (e.g., Dwivedi and Alavalapati 2009; Joshi et al. 2018) and generated perception maps, which illustrate differences in global priorities and allow direct comparisons among all SWOT factors and between stakeholder groups. We also applied Manfredo et al.'s (2003) potential for conflict index (PCI) to visualize responses to Survey 2 in a way that lends additional insight into potential conflicts in stakeholder perceptions (Vaske et al. 2010) that might limit progress in addressing bird-window collisions. The PCI_2, an extension of PCI that is used for response data from a scalar survey, visually displays degree of conflict (i.e., opposite of agreement) in responses among respondents in a stakeholder group, as well as neutrality of responses (Manfredo et al. 2003; Vaske et al. 2010). In this case, the scalar survey questions were pairwise comparisons that participants responded to in Survey 2. With regard to neutrality, pairwise comparisons that score near zero for a stakeholder group indicate factors perceived as *Equally important* (indicated as bubbles close to the x-axis on bubble graphs). Comparisons that score much higher toward either of the factors being compared represent an average group perception that one factor is *Extremely important* relative to the other (bubbles farther from the x-axis). Regarding degree of conflict, this value ranges between 0 and 1, with values close to 0 indicating little conflict (strong agreement on a pairwise comparison among all respondents in a group, indicated as small bubbles), and values close to 1 indicating complete conflict (i.e., responses on a pairwise comparison equally divided between the two extreme values on the response scale, indicated as large bubbles) (Manfredo et al. 2003; Lute et al. 2018).

Results

Stakeholder SWOT Group Priorities

We received survey responses from at least 18 U.S. states, and from Canada, but this may be an underestimate of the geographical scope of our study as the snowball sampling approach extended to people beyond our immediate circle. A summary of SWOT factor, group, and global priorities for homeowners and conservation practitioners is in **Table 2**. For all except 2 pairwise comparisons in Survey 1, consistency ratios were <10%, indicating consistent responses within stakeholder groups. For conservation practitioners, weaknesses and opportunities had consistency ratios of 18% and 19%, respectively, indicating some inconsistency. Nonetheless, consistency ratios <20% are considered acceptable for drawing inferences (Catron et al. 2013; Joshi et al. 2018). Group priorities for homeowners for strengths, weaknesses, opportunities, and threats were 24%, 15%, 40%, and 21%, respectively, and group priorities for conservation practitioners were 24%, 15%, 52%, and 9%, respectively. For homeowners and conservation practitioners, perceptions about potential outcomes of bird-window collision mitigation and prevention were generally positive, as evidenced by summed percentages of strengths and opportunities (64% and 76% for homeowners and conservation practitioners, respectively).

Stakeholder SWOT Factor Priorities

Homeowners prioritized opportunities overwhelmingly over strengths, weaknesses, and threats. For opportunities, *Recovering bird populations* was the top factor priority (34%), followed by *Consideration of birds in building design becoming a norm/standard* (25%) and *Greater energy efficiency of buildings* (23%). Homeowners prioritized strengths next; highest priority strengths were *Fewer collisions* (46%) and *Fewer stunned birds that die of other causes while recovering from colliding* (34%). The anthropocentric strengths received lower priority, including: *Fewer carcasses to clean up* (11%) and *Fewer people witnessing collisions* (9%). For threats, which homeowners prioritized only slightly behind strengths, the top factor was *No federal/state policy in many areas* (31%), followed by two equally ranked (25%) priorities: *Lack of understanding of federal/state policy on bird-window collisions* and *Reduced resources available to spend on other facilities maintenance/improvements)*. Homeowners prioritized weaknesses lowest, with *Lack of availability of expert consultation for bird-friendly design* being the top priority (31%) within this category **(Table 2)**.

Conservation practitioners also prioritized opportunities as most important; for opportunities, *Recovering bird populations* was the top priority factor (45%). Strengths was the second-highest prioritized category, and top factors in this category were *Fewer collisions* (60%) and *Fewer stunned birds that die of other causes while recovering from colliding* (27%). Conservation practitioners gave weaknesses and threats lowest priority. The most highly prioritized weakness was *No economic incentives for building bird-friendly buildings* (36%); the two top threats were *Reduced resources available to spend on other facilities maintenance/improvements* (36%) and *No federal/state policy in many areas* (35%) **(Table 2)**.

Stakeholder SWOT Global Priorities

Perception maps **(Figure 2A, 2B)** illustrate differences in global priorities and allow direct comparisons among all SWOT factors and between stakeholder groups. For homeowners, the opportunity *Recovering bird populations* (O1) received the highest global priority among all SWOT factors, closely followed by the strength *Fewer collisions* (S1). Although homeowner priorities for weaknesses and threats were lower than for strengths and opportunities, all threats and some weaknesses still received higher global priorities than the strengths *Fewer people witnessing collisions* (S2) and *Fewer carcasses to clean up* (S3). The opportunity *Recovering bird populations* (O1) followed by the strength *Fewer collisions* (S1) also received the two highest global priorities for conservation practitioners. Additionally, this group prioritized weaknesses over threats while homeowners ranked these categories in the opposite order.

