This document has been updated for minor grammatical errors and the addition of a cover image, a glossary, and an avian index for improved usability. All information remains the same as the June 2020 ProQuest document.

Birds and the Built Environment: The Impacts of Architecture, Structures, and Green Spaces on Avian Populations in the United States

Judy Bowes

Birds and the Built Environment: The Impacts of Architecture, Structures, and Green Spaces on Avian Populations in the United States

Judy Bowes

A thesis
submitted in partial fulfillment of the
requirements of the degree of

Master of Science

University of Washington
2020

Committee:
Alex Anderson
Ann Huppert
Kaeli Swift

Program Authorized to Offer Degree:
Architecture

University of Washington

Abstract

Birds and the Built Environment: The Impacts of Architecture, Structures, and Green Spaces on Avian Populations in the United States

Judy Bowes

Chair of the Supervisory Committee:
Professor Alex Anderson
Department of Architecture

The history of modern bird conservation in the United States built environments starts with the success story of the peregrine falcon in the 1970s. Architecture was crucial to the recovery of this once-endangered bird. Architecture and designed green spaces also have been beneficial to the many other species that have successfully adapted to environments dominated by people. In turn, people have valued the enlivening, beneficial presence of birds in cities, parks, neighborhoods, and farms. This history demonstrates that birds are integral to the built environment. However, the built environment can also cause great harm to birds. Bird building collisions are one of the leading anthropogenic threats to birds, killing 365-998 million birds a year in the United States. Glass, lighting, and landscape elements contribute to this enormous loss. Solar and wind energy sources and infrastructure and communication towers also present significant hazards. These dangers in the built environment will have long term impacts on the overall population of birds in the United States and have contributed to a net loss of 29% of the bird population in North America since 1970. Mitigating the threats facing urban resident birds and migrating bird populations in the built environment depends on a clear understanding of birds as integral and essential to our built environment, a comprehensive assessment of built-environment threats birds face, a balanced approach to implementing effective collision mitigating design strategies, and development of regulations, policies and educational resources related to bird preservation in built environments. Building first on a history of birds and architecture, this thesis seeks to provide designers and architects with knowledge about how birds interact with the built environment, a critical assessment of design strategies and architecture-specific policies that benefit urban birds, and proposals for making built environments more amenable to birds through design, policy, and education.

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my committee for remaining positive, encouraging, available, and supportive throughout this process. Their constant reassurance that I could produce my best work, even during trying circumstances, made this document possible. A sincere thank you to my committee chair, Alex Anderson, for encouraging me to research an unconventional topic and enthusiastically agreeing to chair my committee. I am incredibly proud of the work I've produced with his guidance. I am grateful for Ann Huppert's valuable advice and encouragement over the past year. Ann brought clarity to my writing that will allow readers from any field to appreciate the role of birds in the built environment. I will forever appreciate Kaeli Swift's endless patience as I balanced two fields of information and standards while contributing her avian expertise to this document. Kaeli's exceptional ability to guide me to the material I needed to learn, without making me feel incapable, gave me the confidence to fully embrace this topic as my career.

I would like to acknowledge the kindness and support I received from the faculty, staff, and fellow students in the Department of Architecture and the College of the Built Environments. Thank you to Louisa Iarocci and Laure Heland for their thought-provoking lectures, teaching style, and support. They were instrumental in the foundation of my research.

Thank you to "my birds" for teaching me patience, resilience and that humans must *do better* to protect birds from preventable harm. Their histories, and an unforgettable volunteering experience, inspired me to study birds and the built environment. The following are some of the birds I worked with and how anthropogenic hazards left them permanently injured: Tussey, a majestic golden eagle (*Aquila chrysaetos*), lives with injuries from colliding with powerlines. Barbi, a magnificent great-horned owl (*Bubo virginianus*), was injured by a barbed-wire fence. Vehicle collisions injured beautiful Jerudi, a barred owl (*Strix varia*), sweetheart Novia, a barn owl (*Tyto alba*), triumphant Neo, a turkey vulture (*Cathartes aura*), and multiple avian ambassadors. Additionally, Alula, a prodigious red-tailed hawk (*Buteo jamaicensis*), and Millie, a dynamic peregrine falcon (*Falco peregrinus*), are powerful representatives of two species that symbolize the connection between birds and human civilizations throughout history while inspiring stewardship in urban environments. I'm thankful for our years of building trust together.[1]

[1] The adjectives describing the avian ambassadors are from my human perspective and experience. My intent is not to assign emotions, personalities, expectations, or limitations to them or their species but to show respect and honor them linguistically.

For Chantey, Kestrel, Rachel, Short-Eared, Two-Eyed, and all "my birds."

TABLE OF CONTENTS

LIST OF FIGURES

INTRODUCTION

Culturally, in western institutions and the English language, we discuss and perceive urban areas as detached or separate from nature, and we seem unable to move beyond this dualist world view.[2] However, central to the idea of ecology is that people and nature are inherently interconnected. They are influenced by each other, and this coupled human-nature system is abundantly present in the built environment.[3] How can birds aid in ending the perceived bifurcation of nature and city as self-contained and different entities? The study of birds that inhabit areas that include wilderness and dense urban spaces provides a tractable means of studying these various systems, and it provides a lens through which to view the world around us.[4] This is particularly true in urban areas, where birds show that nature is as alive in cities as it is beyond their limits.[5] Birds have unique relationships with architecture and built structures, which can be both beneficial and detrimental.

Birds have been living in built spaces with humans for millennia. The imagery of birds is found as early as 3200 BCE on the Narmer Palette from Ancient Egypt and in scenes of conquest on the 2400 BCE Stele of Vultures from Mesopotamia.[6] Birds were portrayed throughout Ancient Egyptian iconography and language even with species-specific details, as seen with the barn owl (*Tyto alba*) in Figure 1.[7] Bird sightings were first recorded in written form in Vedas, Sanskrit, as early as 1500 BCE.[8] Vultures were integral to death rituals by performing the ecological service of disposing of the dead at the Towers of Silence located in present-day Iran from the 5th century BCE.[9] Peregrine falcons (*Falco peregrinus*) were found nesting on buildings during the Middle Ages, spotted perching atop towering cathedrals, and were first documented in

---

[2] Ingrid Leman Stefanovic and Stephen Bede Scharper, *The Natural City Re-Envisioning the Built Environment* (Toronto, ON: University of Toronto Press, 2014), 11-12.
[3] Michael L. Morrison, *Ornithology: Foundation, Analysis, and Application* (Baltimore, MD: Johns Hopkins University Press, 2018), 886-7.
[4] Ibid., 8.
[5] Stefanovic and Scharper, *The Natural City Re-Envisioning the Built Environment*, 14.
[6] Hartwig and Melinda, *A Companion to Ancient Egyptian Art* (John Wiley & Sons, 2014), 62.; Ann Clyburn Gunter, *A Companion to Ancient Near Eastern Art* (Hoboken, NJ: Wiley Blackwell, 2019), 292.
[7] Rozenn Bailleul-LeSuer and Anna Ressman, *Between Heaven and Earth: Birds in Ancient Egypt* (Chicago, IL: Oriental Institute of the University of Chicago, 2012), 175.
[8] Morrison, *Ornithology: Foundation, Analysis, and Application*, 892.
[9] Ibid., 897.

North American cities in the 1930s.[10] As civilizations documented and recorded the human narrative through time, birds have been included in art and text, observed in our daily lives, incorporated in our rituals, and valued for their services. This relationship with birds has continued into the modern era.

Figure 1. Birds and Ancient Civilizations
Top: Stele of Vultures, Mesopotamia, 2400 BCE, Louvre, Paris.
Bottom Left: Narmer Palette, Egypt, 3200 BCE, Egyptian Museum, Cairo.
Bottom Right: Head of an Owl (*Tyto alba*), Egypt, 664 BCE.

---

[10] Clint W. Boal and Cheryl R. Dykstra, *Urban Raptors: Ecology and Conservation of Birds of Prey in Cities* (Seattle, WA: Island Press, 2018), 258-272.

Pale Male, a light-colored red-tailed hawk (*Buteo jamaicensis*), is a modern-day representative of our relationship with birds in the built environment. As recorded by birders in Central Park in New York City, the first significant event in Pale Male's life was colliding with a building. Pale Male and his first known partner were documented nesting in Central Park in the early 1990s. After building their nest and laying eggs, local crows had distracted both parents during flight, resulting in building collisions for both birds on separate days. Pale Male returned to the park after observation for a concussion at a New York wildlife rehabilitation center. Unfortunately, his partner was sent to a rehabilitation center in New Jersey and was released but did not return to Central Park.[11]

Pale Male is most famously known for his connection to the people of New York City. Frederic Lilien documented Pale Male's daily life and relationship with the urban residents in *The Legend of Pale Male*. Citizens rallied around in awe of the hawk as he nested on an affluent 5th Avenue apartment building on a 12th-floor cornice. Hundreds of people visited the viewing location in Central Park. New York citizens became enthralled with Pale Male's every action. Some citizens were moved to tears by watching him catch a meal, celebrated each fledgling's first flight, and held yearly Father's Day parties for the hawk. Unfortunately, the building residents were not happy with his choice of nesting site that brought crowds to their neighborhood. In 2014, after 15 years and four mates, the building's Co-Op Board dismantled the nest and removed the bird-repelling spikes that held it in place. The citizens were horrified and stood vigil outside of the building. Rallies intensified, chanting lasted day and night as citizens called to return the nest. In just six days, the protesters, along with the New York Audubon Society, who at the time only had three staff members, negotiated with the Co-Op Board. The board hired New York City architect Dan Ionescu to design a permanent nest shown in Figure 2. The designed nest was bolted to the building. Immediately Pale Male and his mate Lola began filling it out with sticks.

Six nesting seasons went by without one viable egg. People began to question if the human-designed nest interfered with nesting. However, after Lola passed away and Pale Male found a new mate, the next breeding season brought viable chicks that fledged. The couple has

---

[11] Marie Winn, *Red-Tails in Love: Pale Male's Story--a True Wildlife Drama in Central Park* (New York, NY: Vintage Departures, 2005), 39-59.

had 19 additional young by 2020 for a total of 46 offspring for Pale Male.[12] On April 30th, 2020, Pale Male turned 30 years old.[13] While this advanced age is rare for his species in the wild, an abundance of food, human protection, a personal architect, and luck may all have contributed to his legendary survival.[14] Pale Male is an avian ambassador for urban birds showing how strong the connection between birds and humans can be in the built environment.

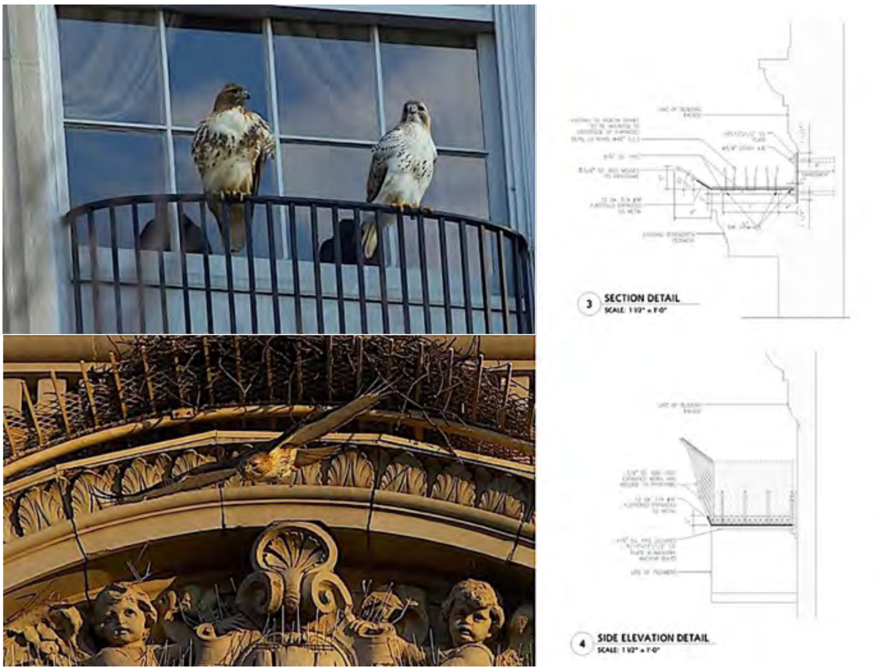


Figure 2. Pale Male with His Mate and Designed Nest
Top left: Pale Male and Lola on a resident's window. Bottom left: Pale Male's architect-designed nest. Right: Detail of Ionescu's nest design.

Birds have economic value as well as cultural and environmental value. Over 53 million people feed birds in the United States, creating a cycle of positive services from humans to birds leading to an increased number of species in areas where feeding is more prevalent.[15] The

[12] The Legend of Pale Male (Distribber, 2009), https://www.thelegendofpalemale.net/.
[13] "The Legend of Pale Male / New York / Nature Films," The Legend of Pale Male, accessed April 22, 2020, https://www.thelegendofpalemale.net/.
[14] The Legend of Pale Male (Distribber, 2009), https://www.thelegendofpalemale.net/.
[15] Morrison, *Ornithology: Foundation, Analysis, and Application*, 891.

visibility and accessibility of birds relative to most other wildlife makes bird-watching, ecotourism, and enjoying birds valuable economically. The U.S. Fish and Wildlife Service's 2016 report indicated 45 million Americans actively observed birds around their homes or on trips.[16] Additionally, they spent over 12 billion dollars on wildlife observing equipment, including bird feeders and binoculars.[17] Birds also provide essential ecological services, including the pest control of insects, small mammals, and weeds; seed dispersal and pollination; scavenging to remove dead carcasses, and nutrient cycling.[18] Although the economic value of birds is hard to measure outside of the poultry industry and the use of feathers in products, it is clear that their value is significant.[19] Great tits (*Parus major*) in the Netherlands reduced caterpillar damage on a Dutch apple orchard that would cost $44-105 per hectare for professional, human-led, pest removal services. Similarly, a pair of Eurasian jays (*Garrulus glandarius*) is valued between $4,900 and $22,000 over their lifetime for their pest control services.[20]

Urban birds show they are among the most vulnerable wildlife to air, noise, and light pollution. Often birds show signs of environmental stressors of urban life earlier than humans, providing insight into how these stresses affect living beings, including humans. Consequently, birds are indicators of our current environmental conditions. House sparrows (*Passer domesticus*), a globally distributed species that dominate highly urbanized areas, show increased oxidative stress due to pollution and poor-quality diets, which could contribute to their population decrease in European cities over the last few decades.[21] Great tits were observed singing at a higher frequency to prevent their song from being masked by low-frequency urban noise such as road and air traffic.[22] These changes in vocalizations can interfere with a bird's ability to survive and reproduce.

---

[16] "2016 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation," October 2018, https://www.census.gov/library/publications/2018/demo/fhw-16-nat.html.
[17] Ibid.
[18] Morrison, *Ornithology: Foundation, Analysis, and Application*, 891.
[19] Ibid.
[20] Ibid.
[21] Oxidative stress is defined as the occurrence of enzymatic and non-enzymatic antioxidants that cannot fully neutralize the free radicals produced in the cells of living organisms.; Amparo Herrera-Dueñas et al., "The Influence of Urban Environments on Oxidative Stress Balance: A Case Study on the House Sparrow in the Iberian Peninsula," *Frontiers in Ecology and Evolution* 5 (2017).
[22] Hans Slabbekoorn and Margriet Peet, "Birds Sing at a Higher Pitch in Urban Noise," *Nature* 424, no. 6946 (2003): 267-267.

Additionally, along with habitat loss and pollution, bird building collisions have become one of the most significant factors in many avian species' long-term survival.[23] Nearly half of North American migrant birds have declined in numbers by at least 50% since the 1970s, and bird building collisions have likely contributed to this number.[24] A staggering 365 to 988 million birds die each year due to bird building collisions alone.[25]

Mitigating environmental stresses and reducing bird building collisions are both attainable with sustainable architecture. To build sustainably, designers must factor in environmental matters.[26] Some sustainable design principles that specifically impact birds include designs that coevolve with nature, designs to heal the planet, designs with nature, and understanding that landscapes or green spaces should not be fragmented based on building footprints or boundaries.[27] These principles help safeguard birds from urban threats but do not directly protect residents or migrating birds from casualties caused by structures and buildings. Restorative environmental design, a combination of sustainable design and design focused on human well-being, aims to achieve a harmonious relationship between nature and humans in the built environment by reducing adverse effects of design on nature and human health while promoting a connection between people and nature.[28] This principle of sustainable design should protect birds in the built environment through collision mitigation. However, birds are rarely a primary focus in restorative environmental design and, as a result, are still in harm's way. Positive environmental impact or *biophilic design* enhances human well-being by connecting humans and nature through building and landscape design with direct, indirect, or symbolic experience of natural or place-based designs.[29] However, outside of creating space for biodiversity, often overlooked are birds and their relationship to human well-being.[30] When

---

[23] Ondi L. Crino et al., "Effects of Experimentally Elevated Traffic Noise on Nestling White-Crowned Sparrow Stress Physiology, Immune Function and Life History," *The Journal of Experimental Biology* 216, no. 11 (2013), 2055.
[24] Kenneth V. Rosenberg et al. "Decline of the North American Avifauna." *Science* (New York, N.Y.) 366, no. 6461 (2019): 120-124.
[25] Scott R. Loss et al., "Bird–building Collisions in the United States: Estimates of Annual Mortality and Species Vulnerability," *The Condor* 116, no. 1 (2014): 2.
[26] Stefanovic and Scharper, *The Natural City Re-Envisioning the Built Environment*, 13.
[27] Stephen R. Kellert, *Building for Life: Designing and Understanding the Human-Nature Connection* (Washington, DC: Island Press, 2005), 97.
[28] Ibid., 93.
[29] Kellert, *Building for Life: Designing and Understanding the Human-Nature Connection*, 96.
[30] Giuseppe Carrus et al., "Go Greener, Feel Better? the Positive Effects of Biodiversity on the Well-being of Individuals Visiting Urban and Peri-Urban Green Areas," *Landscape and Urban Planning* 134 (2015): 221-228.

designers open buildings with large glass walls to increase natural light and connect people visually with nature, they place birds in harm's way. While recent design movements strive to connect humans with natural systems in the built environment, "sustainable," "restorative," or "biophilic" principles of sustainable design must not be merely in the interests of humans. They should create built environments in harmony with the natural environment.[31] Architects and designers have been focused on sustainability to preserve the planet and biophilic design to increase our species' well-being but often overlook the negative impacts these designs have on avian species. Structures awarded for their commitment to meeting sustainability standards should not kill birds routinely.[32] Protecting birds through design strategies must be upheld as a vital component of comprehensive sustainable design standards, policies, and education.

Beginning with the modern history of birds in the built environment, chapter one narrates the generally symbiotic relationship between architecture and urban birds as it has unfolded in built environments in the United States. This history begins with the compelling story of the peregrine falcon's return from the brink of extinction that took place on the concrete cliffs of major American cities. Next, this chapter discusses preferences for urban spaces with two examples of urban adaptors the Anna's hummingbird (*Calypte anna*) and the dark-eyed junco (*Junco hyemalis*). The second half of this chapter focuses on the benefits of green urban habitats and food sources to some bird species. These habitats include green walls, green roofs, and using native plants in landscapes.

Chapter two examines the threats posed by the built environment for resident and migrating birds. This chapter outlines the specific negative impacts of building design, beginning with a brief overview of structures in the built environment hazardous to birds. Energy infrastructure accounts for millions of bird deaths each year in the United States.[33] Solar panels, wind energy, and powerlines all contribute to this loss.[34] Communication towers, transportation, and common structures such as fencing add to birds' unique threats in the built environment.[35] This chapter briefly discusses these significant contributors to bird mortality in the built

---

[31] Kellert, *Building for Life: Designing and Understanding the Human-Nature Connection*, 92.
[32] The U.S. Bank Stadium in Minneapolis, Minnesota as certified LEED Platinum in 2019, the first professional sports stadium to do so. However, its reflective glass facade kills over 100 birds every year.
[33] USAGov. "Migratory Bird Conservation Commission: USAGov." Official Website of the United States Government, https://www.usa.gov/federal-agencies/migratory-bird-conservation-commission.
[34] Ibid.
[35] Ibid.

environment and their solutions.[36] However, this chapter focuses on the threats posed by architecture, lighting, and landscape design primarily in the urban built environment. One of the leading anthropogenic threats resident and migrating birds face in the built environment is bird building collisions.[37] Reflective and transparent glass windows and facades cause the most casualties. Lighting also causes significant harm to birds in the built environment through light pollution, lighting that illuminates transparent glass at night, and floodlighting used to illuminate facades. Finally, landscape design, specifically the location of trees, shrubs, and other vegetation, is another influential factor in bird building collisions.

The design solutions outlined in chapter three include efforts to reduce and eliminate bird building collisions, methods used to reduce light pollution and behavior disruptors, and the importance of understanding how avian species interact with built environments.[38] The available glass solutions are evaluated based on the testing methods, limitations, and ability to reduce window collisions in controlled experiments and case studies. The section first explains the science behind the most commonly recommended solution by avian conservation organizations to reduce collisions: horizontal and vertical line patterns and frit dot patterns. This is followed by an examination of ultraviolet or UV films and patterns. Next, the chapter addresses the limitations of decals and angled glass. This chapter also addresses glass solutions tested in the American Bird Conservancy's experiments and their threat factor rating system. Next, the chapter presents straightforward methods to prevent light pollution and reduce harmful lighting, followed by a brief section outlining how to mitigate collisions due to landscape design choices. This includes incorporating knowledge beyond design by understanding avian behavior, migration patterns, and life histories of resident and migrating birds. Finally, chapter three ends with three case studies that provide examples of preventative design strategies.[39]

Chapter four compiles current legislation and sustainable design guidelines intended to protect birds in the United States. This chapter begins with a brief history of the acts, policies, and programs that aim to protect bird populations in the built environment. Next, the chapter

[36] USAGov. "Migratory Bird Conservation Commission: USAGov." Official Website of the United States Government, https://www.usa.gov/federal-agencies/migratory-bird-conservation-commission.
[37] Anthropogenic is the result of the influence of human beings on nature.
[38] The phrase "bird building collisions" is crucial to use consistently to communicate that window strikes or window collisions are not the only threat facing birds in the built environment. Birds can collide with illuminated structures and materials other than glass.
[39] A life history is the changes through which an organism passes in its development from the primary stage to its natural death.

details sustainable design guidelines that aim to encourage construction of buildings that coexist with local ecosystems, like the Living Building Challenge, or that explicitly incorporate guidelines to protect birds, like LEED’s Pilot Credit 55. The last section reviews city and federal policies aimed to reduce bird building collisions. The chapter provides recommendations and revisions to sustainable design guidelines and legislation based on the evaluation of currently available solutions.

Chapter five outlines education strategies to communicate the best available solutions to reduce bird building collisions and to promote the value of birds. First, the important task of communicating these solutions to architects and designers is achievable by integrating collision mitigating strategies into sustainable design education and college campus policies. Advocating for birds through avian conservation organizations plays a vital role in educating the public about mitigating bird building collisions and the value of urban birds. Finally, aviaries and avian rehabilitation centers connect the public to resident birds' personal stories fostering stewardship and offering examples of collision mitigation techniques to the public through their building designs.

CHAPTER 1 ADAPTATIONS AND BENEFITS OF THE BUILT ENVIRONMENT

Birds occupy most areas of the built environment, from rural landscapes with few built structures, to small towns with sporadically placed homes between fields, through suburbs with manicured back yards and human-provided food sources, and even dense urban areas where concrete cliffs offer roosting and breeding habitat. Some birds have benefited from found or designed habitats throughout these various spaces of the built environment and adapted to our diverse landscape modifications. These birds are identified as urban exploiters or urban adaptors.[40] The abundance of resources birds require (food, water, areas for perching, roosting, and nesting sites) changes with the level of urban development, and individual bird species respond differently to these changes.[41] Urban exploiters, such as American crows (*Corvus brachyrhynchos*), can exploit and are specifically attracted to heavily developed areas. Urban adaptors, such as dark-eyed juncos (*Junco hyemalis*), can exploit the diverse and abundant resources provided by a moderate to lower level of development.[42] Not all birds can adapt to urban development. Urban avoiders, such as Pacific wrens (*Troglodytes pacificus*), avoid areas with minimal landscape development.[43] Often the preferred habitats of urban exploiters and adaptors resemble our general idea of prime habitat. These birds make use of green spaces, but they also challenge our presumptions about proper habitat by nesting on window ledges of high rises, flat gravel roofs, or steel beams, and still successfully fledge offspring. These birds occupy office buildings and residences with the same right to be there as humans while also demonstrating that overlooked architectural features such as substrate, gravel, or ledges can be prime real estate for birds. In specific cases, they can creatively adapt to altered and constructed environments. This chapter provides examples of how some bird species have benefited from or adapted to our human-centric designs and describes ways design can offer more resources to support these species.

---

[40] John M. Marzluff et al., "The Causal Response of Avian Communities to Suburban Development: A Quasi-Experimental, Longitudinal Study," *Urban Ecosystems* 19, no. 4 (April 2015): 1597-1621.
[41] Robert B. Blair, "Land Use and Avian Species Diversity Along an Urban Gradient," *Ecological Applications* 6, no. 2 (1996): 507.
[42] These resources are provided by structural diversity in buildings and vegetation such as increased perching areas or ornamental vegetation; Blair, "Land Use and Avian Species Diversity Along an Urban Gradient,": 512-3.
[43] Ibid., 514.

THE PEREGRINE FALCON IN URBAN HABITATS

The most well-known narrative of the peregrine falcon (*Falco peregrinus*) takes place in the modern built environment. However, peregrine falcons have nested on buildings as early as the Middle Ages; they have been nesting on Salisbury Cathedral in Wiltshire, England since 1860, and were first documented in North American cities in the 1930s.[44] In the mid-20th century, the role of architecture and the urban environment was a fundamental component to the recovery of the peregrine falcon, a species that until the 1960s was known to have only 350-400 pairs in the Midwestern and Eastern United States. By the 1960s, peregrine falcons were no longer residents of cities and were rarely seen during the migration season. Their dramatic decline was due to a buildup in the environment of the organochlorines DDE, a byproduct of the pesticide DDT, which was widely applied to croplands. The chemical moved its way up the food chain to the fastest land predator, the peregrine falcon. By inhibiting calcium absorption, abnormal reproduction in peregrine falcon led to thin eggshells that easily broke under the female's weight during incubation.[45] Ultimately this led to nest failure leaving one last breeding pair in the city of Chicago in 1951. In 1972, Rachel Carson made the dangers of DDE to wildlife and humans widely known in her seminal book, *Silent Spring*. The United States banned DDT, and in 1973 peregrine falcons were placed on the U.S. Endangered Species List.[46]

These legal measures helped to protect the remaining pairs of peregrine falcons and organize a recovery effort to protect the species. The Peregrine Fund, then based at Cornell University, developed a program to captively breed and release peregrine falcons. Falconers-turned-breeders in the Midwest eventually took this over. Chicago became the center for the release of young falcons through the Chicago Peregrine Program.[47] After over 7,000 captive-bred peregrine falcons were successfully released in North America in the late 1970s, the population increased as the peregrine falcon nested in remote areas and built environments, like Chicago, that supported dense human populations near bodies of water. Cities near rivers, lakes,

---

[44] Clint W. Boal and Cheryl R. Dykstra, *Urban Raptors: Ecology and Conservation of Birds of Prey in Cities* (Seattle, WA: Island Press, 2018), 258-272.

[45] Mary Hennen et al., *The Peregrine Returns: The Art and Architecture of an Urban Raptor Recovery* (Chicago, IL: The University of Chicago Press, 2017), 2-6, 10.

[46] Ibid.

[47] Ibid., 16-21.

or oceans provide "ample diverse prey, structures with ledges for nests and perches, and open sky to hunt and soar."[48] Cities also offer a habitat with few natural predators.[49] The recovery effort was so successful that peregrine falcons started to breed in Illinois and expanded to Indiana, Minnesota, Iowa, Missouri, Ohio, Nebraska, Wisconsin, and today, peregrine falcons live on both coasts of the United States.[50]

Peregrine falcons are an idyllic example of how some bird species have adapted to the urban environment without needing extensive human support once they have established themselves there. Peregrine falcons now call the urban Chicago canyons of neoclassical buildings and skyscrapers their year-round habitat, even though the city was not designed with birds in mind (see Figure 3). The first pair to nest in Chicago was in 1987 on the Willis Tower (then called the Sears Tower). Peregrine falcons are typically cliff-dwelling species and use ledges often with gravel substrate as nesting areas. No nest building is required beyond making a small depression in the substrate called a *scrape*.[51] In some cases, nests on bare steel beams have been viable.[52] Buildings along Wacker Street in downtown Chicago, including the Willis Tower, have been continuous nesting sites for pairs of peregrine falcons for over 33 years. The nesting sites along Wacker Street are chosen not for the building's size but because of the cliff-like ledges, which allow a full 360° view when incubating eggs. These buildings provide a balance between protection and few confining tall walls. Spaces that are more cave than cliff-like also allow nesting high above the city, with little interference from humans. This can be seen in the abandoned historical clock tower in the Central Manufacturing District, which has been occupied by peregrine falcons since 2009.[53] (See Figure 3.)

---

[48] Boal and Dykstra, *Urban Raptors*, 180-195.
[49] Ibid., 258-272.
[50] Mary Hennen et al., *The Peregrine Returns*, 16-21.
[51] Ibid., 24-6.
[52] Boal and Dykstra, *Urban Raptors*, 180-195.
[53] Mary Hennen et al., *The Peregrine Returns*, 42-6.

Figure 3. Peregrine Falcons (*Falco peregrinus*) on Built Structures
Top: Cliff-like Ledges.
Bottom left: Historical Clock Tower. Bottom Right: Water Intake Crib.

Once suitable nests are established, peregrine falcons have high nest fidelity, meaning they will only choose a new nesting site if breeding is unsuccessful or the site is damaged and unusable. Sites such as a gutter can wash away nests, balcony planters can cause disturbances for both peregrine falcons and humans, and bridges over water could lead fledglings to drown.[54] Protected landmarks are also not ideal places for the peregrine falcon, though as a result of human conflicts rather than ecological unsuitability, particularly when the owners and residents aim to preserve the landmark. For example, when a pair attempted to nest on the historic Powhatan building in Chicago, managers recommended outfitting the roof with a nest box. However, the residents did not want to share their space with the protected falcons, perhaps because of their loud calls and damaging excrement.[55] A compromise was made to allow the pair to complete that year's breeding attempt in the safety of a supplied nest box. The box was to be removed 45 days after the young fledged to preclude future attempts. The pair successfully relocated to a site over a mile away.[56]

---

[54] Mary Hennen et al., *The Peregrine Returns*, 50-2.
[55] Ibid., 107-14.
[56] Ibid., 50-2.

Peregrine falcons also choose unusual or unwanted nesting sites on building types different from those the first breeding pairs chose in the 1970s, such as water intake cribs shown in Figure 3. Their unique shape mimics rock ledges.[57] Private balconies also can have excellent nesting habitats. Planters with a natural substrate and a covered but not enclosed area on the side of a building produce safe nesting spots.[58] Unfortunately, some building residents may not welcome excretion stains or leftover parts of peregrine meals on or near their buildings. (See Figure 4.)

Figure 4. Peregrine Falcons (*Falco peregrinus*) Nesting on Buildings

The presence of the peregrine falcon in urban areas helps to promote conservation efforts. This is achieved through live streams of nests on buildings, which provide comprehensive data from 24-hour monitoring.[59] Since peregrine falcons are protected, their nests cannot be removed,

[57] Mary Hennen et al., *The Peregrine Returns*, 141-55.
[58] Ibid.
[59] Boal and Dykstra, *Urban Raptors*, 180-195.

and residents who inadvertently host breeding pairs must wait until the falcons abandon their nests or the chicks fledge.[60] While some residents welcome their new neighbors, mess and all, the addition of a nesting box may be an option for those who are uncomfortable sharing space with a raptor family. Education efforts to inform residents about ecological services peregrines perform, such as pest control, could further persuade them to allow nesting.

A survey in 2017 indicated that all but seven US states are home to the peregrine falcon, and their urban habitats vary from small towns to metropolises.[61] Even some peregrine falcons that were released in remote areas eventually migrated to cities, becoming many of the urban peregrine falcons that occupy cities on the West Coast of North America.[62] Designing for peregrine falcons helps further conservation efforts and provides desired ecosystem services. Scientists have designed nest trays and integrated pea gravel onto ledges to provide adequate nesting substrate for peregrine falcons.[63] In a study of 87 urban nests in eastern North America, human-made nest ledges and gravel-lined trays or boxes had almost three times the total number of young fledge than those without human-made additions. Several building and bridge managers have investigated how to attract peregrine falcons to control starling and pigeon populations. They have suggested the presence of peregrine falcons has lessened maintenance costs.[64] The species has shown they can adapt to architecture that mimics their natural habitat. Little additional designed space is needed to help make their urban habitat more successful. However, it is important to remember peregrine falcon nesting requirements when designing new buildings as not inadvertently to remove their preferred habitat space.

Examples of how some birds have adapted to urban and suburban spaces are often clearly displayed by raptors or birds of prey through their visible interactions with architecture and modified urban landscapes. While not all birds of prey can exploit urban areas like the peregrine falcon, a group of hawks called *accipiter* hawks prefer peri-urban spaces resulting in a 26%-67% increase, over 30 years, in peri-urban and suburban areas of Chicago.[65] Moreover, a few species

---

[60] Mary Hennen et al., *The Peregrine Returns*, 142-145.
[61] Boal and Dykstra, *Urban Raptors*, 180-195.
[62] Ibid.
[63] Ibid.
[64] Ibid.
[65] Justin H White et al., “Raptor Nesting Locations along an Urban Density Gradient in the Great Basin, USA,” *Urban Ecosystems* 21, no. 1 (February 2017): 51-60.

of owls have adapted to a moderate level of urbanization.[66] However, a preference for urban, peri-urban and suburban spaces, and some bird species' ability to adapt to their resources, is not exclusive to raptors.[67] Some hummingbirds like the Anna's hummingbird (*Calypte anna*) and passerines like the dark-eyed junco, have successfully adapted to moderately urbanized areas of the built environment.[68]

ADAPTING TO PERI-URBAN AND SUBURBAN SPACES

As humans modify the landscape and contribute to climate change, some animal populations are forced to move to new habitats and modify their behaviors in response to these new ecological and evolutionary pressures.[69] Birds need to respond to environmental changes as quickly as humans cause them.[70] Some birds can adapt to these changes and benefit from the resources provided by peri-urban and suburban spaces like the Anna's hummingbird and the dark-eyed junco (see Figures 5 and 6).

The Anna's hummingbird's traditional winter range was the Pacific slope of northern Baja California and north to California's San Francisco Bay area. Since the mid-1930s, the species' winter range has been expanding and now extends as far north as Vancouver Island in British Columbia and inward towards southern Arizona and West Texas.[71] To understand what could account for this range expansion, Greig et al. examined how climate, housing density, and supplementary feeding data predicted winter occupancy of Anna's hummingbirds over 17 years

[66] However, for burrowing owls (*Athene cunicularia*) and snowy owls (*Bubo scandiacus*), their occasional preference for peri-urban or moderately urbanized landscapes can provide habitat space but can expose them to dangers in the built environment.; Courtney J. Conway, "Burrowing Owls: Happy Urbanite or Disgruntled Tenant?" *Urban Raptors*, 2018: 166-179.; Jean-François Therrien et al., "Winter Use of a Highly Diverse Suite of Habitats by Irruptive Snowy Owls," *Northeastern Naturalist* 24, no. sp7 (2017): 81-7.

[67] Peri-urban refers to the location immediately surrounding an urban area.

[68] Passerines belong to a large order of birds, *Passeriformes*, with toes that facilitate perching, they include songbirds but are not exclusively songbirds.

[69] Emma I. Greig et al., "Winter Range Expansion of a Hummingbird Is Associated with Urbanization and Supplementary Feeding," *Proceedings of the Royal Society B: Biological Sciences* 284, no. 1852 (2017): 1.; Ellen Ketterson, "Journey of the Juncos: Migration and Adaptation in Our Changing World," *Bird Academy, Cornell University* (October 7, 2019).

[70] Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).

[71] Clark and Russell. Anna's Hummingbird (*Calypte anna*), version 1.0. In Birds of the World (A. F. Poole, Editor). (2020) Cornell Lab of Ornithology, Ithaca, NY, USA.

(1997-2013) across the West Coast.[72] They found that over this timespan, Anna's hummingbirds were able to become residents in urban and suburban areas they previously migrated out of during the winter. Housing density and human-modified habitat predicted colonization in the expanded range but not in their historical range.[73] These urban areas allow the species to survive colder thermal limits due to local heat retention or the "heat island effect." In addition, while warmer winters supported this shift, they found that it was primarily supplemental food in the form of non-native flowers and nectar feeders that best modeled this change in winter occupancy.[74] These findings suggest that the Anna's hummingbird's winter range expansion is due to the species' ability to utilize urbanization, cultivated urban and suburban exotic plants, and supplementary feeding through human-provided feeders.[75] The nectar feeders demonstrate the connection between human modifications of the environment, human behaviors, and the adaptation and support of a species. Through land modification and resource availability, humans have altered the Anna's hummingbird's distribution and potentially the species' migratory behavior.[76]

Figure 5. Female Anna's Hummingbird (*Calypte anna*)

[72] Greig et al., "Winter Range Expansion of a Hummingbird Is Associated with Urbanization and Supplementary Feeding," (2017).
[73] Ibid., 5.
[74] Ibid., 6-7.
[75] Ibid., 1-7.
[76] Ibid.

The dark-eyed junco is one of the most recognizable passerines in North America.[77] This common and abundant species is found from northern Alaska to northern Mexico.[78] The dark-eyed junco is known as the "snowbird" for its ground foraging winter flocks often observed around suburban feeders. This species is located throughout the built environment in backyards, edges of parks and modified landscapes, farms, and rural roadsides in addition to their ancestral mountain breeding habitat.[79] The dark-eyed junco's ability to adapt to peri-urban and suburban settings has provided essential ecological research of avian evolution and migration. In the 1980s, a small population of dark-eyed juncos successfully colonized the University of California campus in the coastal city of San Diego, California.[80] This "city" or "coastal" population had a twice as long breeding season than their ancestral "mountain" populations and fledged twice as many young.[81] The dark-eyed juncos in San Diego ceased migrating and were breeding in the city, which offered a milder climate and reliable food sources.[82]

Figure 6. Dark-Eyed Junco (*Junco hyemalis*), Oregon Phase

[77] Nolan et al. Dark-eyed Junco (*Junco hyemalis*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). (2020) Cornell Lab of Ornithology, Ithaca, NY, USA.
[78] Ibid.
[79] Ibid.
[80] Pamela J. Yeh and Trevor D. Price, "Adaptive Phenotypic Plasticity and the Successful Colonization of a Novel Environment," *The American Naturalist* 164, no. 4 (2004): 531.
[81] Yeh and Price, "Adaptive Phenotypic Plasticity and the Successful Colonization of a Novel Environment," (2004): 531.; Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).
[82] Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).; Yeh and Price, "Adaptive Phenotypic Plasticity and the Successful Colonization of a Novel Environment," (2004).

Studies demonstrating how this population adapted to urban environments include significant biological and behavioral changes over a few decades. Yeh's 2004 study found that city dark-eyed juncos exhibited a change in plumage rather quickly. They showed less white coloring on the tails, more brown coloring on the crown, and a slightly shorter wing length.[83] City juncos were also less aggressive,[84] showed fewer signs of stress when handled, were calmer, and allowed a closer approach to humans than mountain juncos.[85] Additionally, compared to mountain juncos, city juncos had fewer extra-pair fertilizations,[86] males tended to young more often,[87] and they sang at a higher pitch to be heard over the urban environment's background noise.[88] These observed changes in urban or city juncos show the species' ability to quickly adapt to the rapid modification of the environment while at the same time illustrating how anthropogenic changes to the landscape and climate can dramatically impact avian species.

The Anna's hummingbird and dark-eyed junco have adapted to land modifications and resources available in peri-urban and suburban areas. The dark-eyed junco was observed nesting in vines on the University of California, San Diego campus,[89] and hummingbirds visit the green wall of the Sam Cuddleback Assembly Wing in San Francisco, California.[90] The built environment can offer additional habitat space and vital resources for these urban adaptors and other bird species by incorporating green walls and green roofs into building designs and using native plants in urban and suburban green spaces.

---

[83] Pamela J. Yeh, "Rapid Evolution of a Sexually Selected Trait Following Population Establishment in A Novel Habitat," *Evolution* 58, no. 1 (2004).; Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).

[84] Melissa M. Newman, Pamela J. Yeh, and Trevor D. Price, "Reduced Territorial Responses in Dark-Eyed Juncos Following Population Establishment in a Climatically Mild Environment," *Animal Behaviour* 71, no. 4 (2006): 893-899

[85] Jonathan W. Atwell et al., "Boldness Behavior and Stress Physiology in a Novel Urban Environment Suggest Rapid Correlated Evolutionary Adaptation," *Behavioral Ecology* 23, no. 5 (2012): 960-969.; Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).

[86] Jonathan W. Atwell et al., "Hormonal, Behavioral, and Life-History Traits Exhibit Correlated Shifts in Relation to Population Establishment in a Novel Environment," *The American Naturalist* 184, no. 6 (2014).

[87] Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).

[88] Gonçalo C. Cardoso and Jonathan W. Atwell, "On the Relation between Loudness and the Increased Song Frequency of Urban Birds," *Animal Behaviour* 82, no. 4 (2011).

[89] Ketterson, "Journey of the Juncos," *Bird Academy, Cornell University* (October 7, 2019).

[90] Greenroofs, "Drew School Sam Cuddleback III Assembly Wing Vertical Garden," Greenroofs.com, 2020, https://www.greenroofs.com/projects/drew-school-sam-cuddleback-iii-assembly-wing-vertical-garden.

GREEN WALLS AND ROOFS AS HABITAT

Green walls have been used on buildings for over 2000 years, with the earliest vertical gardens being attributed to Mediterranean cities.[91] Traditionally, green walls use self-adhering plants rooted in the ground, planters that spread along vertical surfaces of structures, or they use plants that drape down from planters on parapets, sills, or balconies. Contemporary green walls, or living walls, grow from systems installed directly onto building walls. (See Figure 7.) They are typically intricate systems with regulated water and other optimized growing variables installed onto building facades. While traditional and contemporary systems can vary dramatically regarding the plants used and how they are maintained, both systems can provide valuable green space that improves the aesthetics, building integrity, and health and wellbeing of human occupants.[92] Green walls in the urban environment benefit humans by providing insulation and removing particulates and carbon dioxide from the air.[93] While clinging plants, such as ivy, can be destructive to brick and mortar surfaces, they can also protect walls through temperature and humidity regulation while also reducing storm-water flows.[94] In addition, green walls can reduce noise pollution and light pollution in urban environments. In addition to the human benefits, these kinds of green spaces can also offer significant habitats to native plants, insects, and birds.

