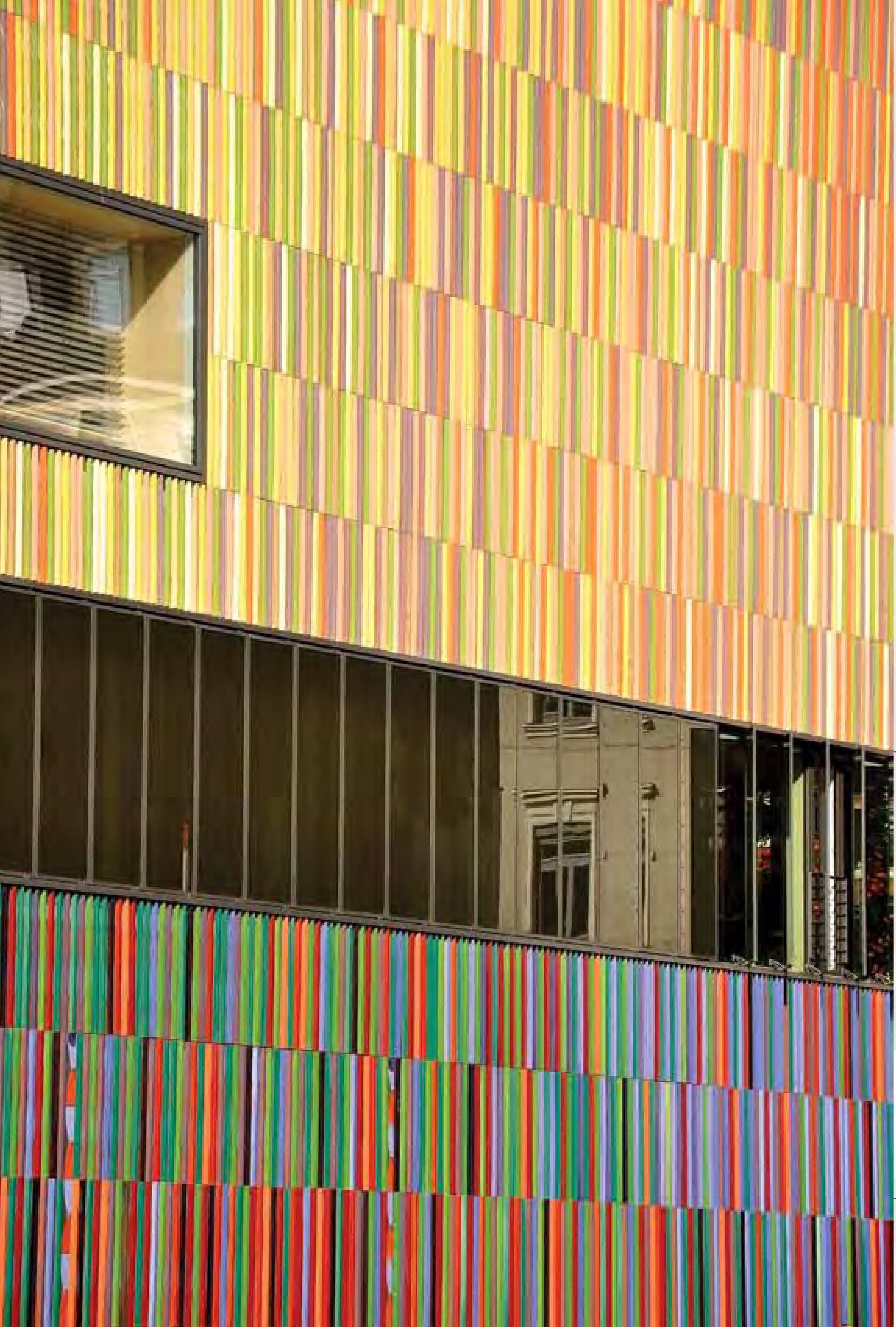
Bird-Friendly Building Design



The area of glass on a façade is the strongest predictor of threat to birds. The façade of Sauerbruch Hutton's Brandhorst Museum in Munich is a brilliant example of the creative use of non-glass materials. Photos: Tony Brady (left), Anton Schedlbauer (background)

The following have endorsed this document as the most current source for information about bird collisions:

Chicago Ornithological Society · NH Audubon · Lights Out Indy · Forsyth Audubon · Chicago Bird Collision Monitors · Safe Passage Great Lakes · New York City Audubon · Audubon Society of Portland · Bird-Safe Glass Foundation · FXFOWLE · Prendergast Laurel Architects

ORNILUX Bird Protection Glass by Arnold Glas

The cost of printing *ABC's Bird-Friendly Building Design* guidebook was supported by a generous grant from Arnold Glas, manufacturer of ORNILUX Bird Protection Glass. The funder had no role in the study design, data collection and analysis, decision to publish, or preparation of this document.

(Front cover) Boris Pena's Public Health Office building in Mallorca, Spain, sports a galvanized, electro-fused steel façade. Photo courtesy of Boris Pena

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Ruby-throated Hummingbird: Greg Lavaty

For updates and new information, see **collisions.abcbirds.org**

41 Cooper Square in New York City, by Morphosis Architects, features a skin of perforated steel panels fronting a glass/aluminum window wall. The panels reduce heat gain in summer and add insulation in winter while also making the building safer for birds. Photo: Christine Sheppard, ABC

Issues of cost prompted Hariri Pontarini Architects, in a joint venture with Robbie/Young + Wright Architects, to revise a planned glass and limestone façade on the School of Pharmacy building at the University of Waterloo, Canada. The new design incorporates watercolors of medicinal plants as photo murals. Photo: Anne H. Cheung

Executive Summary

Collision with glass is the single biggest known killer of birds in the United States, claiming hundreds of millions or more lives each year. Unlike some sources of mortality that predominantly kill weaker individuals, there is no distinction among victims of glass. Because glass is equally dangerous for strong, healthy, breeding adults, it can have a particularly serious impact on populations.

Bird kills at buildings occur across the United States. We know more about mortality patterns in cities, because that is where most monitoring takes place, but virtually any building with glass poses a threat wherever it is. The dead birds documented by monitoring programs or turned in to museums are only a fraction of the birds actually killed. The magnitude of this problem can be discouraging, but there are solutions if people can be convinced to adopt them.

In recent decades, advances in glass technology and production have made it possible to construct buildings with all-glass curtain walls, and we have seen a general increase in the amount of glass used in construction. Constructing bird-friendly buildings and eliminating the worst existing threats requires imaginative design and recognition that not only do birds have a right to exist, but their continued existence is a value to humanity.

New construction can incorporate bird-friendly design strategies from the beginning. However, there are many ways to reduce mortality from existing buildings, with more solutions being developed all the time. Because the science is constantly evolving, and because we will always wish for more information than we have, the temptation is to postpone action in the hope that a panacea is just round the corner, but we can't wait to act. We have the tools and the strategies to make a difference now. Architects, designers, city planners, and legislators are key to solving this problem. They not only have access to the latest building construction materials and concepts, they are also thought leaders and trend setters in the way we build our communities and prioritize building design issues.

A bird, probably a dove, hit the window of an Indiana home hard enough to leave this ghostly image on the glass. Photo: David Fancher

This publication, originally produced by the NYC Audubon Society, and reconceived by American Bird Conservancy (ABC), aims to provide planners, aims to provide planners, architects, designers, bird advocates, local authorities, and the general public with a clear understanding of the nature and magnitude of the threat glass poses to birds. This edition includes a review of the science behind available solutions, examples of how those solutions can be applied to new construction and existing buildings, and an explanation of what information is still needed. We hope it will spur individuals, businesses, communities, and governments to address this issue and make their buildings safe for birds.

ABC's Collisions Program works at the national level to reduce bird mortality by coordinating with local organizations, developing educational programs and tools, conducting research, developing centralized resources, and generating awareness of the problem.

Introduction

Why Birds Matter

For many people, birds and nature have intrinsic worth. Birds have been important to humans throughout history, often used to symbolize cultural values such as peace, freedom, and fidelity.

In addition to the pleasure they can bring to people, we depend on them for critical ecological functions. Birds consume vast quantities of insects, and control rodent populations, reducing damage to crops and forests, and helping limit the transmission of diseases such as West Nile virus, dengue fever, and malaria. Birds play a vital role in regenerating habitats by pollinating plants and dispersing seeds.

Birds are also a vast economic resource. According to the U.S. Fish and Wildlife Service, bird watching is one of the fastest growing leisure activities in North America, and a multi-billion-dollar industry.

The Legal Landscape

At the start of the 20th Century, following the extinction of the Passenger Pigeon and the near extinction of other bird species due to unregulated hunting, laws were passed to protect bird populations. Among them was the Migratory Bird Treaty Act (MBTA), which made it illegal to kill a migratory bird without a permit. The scope of this law, which is still in effect today, extends beyond hunting, such that anyone causing the death of a migratory bird, even if unintentionally, can be prosecuted if that death is deemed to have been foreseeable. This may include bird deaths due to collisions with glass, though there have yet to be any prosecutions in the United States for such incidents. Violations of the MBTA can result in fines of up to $500 per incident and up to six months in prison.

The Bald and Golden Eagle Protection Act (originally the Bald Eagle Protection Act of 1940), the Endangered Species Act (1973), and the Wild Bird Conservation Act (1992) provide further protections for birds that may be relevant to building collisions.

Recent legislation, primarily at the city and state level, has addressed the problem of mortality from building collisions and light pollution. Cook County, Illinois, San Francisco, California, Toronto, Canada, and the State of Minnesota have all passed laws or ordinances aimed at reducing bird kills, while other authorities have pushed for voluntary measures.

The International Dark Skies Foundation, an environmental organization whose mission is "to preserve and protect the nighttime environment" now actively supports legislation designed to protect birds by curbing light emissions.

Glass: The Invisible Threat

Glass can be invisible to both birds and humans. Humans learn to see glass through a combination of experience (how many of us at some time in our lives have walked into a glass door or seen somebody do so?), visual cues, and expectation, but birds are unable to use these signals. Most birds' first encounter with glass is fatal when they collide with it at full speed.

No one knows exactly how many birds are killed by glass – the problem exists on too great a scale, both in terms of geography and quantity – but estimates range from 100 million to one billion birds each year in the United States. Despite the enormity of the problem, however, currently available solutions can reduce bird mortality while retaining the advantages that glass offers as a construction material, without sacrificing architectural standards.

The hummingbird habit of 'trap-lining' – flying quickly from one feeding spot to another – causes collisions when flowers or feeders are reflected in glass. Photo: Terry Sohl

Lighting: Exacerbating the Threat

The problem of bird collisions with glass is greatly exacerbated by artificial light. Light escaping from building interiors or from exterior fixtures can attract birds, particularly during migration on foggy nights or when the cloud base is low. Strong beams of light can cause birds to circle in confusion and collide with structures, each other, or even the ground. Others may simply land in lighted areas and must then navigate an urban environment rife with other dangers, including more glass.

Birds and the Built Environment

Humans first began using glass in Egypt, around 3500 BCE. Glass blowing, invented by the Romans in the early First Century CE, greatly increased the ways glass could be used, including the first use of crude glass windows. Although the Crystal Palace in London, England, erected in 1851, is considered by

(Opposite) The White-throated Sparrow is the most frequent victim of collisions reported by urban monitoring programs. Photo: Robert Royse architects to mark the beginning of the use of glass as a structural element, the invention of float glass in the 1950s allowed mass production of modern windows. In the 1980s, development of new production and construction technologies culminated in today's glass skyscrapers.

Sprawling land-use patterns and intensified urbanization degrade the quality and quantity of bird habitat across the globe. Cities and towns encroach on riverbanks and shorelines. Suburbs, farms, and recreation areas increasingly infringe upon wetlands and woodlands. Some bird species simply abandon disturbed habitat. For species that can tolerate disturbance, glass is a constant threat, as these birds are seldom far from human structures. Migrating birds are often forced to land in trees lining our sidewalks, city parks, waterfront business districts, and other urban green patches that have replaced their traditional stopover sites.

The amount of glass in a building is the strongest predictor of how dangerous it is to birds. However, even small areas of glass can be lethal. While bird kills at homes are estimated at one to ten birds per home per year, the large number of homes multiplies that loss to millions of birds per year in the United States. Other factors can increase or decrease a building's impact, including the density and species composition of local bird populations, local geography, the type, location, and extent of landscaping and nearby habitat, prevailing wind and weather, and patterns of migration through the area. All must be considered when planning bird-friendly buildings.