Although the two groups had similar broad priorities, such as valuing strengths and opportunities over weaknesses and threats, conservation practitioners gave higher priority to the top factor in some categories, suggesting stronger perceptions toward these factors. Specifically, although *Recovering bird populations* (O1) was the highest global priority among all SWOT factors for both stakeholder groups, it received a greater global priority score for conservation practitioners (0.23) than homeowners (0.14). Similarly, the top strength (and second highest global priority among all SWOT factors) for both stakeholder groups *(Fewer collisions)* received a greater global priority score for conservation practitioners (0.15) than for homeowners (0.11) **(Table 2)**. Global priorities also illustrated that both homeowners and conservation practitioners gave low priority to

Fewer people witnessing collisions (S2) and *Fewer carcasses to clean up* (S3) relative to other strengths and many other weakness and threats.

Regarding potential for conflict indices (PCI_2) for Survey 2, comparison of the bubbles for homeowners (**Figure 3A)** and conservation practitioners **(Figure 3B)** for each pairwise comparison illustrates there was more conflict among responses for homeowners than conservation practitioners for 5 of 6 comparisons. Additionally, relative locations of bubbles on the y-axis (which indicates the difference in preference for each priority in a pairwise comparison) illustrate that homeowners were more neutral than conservation practitioners for all 6 pairwise comparisons.

Discussion

Our results suggest that both homeowners and conservation practitioners have an overall positive perception toward potential benefits related to bird-window collision mitigation and prevention measures. This indicates stakeholders likely believe that benefits of implementing mitigation and prevention techniques to reduce bird-window collisions outweigh any obstacles that may impede such measures. Although generally similar in their positive views, the two respondent groups displayed some differences in their specific priorities regarding the strengths, weaknesses, opportunities, and threats surrounding this issue. Specifically, homeowners give greater priority than conservation practitioners to threats, indicating more concern among homeowners about external obstacles (policy and financial-related) that may impede bird-window collision mitigation and prevention.

Stakeholder Perceptions About Bird-Window Collision Management

Results indicate that the homeowner and conservation practitioner groups, while in general agreement on their positive perceptions about managing bird-window collisions, each have unique aspects of their perception of this issue that are important to consider in order to make headway in addressing this conservation issue. Specifically, homeowners had more conflict in their responses to pairwise comparisons than conservation practitioners, indicating differing opinions within the group. Homeowners also were more neutral than conservation practitioners in their responses, demonstrating differing or a potential lack of perceptions within the group. Although we provided contextual information about this project in the participant information form, a lack of prior knowledge about the issue, which was anecdotally revealed from homeowner comments, could have contributed to their relatively neutral perceptions and conflicting responses. The less-conflicting responses within the conservation practitioner group could be due to greater knowledge about the issue or more cohesion within the group due to a shared field of profession and its associated sources of information. Specifically, those in the field of wildlife conservation likely have greater, and perhaps more consistent, exposure to major bird conservation issues through training opportunities, professional conferences, social media networks, newsletters, and scientific publications. It is important to note that the homeowner group is a more diverse group of individuals from various professional backgrounds, which may explain the lesser degree of agreement within the group.

Our results indicate that both groups of stakeholders have positive views about bird-window collision mitigation and prevention measures and may be willing to participate in or support implementation of such measures to reduce this source of human-caused avian mortality. Because the top ranked strengths and opportunities capture outcomes related to bird conservation and welfare (e.g., recovering bird populations), not anthropocentric benefits (e.g., no longer having to clean up or observe collisions), our results suggest that stakeholders value mitigating and preventing collisions for the sake of the birds themselves. This result demonstrates that stakeholders may have a general sense of caring and responsibility for birds—and/or that they view birds as aesthetically, culturally, or economically valuable (Sekercioglu et al. 2016; Hedblom et al. 2017)—which lends additional support to the potential acceptability and implementation of mitigation and prevention measures. Since many homeowners in our study were not previously aware of bird-window collisions and underlying challenges, our findings suggest a strong need for public education on this issue.

Advantageously, the positive perceptions about reducing bird-window collisions, and the apparently bird-centric reasons behind these positive perceptions, suggest that members of the public may be receptive to further education about this issue. Menacho-Odio (2018) also investigated public perception and knowledge of bird-window collisions in Monteverde, Costa Rica, and concluded that while participants had general knowledge of the issue, few were aware of the magnitude of the problem. This previous study recommended targeted education that informs people about the large number of bird-window collisions that occur, as well as methods likely to be effective in preventing collisions. There are multiple publicly available resources from which individuals can learn about bird-window collisions and ways to reduce them. For example, the American Bird Conservancy (ABC), has published a website geared toward the public (ABC 2021), a Bird-Friendly Building Design booklet targeting all types of building owners and managers, as well as architects (Sheppard et al. 2011), interactive web resources and educational materials for homeowners and architects, and a framework to help policy makers develop ordinances and legislation to reduce collisions. Similar and complementary resources to improve stakeholder knowledge about bird-window collisions have also been developed by other conservation organizations and agencies (e.g., USFWS 2018; National Audubon Society 2021; FLAP Canada 2019). While many resources exist and are available, active education on this topic would also be beneficial. Specifically, increased funding and staffing to expand the delivery and interpretation of such resources to audiences, along with research to improve understanding of how best to develop and distribute these resources to ensure they are used, are needed to make further headway in reducing bird-window collisions.