Figure 7. Green Wall on the Sam Cuddleback III Assembly Wing, San Francisco, CA

[91] Manfred Kohler, "Green Facades – A View Back and Some Visions," *Urban Ecosyst* 11, (2008): 423.
[92] Ibid.
[93] Caroline Chiquet et al., "Birds and the Urban Environment: The Value of Green Walls," *Urban Ecosystems* 16, no. 3 (2013): 453-459.
[94] Ibid.

A 2013 study by Chiquet et al. found that self-adhering, green walls indicated immense value to resident avian populations by providing shelter, refuge, and food sources.[95] They monitored 27 green walls and 27 bare walls in Staffordshire, UK, during the summer and winter months. They found that birds used the upper half of the green walls consistently, with no variation between season. There was also an increase of birds on the roofs of buildings with green walls and surrounding vegetation compared to the bare control walls. The walls in the study ranged in size from 2 m to 6 m high. On each of the green walls, 100% of the surface was covered with vegetation. The walls were surveyed for five months over two seasons: Summer (July and August) and Winter (January, February, March). They observed 83 individual birds comprising nine species, with some arriving in mixed flocks that were more than double the number in flocks found on bare walls.[96] Birds on green walls were more abundant in the morning than evening but showed no difference in numbers throughout the day on the bare walls. The preference for morning indicates insectivorous birds used the green wall for a food source at a time in the day when insects are least active and easier to prey upon.[97] Seasons did not affect the abundance of birds compared to bare walls, but more birds were found on green walls in the winter than in the summer and were associated with evergreen plants more strongly than with deciduous plants in the winter. This study indicated the foliage provides important shelter, refuge, and nesting space. Evergreen plant species can also produce food for birds in the winter months. No significant difference in birds present on evergreen or deciduous green walls was reported in the summer months.[98]

Green walls can provide a range of resources for urban and migrating birds that either complement existing land-based green areas or offset an absence of such resources.[99] For humans, plants provide increased well-being, health benefits, and recreational benefits, as well as various ecosystem services.[100] The benefits of plants, and the increased biodiversity they offer, are typically more visible to humans on green walls than green roofs or even some land-based green spaces. In this case, green walls can work in combination with green roofs to create larger

---

[95] Chiquet et al., "Birds and the Urban Environment: The Value of Green Walls,": 453-459.
[96] Ibid.
[97] Ibid.
[98] Ibid.
[99] Ibid.
[100] Ibid.

biodiverse habitat areas in dense urban areas where green areas are limited. This design element could be especially beneficial in areas that do not provide people with connections to green spaces or natural areas, particularly if used on walls that face windows where people work and live.[101]

Much like green walls, green roofs are an old technology rooted in the vernacular architecture of many cultures across the globe. In the Middle Ages, green roofs were used at some Benedictine Monasteries, and 20th-century architects incorporated green roofs into their celebrated designs. Le Corbusier listed green roofs as one of his five points of architecture, and Frank Lloyd Wright used green roofs to integrate architecture into the natural landscape. Modern green roofs flourished in Europe after the Second World War as countries like Germany aimed to rebuild greener cities.[102] By the 1960s, Germany, particularly Berlin, began to standardize the green roofs we see most commonly today, and by 1970 the standard plants used were *Sedums*. These succulents are tolerant of harsh conditions and can absorb water. By the 1980s, the green roof's ability to store water and reduced runoff became one of the main purposes for incorporating them into building designs.[103]

Today, two types of green roofs are found across Europe and North America: intensive and extensive green roofs. Intensive roofs are formal gardens that require a deep, flat soil layer to plant larger vegetation like shrubs or trees. Extensive green roofs have shallow soil levels and can adapt to roofs with slopes up to 40 degrees. Pre-grown *Sedum* mats are often rolled out onto roof membranes to create an extensive green roof instantly. However, mats offer little biomass limiting the diversity of organisms that can live in them. However, using a substrate material with seeded or planted *sedums* can offer more biodiversity by allowing species to colonize as the green roof develops.[104] To avoid birds prematurely visiting the space and destroying the young plants, the use of seeding or plugs as the starting vegetation can mitigate this issue.[105]

Green roofs can provide habitat for urban and migrating birds by offering food, water, cover, and space while at the same time benefiting human wellbeing by adding vital green space.

---

[101] Chiquet et al., "Birds and the Urban Environment: The Value of Green Walls,": 453-459.
[102] R. Fernandez-Canero and P. Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review," *Journal of Animal and Veterinary Advances* 9, no. 15 (January 2010): 2041.
[103] Dusty Gedge and Kadas Gyongyver, "Green Roofs and Biodiversity," *Biologist* 52, no. 3 (July 2005): 160-2.
[104] Gedge and Gyongyver, "Green Roofs and Biodiversity,": 160-2.
[105] Bowes, Judy, and Matthew J Eckess. Green Roof Planting. Personal, March 1, 2020.

However, a green roof's benefit to birds depends on its design, vegetation, and maintenance.[106] When attracting birds to green roofs, food is the most important benefit, so they should be maintained as habitat for invertebrates that birds eat. Birds use green roofs more often in urban areas than in the suburbs since they are an essential food resource where food may be scarce otherwise.[107] Seed and fruit-bearing plants on roofs are also important food sources, as are food-bearing street trees. In some cases, green roofs could provide coverage to protect birds from predators or weather, particularly when birds use roofs as nesting areas.[108] A wide variety of birds can nest on green roofs; these include birds that would typically prefer cliffs, open grasslands, or stony substrate as nesting habitats.[109] Providing water is crucial to attracting birds to green roofs. Some birds can drink the water from planted succulents or benefit from water retaining substrates, and some species can still nest and breed successfully without supplemental irrigation.[110] However, the most attractive designs incorporate supplemental irrigation or small areas of water like a pond or fountain. While green roof space is limited by the roof space available, it is essential to understand the size and habitat needed by the bird species a design is aiming to attract. Not all rooftops will be large enough to accommodate species with extensive space needs or large populations of species. Adding green walls can increase the available habitat.[111] Building height and species mobility contribute to attracting birds to green roofs. While taller buildings may provide respite sites for migrating birds, resident birds may not be as likely to nest on the same building.[112]

While design tactics can attract birds to green roofs, few studies explain how to promote nesting on green roofs or have observed species of birds that do. Green roofs using extensive amounts of *sedum* can provide habitat for many urban adapters, but attention to habitat design on intensive roofs can create space for vulnerable species. While green roofs do not fully replace land lost to urbanization and other types of habitat destruction, some species return to dense urban areas with the introduction of green roofs. The Waterfowl and Wetland Trust in the United Kingdom designed their green roof to provide space for mallards (*Anas platyrhynchos*) to nest.

---

[106] Fernandez-Canero and Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review,": 2043, 2045.
[107] Ibid.
[108] Ibid.
[109] Ibid.
[110] Ibid.
[111] Ibid.
[112] Ibid.

Species of skylarks, finches, and thrushes also have successfully nested on the roof.[113] Gedge and Kadas explained in their 2005 article that green roofs can be useful tools for conservationists. For example, they report that the London Biodiversity Partnership is working with developers to create green roofs to promote urban occupation by the black redstart (*Phoenicurus ochruros*), the UK's rarest breeding bird (50-100 breeding pairs). To mimic this species' preferred habitat and provide a safe space for breeding, the developers designed "brown roofs" with little vegetation and increased substrate.[114] In the United States, The Ford Motor Company's River Rouge Assembly Plant in Dearborn, Michigan, is home to two nesting species, the near threatened olive-sided flycatcher (*Contopus cooperi*) and the killdeer (*Charadrius vociferous)*; see Figure 8. Killdeer also have been found nesting on the green roofs at the O'Hare International Airport in Chicago. The city of Portland, Oregon, has listed over eight species using their green roofs.[115] Furthermore, the Jacob Javits Convention Center in New York City listed 29 identified species in 2018, including the Eastern bluebird (*Sialia sialis*) and red-tailed hawk (*Buteo jamaicensis*), and over 100 herring gull (*Larus argentatus*) nests were recorded in 2019; see Figure 9.[116] It is evident in these few examples that various species can be attracted to green roofs, and their addition to urban areas can lead to significant improvement of habitat for birds. However, more design elements may be needed to provide adequate nesting habitat. For example, artificial nesting boxes can be incorporated onto green roofs to entice cavity-nesting species to inhabit the area. They can be placed on poles or in vegetation on roofs with a thicker substrate but must be oriented away from direct sunlight.[117] Green roofs can provide habitat for urban birds or refuge to migrating birds with the correct design components (water, food, space, and cover). Green roofs can also be designed as a space for particular bird species as part of broader conservation efforts while at the same time meeting sustainability goals that protect all species.

---

[113] Fernandez-Canero and Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review,": 2043, 2045.
[114] Gedge and Gyongyver, "Green Roofs and Biodiversity,": 163.
[115] Fernandez-Canero and Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review,": 2044-5.
[116] "An Unconventional Oasis: Sustainability Report 2019" (Jacob Javits Convention Center, 2019), https://issuu.com/javitscenter/docs/8725_javits_sustainabilityreport201).
[117] Fernandez-Canero and Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review,": 2047.

Figure 8. Ford Rouge Factory Green Roof Habitat, Dearborn, MI
Top right: olive-sided flycatcher (*Contopus cooperi*).
Bottom right: killdeer (*Charadrius vociferous*).

Much like green walls, green roofs can provide biodiverse green space for birds while also increasing overall well-being for humans.[118] Since the public cannot occupy some green roofs outside of a guided tour, they offer an undisturbed habitat for nesting birds increasing local urban biodiversity. Even without access to the public, they can be viewed from adjacent buildings or from floors allowing the occupants to have a visual connection with nature providing psychological benefits such as stress recovery and improved concentration.[119] Additional sustainable benefits include insulating properties and storing or controlling water runoff. The Jacob Javits Convention Center's green roof cooled the exterior roof surface by 31%, reduced the heat flux into the building by 46%, and collects, on average, 77% of rainfall-runoff.

Green walls and green roofs can provide an additional design element that urban and suburban landscapes often lack but are beneficial to bird populations: native plants. Native plants are often particularly helpful for insectivorous bird species, many of which are declining or no

[118] Stephen R. Kellert, Judith Heerwagen, and Martin Mador, *Elements of Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life* (Hoboken: Wiley, 2008).
[119] Ibid.

Figure 9. Jacob Javits Convention Center Green Roof Habitat, New York City, NY
Featuring herring gull (*Larus argentatus*) nests.

longer observed in urban areas.[120] In residential areas of Washington D.C., Narango et al.'s 2018 study found that the overuse of nonnative plants in residential and urban areas may contribute to the Carolina chickadees' (*Poecile carolinensis*) decline by decreasing the abundance of native plants that support critical food resources. This can cause Carolina chickadees to alter their typical diets of 90% insects and spiders and 10% seeds and fruit[121], resulting in fewer young and lower reproductive success.[122] Areas with vegetation consisting of less than 70% of native plants can create a population sink that cannot sustain population growth. These results were not seen in areas with more than 70% native plants. Narango et al. suggest that to support insectivorous bird species, plants in urban and suburban areas should consist of no more than 30% nonnative species. Not only do nonnatives plants impact the quality of food, but they also affect the quality of habitat and nesting area for birds, which can impact breeding success. The widespread use of

[120] Desirée L. Narango et al., "Nonnative Plants Reduce Population Growth of an Insectivorous Bird," *Proceedings of the National Academy of Sciences* 115, no. 45 (2018): 11549-11552.
[121] Mostrom, A. M., L. Curry, and B. Lohr. "Carolina Chickadee (Poecile carolinensis), Version 1.0." Ithaca, NY, 2020. Carolina Chickadee.
[122] Narango et al., "Nonnative Plants Reduce Population Growth of an Insectivorous Bird,": 11549-11552.

nonnative plants by designers and residents has created a "food desert" for native insects. This reduces the number of birds in urban spaces, including birds that are considered urban adaptors.[123] Narango et al. recommend to curate habitat restoration to support viable and sustainable food webs rather than incorporating native plants indiscriminately.[124]

Since 1970, habitat loss has been the single largest contributor to the 2.9 billion net decline of birds in the United States.[125] A frequently suggested way to reduce habitat loss is to stop building and expanding the built environment into formerly wildland areas. Given that the world's human population size will continue to grow,[126] continued expansion into wildland areas is inevitable. However, green or living walls and green rooftops are design strategies that can bring back some of the vital lost habitats many resident and migrating species depend on for survival. Further improving these spaces by using native plants will promote traditional ecological food webs.

This chapter began with an example of how some bird species can thrive in built environments not explicitly designed for birds through exploiting or adapting to the available resources. Peregrine falcons made an astonishing comeback on minimally designed and often forgotten ledges of office buildings, abandoned clocks, water intake cribs, and bare steel bridge beams. They adapted to the built habitat because, while humans often see cities as void of nature, peregrine falcons used buildings as cliffs and rock outcrops, natural elements they prefer. The Anna's hummingbird and dark-eyed junco demonstrated that some bird species can quickly adapt to the resources provided by suburban and peri-urban spaces.

Through green walls and green roofs, design can curate nesting spaces and supply plentiful insects and berries, vital water sources, and protection from predators and the elements. Green or living walls and green roofs are beneficial for birds, buildings, and humans. In many cases, the level of adaptation required for birds to nest on rooftops or walls is minimal. The incorporation of these green elements on structures is also minimal. For buildings without these green structures, surrounding green spaces that include at least 70% of native plants can be

---

[123] Narango et al., "Nonnative Plants Reduce Population Growth of an Insectivorous Bird,": 11549-11552.
[124] Ibid.
[125] Kenneth V. Rosenberg et al. "Decline of the North American Avifauna." *Science* (New York, N.Y.) 366, no. 6461 (2019): 120–24.
[126] United Nations, Department of Economic and Social Affairs, Population Division (2019). World Population Prospects 2019: Highlights (ST/ESA/SER.A/423).

especially beneficial to birds that rely on the food source they support. By examining how specific species have benefitted from the built environment and adapt to our built structures, we begin to see how birds interact with the built environment. It is important to remember that each bird species behaves differently to spaces we design for them or humans. The study of how birds adapt to or benefit from designed space provides knowledge of how to support avian species in urban, peri-urban, and suburban spaces while promoting a connection to nature through providing space to encourage their presence in built environments.

CHAPTER 2 NEGATIVE IMPACTS OF ARCHITECTURE AND THE BUILT ENVIRONMENT

Despite some birds' ability to adapt to or exploit the built environment, the infrastructure needed to support modern humans can often be devastating to their populations. Along with habitat loss and pollution, dangers in the built environment are significant factors in many avian species' long-term survival.[127] These dangers include energy infrastructure, communication towers, transpiration, and common structures such as fences, which kill up to 405 million birds a year in the United States. While this estimate is shocking, architecture, lighting, and landscape design all contribute to bird building collisions that are estimated to kill up to one billion birds each year in the United States.[128] Since the 1970s, nearly half of North American migratory birds have declined in numbers by at least 50%.[129]

This chapter begins with a brief review of the many dangerous structures that birds face in the built environment; it then focuses on glass, lighting, and landscape design. By understanding why a large number of bird deaths occur in the built environment, we can evaluate currently proposed solutions and develop the most effective solutions to mitigate these deaths.

DANGEROUS STRUCTURES IN THE BUILT ENVIRONMENT

Wind turbines are often vilified as one of the deadliest types of structures for birds in the built environment. However, the U.S. Fish & Wildlife Service's Migratory Bird Program estimates less than one million birds die each year due to collisions with wind turbines.[130] In contrast, between 8 and 57 million birds die from electrocution on powerlines or collisions with them.[131] Solar and oil-based energy production also kill many birds each year, but reliable

[127] Kenneth V. Rosenberg et al. "Decline of the North American Avifauna." *Science* (New York, N.Y.) 366, no. 6461 (2019): 120-124.
[128] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City." *PLoS ONE* 14, no. 11 (2019).
[129] Rosenberg et al. "Decline of the North American Avifauna.": 120-124.
[130] U.S. Fish & Wildlife Service. "Wind Turbines," U.S. Fish & Wildlife Service - Department of the Interior, accessed March 1, 2020, https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/wind-turbines.php
[131] U.S. Fish & Wildlife Service. "Electric Utility Lines," U.S. Fish & Wildlife Service - Department of the Interior, accessed March 8, 2020, https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/electric-utility-lines.php.

estimates of these deaths for the United States are not available. Therefore, the current total estimate of 9-58 million birds killed by energy infrastructure is low. Airplane strikes tend to receive the most attention of transportation-related deaths since they have led to human casualties. However, they account for less than .0002% of bird fatalities from all transportation threats. Roadways, particularly collisions with vehicles, cause far more bird deaths than airplane strikes. Communication towers kill 6.8 million birds a year due to their height and behavior-disrupting lights.[132] Finally, common structures like fences and pipes killed over 13,000 birds in New Mexico in one year.[133] There is little research on these causes of bird deaths in other locations, making this understudied threat likely to be grossly underrepresented. The estimates currently available (shown in Figure 10) suggest that structures other than buildings kill 104-405 million birds each year. This area needs extensive research to find future design strategies to mitigate these large numbers of bird fatalities.

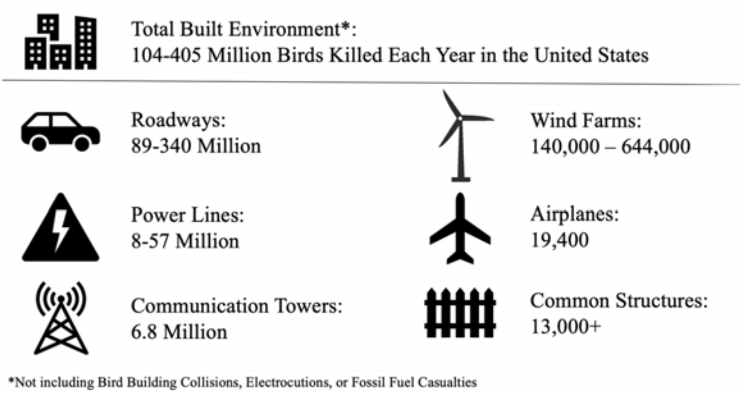


Figure 10. Dangers of the Built Environment

The total impact of energy sources and infrastructure on birds is complex since renewable energy structures cause large numbers of bird fatalities while also reducing the pollution and habitat destruction caused by the fossil fuel industries. The U.S. Energy Information

---

[132] U.S. Fish & Wildlife Service. "Communication Towers," U.S. Fish & Wildlife Service - Department of the Interior, accessed March 2, 2020, https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/communication-towers.php.
[133] Michael L. Morrison, *Ornithology: Foundation, Analysis, and Application* (Baltimore, MD: Johns Hopkins University Press, 2018): para. 27056-71.

Administration (EIA) reported in 2017 that 8% of the total United States energy carrying capacity was wind energy. The Department of Energy has set goals for increasing this to 20% of the nation's energy by 2030 by building wind energy infrastructure in all 50 states. The effects of wind farms on birds are still being studied. Monopole wind turbines kill 250,000 birds each year in the U.S., as Loss et al. reported in 2014. This number is predicted to climb as the numbers of turbines increase, and larger turbines come on line. Over 200 documented species of birds are killed by wind turbines, comprising mostly passerines but including birds of prey, such as the golden eagle (*Aquila chrysaetos*). Regionally, casualties are highest in California and mountainous regions in the east,[134] whereas temporally, birds are most at risk during migration, particularly at night.[135] In the western United States, raptors are the primary casualties, whereas migrating Neotropical songbirds collide with wind turbines most frequently in the central and eastern United States.[136] Beston et al. reported in their 2016 study that birds of prey such as the golden eagle and ferruginous hawk (*Buteo regalis*) are expected to experience declining populations due to wind farms.[137]

Solar energy is expected to grow faster than any other energy source, and most of this will happen in the Southwest of the United States.[138] Its growth threatens a variety of bird species.[139] Waterbirds can perceive the reflective or mirrored surfaces of solar panels as one large body of water. They then can collide with them in an attempt to land or when foraging in flight for surface insects. Their hot, mirrored surfaces can also be deadly if birds attempt to land on them. Flying near the light concentration towers of solar power facilities can fatally burn or singe birds as well.[140]

Powerlines are also a sizeable threat to birds through habitat fragmentation but can be fatal when encountered directly. Electrocution and collisions with transmission lines are common causes of death. Loss et al. estimated in 2014 that 8-57 million birds die from powerline

---

[134] Scott R. Loss et al., "Bird–building Collisions in the United States: Estimates of Annual Mortality and Species Vulnerability," *The Condor* 116, no. 1 (2014): 8-23.
[135] U.S. Fish & Wildlife Service. “Wind Turbines.”
[136] Michael L. Morrison, *Ornithology: Foundation, Analysis, and Application* (Baltimore, MD: Johns Hopkins University Press, 2018): para. 26824-40.
[137] Ibid.; Wind energy can also indirectly impact birds due to loss or modification of habitat.
[138] Morrison, *Ornithology: Foundation, Analysis, and Application*, para. 26855-74.
[139] Ibid.
[140] Ibid., 26-8.

collisions, and 1-11 million birds die from electrocution each year. Powerlines affect many bird species because they are hard to see and are often in locations where birds frequently travel. They are even less visible in poor weather conditions or darkness.[141] Additionally, collisions with powerlines and electrocutions from transformers or wires have negatively impacted recovery efforts of the golden eagle in the Western United States and the Ridgway's hawk (*Buteo ridgwayi*) in the Dominican Republic.[142]

We often hear of fossil fuels as harmful to birds because of the pollution they produce, but their extraction also impacts birds' habitats. The extraction of oil and natural gas alters habitat to the point that some species have been reported to avoid conventional sites with oil rigs used for extraction and unconventional sites, which may use fracking instead of traditional oil rigs.[143] Some species may be actively attracted to extraction sites, as is the case with synanthropic (human-adapted) avian species. In Pennsylvania, oil and gas sites altered entire communities of breeding forest birds.[144] In 2006, it was estimated that one half to one million birds drowned throughout the United States at open pits and tanks that dispose of oil by-products, and more than 1,000 birds have died from being attracted to and burned at flares created through combustions at the energy sites. An unknown number of birds collide with structures lit at night on oil and gas sites.[145] Future studies of the impact of the oil and natural gas industry on birds will focus on the new extraction processes through oil sands and fracking.[146]

Structures in the built environment, such as communication towers, kill over 6.8 million birds each year in the United States. The first documented case of birds colliding with communication towers was in 1949; on some nights, thousands were recorded.[147] In 1998, three towers killed 5,000-10,000 birds in a single night in western Kansas.[148] A more recent observation by Longcore et al. in 2013 indicated that 6.8 million birds of 350 different species,

---

[141] U.S. Fish & Wildlife Service. "Electric Utility Lines."
[142] James F. Dwyer et al., "Retrofitting Power Poles to Prevent Electrocution of Translocated Ridgway's HaFwks (*Buteo ridgwayi*)," *The Journal of Caribbean Ornithology* 32 (2019): 4-10.
[143] "Conventional Oil vs. Unconventional Oil," Keystone Energy Tools, May 26, 2020, https://www.keystoneenergytools.com/conventional-oil-vs-unconventional-oil/).; Morrison, *Ornithology: Foundation, Analysis, and Application* (Baltimore, MD: Johns Hopkins University Press, 2018): para. 26904-20
[144] Morrison, *Ornithology: Foundation, Analysis, and Application*, para. 26904-20
[145] Ibid.
[146] Ibid.
[147] Ibid, para. 27026-45.
[148] U.S. Fish & Wildlife Service. "Electric Utility Lines."

mostly long-distance migrants, collide with communication towers each year in the United States. Longcore et al. documented high species-level mortality rates in some species. The yellow rail (*Coturnicops noveboracensis*) loses 9% of its population each year through collisions with communication towers, and 8.9% of all Swainson's warblers (*Limnothlypis swainsonii*) die by colliding with communication towers each year in the United States.[149] While flashing and non-flashing lights can cause disorientation or attract birds to the towers, height can increase fatalities.[150] Supporting guy wires, heights over 350 feet, and placement of towers along migratory paths and ridgelines also increase mortality rates.[151]

Collisions with vehicles kill 89-340 million birds each year.[152] Ground-nesting or dwelling birds, fruit-eating birds, water birds, and even birds of prey are drawn to roadways and killed each year. Examples of ground-dwelling birds include turkeys and pheasants that cannot quickly maneuver away from vehicles [153] Water birds often collide with vehicles as the wind currents carry them into traffic on bridges. Owls that fly at the same height as vehicles and hunt at night also are vulnerable.[154] Birds can also be drawn to roads because of carcasses of road-killed animals, as with corvids or vultures. Hawks and eagles can be attracted to rodents along the roads that may be feeding on scraps of food or fruit-bearing plants.[155] In addition to vehicles, airplanes kill over 19,000 birds a year due to strikes. While the strikes can happen at any time, they often occur at low altitudes during takeoff and landing. Because these strikes have caused plane crashes and over 250 human deaths, they are very consequential, even though the relative numbers of birds killed by planes are small.[156]

Other structures in the built environment can be inconspicuous but still deadly to birds. In Oklahoma, Wolfe et al. studied bird mortality caused by wire fences in 2009. They found, on average, one bird killed for every mile of the fence. After marking the fence with small white

---

[149] Travis Longcore et al., "Avian Mortality at Communication Towers in the United States and Canada: Which Species, How Many, and Where?" *Biological Conservation* 158 (2013): 410-419.
[150] Morrison, *Ornithology: Foundation, Analysis, and Application* (Baltimore, MD: Johns Hopkins University Press, 2018): para. 27026-45.
[151] U.S. Fish & Wildlife Service. "Communication Towers."
[152] U.S. Fish & Wildlife Service. "Road Vehicles," U.S. Fish & Wildlife Service - Department of the Interior, accessed March 3, 2020, https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/road-vehicles.php.
[153] Ibid.
[154] Ibid.
[155] Ibid.
[156] U.S. Fish & Wildlife Service. "Communication Towers."

clips, no fatalities were reported. Open metal and PVC pipes used as signposts or ventilation for toilets can be attractive but deadly nesting cavities for birds. The birds often become trapped and die in the pipes.[157] A 2014 study in New Mexico found that out of 100 pipes, 24 had dead birds, 61% being the western bluebird (*Sialia mexicana*), a cavity nester. The same study estimated that 13,580 birds die in New Mexico each year due to uncovered pipes.[158] There is an urgent need for a comprehensive evaluation of the dangers that birds face, how this impacts conservation efforts, and the effectiveness of the solutions currently available.

Current solutions to the danger birds face in the built environment fall into immediate solutions and future solutions. Immediate solutions can be implemented if the public is aware of capping or placing screens over open pipes and marking fencing. However, most solutions require further study to provide viable options to reduce bird deaths. One main area of the built environment that needs additional study to understand how to reduce bird deaths is energy infrastructure. Once wind turbines or solar panels are installed, few mitigation techniques can be implemented. Monitoring can be helpful if it triggers mechanisms for protecting birds and for devising long-term solutions. Wind turbines in Wyoming are monitored manually or with heat-detecting cameras for species such as the golden eagle. The turbines can be manually or automatedly stopped so the birds can safely fly by the turbines. Additionally, one study tested turbine lighting but found that it did not reduce or increase impacts.[159] Thoughtful placement of wind turbines and solar panels away from vulnerable species of birds or their paths of movement is one of the most effective solutions for reducing bird deaths currently being used. A few studies propose solutions for preventing electrocution on distributing poles or preventing collisions with power lines. Correctly retrofitting transformers and energized wires, shown in Figure 11, are proven to effectively reduce the number of electrocutions.[160] Additional tactics proven effective

---

[157] Morrison, *Ornithology: Foundation, Analysis, and Application*, para. 27056-95.
[158] Ibid.
[159] U.S. Fish & Wildlife Service. "Wind Turbines."
[160] James F. Dwyer et al., "Retrofitting Power Poles to Prevent Electrocution of Translocated Ridgway's Hawks (*Buteo ridgwayi*), 4-10.

at reducing collisions are common-sense solutions, such as marking lines, removing grounding wires, and burying lines when possible.[161]

Fig. 2. Correctly retrofitted power poles. (A) Three-phase pole with all energized wires covered. (B) Three-phase pole with all energized wires covered and a supplemental perch (the supplemental perch alone would not correctly retrofit the pole). (C) Transformers correctly retrofitted with bushing covers and jumper covers on energized components (the uncovered bushings and jumpers are not energized). (D–F) A Ridgway's Hawk moving from (D) concrete pole top, through (E) the air gap between the grounded pole top and the energized wire, to (F) perching on a conductor cover preventing contact with the energized wire.

Figure 11. Wind Farm Monitoring and Retrofitted Power Poles
Power Poles Caption by Dwyer et al., 2019.

Adding lights on communication towers is one way to reduce their impact on birds; however, lights should not be strobing lights or red lights, as they can cause disorientation, attraction, or disrupted behaviors like migration. Other solutions include careful placement such as selecting already degraded areas, avoiding areas near wetlands, refuges, migratory routes, ridgelines, coastal areas, breeding areas, or critical habitats of concern. Reducing tower heights to less than 199 feet and using free-standing towers to avoid guy wires can also reduce deaths.[162]

Animal bridges that allow for safe passage of animals across busy roadways are especially helpful to birds of prey often hit by vehicles when hunting smaller prey. The smaller

[161] U.S. Fish & Wildlife Service. "Electric Utility Lines."
[162] U.S. Fish & Wildlife Service. "Communication Towers."

prey may reroute to the animal bridge away from deadly roadways. However, until constructed, immediate solutions include barriers such as low fences or diversion poles along bridges and removal of food sources from roadways.[163] Additionally, understanding how species interact with infrastructure, such as roadways, can help reduce collisions by providing information to the public and local municipalities to prevent vulnerable species from being hit by vehicles. Current strategies to reduce airplane strikes include modifying flight schedules when possible and bird removal or hazing.[164] Site management, such as removing attractive bird habitats, is also used to prevent airplane strikes.[165] However, reducing habitat space should be a last resort. Strategically placing green roofs at airports could lead birds to safe spaces away from airplane flight paths, as has proven to be true at the large-scale green roofs located at O'Hare International Airport in Chicago.[166]

Common structures such as oil pits, fencing, and open pipes can be remedied easily with large covers, markers, and pipe caps. However, unlike the solutions for these common structures, most dangers that threaten birds in the built environment need more research to understand how to mitigate the dangers and understand how birds interact with the built environment more clearly.

BIRD BUILDING COLLISIONS

One of the leading anthropogenic threats resident and migrating birds face in the built environment is collisions with buildings.[167] A 2014 estimate provided by Loss et al. indicated a staggering range of 365 to 988 million bird deaths a year in the United States directly caused by building collisions.[168] This estimate is broken down into three building types: commercial

[163] U.S. Fish & Wildlife Service. "Road Vehicles."
[164] This includes lethal removal and capture and release.
[165] U.S. Fish & Wildlife Service. "Aircraft," U.S. Fish & Wildlife Service - Department of the Interior, accessed March 2, 2020, https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/aircrafts.php.
[166] R. Fernandez-Canero and P. Gonzalez-Redondo, "Green Roofs as a Habitat for Birds: A Review," *Journal of Animal and Veterinary Advances* 9, no. 15 (January 2010): 2045.
[167] The phrase *bird building collisions* communicates that window strikes are not the only threat facing birds in the built environment.
[168] Loss et al., "Bird–building Collisions in the United States: Estimates of Annual Mortality and Species Vulnerability,": 2.

buildings (4-11 stories tall) account for about 60% of the yearly collisions,[169] residential buildings (1-3 stories tall), about 40%, and skyscrapers less than 1% or 500,000 collisions a year.[170] These are the immediate fatalities, but fatalities are not the only repercussions of collisions with buildings. Non-fatal collisions can lead to subsequent deaths, impair behaviors, make birds easier prey, and cause the inability to complete migration and reproduce.[171]

Building elements that most strongly affect the likelihood of collisions include the types of glass used, lighting design, and the surrounding landscapes' design. Reflective and transparent glass windows and facades are the leading cause of bird building collisions.[172] Transparent glass is dangerous when birds cannot perceive it as a solid impediment but instead see it as a clear passageway. Glass that reflects green spaces, transparent flyways, and open skies is just as deadly because it appears free of obstruction, offering a clear flight path.[173] Similarly, floodlighting used as a safety measure to make large buildings visible, like the Washington Monument and the One Moody Plaza Tower, has the negative impact of attracting migrating birds, or birds pursuing food sources, to the light.[174] Landscape design is the third design factor that influences bird building collisions. Trees, shrubs, and other vegetation can be dangerous if reflected in the glass, lie behind transparent glass, or appear as food sources and attract birds towards the transparent or reflective glass.

Buildings are often designed with large panes of glass to create an illusion of a continuous connection with the landscape outside. This is driven by the desire to find balance with nature and utilize its healing benefits. However, designers must be aware of how structures interact with and impact various aspects of the environment. They should mitigate the harmful effects of some sustainable features, such as green spaces near or behind transparent glass and the use of expansive glass to allow a view of nature and increase natural light.

---

[169] This does not account for buildings like U.S. Bank Stadium that fall into the category of commercial buildings based on the building's height of six stories but has a large footprint and extensive use of glass.
[170] Loss et al., "Bird–building Collisions in the United States: Estimates of Annual Mortality and Species Vulnerability,": 2.
[171] Ibid.
[172] Daniel Klem, "Preventing Bird–Window Collisions," *The Wilson Journal of Ornithology* 121, no. 2 (2009).; Daniel Klem and Peter G. Saenger, "Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions," *The Wilson Journal of Ornithology* 125, no. 2 (2013).
[173] Reflective glass includes tinted windows. (Schneider et al., 2018)
[174] The Washington Monument was made visible to pilots in 1930 using floodlights that caused 300 bird building collisions on a clear night and 500 bird building collisions on an overcast night during migration season.

How birds see the built environment is dramatically different from how humans do. Instead of moving forward and assessing the pathway ahead as humans do, most birds assess danger behind and to the sides. If they are startled by something in their peripheral vision, they can become disoriented and shift any remaining frontal focus away from obstacles straight ahead. Even the windows and mirrored walls a bird has already accounted for in its flight path can become dangerous when a bird is disoriented. Additionally, some birds' high-resolution sight may be concentrated laterally instead of straight ahead, decreasing their ability to see fine details.[175] If this glass is not clearly marked, it can be deadly. Most birds travel quickly, between twenty and thirty miles per hour, making many collisions with buildings fatal.[176] Examples of reflective and transparent glass can be seen in Figures 12 and 13.

Figure 12. Examples of Reflective Glass
Top Left: U.S. Bank Stadium. Bottom Left: Population Health Facility, University of Washington.
Right: 4th and Vine Street Office Building, Seattle, WA

[175] Martin Rössler, Erwin Nemeth, and Alexander Bruckner, "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More," *Biologia* 70, no. 4 (2015): 540.
[176] Ibid.

Figure 13. Examples of Transparent Glass
Upper Left: UW Link Light Rail Station, University of Washington. Lower Left: PACCAR Hall, University of Washington, Seattle, WA. Upper Right: Ford Foundation Building Atrium, New York City, NY. Lower Right: U.S. Bank Stadium, Minneapolis, MN.

The data from the 2019 study of the U.S. Bank Stadium and 20 other buildings in downtown Minneapolis, Minnesota, by Loss et al., shows that the four buildings with the highest bird building collision casualties had the largest glass area. Three out of the four of these buildings also had the highest proportion of vegetation within 50 m (see figures in Appendix 1). The study's findings indicate that a high proportion of vegetation and a lower proportion of glass is just as deadly as a high proportion of glass and a lower proportion of vegetation. This clarifies that understanding how the landscape impacts design materials is crucial to mitigating bird building collisions. This study also found that increased glass area, proportion lighted,[177] and vegetation within 50 m of buildings correlated with increased species that collide with the buildings.[178] When viewed by season, the data for the four top buildings indicate that spring

---

[177] Proportion lighted is defined in Loss et al.'s 2019 study as the proportion of the façade that is lit compared to the portion that is not lit by artificial light.

[178] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 15.

fatalities increased with an increased proportion of lit building surface and vegetation at 50 m and 100 m. In the fall, increased glass area and vegetation within 100 m increased collisions.[179] Increased glass, building height, and nearby vegetation cause confusion, especially with unbroken glass reflections and transparent spaces. Increased glass almost always means increased light emission at night that attracts nocturnal migrants.[180] The dangers associated with light and landscape may seem minimal but are vastly magnified when coupled with reflective or transparent glass in designed spaces.

As with global environmental changes caused by greenhouse gas emissions and destruction of habitat, artificial light introduces large-scale, preventable dangers to the environment. Artificial light has an adverse effect on birds.[181] It can disturb circadian rhythms, causing birds to sing earlier before dawn or at night, and disturb the timing of migration, leading to early or late breeding.[182] Artificial light from street lights has a significant negative effect on ground breeding birds, and light cues can disturb their migration, egg-laying, and quality of diet.[183] Artificial light also disrupts foraging and feeding patterns, reproduction, predator-prey balance, communication between birds, and can be mistaken for celestial guides used by birds during migration. This is especially true during overcast conditions.[184] However, an additional light source, polarized light, is believed to aid birds during migration. Polarized light is emitted from dark surfaces from solid areas of buildings, solar panels, and roads.[185] Birds may use this light to guide migration routes by calibrating their magnetic compass to polarized light patterns in the sky at twilight.[186] According to a 2020 study by Lao et al., unlike artificial light, polarized light was not found to result in bird building collisions.[187]

The Central and Eastern areas of the United States have the highest species richness of migration rages globally and a higher amount of light pollution located in these migration

---

[179] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 12.
[180] Ibid., 18.
[181] Catherine Rich and Travis Longcore, *Ecological Consequences of Artificial Night Lighting* (Washington, DC: Island Press, 2006): 100-05.
[182] Ibid., 115-6.
[183] Ibid., 129-30.
[184] Ibid., 414-5.
[185] Sirena Lao et al., "The Influence of Artificial Light at Night and Polarized Light on Bird-Building Collisions," *Biological Conservation* 241 (2020): 2.
[186] Ibid.
[187] Ibid., 5.

passageways.[188] Short-distance migrants spend their full annual cycle in North America's bright regions and occupy higher amounts of light pollution than long-distance migrants.[189] These areas of light pollution are greater in temperate regions where urbanization is widespread. This leads to higher migrant stopover at green spaces in urban and peri-urban areas.[190] The effects of light pollution during migration make some species more susceptible to building collisions, especially nocturnal migrants.[191]

In addition to behavioral impacts and light pollution, artificial light emitted from structures can attract birds to buildings, particularly if the light is near reflective materials or illuminates solid facades. Insects gather at these solid facades causing insectivorous birds to collide with the building. When light is near or behind reflective or transparent materials, it also can act as a beacon, as with solid surfaces. However, it has an added danger of presenting the illusion of open space, and birds fly into the windows thinking they can navigate through the lit, open space.

This beacon effect was recently observed in October 2019 at the NASCAR Hall of Fame in Charlotte, North Carolina. The Carolina Waterfowl Rescue group reported that 310 chimney swifts (*Chaetura pelagica*) hit the building's large glass façade. They reported that about 100 swifts had died on impact and were rehabilitating about another 100 birds from this vulnerable species. Researchers believe the migrating birds were resting at night and were disturbed, which attracted them to the lit façade.[192] Videos circulated on social media and news outlets reported the "mysterious" event of birds "killing themselves" as a bizarre one-off.[193] However, when considering the location, it seems evident that this isolated event was indicative of a widespread problem. This beacon of light illuminates the large glass façade, and light spreads out across the concrete plaza like the morning sun across a landscape. The buildings behind the beacon are dark or sparsely lit, further consolidating the light emitting from the NASCAR Hall of Fame seen in

---

[188] Sergio A. Cabrera-Cruz, Jaclyn A. Smolinsky, and Jeffrey J. Buler, "Light Pollution Is Greatest within Migration Passage Areas for Nocturnally-Migrating Birds around the World," *Scientific Reports* 8, no. 1 (2018): 2.
[189] Ibid.
[190] Ibid., 5.
[191] Ibid.
[192] Amanda Watts and Eric Levenson, "Over 300 Migrating Birds Smashed into Charlotte's NASCAR Building," https://www.cnn.com/2019/10/16/us/birds-nascar-building-trnd/index.html (Accessed November 1st, 2019).
[193] Gary Gastelu, "The Big One? 300 Birds Mysteriously Crash into NASCAR Hall of Fame," https://www.foxnews.com/auto/the-big-one-300-birds-mysteriously-crash-into-nascar-hall-of-fame (Accessed November 1st, 2019).

Figure 14. Artificial light emitting from buildings correlates with increased bird building collisions.[194] The lighted area of a building is a better predictor of bird building collisions than the percentage of glass, amount of glass used, or the panes' size.[195] While increased use of glass and light influences bird building collisions, this finding supports that turning lights off at night will effectively reduce bird building collisions caused by artificial light radiating from inside a building like at the NASCAR Hall of Fame.[196]

Figure 14. NASCAR Hall of Fame at Night, Charlotte, NC

Brightly lit structures and floodlighting can also capture birds at night, leading to an estimated 4-50 million fatalities a year in the US.[197] These lights, which include lighted buildings, floodlights, and spotlights, can attract hundreds of bird species that migrate at night. While evidence shows how artificial light attracts birds at night, studies have suggested that flying into artificial light disrupts visual references, causing spatial disorientation. Birds' flight paths can be shifted by their reaction to the light source. The glow from cities on the horizon can

---

194 Sirena Lao et al., "The Influence of Artificial Light at Night and Polarized Light on Bird-Building Collisions," *Biological Conservation* 241 (2020): 5.
195 Ibid.
196 Ibid., 6.
197 Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 117.

also influence migratory birds' orientation, especially immature birds that orient themselves towards the city instead of their proper flight paths.[198] Being captured by artificial light can also affect migrating birds' energy stores, delay arrival at breeding or wintering grounds, and contribute to collisions with glass.[199] Very bright light sources can also visually stun the birds. F.J. Vergeijen argues strongly for the use of the word "capture," in reference to the way birds are drawn to light, which is more descriptive than "attract," as birds captured by lights can encircle them for hours.[200] Once a bird is captured by light at night, it often will not leave that zone. The birds can collide with each other, exhaust themselves, or become vulnerable to predators.[201] An example of capturing is shown in Figure 15. Evans Ogden's 2002 report for the Canadian-based Fatal Light Awareness Program (FLAP) proved that artificial light emissions significantly impact birds and increase bird deaths. The report monitored sixteen buildings in Toronto, Canada ranging in height from 8 to 72 stories. While height did not have a significant impact on bird mortality, total building light emissions did. The study concluded that an increased number of birds captured by the light would lead to more deaths. The 2019 study results by Loss et al. that included U.S. Bank Stadium, a large building with a large glass façade, further supports the conclusion that the amount of light emitted proportional to the building's surface lead to increased bird building collisions.[202]

---

198 Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 68-9.
199 Ibid., 71.
200 Ibid., 68-9; 97-8.
201 Ibid., 117.
202 Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City."