Warblers, such as this Black-and-white, are often killed by window collisions as they migrate. Photo: Luke Seitz

Impact of Collisions on Bird Populations

About 25% of species are now on the U.S. WatchList of birds of conservation concern (www.abcbirds.org/abcprograms/science/watchlist/index.html), and even many common species are in decline. Habitat destruction or alteration on both breeding and wintering grounds remains the most serious man-made problem, but collisions with buildings are the largest known fatality threat. Nearly one third of the bird species found in the United States, over 258 species, from hummingbirds to falcons, are documented as victims of collisions. Unlike natural hazards that predominantly kill weaker individuals, collisions kill all categories of birds, including some of the strongest, healthiest birds that would otherwise survive to produce offspring. This is not sustainable and most of the mortality is avoidable. This document is one piece of a strategy to keep building collisions from increasing, and ultimately, to reduce them.

The Impact of Trends in Modern Architecture

In recent decades, advances in glass technology and production have made it possible to construct buildings with all-glass curtain walls, and we have seen a general increase in the amount of glass used in construction. This is manifest in an increase in picture windows on private homes and new applications for glass are being developed all the time. Unfortunately, as the amount of glass increases, so does the incidence of bird collisions.

In recent decades, growing concern for the environment has stimulated the development of "green" standards and rating systems. The best known is the Green Building Council's (GBC) Leadership in Energy and Environmental Design, or LEED. GBC agrees that green buildings should not threaten Wildlife, but until recently, did not include language addressing the threat of glass to birds.

Their Resource Guide, starting with the 2009 edition, calls attention to parts of existing LEED credits that can be applied to reduce negative impacts on birds. (One example: reducing light pollution saves energy and benefits birds.) As of October 14, 2011, GBC has added Credit 55: Bird Collision Deterrence, to their Pilot Credit Library (http://www.usgbc.org/ShowFile.aspx?DocumentID=10402), drafted by ABC, members of the Bird-safe Glass Foundation, and the GBC Site Subcommittee.

The Common Yellowthroat may be the most common warbler in North America and is also one of the most common victims of collisions with glass. Photo: Owen Deutsch

Essential to this credit is quantifying the threat level to birds posed by different materials and design details. These threat factors are used to calculate an index representing the building's façade and that index must be below a standard value to earn the credit. The credit also requires adopting interior and exterior lighting plans and post-construction monitoring. The section on Research in Appendix I reviews the work underlying the assignment of threat factors.

ABC is a registered provider of AIA continuing education, with classes on bird-friendly design and LEED Pilot Credit 55 available in face-to-face and webinar formats. Contact Christine Sheppard, csheppard@abcbirds.org, for more information.

Defining What's Good for Birds

It is increasingly common to see the phrase "bird-friendly" used in a variety of situations to demonstrate that a particular product, building, legislation, etc., is not harmful to birds. All too often, however, this term is unaccompanied by a clear definition, and lacks a sound scientific foundation to underpin its use.

Ultimately, defining "bird friendly" is a subjective task. Is bird-friendliness a continuum, and if so, where does friendly become unfriendly? Is "bird-friendly" the same as "bird-safe?" How does the definition change from use to use, situation to situation?

It is impossible to know exactly how many birds a particular building will kill before it is built, and so realistically, we cannot declare a building to be bird-friendly before it has been carefully monitored for several years. However, there are several factors that can help us predict whether a building will be particularly harmful to birds or generally benign, and we can accordingly define simple "bird-smart standards" that, if followed, will ensure a prospective building poses a minimal potential hazard to birds.

ABC's Bird-Friendly Building Standard

A bird-friendly building is one where:

- At least 90% of exposed façade material from ground level to 40 feet (the primary bird collision zone) has been demonstrated in controlled experiments[1] to deter 70% or more of bird collisions
- At least 60% of exposed façade material above the collisions zone meets the above standard
- There are no transparent passageways or corners, or atria or courtyards that can trap birds
- Outside lighting is appropriately shielded and directed to minimize attraction to night-migrating songbirds[2]
- Interior lighting is turned off at night or designed to minimize light escaping through windows
- Landscaping is designed to keep birds away from the building's façade[3]
- Actual bird mortality is monitored and compensated for (e.g., in the form of habitat preserved or created elsewhere, mortality from other sources reduced, etc.)

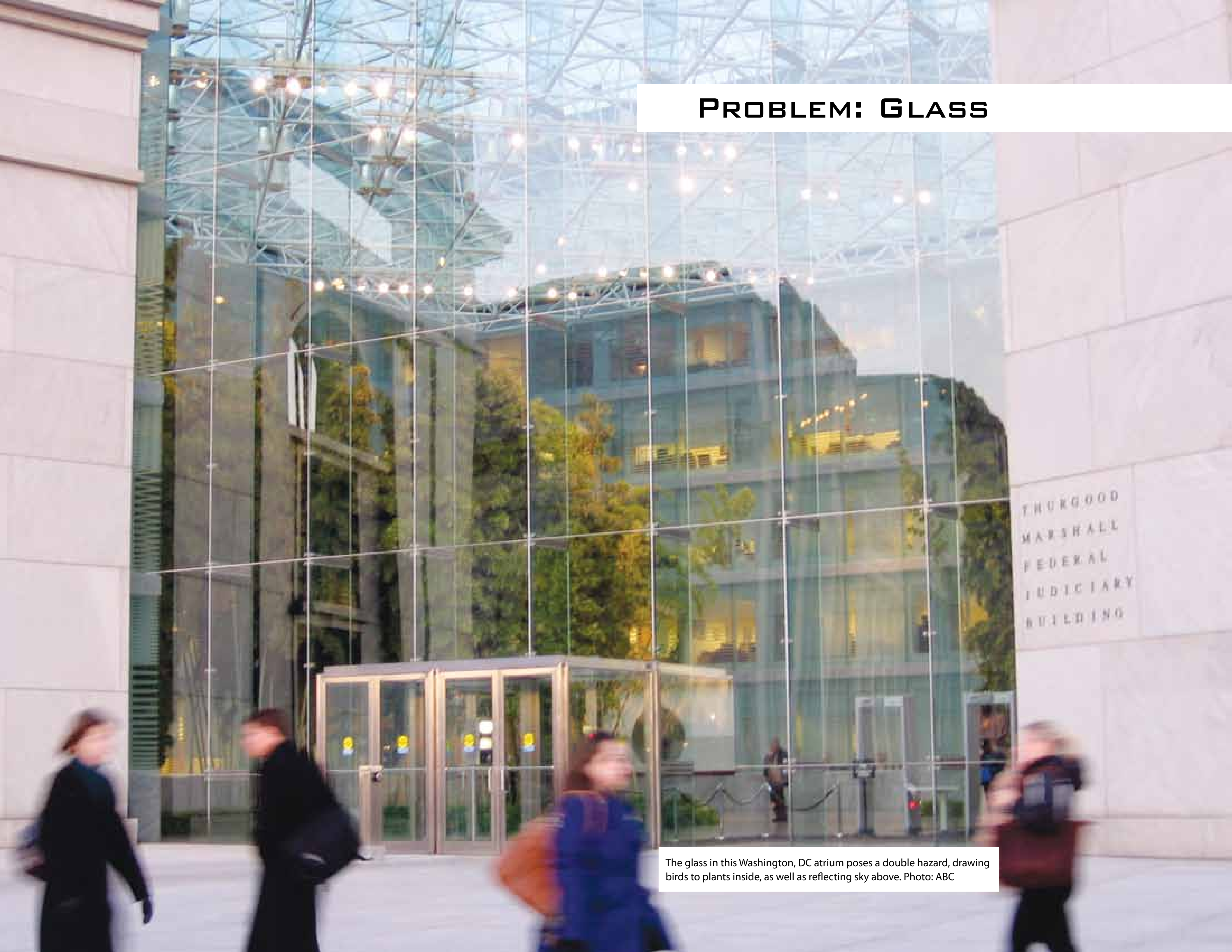
[1]See the section *Research: Deterring Bird Collisions* in Appendix I for information on these controlled studies.

[2]See the section *Solutions: Lighting Design* on page 31

[3]See *Landscaping and Vegetation,* Appendix I on Page 40

The Hotel Puerta America in Mexico City was designed by Jean Nouvel, and features external shades. This is a flexible strategy for sun control, as well as preventing collisions; shades can be lowered selectively when and where needed. Photo: Ramon Duran

Problem: Glass



The glass in this Washington, DC atrium poses a double hazard, drawing birds to plants inside, as well as reflecting sky above. Photo: ABC

The Properties of Glass

Glass can appear very differently depending on a number of factors, including how it is fabricated, the angle at which it is viewed, and the difference between exterior and interior light levels. Combinations of these factors can cause glass to look like a mirror or dark passageway, or to be completely invisible. Humans do not actually "see" most glass, but are cued by context such as mullions, roofs or doors. Birds, however, do not perceive right angles and other architectural signals as indicators of obstacles or artificial environments.

The glass-walled towers of the Time-Warner Center in New York City appear to birds as just another piece of the sky. Photo: Christine Sheppard, ABC

Reflection

Viewed from outside, transparent glass on buildings is often highly reflective. Almost every type of architectural glass, under the right conditions, reflects the sky, clouds, or nearby habitat familiar and attractive to birds. When birds try to fly to the reflected habitat, they hit the glass. Reflected vegetation is the most dangerous, but birds also attempt to fly past reflected buildings or through reflected passageways.

Transparency

Birds strike transparent windows as they attempt to access potential perches, plants, food or water sources, and other lures seen through the glass. Glass "skywalks" joining buildings, glass walls around planted atria, windows installed perpendicularly on building corners, and exterior glass handrails or walkway dividers are dangerous because birds perceive an unobstructed route to the other side.

Black Hole or Passage Effect

Birds often fly through small gaps, such as spaces between leaves or branches, nest cavities, or other small openings. In some light, glass can appear black, creating the appearance of just such a cavity or "passage" through which birds try to fly.

Factors Affecting Rates of Bird Collisions for a Particular Building

Every site and every building can be characterized as a unique combination of risk factors for collisions. Some, particularly aspects of a building's design, are very building-specific. Many negative design features can be readily countered, or, in new construction, avoided. Others, for example a building's location and siting, relate to migration routes, regional ecology, and geography–factors that are difficult if not impossible to modify.

Transparent handrails are a dangerous trend for birds, especially when they front vegetation. Photo: Christine Sheppard, ABC

Architectural cues show people that only one panel on the face of this shelter is open; to birds, all the panels appear to be open. Photo: Christine Sheppard, ABC

Large facing panes of glass can appear to be a clear pathway. Photo: Christine Sheppard, ABC

The same glass can appear transparent or highly reflective, depending on weather or time of day. Photo: Christine Sheppard, ABC

Building Design

Glass causes virtually all bird collisions with buildings. The relative threat posed by a particular building depends substantially on the amount of exposed glass, as well as the type of glass used, and the presence of glass "design traps". Klem (2009) in a study based on data from Manhattan, New York, found that a 10% increase in the area of reflective and transparent glass on a building façade correlated with a 19% increase in the number of fatal collisions in spring and a 32% increase in fall.

Type of Glass

The type of glass used in a building is a significant component of its danger to birds. Mirrored glass is often used to make a building "blend" into an area by reflecting its surroundings. Unfortunately, this makes those buildings especially deadly to birds. Mirrored glass is reflective at all times of day, and birds mistake reflections of sky, trees, and other habitat features for reality. Non-mirrored glass can be highly reflective at one time, and at others, appear transparent or dark, depending on time of day, weather, angle of view, and other variables, as with the window pictured below. Tinted glass reduces collisions, but only slightly. Low-reflection glass may be less hazardous in some situations, but does not actively deter birds and can create a "passage effect," appearing as a dark void that could be flown through (see page 11).

Building Size

As building size increases for a particular design, so usually does the amount of glass, making larger buildings more of a threat. It is generally accepted that the lower stories of buildings are the most dangerous because they are at the same level as trees and other landscape features that attract birds. However, monitoring programs accessing setbacks and roofs of tall buildings are finding that birds also collide with higher levels.

Building Orientation and Siting

Building orientation in relation to compass direction has not been implicated as a factor in collisions, but siting of a building with respect to surrounding habitat and landscaping can be an issue, especially if glass is positioned so that it reflects vegetation. Physical features such as outcrops or pathways that provide an open flight path through the landscape can channel birds towards or away from glass and should be considered early in the design phase.

Design Traps

Windowed courtyards and open-topped atria can be death traps for birds, especially if they are heavily planted. Birds fly down into such places, and then try to leave by flying directly towards reflections on the walls. Glass skywalks and outdoor handrails, and building corners where glass walls or windows are perpendicular are dangerous because birds can see through them to sky or habitat on the other side.