As was evident from our results, homeowners highly prioritized policy-related obstacles to bird-window collision mitigation and prevention. However, importantly, there are already several such policies across North America. Multiple states, cities, and municipalities have passed bird-window collision policies, including San Francisco, California, U.S.A. (San Francisco Planning 2019) and Minnesota, U.S.A. (Regents of the University of Minnesota 2017). The U.S. House of Representatives also approved legislation (Bird-Safe Buildings Act of 2019) that would require bird-friendly measures at many new and renovated U.S. federal buildings; however, this act has not yet passed the U.S. Senate. Thus, while there is concern among homeowners about potential policy-related obstacles to addressing this issue, many may not know that policies already exist. This points again to the importance of education, as increasing awareness of existing and proposed policies could increase support for them among the public, and therefore, among policymakers.

Beyond educating homeowners about existing and planned policies related to bird-window collisions, homeowners should also be informed that implementing bird-friendly measures at home might be their responsibility even with the existence of policy. To date, no legislation and policies have focused on residential structures, and the proposed U.S. federal bill only focuses on public buildings. Thus, there are no formal mechanisms to ensure that collisions are reduced at residences, even though residences collectively cause a large proportion of total bird collisions (Machtans et al. 2013; Loss et al. 2014). Although public education programs may encourage some homeowners to expend their own resources on measures to reduce bird-window collisions, formal programs to encourage these actions may be necessary to ensure that a large proportion of homes become bird-friendly in the future, especially for lower income residents that lack expendable resources to pay for such measures. Examples of such programs include conservation grants/subsidies that help pay for materials that make existing windows more bird friendly, and revisions to existing sustainability or wildlife-friendly certification programs to specifically incorporate considerations related to reducing bird-window collisions.

Management Implications and Future Research

While this research provides valuable information to advance efforts to manage bird-window collisions, it is essential to acknowledge limitations and potential biases related to our analyses. We were, for example, unable to analyze perspectives of architects as an independent stakeholder group due to limited recruitment for participation in our surveys. Architects are a crucial stakeholder in the issue of bird-window collisions, and further research should seek to thoroughly evaluate their perceptions about this topic. The low survey response rate for architects leads to the question of how best to reach and engage with this stakeholder group. Potential routes to engage architects include having bird-window collision researchers present at architectural society conferences, creating publication materials geared toward architects, or reaching out directly to architectural societies or firms about bird-window collisions.

Another limitation is that the snowball sampling (Bernard 2017) we used to recruit homeowners could have biased responses toward bird enthusiasts rather than a broader representation of the diversity within this stakeholder group. However, despite this issue, our sample of homeowners contained many respondents that we did not know personally, indicating some degree of variation in levels of interest in or support for bird-window collision mitigation and prevention, as well as wildlife conservation more broadly.

Our results lay a foundation for future research into stakeholder perceptions and priorities related to bird-window collision mitigation and prevention. One essential area of future research is to evaluate stakeholders' willingness to pay (WTP) for measures to reduce bird-window collisions. Our study shows that the stakeholder groups we evaluated are receptive to bird-window collision mitigation and prevention, but that does not necessarily translate into a willingness to pay for those measures, especially if doing so at the level of private residences is left to the responsibility of individuals. Broadly, past research evaluating WTP for conservation practices indicates that the public is generally receptive to wildlife conservation and is willing to pay for it (Tsi et al. 2008; Zander et al. 2014; Steven et al. 2017; Getzner et al. 2018). One study found that the public's WTP for conservation practices was heavily influenced by sense of place, or the value and meaning that individuals attach to a physical location (Kudryavtsev et al. 2012; Nielsen-Pincus et al. 2017). This suggests that informational materials that tie the issue of bird-window collisions to an individual's location or experience may be a particularly effective way to increase WTP. For example, locally or regionally targeted educational materials could highlight the likely number of collisions that occur in areas where residents live and how collisions may be affecting locally important bird species. Another study found that while members of the public were willing to pay for bird conservation, they believed the government should also play a role (Steven et al. 2017), a finding that lends additional support to grant, subsidy, and/or certification programs specifically geared toward reducing bird-window collisions. Although homeowners are a critical stakeholder group to examine with regard to WTP to reduce bird-window collisions, other stakeholders such as business owners and agencies that operate out of larger buildings are also important stakeholders worthy of research.

Birds face multiple human-related threats, including climate change, habitat loss, and other direct mortality sources (e.g., cat predation, other types of collisions) (Loss et al. 2015). While it is important to investigate bird-window collisions specifically, understanding human perceptions of other threats is also necessary because this may lead to insights about which conservation actions are most and least likely to be supported and implemented by the public. Understanding perceptions of different threats, as well as willingness to pay and/or willingness to change behaviors in ways that mitigate these threats, could also lead to more effective conservation strategies that optimize the tradeoff between addressing the most substantial threats and addressing the threats for which substantial management inroads are possible.

Conclusions

This study provides novel insight into how important stakeholder groups might prioritize different bird-window collision mitigation and prevention options. Our research suggests that substantial in-roads can be made to reduce bird-window collisions because both homeowners and conservation practitioners had positive views, indicating their receptivity toward and acceptability of collision mitigation and prevention measures. However, because of their more neutral views and more conflicting responses, our results also highlight the importance of targeting homeowners with education materials that provide information about bird-window collisions and about existing and proposed policies and publicly available solutions that help reduce collisions. Homeowners are a critical stakeholder group because a large proportion of collisions occur at residential buildings; having their support and participation in bird-window collision mitigation and prevention would have a significant impact in reducing collisions. Future research opportunities related to the human dimensions of bird-window collisions and other avian mortality sources include evaluating perceptions of additional stakeholder groups (e.g., architects and policy-makers), determining willingness to pay for bird-window collision mitigation and prevention, and clarifying relative perceptions about impacts and management of human-related threats other than bird-window collisions. Because bird-window collisions are a human-caused phenomenon, understanding human perspectives and priorities about this issue will be crucial to addressing this threat and thus benefitting bird populations.