Figure 15. Birds Captured by World Trade Center Memorial Lights, New York City, NY

As human populations increase, so does the use of artificial lights, to a point where it is hard to find land that is not illuminated or influenced by artificial lighting. In 1981, the term *photo pollution* was devised to describe situations when artificial light adversely affects wildlife.[203] At the Washington Monument in Washington, D.C., shown in Figure 16, the first incidents of bird building collisions caused by artificial light were recorded in the 1930s.[204] The monument had first used a red light to indicate its location for aircraft but was not monitored for bird building collisions. After installing floodlighting to illuminate the entire structure, the building killed 300 birds in one night during migration season. During an overcast night, over 500 birds were killed.[205] Details of recent building collisions or measures to reduce or turn off the Washington Monument's floodlighting are not available. This information is also not included in Lights Out DC's yearly bird collision statistics gathered from the DC area.[206] Most

[203] Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 67-8.
[204] Robert Overing, "High Mortality at the Washington Monument," The Auk 55, no. 4 (1938), 679.
[205] Ibid.
[206] The American Bird Conservancy suggests that building collisions are no longer an issue for the Washington Monument as it is now surrounded by various sources of light creating a larger area of light pollution expanding beyond the Washington Monument.

recently, in May 2017, the dangers of floodlighting were observed at One Moody Plaza in Galveston, Texas. The floodlighting at this building killed 395 migrating birds in one night. The birds were attracted to and collided with the surface illuminated by twenty white floodlights (see Figure 16).[207] These and many other examples demonstrate that illuminating chimneys, buildings, bridges, and monuments with floodlighting contribute significantly to migrating bird fatalities.[208]

Figure 16. Dangerous Floodlights: One Moody Plaza and The Washington Monument
Left: One Moody Plaza with flood lights on (top) and off (bottom). Right: The Washington Monument showing a floodlit structure and two red warning lights.

Communication towers and ceilometers have also been factors in large numbers of fatalities for migrating birds.[209] Bird collisions with these structures are more closely related to the intensity and color of light and constant or strobing patterns than the structures' materials or

[207] Purbita Saha, "Lights Out for the Texas Skyscraper That Caused Hundreds of Songbird Deaths," Audubon, July 2, 2019, https://www.audubon.org/news/lights-out-texas-skyscraper-caused-hundreds-songbird-deaths).
[208] Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 74.
[209] A ceilometer measures the height of a cloud ceiling or cloud base using a laser or light source.

landscaping.[210] From the study of ceilometers, researchers discovered that a bird's ability to see wavelengths in the light spectrum differs from humans. This is indicated by the increased nonlinear flight behavior near a tower with white strobing light and the tower with a red light compared to a control with no light.[211] These findings indicated that birds become disoriented by red lights or steady light sources but in different ways. Red lights can disorient birds during migration, mimicking the rising and setting sun on the horizon. As previously stated, steady beaming white lights can capture birds or attract them to solid surfaces. Birds are less strongly affected by strobing or white to blue wavelengths of lights.[212]

While the dangers of artificial light on wildlife and in combination with built structures are well known, landscape features can lead birds to dangerous areas resulting in bird building collisions. A 2015 study of Bryant Park, located in New York City, shows that urban parks provide stopover habitat for migrant birds and lead to collisions.[213] Light-emitting from the buildings surrounding the park increased the number of collisions but so did the surrounding landscape. The buildings surrounding Bryant Park are lined with trees, and the landscape includes flowers and shrubs often reflected in the glass of the buildings. The study found the more glass used in the building's façade, the more it reflected the vegetation, increasing collisions.[214] These findings were also reported in Argentina by Rebolo-Ifran et al. in 2019.[215] Buildings located in a landcover matrix with tall vegetation reflected in the windows caused more collisions than buildings surrounded by urban landscapes.[216] The study also showed that as urbanization increased, collisions decreased.[217] The effects of light on collisions can often be mitigated by turning off the lights. However, eliminating natural landscapes in urban or built environments is not a logical solution. The solution requires a balance between landscape and protecting birds from collisions.

---

[210] Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 76-84.
[211] Ibid.
[212] Ibid.
[213] Kaitlyn L. Parkins et al. "Light, Glass, and Bird Building Collisions in an Urban Park." *Northeastern Naturalist* 22, no. 1 (2015): 84-91.
[214] Ibid.
[215] Most cited research on the topic of bird building collisions is from North America. Argentina is home to 10% of the world's biodiversity, indicating the urgency to research the issue of bird building collisions and available solutions beyond North America.
[216] Natalia Rebolo-Ifrán, Agustina Di Virgilio, and Sergio A. Lambertucci, "Drivers of Bird-Window Collisions in Southern South America: A Two-Scale Assessment Applying Citizen Science," *Scientific Reports* 9, no. 1 (2019).
[217] Ibid.

The 2015 interdisciplinary article by Carrus et al. states that in people, “natural settings are, more consistently than others, capable of promoting psychological well-being by reducing psychophysical stress, inducing positive emotions, and facilitating the renewal of cognitive resources." This is based on the Biophilia Hypothesis that "human beings evolved in natural environments and developed an innate tendency to respond positively to natural settings.” The findings of their study indicate that “biodiversity increases the psychological benefits associated with the ‘green’ experience.”[218] This result is still compatible with an evolutionary perspective, as biodiversity plays a fundamental role in life support and ecosystem continuity, and the natural quality of a place is positively linked to preferences expressed by users.[219] This study associates the increase of green areas in cities as beneficial to human well-being. While the biodiversity discussed in this study primarily included species of birds and insects, this is still a human-based perception of nature.[220] Understanding how birds interact with green spaces and their locations, beyond the human benefits, can lead to design solutions aimed at mitigating collisions.

Green rooftops create a centering experience for humans and provide much needed clean air and contribute to well-being. However, positioning them on buildings that incorporate reflective or transparent glass, enclosed areas where natural or human-made perches attract birds can be deadly. Transparent windows giving people the benefit of viewing the green roof are often not detectable by birds trying to enter or exit the space. This is especially dangerous for birds seeking trees and shrubs in green spaces enclosed in glass because the green space may attract birds to a building they may not otherwise encounter.[221] Additionally, landscape and green spaces near glass structures increase bird building collisions.

Loss et al.’s 2019 study of the U.S. Bank Stadium and 20 downtown Minneapolis, Minnesota buildings demonstrates the dangers of landscape features near buildings. The location is immediately west of the Mississippi River, which, as the largest river system in North America, is part of a vital migration passageway.[222] This study is the first to include a multi-use

---

[218] Giuseppe Carrus et al., "Go Greener, Feel Better? the Positive Effects of Biodiversity on the Well-being of Individuals Visiting Urban and Peri-Urban Green Areas," *Landscape and Urban Planning* 134 (2015): 221-228.
[219] Ibid.
[220] Juliette Bailly et al., "Negative Impact of Urban Habitat on Immunity in the Great Tit Parus Major," *Oecologia* 182, no. 4 (2016), 1053-1062.
[221] C. J. Eakin et al., "Avian Response to Green Roofs in Urban Landscapes in the Midwestern USA," *Wildlife Society Bulletin* 39, no. 3 (2015), 574-582.
[222] Ibid., 574-582.

stadium, the U.S. Bank Stadium, in monitoring bird building collision. Stadiums tend to be large, lit at night, and designed with large glass facades, all dangerous design choices for birds.[223] They often are illuminated internally or externally during spring and/or fall migration periods.[224] The surface of the stadium building is 37% highly reflective glass and includes 6,000 square meters of uninterrupted glass on the northwest façade facing an open landscape with trees and lawn. (See Figure 17.) LED lighting is used inside, outside, directed into the stadium, and in ground-based lighting.[225] Additionally, the landscape that surrounds the stadium, and the urban downtown area, increase collisions. These landscapes include forests, deciduous woodlands, lakes, wetlands, croplands, and limited grassland.[226] This study also documented the species killed by collisions. The top five species with the most fatalities were the common yellowthroat (*Geothlypis trichas*), ovenbird (*Seiurus aurocapilla*), Tennessee warbler (*Leiothlypis peregrina*), Nashville warbler (*Leiothlypis ruficapilla*), and white-throated sparrow (*Zonotrichia albicollis*). (Species are depicted in Figure 18.) These species are all migratory songbirds that travel primarily at night. This similarity among the top five species could be because the study did not monitor for collisions outside of four migration seasons. A study from 2018 by Schneider et al. monitored the Virginia Tech Corporate Research Center year-round. The study results showed that breeding season (July) had the next highest fatalities

[223] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 1.
[224] Ibid., 2.
[225] Ibid.
[226] Ibid.

outside of migration seasons. The resident species, the American robin (*Turdus migratorius*), made up most casualties.[227]

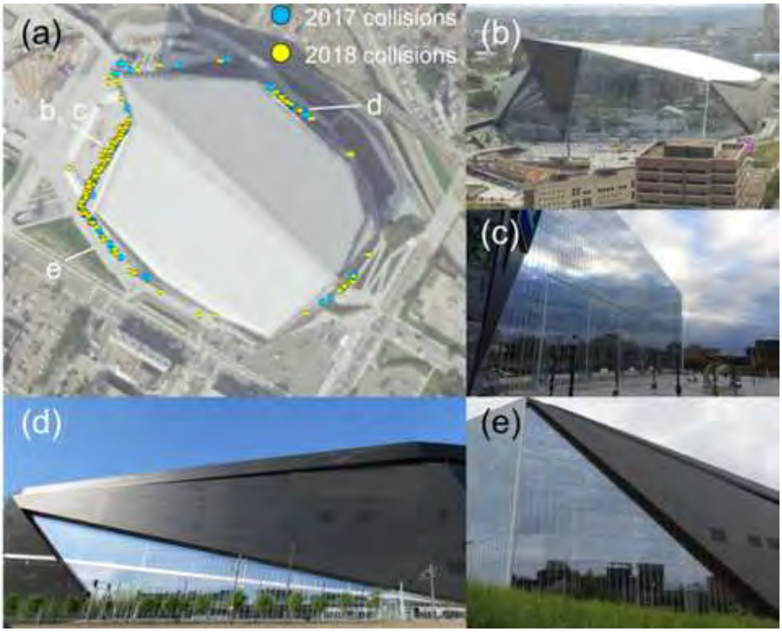


Figure 17. U.S. Bank Stadium, Minneapolis, MN
Bird collisions at U.S. Bank Stadium. (a) Locations of 229 bird collisions observed during monitoring at U.S. Bank Stadium in downtown Minneapolis, Minnesota, USA, 2017–2018; (b, c) the largest unbroken span of glass (~6,000 m^2) where 52% of all collisions at the stadium occurred; (d) a glass surface on the northeast façade where 11% of collisions occurred; (e) a glass surface on the southwest façade where 17% of collisions occurred.
(Caption by Loss et al., 2019)

The landscape surrounding the 21 buildings in the downtown area helped attract birds to the area contributing to the frequency of bird building collisions. This study monitored bird collisions over four migration seasons. It quantified how the building's design features influence fatalities caused by bird building collisions, including height, area of glass, area of light, the proportion of light emitted at night, footprint, and the surrounding vegetation at a 50 m and 100

[227] Rebecca M. Schneider et al., "Year-Round Monitoring Reveals Prevalence of Fatal Bird-Window Collisions at the Virginia Tech Corporate Research Center," *PeerJ* 6 (2018): 13.

m buffer.[228] Surrounding vegetation is included in the features that could potentially increase collisions by attracting birds to the landscape surrounding a building. In 2018, Schneider et al. found that increased lawn area and trees within 50 m of a building increased collisions.[229]

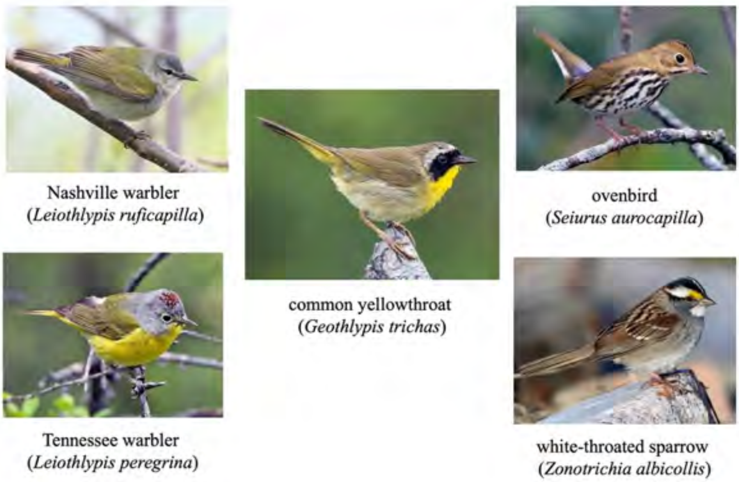


Figure 18. Five Species with the Highest Number of Fatalities in Minneapolis, MN

In terms of overall collision number, the four most fatal buildings in Minneapolis had 79-216 fatalities a year, with 111 fatalities from the U.S. Bank Stadium. (For comparison: Loss et al.'s 2014 study estimated that U.S. high rises kill 5-77 birds a year). The design features that cause the high numbers of collisions among these four buildings include large amounts of glass reflecting surrounding vegetation. But these design features did not necessarily contribute to bird building collisions at typical building types in the downtown area. However, both buildings show that an increased proportion of lighted glass increases overall fatalities in the spring. There is also an increase in the number of different species colliding with buildings in the spring.[230] The

---

[228] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 1.
[229] Rebecca M. Schneider et al., "Year-Round Monitoring Reveals Prevalence of Fatal Bird-Window Collisions at the Virginia Tech Corporate Research Center," *PeerJ* 6 (2018): 7.
[230] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 16-17.

Minnesota Audubon Society and concerned citizens approached the U.S. Bank Stadium in 2012 and 2013 about the collisions. The building owner's inaction led to Loss et al.'s 2019 study.[231]

Overall fatalities of all species were correlated with glass area, the amount of light emitted proportional to the building's surface, and vegetation within 100 m. Although vegetation within 100 m was important year-round, fatalities were also correlated with proportional light in the spring, while in the fall, glass area played a more significant role. When broken down by the top species impacted, glass had a greater effect on white-throated sparrows and ovenbirds. The Nashville warbler collided with buildings that were the tallest, had the largest footprint, and vegetation within 50 m of the building. The common yellowthroat was found to be attracted to vegetation near buildings beyond the 50 m buffer. The 100 m vegetation buffer was the highest indicator of predicted common yellowthroat deaths. However, for the Tennessee warbler, none of the tested variables explained why they collided with the buildings based on the specific design aspects monitored.[232]

When considering the life history of these five species, we can understand the impact of the surrounding landscape of the downtown buildings and birds vulnerable to collisions vary in their familiarity with urban space, preferred habitat, migration, food sources, and size. The white-throated sparrow prefers coniferous and deciduous forest habitat.[233] During migration, they can be found along the edges of woodlots, thickets, or weedy fields, as well as backyards, city parks, and green spaces in the suburbs, so low vegetation reflected in building glass is a significant danger to them.[234] Ovenbirds prefer mature forests in the summer. In the winter, they do not require mature forests but will avoid open fields and cultivated areas. During migration, ovenbirds migrate in large numbers during storm fronts and are reported being killed by towers and tall buildings in their path where lit glass windows become dangerous beacons in overcast

---

[231] Alisa Opar, "Minnesota's Newest Sports Stadiums Take Very Different Approaches to Bird Safety," Audubon, October 24, 2018, https://www.audubon.org/news/minnesotas-newest-sports-stadiums-take-very-different-approaches-bird-safety).
[232] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 16.
[233] Coniferous trees are cone bearing trees that retain their leaves or needles. Deciduous trees drop their leaves or needles in early to late autumn.
[234] Falls and Kopachena (2020). White-throated Sparrow (*Zonotrichia albicollis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

conditions.[235] The Nashville warbler prefers mixed open forest areas with shrubs and undergrowth, forest edges, bogs, abandoned fields, and mountain pastures.[236] Open areas surrounding downtown Minneapolis could account for these birds' attraction to green spaces within 50 m of downtown buildings. Their life history does not account for why they were most susceptible to larger (in footprint and height) buildings. However, some species are more susceptible to collisions with glass. Sabo et al. suggest in a 2016 article that resident birds can learn to avoid collisions with glass; therefore, migrant birds more susceptible to collisions.[237] The Tennessee warbler spends most of its time in high trees, and migration is spent passing between the boreal forests of Canada and Central America, preferring most types of forest or woodlands.[238] No design features were directly attributed to their high number of fatalities other than the significant fact that the buildings monitored are located in a high migration area. The common yellowthroat is found most often in low tangled vegetation near marshes and wetlands. They are also attracted to low-growing grasses and low trees or bushes in back yards.[239] The landscape surrounding the U.S. Bank Stadium, shown in Figure 19, includes low-growing grass and trees, which may have contributed to the yellowthroat's mortality during migration.

[235] This is not unlike the effect the Washington Monument had on hundreds of birds that collided with the lit structure during overcast nights in 1930.

[236] Lowther and Williams (2020). Nashville Warbler (*Leiothlypis ruficapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

[237] Ann M. Sabo et al., "Local Avian Density Influences Risk of Mortality from Window Strikes," *PeerJ* 4 (2016): 1, 9.

[238] Rimmer and McFarland (2020). Tennessee Warbler (*Leiothlypis peregrina*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

[239] Guzy and Ritchison (2020). Common Yellowthroat (*Geothlypis trichas*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Figure 19. Landscape Surrounding the U.S. Bank Stadium

The overall findings of Loss et al.'s 2019 study were that four of the 21 buildings accounted for over half the total collisions during the study. These buildings showed a positive correlation between building collisions and a large amount of glass and surrounding vegetation. Additionally, the factors that influence bird building collisions on the 17 other buildings varied with the season (specifically between spring and fall migration) varied by species and varied with the proportion and area of light emitted from the buildings at night. These findings support the argument that building-specific and species-specific bird protecting designs, especially regarding landscape features, could be more effective than applying identical designs solutions to all sizes of downtown buildings.[240] Loss et al. suggest focusing on the buildings with the largest fatalities first when considering bird protecting designs and increasing research on the effectiveness of design solutions for these buildings.[241]

Anthropogenic dangers are a primary source of bird fatalities in the built environment contributing to the loss of 3 billion net birds since 1970 in North America. This includes infrastructure like powerlines, energy infrastructure including wind and solar farms, roadways,

[240] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 1.
[241] Ibid., 17.

and communication towers. Mitigating environmental stresses, preventing loss of habitat, and reducing direct hazards contributing to bird building collisions must all be considered to attain truly sustainable buildings. Designers and architects who intend to design sustainably must consider the threat facing birds in sustainable and environmentally friendly design. To do so, all architects and designers should be aware of five design or location features that most negatively impact birds: reflective and transparent glass, lit structures and light pollution, green spaces and water sources within 100 m of built structures, building location relative to migration passageways, and how bird species interact with these four features. The information gathered in this chapter clarifies that solutions will not be provided by a single expert or the findings of one study. To develop effective mitigation strategies to bird building collisions, understanding how birds interact with the built environment as a whole and on a species level is imperative.

CHAPTER 3 PREVENTING BIRD BUILDING COLLISIONS

Finding effective design options to eliminate bird building collisions is challenging because few case studies and primary source materials address these solutions. Additionally, this information is widely scattered among studies and organizations, making it difficult to compare data and evaluate the most effective solutions for reducing collisions. This chapter identifies the current best practices based on the available primary source material, such as experiments, monitoring studies, and case studies. It consolidates this information to evaluate the effectiveness and limitations of collision prevention strategies. The mitigation strategies outlined in this chapter begin with glass solutions, followed by lighting and landscape solutions.

Collision mitigation techniques focus primarily on window collisions, as transparent and reflective glass are the most dangerous elements of the built environment leading to bird deaths. However, lighting design, landscape design, and avian behavior can increase or decrease the likelihood of window collisions. Among the three primary mitigation design strategies in this chapter, glass, lighting, and landscape, lighting solutions and the effect of artificial light on urban wildlife are the most well studied. Extensive research on light mitigation strategies show that complicated solutions are not needed to provide successful outcomes. Simply turning out the lights at night during migration can significantly reduce bird building collisions. This chapter also examines the additional mitigation strategies available to reduce artificial light's negative impact on birds in built environments. Studies of landscape design strategies show a clear and direct way to reduce bird fatalities using landscape design is to reduce reflections of vegetation in glass that is not treated with collision deterrence methods. Additional solutions for preventing bird building collisions through landscape design rely heavily on understanding avian behavior and life history.

GLASS SOLUTIONS

Effective design solutions for preventing birds from colliding with building glass must signal to a bird that it cannot fly through the glass. These designs aim to protect the birds from fatal head-on collisions and injury from diverting too late. Usually, this involves applying patterns on exterior glass surfaces, such as opaque or translucent lines, dots, triangles, or other shapes. These must be expansive and grouped closely to make the glass visible as a solid to flying birds, in enough time for them to avoid colliding with it. The following experiments test various glass treatments.

An initial leader in the research on window collisions solutions, Daniel Klem, published three studies in 1990, 2009, and 2013 providing the foundation of the most commonly used window collision mitigation techniques including frit dots, lines, and ultraviolet patterns.[242] Today, these solutions are widely promoted by the Audubon Society and American Bird Conservancy. However, a detailed evaluation of the results of Klem's experiments shows that some popular solutions, such as spaced lines and ultraviolet patterns, do not consistently prevent collisions and require further study. Additionally, the testing methods used in the three studies have limitations that may affect the test results.

Klem's experiments use two methods of testing. The flight tunnel tests require a dark-eyed junco (*Junco hyemalis*) or white-throated sparrow (*Zonotrichia albicollis*) to fly towards a control pane of transparent glass and a glass pane with and collision deterrence pattern or film. The open field experiments use wood-framed picture windows in a mowed field facing a forest allowing various wild birds species to come in contact with the windows (see Figure 20). A feeder was placed one meter from a pane of glass in the test and was randomly rotated to a different window each day.[243] Each of these two methods have limitations that could affect the outcome of the experiments. The flight tunnel test limitation is that no reflections of vegetation or the sky can be projected onto the glass. The open-field test allows birds to fly around the structures and do no replicate buildings. Additionally, the published studies do not have images of the patterns or comprehensive charts of the results, so their findings can be challenging to interpret. Figures 21 through 24 recreate some of these data and patterns based on the details

[242] "Collisions Between Birds and Windows: Mortality and Prevention." (1990); "Preventing Bird–Window Collisions." (2009); and "Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions" (2012).
[243] Daniel Klem, "Preventing Bird–Window Collisions," *The Wilson Journal of Ornithology* 121, no. 2 (2009): 314-321.

from Klem's studies. (Appendix 2 shows charts listing the results of Klem's 2009 and 2013 experiments.)

Figure 20. Klem's Open Field Window Experiments

In Klem's 1990 experiment, he tested collision preventing window patterns with dark-eyed juncos. These patterns consisted of vertical or horizontal cloth strips with a width of 2.5 cm creating line or mesh patterns shown in Figure 21.[244] These experiments are the basis of the widely used "2 by 4" rule promoted in bird-safe or bird-friendly guidelines by the Audubon Society and American Bird Conservancy.[245] This rule advises spacing lines, decals, or dots two inches horizontally or four inches vertically apart.[246] This is based on Klem's experiments with cloth strips on transparent glass spaced at 5 cm horizontally or 10 cm apart vertically. These two experiments prevented collisions by 100% when compared to the transparent glass control for dark-eyed juncos. Vertical lines spaced at 10 cm were tested in a flight tunnel by Rossler et al. in

---

[244] Daniel Klem, "Collisions Between Birds and Windows: Mortality and Prevention." 1990. *Journal of Field Ornithology* 61 (1). Association of Field Ornithologists, Inc.: 120–28.

[245] The terms bird-safe and bird-friendly are not defined by data indicating the building or structure is free of collisions. Most of the time, they indicate the use of any collision mitigation strategies.

[246] The "2 by 4 rule" states lines should be spaced two inches (5 cm) apart horizontally or 4 inches (10 cm) apart vertically.

2015 and reduced collisions by 94%.[247] Shepard et al. also tested 10 cm horizontal lines four years later in the same flight tunnel as Rossler et al. and had the same result: collisions reduced by 94%.[248] The lines were spaced based on this species' wingspan of 18-25 cm because it is thought birds will not try to fly through spaces too narrow or may harm their wings.[249] However, the results of the experiment seem counterintuitive: for example, if birds avoided the 10 cm spaced vertical lines because the obstacles were too close together to fly through, spacing them at 5 cm vertically should have resulted in collisions reduced by 100% as well, but they were only reduced by 75%. Klem's experiment also tested transparent glass covered with cloth strips to create a mesh leaving 13 cm openings from corner to corner. This method reduced collisions by 100% even though the open space was larger than the 10 cm vertical lines. Rossler et al. tested a

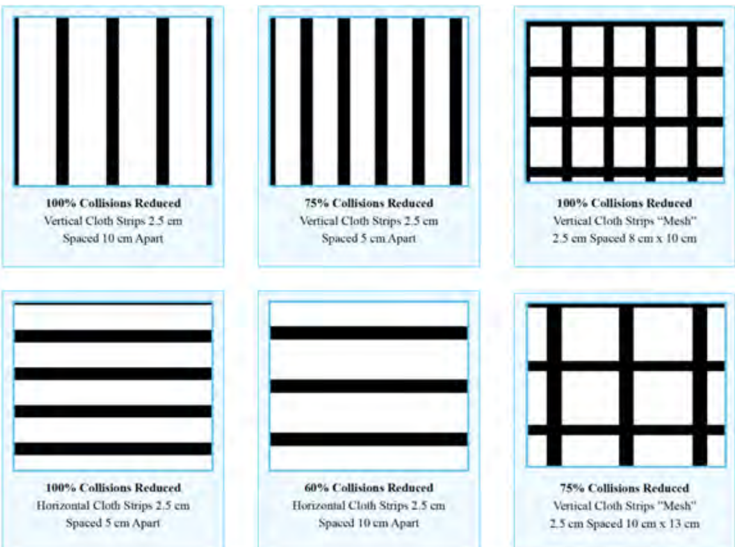


Figure 21. Klem's 1990 Collision Reducing Experiments

[247] Martin Rössler, Erwin Nemeth, and Alexander Bruckner, "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More," *Biologia* 70, no. 4 (2015): 537-540.
[248] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass," *Global Ecology and Conservation* 20 (2019): 7-8.
[249] The American Bird Conservancy has now updated this rule to two inches by two inches or 5 cm by 5 cm to accommodate birds with smaller wingspans like hummingbirds. However, the Anna's hummingbird's (*Calypte anna*) wingspan is 12 cm.

grid pattern spaced 10 cm vertically and 13 cm horizontally, reducing 95% of the collisions.[250] It is unclear if the spacing or the pattern successfully reduced collisions in the mesh experiments.

Klem himself attributes the success of the 5 cm spaced horizontal line patterns or 10 cm spaced vertical line patterns to birds maneuvering through trees, claiming that horizontal branches are close together, and vertical tree trunks are spaced further apart. Therefore, Klem claims that the spacing mimics the natural environment.[251] This hypothesis may partially explain the mesh pattern results, but horizontal and vertical lines alone do not accurately mimic tree trunks and branches, nor does it account for the successful results of narrower spacing. Additionally, not all bird species interact with forested habitats, have the same wingspan, or maneuver through obstacles in the same way. Not studied are the physiological reasons behind why the birds tested avoided colliding with vertical and horizontal lines at various spacings. Therefore, why these techniques successfully prevented collisions in the experiment remains inconclusive.

In 2009, Klem tested equally sized and spaced ceramic etched frit dots on the surface of the glass in Experiment 3. These frit dots were sized at 0.32 cm and spaced equally apart at 0.32 cm. Ceramic etched frit dots are etched into the surface of the glass; they can be seen by humans standing in close proximity but appear transparent when viewed from a distance. The frit dots were tested in flight tunnel experiments using the dark-eyed junco and the house sparrow (*Passer domesticus)* using a forced-choice test in which the birds had to choose between a transparent glass control or the frit dotted glass to escape. The frit dots prevented 100% of the collisions when compared to the control.[252] Christine Sheppard tested white dots, not ceramic etched frit dots, that were equally sized and spaced at 0.32 cm resulting in collisions reduced by 59%.[253] Rossler et al. tested white dots sized 1.8 cm spaced at 3.2 cm with a 100% reduction in collisions.[254] These two results indicate that ceramic etched frit dots are more visible to birds and

---

[250] Martin Rössler, Erwin Nemeth, and Alexander Bruckner, "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More,": 537-540.
[251] Daniel Klem, "The Effects of Glass in Buildings on Bird Mortality," *Audubon Chapter of Minneapolis' Session on the U.S. Bank Stadium* (March 23, 2018), https://www.youtube.com/watch?v=z2HssOtP1JQ&feature=youtu.be).
[252] Daniel Klem, "Preventing Bird–Window Collisions,": 314-321.
[253] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass,": 7-8.
[254] Martin Rössler, Erwin Nemeth, and Alexander Bruckner, "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More,": 537-540.

could be communicating the glass surface is solid, whereas the 0.32 cm white surface dots were not as detectable. If white surface dots are used instead of ceramic etched frit dots, they should be larger in size to be detectable but less than 5.64 cm in diameter. Rossler et al.'s test of 5.64 cm wide white dots only reduced collisions by 96%.[255] Additionally, Christine Sheppard tested 0.32 cm dots in two experiments placing them in a line rather than covering the glass uniformly. The vertical lines of dots spaced 1.28 cm apart reduced collisions by 90% and horizontal lines by 94%, indicating that 0.32 cm white dots in a line could be more effective than solid lines covering the surface of the glass.[256] This could be due to the pattern creating a signal the glass is solid rather than using a maneuverable obstacle. The ceramic etched frit dots used in Klem's experiment were not opaque, like the cloth strips in the 1990 experiments or those used by Rossler et al. and Sheppard. They are not as transparent as the ultraviolet patterns tested in Klem's study but offer an effective solution to mitigating bird building collisions while

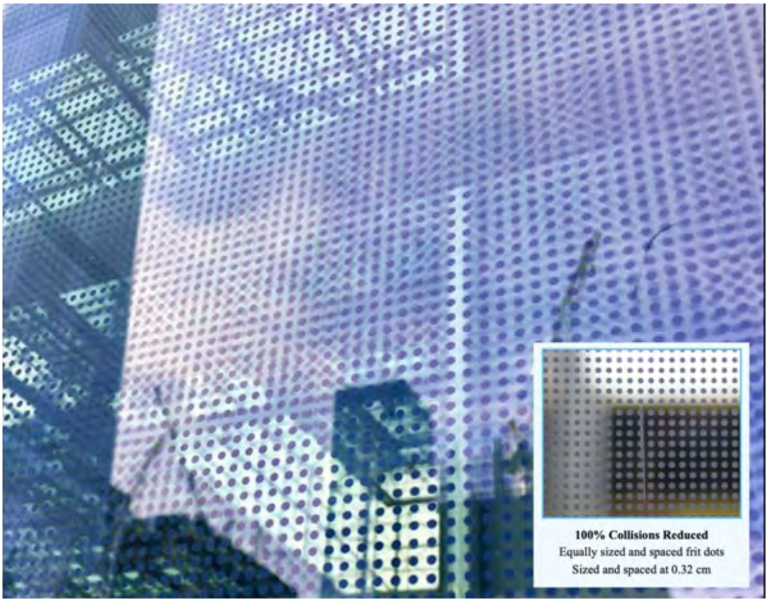


Figure 22. Ceramic etched Frit Dots on the Jacob Javits Convention Center and Detail

[255] Martin Rössler, Erwin Nemeth, and Alexander Bruckner, "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More,": 537-540.
[256] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass,": 7-8.

maintaining the desired aesthetics and performance. As seen at the Jacob Javits Convention Center in Figure 22, light still enters the space and retains the transparency of the glass.

Ultraviolet, or UV, solutions are promoted by the Audubon Society and the American Bird Conservancy as the best compromise between designers wanting unobtrusive collision prevention solutions and those advocating the maximum reduction of bird building collisions. The product's advertisers claim the human eye cannot detect the pattern but that birds can see the UV material. Klem's 2009 experiment with UV window treatments used the flight tunnel and field testing methods. Figure 23 shows the key results. The experiments indicate that UV decals in the shape of maple leaves only reduce collisions by half. UV lines yielded surprising results. UV lines spaced at 10 cm vertically only reduced collisions by 20% even though their spacing was the same as the opaque black cloth strips that prevented 100% of collisions. By contrast, UV lines spaced at 5 cm horizontally reduced collisions by 100%, just as similarly spaced cloth strips did. Further, covering 50% of the surface of the glass with vertical UV strips equally spaced only reduced collisions by 60%.[257] Christine Sheppard tested the same UV product (CPFilms) in 5 cm vertical strips spaced 5 cm apart. The flight tunnel test showed the film reduced collisions by 83%. Sheppard conducted three additional UV tests using a product reflecting UV wavelengths thought to be visible to birds (UV Blast) at the same 5 cm width and spacing. The results showed that the UV patterns reduced collisions by 64%, 71%, and 86%.[258] These mixed results raise some uncertainty about the testing method, the role of pattern, and the effectiveness of both cloth strips and UV treatments in preventing collisions.

---

[257] Klem, "Preventing Bird–Window Collisions,": 314-321.

[258] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass,": 7-8.

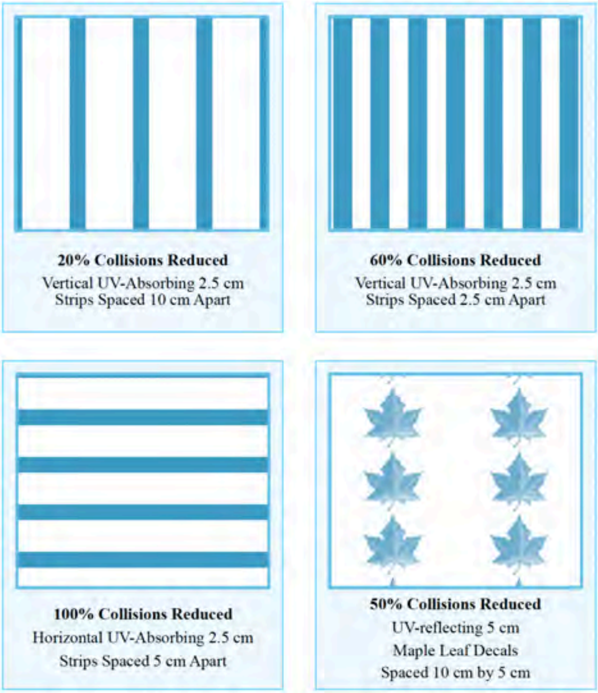


Figure 23. Daniel Klem's 2009 UV Flight Tunnel Experiments: Lines and Decals

Data from Klem's 2009 field experiments testing UV line patterns shown in Appendix 2 (Chart 1) indicate that only half of the 18 tests reduced collisions by 85% or more. These outcomes further suggest that UV solutions do not consistently reduce collisions. Six total experiments were conducted using UV film or strips, each with a transparent glass control. The field experiments were manually monitored for the number of collisions. One experiment describes results from both the field and four flight tunnel tests. Again, 2.5 cm wide UV strips were spaced 5 cm apart in two field experiments but had different results. Experiment 1 showed that glass with 2.5 cm UV strips spaced 5 cm apart had reduced collisions by 100%. Experiment 4 of the same spacing had only reduced collisions by 55%. However, Klem indicated the thick plastic edges of the UV strips were visible in Experiment 1 and could have been visible to the birds.[259] Experiment 2 testing the 5 cm spacing again resulted in reduced collisions by 66%. In Experiment 5 (shown in Figure 24), the flight tunnel experiment testing UV patterns had the highest average of collisions reduced, at 95%. It is not clear why these outcomes are much higher than the field experiments. This flight tunnel experiment also tested the perforated vinyl film CollidEscape which is not a UV product. It reduced collisions by 98%. This film makes the glass surface appear white to the birds, [260] similarly to etched frit dots, making the glass surface appear solid.

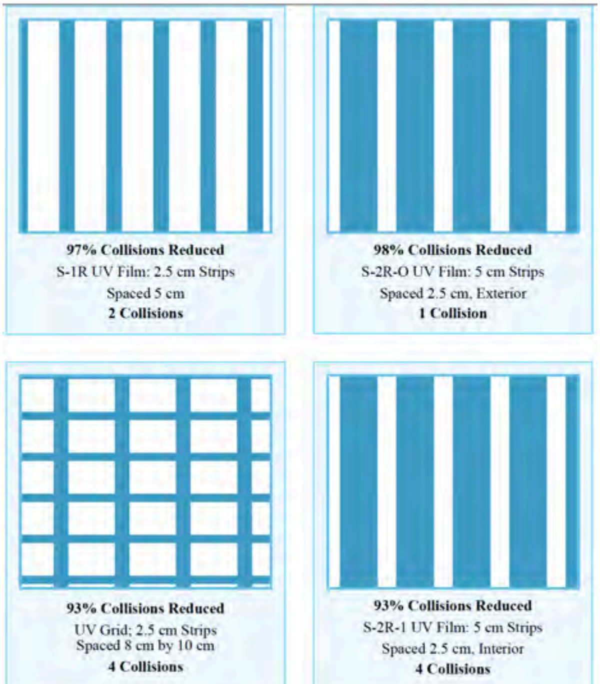


Figure 24. Klem's 2009 UV Flight Tunnel Experiments: Lines and Mesh

[259] Klem, "Preventing Bird–Window Collisions,": 314-321.
[260] Ibid.

ORNILUX is a commercial UV coating that covers the glass in a random complex transparent pattern that mimics a spiderweb, according to the company's marketing literature. The company claims that ORNILUX mitigates collisions while being nearly undetectable by the human eye.[261] (See Figure 25.) Klem and Saenger's 2013 study published two experiments testing ORNILUX UV coating and UV strips in the same open field setup used in 1990 and 2009.[262] They tested the film on transparent glass and a black matte panel with transparent glass and reflective glass controls. The tests were monitored for wild bird collisions and fatalities for less than four hours a day over about 16 days. Experiment 1 showed the UV coated glass using ORNILUX had 28% more collisions than the transparent glass control and 19% more fatal collisions. (See Chart 2 in Appendix 2.) This test indicates that ORNILUX may act more strongly than mirrored glass in attracting birds to its surface through reflection or attraction to the UV film. Experiment 2 reinforces this result as ORNILUX tested on a black opaque panel had

Figure 25. ORNILUX Treated Windows at the Denning House, Stanford University, CA

[261] "The Clear Solution," Welcome | ORNILUX Bird Protection Glass, accessed April 6, 2020, http://Ornilux .com/).
[262] Daniel Klem and Peter G. Saenger, "Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions," *The Wilson Journal of Ornithology* 125, no. 2 (2013): 406-411.

over half the number of collisions compared to a transparent glass control.[263] The use of the black panel in this experiment indicates that even on a solid opaque surface or on unlighted windows at night, both typically not a threat to most birds becomes deadly when birds are attracted to the UV pattern used by ORNILUX.

Klem's 2013 experiment testing ORNILUX recorded an increase in collisions compared to transparent or mirrored glass controls. Given that UV light is detectable by some birds and some species use UV to detect prey, it may result in unintended attraction. For example, in a 2015 study by Habberfield and St. Clair, cameras located at feeders recorded the birds' response to different UV sources: a pulsating UV light, a light-reflecting compact disk, an unlit UV light acting as a novel object, and a control feeder with no UV object. They found that none of these methods using UV light deterred birds and that there was a slight elevation in attraction to the three feeders with UV objects than the control.[264] Until we fully understand how birds see and use UV light, UV treatments should not be recommended as an effective collision reduction solutions.

Decals and angled glass are two proposed solutions that are not effective in reducing collisions or safeguarding birds. Spaced decals are recommended by the American Bird Conservancy to reduce collisions if they are separated by no more than 5 cm. However, these floating decals have not been proven to be effective in experiments or case studies. Again, the presumption has been that birds will not fly between the decals spaced closer than their wingspan, though this has not been thoroughly tested across various wingspans of different bird species. Decals can be successful when used to communicate that glass is solid to birds by using a pattern that replicates an intricate interconnecting design, as seen with a design used by the University of British Columbia in Figure 26. However, using a single decal to simulate the appearance of a predator is ineffective, as birds do not perceive these decals as a threat.[265] Additionally, in 1990 Klem tested a falcon silhouette and a barred owl (*Strix varia*) silhouette, both only reduced collisions by 20%.[266] In 2009, Klem tested a single maple leaf UV decal,

[263] Klem and Saenger, “Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions,”: 406-411.
[264] Michael W. Habberfield and Colleen Cassady St. Clair, “Ultraviolet Lights Do Not Deter Songbirds at Feeders,” *Journal of Ornithology* 157, no. 1 (April 2015): 239-248.
[265] Thaís Brisque et al., "Relationship between Bird-of-Prey Decals and Bird-Window Collisions on a Brazilian University Campus," *Zoologia* (Curitiba) 34 (2017).
[266] Daniel Klem, “Collisions Between Birds and Windows: Mortality and Prevention.”: 120–28.

which reduced collisions by only 25%.[267] In some cases, ineffective techniques such as floating and predator decals may briefly appear to work due to the *novel effect*, where new additions to the habitat preclude birds from approaching. Unfortunately, once birds become habituated to the decals, collisions resume.[268] A future study could examine how long these novel window additions influence bird behavior.

Figure 26. UBC's Bird-Friendly Line Pattern Decal, Vancouver, BC

In 2004, Klem tested angled glass panes in an open field test and found that angling glass from a bird's flight path can be partially effective. Tilting the glass by 20 degrees reduced collisions by half, and by 40 degrees, reduced collisions by over 70%.[269] However, researchers with the Fatal Light Awareness Program have disputed these findings. Their research suggests that when viewed by birds from below, the reflection of the ground or vegetation in the angled glass can be dangerous and conducive to collisions.[270] Given these conflicting findings, angled glass should not be recommended as a bird protecting design. This also reinforces the need for monitoring designs on real-life buildings before they are recommended as sustainable or bird protecting designs.

Based on the available research on bird building collisions, the American Bird Conservancy (ABC), in a study led by Christine Sheppard, has compiled guidelines for

---

[267] Daniel Klem, "Preventing Bird–Window Collisions,": 314-321.
[268] Habberfield and St. Clair, "Ultraviolet Lights Do Not Deter Songbirds at Feeders,": 239-248.
[269] Daniel Klem, "Preventing Bird–Window Collisions,": 314-321.
[270] Fatal Light Awareness Program (FLAP) Canada, "FLAP - Fatal Light Awareness Program," https://flap.org (Accessed November 1, 2019).

mitigating bird building collisions. These guidelines have provided the groundwork for many city bird-safe policies and the creation of ABC's Bird-Smart resources. Since 2008, ABC has tested over 150 materials and over 20 commercially available options using a flight tunnel located at Powdermill Avian Research Center in Pennsylvania. The following paragraphs explain how their experiments are performed, the threat rating system based on the test outcomes, limitations of the tests and rating system, and novel collision deterrence options.

ABC's flight tunnel is made of wood, is 30 feet long, and can test transparent and reflective glass. Wild migratory songbirds captured for other scientific studies are flown in the flight tunnel one time and released immediately after the test. A "nearly invisible" netting protects the birds from flying into the glass. Birds flown in the flight tunnel choose between the control, a transparent or reflective pane of glass, and the design or pattern being tested to reduce collisions. The tunnel can simulate reflections by using mirrors to simulate a sky pattern or landscape onto the glass surface.[271] The results of the flight tunnel tests are used to determine how dangerous a material is to birds. This is called the *threat factor*. The threat factor ratings for façade materials are referenced by policies and guidelines developed for cities by the American Bird Conservancy and the U.S. Green Building Council. The threat factor scale is 0-100, with 100 being the most dangerous materials, glass, and reflective surfaces, and 0 being the least dangerous materials, stone, brick, and wood. A material with a threat score of 30 indicates it was avoided 70% of the time in the flight tunnel tests. ABC determines that a material is Bird-Smart if it has a threat factor of 30 or less (birds avoid it in at least 70 percent of the test flights). For a

[271] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass,": 1-10.

material to be approved by the U.S. Green Building Council, it must have a threat factor of 15 or less (see Figure 27).

