FACTORS AFFECTING MIGRATORY BIRD-WINDOW COLLISIONS AND EFFECTIVE MITIGATION STRATEGIES

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ABSTRACT
Bird-window collisions pose a major threat to bird populations, killing up to a billion birds annually in the United States alone. Migratory birds, many of which use the stars and Earth's magnetic field to navigate during the night, are particularly vulnerable to collisions since anthropogenic factors such as light pollution can disrupt their ability to navigate. Factors such as species behavior, surrounding vegetation, and window design have been found to influence collision rates. Research has also identified several effective mitigation strategies, including bird-safe window treatments, reduced artificial light at night, and public education. Addressing the threat of window collisions is crucial to protect avian biodiversity worldwide and preserve the ecological benefits provided by birds.

INTRODUCTION

Volunteers from the Chicago Field Museum were met with a gruesome sight after the night of October 4th, 2023, one of the largest migration nights of the season: approximately a thousand dead birds were scattered by the windows of Chicago's McCormick Place. The building had already been known to be problematic to birds due to its extensive glass facade, but a particularly significant migration night and poor weather conditions led to the largest number of deaths ever recorded at the building. Since then, bird-safe film has been installed in all the building's windows after a $1.2 million project, leading to a 95% reduction in collisions according to McCormick Place (2025).

Figure 1: The new bird-safe film installed at McCormick Place, Chicago (Groleau 2024)

The tragedy at McCormick Place is just one example of how bird-window collisions pose an extreme threat to the stability of bird populations, with such strikes estimated to lead to up to a billion bird deaths in the US alone each year (Loss et al. 2014). This firmly places window collisions as the second leading cause of death in the US for birds, only surpassed by cats. Window collisions often occur because birds are unable to perceive windows as barriers due to their transparent properties. Furthermore, windows can reflect surrounding habitat, causing the bird to mistake a window as vegetation that they then fly towards (Klem 1989). While window collisions pose a threat to all birds, migratory birds are especially at risk due to their tendency to migrate at night. Many species of birds use the stars to help navigate at night, meaning that light pollution from cities can disorient and attract them, consequently increasing the risk of a window collision as birds are drawn to more urbanized environments. A significant number of temperate birds migrate during the fall and spring seasons to follow seasonal resource availability among other benefits. Approximately 70% of terrestrial birds that regularly occur in North America are considered to be migratory (Horton et al. 2019). This widespread migratory behavior means that many species in North America are vulnerable to window collisions, putting their populations in greater risk of decline.

Research has shown that around 57% of North American bird species have seen population declines since 1970, corresponding to a decrease of 3 billion birds. This is a loss of 29% of 1970 bird abundance levels (Rosenberg et al. 2019). Such staggering losses underline the need to focus on the primary threats to birds, such as window collisions, and identify effective mitigation strategies to ensure the long-term stability of bird populations. Birds provide a range of ecosystem services, including pollination, seed dispersal, and pest control, so it is important to preserve these populations in order to prevent any associated losses in ecological stability in the process (Whelan, Wenny, & Marquis 2008).

OVERVIEW OF BIRD MIGRATION BIOLOGY

Migration plays an important role in many avian species since the change of seasons leads to fluctuations in the availability of resources in their habitats. Birds that most commonly migrate include songbirds (order Passeriformes), waterfowl (order Anseriformes), and shorebirds (order Charadriiformes). These birds aim to move to areas with increasing resources while leaving areas with decreasing resources. Approximately 80% of migratory birds in North America choose to migrate in the night for reasons that are not fully understood yet (Horton et al. 2019). However, some evidence has been found to support the hypothesis that nocturnal behavior helps animals face reduced competition and fewer predators (Wcislo et al. 2004).

A variety of methods are used by birds to navigate the skies during migration, many of which can be disrupted by anthropogenic factors. Scientists in 1977 performed an experiment that observed bird flight

patterns of the garden warbler (*Sylvia borin*) and the European robin (*Erithacus rubecula*) under various conditions, finding that the presence of stars had a positive effect on the ability of these birds to maintain a flight direction, and that robins were unable to choose a meaningful direction under the absence of a magnetic field (Wiltschko 1978). Recent studies have confirmed and added on to these findings over the decades. Foster et al. describe in their review article that many night-migrating birds identify the star-filled sky's center of rotation as their reference of orientation (2018). It was also discovered that space weather can disrupt nocturnal bird migration, given that birds rely on Earth's magnetic field. There was a 9 to 17% decrease in migration intensity observed during severe space weather events such as bursts of solar energy, which affect Earth's magnetic field (Gulson-Castillo et al. 2023). The methods birds use to navigate during migration are still not fully understood at the moment, with more research currently being conducted on the topic. Understanding the mechanisms that underlie migration helps with recognizing the potential effects of light pollution on migration and how it factors into bird-window collisions.