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Tables and Figures

Table 2.1. Finalized list of strengths, weaknesses, opportunities, and threats (SWOT) containing the top four factors for each category that were used in Survey 1 to evaluate perceptions regarding bird-window collisions for both residential homeowners and conservation practitioners. This final list was developed based on expert elicitation to rank factors on a longer preliminary SWOT list (see text for details).

Strengths	**Weaknesses**
S1: Fewer collisions	W1: No economic incentives building for bird-friendly buildings
S2: Fewer carcasses to clean up	W2: Lack of architect experience in bird-friendly design
S3: Fewer people witnessing collisions	W3: Lack of availability of expert consultation for bird-friendly design
S4: Fewer stunned birds that die of other causes while recovering from colliding	W4: Financial burden of treating glass or including bird-friendly design in building process
Opportunities	**Threats**
O1: Recovering bird populations	T1: Unknown social acceptance of bird-friendly treatments and design
O2: Public exposure to bird-friendly options	T2: Lack of understanding of federal/state policy on bird-window collisions
O3: Consideration of birds in building design becoming a norm/standard	T3: Reduced resources available to spend on other facilities maintenance/improvements
O4: Greater energy efficiency of buildings	T4: No federal/state policy in many areas

Factors	9	7	5	3	1	3	5	7	9	Factors
	←					→				
Fewer collisions										Fewer carcasses to clean up
Fewer collisions										Fewer people witnessing collisions
Fewer carcasses to clean up										Fewer stunned birds that die of other causes while recovering from colliding
Fewer carcasses to clean up										Fewer people witnessing collisions
Fewer people witnessing collisions										Fewer stunned birds that die of other causes while recovering from colliding
1=Equally important; 3=Moderately more important; 5=More important; 7=Very important; 9=Extremely important										

Figure 2.1. Examples of pairwise comparisons within the Strengths category of the strengths, weaknesses, opportunities, and threats (SWOT) analysis; these examples illustrate the format of the initial survey (Survey 1) distributed to two stakeholder groups, residential homeowners and conservation practitioners, to evaluate their perceptions regarding bird-window collisions.

Table 2.2. For a study to evaluate perceptions about potential outcomes of bird-window collision mitigation and prevention, a summary of factors used in strength, weaknesses, opportunities, and threats (SWOT) analyses, their factor priority values, global priority values, and group priority values for homeowner and conservation practitioner stakeholder groups. Top factor and group priorities are in bold.

SWOT Factors	**Factor Priority**		**Global Priority**	
	Homeowner	Conservation Practitioner	Homeowner	Conservation Practitioner
S1: Fewer collisions	**0.46**	**0.60**	0.11	0.15
S2: Fewer carcasses to clean up	0.11	0.06	0.03	0.02
S3: Fewer people witnessing collisions	0.09	0.07	0.02	0.02
S4: Fewer stunned birds that die of other causes while recovering from colliding	0.34	0.27	0.08	0.07
			0.24	**0.24**
W1: No economic incentives for building for bird-friendly buildings	0.23	**0.36**	0.03	0.05
W2: Lack of architect experience in bird-friendly design	0.18	0.13	0.03	0.02
W3: Lack of availability of expert consultation for bird-friendly design	**0.31**	0.26	0.05	0.04
W4: Financial burden of treating glass or including bird-friendly design in building process	0.28	0.25	0.04	0.04
			0.15	**0.15**
O1: Recovering bird populations	**0.34**	**0.45**	0.14	0.23
O2: Public exposure to bird-friendly options	0.18	0.15	0.07	0.08
O3: Consideration of birds in building design becoming a norm/standard	0.25	0.20	0.10	0.10
O4: Greater energy efficiency of buildings	0.23	0.21	0.09	0.11
			0.40	**0.52**
T1: Unknown social acceptance of bird-friendly treatments and design	0.19	0.14	0.04	0.01
T2: Lack of understanding of federal/state policy on bird-window collisions	0.25	0.16	0.05	0.01
T3: Reduced resources available to spend on other facilities maintenance/improvements	0.25	**0.36**	0.05	0.03
T4: No federal/state policy in many areas	**0.31**	0.35	0.07	0.03
			0.21	**0.09**