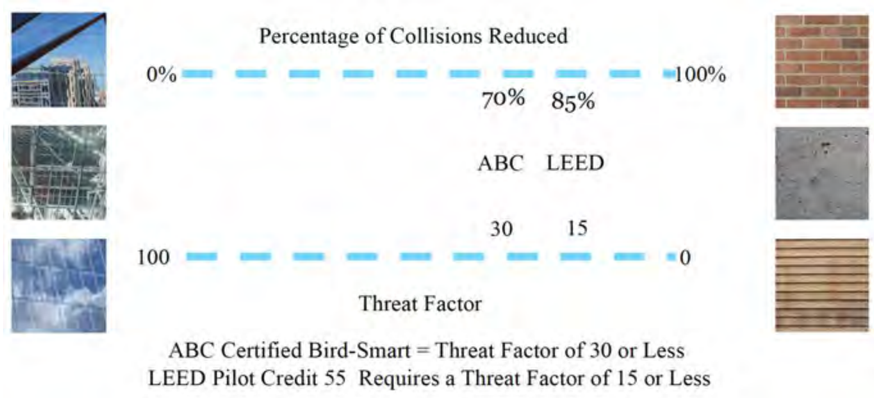


Figure 27. ABC's Threat Factor Rating Scale

While not all 150 tests can be detailed in this chapter, it summarizes the glass treatments that reduce collisions by at least 90%, as well as UV and colored film. Materials with a threat factor of 10 or less primarily include coatings with patterns that make the glass surface appear solid or closely spaced obstacles. These materials include continuously etched glass, 50% perforated vinyl film, insect screens or netting, and ceramic etched frit dots. Continuously etched panes of glass, perforated vinyl film, and insect screens have a threat level of 2. Frit dots equally sized and spaced at 0.75 cm and frit dots creating vertical lines spaced 9 cm or 10 cm received threat factor scores less than 5. Somewhat less successful were horizontal and vertical lines 0.32 cm thick and spaced 4 cm vertically, and 2 cm horizontally received threat factors between 5 and 8. These measurements are half the 5 cm by 10 cm spacing recommended by Klem, indicating lines spaced closer can reduce a large number of collisions. However, horizontal and vertical external slats that were at least 0.32 cm thick and spaced 4 cm horizontally and 10 cm vertically were given a threat factor of 5.[272]

Commercial glass and vinyl manufacturers use ABC's threat factors to promote their products as Bird-Smart.[273] Appendix 3 outlines the manufactured products recommended by

[272] American Bird Conservancy. "Stop Birds Hitting Windows," American Bird Conservancy, May 21, 2020, https://abcbirds.org/get-involved/bird-smart-glass/).
[273] Ibid.

ABC, their threat factors, and product images. The following selected results are for UV film and colored film.

ABC tested Ultraviolet materials, but as in Klem's experiments, they did not consistently reduce collisions. Square UV-reflecting decals spaced 4 cm horizontally and 10 cm vertically received a threat factor of 10. However, the four other UV patterns tested scored between 21 and 27 on the threat factor scale. These consisted of three webbed patterns provided by ORNILUX with no more than a 4 cm opening in the pattern and a transparent film by GlasPro of vertical strips spaced 5.7 cm alternating with non-UV strips.[274] One of the four ORNILUX tests fell outside of the 30 or less threat factor required for designation as Bird-Smart by ABC. None of the four meets the standard for LEED 55 (threat factor ≤ 15). The maker of ORNILUX, Arnold Glass, lists additional threat factors for their 13 products, ranging from 20-33 with an average of 28.[275] The ABC threat factor ratings offer 32 UV materials with collision deterrence patterns that score better than the widely promoted ORNILUX.

Decorative Films produces two films that apply to the exterior glass, each with identical image patterns; these produced concerning flight tunnel results. One film is colored with bright images of plants and birds; the other uses the same image that is frosted, appearing transparent where the image is white (see Appendix 3). They have a 15-point difference: 5 for the frosted vinyl and 20 for the colored vinyl. This point difference is significant enough for the frosted film to be approved by LEED and the colored film not.[276] The 15 point difference of the same pattern indicates limitations of the testing method, that color is a less reliable deterrent, accurately depicted bird species may confuse real-life birds, or an aspect of avian physiology not yet understood.

The experiments conducted by the American Bird Conservancy have limitations, and ABC acknowledges that none of the listed window products or listed guidelines guarantee the elimination of bird building collisions. A note at the bottom of each Bird-Smart webpage provides this caveat and indicates that results vary based on landscape, design features, resident bird populations, and product limitations.[277] One limitation is using the "nearly invisible" netting

---

[274] "Bird Safe," GlasPro, accessed April 7, 2020, http://www.glas-pro.com/products/glas-pro-bird-glass/).
[275] Ibid.
[276] American Bird Conservancy. "Stop Birds Hitting Windows."
[277] Ibid.

to prevent harm to the birds used in the flight tunnel.[278] It is not known whether the netting interferes with the results of the tests. In addition, ABC indicates an effort to compensate for real-world limitations such as sky and landscape reflections, but their experiments do not account for artificial light. Artificial light can transform the least threatening materials such as brick into a beacon attracting birds to its surface at night, leading to collisions. Klem's flight tunnel experiments do not use this mesh, nor can they reproduce reflections onto the glass surface.[279] Considering birds only have two options in a flight tunnel, a transparent passageway (control glass) or an obstacle (patterned glass), the flight tunnel experiments essentially test if birds can see an obstacle rather than effectively communicate the glass is not maneuverable or appears solid. Klem's 2009 UV flight tunnel experiments produced highly effective results reducing collisions over 90%.[280] However, it is unknown if this is due to UV's effectiveness, which performed more poorly in open field tests or the testing method.

The American Bird Conservancy often promotes UV collision deterrence methods. However, the limitations of UV field experiments and limited research about how different bird species see and use UV light indicate that more studies are needed to support this solution. Klem indicated in his 2009 study that the wood-framed picture windows in the field experiments "accurately simulate those in houses."[281] In a 2019 presentation, Klem also indicated that these field tests are the only experiments that simulate real-world buildings.[282] However, Figure 20, a photo taken by Klem of the field experiments referenced in his 2009 study, show that the wood-framed picture windows do not account for windows being surrounded by additional solid materials of the building. Birds in the field experiments could divert around the wood-framed windows, which would be less likely if the windows were part of a building. The field experiments do not account for windows illuminated from within a structure at night, nor do they reflect vegetation typically surrounding urban or suburban structures. Additionally, Schmid and Sierro found in a 2000 experiment that any pattern on transparent free-standing glass surfaces

---

[278] American Bird Conservancy. "Stop Birds Hitting Windows."
[279] Daniel Klem, "Preventing Bird–Window Collisions,": 314-321.
[280] Ibid.
[281] Daniel Klem, "Audubon Chapter of Minneapolis' Session on the U.S. Bank Stadium," (March 23, 2018), https://www.youtube.com/watch?v=z2HssOtP1JQ&feature=youtu.be).
[282] Ibid.

can reduce collisions.[283] They placed various patterns of black and white stripes and squares are varying distances on a transparent traffic road noise barrier resulting in an 80% reduction in collisions.[284] This further supports that freestanding glass does not always represent the effectiveness of patterns on glass in a built structure. Considering the limitations of the field experiments, their results do not replace real-world data from case studies when determining the effectiveness of collision deterrence methods. While helpful in providing some baseline information, Klem's 2009 and 2013 UV tests do not offer conclusive evidence that UV mitigation techniques successfully protect birds.

Limitations of UV patterns lie not only with the testing methods but bird behavior and physiology. Bob Beason, an avian sensory expert, is skeptical of the ORNILUX spiderweb pattern as some birds "burst through" spiderwebs, not seeing them as an obstacle.[285] Klem found in his 2009 study that reflective UV patterns that are 13% reflective reduce collisions far less than UV that is 80% reflective. Additionally, how birds see color signals across wavelength need to be considered. UV wavelengths of blue or purple are associated with attraction, sexual behavior, and food to some avian species. Wavelengths of yellow, orange, and red communicate danger to some species as well.[286]

The results of the flight tunnel and open field experiments and the ABC threat factors that result help determine which materials could be an appropriate fit for a project, but they should not be the only resource used to determine the potential threat of a building to birds. Artificial lighting, landscape within 100 m, the reflection of structures and transparent flyways, location of the site relative to migration flyways, species variation, and overall project design determine also contribute to building collisions. The flight tests' limitations are not communicated in guidelines, such as LEED's Pilot Credit 55, which merely indicates which materials are approved for use based on the data gathered from these experiments alone. Additionally, no collision deterrence methods have been tested for their impact on glass performance, an essential feature of façade and envelope design, lighting design, and sustainability, that cannot be overlooked.

---

[283] H. Schmid and A. Sierro. "Test of measures to prevent bird-strikes on transparent noise- protection walls." *Natur und Landschaft* 75 (2000).
[284] Ibid.
[285] Lesley Evans Ogden, "Does Green Building Come up Short in Considering Biodiversity?: Focus on a Growing Concern.," *BioScience* 64, no. 2 (2014): 86.
[286] Daniel Klem, "Preventing Bird–Window Collisions,": 314-321.

LIGHTING AND LANDSCAPE SOLUTIONS

Lighting influences the risk of birds colliding with glass windows, and the easiest way to mitigate this added threat is to turn out building lights at night. However, light solutions go further than turning out the lights to prevent window collisions. As human populations increase, so does the use of artificial lights to a point where it is hard to find space that is not illuminated or influenced by artificial lighting. Illuminating chimneys, buildings, bridges, and monuments with floodlighting contributes significantly to migrating bird fatalities.[287] Communication towers and ceilometers have also been factors in large numbers of fatalities for migrating birds.[288] Gautreaux Jr. and Belser have recorded two changes reducing bird deaths relating to ceilometers: filtering the wavelengths so only UV light remains and rotating the beam of light so it is not a constant strobe. This strategy is more closely related to the intensity and color of light and constant or strobing patterns than the buildings' materials or landscaping. [289] However, from the study of ceilometers, researchers discovered that a bird's ability to see wavelengths in the light spectrum differs from humans. The findings suggest that the increased nonlinear flight behavior near a tower with white strobing light and a significantly greater increase of nonlinear flight behavior near the towers with a red light compared to a control with no light.[290] These findings indicated that birds become disoriented by red lights or solid light sources and are less strongly affected by strobing or white lights. Also, certain wavelengths can disrupt a bird's magnetoreception compass used for migration navigation.[291] This is one reason red light disorients birds.[292] A 2002 study by Wiltschko and Wiltschko found that dim blue-green light did not create the same disorientation or attraction.[293]

While light pollution in urban areas causes stress and internal clock disruption in birds, lights also attract migratory birds to lit buildings. Evans Ogden's 1996 and 2002 reports offer the best solutions to prevent building collisions due to artificial light.[294] The recommendations are

---

[287] Catherine Rich and Travis Longcore, *Ecological Consequences of Artificial Night Lighting* (Washington, DC: Island Press, 2006), 74.
[288] A ceilometer measures the height of a cloud ceiling or cloud base using a laser or light source.
[289] Catherine Rich and Travis Longcore, *Ecological Consequences of Artificial Night Lighting*, 76-84.
[290] Ibid., 85.
[291] Magnetoception allows an organism to detect magnetic fields to determine direction, altitude, or location.
[292] Rich and Longcore, *Ecological Consequences of Artificial Night Lighting*, 74.
[293] Ibid., 85-6.
[294] *Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds* (1996); *Summary Report on the Bird-Friendly Building Program: Effect of Light Reduction on Collision of Migratory Birds* (2002)

to reduce light emissions by enforcing tenant awareness about reducing light use at night through signage and educational materials. His study also used computer-controlled lighting systems to turn off lights at night and found automatically turning off the lights was the best available solution to reduce fatalities. Ogden's proposed solutions are to direct light downward to prevent capturing birds above the buildings or light sources, use vegetation as light buffers for lower-level lighting, and replace beacon lights with UV lights or strobe blue-white or blue-green lights that will not capture birds.[295] While these recommendations have been referenced in several bird-safe guides and on the FLAP (Fatal Light Awareness Program) website, how varying wavelengths of artificial light disorient specific species need further research to create a specific set of guidelines to reduce light emissions negatively affecting birds. Current data suggest that illumination of buildings at night should be restricted, especially during periods of bird migration. Being lit from the outside or inside causes collisions. Limiting illumination on building surfaces, using other proven techniques, such as making the reflective and transparent glass appear opaque at night through turning off the lights or using blinds can help reduce bird building collisions during migration.[296]

Light pollution has been well studied and offers many solutions to safeguard birds; however, landscape solutions have not been as well studied. A building's surrounding green landscape connects humans with nature, but it often causes disorientation for birds. Native or naturalized plants attract resident and migrating birds that flock to urban areas to feed or rest in maintained green spaces. The areas are especially important refuges for birds during times of drought and fire, but green spaces near buildings can also contribute to the loss of birds through building collisions. Implementing careful landscape design solutions can reduce these losses.[297] The U.S. Green Building Council offers credit for these types of bird protecting landscape designs in their LEED 55 Pilot Credit. The credit requires that any disturbances to the natural landscapes must be limited—including at the building perimeter, parking garages, surface walkways and patios, and constructed areas. Designers must also allow at least 12 m between the

[295] Lesley J. Evans Ogden. "Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds." Special report prepared for World Wildlife Fund and the Fatal Light Awareness Program. WWF, Toronto, Ontario, Canada (1996): 9-28.
[296] Blinds are not effective in preventing daytime bird building collisions. (Schneider et al., 2018)
[297] C. J. Eakin et al., "Avian Response to Green Roofs in Urban Landscapes in the Midwestern USA," *Wildlife Society Bulletin* 39, no. 3 (2015): 574-582.

building and the vegetation or natural habitats. This buffer eliminates some of the danger birds face when they mistake reflections for habitable vegetation or food sources.[298] If the vegetation cannot be placed 40 m from the building, keeping it closer—no more than one meter away from where the building is reflective—can minimize fatal collisions. Daniel Klem found in his 2004 study that feeders placed within one meter of glass windows were not deadly, but feeders placed between 5 and 10 m were deadly.[299] In this case, the short flight from the vegetation to the window does not provide enough space for most birds to build enough momentum for impact leading to injuries or deaths.[300]

While the LEED recommendation for keeping vegetation closer to buildings at one meter is still the recommended distance from glass, recent data suggests the vegetation-building buffer should be extended from 12 m to 50 m. Loss et al. 's recent November 2019 study indicates that a building's surrounding vegetation at a 50 m and 100 m buffer influences fatalities by attracting birds to vegetation near dangerous reflective or transparent glass windows. Of the top five species recorded to collide with windows in the downtown area of Minneapolis, Minnesota in Loss et al.'s 2019 study found that four out of the five avian species were attracted to the buildings by vegetation within 50 m of the building and one species within 100 m of the building resulting in fatal collisions.[301] Reducing vegetation near reflective materials, at least within the 50 m buffer, is recommended to reduce collisions. If this is not possible, applying effective bird protecting designs to reflective surfaces that reflect vegetation near the building will reduce collisions.

CASE STUDIES

Few case studies document bird protecting designs' effectiveness, whether applied directly to existing glass, replacing the glass, or designing a building using little glass. This section contains detailed examples of all three methods and their reported effectiveness. This data is rare, and there is a critical need for additional monitoring efforts when using bird

[298] The U.S. Green Building Council, "USGBC Site Development - Protect and Restore Habitat," www.usgbc.org/credits/ss51 (Accessed 10/01/, 2019).
[299] Daniel Klem, "Preventing Bird–Window Collisions,": 69.
[300] Klem, "Collisions between Birds and Windows: Mortality and Prevention,": 120-8.
[301] Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City. *PLoS ONE* 14, no. 11 (2019): 1.

protecting designs. When choosing a bird protecting design, the data from these case studies, not experiments alone, will help designers determine the best solution.

Two university campuses in the United States, Duke University and the University of Utah, reported using the commercial collision solution, Feather Friendly. The three monitoring studies from the universities provide valuable collision data before and after applying the mitigation strategy to windows on campus buildings with high collision rates.

The buildings on the west campus of Duke University in Durham, Carolina, are mostly Collegiate Gothic in style. This style generally uses relatively little transparent and reflective glass; however, recent building additions to the campus incorporate contemporary design features such as large windows, increased height up to four stories, glass passageways, glass corners, and multiple wings.[302] The Fitzpatrick building is Certified LEED Silver.[303] The building has the largest percentage of overall glass surface area (57%) and surrounding forest cover (33%) than other buildings on campus and included glass walkways.[304] Over 21 days in the fall of 2014 and spring 2015, 86 bird collisions were reported, and the Fitzpatrick Building had the highest number of reported bird collisions on campus with 61 collisions. Most of the species that collided with the building were migratory species, the top being the cedar waxwing (*Bombycilla cedrorum*), and the ovenbird (*Seirurus aurocapilla*). Ocampo-Penuela et al. suggests that the fermented berries consumed by the cedar waxwing disturb the birds' sense of orientation. They further suggest the ovenbird is highly vulnerable to collisions due to being an understory specialist.[305] Two resident birds were frequent collision victims: the northern cardinal (*Cardinalis cardinalis*) and the tufted titmouse (*Baeolophus bicolor*).[306] This further proves that while migratory birds are most vulnerable to collisions, collisions happen year-round and impact resident species. In 2015, the Fitzpatrick Building was retrofitted with vinyl dots of equal size and spaced equally at 2.5 cm apart on the glass exterior provided by the company Feather

302 Natalia Ocampo-Penuela et al., "Patterns of Bird-Window Collisions Inform Mitigation on a University Campus," *PeerJ* 4, no. 2 (2016): 3.
303 LEED certification is a U.S. Green Building Council certification centered on a credit system of points given based on the potential environmental impacts and human benefits. There are four levels of certification: Certified, Silver, Gold, and the highest, Platinum.
304 Natalia Ocampo-Penuela et al., "Patterns of Bird-Window Collisions Inform Mitigation on a University Campus,": 5.
305 Ibid.
306 Ibid.

Friendly.[307] This method was tested by the American Bird Conservancy and found to be 83-97% effective in reducing collisions.[308] (See Figure 28.)

Figure 28. Fitzpatrick Building, Duke Campus, Durham, NC
Building (1); Transparent Glass Corridor (2); Detail of Transparent Glass Corridor (3); Detail of Dots (4).

A follow-up study from 2018 researching the flight path of birds on the Duke campus reported that the alteration of the glass on the Fitzpatrick building had reduced collisions but only by about half, resulting in a yearly average of 47 collisions between 2016 and 2017.[309] The follow-up report also indicated the vinyl dots were spaced at 5 cm, not 2.5 cm apart, as indicated in the first study. After the retrofit, the Fitzpatrick building still caused 47-67% of the campus' collisions. However, collisions at the transparent glass passageway were drastically reduced.[310] The mere 50% reduction in window collisions was due to inconsistencies in the application or

---

[307] Natalia Ocampo-Penuela et al., "Patterns of Bird-Window Collisions Inform Mitigation on a University Campus,".
[308] Feather Friendly, “Feather Friendly,” https://www.featherfriendly.com, accessed April 7, 2020, https://www.featherfriendly.com/)
[309] R. S. Winton, Natal Ocampo-Penuela and Nicolette Cagle, "Geo-Referencing Bird-Window Collisions for Targeted Mitigation. (Report)," *PeerJ* 6, no. 1 (2018), 8-10.
[310] Ibid.

the mitigation method chosen. The follow-up report indicated that only one-fourth of the glass surface had been covered by Feather Friendly (white vinyl dots spaced 5 cm apart) in areas with transparent passageways or corners. The vinyl dots were not applied to windows where reflections of vegetation were visible.[311]

Three buildings at the University of Utah campus use collision mitigation techniques. Brown et al.'s 2019 study evaluates the effectiveness of Feather Friendly, frit dots, and ORNILUX to prevent bird building collisions. During their first winter (November 2017 – January 2018) monitoring of what the study called the "mitigation building," 7 collision fatalities were reported under the mirrored façade, and 15 fatalities total for the building. In November 2018, Feather Friendly was applied to the mirrored exterior on the north side and left the western side untreated as a control. The study monitored eight total buildings in the second winter (November 2018 – January 2019) and found 22 total collisions. Mirrored windows that faced pear trees (*Prunus calleryana*) increased collisions specifically for cedar waxwings. In winter one, 13 out of the 15 fatalities were cedar waxwings, and in winter two, all ten fatalities were cedar waxwings.[312]

The results of monitoring Feather Friendly as a collision mitigation solution showed a 71% reduction in collisions. The collisions had declined from seven to two after application. The control area had eight collisions. Two of the eight monitored buildings had ceramic etched frit dots and ORNILUX UV film on their windows at the time of the study. During winter two monitoring, these windows only had one fatality, but the study noted with low collision fatality numbers, this data does not indicate they significantly reduced collision risks.[313]

These three studies indicate the importance of testing and monitoring mitigation techniques on real-world buildings before recommending their use and making informed decisions when choosing mitigation techniques. In the Duke campus case, thorough research understanding why birds collide with buildings could have indicated the need to apply Feather Friendly to more areas of the building in addition to transparent passageways and corners. These studies show that the effectiveness of Feather Friendly to reduce collisions is lower than

---

[311] R. S. Winton, Natal Ocampo-Penuela and Nicolette Cagle, "Geo-Referencing Bird-Window Collisions for Targeted Mitigation. (Report)," *PeerJ* 6, no. 1 (2018), 8-10.

[312] Barbara B. Brown et al., "Winter Bird-Window Collisions: Mitigation Success, Risk Factors, and Implementation Challenges," *PeerJ* 7 (2019).

[313] Ibid.

indicated by the flight tunnel testing conducted by the American Bird Conservancy. On the Duke University campus, collisions were reduced by only half, and on the University of Utah's campus, collisions were reduced by 71%, slightly lower than the 77% predicted by the American Bird Conservancy. While each site's understanding and budget limited the product's application to all glass surfaces of the building, considering real-world results when choosing mitigation strategies is necessary when choosing the most effective product.

Few case studies document the use of techniques to prevent building collisions and provide data from both before and after retrofitting. A successful retrofitting of glass using equally sized and spaced ceramic etched frit dots at the Jacob K. Javits Convention Center in New York City is vital for its success story. This self-proclaimed model of sustainability promises to have minimal impact on the environment. It not only uses the most effective bird protecting design but offers habitat space on its green rooftop for 29 species of birds, five species of bats, and beehives that produce rooftop honey. As reported in 2009 by the New York

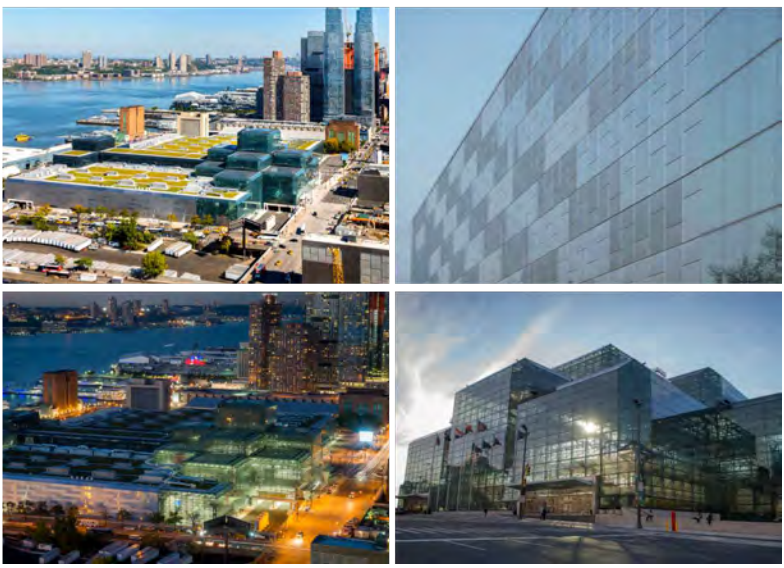


Figure 29. Jacob Javits Convention Center, New York City, NY
Left Top and Bottom: Javits Convention Center Day and Night. Right Top: Detail of Opaque Glass. Right Bottom: Glass Façade Entrance.

Audubon Society, the Javits Convention Center had one of the highest rates of building collisions in New York City, killing 100 birds a year. The building's façade made primarily of transparent glass, was retrofitted in 2014 with opaque panels at street level on the north and south sides of the building and with equally sized and spaced ceramic frit dots (0.32 cm) covering the glass entrances on the east and west sides of the building. (See Figure 29.) The frit dots resulted in a 90% decrease in bird building collisions, as recorded in 2015. (See Figure 22 for frit dot images.)

The 7-acre green roof of the Jacob K. Javits Convention Center shown in Figure 30 is enticing to birds and would have been extremely conducive to window collisions, as its location is on top of a building constructed of transparent glass with visible support beams. It is also situated near the Hudson River and in a migration flyway. However, the fritted glass mitigates most of this danger. The rooftop is home to 29 nesting species and includes 100 gull nests. The Javits Center is an example of effective glass technology to reduce collisions. The dangers posed by artificial lighting are reduced as the illuminated glass includes frit dots or opaque panels,

Figure 30. Jacob Javits Convention Center Green Roof, New York City, NY
Left Top and Bottom: Javits Convention Center Green Roof. Right Top: Herring gull (*Larus argentatus*) Family. Right Bottom: Glass Façade and Beehives.

reducing reflections by communicating to the migrating and resident birds that this building's glass is solid. Klem's 2009 experiments showed that frit dots reduced collisions by 100%; however, in this real-world case study, the ceramic etched frit dots were 90% effective in reducing collisions. This 10% difference is a signal that experiments are a starting point to determine which methods have the potential of reducing collisions, but many of the results may vary due to factors on real-world buildings the tests cannot replicate. Frit dots were used successfully at two colleges in Pennsylvania: Swarthmore College in Swarthmore and Muhlenberg College in Allentown. Swarthmore had two known collisions a year, and Muhlenberg had none.[314] While the Javits Center is a success story due to the addition of the closely spaced ceramic etched frit dots, it is also a reminder that materials tested in experiments may not perform equally on real-world structures. After applying bird protecting designs, monitoring their effectiveness is vital to the future study of reducing collisions.

The Allianz Field stadium, located in Saint Paul, Minnesota, completed in 2019, is revered by bird conservation organizations for the designers' commitment to preventing bird building collisions and light pollution.[315] Structural engineer Walter Moore designed the Allianz Field to minimize environmental impact. The designers were dedicated to making the building bird-safe as they recognized that Saint Paul, Minnesota sees over 300 species of birds during the migration season. As their website states, they wanted to make "this large building as safe as possible for our feathered friends."[316] They decided to cover 70% of their building with PTFE fabric that wraps around the structure to limit reflective or transparent glass. The stadium designers report that PTFE fabric prevents reflections and giving the illusion of a clear passageway. Avoiding reflective or transparent glass means the landscape can be designed with native trees without the risk of their reflections in the glass confusing birds or luring birds to food sources near-transparent glass. Both scenarios would lead to increased bird building collisions. The glass doors by the entrance gate recede behind the edge of the PTFE fabric above and use a bird protecting frit pattern. Additionally, the PTFE fabric reduces light pollution, and

---

[314] Daniel Klem, "Preventing Bird–Window Collisions,".

[315] Alisa Opar, "Minnesota's Newest Sports Stadiums Take Very Different Approaches to Bird Safety," Audubon, October 24, 2018, https://www.audubon.org/news/minnesotas-newest-sports-stadiums-take-very-different-approaches-bird-safety.

[316] Minnesota United FC, "Allianz Field is for the Birds," https://www.mnufc.com/post/2019/02/11/allianz-field-birds.

the LED lights used at the stadium face inward rather than beaming up and out into the night sky.[317] The stadium, landscape, and the PTFE fabric detail are shown in Figure 31. This case study approached bird protecting designs by using new bird-safe materials to enclose the stadium and bird protecting lighting and landscape. However, there is one vital component of bird-safe design that is missing: monitoring for collisions. Collecting data proving the stadium effectively prevents collisions would strengthen the case for the bird protecting designs used by the designer. Located in the neighboring city from the deadly U.S. Bank Stadium in Minneapolis, this stadium is a reminder that designers and architects who value birds can incorporate bird protecting designs into their sustainability efforts. The Allianz Stadium in St. Paul, Minnesota is an example of what is attainable when innovative bird protecting designs are part of the building plan early in the concept.

Figure 31. Allianz Field Stadium Saint Paul, MN and PTFE Detail

[317] Minnesota United FC, "Allianz Field is for the Birds," https://www.mnufc.com/post/2019/02/11/allianz-field-birds.

Finding innovative ways to communicate that glass is solid or that the entire structure is solid, impassible material is essential to the future of bird protecting designs. Based on the evaluation of designs in experiments and case studies, equally sized and spaced ceramic etched frit dots, perforated films like CollidEscape, or breathable but solid appearing materials like PTFE achieve this goal. As opposed to UV patterns and films, new materials such as electrochromic glass can offer a more customizable balance between human desired aesthetics or the benefits of glass and designs that reduce collisions. Electrochromic glass reduces glare by implementing a tinting technique based on the needs of humans inside the building and the weather. They also offer customizable controls.[318] With more research, this glass could incorporate tinting techniques that resemble frit dots or perforated vinyl to deter collisions. With the customizable controls, these mitigation techniques could be automatically adjusted or set on a timer to turn on during migration seasons or during months with high numbers of collisions while reducing light pollution at night.

Daniel Klem has built a foundation for reducing window collisions by providing controlled experiments of glass solutions. Further, the American Bird Conservancy and Christine Sheppard offer more test results and valuable information about the effectiveness of commercially manufactured solutions. However, it is important to remember that these experiments, including Rossler et al.'s, offer a basic understanding of collision deterrence methods. Evaluating each suggested solution for effectiveness in the field, on and around buildings, and in closed experiments will offer a complete understanding of which collision mitigation techniques are the most reliable. This also applies to the Bird-Smart glass resources provided by the American Bird Conservancy, which does not guarantee effectiveness in the field.[319]

Landscape and lighting design offer straightforward solutions that can reduce collisions through thoughtful landscaping or comprehensively researched lighting solutions. Reducing light use at night is the most effective and most accessible solution to reduce collisions. When this is not possible, treating glass with solutions such as ceramic etched frit dots or perforated vinyl and reducing floodlighting can decrease collisions and behavior disruptors. Understanding landscape

[318] View, "Electrochromic (Smart Glass)" https://view.com/product/how-it-works.
[319] American Bird Conservancy, "Bird Smart Glass," https://abcbirds.org/get-involved/bird-smart-glass/ (Accessed November 1st, 2019).

design impacts vegetation, surface area, and surrounding native landscapes on native and migrating species allows mitigation techniques to be customized to specific locations. Moving places of respite, nesting, and food sources away from reflective glass and eliminating their use behind glass is the most effective prevention method.

While many solutions to problematic glass, lighting, and landscape designs have been evaluated and proposed in this chapter, there is a vital need for collision reduction methods that effectively reduce collisions and provide building occupants with natural light and a view of nature. This is a critical area of study that needs to be tackled from an interdisciplinary approach, involving experts in building design, landscaping, lighting, ornithology, and researchers or innovators passionate about finding proven effective solutions to mitigating bird building collisions. For solutions to be widely effective in reducing collisions in the United States, they must be implemented in policies devoted to sustainable practices and sustainability education.

CHAPTER 4 AVIAN PROTECTING POLICIES AND DESIGN GUIDELINES

The modern era of environmental research and policy in the United States brought awareness of the impact of human actions and development on nature and birds. From the 1920s to the 1960s, America needed to rethink its relationship with nature as urban and rural growth increased, and the population expanded into urban areas.[320] In 1948 the first effects of DDT on bird populations were detected by conservationist Fairfield Osborn. Osborn's early opposition to pesticide use and his book *Our Plundered Planet* were the beginning stages of a movement towards protecting the environment from anthropogenic threats. [321] The Environmental Movement in America of the 60s and 70s was ushered in by Rachel Carson and her book *Silent Spring*. It warned of an endless stillness and the end of all bird songs if humans did not change their indiscriminate use of insecticides and abandon their conquest of nature. Largely in response to the literary work of Carson, this era also brought the foundation of the Environmental Defense Fund and the Endangered Species Act.[322] The Endangered Species Act, passed in 1973, allows state and federal governments to protect species threatened with extinction in the United States and its territories. This act shaped the legislation used to protect the peregrine falcon (*Falco peregrinus*) and led to the species' successful recovery.[323] The 80s and 90s brought more complex and controversial conservation policies as movements felt pushback from lawmakers. The Coastal Barrier Resources Act of 1981 included a federal bill that protected habitats for migratory birds and other wildlife along the Atlantic and Gulf coasts of the United States, highlighting the fundamental conflict between land development and conservationists.[324] The 20th century introduced the green building revolution through the U.S. Green Building Council and LEED certifications, aiming to reduce the vast amount of energy buildings consume in their construction and operation. The voluntary policies also brought awareness of protecting undeveloped land, reducing light pollution, a site's impact on the local ecosystem, and reducing

---

320 Peninah Neimark and Peter Rhoades Mott, *The Environmental Debate: A Documentary History with Timeline, Glossary, and Appendices* (Amenia, NY: Grey House Publishing, 2017), 170.
321 Ibid.
322 Ibid., 227-9.
323 U.S. Fish and Wildlife Service/Endangered Species Program, "Endangered Species Act: Overview," Official Web page of the U S Fish and Wildlife Service, Accessed June 7, 2020, https://www.fws.gov/endangered/laws-policies/).
324 Neimark and Mott, *The Environmental Debate*, 264-5.

CO_2 emissions, all areas of concern for bird conservation efforts.[325] Currently, we face new conservation and policy issues as increased use of glass, light pollution, and loss of habitat from urbanization threaten bird populations across North America. Conservation policies and sustainability guidelines need to clearly outline how they are protecting avian species in addition to preventing habitat loss, reversing climate change, and providing a visual connection to nature. Visually opening buildings, allowing a connection between humans and nature to increase overall human well-being should not kill a large number of birds.

This chapter summarizes selected acts and programs aimed to protect avian populations in the United States. The chapter then outlines and evaluates three sets of sustainable design guidelines, as developed by the Living Building Challenge, the U.S. Green Building Council's LEED Pilot Credit 55, and the American Institute of Architects, for their ability to safeguard bird populations in the built environment. Proposed revisions and additional guidelines are provided based on an analysis of available collision solutions. Finally, city and state policies from across the United States, primarily San Francisco, New York City, and Minnesota, are outlined, compared to each other, and to a proposed federal policy, the Bird Safe Building Act of 2019. This chapter proposes state and federal policy guidelines to create a more united front and consistent format at the end of the chapter. The scope of this chapter is to outline policies and guidelines focusing primarily on the mitigation of the dangers birds face in the built environment.

ACTS AND PROGRAMS

The U.S. Department of the Interior administers the Migratory Bird Treaty Act under the Fish and Wildlife Service agency. This federal act of 1918 "makes it illegal to take (kill), possess, import, export, sell, purchase, barter, or offer for sale, purchase, or barter any migratory bird, or the parts, nests, or eggs of such bird except under the terms of a valid permit."[326] The act also implements conventions between the United States and Canada, Mexico, Japan, and Russia to protect migratory birds.[327]

---

[325] Neimark and Mott, *The Environmental Debate*, 631-3.
[326] "Migratory Bird Treaty Act," U.S. Fish & Wildlife Service - Department of the Interior, Accessed April 7, 2020, https://www.fws.gov/birds/policies-and-regulations/laws-legislations/migratory-bird-treaty-act.php).
[327] Ibid.

Although the Migratory Bird Treaty Act has been modified a few times over its history, it is the interpretation of "take" that has undergone the most changes and challenges in the past two decades. The dispute rests on whether the interpretation of "take" includes incidental bird deaths, such as collisions with structures or mortality that results from industrial accidents, or exclusively towards activities whose intent is to kill birds. Throughout most of the Act's history, the Fish and Wildlife Service interpreted take to include incidental killing; however, there was enough legal ambiguity that the courts did not uniformly enforce this interpretation. It was also the unofficial practice of the Fish and Wildlife Service to limit the prosecution of incidental takes, as there was no regulated mechanism to exempt incidental take outside of military activates.[328] Still, under the Obama administration, there were at least two high profile examples of the federal government holding non-federal actors responsible for incidental bird deaths, including one that involved collisions with built structures.

In 2013, based on the Migratory Bird Treaty Act, a court ruled that two wind farms in Wyoming would be penalized 1 million dollars and 2.5 million dollars in one year for killing protected birds, including the golden eagle (*Aquila chrysaetos*). In 2015, the U.S. Fish and Wildlife Service announced it would consider holding industries more accountable for bird deaths caused by wind turbines, infrastructure such as power lines and cell phone towers, and byproducts of energy production such as oil pits and gas flares.[329] A statement made by Robert G. Dreher, acting assistant attorney general for the Justice Department's Environment and Natural Resources Division, declared that the wind farm owners, Duke Energy Renewables, "constructed these wind projects in a manner it knew beforehand would likely result in avian deaths."[330] While Duke Energy Renewables claimed that their goal is to provide clean and safe wind energy, the American Bird Conservancy president, George Fenwick, pointed out that clean energy that kills "hundreds of thousands of birds" is not green.[331] In an effort to make such accountability more commonplace, in January 2017, the acting Interior-Solicitor, Hilary

---

[328] Andrews G. Ogden "Dying for a Solution: Incidental Taking under the Migratory Bird Treaty Act." *William and Mary Environmental Law and Policy Review* 38, no. 1 (2013): 80.
[329] Ibid.
[330] Dina Cappiello and The Associated Press. "Eagle Deaths at Wind Turbine Farm: Duke Energy Agrees to Pay $1 Million." NBCNews.com. NBCUniversal News Group, November 23, 2013. https://www.nbcnews.com/news/us-news/eagle-deaths-wind-turbine-farm-duke-energy-agrees-pay-1-flna2D11644504.
[331] Ibid.

Tompkins, issued a legal opinion, Opinion M-37041, affirming the longstanding interpretation of the Act to include incidental take. [332]

In less than a year, however, the new Interior-Solicitor, Daniel Jorjani, permanently withdrew the actions of his predecessor and issued a new interpretation under Opinion M-37050, which states that "the take [killing] of birds resulting from an activity is not prohibited by the Migratory Bird Treaty Act when the underlying purpose of that activity is not to take birds."[333] This new interpretation could be understood as pardoning the elimination of a building known to have an active nest of vulnerable birds. If the building owner is not killing the birds directly but demolishing the building, they cannot be penalized.[334] It also would not hold building owners responsible for killing hundreds of birds a year through known bird building collisions if the building was not built to kill birds. The vice-president of conservation for the Audubon Society, Sarah Greenberger, adds that the Migratory Bird Treaty Act "has been the tool the Fish and Wildlife Service has used to work with industry to implement basic management practices." Without having guidelines to hold businesses accountable, they will have no compelling reasons to implement measures like covering tar pits that kill up to a million birds a year.[335]

Under the current migratory Bird Treaty Act ruling, the 2013 penalties imposed on the two Wyoming wind farms would not occur. Cappiello's 2013 article reported that the wind turbines are being monitored after the golden eagle deaths and turned off if eagles were detected in the area. Also, at least half of the penalty fee was used to create protected habitats for Wyoming's golden eagles. These regulations and penalties ensured there were consequences for taking birds and places value on their lives, even if monetarily. Another option to place value on the lives of birds would be implementing an education program about mitigating wind farm casualties or bird building collisions. This has been a successful strategy of FLAP and Lights Out! to persuade building owners to protect birds.

FLAP or the Fatal Light Awareness Program is a Canadian based program founded by Michael Mesure in 1993 after witnessing the delayed death of a bird building collision victim, a

---

[332] Ogden, "Dying for a Solution": 80.
[333] Ibid.
[334] Darryl Fears and Dino Grandoni. "The Trump Administration Has Officially Clipped the Wings of the Migratory Bird Treaty Act." The Washington Post. WP Company, April 13, 2018. https://www.washingtonpost.com/news/energy-environment/wp/2018/04/13/the-trump-administration-officially-clipped-the-wings-of-the-migratory-bird-treaty-act/.
[335] Ibid.

common yellowthroat (*Geothlypis trichas*). FLAP is a Canadian non-profit that leads the country on bird building collision mitigation by safeguarding migratory birds in the built environment. This achievable through education, policy, and research.[336] As the name indicates, the program's initial focus was on reducing light pollution and lit structures contributing to bird building collisions. The program quickly started to incorporate design strategies to mitigate deaths caused by transparent and reflective glass. FLAP's work with researchers like L. J. Evans Ogden and cities across Canada to reduce light pollution threats on avian populations influenced the Lights Out! Program in the United States.[337]

The successful Lights Out! collision mitigation program was formed in 1999 by the Audubon Society.[338] The first city to adopt the program was Chicago, Illinois. The Audubon Society has now established Lights Out! Programs across 40 cities in the United States. This national effort aims to reduce the bright artificial lights and skyglow of cities that lead to collisions with buildings or windows and cause confusion or exhaustion, making birds vulnerable to other threats. The program's strategy is to convince building owners and managers to turn off excess lighting, particularly during migration periods. These strategies include turning off decorative lighting and lighting of higher stories, avoiding floodlights and strobe lighting, reducing atrium lighting, down-shielding exterior lighting, and using motion sensors and controls.[339] Most of the city and state bird-safe policies in this chapter reference The Lights Out! Program as well as the guidelines for the Urban Bird Treaty.

The Urban Bird Treaty is a collaborative effort between the U.S. Fish and Wildlife Service and cities in the United States to support city partners in conserving birds and their habitats. Thirty cities have joined the program since 1999. This program supports its partners to conserve urban habitats for birds, reduce urban hazards, and educate and engage urban communities. This program's goal is for cities to become sanctuaries for birds while increasing the health and well-being of people living in and visiting cities across the United States. The Urban Bird Treaty also focuses on community-based solutions to bird conservation intending to

---

[336] Fatal Light Awareness Program Canada, "About FLAP," FLAP Canada, Accessed April 7, 2020, https://flap.org/about/).
[337] "Ibid.
[338] National Audubon Society. "Existing Lights Out Programs," Audubon, January 15, 2020, https://www.audubon.org/conservation/existing-lights-out-programs).
[339] Ibid.

connect humans through healthy, beautiful, bird-friendly cities.[340] However, to make urban areas truly safe for birds, sustainable guidelines must add standards to safeguard birds.