Birds flying from a meadow on the left are channeled towards the glass doors of this building by a rocky outcrop to the right of the path. Photo: Christine Sheppard, ABC

Mirrored glass is dangerous at all times of day, whether it reflects vegetation, sky, or simply open space through which a bird might try to fly. Photo: Christine Sheppard, ABC

Plantings on setbacks and rooftops can attract birds to glass they might otherwise avoid. Photo: Christine Sheppard, ABC

Vines cover most of these windows, but birds might fly into the dark spaces on the right. Photo: Christine Sheppard, ABC

Reflections on home windows are a significant source of bird mortality. The partially opened vertical blinds seen here may break up the reflection enough to reduce the hazard to birds. Photo: Christine Sheppard, ABC

Reflected Vegetation

Glass that reflects shrubs and trees causes more collisions than glass that reflects pavement or grass (Gelb and Delec-retaz, 2006). Studies have only quantified vegetation within 15-50 feet of a façade, but reflections can be visible at much greater distances. Vegetation around buildings will bring more birds into the vicinity of the building; the reflection of that vegetation brings more birds into the glass. Taller trees and shrubs correlate with more collisions. It should be kept in mind that vegetation on slopes near a building will reflect in windows above ground level. Studies with bird feeders (Klem *et al.*, 1991) have shown that fatal collisions result when birds fly towards glass from more than a few feet away.

Green Roofs and Walls

Green roofs bring habitat elements attractive to birds to higher levels, often near glass. However, recent work shows that well designed green roofs can become functional ecosystems, providing food and nest sites for birds. Siting of green roofs, as well as green walls and rooftop gardens should therefore be carefully considered, and glass adjacent to these features should have protection for birds.

Local Conditions

Areas where fog is common may exacerbate local light pollution (see below). Areas located along migratory pathways or where birds gather prior to migrating across large bodies of water, for example, in Toronto, Chicago, or the southern tip of Florida, expose birds to highly urban environments and have caused large mortality events (see Appendix II for additional information on how migration can influence bird collisions).

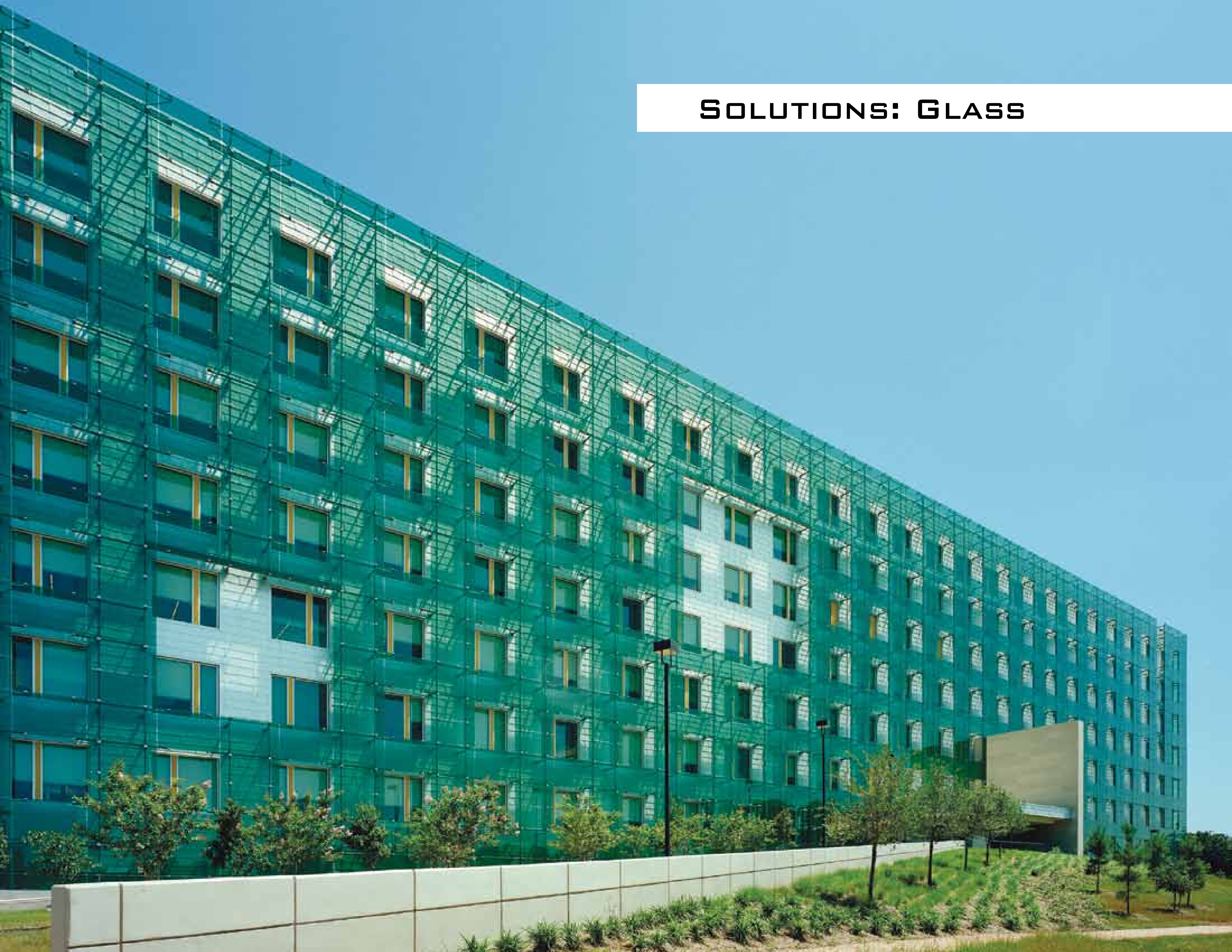
Lighting

Interior and exterior building and landscape lighting can make a significant difference to collisions rates in any one location. This phenomenon is dealt with in detail in the section on lighting.

Planted, open atrium spaces lure birds down, then prove dangerous when birds try to fly out to reflections on surrounding windows. Photo: Christine Sheppard, ABC

This atrium has more plants than anywhere outside on the surrounding streets, making the glass deadly for birds seeking food in this area.
Photo: Christine Sheppard, ABC

SOLUTIONS: GLASS



It is possible to design buildings that can reasonably be expected not to kill birds. Numerous examples exist, not necessarily designed with birds in mind, but to be functional and attractive. These buildings may have windows, but use screens, latticework, grilles, and other devices outside the glass or integrated into the glass.

Finding glass treatments that can eliminate or greatly reduce bird mortality while minimally obscuring the glass itself has been the goal of several researchers, including Martin Rössler, Dan Klem, and Christine Sheppard. Their research, discussed in more detail in Appendix I, has focused primarily on the spacing, width, and orientation of lines marked on glass, and has shown that patterns covering as little as 5% of the total glass surface can deter 90% of strikes under experimental conditions. They have consistently shown that most birds will not attempt to fly through horizontal spaces less than 2" high nor through vertical spaces 4" wide or less. We refer to this as the **2 x 4 rule**. There are many ways that this can be used to make buildings safe for birds.

Designing a new structure to be bird friendly does not need to restrict the imagination or add to the cost of construction. Architects around the globe have created fascinating and important structures that incorporate little or no exposed glass. In some cases, inspiration has been born out of functional needs, such as shading in hot climates, in others, aesthetics; being bird-friendly was usually incidental. Retro-fitting existing buildings can often be done by targeting problem areas, rather than entire buildings.

(Opposite) The external glass screen on the GSA Regional Field Office in Houston, TX, designed by Page Southerland Page, means windows are not visible from many angles. Photo: Timothy Hursley

Emilio Embasz used creative lighting strategies to illuminate his Casa de Respira Espiritual, located north of Seville, Spain. Much of the structure and glass are below grade, but are filled with reflected light. Photo courtesy of Emilio Ambasz and Associates

FOA made extensive use of bamboo in the design of this Madrid, Spain public housing block. Shutters are an excellent strategy for managing bird collisions as they can be closed as needed. Photo courtesy of FOA

Facades, netting, screens, grilles, shutters, exterior shades

There are many ways to combine the benefits of glass with bird-safe or bird-friendly design by incorporating elements that preclude collisions without completely obscuring vision. Some architects have designed decorative facades that wrap entire structures. Recessed windows can functionally reduce the amount of visible glass and thus the threat to birds. Netting, screens, grilles, shutters and exterior shades are more commonly used elements that can make glass safe for birds. They can be used in retrofits or be an integral part of an original design, and can significantly reduce bird mortality.

The façade of the New York Times building, by FX Fowle and Renzo Piano, is composed of ceramic rods, spaced to let occupants see out, while minimizing the extent of exposed glass. Photo: Christine Sheppard, ABC

Before the current age of windows that are unable to be opened, screens protected birds in addition to their primary purpose of keeping bugs out. Screens and nets are still among the most cost-effective methods for protecting birds, and netting can often be installed so as to be nearly invisible. Netting must be installed several inches in front of the window, so impact does not carry birds into the glass. Several companies sell screens that can be attached with suction cups or eye hooks for small areas of glass. Others specialize in much larger installations.

Decorative grilles are also part of many architectural traditions, as are shutters and exterior shades, which have the additional advantage that they can be closed temporarily, specifically during times most dangerous to birds, such as migration and fledging (see Appendix II).

Functional elements such as balconies and balustrades can act like a façade, protecting birds while providing an amenity for residents.

External shades on Renzo Piano's California Academy of Sciences in San Francisco are lowered during migration seasons to eliminate collisions. Photo: Mo Flannery

For the Langley Academy in Berkshire, UK, Foster + Partners used louvers to control light and ventilation, also making the building safe for birds. Photo: Chris Phippen Ofis

The combination of shades and balustrades screens glass on Ofis Architect's Apartments on the Coast in Izola, Slovenia. Photo courtesy of Ofis

Instead of glass, this side of Jean Nouvel's Institute Arabe du Monde in Paris, France features motor-controlled apertures that produce filtered light in the interior of the building. Photo: Vicki Paull

A series of balconies, such as those pictured here, can hide glass from view. Photo: Elena Cazzaniga

Overhangs block viewing of glass from some angles, but do not necessarily eliminate reflections. Photo: Christine Sheppard, ABC

Reflections in this angled façade can be seen clearly over a long distance, and birds can approach the glass from any angle. Photo: Christine Sheppard, ABC

Awnings and Overhangs

Overhangs have been said to reduce collisions, however, they do not eliminate reflections, and only block glass from the view of birds flying above. They are thus of limited effectiveness as a general strategy.

UV Patterned Glass

Birds can see into the ultraviolet (UV) spectrum of light, a range largely invisible to humans (see page 36). UV-reflective and/or absorbing patterns (transparent to humans but visible to birds) are frequently suggested as the optimal solution for many bird collision problems. Progress in the search for bird-friendly UV glass has been slow, however, due to the inherent technical complexities, and because, in the absence of widespread legislation mandating bird-friendly glass, only a few glass companies recognize this as a market opportunity. Research indicates that UV patterns need strong contrast to be effective.

Angled Glass

In a study (Klem et al., 2004) comparing bird collisions with vertical panes of glass to those tilted 20 degrees or 40 degrees, the angled glass resulted in less mortality. For this reason, it has been suggested that angled glass should be incorporated into buildings as a bird-friendly feature. While angled glass may be useful in special circumstances, the birds in the study were flying parallel to the ground from nearby feeders. In most situations, however, birds approach glass from many angles, and can see glass from many perspectives. Angled glass is not recommended as appropriate or useful strategy. The New York Times printing plant, pictured opposite, clearly illustrates this point. The angled glass curtain wall shows clear reflections of nearby vegetation, visible from a long distance away.

Deeply recessed windows, such as these on Stephen Holl's Simmons Hall at MIT, can block viewing of glass from most angles. Photo: Dan Hill

Translucent glass panels on the Kunsthaus Bregenz in Austria, designed by Atelier Peter Zumthor, provide light and air to the building interior, without dangerous reflections. Photo: William Heltz

The glass facade of SUVA Haus in Basel, Switzerland, renovated by Herzog and de Meuron, is screen-printed on the outside with the name of the company owning the building. Photo: Miguel Marqués Ferrer

Dense stripes of internal frit on University Hospital's Twinsburg Health Center in Cleveland, by Westlake, Reed, Leskosky will overcome virtually all reflections. Photo: Christine Sheppard, ABC

Patterns on Glass

Patterns are often applied to glass to reduce the transmission of light and heat; they can also provide some design detail. When designed according to the 2 x 4 rule, (see p. 17) patterns on glass can also prevent bird strikes. External patterns on glass deter collisions effectively because they block glass reflections, acting like a screen. Ceramic dots or 'frits' and other materials can be screened, printed, or otherwise applied to the glass surface. This design element, useful primarily for new construction, is currently more common in Europe and Asia, but is being offered by an increasing number of manufacturers in the United States.