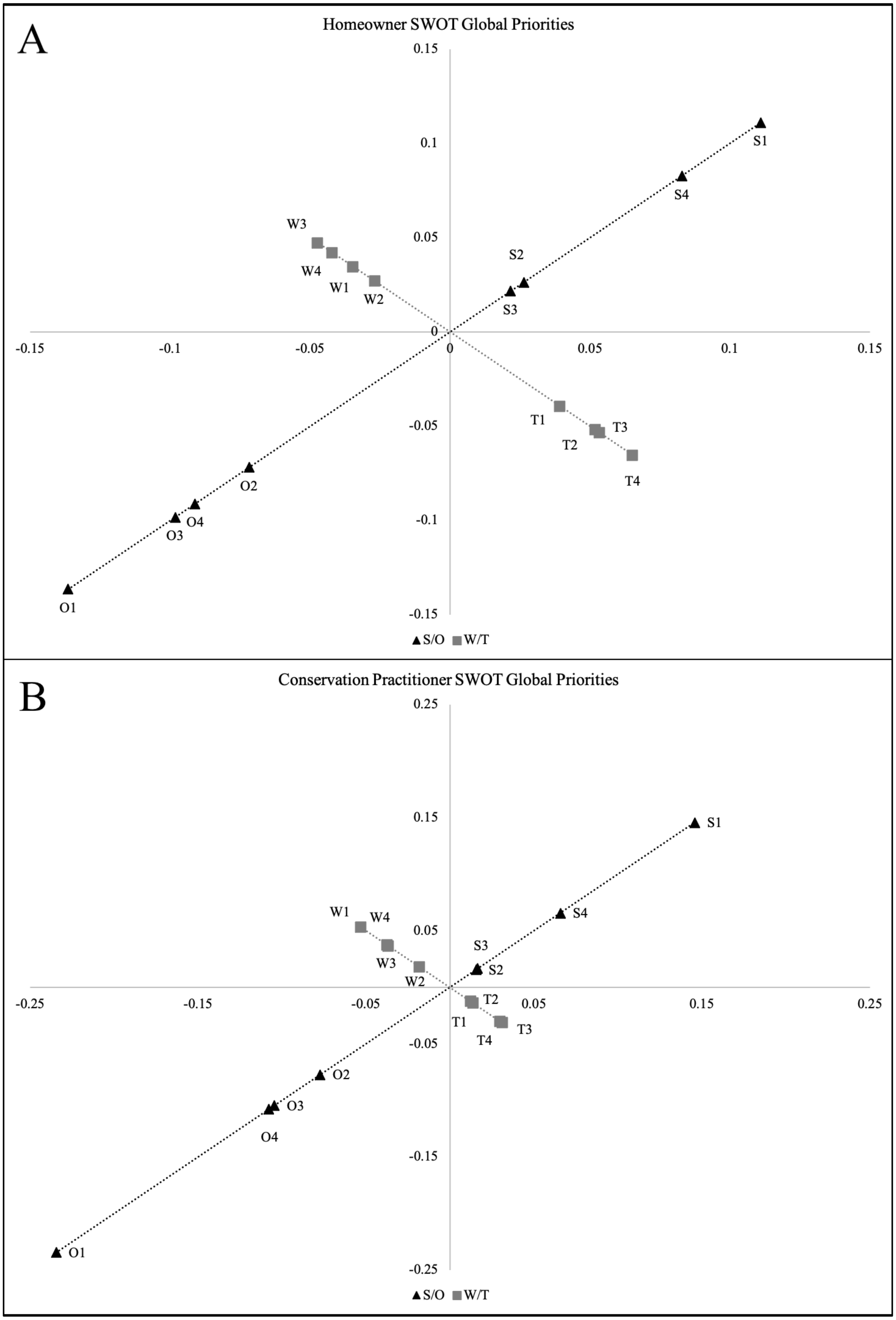

A
Homeowner SWOT Global Priorities
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
-0.15
-0.1
-0.05
0
0.05
0.1
0.15
S1
S4
S2
S3
W3
W4
W1
W2
T1
T3
T2
T4
O2
O4
O3
O1
▲S/O ■W/T
B
Conservation Practitioner SWOT Global Priorities
0.25
0.15
0.05
-0.05
-0.15
-0.25
-0.25
-0.15
-0.05
0.05
0.15
0.25
S1
S4
S3
S2
W1
W4
W3
W2
T2
T1
T3
T4
O2
O3
O4
O1
▲S/O ■W/T

Figure 2.2(A, B). For a study to evaluate perceptions about potential outcomes of bird-window collision mitigation and prevention, a perception map showing homeowner strength, weakness, opportunity, and threat (SWOT) global priorities. Factors with the highest global priority are farthest from the origin. **S1**: Fewer collisions; **S2**: Fewer carcasses to clean up; **S3**: Fewer people witnessing collisions; **S4**: Fewer stunned birds that die of other causes while recovering from colliding. **W1**: No economic incentives for building for bird-friendly buildings; **W2**: Lack of architect experience in bird-friendly design; **W3**: Lack of availability of expert consultation for bird-friendly design; **W4**: Financial burden of treating glass or including bird-friendly design in building process. **O1**: Recovering bird populations; **O2**: Public exposure to bird-friendly options; **O3**: Consideration of birds in building design becoming a norm/standard; **O4**: Greater energy efficiency of buildings. **T1**: Unknown social acceptance of bird-friendly treatments and design; **T2**: Lack of understanding of federal/state policy on bird-window collisions; **T3**: Reduced resources available to spend on other facilities maintenance/improvements; **T4**: No federal/state policy in many areas.