SUSTAINABLE DESIGN GUIDELINES

There is a link between all aspects of green or sustainable building design and biodiversity. Energy, water, livability, and human health are all connected to the biodiversity of the site.[341] However, according to Mark Hostler, a system ecologist from the University of Florida, sustainable building guidelines are "failing on biodiversity." Hostler claims this is due to biodiversity not being particularly well understood and therefore is considered last when building sustainably.[342] In 2008, Marzluff and Rodewald suggested that "all urban areas have the potential to contribute to the conservation of biodiversity."[343] Their recommendations outline six principles to preserve and restore wildlife habitats in urban areas to conserve avian diversity.[344] (See Appendix 4). Yet, over a decade later, sustainable guidelines offer little protection of biological diversity, but there are ways designers can actively protect local biodiversity through design strategies. In this section, sustainable design guidelines are outlined based on their ability to protect biodiversity, specifically bird populations.

The Living Building Challenge asks designers to imagine buildings that are not dependent on fossil fuels, are self-sustaining, function as efficiently as nature while in line with nature, and truly build sustainably. The goal of the Living Building Challenge is to "make the world work for 100% of humanity in the shortest possible time through spontaneous cooperation without ecological offense or the disadvantage of anyone". [345] The ethos of this challenge is to build in a way that is socially just, culturally rich, and ecologically restorative by providing a framework for design, construction, and reshaping humanity's relationship with nature. It proposes reshaping the connection between humans and nature as a symbiotic relationship primarily

---

[340] "Urban Bird Treaty," U.S. Fish & Wildlife Service - Department of the Interior, Accessed April 7, 2020, https://www.fws.gov/birds/grants/urban-bird-treaty.php).
[341] Lesley Evans Ogden, "Does Green Building Come up Short in Considering Biodiversity?: Focus on a Growing Concern.," *BioScience* 64, no. 2 (2014): 84-5.
[342] Ibid.
[343] John M. Marzluff and Amanda D. Rodewald, "Conserving Biodiversity in Urbanizing Areas: Nontraditional Views from a Bird's Perspective," *Cities and the Environment* 1, no. 2 (2008): 1.
[344] Ibid., 12-3.
[345] International Living Future Institute, *Living Building Challenge 4.0* (2019): 1-13.

through designing regenerative projects that do not simply avoid negative environmental impacts but help realign our ecological footprint. The Living Building Challenge aims to achieve these high building and community standards over the next ten years through seven "petals" that incorporate 20 imperatives.[346] (See Figure 32.). The Living Building Challenge 4.0, released in June 2019, details each of these imperatives and includes five certification levels based on the adherence to imperatives in each petal. The seven petals include Place, Water, Energy, Health and Happiness, Materials, Equity, and Beauty. This thesis focuses on three petals: Place, Health and Happiness, and Beauty. These and the three additional petals, Water, Energy, and Materials, address design standards that may positively impact bird populations indirectly; however, they do not provide specific safeguards for bird populations. By reviewing the eight imperatives of the three petals Place, Health and Happiness, and Beauty, this document will outline why direct

Figure 32. Living Building Challenge Petals and Imperatives

[346] International Living Future Institute, *Living Building Challenge 4.0* (2019): 1-13.

bird protecting guidelines are needed and how the Living Building Challenge guidelines can implement them. Finally, the proposal of an eighth petal, Wildlife Protection, intends to balance the human-centric Challenge and foster a cooperative relationship between humans and nature, echoing the ethos this challenge strives to achieve.

The Living Building Challenge is committed to preventing habitat loss, reducing factors that lead to climate change, providing a connection to nature, and preserving the ecology of place. These factors all positively impact bird populations. However, the challenge lacks specific provisions to reduce harm to birds, such as reducing bird building collisions in projects that use a large amount of glass. The ethos of the Living Building Challenge could be revised to incorporate specific bird protecting standards; it can also include provisions to support wildlife as a contributor to human well-being by connecting to nature through birds and other animals. Three out of the seven petals could include provisions for bird protecting designs. Connection to nature through birds could be added to four of the 20 imperatives, three of which are Core Imperatives required to be labeled a Living Building. The Ecology of Place, a core imperative, should emphasize the importance of including considering birds in every project. Access to Nature should emphasize bird protecting standards if a project uses transparent or reflective glass. Finally, Beauty and Biophilia and Education and Inspiration can incorporate birds by connecting humans to birds through designs promoting biodiversity. Additionally, providing educational examples of why bird protecting designs are integral to sustainability standards will support these efforts.

Ecology of Place is part of the first petal, Place. This imperative intends to "protect wild and ecologically significant places."[347] This imperative requires all projects to demonstrate that they "contribute positively to the ecology of their place and restore or enhance the ecological performance of the site towards a healthy ecological baseline."[348] This includes cultural and social equity factors, zero use of petrochemical fertilizers or pesticides, and landscape guidelines to emulate the local habitat's functionality. Additionally, it requires that projects "avoid building on pristine greenfield, wilderness, prime farmland or in a floodplain unless they meet an exception."[349] Preventing petrochemical pollution and ensuring a native landscape while

---

[347] International Living Future Institute, *Living Building Challenge 4.0* (2019): 1-13.
[348] Ibid.
[349] Ibid., 30.

protecting wild and ecologically significant places will positively contribute to the local ecology and local species of birds. However, this imperative ignores the disruption of the local ecology by a structure occupying a three-dimensional space and potentially placing birds in danger.

The second and third imperatives of the Place petal are Urban Agriculture and Habitat Exchange. These are not core requirements but are required to achieve the Living Certification. Urban Agriculture intends to connect the community to locally grown food. While this imperative is rightfully human-centric, agriculture and green spaces will attract bird species and additional wildlife. The Habitat Exchange imperative requires the project to set aside a quantity of land approved by Land Trust or the Institute's Living Future Habitat Exchange Program that is equal to the project area and away from the site, to reduce habitat loss due to urbanization.[350] While the Place petal indirectly benefits birds, the Health and Happiness petal put birds in direct danger.

The intent of the Health and Happiness petal is to foster optimal physical and physiological health and the overall well-being of humans interacting with the project. This petal's three imperatives promote "healthy spaces that allow all species to thrive by connecting people to nature." This is primarily achieved using large glass windows. This petal ensures that interior spaces have "healthy air and natural light," as this connection to nature, through daylight, directly affects productivity, creativity, and countering stress.[351] The core imperative, Healthy Interior Environment, requires outdoor views and daylight for 75% of regularly occupied spaces. The Healthy Interior Performance imperative, which is not a core imperative, requires a higher percentage of access to outside views and daylight in 95% of the regularly occupied spaces. These two imperatives mean that more glass will be used on projects to meet these standards. The third imperative, Access to Nature, requires all projects to connect people and nature through interactions and connectivity, primarily through the benefits of daylight, fresh air, and landscape, and complete a post-occupancy evaluation of health benefits.[352] While the beneficial aspects of this human connection to nature are well documented, costs to wildlife are not. For example, bird building collisions increase, sometimes significantly, with increased transparent glass used in a building. The Living Building Challenge fails to mention that bird protecting

---

[350] International Living Future Institute, *Living Building Challenge 4.0* (2019): 28-33.
[351] Ibid., 45-49.
[352] Ibid.

design solutions should be applied to all glass to balance nature and the ecology surrounding the project.

The Beauty petal has two core imperatives, Beauty and Biophilia, and Education and Inspiration. Both imperatives intend to connect people to nature to inspire preservation and conservation of nature. This petal ideally strives to “inspire us to be better than we currently are.”[353] The core imperative of Beauty and Biophilia intends to connect humans to nature through the beauty of nature, through natural materials, and biophilic design. Project designers must spend at least one full day of exploration of biophilic designs for the potential project. The second core imperative of the Beauty Petal is Education and Inspiration. This imperative intends to provide educational materials and information on the project's performance to the public and its occupants.[354]

The four imperatives from the three petals, Place, Health and Happiness, and Beauty can all be achieved simultaneously with the Living Certification. Three of the four imperatives, Ecology of Place, Beauty and Biophilia, and Education and Inspiration, are achievable with the Petal Certification and the Core Green Building Certification. However, requiring Ecology of Place and Access to Nature in all three certifications will help to protect bird populations and make the two main aspects of the Living Building Challenge comprehensive. As is, there is no mention of bird protecting designs or other wildlife protection in the three petals and seven imperatives. Currently, the Living Building Challenge is producing buildings that reduce their impact on the earth for the sake of humans, but it lacks action to safeguard surrounding ecology that may be disrupted by structures. This set of guidelines fails to protect the creatures that occupy the habitat space the program strives to protect. It also overlooks the vital role of species, such as birds. The Living Building Challenge must not endanger birds while providing a connection to nature by using large amounts of glass. To design in balance with nature, designing for human benefits should not harm other living beings. To achieve this balance, this thesis proposes an eighth petal, Wildlife Protection. (See Figure 33.) Experts in various fields of biology and environmental science and design and architecture are needed to draft a comprehensive plan to protect the wildlife living at the site year-round or migrating to the area. While an interdisciplinary approach is vital, the petal is outlined below.

---

[353] International Living Future Institute, *Living Building Challenge 4.0* (2019): 64-68.
[354] Ibid.

The proposed petal, Wildlife Protection, has two core imperatives and five total imperatives. The first core imperative of the eighth petal, Hazard Reduction and Bird Protecting Designs, should outline mitigation techniques to structural hazards for birds such as transparent and reflective glass, landscaping near reflective glass, and any transparent structures. This imperative should also address hazards the built structure and its design could impose on additional wildlife

Core Imperative

PETAL	IMPERATIVE
WILDLIFE PROTECTION	1 Hazard Reduction and Bird Protecting Designs (Core Imperative)
	2 Light Pollution (Core Imperative)
	3 Wildlife Conservation
	4 Safe Energy
	5 Stewardship

Figure 33. Proposed Wildlife Protection Petal and Imperatives

species. The second core imperative, Light Pollution, should address light pollution and propose/introduce mitigation techniques to ensure the project limits attraction or disorientation for migrating birds or wildlife sensitive to artificial light. A third imperative, Wildlife Conservation, would allow the project to incorporate nesting boxes, green spaces, and preserve habitat aiding in conservation efforts. The land set aside in the Habitat Exchange imperative could be listed under this imperative if steps were taken to support declining species, such as the American kestrel (*Falco sparverius)*, by providing nesting space. Under the Urban Agriculture imperative, Wildlife Conservation can expand to support local wildlife such as bees and birds by emphasizing native plants that can produce food for humans and wildlife as well as increasing overall biodiversity. The fourth imperative, Bird Safe Energy, would address energy and infrastructure. Renewable energy sources such as solar or wind power and infrastructure, such as powerlines, can kill up to half a billion birds each year in the United States. Whether on the building or not, the source of renewable energy should be evaluated for being a high risk to birds and other wildlife. Finally, the fifth imperative, Stewardship, would require the project to provide educational resources about the wildlife the project is striving to protect and how to do so. The focus of the eighth petal goes beyond the protection of birds. It is a place to provide guidelines to protect the ecology of place and the surrounding environment as a system to be preserved as a whole rather than a system to be preserved for humans alone. This balance is included in the U.S. Green Building Council and the American Institute of Architects' bird protecting guidelines.

The U.S. Green Building Council has one LEED Pilot Credit to help protect birds from bird building collisions.[355] The intent of Pilot Credit 55: Bird Collision Deterrence is to "reduce bird injury and mortality from in-flight collision with buildings."[356] This credit relies heavily on the American Bird Conservancy's Bird-Safe Guidelines. The credit requires that a façade appears as a physical barrier to birds; it also necessitates the elimination of conditions that create reflections. The façade requirements use the threat factors applied to façade materials by the American Bird Conservancy.[357] LEED provides 18 example patterns the American Bird Conservancy has indicated as having a threat factor of 15 or less. Also included in the options are plexiglass, translucent plastics, screens, and external shutters. Only screens and external shutters have been tested; their threat factors are under the recommended 15 or less.

To achieve the LEED credit, the fulfillment of the façade requirements must accompany three other requirements: interior lighting, exterior lighting, and monitoring. To achieve the interior lighting requirements requires either that nighttime personnel turn off the lights from at least midnight to 6 am or that an automatic system turns off the lights after 30 minutes of inactivity in the space. (An exception is the lighting needed for health and safety.) The exterior lighting requirements include reducing or eliminating light trespass from exterior fixtures with fixture shielding and automatic shutoff (or following the LEED SS Credit 8, Light Pollution Reduction). Finally, the credit requires a three-year monitoring plan to assess the design's effectiveness in mitigating bird building collisions. This information must include identifying species, location, quantity, date, time, and features contributing to the collision.[358] Although the LEED 55 credit requires tested materials that reduce collisions by 85% or more in flight tunnel testing, there is room for improvement. This should include implementing a rating system for

---

[355] A pilot credit allows projects to test innovative credits that have not completed the drafting and balloting process.
[356] U.S. Green Building Council. "Bird Collision Deterrence," U.S. Green Building Council, Accessed April 7, 2020, https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthc-212?view=language).
[357] Ibid.
[358] Ibid.

materials and collision mitigation designs based on their three-year monitoring plan, including lighting, landscape, and location details. Designers and building owners could then compare which collisions solutions would be appropriate for their specific project or building.

Additionally, the points awarded for this credit are not enough to offset the points awarded for using large amounts of glass near green spaces. One point is awarded for this credit when requirements are met. However, four total points can be awarded for daylighting 75% of the floor area (3 points) and ensuring an unobstructed view of the landscape (1 point) that often falls within the 50 m vegetation buffer that attracts birds to dangerous transparent glass.[359] While this credit may bring awareness to bird building collisions in sustainability guidelines, it does not offer enough incentive to safeguard birds when the point system prioritizes the human benefits. This credit has room to improve by providing comprehensive nature-focused solutions similar to the American Institute of Architects' Design for Ecology guidelines.

The American Institute of Architects (AIA) guidelines for bird-safe design constitute the most comprehensive, nature-focused set of recommendations currently available. The AIA is dedicated to sustainable design projects that aim to benefit natural ecosystems and habitats in the built environment by responding to the ecology of place, connecting with place and regional ecosystems, minimizing negative impacts on birds and other animals, and contributing to biodiversity and the preservation or restoration of habitats and ecosystem services.[360] One specific measure outlined in the AIA Committee on the Environment Top Ten sustainable design measurements, Measure 3: Design for Ecology, directs designers to focus "solely on nature."[361] This measure aims to direct design teams to "think beyond the anthropocentric world of traditional architecture and to design specifically for the rest of biodiversity."[362] This measure's top strategy is to use landscapes with native plants, a high-impact strategy for saving water, decrease maintenance costs, and provide a habitat for local animals and insects. Additional strategies include lighting, bird collision deterrence, and site acoustics.[363]

---

[359] Barbara B. Brown et al., "Winter Bird-Window Collisions: Mitigation Success, Risk Factors, and Implementation Challenges," *PeerJ* 7 (2019): 14.
[360] The American Institute of Architects. "History." The American Institute of Architects. Accessed April 7, 2020. https://www.aia.org/history.
[361] The American Institute of Architects. "Designing for Ecology," The American Institute of Architects, Accessed April 8, 2020, https://www.aia.org/showcases/6082454-designing-for-ecology).
[362] Ibid.
[363] Ibid.

The AIA's Design for Ecology's three measures—landscaping, lighting, and bird collision deterrence—are currently the most comprehensive nation-wide guidelines regarding bird-safe designs. Landscaping and green spaces are crucial to support biodiversity and avian habitats in the built environment. The points discussed in this measure include covering as much non-building area with a broad diversity of native plants that thrive in the local environment and encouraging designers to have/develop an understanding of the local ecology and ecological services of the site before design to protect or restore the ecological services of the land. These guidelines also encourage design to preserve mature trees and preserve or create habitat for local flora and fauna. The guidelines encourage the use of birdhouses and bat boxes. Finally, the landscape guidelines value ecosystem services like natural pest control and the importance of even the smaller green spaces to support biodiversity.[364]

AIA also follows the guidelines produced by Dark Skies, a program by the Dark Sky Society, an organization working to reduce light pollution. The Dark Skies program aims to support education and legislative efforts to eliminate light pollution. The program consists of five points addressing interior and exterior lighting design and use.[365] The first point suggests maintaining a dark natural environment by carefully designing exterior lighting according to the Dark Sky Society guidelines.[366] In Appendix 5, a diagram of fixtures from their Guidelines for Good Exterior Lighting Plans outlines acceptable and unacceptable lighting fixtures.[367] Point two indicates that exterior light should fully cut off at the top of the fixture and illuminate the specific surface desired. Point three suggests that indoor lights' timing should be limited to when the building is in use after sunset, and interior lights should not be on all night. Point five advises nighttime security should use night-vision cameras and motion active lights. Finally, point five suggests using a computer simulation to verify external lighting will not fall in line with windows attracting birds to its surface.[368]

AIA's Bird Collision Deterrence guidelines outline the causes of bird building collisions. AIA guidelines cite areas of refuge and reflections of these areas in design as deadly to birds. Additionally, the guidelines state that human well-being is also negatively impacted as it is

---

[364] The American Institute of Architects. "Designing for Ecology."
[365] Dark Sky Society. "Dark Sky Society - Home," Dark Sky Society - Home, accessed April 7, 2020, http://www.darkskysociety.org/).
[366] Ibid.
[367] Ibid.
[368] Ibid.

stressful for those who witness bird building collisions. The first mitigation technique listed is to keep the window to wall ratio below 40 percent to improve energy performance, daylighting, thermal comfort, and prevent bird deaths. Design teams should also limit glazing and use shading and glare control. Buildings with high-risk areas such as facades in the "tree zone," near green spaces like green roofs, free-standing glass structures like bus stops or bridges, or transparent glass corners or atriums should use design strategies to make these areas visible to birds. The guidelines suggest using the American Bird Conservancy's Bird-Friendly Design Guide and UV glazing techniques or evaluate a whole-building approach to reducing bird building collisions. Finally, all graphics and bird-friendly design solutions must be documented and communicated to stakeholders to ensure the bird-safe plan is not overlooked.

The AIA has a solid foundation to provide guidance across the United States and help revise state and federal policies addressing bird-safe design. If they can reinforce their bird protecting designs in solutions that include data indicating they reduce the majority of collisions, bird protecting designs can become a part of sustainable building standards across the country. For this to become a reality, a few changes must be made to their guidelines.

The guidelines for Dark Skies offer five useful points to help eliminate light pollution, which would help to curb behavior disruptors in birds and prevent bird building collisions. One aspect missing from the guidelines is considering the wavelength of light (see Chapter 3). Lighting design could implement blue or green lights, rather than red lights, for security or marking of structures. Additionally, with sustainability standards indicating the importance of daylight when trying to increase the occupants' overall well-being, AIA could add more information about balancing the need for people to connect to the natural rhythms of nature and bird-safe designs.

The bird collision deterrence suggestions outlined by the AIA are comprehensive and deliver an understanding of the causes of bird building collisions. However, relying on the American Bird Conservancy's flight tunnel experiments to determine the best bird collision deterrence methods for glass should be revised to include data from any available case studies. Currently, there is little research in the area of solutions, so until more comprehensive data than the American Bird Conservancy's solutions are available, projects should have mandatory three-year monitoring for bird building collisions like that required for LEED's Pilot Credit 55 and avoid solutions not proven to be effective, like UV glazing. Finally, there needs to be an education program at AIA to spread awareness of bird building collisions among architects and designers.

The AIA understands that sustainability is not a movement to save the planet solely for humankind. Sustainability is a movement to protect the earth's ecology and preserve the symbiotic relationship between nature and humankind. The AIA's sustainability guidelines strive to place nature first in their Design for Ecology Measure. This is missing from the most celebrated sustainable guidelines provided by the U.S Green Building Council and the Living Building Challenge. The design suggestions outlined for AIA improvements are crucial to mitigating bird deaths. AIA understands that as designers and architects share the responsibility to protect nature for the sake of all living things, not just humans.

BIRD PROTECTING LEGISLATION

City, state, and federal policies can ensure that architects, designers, and building administrators know the importance of implementing bird-safe designs. Unlike the voluntary guidelines discussed above, these can also assure enforcement of bird protecting design policies. Currently, there are seventeen city bird-safe policies and one state bird-safe policy in the United States. While each location poses its unique challenges based on local bird populations, ecology, landscape, and structures, many have similar guidelines. This section reviews the policies of five cities and one state: San Francisco, California; Oakland, California; Portland, Oregon; Minneapolis, Minnesota; New York City, New York; and the state of Minnesota. These places, all located in migration flyways, allow a caparison of policies for three locations in the United States that represent varying climates, landscapes, natural resources, and levels of urbanization. These locations were also chosen based on their guidelines. Cities in California and Minnesota have paved the way for other cities to adopt bird protecting guidelines. However, this also means many guidelines outline similar recommendations and are not included in this document. Additionally, this section reviews a Federal bill, the Bird-Safe Building Act of 2019, that is currently proposed to the House of Representatives. Finally, this section suggests guidelines for city policies and a federal act based on evaluating currently available bird building collision solutions.

West Coast Cities (San Francisco, Oakland, and Portland)

San Francisco introduced the first city policy or ordinance to establish bird-safe design standards for buildings in October 2009 and adopted the policy in July 2011. The purpose of this bill is to establish "Bird-Safe Standards" for new building construction and retrofit facades to reduce bird mortality due to bird building collisions.[369] The first standard listed in the policy indicates using bird-safe glazing on transparent or reflective windows. This treatment can include fritting, netting, stencils, frosted glass, screens, physical grids, or UV patterns. Any patterns should be 1/4 inches wide and spaced 4 inches apart vertically, or 1/8 of an inch in width spaced 2 inches apart horizontally.[370]

The second standard suggests where these treatments should be applied by indicating hazard areas. These hazard areas are based on the location of the building or the building features. All standards should be applied to new construction, additions that create a hazard, and any replacement of 50% or more of the glazing of an existing bird hazard. Hazards defined by location are indicated as those having open-spaced dominated by vegetation or open water or being within 300 feet of an Urban Bird Refuge.[371] Facades indicated as hazards should consist of no more than 10% untreated glazing when facing an Urban Bird Refuge. Treatment guidelines also include using treatments on the ground floor, and lobby entrances and treatment added to glass in the "Bird Collision Zone" defined by the first 60 feet of the façade and glass facades adjacent to green roofs two acres or larger. In addition, lighting should be minimal, no up-lighting is permitted, and searchlights are prohibited. Wind generators must be monitored for their impact on wildlife. Feature-related hazards including glass walls, wind barriers, skywalks, balconies, greenhouses on rooftops, and any glazed segments of the structure that are 24 square feet or larger must use bird-safe treatments.[372]

There are several exceptions to the policy. These include residential buildings less than 45 feet high with façades of less than 50% glass. If the building has more than 50% glass, it must use bird-safe treatments. Historical buildings are exempt unless the glass is replaced, then it must

---

[369] San Francisco Planning Department, *Standards for Bird-Safe Buildings* (2019).
[370] Ibid.
[371] The city of San Francisco defines Urban Bird Refuges as open spaces 2 acres and larger dominated by vegetation, vegetated landscaping, forest, meadows, grassland, wetlands, or open water.
[372] San Francisco Planning Department, *Standards for Bird-Safe Buildings* (2019).

be treated. Reversible treatment methods such as netting, films, grates, and screens are suggested.[373]

The San Francisco Policy includes an easy to follow design guide, though not all its elements are based on currently available studies. This includes glazing options such as the UV film ORNILUX, glass with photovoltaic cells or solar panels, colored glass, silk-screens that create an opaque image on the glass, etched glass, and films.[374] This guide also includes solutions not proven to reduce collisions, such as louvers and angled glass. Louvers have not been tested, and FLAP has advised avoiding angled glass as it endangers ground-feeding birds. Additional solutions like screening or netting have been deemed Bird-Smart by ABC.[375] However, the suggestion to add options that are not proven to be effective is concerning, and the policy should be updated to reflect currently available data.

Improvements to the San Francisco city policy would conform with newer research indicating which treatments effectively reduce collisions and eliminate UV films and angled glass completely until more research is conducted. Additionally, mandatory three-year monitoring after bird-safe treatments are used on buildings will provide evidence of the solutions work to reduce collisions.

While the City of Oakland has outlined similar façade treatments in their Bird Safety Measures, their light pollution plan and descriptions of potentially dangerous structures are more comprehensive.[376] The city of Oakland requires installing minimum intensity white strobe lights to replace solid red lights on large buildings, to reduce behavior disruptions for birds. Their measures suggest minimizing rooftop structures or antennas and that monopole structures or antennas cannot use guy wires. Nighttime lights are to be shut off during migration seasons, and lights should be on a sensor year-round from at least 11 pm to sunrise. Buildings must reduce perimeter lighting and minimize light pollution by using cut off, shielded, or directional light. No beams of light pointing into the sky are allowed in the spring or fall migration. Additionally,

---

[373] San Francisco Planning Department, *Standards for Bird-Safe Buildings* (2019).
[374] Ibid.
[375] American Bird Conservancy. "Glass Collisions," American Bird Conservancy, April 29, 2020, https://abcbirds.org/program/glass-collisions/)
[376] City of Oakland, *Bird safety Measures* (2013).

Oakland requires solution monitoring and distributing educational materials. [377] While Oakland focuses primarily on light solutions, Portland outlines numerous glass solutions.

In 2013, Portland, Oregon, prepared a resolution to direct city bureaus to incorporate bird-friendly design into city plans and projects. Projects using transparent or reflective glass must use UV glass, acid etching, frit patterns, or films on the first floor.[378] The upper floors up to 60 feet and the first floor adjacent to green roofs must use "more robust" bird-safe materials; however, neither set of solutions provide information on their effectiveness. Ground floor line, dot, or UV patterns must follow the 2 inches by 4 inches rule. Lines must be at least 1/8-inch-wide, dots ¼ inch in diameter, and UV markers 1/16 inch thick. UV markers can be placed randomly. Floors from the second floor up to 60 feet require one of six materials: fritted glass, etched glass, UV coated glass, window films that cover the entire glazed surface, permanent stencils or frosting, or exterior materials such as screens, grills, netting, louvers, fins, or mullions. The second floor through 60 feet follows the same guidelines as the first floor for lines, dots, and UV treatments. Exterior materials such as screens, grills, or netting must be at least 1/8-inch-thick and spaced no more than two inches apart. Louvers, fins, or mullions must be at least 1/8-inch-thick with a maximum spacing of one to one with a nine-inch limit.[379] The Portland resolution relied heavily on references from the American Bird Conservancy, San Francisco's Bird-Safe policy, and the Fatal Light Awareness Program. However, these guidelines do not specifically mention which solutions effectively reduce collisions, nor do they include detailed lighting regulations. UV is still an option provided by Portland, as it is for San Francisco, even though research does not show that it consistently prevents collisions, especially in a random pattern. The 2 inches by 4 inches rule is relied upon even though ABC follows the 2 inches by 2 inches, indicating that these policies need an update. Additionally, some solutions such as louvers, fins, and mullions have not been tested or monitored for their effectiveness. Finally, monitoring is not required but is a vital aspect of gathering data about the effectiveness of collision solutions and must be included in every bird-safe policy.

---

[377] City of Oakland, *Bird safety Measures* (2013).
[378] City of Portland Bureau of Planning and Sustainability, *Bird-Safe Window List* (2018).
[379] Ibid.

Minnesota

Minnesota has two building guidelines that impact bird populations in the state, and one specifically for Minneapolis. The first guideline, published by the University of Minnesota's College of Design, intends to protect and support animal habitat resilience at the site by reducing the negative impact of the built environment on species.[380] Additionally, the guidelines state the project should provide a supporting environment for "at-risk native species" deemed "essential to ecosystem health." These guidelines apply to all projects with new or renovated glazing. The first of two points addressed in the guidelines is the need to indicate which areas of the project have a high "Threat Factor," including the "Whole Building Threat Factor." These threat factors are based on the American Bird Conservancy's threat rating system. Once the threat is determined, any "High-Risk Surface" cannot use a material with a high threat factor, 75 or greater. High-Risk Surfaces are defined as large atriums or glazed corners larger than 20 feet across and any surface within 50 feet of the building, including landscape elements such as vegetation including green roofs or open water. Bird safety "traps" include surfaces with a threat factor greater than 25, including glass walkways and small atriums and glass corners 20 feet or less across.[381] The Minnesota guidelines work closely with ABC while implementing strict skyway regulations. What is potentially confusing about the outlines is that mitigation techniques are not directly discussed in the guidelines. A helpful addition would be information about available solutions and their ability to reduce collisions from the American Bird Conservancy or as outlined in LEED's Pilot Credit 55. The guidelines also require one-year monitoring of the building with at least two observations each week to record any bird building collisions.

The Minnesota state guidelines outline a Lights Out! management program to address when lights should be turned out to be most effective in reducing collisions. These procedures are required by law for state-owned and managed buildings. The Light Out! program advises turning off building lights during migration dates between March 15th and May 31st and between August 15th and October 31st each year. Lights should be out between midnight and dawn each day except for lights that are necessary for normal use.[382] Additionally, the Minnesota guidelines require the protection of rare, threatened, or endangered species. If the project site is within two

[380] University of Minnesota's College of Design, *Code of Ordinances Article XIII – Skyways* (2016).
[381] Ibid.
[382] "Guideline S.9," B3, May 7, 2020, https://www.b3mn.org/guidelines/3-0/s_9/).

miles of the listed species, the project must include a perimeter exclusion fence of at least 42 inches, an interpretive sign about the species, and provide a supported habitat for the listed species. Beyond the initial design, the project must also be managed to protect and enhance the viability of the rare, threatened, or endangered species until that species is no longer listed as such.[383]

The city of Minneapolis has specific guidelines for skyways that are more concise than those for the state and offers mitigation techniques in their guidelines. A skyway is an enclosed and elevated pedestrian bridge extending from a building face to another façade, which spans a street or alley or within private property. The zoning administrator must approve all skyways. Additionally, at least 85% of the skyway's glazing area of the exterior sidewall must meet bird-safe guidelines. Bird-safe glazing is defined by ABC’s Threat Factors as outlined in the state guidelines.[384] Additionally, the policies protect vulnerable species. However, none of the regulations have been applied to the U.S. Bank Stadium, a building that is a threat to some vulnerable bird species. This shows that not all policies can be enforced in every instance but should limit how many birds can be killed by one building even if its construction began before the policy went into effect.

New York City, New York

The New York City Council passed bird-friendly legislation, 1482-B, in January 2020; it will go into effect in January 2021.[385] This legislation defines bird-friendly material according to the American Bird Conservancy’s threat factors requiring the material to have a threat factor of 25 or less. According to ABC, bird hazards are clear glazing and transparent glass, including awnings, handrails, guards, windbreak panels, or acoustic barriers. Fly-through conditions that may be hazards are glass that creates the illusion of a void on the other side and parallel glass elements such as corners. The legislation requires the exterior wall envelope to use bird-friendly materials for the first 75 feet of the building. Identified bird hazards should be remedied with bird-friendly materials at any height above grade. Fly-through conditions at 75 feet or less must use bird-friendly materials as well as the first 12 feet adjacent to green roofs.[386] While this is a

---

383 “Guideline S.9,” B3, May 7, 2020, https://www.b3mn.org/guidelines/3-0/s_9/).
384 Ibid.
385 The New York City Council, *Bird Friendly Materials* (2019).
386 Ibid.

respectable start, there is no information about lighting or landscape design solutions outside of green roofs. This bill is similar to a pending federal bill as it has a basic structure of bird protecting guidelines but does not go far enough to make it clear which options are the most effective to reduce or prevent collisions. This bill could use the success of the Jacob Javits Convention Center's use of ceramic etched frit glass and opaque wall panels as clear examples of effective, appropriate collision deterrence methods.

Bird-Safe Building Act of 2019

The Bird-Safe Building Act of 2019 is a federal bill titled is backed by the Audubon Society and sponsored by Representative Mike Quigley from Illinois that aims to make public buildings bird-safe across the United States.[387] The bill was introduced in the House of Representatives on January 30th, 2019, with 46 additional supporters. The bill requires that more than 50% of the façade of public buildings be required to meet five standards. The first standard requires at least 90% of the façade in the first 40 feet cannot be composed of glass or must use modified glass. Modified glass, in this instance, refers to using elements that do not entirely obscure the vision of the occupants, such as a second facade, netting, screens, shutters, and shades. Modifications also should include UV patterns or "contrasting" patterns visible to birds, though no further explanation of contrasting is provided. Modifications can follow the 2 inches by 4 inches rule and the use of opaque, etched, stained, frosted, or translucent glass. Any combination of the modification can also be used. The second standard states at least 60 percent of the façade above 40 feet should be modified according to the first standard. Standard three prohibits all transparent passageways and corners. Standard four requires all glass to be modified as listed in standard one if it is adjacent to green spaces or water. Finally, the fifth standard addresses electric light and requires shielding lights unless used for security.[388]

Existing buildings are allowed exemptions or modified requirements under the bill. The latter includes automatic controls for existing lighting rather than installing shields or limiting light to security use only. Administrators of existing buildings may also "employ any available methods and strategies that are in accordance with best practices to reduce bird mortality."

---

[387] U.S. Congress. 2019. 116th Congress H.R. 919 (Introduced in the House), Bird-Safe Buildings Act of 2019, Bill Text. https://search.proquest.com/congressional/view/app-gis/billtext/116_hr_919_ih.

[388] Ibid.

Financially, existing buildings can be excused from bird-safe designs if the "required building materials and design features result in a significant additional cost for the project." Finally, buildings listed on the National Register of Historic Places and federal buildings, including The White House, Supreme Court, and United States Capitol Building and their grounds are entirely exempt.[389]

The federal policy includes one essential but often overlooked requirement of bird-safe policy, monitoring to determine if the mitigation solutions work. This act requires monitoring for bird mortality; however, it does not indicate the monitoring length or frequency.[390] This bill has additional limitations, such as not offering explicit guidelines to use the most effective methods to reduce collisions. It recommends UV and contrasting patterns with no further direction for designers. Additionally, prohibiting design features without additional options limits designers' ability to find creative solutions. Finally, the lighting and landscape solutions are not comprehensive and do not offer explicit guidelines to safeguard birds based on available studies which are outlined in this document.

PROPOSED CITY, STATE, AND FEDERAL BIRD PROTECTING POLICIES

Solving the problems birds face in the built environment does not depend solely on one discipline, a single organization, or a leading expert. This is an interdisciplinary task. However, general guidelines ensure that the methods used to mitigate bird building collisions effectively reduce collisions. They should also allow for innovative designs. The federal policy should ensure that the states and cities work towards a common goal and communicate with the same terms and definitions. The state and city policies address the fundamental areas of bird protecting design required to mitigate bird deaths due to bird building collisions while allowing room for customization. This document outlines the recommended federal and city or state policy guidelines based on the evaluation of current available acts, programs, and policies. The guidelines below are provided as a starting point to update existing policies and as a foundation for future policies.

[389] U.S. Congress. 2019. 116th Congress H.R. 919.
[390] Ibid.

Federal Bird Protecting Guidelines

1. Cities and municipalities in the United States must have a bird protecting design plan or policy for public buildings and structures.
2. The organization of at least one avian protection task force for each state should include the following: an ornithologist, biologist, or environmental scientist; an architect, ideally with experience in bird protecting designs or lighting and materials; a landscape designer or ecologist; and a researcher in any of the fields mentioned. Establishing a monitoring group is required to ensure bird protecting designs reduce or prevent collisions. This group should involve citizen scientists.
3. Monitoring for collisions is mandatory for a minimum of three-years at the building or structure after its completion or application of bird protecting designs.[391]
4. State and city policies must use uniform terms and definitions.
5. States and cities can customize their policy to match the demands of resident avian species and populations, built environment, landscape, climate, sustainability goals, and conservation issues.
6. Each state or city must have a Lights Out! plan at least during migration seasons, ideally, reducing light pollution year-round.
7. Each state would be required to produce a plan to protect birds from transportation and energy infrastructure relevant to their state, including roadways and bridges, powerlines, commination towers, solar panels, wind farms, and structures related to the fossil fuel industry. The plan should promote awareness of threats caused by airplanes, fencing, open pipes, and other known dangers in the built environment.
8. Updates: The federal bill must be updated every five years after reviewing any new data regarding bird protecting designs.

[391] This is based on LEED's Pilot Cred 55 three-year monitoring rule and Loss et al.'s 2019 two-year study of the U.S. Bank Stadium.

City or State Bird Protecting Guidelines

1. Glass: All glass from grade to 75 feet should be treated with bird protecting designs that have been documented to reduce collisions by at least 85%, following the LEED Pilot Credit 55 requirement, but strive for designs that are 95% effective.[392] This includes designs that communicate that glass is solid, like ceramic etched frit dots, perforated films, and screens, rather than obstacles such as lines that follow the 2 inches by 4 inches rule. If using patterns that communicate the glass is an obstacle, it must not allow any space larger than 2 inches (5 cm). No ultraviolet (UV) glass or films, single decals, or angled windows currently qualify as bird-safe designs. If the bird-safe design is not proven to reduce bird building collisions by at least 85% in a case study, then the project must be monitored for collisions over three years, and the data shared publicly. If the design solutions are unsuccessful, the project should retrofit the building or structure.
2. Lighting: All floors above 75 feet must turn out lights at night during migration season. Required security lights or lights needed during the use of the building require drawing internal shades during migration season. Timers and sensors may be used for external security. If this is not possible, no exterior lights should point upwards or illuminate large areas of the building or structure. Lighting guidelines from the Lights Out! Program are recommended.
3. Landscape: Green spaces within 100 m of the building or structure will require any glass used in the design to use collision deterrence patterns. Green walls, green roofs, and green retaining walls adjacent to glass on the building or structure will require the glass to use bird protecting designs.
4. Exceptions: Historical Buildings can be exempt from bird protecting glass solutions if the glass is vital to the building's historic nature. However, suitable bird protecting options, like removable vinyl films or patterns, should be considered.
5. Conservation and Education: Project designers must be aware of sensitive habitats, threatened or endangered species, and migratory birds that may encounter their site.

---

[392] Due to the reduced effectiveness of tested solutions on real-life buildings, a higher collision deterrence percentage derived from experiments is crucial. Example: Ceramic etched frit dots on the Jacob Javits Center in New York City was 100% effective in experiments and 90% effective in reducing collisions in real life.

Conservation efforts must preserve and protect these species. Educational documents or information should be made available to the public, including monitoring data and local species impacted negatively or positively by the building or structure.

6. Transportation and Energy Infrastructure: Each city or state must produce a plan to protect birds from transportation and energy infrastructure relevant to their area, including roadways and bridges, powerlines, commination towers, solar panels, wind farms, and structures related to the fossil fuel industry. The plan should promote awareness of threats caused by airplanes, fencing, open pipes, and other known dangers in the built environment.
7. Monitoring and Updates: All buildings should be monitored for three years per the proposed federal policy. City or state policies must be updated every five years after reviewing any new data regarding bird protecting designs.

The current policies and guidelines to protect birds through bird-safe design in the United States show that cities, designers, architects, and policymakers are receptive to bird-safe design strategies. However, a review of these policies reveals little cohesion among them, aside from their adherence to two organizations' guidelines: The Lights Out! Program supported by the Audubon Society and the Bird Collision Deterrence guidelines provided by the American Bird Conservancy. Both organizations are crucial in the education and support of avian conservation efforts. The Lights Out! Program has based its tactics on Evans Ogdon and other researchers who examine the harmful effects of artificial light on various species. The American Bird Conservancy's Bird Collision Deterrence can be complicated to follow and is based on flight tunnel tests that do not account for external factors such as lighting or green spaces (other than reflections of vegetation) when determining the threat factor of façade materials. While these guidelines are helpful, since the research in this area is limited, monitoring the suggested mitigation strategies should be more thoroughly investigated and supported by case studies of buildings and structures.

One aspect missing from all federal, state, and city policies is the connection to nature. The sustainable guidelines, especially from AIA, offer mitigation strategies and an understanding that birds are vital to the ecology of the built environment and even the occupants' well-being. If birds in the built environment can improve overall well-being by increasing biodiversity and providing a connection to nature, watching a bird collide with a window or finding dead birds would have a profoundly negative effect on occupant well-being. The AIA has the only set of guidelines to point out this honest consequence of dangerous design strategies. All guidelines for sustainable design and bird-safe solutions should strive to find a balance between conserving nature, protecting bird species, and fostering human well-being.

CHAPTER 5 EDUCATION AND ADVOCACY

Conservationists alone cannot mitigate the dangers birds face in the built environment. As Mark Cocker states in his book *Birds & People*, “It is only when whole societies collectively believe in the goal that it is attainable.” Because wild birds are the main form of wildlife interaction for people living in urban areas, protecting birds in the built environment is crucial for maintaining public advocacy for birds more generally.[393] This chapter focuses on three areas of education and outreach that engage citizens, including architects and designers, to build a connection to nature through birds and take actions leading to their protection. These areas begin with using examples of bird-safe design to educate professionals in the field of built environments. Second, advocating for birds and bird conservation through avian conservation organizations, citizen science, and avian ambassadors demonstrates the importance of educating the public about bird conservation issues. Finally, this chapter will discuss how aviaries and rehabilitation centers are focused on fostering a connection between humans and birds.

In this chapter, the designers of projects have committed to using “bird-safe” or “bird-friendly” designs on one or more buildings or for their campuses. For this chapter, the term “bird-safe” or “bird-friendly” refers to the action taken to reduce bird building collisions using materials marketed as such. The owners of the buildings described here have reported that collisions have reduced dramatically, but, in all cases, data outlining the numbers of birds lost before and after a building has become “bird-safe” or “bird-friendly” are not available. Therefore, quantifying the terms “bird-safe” and “bird-friendly” based on how many birds were protected or how many collisions were prevented is not possible. The purpose of evaluating these projects is not to demonstrate their quantifiable effectiveness in reducing bird building collisions but to promote them as educational tools to bring awareness to threats birds face in the built environment.

Today, many gaps remain in knowledge about the relationship between birds and the built environment. These gaps exist in academia and extend to public avian programs. They can profoundly influence the design and management of the urban landscape and the roles the built

---

[393] Daniel T. C. Cox and Kevin J. Gaston, “Urban Bird Feeding: Connecting People with Nature,” *Plos One* 11, no. 7 (2016): 2.

environment can play in promoting conservation, ecosystem services, and environmental justice.[394] Education and understanding the benefits of birds in the built environment can create a movement towards incorporating bird-safe designs in architecture as enthusiastically as toward biophilic design and sustainable elements of the built environment

Educators in built environment fields have access to examples of projects that encourage innovative solutions and incorporate examples of "bird-safe" designs as part of sustainable design projects. This can be seen, for example, in Studio Gang's "bird-safe" projects. Studio Gang is an architecture and urban design practice located in Chicago, with additional offices in New York, San Francisco, and Paris. Their website lists eight "bird-safe" projects that are designed with bird-safe glass and innovative project designs. The following are two projects that represent each approach.

Figure 34. North Residential Commons, University of Chicago Campus, IL

[394] Christopher A. Lepczyk and Paige S. Warren, *Urban Bird Ecology and Conservation* (Berkeley; Los Angeles; London: Cooper Ornithological Society, 2012), 492.

The North Residential Commons was built on the University of Chicago campus in 2016 and achieved LEED Gold certification. Studio Gang designed the building to optimize north-south light. Where windows do not require panels or metal grills for solar shading, argon-filled low E insulated glass features a ceramic etched frit pattern that allows for excellent views and daylight to enter the space while protecting birds from collisions.[395] (See Figure 34.)