More commonly, patterns are applied to an internal surface of double-paned windows. Such designs may not be visible if the amount of light reflected from the frit is insufficient to overcome reflections on the glass' outside surface. Some internal frits may only help break up reflections when viewed from some angles and in certain light conditions. This is particularly true for large windows, but also depends on the density of the frit pattern. The internet company IAC's headquarters building in New York City, designed by Frank Gehry, is composed entirely of fritted glass, most of high density. No collision mortalities have been reported at this building after two years of monitoring by Project Safe Flight. Current research is testing the relative effectiveness of different frit densities, configurations, and colors.

The Studio Gang's Aqua Tower in Chicago was designed with birds in mind. Strategies include fritted glass and balcony balustrades. Photo: Tim Bloomquist

The dramatic City Hall of Alphen aan den Rijn in the Netherlands, designed by Erick van Egeraat Associated Architects, features a façade of etched glass. Photo: Dik Naagtegal

RAU's World Wildlife Fund Headquarters in the Netherlands uses wooden louvers as sunshades; they also diminish the area of glass visible to birds. Photo courtesy of RAU

External frit, as seen here on the Lile Museum of Fine Arts, by Ibos and Vitart, is more effective at breaking up reflections than patterns on the inside of the glass. Photo: G. Fessy

A detail of a pattern printed on glass at the Cottbus Media Centre in Germany. Photo: Evan Chakroff

While some internal fritted glass patterns can be overcome by reflections, Frank Gehry's IAC Headquarters in Manhattan is so dense that the glass appears opaque. Photo: Christine Sheppard, ABC

Opaque and Translucent Glass

Opaque, etched, stained, frosted glass, and glass block can are excellent options to reduce or eliminate collisions, and many attractive architectural applications exist. They can be used in retrofits but are more commonly used in new construction.

Frosted glass is created by acid etching or sandblasting transparent glass. Frosted areas are translucent, but different finishes are available with different levels of light transmission. An entire surface can be frosted, or frosted patterns can be applied. Patterns should conform to the 2 x 4 rule described on page 17. For retrofits, glass can also be frosted by sandblasting on site.

Stained glass is typically seen in relatively small areas but can be extremely attractive and is not conducive to collisions.

Glass block is extremely versatile, can be used as a design detail or primary construction material, and is also unlikely to cause collisions.

Renzo Piano's Hermes Building in Tokyo has a façade of glass block. Photo: Mariano Colantoni

UN Studio's Het Valkhof Museum in Nijmegan, The Netherlands, uses translucent glass to diffuse light to the interior, which also reduces dangerous reflections. Photo courtesy of UN Studio.

Frosted glass façade on the Wexford Science and Technology building in Philadelphia, by Zimmer, Gunsul, Frasca. Photo: Walker Glass

A dramatic use of glass block denotes the Hecht Warehouse in Washington, DC, by Abbott and Merkt. Photo: Sandra Cohen-Rose and Colin Rose

ABC BirdTape

ABC, with support from the Rusinow Family Foundation, has produced ABC BirdTape to make home windows safer for birds. This easy-to-apply tape lets birds see glass while letting you see out, is easily applied, and lasts up to four years.
For more information, visit www.ABCBirdTape.org

Photos : Dariusz Zdziebkowski, ABC

Internal Shades, Blinds, and Curtains

Light colored shades are often recommended as a way to deter collisions. However, they do not effectively reduce reflections and are not visible from acute angles. Blinds have the same problems, but when visible and partly open, they are more likely to break up reflections than solid shades.

Window Films

Currently, most patterned window films are intended for use inside structures as design elements or for privacy, but this is beginning to change. CollidEscape, a perforated window film similar to 3M™ Scotchcal™ Perforated Window Graphic Film, but designed to last for 10 years or more on the exterior surface of glass, is a well-known external solution. It covers the entire surface of a window, appears opaque from the outside, but still permits a view out from inside. Interior films, when applied correctly, have held up well in external applications, but this solution has not yet been tested over decades. A film with a pattern of narrow, horizontal stripes was applied to a building, in Markham, Ontario and successfully eliminated collisions. Another film has been effective at the Philadelphia Zoo's Bear Country exhibit (see photo on opposite page). In both cases, the response of people has also been positive.

Temporary Solutions

In some circumstances, especially for homes and small buildings, quick, low-cost, temporary solutions such as making patterns on glass with tape or paint can be very effective. Even a modest effort can reduce collisions. Such measures can be applied when needed and are most effective following the 2 x 4 rule. For more information, see ABC's informative flyer "You Can Save Birds from Flying into Windows" at www.abcbirds.org/abc

Decals

Decals are probably the most popularized solution to bird collisions, but their effectiveness is widely misunderstood.

Birds do not recognize decals as silhouettes of birds, spider webs, or other items, but simply as obstacles that they may try to fly around. Decals are most effective if applied following the 2 x 4 rule, but even a few may reduce collisions. Because decals must also be replaced frequently, they are usually considered a short-term strategy for small windows.

A single decal is minimally effective for collision prevention on a window of this size, as there is still a substantial amount of untreated glass. Photo: Christine Sheppard, ABC

Tape decals (Window Alert shown here) placed following the 2 x 4 rule can be effective at deterring collisions. Photo: Christine Sheppard, ABC

This window at the Philadelphia Zoo's Bear Country exhibit was the site of frequent bird collisions until this window film was applied. Collisions have been eliminated, with no complaints from the public. Photo courtesy of Philadelphia Zoo

Problem: Lighting

Each white speck seen here is a bird, trapped in the beams of light forming the *9/11 Tribute in Light* in New York City. Volunteers watch during the night and the lights are turned off briefly if large numbers of birds are observed. Photo: Jason Napolitano

Artificial light is increasingly recognized as a negative factor for humans as well as wildlife. Rich and Longcore (2006) have gathered comprehensive reviews of the impact of "ecological light pollution" on vertebrates, insects, and even plants. For birds especially, light can be a significant and deadly hazard.

Beacon Effect and Urban Glow

Light at night, especially during bad weather, creates conditions that are particularly hazardous for night-migrating birds. Typically flying at altitudes over 500 feet, migrants often descend to lower altitudes during inclement weather, where they may encounter artificial light from buildings. Water vapor in very humid air, fog, or mist refracts light, forming an illuminated halo around light sources.

There is clear evidence that birds are attracted to light, and once close to the source, are unable to break away (Rich and Longcore, 2006; Poot et al., 2008; Gauthreaux and Belser, 2006). How does this become a hazard to birds? When birds encounter beams of light, especially in inclement weather, they tend to circle in the illuminated zone, appearing disoriented and unwilling or unable to leave. This has been documented recently at the *9/11 Memorial in Lights*, where lights must be turned off briefly when large numbers of birds become caught in the beams. Significant mortality of migrating birds has been reported at oil platforms in the North Sea and the Gulf of Mexico. Van de Laar (2007) tested the impact on birds of lighting on an off-shore platform. When lights were switched on, birds were immediately attracted to the platform in significant numbers. Birds dispersed when lights were switched off. Once trapped, birds may collide with structures or each other, or fall to the ground from exhaustion, where they are at risk from predators.

While mass mortalities at very tall illuminated structures (such as skyscrapers) during inclement weather have received the most attention, mortality has also been associated with ground-level lighting during clear weather. Light color also plays a role, with blue and green light much safer than white or red light. Once birds land in lighted areas, they are at risk from colliding with nearby structures as they forage for food by day.

In addition to killing birds, overly-lit buildings waste electricity, and increase greenhouse gas emissions and air pollution levels. Poorly designed or improperly installed outdoor fixtures add over one billion dollars to electrical costs in the United States every year, according to the International Dark Skies Association. Recent studies estimate that over two thirds of the world's population can no longer see the Milky Way, just one of the nighttime wonders that connect people with nature. Together, the ecological, financial, and cultural impacts of excessive building lighting are compelling reasons to reduce and refine light usage.

Overly-lit buildings waste electricity and increase greenhouse gas emissions and air pollution levels, as well as posing a threat to birds. Photo: Matthew Haines

Houston skyline at night. Photo: Jeff Woodman


SOLUTIONS: LIGHTING DESIGN

Reducing exterior building and site lighting has proven effective at reducing mortality of night migrants. At the same time, these measures reduce building energy costs and decrease air and light pollution. Efficient design of lighting systems plus operational strategies to reduce light "trespass" or "spill light" from buildings while maximizing useful light are both important strategies. In addition, an increasing body of evidence shows that red lights and white light (which contains red wavelengths) particularly attract and confuse birds, while green and blue light have far less impact.

Light pollution is largely a result of inefficient exterior lighting, and improving lighting design usually produces savings greater than the cost of changes. For example, globe fixtures permit little control of light, which shines in all directions, resulting in a loss of as much as 50% of energy, as well as poor illumination. Cut-off shields can reduce lighting loss and permit use of lower powered bulbs.

Most "vanity lighting" is unnecessary. However, when it is used, building features should be highlighted using down-lighting rather than up-lighting. Where light is needed for safety and security, reducing the amount of light trespass outside of the needed areas can help by eliminating shadows. Spotlights and searchlights should not be used during bird migration. Communities that have implemented programs to reduce light pollution have not found an increase in crime.

Using automatic controls, including timers, photo-sensors, and infrared and motion detectors is far more effective than reliance on employees turning off lights. These devices generally pay for themselves in energy savings in less than a year. Workspace lighting should be installed where needed, rather than lighting large areas. In areas where indoor lights will be on at night, minimize perimeter lighting and/or draw shades after dark. Switching to daytime cleaning is a simple way to reduce lighting while also reducing costs.

Shielded light fixtures are widely available in many different styles. Photo: Susan Harder

Reprinted courtesy of DarkSkySociety.org

Lights Out Programs

Birds evolved complex, complementary systems for orientation and vision long before humans developed artificial light. We still have much more to learn, especially the differences between species, but recent science has begun to clarify how artificial light poses a threat to birds, especially nocturnal migrants. These birds use a magnetic sense which is dependent on dim light from the blue-green end of the spectrum.

Research has shown that different wavelengths cause different behaviors, with yellow and red light preventing orientation. Different intensities of light also produce different

(Opposite) Fixtures such as these reduce light pollution, saving energy and money, and reducing negative impacts on birds. Photo: Dariusz Zdziebkowski, ABC

Shielded lights, such as those shown above, cut down on light pollution and are much safer for birds. Photo: Susan Harder

reactions. Despite the complexity of this issue, there is one simple way to reduce mortality: turn lights off.

Across the United States and Canada, "Lights Out" programs at the municipal and state level encourage building owners and occupants to turn out lights visible from outside during spring and fall migration. The first of these, Lights Out Chicago, was started in 1995, followed by Toronto in 1997. There are over twenty programs as of mid-2011.

The programs themselves are diverse. Some are directed by environmental groups, others by government departments, and still others by partnerships of organizations. Participation in some, such as Houston's, is voluntary. Minnesota mandates turning off lights in state-owned and -leased buildings, while Michigan's governor proclaims Lights Out dates annually. Many jurisdictions have a monitoring component or work with local rehabilitators. Monitoring programs can provide important information in addition to quantifying collision levels and documenting solutions. Toronto, for example, determined that if short buildings emit more light, they can be more dangerous to birds than tall building emitting less light.

Ideally, Lights Out programs would be in effect year round, saving birds and energy costs and reducing emissions of greenhouse gases. ABC stands ready to help develop new programs and to support and expand existing programs.

Distribution of Lights Out Programs in North America

Lights Out map legend

- **Red:** state ordinance
- **Yellow:** cities in state-wide programs
- **Turquoise:** program in development
- **Blue:** local programs

Downtown Houston during Lights Out. Photo: Jeff Woodman

Solutions: Legislation

Changing human behavior is generally a slow process, even when the change is uncontroversial. Legislation can be a powerful tool for modifying behavior. Conservation legislation has created reserves, reduced pollution, and protected threatened species and ecosystems. Initial efforts to document bird mortality and recommend ways to remediate collisions have more recently given way to legislation that promotes bird-friendly design and reduction of light pollution.

Most of these ordinances refer to external guidelines, rather than specifying how their goals must be achieved, and because there are many guidelines, created at different times and often specific to particular places, this can lead to contradiction, confusion, and cases of 'shopping' for the cheapest option. These ABC guidelines are intended to address collisions at a national level and may be distributed by other groups.