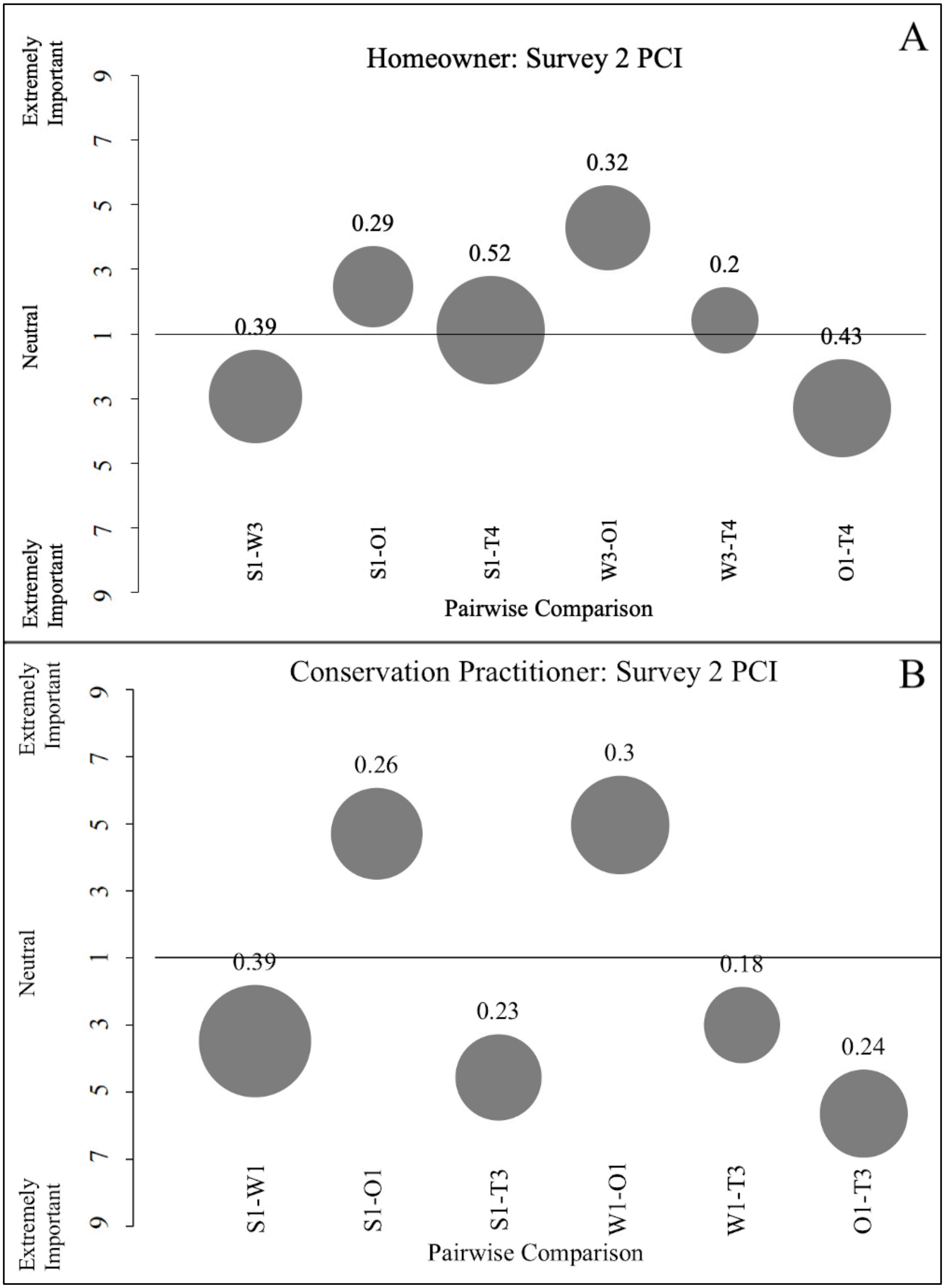
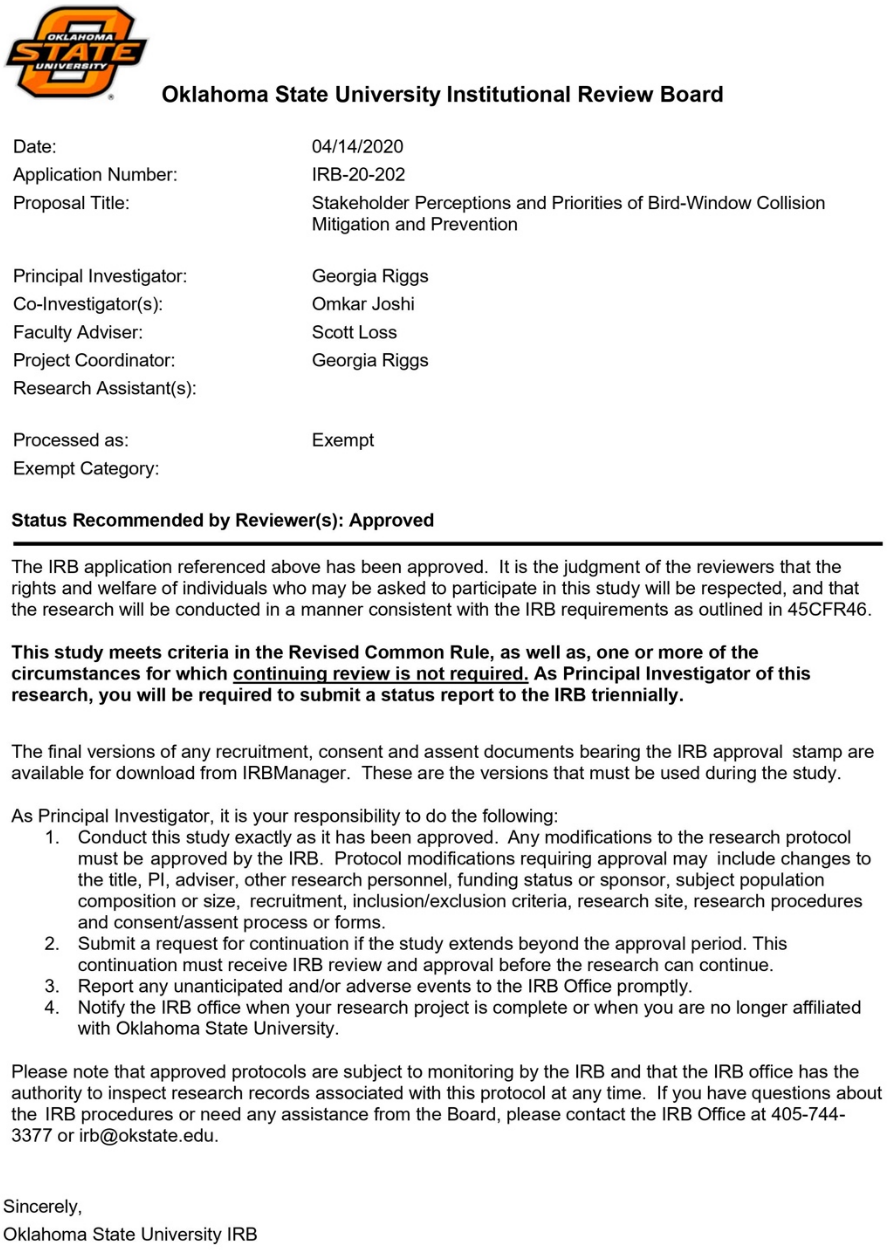