Studio Gang designed the Ford Calumet Environmental Center in 2008. The unbuilt design won the Holcim Award from the Holcim Foundation for Sustainable Construction in 2011 and the “Proggy” Award from the People for Ethical Treatment of Animals in 2009. (See Figure 35.) Studio Gang designed the building to demonstrate the importance of coexistence between industry and ecology. They based the design on a bird’s nest-making process by using discarded and local items such as salvaged steel and recyclable materials to display re-use. Because the project site is located on a resting stop for migratory birds, it was formulated not only for re-use and a visual connection to nature but as a completely bird-safe building. The building description on the firm’s website explains the threat transparent glass poses to birds and the strategies they used to mitigate this threat. These strategies include reclaimed barrel wood slats placed in front of north-facing windows and a south porch that uses a mesh enclosure to protect birds from collisions.[396]

[395] Studio Gang. “University of Chicago Campus North Residential Commons,” Studio Gang, accessed April 7, 2020, https://studiogang.com/project/university-of-chicago-campus-north-residential-commons).
[396] Studio Gang. “Ford Calumet Environmental Center,” Studio Gang, accessed April 7, 2020, https://studiogang.com/project/ford-calumet-environmental-center.

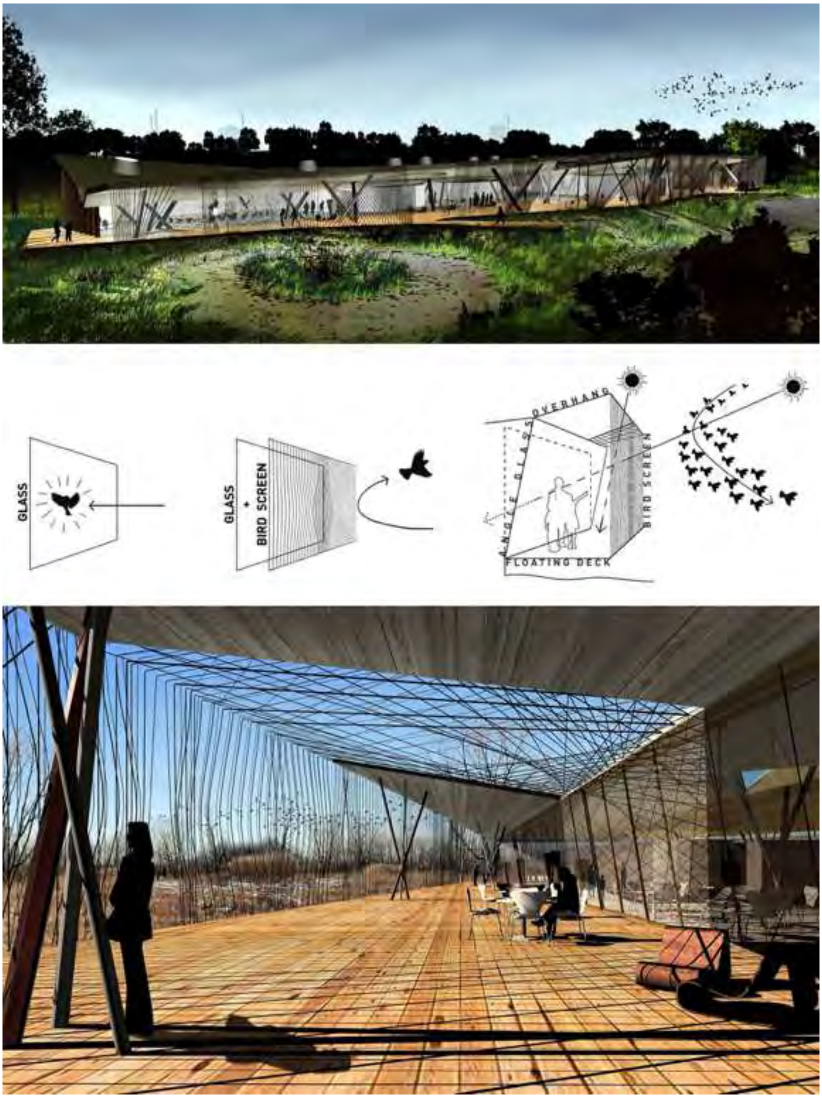


Figure 35. Ford Calumet Environmental Center Proposed Design, Chicago, IL

These projects show well-known collision deterrence methods using materials paired with the innovative design inspired by birds and bird conservation. Educating architects and designers about deterrence strategies using materials and innovative design can lead to awareness of bird building collisions and future innovative mitigation techniques that bring us closer to a bird-safe built environment.

Design educators can also promote holistic sustainability while protecting birds from building collisions. It might be challenging to offer full university-level courses on bird-safe design, given the limited research on the topic. However, another approach to bird-safe building design might refer to the Living Building Challenge's strategy to incorporate biophilic design into building projects. The Living Building Challenge suggests a full day or eight hours exploring biophilic design before the project design begins. Sustainability classes can devote a full lesson to learn about bird building collisions and the solutions, coming together for a charette to understand the goals or intent of bird-safe building, as well as design opportunities. The goal is to demonstrate to students that bird-safe design is ideally addressed at the beginning of the design and show students how to incorporate bird protecting designs in future projects. The skills learned in this experience would allow future architects and designers to be aware of how using large amounts of glass can impact the local ecology due to bird building collisions. This experience could also encourage creative ways to balance human well-being and protecting birds while meeting sustainability goals.

Biophilic and restorative design courses can incorporate bird protecting designs and habitats. While the benefits of biodiversity in the built environment is a newer area of study, there are benefits from feeding and observing birds. A 2016 study by Cox and Gaston found that people feed birds for psychological benefits, including pleasure, attention restoration, and stress reduction.[397] The study also indicated that feeding birds fostered a connection with nature through their concern for bird welfare and a personal orientation towards nature through a sense of belonging. How a person relates to nature is shown to be a strong indicator of their environmental attitudes.[398] Additionally, Belaire et al.'s 2015 study found that residents of a Chicago-area suburb valued many aspects of birds, specifically those relating to the bird's

[397] Attention restoration theory proposed that the natural work promotes recovery from mental fatigue and offers reflection.; Stress reduction theory indicates that natural environments reduces phycological arousal following stress including promoting relaxation and improving mental health.

[398] Cox and Gaston, "Urban Bird Feeding: Connecting People with Nature,": 1-2.

aesthetics and a bird's place in the ecosystem. These studies indicate that urban and suburban residents value birds for cultural and ecosystem services, which leads them to form stronger connections to the natural world. This connection then can foster participation in conservation efforts while increasing the overall well-being of humans. Further, places of education can foster stewardship by using bird-safe designs on campus buildings.

The University of British Columbia (UBC) in Vancouver, Canada, located on the Pacific Flyway, has incorporated bird-safe building designs into its campus sustainability initiatives. Protecting birds from building collisions is an important aspect of campus-wide sustainable design initiatives described in the campus' Green Building Action Plan. The Green Building Action Plan focuses on eight holistic components: biodiversity, energy, water, materials and resources, health and wellbeing, quality, climate adaptation, and place and experience. By 2035, UBC plans to make net positive contributions to humans and natural systems through this plan. Each year, a reported 10,000 birds collided with buildings on the UBC campus with a daily average of 45 outside the migration season and 72 collisions during the migration season per campus building. Mitigating these collisions is a core part of the biodiversity component of the Green Buildings Action Plan. Penny Martyn, a registered architect and the UBC Campus Green Building Manager has introduced guidelines to reduce collisions in a policy document titled UBC Bird Friendly Design Guidelines for Buildings. The guidelines include the studies of campus collisions conducted by students, staff, and Martyn, since 2014. This plan made bird-friendly designs mandatory for all university buildings by the end of 2020 and expanded to include new residential buildings on campus by 2025.[399]

Working with UBC, Martyn incorporated an interdisciplinary approach to bird-safe design and education by collaborating with students, faculty, Environment and Climate Change Canada, and the SEEDS Sustainability Program. In the university's Living Lab, a collaboration between the departments of Applied Science and Geography, researchers developed sensors and software to map and predict bird collisions with campus buildings. This enabled the university to enhance biodiversity in its built environment.[400] Martyn also organized a monitoring system designed by UBC engineering students who eagerly took on the task, with one student stating, "Who doesn't love birds?" They worked to find the appropriate equations to measure the motion of objects so

---

[399] University of British Columbia, *UBC Bird Friendly Design Guidelines* (2019): 3-4.
[400] University of British Columbia, *Annual Sustainability Report* (2018-19): 3-4.

that the device could accurately detect collisions. The device uses an accelerometer to measure vibrations of window glass and transmits the data via Wi-Fi. The system is inexpensive to set up and maintain, but information about its accuracy is not currently available.[401]

The guidelines outline how new and existing buildings can meet their bird-safe goals. Guidelines for buildings aim to minimize the quantity of glass in designs, increase the visibility of glass, block reflections of surrounding vegetation and sky, and incorporate design elements and landscapes that minimize bird building collisions.[402] Retrofit solutions include increasing the visibility of glass and blocking reflections. The guidelines also communicate ineffective strategies, such as a single bird of prey decals, angled glass, tinted glass, and interior screens or blinds. The guidelines suggest using adhesive film, acid etching, or patterns that follow a 5 cm by 5 cm spacing with markers no more than 0.32 cm in size to increase glass visibility. The visible markers are to be applied to the first four floors of the building (or to the top of mature tree height) and at least 3.6 m above a green roof. The guidelines encourage using artistic and creative patterns that follow visual guidelines but communicate a unique building identity or connect people to the landscape. The last option provided is the use of ultraviolet glass if visual markers are not preferred. Examples of these guidelines are found across the UBC campus in the form of artistic glass designs and façade design strategies.[403]

The UBC Bookstore, shown in Figure 36, is described as having densely spaced ceramic etched frit designs that create visual markers on the glass using quotes from the favorite books of faculty, students, staff, and visitors. This creative solution provides a sense of community and public engagement with the site. A retrofitting solution using an artistic design was applied to the glass of the Center for Interactive Research on Sustainability. This was the result of a contest held to mitigate the bird building collisions. The winning design, by English Ph.D. student Lora Zosia Moon, uses closely spaced lines in her artwork.[404] (See Figure 26.) This design was the first bird-safe design on the UBC campus, and the intention was to raise awareness about the issue of bird collisions. This project incorporated a 5 cm by 10 cm spacing based on an earlier version of the campus Bird Friendly Design Guidelines for Buildings. The guidelines were later

[401] Denise Ryan, "Bird-Friendly Windows Reduce Collision Deaths at UBC," Vancouver Sun (Vancouver Sun, April 29, 2019), https://vancouversun.com/news/local-news/bird-friendly-windows-reduce-collision-deaths-at-ubc.
[402] University of British Columbia, *UBC Bird Friendly Design Guidelines* (2019): 3-4.
[403] Ibid.
[404] Denise Ryan, "Bird-Friendly Windows Reduce Collision Deaths at UBC."

updated to limited space between designs to 5 cm to protect smaller species like hummingbirds.[405]

Figure 36. UBC's Library Window Pattern, Vancouver, BC

[405] University of British Columbia, *Annual Sustainability Report* (2018-19): 12, 21-22.

Bird-safe façade design strategies at UBC include green or living walls with mesh screens, shading devices, and external barriers. These measures also have cost-effective co-benefits while they safeguard birds.[406] While no data is available from UBC, mesh netting was applied 10 inches from the Federal Bureau of Investigation in Chicago, reducing collisions by 80%.[407] The Center for Interactive Research on Sustainability features a living wall built of mesh screens and live vines to create a barrier in front of the windows. This technique can provide food, shelter, and nesting habitat for birds. The green wall's co-benefits are seasonal solar shading, reducing solar heat gain, and a view of nature from the interior to increase overall human health.[408] Three additional examples shown in Figure 37. The Campus Energy Centre features metal screens surrounding the upper floors and zinc panels that hide vents and louvers required for ventilation. The panels still allow daylight to enter and function as weather protection for the building.[409] The Beaty Biodiversity Research Centre uses exterior screens on all sides of the building to create a barrier, reducing heat gain and providing shade.[410] The Earth Sciences Building uses shading devices, including screens, mesh, and grilles, to block the reflection of vegetation while reducing solar heat gain and preventing glare for occupants.[411]

[406] University of British Columbia, *Annual Sustainability Report* (2018-19): 33.
[407] Lesley Evans Ogden, "Does Green Building Come up Short in Considering Biodiversity?: Focus on a Growing Concern.," *BioScience* 64, no. 2 (2014): 83-4.
[408] Ibid., 8.
[409] Ibid., 15.
[410] Ibid., 16.
[411] Ibid., 13-14.

Figure 37. UBC’s Bird-Safe Exteriors, Vancouver, BC
Left: Mesh green wall on the Centre for Interactive Research on Sustainability. Right: Screens on the Beaty Biodiversity Research Centre (top), fins and grills on the Earth Sciences Building (middle), and zinc panels on the Campus Energy Centre.

The guidelines include additional recommendations to reduce collisions. These guidelines demonstrate the university's comprehensive approach to bird-safe designs required for maintaining a bird-friendly campus. The recommendations point out that transparent glass flight paths such as glass corners, parallel glass, skywalks, glass guardrails, and glass parapets can be dangerous for birds, and the guidelines suggest applying collision prevention techniques as outlined in the plan. Thoughtful landscape design should aim to reduce vegetation located between 2 to 20 m from untreated glass surfaces.[412] The guidelines recommend reducing "bird traps" by securing enclosed spaces like mechanical ducts, pipes, and intake and exhaust vents.[413] Light pollution reduction follows the FLAP guidelines and uses green or blue light instead of white or red lights to mark tall structures.[414] Occupant strategies, such as applying exterior window screens and nets to block reflections, are also offered.[415] For example, Martyn's education strategy at the UBC campus shows that bird-safe design does not require designers to sacrifice aesthetics, sustainability goals, or significantly increase costs.

Two colleges in the United States have also adopted bird-safe designs on their buildings, though not campus-wide. Like at UBC, these examples reduce bird building collisions while raising awareness about bird building collisions on campus. The Atlantic Cape Community College in Cape May, New Jersey, reported several bird building collisions at their administration building due to a large amount of glass and its location in a migration flyway. Staff and students working in the building reported the upsetting experience of witnessing the collisions. They tried using silhouettes of birds of prey, but they were not successful. They contacted the American Bird Conservancy to discuss the data behind available mitigation techniques and decided to use an opaque film from CollidEscape called the Guaranteed Solution to apply on the outside of the glass. The film has small perforations that allow light to pass through the window and maintain views of the outside while appearing opaque to birds. The project's added benefit was that it reduced direct light and heat gain in the building and reduced

---

[412] University of British Columbia, *Annual Sustainability Report* (2018-19): 19.
[413] Ibid., 29.
[414] Ibid., 30
[415] Ibid., 25.

cooling costs. One year after applying the film, the staff reported they had not noticed any collisions.[416]

Figure 38. Perforated Vinyl on the Stockton University's K-Wing Building, Galloway, NJ

At Stockton University in Galloway, New Jersey, the mural used to mitigate bird collisions was explicitly designed to educate visitors about bird building collisions. The K-Wing building of the School of Arts and Humanity's breezeway was considered a high collision risk because of its expansive double-sided windows facing the Pinelands National Reserve. John Rokita, the assistant supervisor of Academic Lab Services, recorded 851 bird collisions with these windows between 1979 and 2018.[417] The Office of the President granted funds to the campus facilities department to produce a mural to cover the windows. This was created by campus graphic designers using perforated film, much like CollidEscape. It allows light in and maintains a view of the outside; it also creates an opaque non-reflective surface on the glass exterior. As seen in Figure 38, this mural is designed to be a statement piece that brings awareness to the "waste of life" that can be prevented and pay homage to local bird species. One of the goals of the mural is to inspire users of buildings campus-wide to implement mitigation techniques; another is to encourage integrating bird building collision education into the ornithology course offered on

[416] *College Takes Action to Stop Bird Collisions* (American Bird Conservancy, 2017), https://www.youtube.com/watch?time_continue=6&v=dW1-mYOxMFI&feature=emb_logo.

[417] However, thousands of birds that survived impacts were rehabilitated. The campus also has a taxidermy collection of hundreds of birds that were victims of these collisions now housed in The School of Natural Sciences and Mathematics curated by John Rokita.

campus. Visitors to the building are informed about how this mural prevents bird building collisions and includes the large visible message "Art should be striking. Not birds."[418]

These three campuses educate the students, staff, faculty, and visitors through example. Two ways to strengthen these approaches is by providing more detailed literature and making data collected from monitoring available to researchers and the public. Applying a mitigation technique does not have to be the sole means of educating visitors to the building. Offering literature or signage explains how many birds were killed each year before the retrofit, the collision prevention method, how it works, and whether the collisions are reduced or eliminated can communicate the importance of bird-safe buildings beyond these campuses. This information would require systematic monitoring methods. Applying mitigation techniques can solve the immediate problem of bird building collisions. However, to solve the widespread issue of bird building collisions, more data from monitoring needs to be collected and made available.

ADVOCATING FOR BIRDS AND BIRD CONSERVATION

Conservation of bird species in the United States depends on the citizens of cities and towns, as over 80% of land in the contiguous United States is privately owned. The success of future conservation efforts depends on restoration projects on private property and educating the private landowners about conservation concerns in the built environment.[419] Avian conservation organizations in the United States can help educate the public about the ecosystem services and cultural services provided by birds. They also effectively communicate the dangers birds face in the built environment. Three of the most well-known organizations that focus on the relationship between humans and birds through education are the National Audubon Society, the American Bird Conservancy, and The Peregrine Fund.

The National Audubon Society (NAS) is a nonprofit organization that aims to protect birds and their habitats in the Americas through science, advocacy, education, and conservation. The organization has over 500 state programs, local chapters, and partners that reach millions of people each year to educate them about North American birds. The National Audubon Society

[418] Daniel Gambert, "Picture Stockton Using Art to Save Birds," Stockton University (Stockton University, November 21, 2019), https://stockton.edu/news/2019/picture-stockton-using-art-to-prevent-birds-from-striking-windows.html.

[419] Desirée L. Narango, Douglas W. Tallamy, and Peter P. Marra, "Nonnative Plants Reduce Population Growth of an Insectivorous Bird," *Proceedings of the National Academy of Sciences* 115, no. 45 (2018): 11549.

informs policy, designates bird habitats from coast to coast, guides citizen science projects such as the Christmas Bird Count, and promotes education programming at Audubon centers to offer citizens the resources they need to explore conservation issues and defend the natural world. The NAS focuses on nine principal areas to protect birds; bird building collisions is one of these. The Audubon Society is actively promoting the federal Bird-Safe Building Act to prevent bird building collisions across America. National and local Audubon Societies also offer information about bird building collisions deterrence techniques.[420]

The American Bird Conservancy (ABC), founded in 1994 by George Fenwick, is dedicated to conserving resident birds and their habitats in the Americas. ABC has four conservation goals: halting extinctions, protecting habitats, eliminating threats, and building capacity to support bird conservation. Bird building collisions is one of the eight threats that ABC addresses with their conservation goals. Their educational materials, which are available on the organization's website, are divided into residential and professional mitigation techniques.[421] Another threat ABC is researching is wind turbines. ABC has developed a Wind Risk Assessment Map that shows that vulnerable areas where placing wind energy equipment are dangerous for birds. Because there are currently few proven mitigation techniques to wind turbine collisions, preventative measures like this are crucial to incorporate into site plans before wind farms are built.[422]

The Peregrine Fund's primary mission is to conserve birds of prey worldwide. Their team of scientists and researchers work to publish peer-reviewed studies on the topic of raptor conservation. Their research has studied the impact of the built environment on birds, including urban noise and mitigation techniques for powerlines. The Peregrine Fund's strategy is to conserve and engage the public. Conservation is achieved by protecting raptors from extinction, in part by preserving their habitats. The Peregrine Fund is credited with the recovery of the peregrine falcon (*Falco peregrinus*) and is currently researching the decline of the American kestrel (*Falco sparverius)*. The Fund works to encourage people to value raptors and to inspire

---

[420] National Audubon Society. "About Us," Audubon, accessed April 7, 2020, https://www.audubon.org/about).
[421] American Bird Conservancy. "Glass Collisions," American Bird Conservancy, April 29, 2020, https://abcbirds.org/program/glass-collisions/.
[422] American Bird Conservancy. "Wind Risk Assessment Map," American Bird Conservancy, May 3, 2020, https://abcbirds.org/program/wind-energy-and-birds/wind-risk-assessment-map/.

action to change increase raptor conservation.[423] The Peregrine Fund has become the leader in bird of prey conservation due to its dedication to raptor species, education, and research.

These three organizations allow citizens to engage with birds and conservation issues through their educational programming and citizen science projects. Citizen scientists are members of the public who engage in scientific work by collaborating with or working as volunteers for professional scientists or institutions to address real-world problems. Citizens participate in the scientific process by formulating research questions, conducting experiments, collecting and analyzing data, making discoveries, developing new technologies, and solving complex problems in support of project or research leaders. The federal government has listed over 400 citizen science projects on its Citizen Science website. The intent is to accelerate the use of crowdsourcing and citizen science across the United States. The site does so by providing a catalog of projects, a toolkit for maintaining projects, and a gateway to the community of hundreds of practitioners and coordinators.[424] In the context of birds and the built environment, two of the important tasks for citizen scientists to engage in are monitoring bird building collisions and surveying regional and migrating birds.

Two ways of contributing to surveys are through the identification apps iNaturalist and eBird. The app iNaturalist is a joint initiative by the California Academy of Sciences and National Geographic. The app helps users identify plants and animals, connect to a community of over a million scientists, and foster a connection to nature. The data gathered by the app helps researchers and the public better understand and protect nature. Projects can pool information from citizens towards a common interest. A recent project was the City Nature Challenge 2020 held from April 24th to the 27th. The project's goal was to record observations of all wild living organisms in and around the city, including birds. This data was then verified, compiled, and made freely available to the public.[425] iNaturalist collected bird building collisions data in 2016 and 2018 at Duke University's West campus in Durham, North Carolina and at the University of

[423] The Peregrine Fund. "Mission and Vision: The Peregrine Fund," Mission and Vision | The Peregrine Fund, accessed April 7, 2020, https://peregrinefund.org/mission-and-vision.
[424] U.S. General Services Administration. "About CitizenScience.gov," CitizenScience.gov, accessed April 7, 2020, https://www.citizenscience.gov/about/#).
[425] "City Nature Challenge 2020's Journal," iNaturalist, accessed April 7, 2020, https://www.inaturalist.org/projects/city-nature-challenge-2020/journal).

Utah in 2019.[426] Winton et al. suggested that the app could be used to collect valuable and much-needed data regarding collisions, including geo-referencing data.[427]

The eBird app developed by the Cornell Laboratory of Ornithology works similarly to iNaturalist but is for tracking bird sightings. The app has recorded over 100 million bird sightings each year worldwide, making this project the world's largest biodiversity-related citizen science venture. The data collected has documented bird distribution, abundance, habitat use, and trends through a checklist framework indicating the user's location and time. The data is stored and verified by regional experts before being made freely available to the public in a daily updated archive.[428] The conservation impacts of eBird include using the data gathered to inform monitoring for conservation planning, supporting habitat management and protection, providing population assessment and management, and informing law and policy.[429]

Citizen scientists are contributing to the study of bird building collisions by providing their monitoring services. Monitoring buildings for collisions before and after the use of mitigation techniques provides crucial data that researchers and designers can use to make informed decisions about which mitigation techniques are best for their project. Monitoring opportunities are available through local Audubon Societies, Lights Out Programs, and aviaries such as Tracy Aviary in Salt Lake City, Utah, which organize local collision monitoring of buildings. Currently, there is no app similar to iNaturalist and eBird that collect data on the location, species, and date of bird building collisions. However, FLAP does have a website based Global Bird Collison Mapper, but it lacks the convenience and reach of the apps mentioned.

AVIARIES AND REHABILITATION CENTERS

Avian educators are crucial to the movement towards bird-safe building designs because they nurture personal connections between humans and birds. Avian educators are conserving the distinctive relationships between humans and birds experienced across all cultures throughout millennia. Reaching the public is crucial to communicating the need for a bird-safe

---

426 R. S. Winton, Natal Ocampo-Penuela and Nicolette Cagle, "Geo-Referencing Bird-Window Collisions for Targeted Mitigation.(Report)," *PeerJ* 6, no. 1 (2018).; Barbara B. Brown et al., "Winter Bird-Window Collisions: Mitigation Success, Risk Factors, and Implementation Challenges," *PeerJ* 7 (2019).

427 R. S. Winton, Natal Ocampo-Penuela and Nicolette Cagle, "Geo-Referencing Bird-Window Collisions for Targeted Mitigation. (Report),": 8.

428 eBird. "About EBird," eBird, accessed April 7, 2020, https://ebird.org/about).

429 eBird. "Conservation Impacts," eBird, accessed April 7, 2020, https://ebird.org/science/conservationimpacts).

built environment and creating this movement. Citizens are often the ones who push the hardest for change and are stewards for bird conservation. Educating the public about how commercial and public buildings are reducing bird building collisions can be applied to residential buildings. This section explains how two aviaries, the National Aviary and Tracy Aviary use architecture as an educational tool and a potential source of valuable data about mitigation solutions. The data gaps regarding bird building collisions can also be filled by rehabilitation centers that receive birds that have collided with buildings. Additionally, centers like the California Raptor Center, which are home to birds who have been injured by the built environment, can spread awareness of the dangers that birds face.

The National Aviary, located in Pittsburgh, Pennsylvania, is home to over 500 birds representing 150 species worldwide. This indoor non-profit zoo offers a sizeable walk-through habitat to allow for intimate interactions between visitors and free-flying birds. The zoo is also an environmental organization comprised of educators, researchers, and conservationists that works to "inspire respect for nature through an appreciation of birds."[430] In 2018, the aviary sought to upgrade and remodel the greenhouse area that houses both birds and plants in their Tropical Rainforest exhibit. The Executive Director, Cheryl Tracy, indicated that the aviary intended to use bird-friendly glass in the redesign that could benefit both the birds inside of the aviary and outside while retaining the character of the original structure built in 1952.[431] The renovation included over 19,000 square feet of laminated Starphire Ultra-Clear glass by Virto Architecture Glass, which was acid-etched by Walker Glass with AviProtek Velour.[432] This finish communicates a solid surface to birds while allowing high visible light transmittance.[433] This technique also maximized the ultraviolet and natural light transmittance to sustain the plant and wildlife within the space that is home to more than 80 birds.[434] This design is a permanent

---

[430] The National Aviary. "The National Aviary," The National Aviary - About Us, accessed April 7, 2020, https://www.aviary.org/about-us).

[431] Ibid.

[432] Glass on Web. "National Aviary Tropical Rainforest Featuring Acid-Etched STARPHIRE Glass Wins National Award for Exhibit Design," glassonweb.com (glassonweb.com, October 2, 2019), https://www.glassonweb.com/news/national-aviary-tropical-rainforest-featuring-acid-etched-starphire-glass-wins-national-award).

[433] Walker Glass. "Velour Acid-Etched Glass," Verrerie Walker, accessed April 7, 2020, https://www.walkerglass.com/products-options/velour/).

[434] Glass on Web. "National Aviary Tropical Rainforest Featuring Acid-Etched STARPHIRE Glass Wins National Award for Exhibit Design," glassonweb.com (glassonweb.com, October 2, 2019), https://www.glassonweb.com/news/national-aviary-tropical-rainforest-featuring-acid-etched-starphire-glass-wins-national-award).

educational tool that shows the public and designers that collision prevention treatments on glass can still allow natural light to enter the space while communicating that the glass is solid to birds. It is also an example of retrofitting a primarily glass structure while retaining its original design and intended use. As shown in Figure 39, this design won The Association of Zoos and Aquariums 2019 Exhibit Design Award.

Figure 39. National Aviary, Pittsburgh, PA

Located in Salt Lake City, Utah, Tracy Aviary is one of the nation's oldest and largest free-standing aviaries. Tracy Aviary uses education and conservation to inspire curiosity and caring for birds and nature. The aviary's education programs include onsite interactive exhibits, camps, and classes, as well as visits to local neighborhoods and schools. Their education programming reaches over 60,000 children every year. The aviary is also dedicated to the conservation of avian species and their ecosystems. This aviary depends on citizen science volunteers to provide the information that leads to decisions impacting species survival and preserving the area's natural beauty.[435] Tracy Aviary sponsors Nature in the City Programs, focusing on building a connection to nature through urban wildlife and landscapes in Salt Lake City with educational programming open to all ages. The aviary also provides professional workshops to build skills for environmental educators and the public to appreciate nature and birds.[436]

The Visitor's Center at Tracy Aviary includes three types of collision mitigation techniques on its LEED Gold certified building. Figure 40 shows two of these techniques: a metal design outside of the glass to break up the reflection and where glass is visible, and square decals spaced two inches apart horizontally and four inches apart vertically applied to the remaining areas of visible glass. This fulfills LEED Pilot Credit 55's bird-safe guidelines. Additionally, some glass is treated with ORNILUX. These sections of glazing face a pond and trees and were identified by the aviary as occupying a location with a high risk of collisions. The aviary has indicated that they wanted to use ORNILUX as an educational tool to show additional options available to mitigate collisions.[437] A monitoring program is in place; however, the data was not available at the time of this document. The Avian Health Center at Tracy Aviary is LEED-certified Silver and is a bird-safe building. The design features a reduced use of glass and silhouette decals on both sides of the minimal glass surface.[438] While ORNILUX and silhouette decals have been shown in experiments to be ineffective, monitoring data from both buildings would help determine whether these strategies are effective in reducing bird building collisions on real-world structures. Tracy Aviary promotes sustainable building practices that benefit our planet and specifically protect bird species.

---

[435] Johnnae Nardone, "About Us," Tracy Aviary (Tracy Aviary, November 11, 2019), https://tracyaviary.org/about).
[436] Ibid.
[437] Ibid.
[438] U.S. Green Building Council. "Tracy Aviary Avian Health Center," U.S. Green Building Council, accessed April 7, 2020, https://www.usgbc.org/projects/tracy-aviary-avian-health-center).

Tracy Aviary also participates in the Lights Out Salt Lake Program and organizes bird collision monitoring in Salt Lake City.[439] Both programs are part of the aviary's Community Science program. The program is an effort between citizen scientists and researchers at Tracy Aviary to protect birds and study the natural world. The Salt Lake Avian Collision Survey consists of citizen scientists voluntarily walking downtown Salt Lake City looking for evidence of bird building collisions at specific locations. Additionally, the public can report a bird building collision on their website. This is a survey-based collection of data that is not yet available to the public.[440]

Figure 40. Tracy Aviary's Bird-Safe Designs, Salt Lake City, UT

[439] Tracy Aviary. "Lights Out Salt Lake," Tracy Aviary Conservation Science, accessed April 7, 2020, http://www.tracyaviaryconservation.org/lightsoutsaltlake).

[440] Tracy Aviary. "Salt Lake Avian Collision Survey," Tracy Aviary Conservation Science, accessed April 7, 2020, http://www.tracyaviaryconservation.org/slacs).

The California Raptor Center at the University of California, Davis, combines a rehabilitation center and Raptor Aviary in one location. The center is housed in the School of Veterinary Medicine and treats over 300 birds each year. The goal of the center is to release recovered birds back to the wild. However, some of the birds cannot be released and live out their lives at the center. The California Raptor Center has 35 resident birds of prey that are educational ambassadors. Through educational programming, the public learns about conservation issues and can see birds up-close in an intimate venue in ways that are not possible in wilderness settings. While this experience fosters a connection to wildlife, it also gives visitors a personal account of the dangers of the built environment. Four of the resident owls were hit by cars, and two golden eagles (*Aquila chrysaetos*) were found near wind turbines. While their injuries were not life-threatening, they are not able to be released.[441]

Rehabilitation centers such as the Carolina Waterfowl Rescue and Paws Seattle are small nonprofit wildlife rescue centers with valuable bird collision data for local researchers. The Carolina Waterfowl Rescue provides care to over 1,000 birds a year across 40 different species.[442] Their work with local biologists to determine if an illness caused the collisions and their injuries and outcomes could be useful in understanding bird building collisions and collision data such as species and date of the collision.[443] PAWS Seattle Wildlife Center takes on the role of educator and rehabilitator by offering species-specific guides to solving and preventing conflicts with birds, including bird building collisions.[444] Educating the public about threats birds face in the built environment and recording collision data makes rehabilitation centers vital in advocating for a bird-safe built environment.

Every resident of a city or town has had interactions with birds. These interactions can play an essential role in promoting the conservation of nature and building a strong connection between humans and the natural world. Education about bird building collisions offers a unique educational avenue to teach about human-made threats that birds face. However, the study of urban birds and birds in the built environment does not have enough research about how birds

---

[441] UC Davis Veterinary Medicine. "School of Veterinary Medicine," School of Veterinary Medicine, accessed April 7, 2020, https://crc.vetmed.ucdavis.edu/).

[442] Carolina Waterfowl Rescue. "Carolina Waterfowl Rescue," Carolina Waterfowl Rescue, accessed April 7, 2020, https://www.cwrescue.org/).

[443] This is the rescue that treated the over 100 stunned or injured chimney swifts (*Chaetura pelagica*) that collided with the NASCAR Hall of Fame in 2019.

[444] PAWS, "Songbirds," PAWS, accessed April 7, 2020, https://www.paws.org/resources/songbirds/).

interact with designed structures and how they impact society. The use and evaluation of collision mitigation strategies and innovative building designs can fill in both gaps. Examples of collision deterrence methods implemented on campus buildings can help raise awareness to the public while reaching sustainability goals. Thus, making it clear that avian conservation and sustainability are not two separate areas of study in the built environment. Bird conservation organizations and citizen science projects such a species surveys and collision monitoring engage the public in advocating for a bird-safe built environment. Furthermore, in the case of avian ambassadors at aviaries and rehabilitation centers, birds themselves can be their own advocates reminding us to act on behalf of their welfare. Finally, aviaries are the center of public education, and those like Tracy Aviary and The National Aviary highlight, through example, the need for sustainable buildings that do not kill birds.

CONCLUSION

In the 1960s, Rachel Carson played a crucial role in communicating the urgency of limiting the anthropogenic threats to other species. She was particularly concerned with the overuse and careless distribution of pesticides. Today we face additional challenges, such as climate change and habitat loss, that threaten species, including our own. The urgency of sustainable living practices is more evident with each passing year. Despite some bird species' adaptability, they remind us that the infrastructure needed to support our lifestyles can often be devastating to theirs. Buildings and structures in the built environment kill hundreds of millions of birds each year in the United States. Still, professionals in the built environment often overlook one crucial aspect of sustainability that is also preventable with human action: bird building collisions.

To build sustainably, designers must factor in environmental matters.[445] Some principles of sustainable design specifically impact birds positively, like reducing CO2 emissions. However, some impact them negatively, like the extensive use of windows near green spaces. While sustainability strives to connect humans with natural systems in the built environment, "sustainable" solutions must not be merely in the interests of humans. Designers' intent on designing sustainably should strive to create built environments in harmony with the natural environment.[446] The American Institute of Architects offers mitigation strategies and an understanding that birds are vital to the ecology of the built environment and the well-being of the occupants of buildings. The AIA does this in part by explaining that bird collisions will harm the well-being of occupants. All policies and guidelines for sustainable design and bird protecting designs should strive to find a balance between conserving nature, protecting bird species, and enhancing human well-being.

Structures awarded for their commitment to meeting sustainability standards should not kill birds routinely.[447] Protecting birds through design strategies must be upheld as a vital component of comprehensive sustainable standards, policies, and education. Currently, collision

---

[445] *The Brundtland Report: Seizing the Opportunity: IIED Thoughts towards the Follow-up of the WCED Report "Our Common Future."* (London: International Institute for Environment and development, 1987); Ingrid Leman Stefanovic and Stephen Bede Scharper, *The Natural City Re-Envisioning the Built Environment* (Toronto, ON: University of Toronto Press, 2014), 13.

[446] Stephen R. Kellert, *Building for Life: Designing and Understanding the Human-Nature Connection* (Washington, DC: Island Press, 2005), 92.

[447] The U.S. Bank Stadium in Minneapolis, Minnesota as certified LEED Platinum in 2019, the first professional sports stadium to achieve this certification. However, its reflective glass facade kills over 100 birds every year.

mitigation techniques focus primarily on window collisions since transparent and reflective glass are the most dangerous elements of the built environment for birds. However, lighting design, landscape design, and avian behavior and life history are influential factors that affect the likelihood of window collisions. While many solutions to problematic glass, lighting, and landscape designs are evaluated in this thesis, this is a critical area of study that needs further interdisciplinary research. This research requires expertise from the fields of architecture, design, landscaping, lighting, and ornithology. Until there is increased awareness among designers and architects of the dangers that birds face in the built environment and the available solutions, up to one billion migrating and resident birds will continue to die each year in the United States.

It has become commonplace to cite Carson's world-altering book *Silent Spring* when discussing anthropogenic threats to nature that the title's stark meaning escapes us. We forget the startling prediction that there will be a "silent spring"—without the sound of birds—if we do not act quickly. We face this threat even more immanently now than in the 1960s. Birds face climate change, habitat loss, and bird building collisions that have contributed to the substantial net loss of 3 billion birds in North America since 1970.[448] We should feel the same urgency that Carson felt in the 1960s when we understand that human-built structures kill up to one billion birds in the United States each year.

[448] Kenneth V. Rosenberg et al. "Decline of the North American Avifauna." *Science* (New York, N.Y.) 366, no. 6461 (2019): 120-124.

FUTURE WORK

The subject of birds and the built environment spans many topic areas and disciplines, allowing for future opportunities to collaborate with researchers in various fields. Future work related to this project includes a comprehensive monitoring project of a set of buildings, like the University of Washington’s Seattle Campus, to record collisions before and after implementing collision solutions. The monitoring would provide much-needed data indicating the effectiveness of bird protecting designs and if the novel effect leads to reduced effectiveness over time. Included in this work is determining if bird protecting designs for glass can mitigates collisions with solar panels when applied to their reflective surface. Aiding in developing an app like eBird or iNaturalist for exclusively bird building collisions that allow data including design features and photo collection from the location would increase data across the United States. Based on the evaluations in this thesis, a comprehensive guide comparing the effectiveness of all available solutions from various fields in the built environments is vital for educators as well as architects and designers. The degree of awareness of this issue in built environment fields is unknown. A survey evaluating the level of knowledge and concern professionals have for this issue would help direct guidelines and education goals.

This interdisciplinary topic requires collaboration on much of its future work. Future research should include determining, for example, if ultraviolet and vinyl films impact glass performance regarding sustainability, visibility, and natural light. Further, studying how collision mitigation techniques impact an interior space’s natural light or visual connection with nature is needed to find a middle ground between the human experience and protecting birds. Studying birds as part of biodiversity in biophilic design to increase human well-being would support this as well.

It is essential to remember that different avian species can behave differently in the built environment. Studying how birds adapt to or benefit from design is an essential step in mitigating dangers birds face as they interact with the built environment. This work would include using data collected from monitoring to aid in developing software that can indicate dangerous areas of a building in need of collision mitigation solutions and provide species-specific solutions. There are two species-specific topics currently under research regarding this thesis. The first topic is compiling and analyzing species-specific data from currently available studies and reports. The second topic is the impact of the built environment on birds of prey.

Additionally, a better understanding of avian physiology such as sight, particularly UV or color, and maneuverability is crucial to design new collision mitigation techniques, but few studies are available on these two topics. Urban exploiters are a group of birds with species that are rarely listed as bird building casualties; how they maneuver the built environment could aid in this research. Further, using avian ambassadors to understand how birds see glass and structures could inform future design strategies.

Finally, studying the history of birds in the built environment can lead to a better understanding of how birds interact with built spaces and civilizations worldwide. Topics currently under research related to this thesis are the role of specific avian species used in ancient Egyptian language and art, the symbolism of birds of prey in art and architecture, and the history of women in bird conservation.

APPENDICES

APPENDIX 1: LOSS ET AL.'S 2019 FIGURE 3: COLLISION FATALITIES.

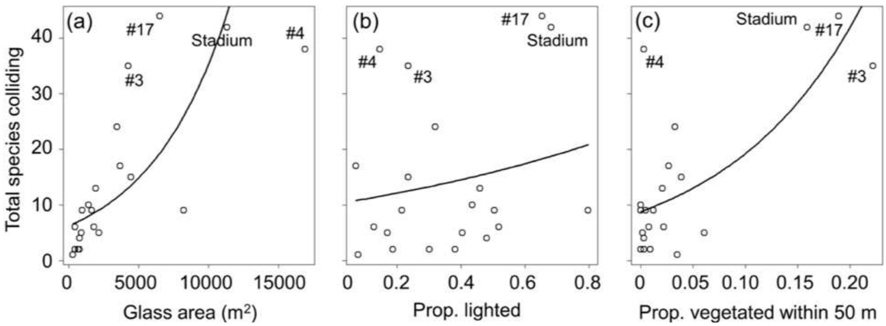


Figure 3. Correlates of numbers of collision fatalities (all buildings).
Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.": 15.

APPENDIX 2: DATA TABLES OF KLEM'S 2009 AND 2013 OPEN FIELD EXPERIMENTS.

Table 1. Daniel Klem's 2009 UV Experiments (Treated Glass in Open Field)

Tested	Total Collisions	% Reduced
Experiment 1		
Clear Glass	14	-
Mirrored Glass	28	-
2.5 cm UV Strips Spaced 5 cm	0	100%
Experiment 2		
Clear Class	35	-
Vertical 2.5 cm UV Film* Strips Spaced 5 cm	12	66%
UV Film*	12	66%
Experiment 3		
Clear Glass	51	-
UV Film: Outside Glass	24	53%
UV Film: Inside Glass	20	61%
UV Film: 65% Visible	30	41%
UV Film: 55% Visible	24	47%
UV Film: High Reflection	21	41%
UV Film: Low Reflection	24	47%
Experiment 4		
Clear Glass	49	-
2.5 cm UV Strips Spaced 5 cm	27	55%
CollideEscape**	1	98%
Experiment 5		
Clear Class	60	-
CUV-O UV Film: Outside Glass	8	87%
CUV-1 UV Film: Inside Glass	7	88%
Experiment 5 - Flight Tunnel (See Figure 24)		
S-1R UV Film: 2.5 cm Strips Spaced 5 cm	2	97%
S-2R-O UV Film: 5 cm Strips Spaced 2.5cm, Exterior	1	98%
S-2R-1 UV Film: 5 cm Strips Spaced 2.5cm, Interior	4	93%
UV Grid: 2.5 cm Strips Spaced 8 cm by 10 cm	4	93%
Experiment 6		
Clear Glass	39	-
CUV-O UV Film	11	72%
S-1R UV Film	3	92%

*UV Film Provided by CPFilms.