One challenge in creating legislation is to provide specific strategies and create objective measures that architects can use to accomplish their task. ABC has incorporated objective criteria into this document and created a model ordinance to be found in Appendix V .

ABC is willing to partner with local groups in creating additions to the Guidelines with local focus and to assist in promoting local, bird-friendly legislation.

Cook County, Illinois, was the first to pass bird-friendly construction legislation, sponsored by then-Assemblyman Mike Quigley.

In 2006, Toronto, Canada, proposed a Green Development Standard, initially a set of voluntary guidelines to promote sustainable site and building design, including guidelines for bird-friendly construction. Development Guidelines became mandatory on January 1, 2011, but the process of translating guidelines into blueprints is still underway. San Francisco adopted Standards for Bird-safe Buildings in September, 2011. Listed below are some examples of current and pending ordinances at levels from federal to municipal.

Federal (proposed)

Illinois Congressman Mike Quigley (D-IL) introduced the Federal Bird-Safe Buildings Act of 2011 (HR 1643), which calls for each public building constructed, acquired, or altered by the General Services Administration (GSA) to incorporate, to the maximum extent possible, bird-safe building materials and design features. The legislation would require GSA to take similar actions on existing buildings, where practicable. Importantly, the bill has been deemed cost-neutral by the Congressional Budget Office. See http://thomas.loc.gov/cgi-bin/query/z?c112:H.R.1643.IH

State: Minnesota (enacted)

Chapter 101, Article 2, Section 54: Between March 15 and May 31, and between August 15 and October 31 each year, occupants of state-owned or state-leased buildings must attempt to reduce dangers posed to migrating birds by turning off building lights between midnight and dawn, to the extent turning off lights is compatible with the normal use of the buildings. The commissioner of administration may adopt policies to implement this requirement. See www.revisor.leg.state.mn.us/laws/?id=101&doctype=Chapter&year=2009&type=0

Song Sparrow: Greg Lavaty

State: Minnesota (enacted; regulations pending)

Beginning on July 1, 2010, all Minnesota State bonded projects – new and substantially renovated –that have not already started the schematic design phase on August 1, 2009 will be required to meet the Minnesota Sustainable Building 2030 (SB 2030) energy standards. See www.mn2030.umn.edu/

State: New York (pending)

Bill S04204/A6342-A, the Bird-friendly Buildings Act, requires the use of bird-friendly building materials and design features in buildings. See http://assembly.state.ny.us/leg/?bn=S04204&term=2011

City: San Francisco (enacted)

The city's Planning Department has developed the first set of objective standards in the nation, defining areas where the regulations are mandated and others where they are recommended, plus including criteria for ensuring that designs will be effective for protecting birds. See http://www.sf-planning.org/index.aspx?page=2506

City: Toronto

On October 27, 2009, the Toronto City Council passed a motion making parts of the Toronto Green Standard mandatory. The standard, which had previously been voluntary, applies to all new construction in the city, and incorporates specific Bird-Friendly Development Guidelines, designed to eliminate bird collisions with buildings both at night and in the daytime.

Beginning January 31, 2010, all new, proposed low-rise, non-residential, and mid- to high-rise residential and industrial, commercial, and institutional development will be required under Tier 1 of the Standard, which applies to all residential apartment buildings and non-residential buildings that are four stories tall or higher. See www.toronto.ca/planning/environment/greendevelopment.htm

United States Capitol, Washington, DC . Photo: stock.xchng

The number of birds killed by collisions with glass every year is astronomical.

Hundreds of species of birds are killed by collisions. These birds were collected by monitors with FLAP in Toronto, Canada. Photo: Kenneth Herdy

APPENDIX I: THE SCIENCE OF BIRD COLLISIONS

Magnitude of Collision Deaths

The number of birds killed by collisions with glass every year is astronomical. Based on studies of homes and commercial structures, Klem (1990) estimated conservatively that each building in the United States kills one to ten birds per year. Using 1986 United States Census data, he combined numbers of homes, schools, and commercial buildings for a maximum total of 97,563,626 buildings. Dunn (1993) surveyed 5,500 people who fed birds at their homes and recorded window collisions. She derived an estimate of 0.65-7.7 bird deaths per home per year for North America, supporting Klem's calculation.

The number of buildings in the United States has increased significantly since 1986, and it has been shown that commercial buildings generally kill more than ten birds per year, as would be expected since they have large expanses of glass (Hager *et al*., 2008; O'Connell, 2001). Thus, one billion annual fatalities is likely to be closer to reality, and possibly even too low.

Klem *et al*., (2009a) used data from New York City Audubon's monitoring of seventy-three Manhattan building facades to estimate 0.5 collision deaths per acre per year in urban environments, for a total of about 34 million migratory birds annually colliding with city buildings in the United States.

Patterns of Mortality

It is difficult to get a complete and accurate picture of avian mortality from collisions with glass. Collision deaths can occur at any time. Even intensive monitoring programs only cover a portion of a city, usually visiting the ground level of a given site at most once a day and often only during migration seasons. Many city buildings have stepped roof setbacks that are inaccessible to monitoring teams. Recognizing these limitations, some papers have focused on reports from homeowners on backyard birds (Klem, 1989; Dunn, 1993) or on mortality of migrants in an urban environment (Gelb and Delacretaz, 2009; Klem *et al*., 2009a, Newton, 1999). Others have analyzed collision victims from single, large-magnitude incidents (Sealy, 1985) or that have become part of museum collections (Snyder, 1946; Blem et al., 1998; Codoner, 1995).

There is general support for the fact that birds killed in collisions are not distinguished by age, sex, size, or health (for example: Blem and Willis, 1998; Codoner, 1995; Fink and French, 1971; Hager et al., 2008; Klem, 1989). However, some species, such as the White-throated Sparrow, Ovenbird, and Common Yellowthroat, seem to be more vulnerable than others, appearing consistently on top ten lists. Snyder (1946), examining window collision fatalities at the Royal Ontario Museum, noted that the majority were "tunnel flyers" – species that frequently fly through small spaces in dense, understory habitat. Recent work (J. A. Clark, pers. comm.) suggests that there may be species differences in attraction to light that could explain these findings. Interestingly, species well adapted to and common in urban areas, such as the House Sparrow and European Starling, are not prominent on lists of fatalities, and there is evidence that resident birds are less likely to die from collisions than migratory birds.

Collision mortality appears to be a density-independent phenomenon. Hager *et al*. (2008) compared the number of species and individual birds killed at buildings at Augustana College in Illinois with the density and diversity of bird species in the surrounding area. The authors concluded that total window area, habitat immediately adjacent to windows, and

A sample of collision victims from Baltimore.
Photo: Daniel J. Lebbin, ABC

behavioral differences among species were the best predictors of mortality patterns, rather than simply the size and composition of the local bird population.

From a study of multiple Manhattan buildings in New York City, Klem *et al* (2009a) similarly concluded that the expanse of glass on a building facade is the factor most predictive of mortality rates, calculating that every increase of 10% in the expanse of glass correlates to a 19% increase in bird mortality in spring, 32% in fall. How well these equations predict mortality in other cities remains to be tested. Collins and Horn (2008) studying collisions at Millikin University in Illinois concluded that total glass area and the presence/absence of large expanses of glass predicted mortality level. Hager *et al* (2008) came to the same conclusion. Gelb and Delacretaz's (2009) work in New York City indicated that collisions are more likely to occur on windows that reflect vegetation.

Dr. Daniel Klem maintains running totals of the number of species reported in collision events in countries around the world. This information can be found at: www.muhlenberg.edu/main/academics/biology/faculty/klem/aco/Country%20list.htm#World

He notes 859 species globally, with 258 from the United States. The intensity of monitoring and reporting programs varies widely from country to country, however. Hager (2009) noted that window strike mortality was reported for 45% of raptor species found frequently in urban areas of the United States, and represented the leading source of mortality for Sharp-shinned Hawks, Cooper's Hawks, Merlins, and Peregrine Falcons.

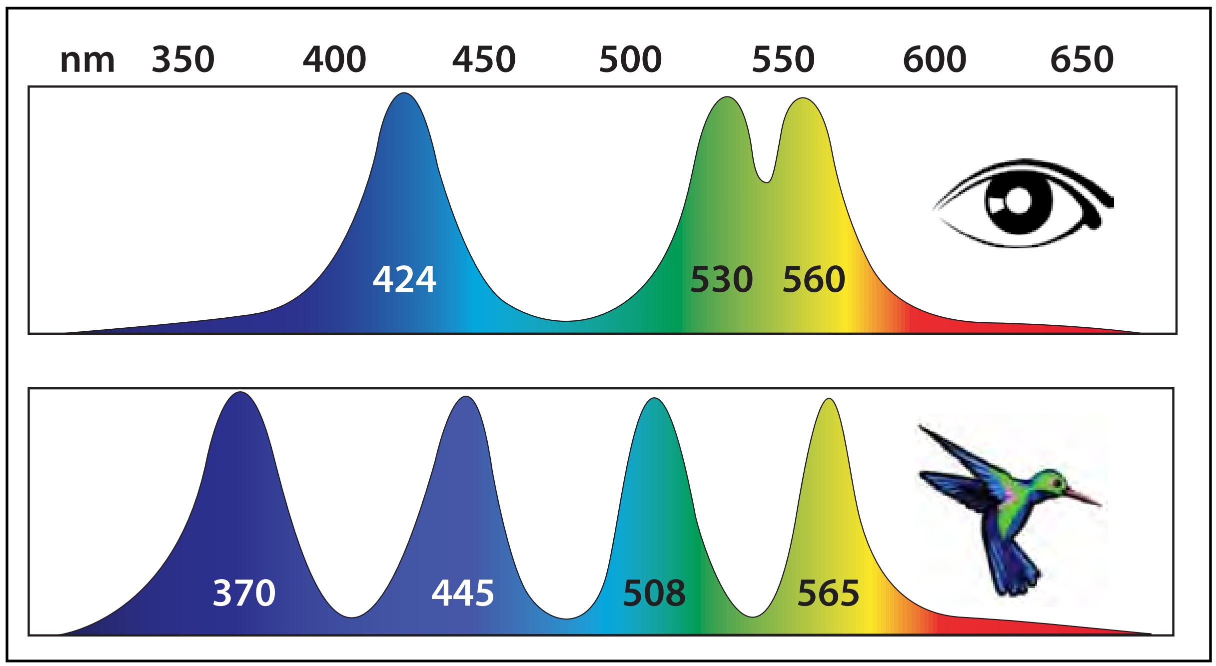
Avian Vision and Collisions

Taking a "bird's-eye view" is much more complicated than it sounds. To start with, where human color vision relies on three types of sensors, birds have four, plus an array of color filters that allow them to see many more colors than people (Varela *et al*., 1993) (see chart below). Many birds, including most passerines (Ödeen and Håstad, 2003) also see into the ultraviolet spectrum. Ultraviolet can be a component of any color (Cuthill *et al*., 2000). Where humans see red, yellow, or red + yellow, birds may see red + yellow, but also red + ultraviolet, yellow + ultraviolet, and red + yellow + ultraviolet, colors for which we have no names. They can also see polarized light (Muheim *et al*., 2006, 2011), and they process images faster than humans; where we see continuous motion in a movie, birds would see flickering images (D'Eath, 1998; Greenwood *et al*., 2004; Evans *et al*., 2006). To top it all off, birds have not one, but two receptors that permit them to sense the earth's magnetic field, which they use for navigation (Wiltschko *et al*., 2006).