A
Homeowner: Survey 2 PCI
Extremely Important
Neutral
Extremely Important
9
7
5
3
1
3
5
7
9
0.39
0.29
0.52
0.32
0.2
0.43
S1-W3
S1-O1
S1-T4
W3-O1
W3-T4
O1-T4
Pairwise Comparison
B
Conservation Practitioner: Survey 2 PCI
Extremely Important
Neutral
Extremely Important
9
7
5
3
1
3
5
7
9
0.26
0.3
0.39
0.23
0.18
0.24
S1-W1
S1-O1
S1-T3
W1-O1
W1-T3
O1-T3
Pairwise Comparison

Figure 2.3(A, B). For a study to evaluate perceptions about potential outcomes of bird-window collision mitigation and prevention, illustration of the Potential for Conflict Index (PCI) based on the homeowner stakeholder group's responses to Survey 2. Bubble size and values correspond and indicate the dispersion (conflict) among respondent answers (larger bubbles/numbers indicate greater conflict). The location of the bubble indicates the scale mean or the direction respondents lean in their answers to pairwise comparisons (e.g., 0 indicates completely neutral; values farther from 0 indicate more non-neutral perceptions). Each bubble is an individual pairwise comparison indicated by the labels below. Pairwise comparisons correspond visually to the y-axis scale (e.g., for S1-W3, -4 corresponds to S1 and 4 corresponds to W3). For a description of all strengths (S), weaknesses (W), opportunities (O), and threats (T), see Table 1.

APPENDICES



Oklahoma State University Institutional Review Board

Date:	04/14/2020
Application Number:	IRB-20-202
Proposal Title:	Stakeholder Perceptions and Priorities of Bird-Window Collision Mitigation and Prevention
Principal Investigator:	Georgia Riggs
Co-Investigator(s):	Omkar Joshi
Faculty Adviser:	Scott Loss
Project Coordinator:	Georgia Riggs
Research Assistant(s):	
Processed as:	Exempt
Exempt Category:	

Status Recommended by Reviewer(s): Approved

The IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in 45CFR46.

This study meets criteria in the Revised Common Rule, as well as, one or more of the circumstances for which continuing review is not required. As Principal Investigator of this research, you will be required to submit a status report to the IRB triennially.