**CollideEscape made the glass appear white.

Table 2. Daniel Klem's 2012 UV Open Field Experiments				
Tested	**Total Collisions**	**% Reduced**	**Fatal Collisions**	**% Fatal**
Experiment 1				
Clear Glass	32	-	2	6%
Mirrored Glass	40	25% Increase	6	15%
UV Coated Glass (ORNILUX)	41	28% Increase	11	27%
Experiment 2				
Clear Glass	69	-	21	30%
Vertical 3.175 mm UV Strips Spaced 8.9 cm	5	93%	Unknown	Unknown
Vertical 3.175 mm UV Strips Spaced 10.8 cm	7	90%	1	14%
UV Coated Black Panel (ORNILUX)	31	55%	Unknown	Unknown

Tables by the author.

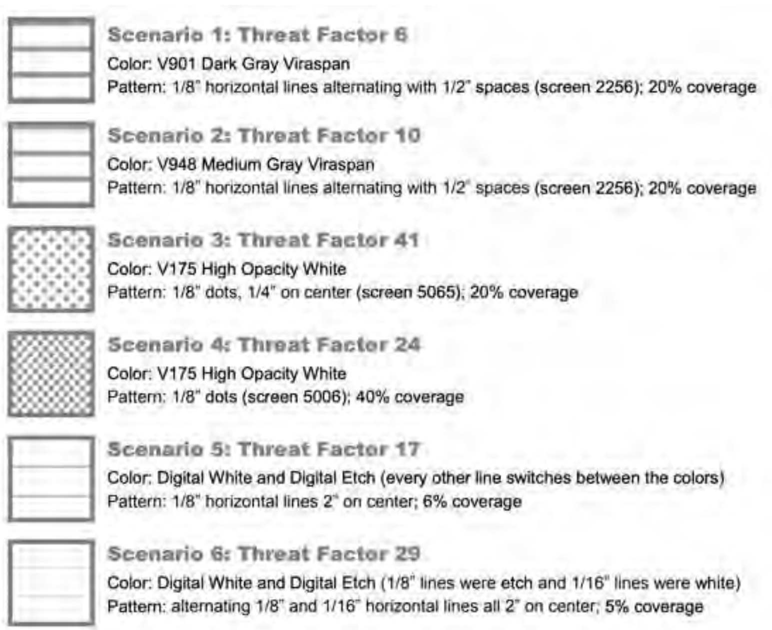
Data in Table 1: Daniel Klem, "Preventing Bird–Window Collisions," *The Wilson Journal of Ornithology* 121, no. 2 (2009).

Data in Table 2: Daniel Klem and Peter G. Saenger, “Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions,” *The Wilson Journal of Ornithology* 125, no. 2 (2013).

APPENDIX 3: THE AMERICAN BIRD CONSERVANCY'S (ABC) THREAT FACTOR RESULTS

The American Bird Conservancy recommends the following manufacturers of commercial or residential bird collision deterrence materials.

I. Viracon uses ABC's threat factor to show the effectiveness of their products.[449] However, it can be confusing for purchasers to understand what they mean without explicit information about the threat factor scale. This product's threat factor results reveal color or contrast and pattern or spacing influence performance. In Scenarios 1 and 2, dark gray lines are slightly more effective. In Scenario 4, the equally sized and spaced dots appearing as a solid are more effective than the wider spacing in Scenario 3. Finally, Scenario 6 alternates vertical line thickness indicating this method is less effective than the uniform thickness and thinner lines used in Scenario 5.



[449] Viracon. "Tech Talks," Viracon, accessed April 7, 2020, https://viracon.com/page/tech-talks).

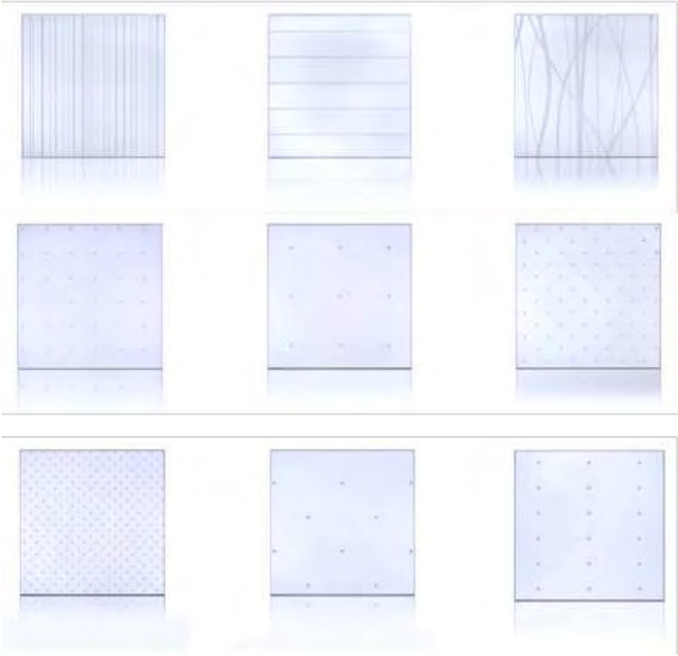
II. Bendheim Glass scored a threat factor of 29 for the Clarissimo finish and 34 for the Rough finish. Their website does not list them as Bird-Smart. The frosted effect of the Rough finish deterred collisions 66%, much lower than could be expected from a non-reflective surface, indicating the need to study avian sight further.[450]

504 Rough Cast™ Channel Glass (Ultra-Brilliant Low-Iron or Regular)

Clarissimo™ Channel Glass (Ultra-Brilliant Low-Iron or Regular)

[450] Bendheim. "Architectural Glass: Product Catalog," Bendheim, accessed April 7, 2020, https://bendheim.com/professional/glass/).

III. Walker Glass' AviProtek has nine bird-friendly glass options with three tested by ABC. Of the three tested, their threat factors are 23, 30, and 30. The six dot designs not tested by ABC are listed as bird-friendly options as they are spaced at least 5 cm horizontally or 10 cm vertically.[451] However, the 5 cm by 10 cm rule tested by Klem used lines, not dots.[452]



IV. CollidEscape provides vinyl window coverings and patterned tape for use on commercial or residential buildings. Their products do not have their threat factors listed; however, their products are divided into guaranteed solutions and high-performance solutions. The guaranteed solutions provide four films that cover the entire window and one repeating dot pattern. ABC tested CollidEscape's white perforated film and assigned the mitigation

---

[451] Walker Glass. "Transparent Bird Friendly Glass: AviProtek T," Verrerie Walker, accessed April 7, 2020, https://www.walkerglass.com/products/transparent-bird-friendly-glass/).

[452] Daniel Klem, "Preventing Bird–Window Collisions," *The Wilson Journal of Ornithology* 121, no. 2 (2009), 314-321.

technique a threat factor of 2, indicating it reduced collisions by 98%. This result is the same as Klem's 2009 experiment. The film appears opaque from the outside but allows light to enter the building and does not block the view. Colored vinyl and customizable images, text, and designs can be ordered as well. The opaque vinyl options claim to absorb or reflect up to 50% of incoming solar heat. However, no studies of their claim were cited.[453] The clear options have not been tested and do not protect against territorial aggression.[454] The dot window covering uses 0.36 cm dots spaced 5 cm apart. The high-performance patterns include clear or white dots sized 1.9 cm spaced 5 cm apart on a single line tape roll. The dots are the same perforated vinyl as the full window covering. The perforated vinyl is also available in strips 1.9 cm to 7.6 cm in width in clear or white in the same single line tape roll format. ABC has not tested the dot and line tape options.[455]

[453] CollidEscape. "Energy Savings," CollidEscape 2020, accessed April 7, 2020, https://www.collidescape.org/copy-of-leed).
[454] Territorial aggression is when birds see their own reflection in a reflective surface such as windows or mirrors and attack the "intruder" to protect its territory.
[455] CollidEscape. "Prevent Birds Hitting Windows: CollidEscape," CollidEscape 2020, accessed April 7, 2020, https://www.collidescape.org/).

V. Decorative Films, a window privacy film company, have six bird safety films. They include horizontal lines 0.32 cm thick spaced 2.54 cm, vertical lines 0.32 cm thick spaced 5 cm, a trellis pattern with 0.32 cm lines leaving 13 cm diamond-shaped openings, a dot pattern size 0.63 cm spaced 5 cm, a frosted bird pattern design, and a colored bird pattern design. ABC tested the frosted and colored bird pattern designs, resulting in threat factors of 5 and 20, respectively.[456] The 15 point difference of the same pattern indicates limitations of the testing method, that color is a less reliable deterrent, accurately depicted bird species may confuse real-life birds, or an aspect of avian physiology not yet understood.

[456] Decorative Film. "Decorative Films: Window Film: Stained Glass: Privacy Film: Window Treatments," Decorative Films, LLC., accessed April 7, 2020, https://www.decorativefilm.com/specialty-bird-safety).

VI. Feather Friendly is a bird collision deterrent manufactured by 3M for residential and commercial use. Square dots sized 0.32 cm are spaced two inches apart and have a threat factor of 23.[457]

[457] Feather Friendly, "Feather Friendly," https://www.featherfriendly.com, accessed April 7, 2020, https://www.featherfriendly.com/).

VII. Window Alert is a residential mitigation technique that sells shaped UV decals. Hawk and maple leaf decals were tested by Klem and did not significantly reduce collisions. ABC tested the 8.9 cm square UV decals spaced 5 cm horizontally and 10 cm vertically. The threat factor was 10, and in Sheppard's 2019 study, they scored a threat factor of 8 when spaced 2.4 cm apart horizontally and 5 cm apart vertically.[458] However, this product has four decals per envelope, and while the directions recommend using the 5 cm by 10 cm spacing, multiple packs would be required to cover one window.[459] Additionally, UV decals do not consistently prevent collisions at a high percentage in experiments.

VIII. GlasPro is a film made of vertical stripes spaced 5.7 cm alternating UV and non-UV strips.[460] This is one of the four UV materials that fall outside of the 30 or less threat factor required to be determined Bird-Smart by ABC.

[458] Christine D. Sheppard, "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass," *Global Ecology and Conservation* 20 (2019): 7.
[459] Window Alert. "Classic Square Decal Envelope - 4 Decals," Window Alert, accessed April 7, 2020, https://windowalert.com/classic-square-decal-envelope-4-decals/).
[460] GlasPro. "Bird Safe," GlasPro, accessed April 7, 2020, http://www.glas-pro.com/products/glas-pro-bird-glass/).

APPENDIX 4: PROMOTING BIRD CONSERVATION IN URBANIZING LANDSCAPES

Box 1. Recommendations to planners and policy-makers interested in promoting bird conservation in urbanizing landscapes.

1. **Protect natural areas as parks or other open spaces within urbanizing landscapes in order to both (a) provide habitat to wildlife and (b) improve the quality of the landscape matrix.** While preserving the largest contiguous areas of habitat possible is always advisable, simply increasing the amount of natural habitat within the landscape improves the ability of all habitat patches to support birds.

2. **Plan explicitly for open spaces and natural habitats within new subdivisions.** By carefully planning the amount and location of habitat within subdivisions, developments are more likely to capture inherently diverse areas and provide suitable habitat to birds.

3. **Within developments, use a variety of arrangements of built and open space.** Because species differ widely in their ecological requirements, no single habitat management approach will meet the needs of the regional suite of avian communities. Application of different management and design approaches ensures that a diversity of species will be supported.

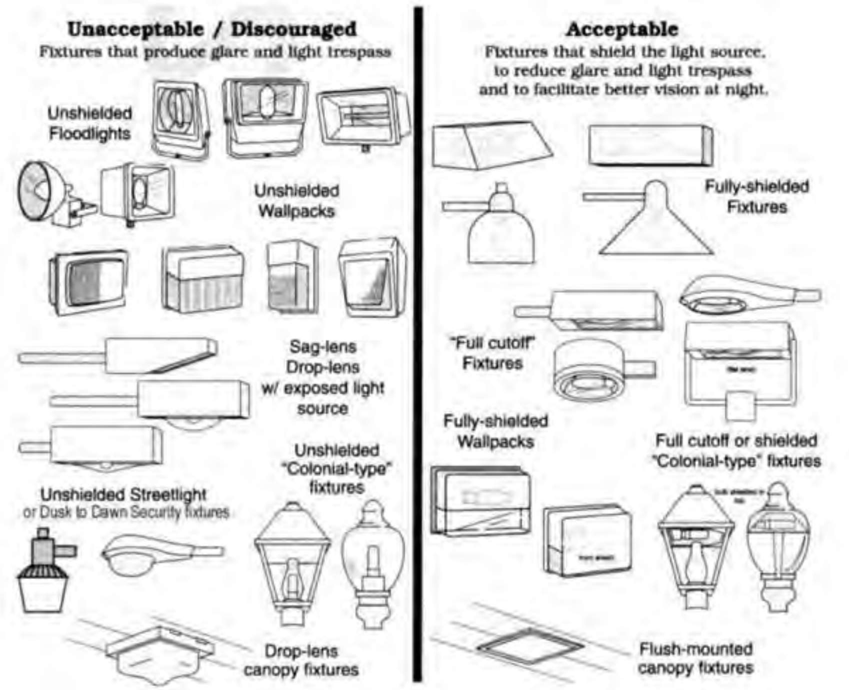
4. **Enhance and restore habitat within existing open green spaces and natural areas.** Though birds generally respond positively to greater structural and floristic diversity of habitat, some species may require more deliberate management to provide their specific requirements (e.g., nest cavities).

5. **Improve habitat quality within the matrix of urban land uses rather than focusing only on management within parks, reserves, and open spaces.** Ultimately there will not be a sufficient number of reserves and parks to conserve biodiversity. Effective conservation requires that we think outside the park and explore creative ways to improve the habitat available to birds within the urban landscape itself.

6. **Celebrate urban biological diversity to foster connections between people and the natural heritage of their local ecosystems and regional biomes.** Not only does interaction with nature enrich our lives, but such interactions foster sensitivity to environmental issues – something needed as we face tremendous global change.

(Marzluff and Rodewald, 2008)

APPENDIX 5: DARK SKY SOCIETY'S GUIDELINES FOR EXTERIOR LIGHTING



Diagrams courtesy of Bob Crelin

GLOSSARY

2 by 4 rule – lines spaced two inches (5 cm) apart horizontally or 4 inches (10 cm) apart vertically based on Daniel Klem's 1990 experiments. Bird-friendly/bird-safe guidelines use these measurements to space decals, dots, and other patterns.

accelerometer – an electrically operated device used to measure acceleration forces.

accipiter hawk – a group of hawks with broad, short wings with long tails and legs, part of the genus *accipiter*. See the Avian Index for images of the North American *accipiter* hawks: Cooper's hawk (*Accipiter cooperii*), northern goshawk (*Accipiter gentilis*), and sharp-shinned hawk (*Accipiter striatus*).

anthropogenic – the results of the influence of human beings on nature.

beacon effect – when a building or structure is lit at night from within or projected onto the surface, causing birds to be attracted to the light, especially during overcast conditions.

biomass – weight or total quantity of living organisms of one species or all the species of a community in an area or volume of habitat.

Biophilia Hypothesis – the theory that human beings evolved in natural environments and developed an innate tendency to respond positively to natural settings.

biophilic design – a concept intended to enhance human well-being by connecting humans and nature through building and landscape design with direct, indirect, or symbolic experience of natural or place-based designs.

bird building collision – a phrase that communicates window strikes are not the only threat facing birds in the built environment; birds can collide with non-glass or windowless structures.

bird-friendly/bird-safe – labels indicating the use of any collision mitigation strategies on a building or structure; however, they are not defined by data that demonstrates the building or structure is free of collisions.

birdphilic design – a concept developed by the author, based on biophilic design, that focuses on protecting avian species as part of sustainable design and fostering a connection to nature through birds and avian art and architecture.

brown roofs – also known as biodiverse roofs, they are designed to be self-sufficient, not with extensive landscape designs or to be trafficked by pedestrians but to create a natural habitat to support various plants, birds, animals, and invertebrates.

built environment –human-built structures and infrastructure.

ceilometer – measures the height of a cloud ceiling or cloud base using a laser or light source.

charette – an intense period of design or planning collaborative session where a group of designers draft a solution to a problem.

collegiate gothic – a subgenre of Gothic Revival architecture taking place in the late 19th and early 20th centuries on North American college campuses inspired by the historical Gothic style of architecture.

coniferous tree – cone-bearing trees that retain their leaves or needles.

conventional oil – a process of extracting oil using traditional methods like drilling and pumping oil to the surface.

corvid – a songbird family of the order *Passeriformes*, including crows, ravens, jays, and magpies.

deciduous tree – trees that drop their leaves or needles in early to late autumn.

diversion pole – poles that produce an illusion of a solid barrier to reduce bird fatalities on roads or bridges.

ecological service – the economic or human-based benefits from the ecological functions of ecosystems.

ecosystem service – outputs, conditions, or processes of natural systems that directly or indirectly benefit humans or social welfare.

ecotourism– tourism directed toward exotic, often threatened, natural environments, intended to support conservation efforts and observe wildlife.

electrochromic – materials, like smart glass, can vary their coloration and transparency to solar radiation in a reversible manner when subjected to a small electric field.

emissions – the release of greenhouse gases (like CO2) into the atmosphere over a specified area and period of time from a stationary source like burning fossil fuels.

envelope (building envelope) – the design and construction of the exterior of a structure, which is a physical barrier between the exterior and interior environments enclosing a structure.

extensive green roofs – having shallow soil levels and can adapt to roofs with slopes up to 40 degrees.

façade – the face or front exterior of a building.

five points of architecture – a set of architectural principles by Le Corbusier. Point five suggests utilizing roof gardens on a flat roof for domestic purposes while protecting the concrete roof.

food desert – limited access to nutritive food due to availability or, in the case of humans, lack of affordability and availability.

footprint – all areas of a building that rests directly or indirectly on the ground, including those supported by columns, piers, or posts making up the structure's full perimeter.

Frank Lloyd Wright – (Born 1867– Died 1959) an American architect and designer who developed the philosophy of organic architecture. Organic architecture is designing in harmony with humanity and its environment.

glazing – modern glass windows of one to three panes or a coating (like Low-E Glaze) that impact a window's performance and energy efficiency.

heat gain /heat loss –how much heat is gained or lost from the outside of the building, measured in BTU per hour.

heat island effect – when urban areas experience higher temperatures than nearby natural areas (green landscapes and water bodies) due to the structures and infrastructure absorbing and re-emitting the sun's heat.

Holcim Award – an international competition awarding sustainable construction projects and concepts.

insectivorous – feeds primarily on insects, worms, and other invertebrates.

intensive roofs – formal gardens that require a deep, flat soil layer to plant larger vegetation like shrubs or trees.

Le Corbusier – (Born 1887– Died 1965) an internationally influential Swiss-born French architect known for combining functionalism of the modern movement with bold expressionism.

LEED – a U.S. Green Building Council certification centered on a credit system of points based on the potential environmental impacts and human benefits. There are four levels of certification: Certified, Silver, Gold, and the highest, Platinum.

life history –the changes through which an organism passes in its development from the primary stage to its natural death.

magnetoception – allows an organism to detect magnetic fields to determine direction, altitude, or location.

migration flyway – the migratory route followed by migratory birds when migrating between nesting and wintering areas. The North American flyways are the Pacific Flyway, Central Flyway, Mississippi Flyway, and Atlantic Flyway.

mullion – a vertical or horizontal bar between the panes of glass in a window.

Narmer Palette – (Dating from the 31st century BC) a shield-shaped Egyptian ceremonial engraving made of siltstone depicting the conquest of king Narmer’s and on the reverse side, Upper and Lower Egypt’s unification. (A palette is a thin board or slab where an artist lays and mixes colors.)

neoclassical – a revival of the classic style of architecture based on the principles of simplicity and symmetry inspired by Ancient Roman and Greek architecture.

Neotropical birds – birds that breed in Canada and the United States during summer and spend winter in Mexico, Central and South America, or the Caribbean.

novel effect – when new additions to the habitat prevent birds from approaching but once habituated to the change, birds will return.

nutrient cycling – using, moving, and recycling nutrients essential to life in the environment.

oxidative stress – the occurrence of enzymatic and non-enzymatic antioxidants that cannot fully neutralize the free radicals produced in the cells of living organisms

Pacific flyway – a north-south flyway extending from Alaska, United States to Patagonia, Argentina.

parapets – a low protective wall along the edge of a balcony, bridge, or roof.

passerines – birds belonging to a large order of birds, *Passeriformes*, with toes that facilitate perching; passerines include all songbirds but are not exclusively songbirds.

peri-urban – the location immediately surrounding an urban area.

photo pollution – when artificial light adversely affects wildlife.

population sink – a location where death rates exceed birth rates.

positive environmental impact (biophilic design) – design that enhances human well-being by connecting humans and nature through building and landscape design with direct, indirect, or symbolic experience of natural or place-based designs.

Proggy Award – a PETA (People for the Ethical Treatment of Animals) award recognizing animal-friendly commerce and cultural achievements.

proportion lighted – the proportion of the façade that is lit compared to the portion that is not lit by artificial light.

PTFE material – a versatile synthetic material that repels water, is non-stick and resistant to high temperatures.

restorative environmental design – a combination of sustainable design and design focused on human well-being, aiming to achieve a harmonious relationship between nature and humans in the built environment by reducing adverse effects of design on nature and human health while promoting a connection between people and nature.

scrape – a shallow depression in the substrate of a falcon's nesting area.

sedum – a genus of flowering plants, also known as stonecrops, with succulent stems and water-storing leaves.

skyway – an enclosed and elevated pedestrian bridge extending from a building face to another façade spanning a street or alley or within private property.

Stele of Vultures – (Dating from the Early Dynastic period, c. 2450 BC) a victory stele from the Sumerian city of Girsu, representing the oldest known historical document.

sustainability – avoidance of the depletion of natural resources to maintain an ecological balance.

sustainable design – designing while considering the environmental, social, and economic impacts from the initial phase to the end of life.

threat factor – the outcome of tests conducted by the American Bird Conservancy to determine how dangerous a material is to birds on a scale of 0 – 100, 0 being least dangerous.

ultraviolet (UV) – a form of lightwave or radiation with a shorter wavelength than visible light. Some birds can detect UV; humans cannot.

unconventional oil – a method of oil extraction that does not include the traditional method of drilling and pumping oil to the surface. Fracking is an unconventional method.

understory – the vegetative layer, especially the trees and shrubs, between the forest canopy and the ground cover.

urban adaptor – can exploit the diverse and abundant resources provided by a moderate to lower level of development.

urban avoider – avoids areas with minimal landscape development.

urban exploiter – can exploit and are attracted explicitly to heavily developed areas.

urbanization – the process by which large numbers of people become permanently concentrated in small areas, forming cities.

U.S. Green Building Council – a private membership-based non-profit organization promoting sustainable building design, construction, and operation. USGBC developed the Leadership and Environmental Design (LEED) rating system.

vernacular – a common building style of a period or place.

water intake crib – structures built to store and protect offshore water intakes used to supply drinking water.

AVIAN SPECIES: IMAGES AND INDEX

The species mentioned in this document are listed below by their common names. The index is organized by their scientific names.

American crow (*Corvus brachyrhynchos*)
American kestrel (*Falco sparverius)*
American robin (*Turdus migratorius*)
Anna's hummingbird (*Calypte anna*)
barn owl (*Tyto alba*)
barred owl (*Strix varia*)
black redstart (*Phoenicurus ochruros*)
burrowing owl (*Athene cunicularia*)
Carolina chickadee (*Poecile carolinensis*)
cedar waxwing (*Bombycilla cedrorum*)
chimney swift (*Chaetura pelagica*)
common yellowthroat (*Geothlypis trichas*)
Cooper's hawk (*Accipiter cooperii*)
dark-eyed junco (*Junco hyemalis*)
Eastern bluebird (*Sialia sialis*)
Eurasian jay (*Garrulus glandarius*)
ferruginous hawk (*Buteo regalis*)
golden eagle (*Aquila chrysaetos*)
great tit (*Parus major*)
great-horned owl (*Bubo virginianus*)
herring gull (*Larus argentatus*)
house sparrow (*Passer domesticus*)
killdeer (*Charadrius vociferous)*
mallard (*Anas platyrhynchos*)
Nashville warbler (*Leiothlypis ruficapilla*)
northern cardinal (*Cardinalis cardinalis*)
northern goshawk (*Accipiter gentilis*)
olive-sided flycatcher (*Contopus cooperi*)
ovenbird (*Seiurus aurocapilla*)
Pacific wren (*Troglodytes pacificus*)
peregrine falcon (*Falco peregrinus*)
red-tailed hawk (*Buteo jamaicensis*)
Ridgway's hawk (*Buteo ridgwayi*)
sharp-shinned hawk (*Accipiter striatus*)
snowy owl (*Bubo scandiacus*)
Swainson's warbler (*Limnothlypis swainsonii*)
Tennessee warbler (*Leiothlypis peregrina*)
tufted titmouse (*Baeolophus bicolor*)
turkey vulture (*Cathartes aura*)
western bluebird (*Sialia mexicana*)
white-throated sparrow (*Zonotrichia albicollis*)
yellow rail (*Coturnicops noveboracensis*)

Cooper's hawk
(*Accipiter cooperii*)
Page: 15

northern goshawk
(*Accipiter gentilis*)
Page: 15

sharp-shinned hawk
(*Accipiter striatus*)
Page: 15

mallard
(*Anas platyrhynchos*)
Page: 23

golden eagle
(*Aquila chrysaetos*)
Avian Ambassador, Tussey
Pages: iii, 31-3, 34, 86-7, 131

burrowing owl
(*Athene cunicularia*)
Page:16

tufted titmouse
(*Baeolophus bicolor*)
Page: 75

cedar waxwing
(*Bombycilla cedrorum*)
Pages: 75, 77

snowy owl
(*Bubo scandiacus*)
Vulnerable Species
Page: 16

great-horned owl
(*Bubo virginianus*)
Avian Ambassador, Cere
Page: iii

red-tailed hawk
(*Buteo jamaicensis*)
Avian Ambassador, Alula
Pages: iii, 3-4, 24

ferruginous hawk
(*Buteo regalis*)
Page: 31

Ridgway's hawk
(*Buteo ridgwayi*)
Located in Haiti and Dominican Republic, Critically Endangered
Page: 32

Anna's hummingbird
(*Calypte anna*)
Pages: 7,16-17, 19, 27, 58

northern cardinal
(*Cardinalis cardinalis*)
Page: 75

turkey vulture
(*Cathartes aura*)
Avian Ambassador, Neo
Page: iii

chimney swift
(*Chaetura pelagica*)
Vulnerable Species
Pages: 41, 131

killdeer
(*Charadrius vociferous)*
Pages: 24-5

olive-sided flycatcher
(*Contopus cooperi*)
Near Threatened Species
Pages: 24-5

American crow
(*Corvus brachyrhynchos*)
Pages: 3,10

yellow rail
(*Coturnicops noveboracensis*)
Page: 33

peregrine falcon
(*Falco peregrinus*)
Avian Ambassador, Susquehanna
Pages: i, iii, 1, 7, 11-15, 27, 84, 124

American kestrel
(*Falco sparverius*)
Avian Ambassador, Kestrel
Pages: 95, 124

Eurasian jay
(*Garrulus glandarius*)
Mainly resident of the United Kingdom
Page: 5

common yellowthroat
(*Geothlypis trichas*)
Pages: 48, 51-2, 89

dark-eyed junco
(*Junco hyemalis*)
Pages: 7, 10, 16, 18-9, 27, 56-7, 59

herring gull
(*Larus argentatus*)
Pages: 24, 26, 79

Tennessee warbler
(*Leiothlypis peregrina*)
Pages: 48, 50-2

Nashville warbler
(*Leiothlypis ruficapilla*)
Pages: 48, 50-2

Swainson's warbler
(*Limnothlypis swainsonii*)
Page: 33

great tit
(*Parus major*)
Resident of Central and
Southern Europe
Page: 5

house sparrow
(*Passer domesticus*)
Pages: 5, 59

black redstart
(*Phoenicurus ochruros*)
Resident south/central Europe,
Asia and north-west Africa.
Page: 24

Carolina chickadee
(*Poecile carolinensis*)
Page: 26

ovenbird
(*Seiurus aurocapilla*)
Pages: 48, 51, 75

western bluebird
(*Sialia mexicana*)
Page: 34

Eastern bluebird
(*Sialia sialis*)
Page: 24

barred owl
(*Strix varia*)
Avian Ambassador, Jerudi
Pages: iii, 65

Pacific wren
(*Troglodytes pacificus*)
Page: 10

American robin
(*Turdus migratorius*)
Page: 49

barn owl
(*Tyto alba*)
Avian Ambassador, Novia
Pages: iii, 1

white-throated sparrow
(*Zonotrichia albicollis*)
Pages: 48, 51, 56

BIBLIOGRAPHY

"Continent-wide Analysis of How Urbanization Affects Bird-window Collision Mortality in North America." *Biological Conservation* 212 (2017): 209-215.

American Bird Conservancy. "Glass Collisions." American Bird Conservancy, April 29, 2020. https://abcbirds.org/program/glass-collisions/.

---. "New Program Rates Bird-Smart Glass Products for Homeowners and Architects." American Bird Conservancy, January 19, 2016. https://abcbirds.org/new-program-rates-bird-smart-glass-products-for-homeowners-and-architects/.

---. "Stop Birds Hitting Windows." American Bird Conservancy. Accessed November 1, 2019. https://abcbirds.org/get-involved/bird-smart-glass/.

---. "Wind Risk Assessment Map." American Bird Conservancy, May 3, 2020. https://abcbirds.org/program/wind-energy-and-birds/wind-risk-assessment-map/.

The American Institute of Architects. "Designing for Ecology." The American Institute of Architects. Accessed April 8, 2020. https://www.aia.org/showcases/6082454-designing-for-ecology.

---. "History." The American Institute of Architects. Accessed April 7, 2020. https://www.aia.org/history.

Atwell, Jonathan W., Gonçalo C. Cardoso, Danielle J. Whittaker, Samuel Campbell-Nelson, Kyle W. Robertson, and Ellen D. Ketterson. "Boldness Behavior and Stress Physiology in a Novel Urban Environment Suggest Rapid Correlated Evolutionary Adaptation." *Behavioral Ecology* 23, no. 5 (2012): 960–69. https://doi.org/10.1093/beheco/ars059.

Atwell, Jonathan W., Gonçalo C. Cardoso, Danielle J. Whittaker, Trevor D. Price, and Ellen D. Ketterson. "Hormonal, Behavioral, and Life-History Traits Exhibit Correlated Shifts in Relation to Population Establishment in a Novel Environment." *The American Naturalist* 184, no. 6 (2014). https://doi.org/10.1086/678398.

Bailleul-LeSuer, Rozenn. *Between Heaven and Earth: Birds in Ancient Egypt*. Chicago, IL: Oriental Institute of the University of Chicago, 2012

Bailly, Juliette, Renaud Scheifler, Marie Belvalette, Stéphane Garnier, Elena Boissier, Valérie-Anne Clément-Demange, Maud Gète, et al. “Negative Impact of Urban Habitat on Immunity in the Great Tit Parus Major.” *Oecologia* 182, no. 4 (2016): 1053–62. https://doi.org/10.1007/s00442-016-3730-2.

Barton, Christine M., Corey S. Riding, and Scott R. Loss. “Magnitude and Correlates of Bird Collisions at Glass Bus Shelters in an Urban Landscape.” *Plos One* 12, no. 6 (2017). https://doi.org/10.1371/journal.pone.0178667.

Bayne, Erin M. M., Corey A. A. Scobie, and Michael Rawson-Clark. “Factors Influencing the Annual Risk of Bird Window Collisions at Residential Structures in Alberta, Canada.” *Wildlife Research* 39, no. 7 (2012): 583-92. (Listed for future review.)

Bendheim. “Architectural Glass: Product Catalog.” Bendheim. Accessed April 7, 2020. https://bendheim.com/professional/glass/.

Bennet, Molly. “How New Technology Is Making Wind Farms Safer for Birds.” Audubon, August 14, 2018. https://www.audubon.org/magazine/spring-2018/how-new-technology-making-wind-farms-safer-birds.

Blair, Robert B. “Land Use and Avian Species Diversity Along an Urban Gradient.” *Ecological Applications* 6, no. 2 (1996): 506–19. https://doi.org/10.2307/2269387.

Boal, Clint W., and Cheryl R. Dykstra. *Urban Raptors: Ecology and Conservation of Birds of Prey in Cities*. Seattle, WA: Island Press, 2018

Borden, W. C., Owen M. Lockhart, Andrew W. Jones, and Mark S. Lyons. "Seasonal, Taxonomic, and Local Habitat Components of Bird-Window Collisions on an Urban University Campus in Cleveland, OH." *The Ohio Journal of Science* 110, no. 3 (06, 2010): 44-52. https://search.proquest.com/docview/868055982?accountid=14784.

Brisque, Thaís, Lucas Andrei Campos-Silva, and Augusto João Piratelli. “Relationship between Bird-of-Prey Decals and Bird-Window Collisions on a Brazilian University Campus.” *Zoologia* 34 (2017): 1–8. https://doi.org/10.3897/zoologia.34.e13729.

Brown, Barbara B., Erika Kusakabe, Angelo Antonopoulos, Sarah Siddoway, and Lisa Thompson. “Winter Bird-Window Collisions: Mitigation Success, Risk Factors, and Implementation Challenges.” *PeerJ* 7 (2019). https://doi.org/10.7717/peerj.7620.

Cabrera-Cruz, Sergio A., Jaclyn A. Smolinsky, and Jeffrey J. Buler. “Light Pollution Is Greatest within Migration Passage Areas for Nocturnally-Migrating Birds around the World.” *Scientific Reports* 8, no. 1 (2018). https://doi.org/10.1038/s41598-018-21577-6.

Canedoli, Claudia, Manenti, Raoul, and Padoa-Schioppa, Emilio. "Birds Biodiversity in Urban and Periurban Forests: Environmental Determinants at Local and Landscape Scales." *Urban Ecosystems* 21, no. 4 (2018): 779-93. (Listed for future review.)

Cappiello, Dina, and The Associated Press. “Eagle Deaths at Wind Turbine Farm: Duke Energy Agrees to Pay $1 Million.” NBCNews.com. NBCUniversal News Group, November 23, 2013. https://www.nbcnews.com/news/us-news/eagle-deaths-wind-turbine-farm-duke-energy-agrees-pay-1-flna2D11644504. (Accessed November 1st, 2019.)

Cardoso, Gonçalo C., and Jonathan W. Atwell. “On the Relation between Loudness and the Increased Song Frequency of Urban Birds.” *Animal Behaviour* 82, no. 4 (2011): 831–36. https://doi.org/10.1016/j.anbehav.2011.07.018.

Carolina Waterfowl Rescue. “Carolina Waterfowl Rescue.” Carolina Waterfowl Rescue. Accessed April 7, 2020. https://www.cwrescue.org/.

Carrus, Giuseppe, Massimiliano Scopelliti, Raffaele Lafortezza, Giuseppe Colangelo, Francesco Ferrini, Fabio Salbitano, Mariagrazia Agrimi, Luigi Portoghesi, Paolo Semenzato, and Giovanni Sanesi. “Go Greener, Feel Better? the Positive Effects of Biodiversity on the Well-Being of Individuals Visiting Urban and Peri-Urban Green Areas.” *Landscape and Urban Planning* 134 (2015): 221–28. https://doi.org/10.1016/j.landurbplan.2014.10.022.

Chiquet, Caroline, John W. Dover, and Paul Mitchell. “Birds and the Urban Environment: The Value of Green Walls.” *Urban Ecosystems* 16, no. 3 (2012): 453–62. https://doi.org/10.1007/s11252-012-0277-9.

City of Oakland, *Bird safety Measures*, Ordinance No. 189000 (Oakland, CA: City of Oakland, 2013), https://goldengateaudubon.org/wp-content/uploads/Oakland-Bird-Safety-Measures.pdf.

City of Portland Bureau of Planning and Sustainability, *Bird-Safe Window List* (Portland, OR: City of Portland Bureau of Planning and Sustainability, 2018), https://www.portlandoregon.gov/citycode/article/692350.

Clark, C. J. and S. M. Russell (2020). Anna's Hummingbird (CALYPTE ANNA), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.annhum.01

Cocker, Mark, Tipling, David, Elphick, Jonathan, and Fanshawe, John. *Birds and People.* London: Jonathan Cape, 2013.

College Takes Action to Stop Bird Collisions. American Bird Conservancy, 2017. https://www.youtube.com/watch?time_continue=6&v=dW1-mYOxMFI&feature=emb_logo.

CollidEscape. "Energy Savings." CollidEscape 2020. Accessed April 7, 2020. https://www.collidescape.org/copy-of-leed.

---. "Prevent Birds Hitting Windows: CollidEscape." CollidEscape 2020. Accessed April 7, 2020. https://www.collidescape.org/.

Cox, Daniel T. C., and Kevin J. Gaston. "Urban Bird Feeding: Connecting People with Nature." *Plos One* 11, no. 7 (2016). https://doi.org/10.1371/journal.pone.0158717.

Crino, O. L., E. E. Johnson, J. L. Blickley, G. L. Patricelli, and C. W. Breuner. "Effects of Experimentally Elevated Traffic Noise on Nestling White-Crowned Sparrow Stress Physiology, Immune Function and Life History." *Journal of Experimental Biology* 216, no. 11 (2013): 2055–62. https://doi.org/10.1242/jeb.081109.

Cusa, Marine, Donald A. Jackson, and Michael Mesure. "Window Collisions by Migratory Bird Species: Urban Geographical Patterns and Habitat Associations." *Urban Ecosystems* 18, no. 4 (2015): 1427–46. https://doi.org/10.1007/s11252-015-0459-3.

Dark Sky Society. "Dark Sky Society - Home." Dark Sky Society - Home. Accessed April 7, 2020. http://www.darkskysociety.org/.

Decorative Film. "Decorative Films: Window Film: Stained Glass: Privacy Film: Window Treatments." Decorative Films, LLC. Accessed April 7, 2020. https://www.decorativefilm.com/specialty-bird-safety.

Distribber. The Legend of Pale Male, 2009. https://www.thelegendofpalemale.net/.

Dwyer, James F., Thomas I. Hayes, Russel Thorstorm, and Richard E. Harness. "Retrofitting Power Poles to Prevent Electrocution of Translocated Ridgway's Hawks." *The Journal of Caribbean Ornithology* 32 (2019): 4–10.

Eakin, Carly J., Henry Campa, Daniel W. Linden, Gary J. Roloff, D. Bradley Rowe, and Joanne Westphal. "Avian Response to Green Roofs in Urban Landscapes in the Midwestern USA." *Wildlife Society Bulletin* 39, no. 3 (2015): 574–82. https://doi.org/10.1002/wsb.566.

eBird. "About eBird." eBird. Accessed April 7, 2020. https://ebird.org/about.

---. "Conservation Impacts." eBird. Accessed April 7, 2020. https://ebird.org/science/conservationimpacts.

Evans Ogden, Lesley J., "Summary Report on the Bird Friendly Building Program: Effect of Light Reduction on Collision of Migratory Birds." Fatal Light Awareness Program (FLAP). 5, (2002).

Falls, J. B. and J. G. Kopachena (2020). White-throated Sparrow (*Zonotrichia albicollis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Fatal Light Awareness Program Canada. "About FLAP." FLAP Canada. Accessed April 7, 2020. https://flap.org/about/.

Fears, Darryl, and Dino Grandoni. "The Trump Administration Has Officially Clipped the Wings of the Migratory Bird Treaty Act." The Washington Post. WP Company, April 13, 2018. https://www.washingtonpost.com/news/energy-environment/wp/2018/04/13/the-trump-administration-officially-clipped-the-wings-of-the-migratory-bird-treaty-act/. (Accessed November 1st, 2019.)

Feather Friendly. "Feather Friendly." https://www.featherfriendly.com. Accessed April 7, 2020. https://www.featherfriendly.com/.

Fernandez-Canero, R., and P. Gonzalez-Redondo. "Green Roofs as a Habitat for Birds: A Review." *Journal of Animal and Veterinary Advances* 9, no. 15 (2010): 2041–52. https://doi.org/10.3923/javaa.2010.2041.2052.

FLAP. "Fatal Light Awareness Program (FLAP) Canada." FLAP Canada. Accessed November 2019. https://flap.org/.

Gambert, Daniel. "Picture Stockton Using Art to Save Birds." Stockton University. Stockton University, November 21, 2019. https://stockton.edu/news/2019/picture-stockton-using-art-to-prevent-birds-from-striking-windows.html.

Gastelu, Gary. "The Big One? 300 Birds Mysteriously Crash into NASCAR Hall of Fame." Fox News, October 16, 2019. https://www.foxnews.com/auto/the-big-one-300-birds-mysteriously-crash-into-nascar-hall-of-fame.

Gedge, Dusty, and Gyongyver Kadas. "Green Roofs and Biodiversity." *Biologist* 52, no. 3 (July 2005): 161–69.

GlasPro. "Bird Safe." GlasPro. Accessed April 7, 2020. http://www.glas-pro.com/products/glas-pro-bird-glass/.

Glass on Web. "National Aviary Tropical Rainforest Featuring Acid-Etched STARPHIRE Glass Wins National Award for Exhibit Design." glassonweb.com. glassonweb.com, October 2, 2019. https://www.glassonweb.com/news/national-aviary-tropical-rainforest-featuring-acid-etched-starphire-glass-wins-national-award.

Greenroofs. "Drew School Sam Cuddleback III Assembly Wing Vertical Garden." Greenroofs.com, 2020. https://www.greenroofs.com/projects/drew-school-sam-cuddleback-iii-assembly-wing-vertical-garden.

Greenspan, Jesse. "The History and Evolution of the Migratory Bird Treaty Act." Audubon, May 22, 2015. https://www.audubon.org/news/the-history-and-evolution-migratory-bird-treaty-act.

Greig, Emma I., Eric M. Wood, and David N. Bonter. "Winter Range Expansion of a Hummingbird Is Associated with Urbanization and Supplementary Feeding." *Proceedings of the Royal Society B: Biological Sciences* 284, no. 1852 (2017): 1–9. https://doi.org/10.1098/rspb.2017.0256.

Gunter, Ann Clyburn. *A Companion to Ancient Near Eastern Art*. Hoboken, NJ: Wiley Blackwell, 2019

Guzy, M. J. and G. Ritchison (2020). Common Yellowthroat (Geothlypis trichas), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Habberfield, Michael W., and Colleen Cassady St. Clair. "Ultraviolet Lights Do Not Deter Songbirds at Feeders." *Journal of Ornithology* 157, no. 1 (April 2015): 239–48. https://doi.org/10.1007/s10336-015-1272-8.

Haffey, William, Clark, Jeffrey A., Lewis, James, Sheppard, Christine, and Wehr, John. *Reducing Bird-glass Collisions: Testing Patterned Glass in a Novel Flight Tunnel*, 2014, ProQuest Dissertations and Theses. (Listed for future review.)

Hager, Stephen B., and Matthew E. Craig. "Bird-Window Collisions in the Summer Breeding Season." *PeerJ* 2 (2014). https://doi.org/10.7717/peerj.460.

Hager, Stephen B., Bradley J. Cosentino, and Kelly J. Mckay. "Scavenging Affects Persistence of Avian Carcasses Resulting from Window Collisions in an Urban Landscape." *Journal of Field Ornithology* 83, no. 2 (2012): 203-11.

Hager, Stephen, Bradley Cosentino, Kelly McKay, Cathleen Monson, Walt Zuurdeeg, and Brian Blevins. "Window Area and Development Drive Spatial Variation in Bird-Window Collisions in an Urban Landscape." *PLoS One* 8, no. 1 (2013): E53371.