Avian Orientation and the Earth's Magnetic Field

Thirty years ago, it was discovered that birds possess the ability to orient themselves relative to the Earth's magnetic field and locate themselves relative to their destination. They appear to use cues from the sun, polarized light, stars, the Earth's magnetic field, visual landmarks, and even odors to find their way. Exactly how this works – and it likely varies among

Comparison of Human and Avian Vision



Based on artwork by Sheri Williamson

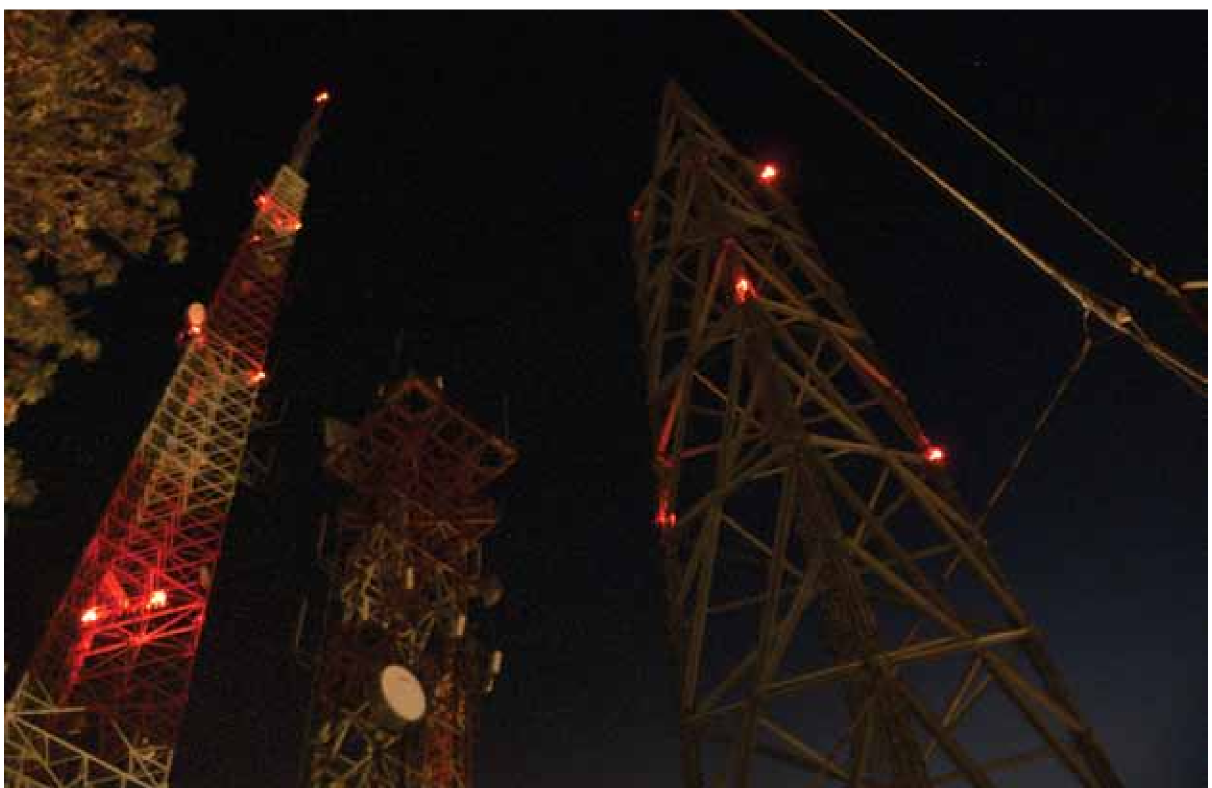
species – is still being investigated, but there have been interesting discoveries that also shed light on light-related hazards to migrating birds.

Lines of magnetism between the north and south poles have gradients in three dimensions. Cells in birds' upper beaks, or maxillae, contain the iron compounds maghemite and magnetite. Micro-synchrotron x-ray fluorescence analysis shows these compounds in three different compartments, a three-dimensional architecture that probably allows birds to detect their "map" (Davila, 2003; Fleissner *et al*., 2003, 2007). Other magnetism-detecting structures are found in the retina of the eye, and depend on light for activity. Light excites receptor molecules, setting off a chain reaction. The chain in cells that respond to blue wavelengths includes molecules that react to magnetism, producing magnetic directional cues as well as color signals. For a comprehensive review of the mechanisms involved in avian orientation, see Wiltschko and Wiltschko, 2009.

Birds and Light Pollution

The earliest reports of mass avian mortality caused by lights were from lighthouses, but this source of mortality essentially disappeared when steady-burning lights were replaced by rotating beams (Jones and Francis, 2003). Flashing or interrupted beams apparently allow birds to continue to navigate. While mass collision events at tall buildings and towers have received most attention (Weir, 1976; Avery *et al*., 1977; Avery *et al*., 1978; Crawford, 1981a, 1981b; Newton, 2007), light from many sources, from urban sprawl to parking lots, can affect bird behavior and cause bird mortality (Gochfeld, 1973). Gochfeld (in Rich and Longcore, 2006) noted that bird hunters throughout the world have used lights from fires or lanterns near the ground to disorient and net birds on cloudy, dark nights. In a review of the effects of artificial light on migrating birds, Gauthreaux and Belser (2006) report on the use of car headlights to attract birds at night for tourists on safari.

Steady-burning red and white lights are most dangerous to birds. Photo: Mike Parr, ABC



Evans-Ogden (2002) showed that light emission levels of sixteen buildings ranging in height from eight to 72 floors correlated directly with bird mortality, and that the amount of light emitted by a structure was a better predictor of mortality level than building height, although height was a factor. Wiltschko *et al* (2007) showed that above intensity thresholds that decrease from green to UV, birds showed disorientation. Disorientation occurs at light levels that are still relatively low, equivalent to less than half an hour before sunrise under clear sky. It is thus likely that light pollution causes continual, widespread, low-level mortality that collectively is a significant problem.

The mechanisms involved in both attraction to and disorientation by light are poorly understood and may differ for different light sources (see Gauthreaux and Belser (2006) and Herbert (1970) for reviews.) Recently, Haupt and Schillemeit described the paths of 213 birds flying through beams uplighting from several different outdoor lighting schemes. Only 7.5% showed no change in behavior. Migrating birds are severely impacted, while resident species may show little or no effect. It is not known whether this is because of differences in physiology or simply familiarity with local habitat.

Light Color and Avian Orientation

Starting in the 1940s, ceilometers, powerful beams of light used to measure the height of cloud cover, came into use, and were associated with significant bird kills. Filtering out long (red) wavelengths and using the blue/ultraviolet range greatly reduced mortality. Later, replacement of fixed beam ceilometers with rotating beams essentially eliminated impact on migrating birds (Laskey, 1960). A complex series of laboratory studies in the 1990s demonstrated that birds required light in order to sense the Earth's magnetic field. Birds could orient correctly under monochromatic blue or green light, but longer wavelengths (yellow and red) caused disorientation (Rappli et al., 2000; Wiltschko *et al*., 1993, 2003, 2007). It was demonstrated that the magnetic receptor cells on the eye's retina are inside the type of cone cell responsible for processing blue and green light, but disorientation seems to involve a lack of directional information.

Fog increases the danger of light both by causing birds to fly lower and by refracting light so it is visible over a larger area. Photo: Christine Sheppard, ABC

Poot *et al*. (2008) demonstrated that migrating birds exposed to different colored lights in the field respond the same way they do in the laboratory. Birds were strongly attracted to white and red light, and appeared disoriented by them, especially under overcast skies. Green light was less attractive and minimally disorienting; blue light attracted few birds and did not disorient those that it did attract (but see Evans *et al*., 2007). Birds were not attracted to infrared light. This work was the basis for development of the Phillips "Clear Sky" bulb, which produces white light with minimal red wavelengths (Marquenie *et al*., 2008) and is now in use in Europe on oil rigs and at some electrical plants. According to Van de Laar *et al*. (2007), tests with this bulb on an oil platform during the 2007 fall migration produced a 50-90% reduction in birds circling and landing. Recently, Gehring *et al*. (2009) demonstrated that mortality at communication towers was greatly reduced if strobe lighting was used as opposed to steady-burning white, or especially red lights. Replacement of steady-burning warning lights with intermittent lights at locations causing collisions is an excellent option for protecting birds, as is manipulating light color.

Weather Impact on Collisions

Weather has a significant and complex relationship with avian migration (Richardson, 1978), and large-scale, mass mortality of migratory birds at tall, lighted structures (including communication towers) has often correlated with fog or rain (Avery et al., 1977; Crawford, 1981b; Newton, 2007) The conjunction of bad weather and lighted structures during migration is a serious threat, presumably because visual cues used by birds for orientation are not available.

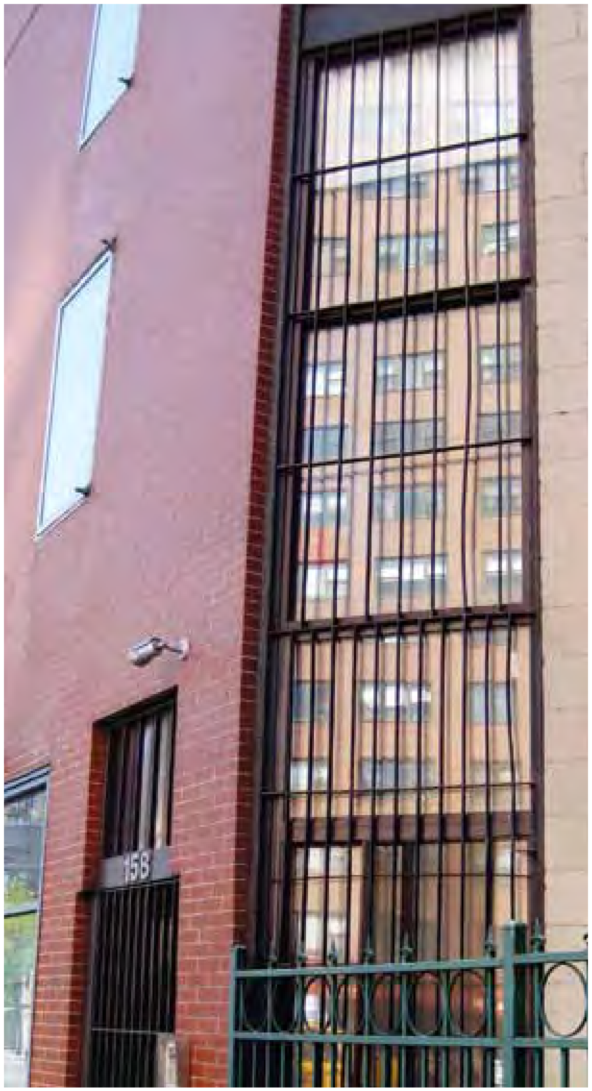
Lower floor windows are thought to be more dangerous to birds because they are more likely to reflect vegetation. Photo: Christine Sheppard, ABC

However, not all collision events take place in bad weather. For example, in a report of mortality at a communications tower in North Dakota (Avery *et al*., 1977), the weather was overcast, usually with drizzle, on four of the five nights with the largest mortality. On the fifth occasion, however, the weather was clear.

Landscaping and Vegetation

Gelb and Delacretaz (2006, 2009) evaluated data from collision mortality at Manhattan building facades. They found that sites where glass reflected extensive vegetation were associated with more collisions than glass reflecting little or no vegetation. Of the ten buildings responsible for the most collisions, four were "low-rise." Klem (2009) measured variables in the space immediately associated with building facades in Manhattan, as risk factors for collisions.

Both increased height of trees and increased height of vegetation increased the risk of collisions in fall. Ten percent increases in tree height and the height of vegetation corresponded to 30% and 13% increases in collisions in fall. In spring, only tree height had a significant influence, with a 10% increase corresponding to a 22% increase in collisions. Confusingly, increasing "facing area" defined as the distance to the nearest structure, corresponded strongly with increased collisions in spring, and with reduced collisions in fall. Presumably, vegetation increases risk both by attracting more birds to an area, and by being reflected in glass.

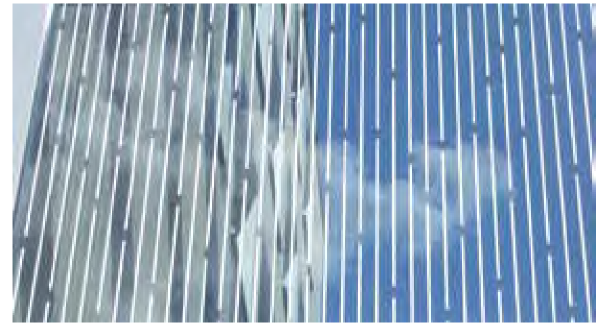


This security grille also creates a pattern that will deter birds from flying to reflections. Photo: Christine Sheppard, ABC

Research: Deterring Collisions

Systematic efforts to identify signals that can be used to make glass visible to birds began with the work of Klem in 1989. Testing glass panes in the field and using a dichotomous choice protocol in an aviary, Klem (1990) demonstrated that popular devices like "diving falcon" silhouettes were only effective if they were applied densely, spaced two to four inches apart. Owl decoys, blinking holiday lights, and pictures of vertebrate eyes were among items found to be ineffective. Grid and stripe patterns made from white material, one inch wide were tested at different spacing intervals. Only three were effective: a 3 x 4 inch grid, vertical stripes spaced four inches apart, and horizontal stripes spaced about an inch apart across the entire surface.