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

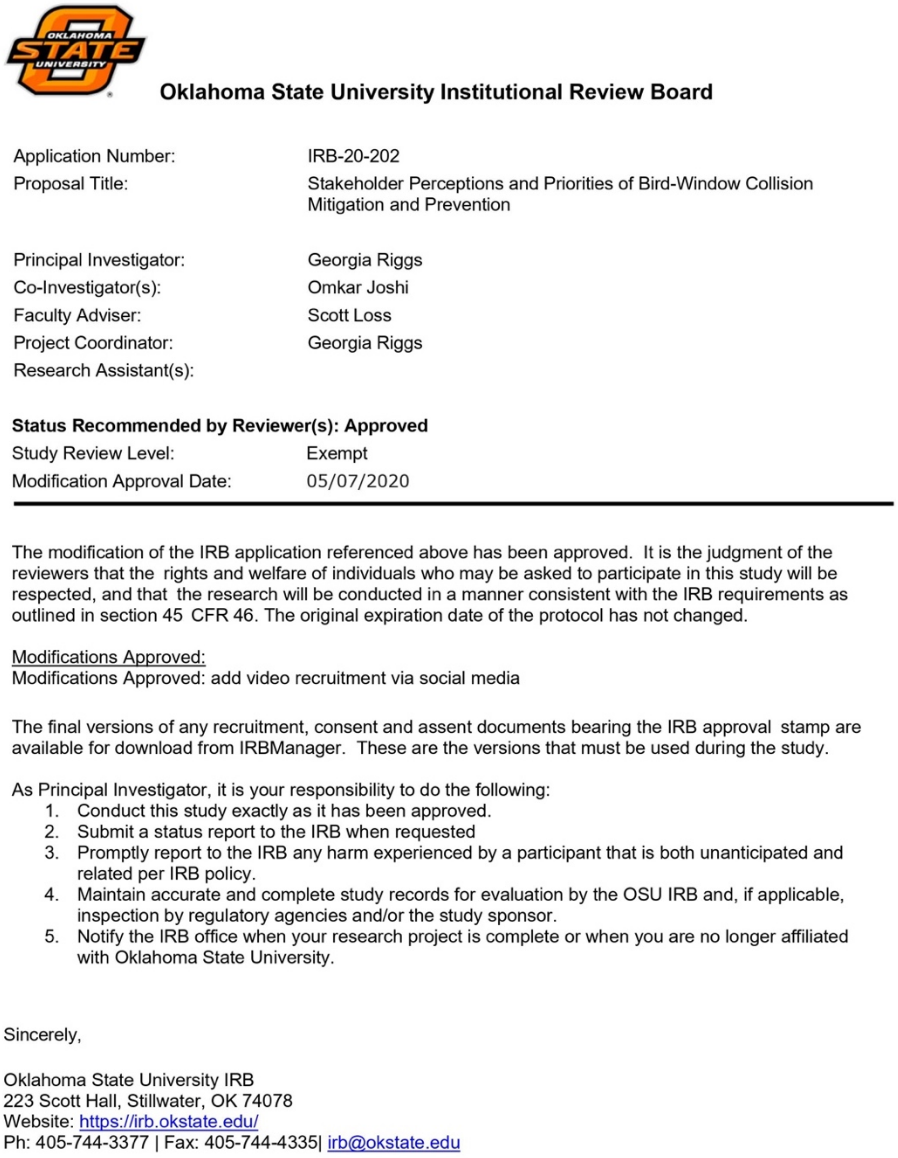
As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved. Any modifications to the research protocol must be approved by the IRB. Protocol modifications requiring approval may include changes to the title, PI, adviser, other research personnel, funding status or sponsor, subject population composition or size, recruitment, inclusion/exclusion criteria, research site, research procedures and consent/assent process or forms.
2. Submit a request for continuation if the study extends beyond the approval period. This continuation must receive IRB review and approval before the research can continue.
3. Report any unanticipated and/or adverse events to the IRB Office promptly.
4. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Please note that approved protocols are subject to monitoring by the IRB and that the IRB office has the authority to inspect research records associated with this protocol at any time. If you have questions about the IRB procedures or need any assistance from the Board, please contact the IRB Office at 405-744-3377 or irb@okstate.edu.

Sincerely,
Oklahoma State University IRB

Figure A1. Oklahoma State University Institutional Review Board letter of approval for exempt status of research project titled “Stakeholder Perceptions of Bird-Window Collisions.”



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Application Number:	IRB-20-202
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Principal Investigator:	Georgia Riggs
Co-Investigator(s):	Omkar Joshi
Faculty Adviser:	Scott Loss
Project Coordinator:	Georgia Riggs
Research Assistant(s):	

Status Recommended by Reviewer(s): Approved

Study Review Level:	Exempt
Modification Approval Date:	05/07/2020

The modification of the IRB application referenced above has been approved. It is the judgment of the reviewers that the rights and welfare of individuals who may be asked to participate in this study will be respected, and that the research will be conducted in a manner consistent with the IRB requirements as outlined in section 45 CFR 46. The original expiration date of the protocol has not changed.

Modifications Approved:
Modifications Approved: add video recruitment via social media

The final versions of any recruitment, consent and assent documents bearing the IRB approval stamp are available for download from IRBManager. These are the versions that must be used during the study.

As Principal Investigator, it is your responsibility to do the following:

1. Conduct this study exactly as it has been approved.
2. Submit a status report to the IRB when requested
3. Promptly report to the IRB any harm experienced by a participant that is both unanticipated and related per IRB policy.
4. Maintain accurate and complete study records for evaluation by the OSU IRB and, if applicable, inspection by regulatory agencies and/or the study sponsor.
5. Notify the IRB office when your research project is complete or when you are no longer affiliated with Oklahoma State University.

Sincerely,

Oklahoma State University IRB
223 Scott Hall, Stillwater, OK 74078
Website: https://irb.okstate.edu/
Ph: 405-744-3377 | Fax: 405-744-4335| irb@okstate.edu

Figure A2. Oklahoma State University Institutional Review Board letter of approval for modification of methods for research project titled “Stakeholder Perceptions of Bird-Window Collisions.”

VITA

Georgia J. Riggs

Candidate for the Degree of

Master of Science

Thesis: BIRD-WINDOW COLLISIONS: FIELD TESTING A POTENTIAL SOLUTION AND EVALUATING STAKEHOLDER PERCEPTIONS

Major Field: Natural Resource Ecology and Management

Biographical:

Education:

Completed the requirements for the Master of Science in Natural Resource Ecology and Management at Oklahoma State University, Stillwater, Oklahoma in July, 2021.

Completed the requirements for the Bachelor of Science in Wildlife, Fish, and Conservation Biology at University of California, Davis, in Davis, California in 2017.

Experience:

- Graduate Research/Teaching Assistant – Oklahoma State University, Dept. of Natural Resource Ecology and Management (2019-2021)
- Avian Research Technician – USGS Patuxent Wildlife Research Center (2017-2018)
- Avian Research Technician – USGS Dixon Field Station (2016-2017)
- Research Intern – USGS Dixon Field Station (2014-2017)

Professional Memberships:

American Ornithological Society, Natural Resource Ecology and Management Graduate Student Organization