Hennen, Mary, Peggy Macnamara, and Stephanie Ware. *The Peregrine Returns: The Art and Architecture of an Urban Raptor Recovery*. Chicago, IL: The University of Chicago Press, 2017

Herrera-Dueñas, Amparo, Javier Pineda-Pampliega, María T. Antonio-García, and José I. Aguirre. "The Influence of Urban Environments on Oxidative Stress Balance: A Case Study on the House Sparrow in the Iberian Peninsula." *Frontiers in Ecology and Evolution* 5 (2017). https://doi.org/10.3389/fevo.2017.00106.

iNaturalist. "City Nature Challenge 2020's Journal." iNaturalist. Accessed April 7, 2020. https://www.inaturalist.org/projects/city-nature-challenge-2020/journal.

International Institute for Environment and Development*, The Brundtland Report: Seizing the Opportunity: IIED Thoughts towards the Follow-up of the WCED Report "Our Common Future* (London, UK: International Institute for Environment and Development, 1987).

International Living Future Institute, *Living Building Challenge 4.0* (Seattle, WA: International Living Future Institute, 2019)

Kellert, Stephen R. *Building for Life Designing and Understanding the Human-Nature Connection*. Washington, DC: Island Press, 2012.

Kellert, Stephen R., Judith Heerwagen, and Martin Mador. *Elements of Biophilic Design: The Theory, Science, and Practice of Bringing Buildings to Life*. Hoboken, NJ: Wiley, 2008.

Kensek, Karen, Ye Ding, and Travis Longcore. “Green Building and Biodiversity: Facilitating Bird Friendly Design with Building Information Models.” *Journal of Green Building* 11, no. 2 (2016): 116–30. https://doi.org/10.3992/jgb.11.2.116.1.

Ketterson, Ellen. “Journey of the Juncos: Migration and Adaptation in Our Changing World.” *Bird Academy, Cornell University*. Lecture presented at the Journey of the Juncos: Migration and Adaptation in Our Changing World, October 7, 2019. https://academy.allaboutbirds.org/live-event/journey-of-the-juncos-migration-and-adaptation-in-our-changing-world%e2%80%af/#_ga=2.48126575.999856792.1592535093-1527917869.1578965765.

Keystone Energy Tools. “Conventional Oil vs. Unconventional Oil.” Keystone Energy Tools, May 26, 2020. https://www.keystoneenergytools.com/conventional-oil-vs-unconventional-oil/.

Klem, Daniel, and Peter G. Saenger. “Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions.” *The Wilson Journal of Ornithology* 125, no. 2 (2013): 406–11. https://doi.org/10.1676/12-106.1.

Klem, Daniel, Christopher J. Farmer, Nicole Delacretaz, Yigal Gelb, and Peter G. Saenger. "Architectural and Landscape Risk Factors Associated with Bird—Glass Collisions in an Urban Environment." *The Wilson Journal of Ornithology* 121, no. 1 (2009): 126-34.

Klem, Daniel, David C. Keck, Karl L. Marty, Amy J. Miller Ball, Elizabeth E. Niciu, and Corry T. Platt. "Effects of Window Angling, Feeder Placement, and Scavengers on Avian Mortality at Plate Glass." *The Wilson Bulletin* 116, no. 1 (2004): 69-73.

Klem, Daniel. "Avian Predators Hunting Birds Near Windows." *Proceedings of the Pennsylvania Academy of Science* 55, no. 1 (1981): 90-92.

---. “Audubon Chapter of Minneapolis’ Session on the U.S. Bank Stadium.” *Audubon Chapter of Minneapolis’ Session on the U.S. Bank Stadium*. March 23, 2018. https://www.youtube.com/watch?v=z2HssOtP1JQ&feature=youtu.be.

---. "Bird-Window Collisions." *The Wilson Bulletin* 101, no. 4 (1989): 606-620.

---. "Bird-Window Collisions: A Critical Animal Welfare and Conservation Issue." *Journal of Applied Animal Welfare Science: Advancing Zoo Animal Welfare Science and Policy: Selected Papers from the Detroit Zoological Society 3rd International Symposium (November 2014)* 18, no. Sup1 (2015): S11-17.

---. *Biology of Collisions Between Birds and Windows*, 1979, ProQuest Dissertations and Theses. (Listed for future review.)

---. "Collisions Between Birds and Windows: Mortality and Prevention." *Journal of Field Ornithology* 61, no. 1 (1990): 120–28.

---. "Landscape, Legal, and Biodiversity Threats That Windows Pose to Birds: A Review of an Important Conservation Issue." *Land (Basel)* 3, no. 1 (2014): 351-61.

---. "Preventing Bird–Window Collisions." *The Wilson Journal of Ornithology* 121, no. 2 (2009): 314-21.

Köhler, Manfred. "Green Facades - A View Back and Some Visions." *Urban Ecosystems* 11, no. 4 (2008): 423–36. https://doi.org/10.1007/s11252-008-0063-x.

Lao, Sirena, Bruce A. Robertson, Abigail W. Anderson, Robert B. Blair, Joanna W. Eckles, Reed J. Turner, and Scott R. Loss. "The Influence of Artificial Light at Night and Polarized Light on Bird-Building Collisions." *Biological Conservation* 241 (2020): 108358. https://doi.org/10.1016/j.biocon.2019.108358.

The Legend of Pale Male. DVD. USA: Distribber, 2009.

Lepczyk, Christopher A., and Paige S. Warren. *Urban Bird Ecology and Conservation*. Berkeley; Los Angeles; London: Cooper Ornithological Society, 2012.

Longcore, Travis, Catherine Rich, Pierre Mineau, Beau Macdonald, Daniel G. Bert, Lauren M. Sullivan, Erin Mutrie, et al. "Avian Mortality at Communication Towers in the United States and Canada: Which Species, How Many, and Where." *Biological Conservation* 158 (2013): 410–19. https://doi.org/10.1016/j.biocon.2012.09.019.

Loss, Scott R., Sirena Lao, Joanna W. Eckles, Abigail W. Anderson, Robert B. Blair, and Reed J. Turner. "Factors Influencing Bird-Building Collisions in the Downtown Area of a major North American City." *Plos One* 14, no. 11 (2019). https://doi.org/10.1371/journal.pone.0224164.

Loss, Scott R., Tom Will, Sara S. Loss, and Peter P. Marra. "Bird–Building Collisions in the United States: Estimates of Annual Mortality and Species Vulnerability." *The Condor* 116, no. 1 (2014): 8–23. https://doi.org/10.1650/condor-13-090.1.

Lowther, P. E. and J. M. Williams (2020). Nashville Warbler (*Leiothlypis ruficapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Marzluff, John M., and Amanda D. Rodewald. "Conserving Biodiversity in Urbanizing Areas: Nontraditional Views from a Bird's Perspective." *Cities and the Environment* 1, no. 2 (2008): 1–27. https://doi.org/10.15365/cate.1262008.

Marzluff, John M., Jack H. Delap, M. David Oleyar, Kara A. Whittaker, and Beth Gardner. "Breeding Dispersal by Birds in a Dynamic Urban Ecosystem." *Plos One* 11, no. 12 (2016). https://doi.org/10.1371/journal.pone.0167829.

Marzluff, John, M. Clucas, Barbara Oleyar, and David DeLap. "The Causal Response of Avian Communities to Suburban Development: A Quasi-experimental, Longitudinal Study." *Urban Ecosystems* 19, no. 4 (2016): 1597-621.

McCabe, Jennifer D., He Yin, Jennyffer Cruz, Volker Radeloff, Anna Pidgeon, David N. Bonter, and Benjamin Zuckerberg. "Prey Abundance and Urbanization Influence the Establishment of Avian Predators in a Metropolitan Landscape." *Proceedings of the Royal Society B: Biological Sciences* 285, no. 1890 (2018): 20182120. https://doi.org/10.1098/rspb.2018.2120.

Minnesota Building, Benchmarks & Beyond, *Guideline S.9: Bird-Safe Building* (Saint Paul, MN: Regents of the University of Minnesota, 2017), https://www.b3mn.org/guidelines/3-0/s_9/.

Minnesota United FC. "Allianz Field Is for the Birds." Minnesota United FC, December 16, 2019. https://www.mnufc.com/post/2019/02/11/allianz-field-birds.

Morrison, Michael L. *Ornithology: Foundation, Analysis, and Application*. Baltimore, MD: Johns Hopkins University Press, 2018.

Mostrom, A. M., L. Curry, and B. Lohr. "Carolina Chickadee (Poecile carolinensis), Version 1.0." Ithaca, NY, 2020. Carolina Chickadee.

Narango, Desirée L., Douglas W. Tallamy, and Peter P. Marra. "Nonnative Plants Reduce Population Growth of an Insectivorous Bird." *Proceedings of the National Academy of Sciences* 115, no. 45 (2018): 11549–54. https://doi.org/10.1073/pnas.1809259115.

Nardone, Johnnae. "About Us." Tracy Aviary. Tracy Aviary, November 11, 2019. https://tracyaviary.org/about.

National Audubon Society. "About Us." Audubon. Accessed April 7, 2020. https://www.audubon.org/about.

---. “Existing Lights Out Programs.” Audubon, January 15, 2020. https://www.audubon.org/conservation/existing-lights-out-programs.

The National Aviary. “The National Aviary.” The National Aviary - About Us. Accessed April 7, 2020. https://www.aviary.org/about-us.

The New York City Council. *Bird Friendly Materials.* Committee on Housing and Buildings. Int 1482-2019. New York City, NY: The New York City Council, 2019. https://legistar.council.nyc.gov/LegislationDetail.aspx?ID=3903501&GUID=21B44B73-D7E1-4C55-83BD-1CA254531416&Options=&Search= (Accessed April 2nd, 2020).

Neimark, Peninah, and Peter Rhoades Mott. *The Environmental Debate: A Documentary History with Timeline, Glossary, and Appendices*. Amenia, NY: Grey House Publishing, 2017.

Newman, Melissa M., Pamela J. Yeh, and Trevor D. Price. “Reduced Territorial Responses in Dark-Eyed Juncos Following Population Establishment in a Climatically Mild Environment.” *Animal Behaviour* 71, no. 4 (2006): 893–99. https://doi.org/10.1016/j.anbehav.2005.08.007.

Nolan Jr., V., E. D. Ketterson, D. A. Cristol, C. M. Rogers, E. D. Clotfelter, R. C. Titus, S. J. Schoech, and E. Snajdr (2020). Dark-eyed Junco (JUNCO HYEMALIS), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.daejun.01

Ocampo-Peñuela, Natalia, R. Scott Winton, Charlene J. Wu, Erika Zambello, Thomas W. Wittig, and Nicolette L. Cagle. “Patterns of Bird-Window Collisions Inform Mitigation on a University Campus.” *PeerJ* 4 (2016): 1–16. https://doi.org/10.7717/peerj.1652.

Ogden, Andrews G. “Dying for a Solution: Incidental Taking under the Migratory Bird Treaty Act.” William and Mary Environmental Law and Policy Review 38, no. 1 (2013): 80.

Ogden, L. J. Evans. “Does Green Building Come up Short in Considering Biodiversity?: Focus on a Growing Concern.” *BioScience* 64, no. 2 (2014): 83–89. https://doi.org/10.1093/biosci/bit019.

---. Rep. *Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds*. Toronto, Ontario: WWF, 1996.

Opar, Alisa. “Minnesota’s Newest Sports Stadiums Take Very Different Approaches to Bird Safety.” Audubon, October 24, 2018. https://www.audubon.org/news/minnesotas-newest-sports-stadiums-take-very-different-approaches-bird-safety.

Opoku, Alex. “Biodiversity and the Built Environment: Implications for the Sustainable Development Goals (SDGs).” *Resources, Conservation and Recycling* 141 (2019): 1–7. https://doi.org/10.1016/j.resconrec.2018.10.011.

ORNILUX. “The Clear Solution.” Welcome | ORNILUX Bird Protection Glass. Accessed April 6, 2020. http://ORNILUX.com/.

Overing, Robert. “High Mortality at the Washington Monument.” *The Auk* 55, no. 4 (1938): 679–79. https://doi.org/10.2307/4078616.

Parkins, Kaitlyn L., Susan B. Elbin, and Elle Barnes. “Light, Glass, and Bird Building Collisions in an Urban Park.” *Northeastern Naturalist* 22, no. 1 (2015): 84-94.

PAWS. “Songbirds.” PAWS. Accessed April 7, 2020. https://www.paws.org/resources/songbirds/.

The Peregrine Fund. “Mission and Vision: The Peregrine Fund.” Mission and Vision | The Peregrine Fund. Accessed April 7, 2020. https://peregrinefund.org/mission-and-vision.

Porneluzi, P., M. A. Van Horn, and T. M. Donovan (2020). Ovenbird (*Seiurus aurocapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Rebolo-Ifrán, Natalia, Agustina Di Virgilio, and Sergio A. Lambertucci. “Drivers of Bird-Window Collisions in Southern South America: A Two-Scale Assessment Applying Citizen Science.” *Scientific Reports* 9, no. 1 (2019). https://doi.org/10.1038/s41598-019-54351-3.

Rep. *An Unconventional Oasis: Sustainability Report 2019*, 2019. https://issuu.com/javitscenter/docs/8725_javits_sustainabilityreport201.

Rep. *The National Survey of Fishing, Hunting, and Wildlife-Associated Recreation*, 2016. https://www.census.gov/library/publications/2018/demo/fhw-16-nat.html.

Rep. *World Population Prospects 2019: Highlights*, July 2019. https://population.un.org/wpp/Publications/Files/WPP2019_10KeyFindings.pdf.

Rich, Catherine, and Travis Longcore. *Ecological Consequences of Artificial Night Lighting*. Island Press, 2013.

Riding, Corey S., and Scott R. Loss. “Factors Influencing Experimental Estimation of Scavenger Removal and Observer Detection in Bird-Window Collision Surveys.” *Ecological Applications* 28, no. 8 (2018): 2119–29. https://doi.org/10.1002/eap.1800.

Riding, Corey, Loss, Scott, O'Connell, Timothy, Grindstaff, Jennifer, and Baum, Kristen. *Factors Affecting Bird-Window Collisions in a Small Urban Area: Stillwater, Oklahoma*, 2019, ProQuest Dissertations and Theses.

Rimmer, C. C. and K. P. McFarland (2020). Tennessee Warbler (*Leiothlypis peregrina*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Rosenberg, Kenneth V, Dokter, Adriaan M, Blancher, Peter J, Sauer, John R, Smith, Adam C, Smith, Paul A, Stanton, Jessica C, et al. 2019. "Decline of the North American Avifauna." *Science (New York, N.Y.)* 366 (6461): 120–24.

Rössler, Martin, Erwin Nemeth, and Alexander Bruckner. "Glass Pane Markings to Prevent Bird-Window Collisions: Less Can Be More." *Biologia* 70, no. 4 (2015). https://doi.org/10.1515/biolog-2015-0057.

Ryan, Denise. "Bird-Friendly Windows Reduce Collision Deaths at UBC." Vancouver Sun. Vancouver Sun, April 29, 2019. https://vancouversun.com/news/local-news/bird-friendly-windows-reduce-collision-deaths-at-ubc.

Sabo, Ann M., Natasha D.g. Hagemeyer, Ally S. Lahey, and Eric L. Walters. "Local Avian Density Influences Risk of Mortality from Window Strikes." *PeerJ* 4 (2016). https://doi.org/10.7717/peerj.2170.

Saha, Purbita. "Lights Out for the Texas Skyscraper That Caused Hundreds of Songbird Deaths." Audubon, July 2, 2019. https://www.audubon.org/news/lights-out-texas-skyscraper-caused-hundreds-songbird-deaths.

San Francisco Planning Department, *Standards for Bird-Safe Buildings*, Ordinance No. 199-11 (San Francisco, CA: San Francisco Planning Department, 2019), https://sfplanning.org/standards-bird-safe-buildings.

Schmid H. & Sierro A. Untersuchungen zur Verhutung von Vogelkollisionen an transparenten Larmschutzwanden [Test of measures to prevent bird-strikes on transparent noise-protection walls]. *Natur und Landschaft* 75 (2000): 426–430.

Schneider, Rebecca M., Christine M. Barton, Keith W. Zirkle, Caitlin F. Greene, and Kara B. Newman. "Year-Round Monitoring Reveals Prevalence of Fatal Bird-Window Collisions at the Virginia Tech Corporate Research Center." *PeerJ* 6 (2018). https://doi.org/10.7717/peerj.4562.

Sheppard, Christine and Glenn Phillips. Bird-Friendly Building Design, 2nd Ed. (The Plains, VA: American Bird Conservancy, 2015)

Sheppard, Christine D. "Evaluating the Relative Effectiveness of Patterns on Glass as Deterrents of Bird Collisions with Glass." *Global Ecology and Conservation* 20 (2019): 1–10. https://doi.org/10.1016/j.gecco.2019.e00795.

Slabbekoorn, Hans, and Margriet Peet. "Birds Sing at a Higher Pitch in Urban Noise." *Nature* 424, no. 6946 (2003): 267. https://doi.org/10.1038/424267a.

Stefanovic, Ingrid Leman, and Stephen Bede Scharper. *The Natural City Re-Envisioning the Built Environment*. Toronto, ON: University of Toronto Press, 2014. Hartwig, Melinda K. *A Companion to Ancient Egyptian Art*. Oxfordshire, England: Wiley-Blackwell, 2015

Studio Gang. "Ford Calumet Environmental Center." Studio Gang. Accessed April 7, 2020. https://studiogang.com/project/ford-calumet-environmental-center.

---. "University of Chicago Campus North Residential Commons." Studio Gang. Accessed April 7, 2020. https://studiogang.com/project/university-of-chicago-campus-north-residential-commons.

Swaddle, John P., and Nicole M. Ingrassia. "Using a Sound Field to Reduce the Risks of Bird-Strike: An Experimental Approach." *Integrative and Comparative Biology* 57, no. 1 (2017): 81–89. https://doi.org/10.1093/icb/icx026. (Listed for future review.)

Therrien, Jean-François, Weidensaul, Scott, Brinker, David, Huy, Steve, Miller, Trish, Jacobs, Eugene, Weber, Drew, McDonald, Tom, Lanzone, Mike, Smith, Norman, and Lecomte, Nicolas. "Winter Use of a Highly Diverse Suite of Habitats by Irruptive Snowy Owls." *Northeastern Naturalist* 24, no. Sp7 (2017): B81-89.

Tracy Aviary. "Lights Out Salt Lake." Tracy Aviary Conservation Science. Accessed April 7, 2020. http://www.tracyaviaryconservation.org/lightsoutsaltlake.

---. "Salt Lake Avian Collision Survey." Tracy Aviary Conservation Science. Accessed April 7, 2020. http://www.tracyaviaryconservation.org/slacs.

U.S. Congress. 2019. 116th Congress H.R. 919 (Introduced in the House), Bird-Safe Buildings Act of 2019, Bill Text. https://search.proquest.com/congressional/view/app-gis/billtext/116_hr_919_ih.

U.S. Fish & Wildlife Service. “Aircraft.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed March 2, 2020. https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/aircrafts.php.

---. “Communication Towers.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed April 1, 2020. https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/communication-towers.php.

---. “Electric Utility Lines.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed April 1, 2020. https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/electric-utility-lines.php.

---. “Migratory Bird Treaty Act.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed April 7, 2020. https://www.fws.gov/birds/policies-and-regulations/laws-legislations/migratory-bird-treaty-act.php.

---. “Road Vehicles.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed March 3, 2020. https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/road-vehicles.php.

---. “Urban Bird Treaty.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed April 7, 2020. https://www.fws.gov/birds/grants/urban-bird-treaty.php.

---. “Wind Turbines.” U.S. Fish & Wildlife Service - Department of the Interior. Accessed March 1, 2020. https://www.fws.gov/birds/bird-enthusiasts/threats-to-birds/collisions/wind-turbines.php.

U.S. Fish and Wildlife Service/Endangered Species Program. “Endangered Species Act: Overview.” Official Web page of the US Fish and Wildlife Service. Accessed June 7, 2020. https://www.fws.gov/endangered/laws-policies/.

U.S. General Services Administration. “About CitizenScience.gov.” CitizenScience.gov. Accessed April 7, 2020. https://www.citizenscience.gov/about/#.

U.S. Green Building Council. “Bird Collision Deterrence.” U.S. Green Building Council. Accessed April 7, 2020. https://www.usgbc.org/credits/new-construction-core-and-shell-schools-new-construction-retail-new-construction-healthc-212?view=language.

---. “Tracy Aviary Avian Health Center.” U.S. Green Building Council. Accessed April 7, 2020. https://www.usgbc.org/projects/tracy-aviary-avian-health-center.

---. "USGBC Site Development - Protect and Restore Habitat." U.S. Green Building Council. Accessed October 1, 2019. http://www.usgbc.org/credits/ss51.

UC Davis Veterinary Medicine. "School of Veterinary Medicine." School of Veterinary Medicine. Accessed April 7, 2020. https://crc.vetmed.ucdavis.edu/.

The University of British Columbia, *Annual Sustainability Report* (Vancouver, BC: University of British Columbia, 2018-19), https://annualreport.ubc.ca/.

---, *UBC Bird Friendly Design Guidelines* (Vancouver, BC: University of British Columbia, 2019),https://sustain.ubc.ca/sites/default/files/files/3276_UBC_BirdFriendlyDesignGuidelines.pdf.

University of Minnesota's College of Design, *Code of Ordinances,* Article XIII – Skyways (Saint Paul, MN: University of Minnesota, 2016).

USAGov. "Migratory Bird Conservation Commission." USAGov, 2020. https://www.usa.gov/federal-agencies/migratory-bird-conservation-commission.

Veltri, Carl J., and Daniel Klem. "Comparison of Fatal Bird Injuries from Collisions with Towers and Windows." *Journal of Field Ornithology* 76, no. 2 (2005): 127-33.

View. "Electrochromic (Smart Glass)." View, Inc. Accessed November 1, 2019. https://view.com/product/how-it-works.

Viracon. "Tech Talks." Viracon. Accessed April 7, 2020. https://viracon.com/page/tech-talks.

Walker Glass. "Transparent Bird Friendly Glass: AviProtek T." Verrerie Walker. Accessed April 7, 2020. https://www.walkerglass.com/products/transparent-bird-friendly-glass/.

---. "Velour Acid-Etched Glass." Verrerie Walker. Accessed April 7, 2020. https://www.walkerglass.com/products-options/velour/.

Watts, Amanda, and Eric Levenson. "Over 300 Migrating Birds Smashed into Charlotte's NASCAR Building." CNN, October 16, 2019. https://www.cnn.com/2019/10/16/us/birds-nascar-building-trnd/index.html.

White, Justin H, Jeremy M Smith, Scott D Bassett, Jessi L Brown, and Zachary E Ormsby. "Raptor Nesting Locations along an Urban Density Gradient in the Great Basin, USA." *Urban Ecosystems* 21, no. 1 (2017): 51–60. https://doi.org/10.1007/s11252-017-0705-y.

Window Alert. "Classic Square Decal Envelope - 4 Decals." WindowAlert. Accessed April 7, 2020. https://windowalert.com/classic-square-decal-envelope-4-decals/.

Winn, Marie. *Red-Tails in Love: Pale Male's Story: A True Wildlife Drama in Central Park*. New York, NY: Vintage Departures, 2005

Winton, R. Scott, Natalia Ocampo-Peñuela, and Nicolette Cagle. "Geo-Referencing Bird-Window Collisions for Targeted Mitigation." *PeerJ* 6 (2018): 1–10. https://doi.org/10.7717/peerj.4215.

Wittig, Thomas W., Nicolette L. Cagle, Natalia Ocampo-Peñuela, R Scott Winton, Erika Zambello, and Zane Lichtneger. "Species Traits and Local Abundance Affect Bird-Window Collision Frequency." *Avian Conservation and Ecology* 12, no. 1 (2017). https://doi.org/10.5751/ace-01014-120117.

Yeh, Pamela J. "Rapid Evolution of a Sexually Selected Trait Following Population Establishment in A Novel Habitat." *Evolution* 58, no. 1 (2004): 166. https://doi.org/10.1554/03-182.

Yeh, Pamela J., and Trevor D. Price. "Adaptive Phenotypic Plasticity and the Successful Colonization of a Novel Environment." *The American Naturalist* 164, no. 4 (2004): 531–42. https://doi.org/10.1086/423825.

FIGURE CREDITS

Cover Image © Judy Bowes

Figure 1
Top: Louvre, Paris. Bottom Left: Egyptian Museum, Cairo. Bottom Right: *In Between Heaven and Earth.* The Oriental Institute: Chicago, 2012

Figure 2
Left: The Legend of Pale Male (Distribber, 2009), https://www.thelegendofpalemale.net/. Right: Special Projects @ Dan Ionescu Architects. Accessed April 25, 2020. https://www.diarch.net/projects/special-projects/.

Figure 3
Top Left: Hildebrand, Frank. 2019. *KCRW*. https://www.kcrw.com/news/shows/press-play-with-madeleine-brand/finding-all-the-biodiversity-in-la. Top Right: Clark, Kathy. 2013. *ENSP*. http://www.conservewildlifenj.org/blog/2013/12/30/save-the-jersey-city-falcon-cam/. Bottom Left and Right: Hennen, Mary, Peggy Macnamara, and Stephanie Ware. *The Peregrine Returns: The Art and Architecture of an Urban Raptor Recovery*. Chicago, IL: The University of Chicago Press, 2017.

Figure 4
Top and Bottom Right: Cudmore, Becca. "Peregrines-and a Photographer-Bunk Out at Chicago Man's Apartment." Audubon, July 14, 2016. https://www.audubon.org/news/peregrines-and-photographer-bunk-out-chicago-mans-apartment.
Bottom Left: Falcons nest on Nebraska state capitol building -- again. Accessed April 25, 2020. https://www.outdoors720.com/2011/04/falcons-nest-on-nebraska-state-capitol.html.

Figure 5
Author, 2020.

Figure 6
Author, 2020.

Figure 7
Greenroofs. "Drew School Sam Cuddleback III Assembly Wing Vertical Garden." Greenroofs.com, 2020. https://www.greenroofs.com/projects/drew-school-sam-cuddleback-iii-assembly-wing-vertical-garden.

Figure 8
Left: 2020. *Henry Ford*. https://www.thehenryford.org/visit/ford-rouge-factory-tour/highlights/living-roof.
Top Right: Altman, B. and R. Sallabanks (2020). Olive-sided Flycatcher (*Contopus cooperi*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.olsfly.01
Bottom Right: Killdeer (*Charadrius vociferus*), Kelly Luckett
https://www.urbanstrong.com/green-roof-habitat-for-the-birds/

Figure 9
Rep. *An Unconventional Oasis: Sustainability Report 2019*, 2019.
https://issuu.com/javitscenter/docs/8725_javits_sustainabilityreport201.

Figure 10
Author, 2020.

Figure 11
Left: Bennet, Molly. "How New Technology Is Making Wind Farms Safer for Birds." Audubon, August 14, 2018. https://www.audubon.org/magazine/spring-2018/how-new-technology-making-wind-farms-safer-birds.
Right: Dwyer, James F., Thomas I. Hayes, Russel Thorstorm, and Richard E. Harness. "Retrofitting Power Poles to Prevent Electrocution of Translocated Ridgway's Hawks." *The Journal of Caribbean Ornithology* 32 (2019): 4–10.

Figure 12
Top Left: Author, 2020.
Bottom Left: "Wrecking Balmer: $47M to Replace Building at the UW." Seattle DJC.com local business news and data. Accessed March 25, 2020.
https://www.djc.com/news/co/12020748.html.
Top Right: Sheppard, Christine and Glenn Phillips. Bird-Friendly Building Design, 2nd Ed. (The Plains, VA: American Bird Conservancy, 2015). Bottom Right: "Parking Guides for Major U.S. Stadiums," Stadium Parking Guides, accessed April 1, 2020, https://stadiumparkingguides.com/.

Figure 13
Top Left: Alisa Opar, "Minnesota's Newest Sports Stadiums Take Very Different Approaches to Bird Safety," Audubon, October 24, 2018, https://www.audubon.org/news/minnesotas-newest-sports-stadiums-take-very-different-approaches-bird-safety. Bottom Left: Author, 2020. Right: Author, 2019.

Figure 14
W. G. Murray/Alamy. "NASCAR Hall of Fame." Digital image. Audubon. 2019. Accessed November 1st, 2019. https://www.audubon.org/news/hundreds-swifts-struck-nascar-hall-fame-last-night-97-died-impact

Figure 15
Merlin. "September 11th Lights." Digital image. New York Times. September 10th, 2019. Accessed November 1st, 2019. https://static01.nyt.com/images/2019/09/10/nyregion/10Sept11-Lights2-print/merlin_160151601_3bc46d81-3dfd-413f-a753-c774f4d8fd2a-jumbo.jpg

Figure 16
Left: Saha, Purbita. "Lights Out for the Texas Skyscraper That Caused Hundreds of Songbird Deaths." Audubon, July 2, 2019. https://www.audubon.org/news/lights-out-texas-skyscraper-caused-hundreds-songbird-deaths.
Right: Author, 2015.

Figure 17
Images and caption by Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a major North American City. PLoS ONE 14, no. 11 (2019), 12.

Figure 18
Guzy and Ritchison (2020). Common Yellowthroat (*Geothlypis trichas*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.
Rimmer and McFarland (2020). Tennessee Warbler (*Leiothlypis peregrina*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.
Lowther and Williams (2020). Nashville Warbler (*Leiothlypis ruficapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.
Porneluzi, P., M. A. Van Horn, and T. M. Donovan (2020). Ovenbird (*Seiurus aurocapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.
Falls, J. B. and J. G. Kopachena (2020). White-throated Sparrow (*Zonotrichia albicollis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.whtspa.01

Figure 19
Opar, Alisa. "Minnesota's Newest Sports Stadiums Take Very Different Approaches to Bird Safety." Audubon, October 24, 2018. https://www.audubon.org/news/minnesotas-newest-sports-stadiums-take-very-different-approaches-bird-safety.

Figure 20
Ogden, Lesley Evans. "Does Green Building Come up Short in Considering Biodiversity?: Focus on a Growing Concern." *BioScience* 64, no. 2 (2014): 83–89. https://doi.org/10.1093/biosci/bit019.

Figure 21
Author, 2020.

Figure 22
Rep. *An Unconventional Oasis: Sustainability Report 2019*, 2019. https://issuu.com/javitscenter/docs/8725_javits_sustainabilityreport201.

Figure 23
Author, 2020.

Figure 24
Author, 2020.

Figure 25
"Stanford University, Denning House." ennead, April 24, 2020. http://www.ennead.com/work/stanford-university-denning-house.

Figure 26
The University of British Columbia, *UBC Bird Friendly Design Guidelines* (Vancouver, BC: University of British Columbia, 2019), https://sustain.ubc.ca/sites/default/files/files/3276_UBC_BirdFriendlyDesignGuidelines.pdf.

Figure 27
Author, 2020.

Figure 28
Natalia Ocampo-Penuelas et al., "Patterns of Bird-window Collisions Inform Mitigation on a University Campus," PeerJ 4 (2016).

Figure 29
Left Top, Left Bottom, Right Bottom: GREEN ROOFS. “Jacob J. Javits Convention Center.” Digital images. GREEN ROOFS. 2014. Accessed 10/01/2019. https://www.greenroofs.com/projects/jacob-k-javits-convention-center/.
Right Top: Heintges. “Jacob J. Javits Convention Center.” Digital image. Heintges. 2018. Accessed 10/01/2019. https://heintges.com/jacob-javits-convention-center/

Figure 30
GREEN ROOFS. “Jacob J. Javits Convention Center.” Digital images. GREEN ROOFS. 2014. Accessed 10/01/2019. https://www.greenroofs.com/projects/jacob-k-javits-convention-center/

Figure 31
MNUFC. “Allianz Field.” Digital images. MNUFC. 2019. Accessed November 1st, 2019. https://www.mnufc.com/stadium

Figure 32
International Living Future Institute, *Living Building Challenge 4.0* (Seattle, WA: International Living Future Institute, 2019)

Figure 33
Author, 2020.

Figure 34
Studio Gang. “University of Chicago Campus North Residential Commons.” Studio Gang. Accessed April 7, 2020. https://studiogang.com/project/university-of-chicago-campus-north-residential-commons.

Figure 35
Studio Gang. “Ford Calumet Environmental Center.” Studio Gang. Accessed April 7, 2020. https://studiogang.com/project/ford-calumet-environmental-center.

Figure 36
The University of British Columbia, *UBC Bird Friendly Design Guidelines* (Vancouver, BC: University of British Columbia, 2019), https://sustain.ubc.ca/sites/default/files/files/3276_UBC_BirdFriendlyDesignGuidelines.pdf.

Figure 37
The University of British Columbia, *UBC Bird Friendly Design Guidelines* (Vancouver, BC: University of British Columbia, 2019), https://sustain.ubc.ca/sites/default/files/files/3276_UBC_BirdFriendlyDesignGuidelines.pdf.

Figure 38
Gambert, Daniel. “Picture Stockton Using Art to Save Birds.” Stockton University. Stockton University, November 21, 2019. https://stockton.edu/news/2019/picture-stockton-using-art-to-prevent-birds-from-striking-windows.html.

Figure 39
Glass on Web. “National Aviary Tropical Rainforest Featuring Acid-Etched STARPHIRE Glass Wins National Award for Exhibit Design.” glassonweb.com. glassonweb.com, October 2, 2019. https://www.glassonweb.com/news/national-aviary-tropical-rainforest-featuring-acid-etched-starphire-glass-wins-national-award.

Figure 40
Top: Scene, The Salt Lake. “Fun Things to Do with Kids in Salt Lake.” Salt Lake City Hotels, Restaurants, Events, Things to Do & Shopping. Visit Salt Lake, June 19, 2018. https://www.visitsaltlake.com/blog/stories/post/fun-things-to-do-with-kids-in-salt-lake/.
Bottom: U.S. Green Building Council. “Tracy Aviary Avian Health Center.” U.S. Green Building Council. Accessed April 7, 2020. https://www.usgbc.org/projects/tracy-aviary-avian-health-center.

Appendix 1
Loss et al., "Factors Influencing Bird-Building Collisions in the Downtown Area of a Major North American City.”: 15.

Appendix 2
Tables by the author.
Data in Table 1: Daniel Klem, "Preventing Bird–Window Collisions," *The Wilson Journal of Ornithology* 121, no. 2 (2009).
Data in Table 2: Daniel Klem and Peter G. Saenger, “Evaluating the Effectiveness of Select Visual Signals to Prevent Bird-Window Collisions,” *The Wilson Journal of Ornithology* 125, no. 2 (2013).

Appendix 3
Viracon. “Tech Talks,” Viracon, accessed April 7, 2020, https://viracon.com/page/tech-talks)
Bendheim. “Architectural Glass: Product Catalog,” Bendheim, accessed April 7, 2020, https://bendheim.com/professional/glass/).

Walker Glass. “Transparent Bird Friendly Glass: AviProtek T,” Verrerie Walker, accessed April 7, 2020, https://www.walkerglass.com/products/transparent-bird-friendly-glass/).
CollidEscape. “Prevent Birds Hitting Windows: CollidEscape,” CollidEscape 2020, accessed April 7, 2020, https://www.collidescape.org/).
Decorative Film. “Decorative Films: Window Film: Stained Glass: Privacy Film: Window Treatments,” Decorative Films, LLC., accessed April 7, 2020, https://www.decorativefilm.com/specialty-bird-safety).
Feather Friendly, “Feather Friendly,” https://www.featherfriendly.com, accessed April 7, 2020, https://www.featherfriendly.com/).
Window Alert. “Classic Square Decal Envelope - 4 Decals,” Window Alert, accessed April 7, 2020, https://windowalert.com/classic-square-decal-envelope-4-decals/).

Appendix 4
Marzluff, John M., and Amanda D. Rodewald. “Conserving Biodiversity in Urbanizing Areas: Nontraditional Views from a Bird’s Perspective.” *Cities and the Environment* 1, no. 2 (2008): 1–27. https://doi.org/10.15365/cate.1262008.

Appendix 5
Light Dark Sky Society. “Dark Sky Society - Home.” Dark Sky Society - Home. Accessed April 7, 2020. http://www.darkskysociety.org/.

Avian Species Index Image Credits:
Images by author:
(*Anas platyrhynchos*) mallards
(*Aquila chrysaetos*) golden eagle
(*Bombycilla cedrorum*) cedar waxwing
(*Bubo scandiacus*) snowy owl
(*Bubo virginianus*) great-horned owl
(*Buteo jamaicensis*) red-tailed hawk
(*Calypte anna*) Anna’s hummingbird
(*Cathartes aura*) turkey vulture
(*Corvus brachyrhynchos*) American crow
(*Falco peregrinus*) peregrine falcon
(*Falco sparverius)* American kestrel
(*Junco hyemalis*) dark-eyed junco
(*Strix varia*) barred owl
(*Turdus migratorius*) American robin
(*Tyto alba*) barn owl

(*Accipiter cooperii*) Cooper's hawk
Rosenfield, R. N., K. K. Madden, J. Bielefeldt, and O. E. Curtis (2020). Cooper's Hawk (*Accipiter cooperii*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.coohaw.01

(*Accipiter gentilis*) northern goshawk
Squires, J. R., R. T. Reynolds, J. Orta, and J. S. Marks (2020). Northern Goshawk (*Accipiter gentilis*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.norgos.01

(*Accipiter striatus*) sharp-shinned hawk
Bildstein, K. L., K. D. Meyer, C. M. White, J. S. Marks, and G. M. Kirwan (2020). Sharp-shinned Hawk (*Accipiter striatus*), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.shshaw.01

(*Athene cunicularia*) burrowing owl
Poulin, R. G., L. D. Todd, E. A. Haug, B. A. Millsap, and M. S. Martell (2020). Burrowing Owl (*Athene cunicularia*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.burowl.01

(*Baeolophus bicolor*) tufted titmouse
Ritchison, G., T. C. Grubb Jr., and V. V. Pravosudov (2020). Tufted Titmouse (*Baeolophus bicolor*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.tuftit.01

(*Buteo regalis*) ferruginous hawk
Ng, J., M. D. Giovanni, M. J. Bechard, J. K. Schmutz, and P. Pyle (2020). Ferruginous Hawk (*Buteo regalis*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.ferhaw.01

(*Buteo ridgwayi*) Ridgway's hawk
Anderson, D. L., R. Thorstrom, C. D. Hayes, and T. Hayes (2020). Ridgway's Hawk (*Buteo ridgwayi*), version 1.0. In Birds of the World (T. S. Schulenberg, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.ridhaw1.01

(*Cardinalis cardinalis*) northern cardinal
Halkin, S. L. and S. U. Linville (2020). Northern Cardinal (*Cardinalis cardinalis*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.norcar.01

(*Chaetura pelagica*) chimney swift
Steeves, T. K., S. B. Kearney-McGee, M. A. Rubega, C. L. Cink, and C. T. Collins (2020). Chimney Swift (*Chaetura pelagica*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.chiswi.01

(*Charadrius vociferous)* killdeer
Jackson, B. J. and J. A. Jackson (2020). Killdeer (*Charadrius vociferous*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.killde.01

(*Contopus cooperi*) olive-sided flycatcher
Altman, B. and R. Sallabanks (2020). Olive-sided Flycatcher (*Contopus cooperi*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.olsfly.01

(*Coturnicops noveboracensis*) yellow rail
Leston, L. and T. A. Bookhout (2020). Yellow Rail (COTURNICOPS NOVEBORACENSIS), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.yelrai.01

(*Garrulus glandarius*) Eurasian jay
Madge, S., J. del Hoyo, D. A. Christie, N. Collar, and G. M. Kirwan (2020). Eurasian Jay (*Garrulus glandarius*), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.eurjay1.01

(*Geothlypis trichas*) common yellowthroat
Guzy and Ritchison (2020). Common Yellowthroat (*Geothlypis trichas*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

(*Larus argentatus*) herring gull
GREEN ROOFS. "Jacob J. Javits Convention Center." Digital images. GREEN ROOFS. 2014. Accessed 10/01/2019. https://www.greenroofs.com/projects/jacob-k-javits-convention-center/

(*Leiothlypis peregrina*) Tennessee warbler
Rimmer and McFarland (2020). Tennessee Warbler (*Leiothlypis peregrina*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

(*Leiothlypis ruficapilla*) Nashville warbler
Lowther and Williams (2020). Nashville Warbler (*Leiothlypis ruficapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

(*Limnothlypis swainsonii*) Swainson's warbler
Anich, N. M., T. J. Benson, J. D. Brown, C. Roa, J. C. Bednarz, R. E. Brown, and J. G. Dickson (2020). Swainson's Warbler (*Limnothlypis swainsonii*), version 1.0. In Birds of the World (P. G. Rodewald, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.swawar.01

(*Parabuteo unicinctus*) Harris's hawk
Dwyer, J. F. and J. C. Bednarz (2020). Harris's Hawk (*Parabuteo unicinctus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.hrshaw.01

(*Parus major*) great tit
Gosler, A., P. Clement, and D. A. Christie (2020). Great Tit (*Parus major*), version 1.0. In Birds of the World (S. M. Billerman, B. K. Keeney, P. G. Rodewald, and T. S. Schulenberg, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.gretit1.01

(*Passer domesticus*) house sparrow
Lowther, P. E. and C. L. Cink (2020). House Sparrow (*Passer domesticus*), version 1.0. In Birds of the World (S. M. Billerman, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.houspa.01

(*Phoenicurus ochruros*) black redstart
Collar, N. (2020). Black Redstart (*Phoenicurus ochruros*), version 1.0. In Birds of the World (J. del Hoyo, A. Elliott, J. Sargatal, D. A. Christie, and E. de Juana, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.blared1.01

(*Poecile carolinensis*) Carolina chickadee
Mostrom, A. M., R. L. Curry, and B. Lohr (2020). Carolina Chickadee (*Poecile carolinensis*), version 1.0. In Birds of the World (A. F. Poole and F. B. Gill, Editors). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.carchi.01

(*Seiurus aurocapilla*) ovenbird
Porneluzi, P., M. A. Van Horn, and T. M. Donovan (2020). Ovenbird (*Seiurus aurocapilla*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

(*Sialia mexicana*) Western bluebird
Guinan, J. A., P. A. Gowaty, and E. K. Eltzroth (2020). Western Bluebird (*Sialia mexicana*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.wesblu.01

(*Sialia sialis*) Eastern bluebird
Gowaty, P. A. and J. H. Plissner (2020). Eastern Bluebird (*Sialia sialis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.easblu.01

(*Troglodytes pacificus*) Pacific wren
Toews, D. P. L. and D. E. Irwin (2020). Pacific Wren (*Troglodytes pacificus*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.pacwre1.01

(*Zonotrichia albicollis*) white-throated sparrow
Falls, J. B. and J. G. Kopachena (2020). White-throated Sparrow (*Zonotrichia albicollis*), version 1.0. In Birds of the World (A. F. Poole, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA. https://doi-org.offcampus.lib.washington.edu/10.2173/bow.whtspa.01