In further testing using the same protocols, Klem (2009) confirmed the effectiveness of 3M™Scotchcal™ Perforated Window Graphic Film (also known as CollidEscape), WindowAlert® decals, if spaced at the 2 x 4 rule, as above, and externally applied ceramic dots or "frits," (0.1 inch dots spaced 0.1 inches apart). Window films applied to the outside surface that rendered glass opaque or translucent were also effective. The most effective deterrents in this study were stripes of highly reflective 40% UV film (D. Klem, pers. comm., March 2011) alternating with



Patterns on the outside of glass, such as that shown above, are more effective than patterns on an inside surface. Photo: Hans Schmid

A dense internal frit pattern on the glass of the Bike and Roll building, near Union Station in Washington D.C., makes it look almost opaque. Photo: Christine Sheppard, ABC

A pattern of narrow horizontal stripes has proven to be highly effective at deterring bird collisions, while covering only about 7% of the surface of the glass. Photo: Hans Schmid high UV absorbing stripes. Completely covering glass with clear or reflective window film that also absorbed UV marginally reduced collisions.

Building on Klem's findings, Rössler developed a testing program in Austria starting in 2004 and continuing to the present (Rössler and Zuna-Kratky, 2004; Rössler, 2005; Rössler, *et al*., 2007; Rössler and Laube, 2008; Rössler, 2009). Working at the banding center at the Hohenau Ringelsdorf Biological Station outside Vienna, Austria made possible a large sampling of birds for each test, in some instances permitting comparisons of a particular pattern under different intensities of lighting. This program has focused primarily on geometric patterns, evaluating the impact of different spacing, orientation, and dimensions. Birds are placed in a "tunnel," where they can view two pieces of glass: one unmodified, (the control) and the other with the pattern to be tested. Birds fly down the tunnel and are scored according to whether they try to exit through the control or the pattern. A mist net keeps the bird from hitting the glass and it is then released. The project focuses not only on finding patterns effective for deterring collisions, but on effective patterns that cover a minimal part of the glass surface. To date, some patterns have been found to be highly effective, while covering only 5% of the glass.

Building on Rössler's work, ABC has collaborated with the Wildlife Conservation Society and the Carnegie Museum to construct a tunnel at Carnegie's Powdermill Banding Station, primarily to test commercially available materials. This project has been supported by the Association of Zoos and Aquarium's Conservation Endowment Fund, the Colcom Foundation, and New York City Audubon. Results from the first season showed that making an entire surface UV reflective was not an effective way to deter birds. With UV materials, contrast seems to be important. Glass fritted in patterns conforming to the 2 x 4 rule, however, scored well as deterrents.

Most clear glass made in the United States transmits about 96% of light falling perpendicular to the outside surface, and reflects about 4%. The amount of light reflected increases at sharper angles – clear glass reflects about 50% of incident light at angles over 70 degrees. Light on the inside of the glass is also partly reflected and partly transmitted. The relative intensities of light transmitted from the inside and reflected from the outside surfaces of glass, plus the viewing angle determine if the glass appears transparent or mirrors the surrounding environment. Patterns on the inside surfaces of glass and objects inside the glass may not always be visible. These changeable optical properties support the

ABC's Chris Sheppard testing a bird in the tunnel at the Carnegie Museum's Powdermill Banding Station in southwestern Pennsylvania. Photo: Susan Elbin, 2011

The tunnel – an apparatus for safely testing effectiveness of different materials and designs for deterring bird collisions. Photo: Christine Sheppard, ABC

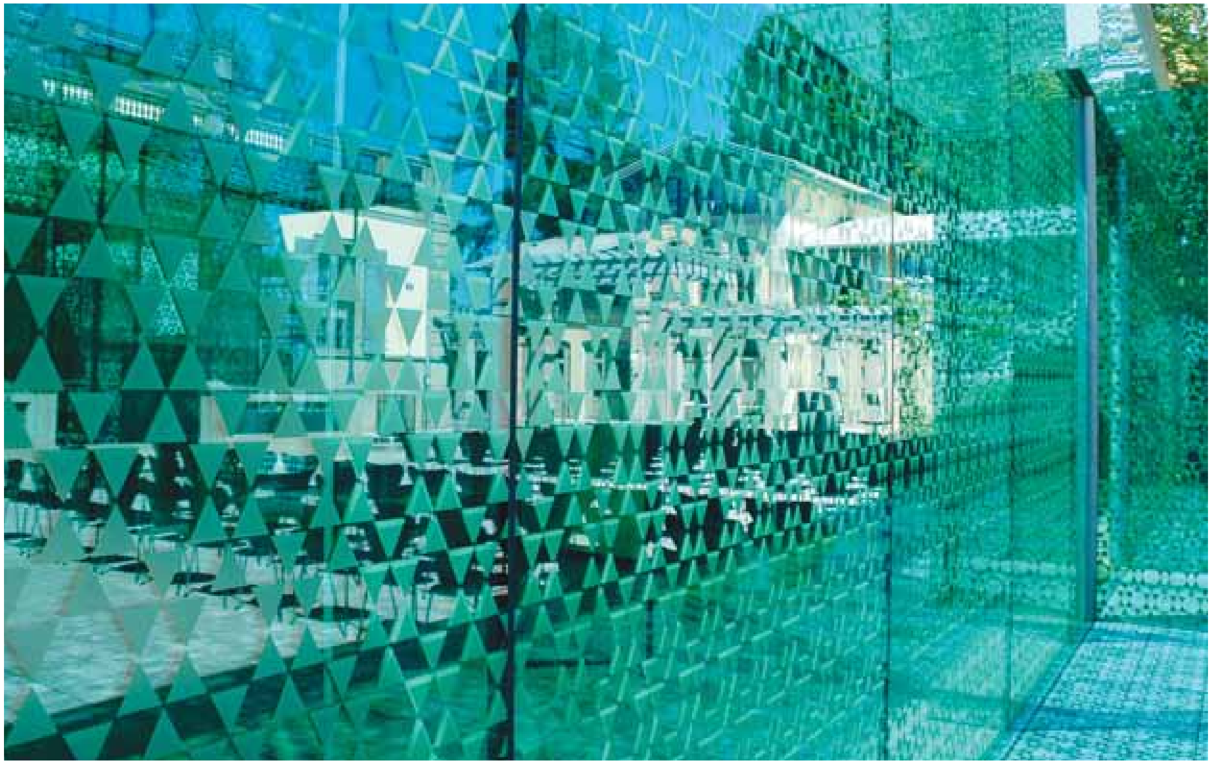
A bird's eye view of glass in the tunnel. Photo: Christine Sheppard, ABC argument that patterns applied to the outer surface of glass are more effective than patterns applied to the inner surface.

The majority of the work described here uses protocols that approximate a situation with free-standing glass – birds can see through glass to the environment on the other side, patterns tested are between the bird and the glass and patterns are primarily back-lit. While this is useful and relevant, it does not adequately model most glass installed in buildings. In that situation, light levels behind the glass are usually substantially lower than light falling on the outside surface. New protocols have been developed to test materials whose effectiveness depends on the glass being primarily front-lit. This includes UV patterns and frit patterns on the inside surfaces of insulated glass.

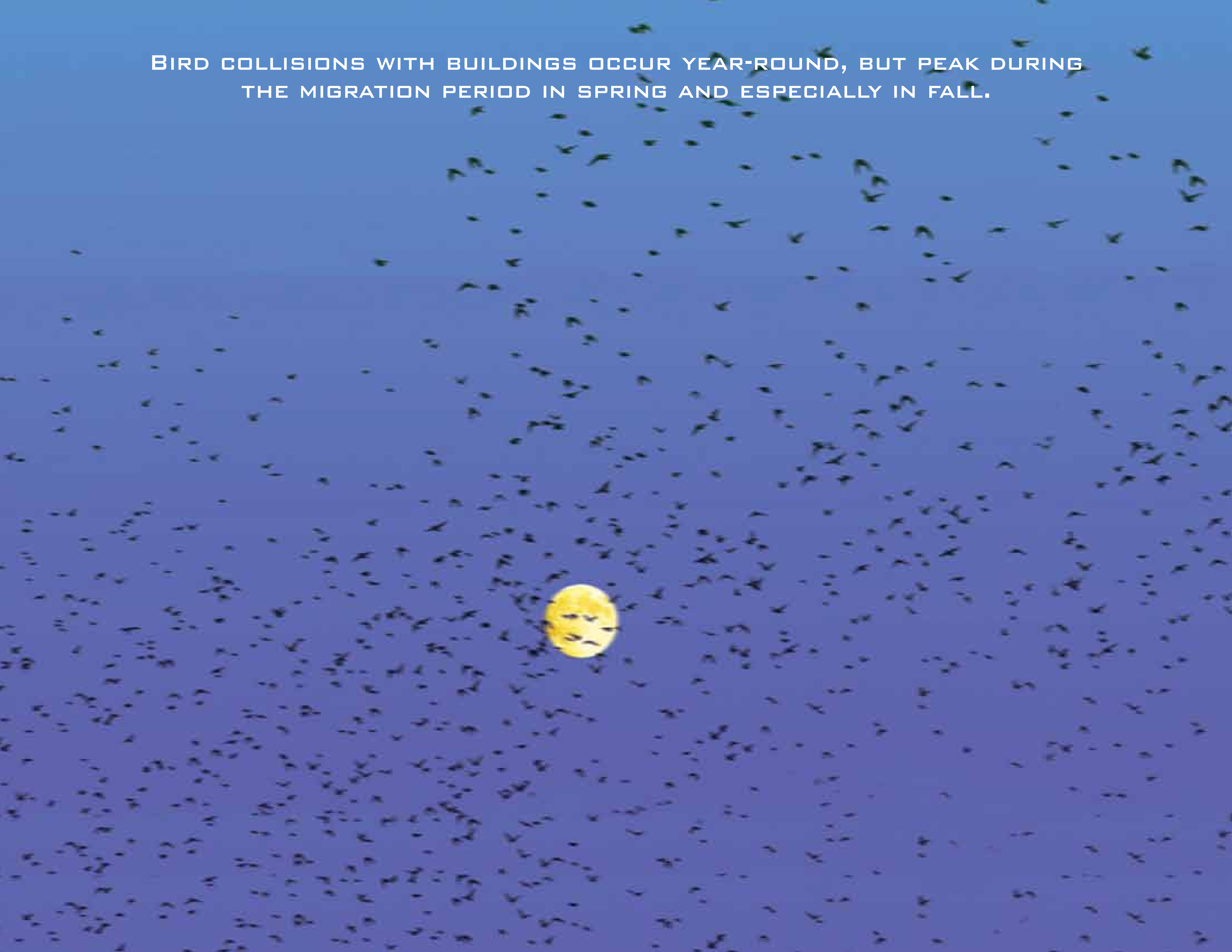
Ornilux Mikado's pattern reflects UV wavelengths. The spiderweb effect is only visible from very limited viewing angles. Photo courtesy of Arnold Glass

All-over patterns such as the one shown above are less effective at deterring collisions. Patterns with more contrast and distinct spaces, such as the one shown on the left, are much more effective. Photo: Christine Sheppard, ABC

A panel of fritted glass, ready for testing. Photo: Christine Sheppard, ABC



This glass facade, of a modern addition to the Reitberg Museum in Zürich, Germany, was designed by Grazioli and Krischanitz. It features a surface pattern formed of green enamel triangles, beautiful and also bird-friendly. Photo: Hans Schmidt



Bird collisions with buildings occur year-round, but peak during the migration period in spring and especially in fall.

APPENDIX II: BIRD MIGRATION

Bird collisions with buildings occur year-round, but peak during the migration period in spring and especially in fall when millions of adults and juvenile birds travel between breeding and wintering grounds. Migration is a complex phenomenon, and different species face different levels of hazards depending on their migration strategy, immediate weather conditions, availability of food, and human-made obstacles encountered on the way.