Migratory birds are particularly vulnerable to population declines due to a variety of factors, which is only exacerbated by their vulnerability to window collisions. Migratory birds move between various geographical regions and can thus be affected by factors in different parts of the world. Scientists from the National Audubon Society have predicted that two thirds of bird species in North America are vulnerable to extinction as a result of climate change. Climate change can lead to a potential mismatch between the emergence of insects and bird migration, posing risks for these populations (Bateman et al. 2020). Moreover, nearly all the bird species at high risk for both low-rise and high-rise birds were found to be migratory since they traverse longer distances over the course of the year, encountering more building types and total buildings (Loss et al. 2014). As scientific research continues to unravel the secrets behind bird migration, there is an urgent need to address the primary conservation challenges migratory birds face due to anthropogenic activity such as bird-window collisions, climate change, and habitat loss. As urbanization accelerates, these dangers will only intensify, putting migratory bird populations at increasing risk.

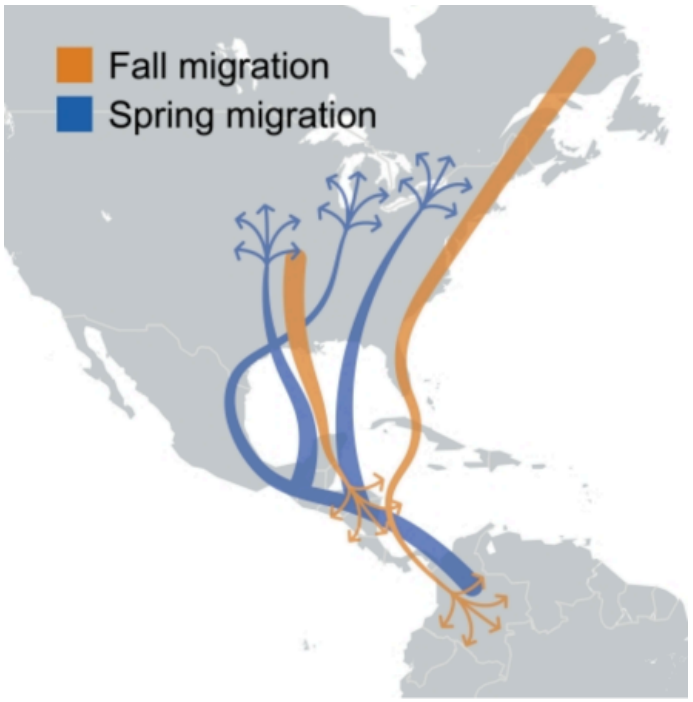

Figure 2: A map depicting the migration routes of birds in North America (U.S. Fish & Wildlife Service 2023)

BIRD-WINDOW COLLISION FACTORS

There are a multitude of factors affecting the rate at which bird-window collisions occur. Understanding these can help pinpoint which mitigation strategies may be the most effective. For one, certain species are more vulnerable due to their behavior and flight patterns. In North America, species of warblers, thrushes, vireos, and sparrows tend to be some of the most commonly found victims, all of which exhibit high levels of migration. The cause of these observations is not fully understood, but it is known that these species tend to fly through densely vegetated areas and are heavily guided by light in their flight, so sources of artificial light can be more disruptive. Other vulnerable species, such as ovenbirds and various thrush species, spend a significant amount of their time on the ground, thus increasing proximity to windows. Furthermore, research suggests that species that primarily migrate at night are more susceptible to window collisions compared to diurnal (daytime) migrants, potentially due to being attracted towards urban areas as a consequence of light pollution (Ogden 1996; Nichols et al. 2018).

Moreover, researchers have found that window proximity to surrounding vegetation and bird feeders plays a significant role in collision rates. A team of researchers in Pennsylvania manipulated the distance of a bird feeder to a window between 1, 5, and 10 meters. Their results showed an increase in window fatalities with a distance of 5 and 10 meters, with a distance of 1 meter leading to no fatalities (Klem et al. 2004). These findings are potentially explained by the fact that birds flying from feeders close to windows do not have enough time to accelerate to a point that a window collision becomes fatal. Another study, taking place in Xalapa, Mexico, found a significant positive relationship between the amount of surrounding vegetation area of a building and the rate of bird-window collisions (Gómez-Martínez et al. 2019). Vegetation is often reflected in windows, confusing birds as they perceive the reflection as actual vegetation that they try to fly to. More vegetation increases the chance this occurs. In summary, greater vegetation near windows increases collisions, while shorter distances between feeders and windows reduce fatal impacts.

Window design, such as the type of window and its angle to the ground is another factor that plays a role in bird-window collisions. Window panels facing the ground have a reduced collision rate, attributed to reduced reflections of surrounding vegetation and the sky (Klem et al. 2004). The size of glass panes had a significant effect on the number of bird collisions with windows. In fact, dividing large glass panes into smaller panels has been found to lead to lower collision rates (Kahle, Flannery, & Dumbacher 2016). Additionally, glass panels that are more reflective in nature increase the chance of collisions, once again due to amplifying reflections of the surrounding environment, drawing birds towards what they perceive as natural habitats (Klem & Saenger 2013).

Perhaps the most significant factor in bird-window collisions is light pollution. Artificial light at night plays an especially important role in bird fatalities. Studies have shown that urban light installations have led to dramatic alterations of nocturnal bird migration. For instance, the beams of the National September 11 Memorial & Museum's "Tribute in Light" in New York City were found to alter the behavior of around 1.1 million birds over seven days, observed over seven years. Observed behavioral changes included decreased flight speeds, circular flight paths, and frequent vocalizations. Bird densities around the area were also 20 times higher than the baseline (Van Doren et al. 2017). This gives credence to the idea that light pollution can increase vulnerability to window collisions, owing to the high number of birds attracted to urbanized areas. Significant fatalities can occur when this is combined with poor weather, like what happened at McCormick Place. Specifically, unfavorable winds and weather that impedes visibility increases the rates of bird-building collisions during migration seasons (Chen et al. 2024). A study taking place in Minneapolis found that the area of glass emitting artificial light at night was the most important factor when it came to collisions, being a better predictor than the glass area, glass percentage, and the maximum and average sizes of glass panes (Lao et al. 2020). Beyond just the lighting area, the proportion of windows lighted was an important predictor. Halving the number of lighted windows was estimated to decrease the number of collisions by a magnitude of 11 in the spring and 6 in the fall (Van Doren et al. 2021). This is a remarkable improvement, underlying the need to turn off lights whenever not in use, especially during the night when nocturnal migrants are active.

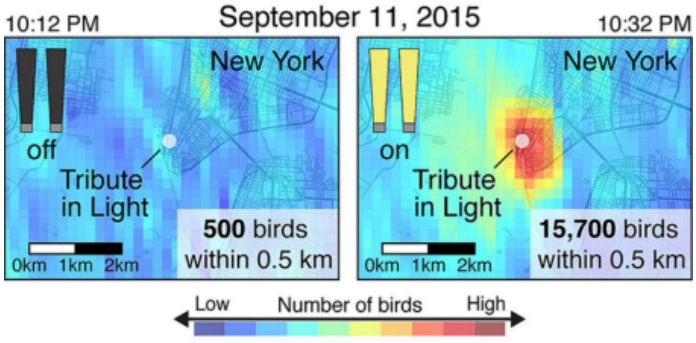

Figure 3: Bird densities at the National September 11 Memorial & Museum "Tribute in Light" display in New York City (Van Doren et al. 2017)

MITIGATION STRATEGIES

Despite the staggering losses caused by bird-window collisions, the issue of bird-window collisions is certainly remediable and researchers have identified several mitigation

strategies that can counter the various factors causing collisions.

Modifying windows to be bird-friendly is one of the most effective mitigation strategies. In the past, suggestions have been made to apply decals and hang objects such as cords in front of glass to prevent collisions, but these were based on educated guesswork rather than empirical evidence. However, recent studies have since shown that these strategies are indeed effective. For instance, a team of researchers at the University of Utah found that applying Feather Friendly® bird deterrent markers to collision-prone windows led to a statistically significant decline in bird-window collisions in contrast to the untreated windows that formed the control group (Brown, Santos, & Ocampo-Peñuela 2021). Another study conducted in Pennsylvania found that stripe and grid patterns of window coverings that are UV-reflecting or UV-absorbing can warn birds of glass while not obstructing the view for humans, since birds are able to see UV wavelengths. The study also found that one-way films that make the outer surface of a window opaque or translucent and windows covered with decals 5-10 cm apart were extremely effective at preventing bird strikes (Klem 2009). Bird-friendly artwork was incorporated at the University of British Columbia, leading to a significant reduction in collisions while also being aesthetically appealing (Crews 2022). Homeowners and conservation practitioners both showed positive views towards bird collision management measures. This suggests that great strides can be made towards increasing the prevalence of bird-friendly windows, underlying the need for education and awareness programs to gain public support for bird-friendly windows (Riggs, Joshi, & Loss 2022).

Even “green” and “environmentally-focused” developments widely use glass panes in their designs, failing to take into account the risk of collisions for birds. This is one of the drawbacks of Leadership in Energy and Environmental Design (LEED) certifications, as LEED-certified buildings tend to have a large portion of its facade being composed of windows, posing a greater danger to birds. Furthermore, the certification promotes increased vegetation around buildings, which has been shown to increase bird-window collisions. These lead to unfortunate side effects despite the intention of being environmentally-friendly (Ocampo-Peñuela et al. 2016). Being environmentally-conscious and bird-friendly, however, are not mutually exclusive. There are assuredly solutions that can be incorporated into the LEED certification process, such as bird-safe window glazings that align with LEED guidelines. Further research is required to determine whether there can be a compromise between surrounding vegetation for LEED certification and bird-friendly building design (Tews 2022).

Figure 4: An example of bird-safe window decals at the University of British Columbia Botanical Garden Pavillion (Crews 2022)

Certain LEED recommendations, however, do benefit bird safety, such as the recommendation to turn off lights when dark out to save energy. Studies have shown that turning off lights, especially in the night, can lead to significant reductions in bird-window collisions. Data taken from the Bird Friendly Building Program (BFB), as part of the Fatal Light Awareness Program (FLAP) in Toronto, Canada revealed that decreases in light emissions from a building were positively correlated with decreases in bird fatalities and injured birds found as a result of window collisions. For this reason, Lights Out programs are crucial to prevent bird fatalities during the busy migration seasons. These programs have now spread to over 30 cities in North America, and continue to gain popularity (Ogden 1996).

These efforts have spread to college campuses as well, such as the Illini Lights Out program, which aims to engage the community to turn off lights around campus for the weekend to conserve energy and reduce artificial light at night. These programs can be made even more effective by identifying heavy migration nights through the use of bird migration forecasting tools, such as BirdCast. Aside from preventing bird deaths, Lights Out programs have the added benefit of reducing power consumption and leading to a reduction in operating costs, thus being a win-win solution for all those involved.

Engaging and educating the public plays an important role as well. Citizen science campaigns are crucial to collect data in order to determine the most effective methods of prevention. Citizen science refers to research conducted with the participation of the general public through volunteering. These campaigns allow for research to be collected in greater numbers than otherwise possible due to limitations. Much of the research previously discussed was conducted with the help of the general public. Loss et al. note how the data provided by citizen science programs have played an important role in advancing bird-window collision research. Additionally, citizens have advocated for bird-friendly building policies and have helped raise awareness of the issue, which has helped increase funding towards research focused on the topic (2023). Numerous successful campaigns have been conducted around the world, including but not limited to Lights Out Texas and the China Anti-Bird Window Collision Action Alliance. Efforts extend to the University of Illinois Urbana-Champaign as well, with members of the UIUC Bird Strike Survey volunteering to record bird-window collisions around campus during the fall and spring migration seasons. It is especially important to raise awareness on a global scale, as the majority of the research conducted on bird-window collisions has been conducted in the Northern Hemisphere, especially in the USA and Canada, despite the diversity of bird species found in the tropics. One of the issues with mitigation is the lack of scientific knowledge regarding bird-window collisions in tropical countries, which can make it difficult to extrapolate findings specific to temperate regions (Basilio, Moreno, & Piratelli 2020). Citizen science programs in these underrepresented regions of the world can help researchers gain a more comprehensive understanding of bird-window collisions. Ultimately, increased awareness of bird-window collisions is crucial to gain support to put into place the various strategies for mitigation, especially since attention from major conservation organizations and the government has been quite limited thus far.

CONCLUSION

Bird-window collisions are a significant threat to the populations of many bird species, with a wide range of consequences. Understanding the various factors that play a role in bird-window collisions (such as artificial light pollution, window proximity to vegetation, and window reflectivity) is critical when it comes to devising effective mitigation strategies. Measures such as limiting artificial light at night and modifying windows with bird-friendly designs can help significantly reduce bird collisions. Moreover, educating the public through citizen science campaigns can lead to increased attention and funding for conservation efforts and allow for better data collection to gain a more comprehensive understanding of bird-window collisions.

However, there are limitations to current research and mitigation efforts. Most studies focus on urban areas in North America and Europe, leaving gaps in understanding bird-window collisions in other regions, particularly in the Global South. Furthermore, while certain mitigation strategies have proven to be effective in controlled settings, large-scale implementation of these ideas remains a challenge due to economic and logistical reasons. Future research needs to be done on the effectiveness of mitigation techniques across a diverse range of environments, long-term population-level impacts, and species-specific vulnerabilities.

If said measures are not adopted and implemented on a wider scale, then threats to birds from window collisions are poised to increase due to the urbanization taking place across the world. Avian fauna contribute a wide variety of ecosystem services and other recreational benefits, so it is pivotal to

address the threat of bird-window collisions to preserve the role birds play in the lives of humans and the overall biosphere.

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