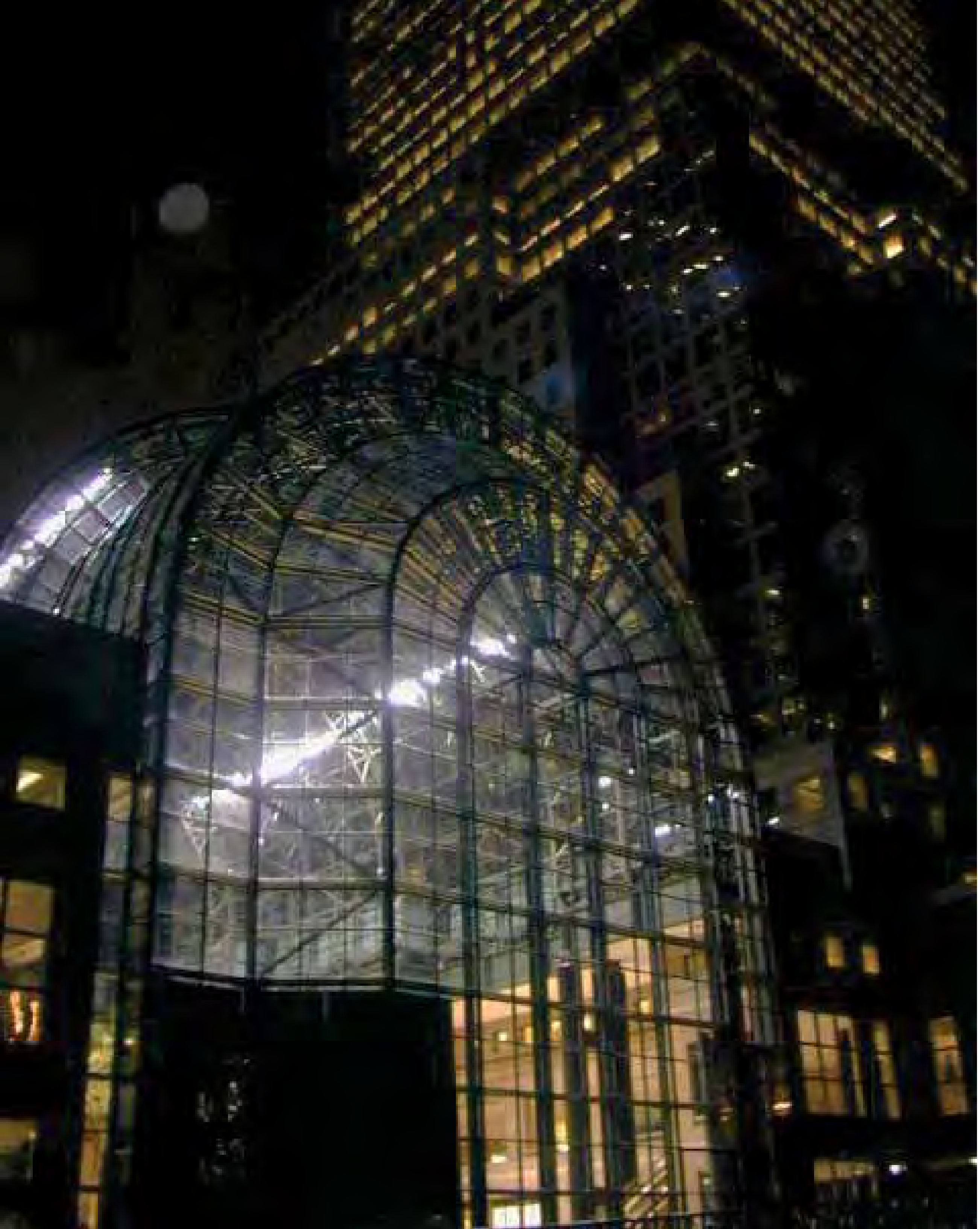
Many species have a migratory pattern that alternates flight with stopovers to replenish their energy stores. Night-flying migrants, including many songbirds, generally take off within a few hours of sunset and land after midnight but before dawn (Kerlinger, 2009). Once birds have landed, they may remain for several days, feeding and waiting for appropriate weather to continue. During that time, they make flights around the local area, hunting for good feeding sites. Almost anywhere they stop – in cities, suburbs or business parks – they run the risk of hitting glass. Most collision monitoring programs involve searching near dawn for birds that have been killed or injured during the night. Programs that also monitor during the day, however, continue to find birds that have collided with windows (Gelb and Delecretaz, 2009; Olson, pers. comm; Russell, pers. comm; Hager, 2008). These diurnal collisions are widespread, and represent the greatest number of bird deaths and the greatest threat to birds.

Diurnal Migrants

Daytime migrants include raptors such as the Broad-winged Hawk and Merlin that take advantage of thermal air currents to reduce the energy needed for flight. Other diurnal migrants, including Red Knots, Canada Geese, and Sandhill Cranes, fly in flocks, and their stopover sites are localized because of their dependence on bodies of water. This means that daytime migration routes often follow land forms such as rivers and mountain ranges as well as coastlines. Birds tend to be concentrated along these routes or "flyways." Some songbird species such as the American Robin, Horned Lark, and Eastern Kingbird also migrate during the day. Diurnal migrant flight altitudes are generally lower than those of nocturnal migrants, putting them at greater risk of collisions with tall buildings.

As seed dispersers, birds such as the Cedar Waxwing play an important role in maintaining many types of habitat. Photo: Chip Miller

Larger birds, such as the Sandhill Crane, migrate in flocks during the day. Photo: Alan Wilson



Nocturnal Migrants

Many songbirds migrate at night, possibly to take advantage of cooler temperatures and less turbulent air, and because they hunt insects or find berries during daylight hours. Generally, these birds migrate individually, not in flocks, spread out across most of the species' range, although local geography may channel birds into narrower routes. Songbirds may fly as many as 200 miles in a night, then stop to rest and feed for one to three days, but these patterns are strongly impacted by weather, especially wind and temperature. Birds may delay departure, waiting for good weather. They generally fly at an altitude of about 2,000 feet, but may descend or curtail flight altogether if they encounter a cold front, rain, or fog. There can be a thousand-fold difference in the number of birds aloft from one night to the next. Concentrations of birds may develop in "staging areas", where birds make ready to cross large barriers such as the Great Lakes or Gulf of Mexico.

Another collision victim – a Yellow-shafted Flicker, found on a Baltimore street. Photo: Daniel J. Lebbin, ABC, October 2008

The glass walls of this atrium, coupled with night-time illumination, create an extreme collision hazard for birds. Photo courtesy of NYC Audubon

Night-migrating songbirds, already imperiled by habitat loss, are at double the risk, threatened both by illuminated buildings when they fly at night (see Appendix I) and by daytime glass collisions as they seek food and shelter.

Millions are thus at risk as they ascend and descend, flying through or stopping in or near populated areas. As city buildings grow in height, they become unseen obstacles by night and pose confusing reflections by day. Nocturnal migrants, after landing, make short, low flights near dawn, searching for feeding areas and running a gauntlet of glass in almost every habitat, from cities to suburbs, and increasingly, exurbs. When weather conditions cause night fliers to descend into the range of lighted structures, huge kills can occur around tall buildings. Urban sprawl is creating large areas lit all night that may be causing less obvious, more dispersed bird mortality.

Local Movements

Glass collisions by migrating songbirds are by far the best known, but mortality of other groups of birds is not insignificant. Fatalities from collisions have been reported for 19 of 42 raptor species in both urban and non-urban environments, with collisions being the leading known cause of death for four species in cities, including the Peregrine Falcon. Breeding birds encounter glass as they search for nest sites or food, patrol territories or home ranges, or flee predators. Mortality increases as inexperienced fledglings leave the nest and begin to fly on their own.

Collisions are the leading known cause of death in city-dwelling Peregrine Falcons. Photo: Peter LaTourrette

The mirrored glass of this office building reflects nature so perfectly that it is easy to see how birds mistake reflection for reality. Photo: Christine Sheppard, ABC

Reflections don't have to be of something attractive to trick birds – as they fly around real buildings in search of food, they may also try to fly around reflected buildings. Photo: Christine Sheppard, ABC

American Woodcock are often victims of collisions. This bird hit a window in Washington D.C. in March, 2011. Photo: Dariusz Zdziebkowski, ABC

Often, only part of a building is responsible for causing most of the collisions. Evaluation and documentation can help develop a program of remediation targeting that area. This can be almost as effective as modifying the entire building, as well as being less expensive. Documentation of patterns of mortality and environmental features that may be contributing to collisions is essential. Operations personnel are often good sources of information as they may come across bird carcasses while performing regular maintenance activities. People who work near windows are often aware of birds hitting them. Initiating regular monitoring not only documents mortality patterns, but also provides a baseline for demonstrating improvement. The following questions can help guide the evaluation and documentation process by identifying features likely to cause collisions.

Seasonal Timing

Are collisions happening mostly during migration or fledging periods, in winter, or year round? If collisions happen only during a short time period, it may be possible to apply inexpensive, temporary solutions during that time and remove them for the rest of the year.

Some birds will attack their own reflections, especially in spring. This is not a true collision. Territorial males, especially American Robins and Cardinals, perceive their reflection as a rival male. They are unlikely to injure themselves, but temporarily blocking the offending window from the outside should resolve the problem.

Diurnal Timing

Are collisions happening at a particular time of day? The appearance of glass can change significantly with different light levels, direct or indirect illumination, and sun angles. It may be possible to simply use shades or shutters during critical times (see Appendix II).

Weather

Do collisions coincide with particular weather conditions, such as foggy or overcast days? Such collisions may be light-related. It may be possible to create an email notification system, asking building personnel to turn off lights when bad weather is forecast.

Comparison of Different Retrofit Options

Material	Effectiveness	Cost	Application	Appearance	Longevity	Upkeep
Seasonal, temporary solutions	*****	$	*	*	na	na
Netting	*****	$$	**	***	****	***
Window film	*****	$$$	****	*****	***	****
Screens	*****	$$	***	****	*****	****
Shutters	*****	$$$	***	****	*****	****
Grilles	*****	$$$	****	*****	*****	****
Replace glass	*****	$$$$$	*****	*****	*****	****
5 stars/$ =	highly effective	expensive	easy	attractive	long-lasting	minimal

Robins are frequently killed by glass on buildings near meadows and lawns. Photo: Christine Sheppard, ABC, July 2009

The white stripes on this glass wall are an easy way to make a very dangerous area safe for birds. Photo: Hans Schmid

While patterns on the exterior surface of glass are most effective, blinds and curtains can help disrupt reflections. Partially open blinds, like those seen here, are most effective. Photo: Christine Sheppard, ABC

Location

Are there particular windows, groups of windows, or building facades that account for most collisions? It may be cost effective to modify only those sections of glass. Is glass located where birds fly between roosting or nesting and feeding sites? Are there areas where plants can be seen through glass – for example, an atrium, courtyard, or glazed passageway? Are there architectural or landscaping features that tend to direct birds towards glass? Examples might be a wall or rock outcropping, or a clear pathway bordered by dense vegetation. Solutions here might include using a screen or trellis to divert flight paths. Are there fruit trees, berry bushes, or other plants near windows that are likely to attract birds closer to glass? These windows should be a high priority for remediation. The glass itself can be modified, but it may also be possible to use live or inanimate landscaping elements, to block the view between food sources and windows.

Local Bird Populations

What birds are usually found in the area? Local bird groups or volunteers may be able to help characterize local and transitory bird populations, as well as the most likely routes for birds making short flights around the area.

Local bird-watchers can be a source of detailed information about local birds and their movements. Photo: Chip Miller

The Indigo Bunting is a common summer resident and migrant in the eastern United States. Photo: Barth Schorre

Research

Research on songbirds, the most numerous victims of collisions, has shown that horizontal spaces must be 2” or narrower, to deter the majority of birds. Vertical spaces must be 4” or narrower. This difference presumably has to do with the shape of a flying bird with outstretched wings. Within these guidelines, however, considerable variation is possible when devising bird-friendly patterns. We recommend that lines be at least ¼” wide, but it is not necessary that they be only vertical or horizontal. Contrast between pattern and background is important, however, be aware that the background – building interior, sky, vegetation – may change in appearance throughout the day. Effective patterns on the exterior surface of glass will combat reflection, transparency and passage effect. In the case of handrails or other applications viewed from both sides, patterns should be applied to both surfaces if birds can approach from either side.

This Barn Swallow flying sideways through a barn door perfectly illustrates the 2 x 4 rule. Photo: Keith Ringland.

The American Birding Association (www.aba.org/resources/birdclubs.html), Bird Watchers Digest (www.birdwatchersdigest.com/bwdsite/connect/birdclubs/clubfinder.php?sc=migrate), Audubon chapters (http://www.audubon.org/search-by-zip), and Birding.com (www.birding.com/organizations.asp) are good places to start finding such resources. Nearby universities, colleges, and museums may also be helpful.

There are many quick, easy, and cost-effective ways to deter collisions on a short term basis. Here, tape stripes, stenciled, and free hand patterns in tempera paint on home windows. Photo: Christine Sheppard, ABC

Madrid's Vallecas 51, designed by Somos Arquitectos, uses open-celled polycarbonate panels – a sustainable and recyclable skin that presents no threat to birds. Photo: Victor Tropchenko

APPENDIX IV: EXAMPLE POLICY

ORDINANCE

Sponsored by: [list names]

WHEREAS, birds provide valuable and important ecological services,

WHEREAS, [location] has recorded [ ] species of resident and migratory bird species,

WHEREAS, birding is a hobby enjoyed by 64 million Americans and generates more than $40 billion a year in economic activity in the United States,

WHEREAS, as many as one billion birds may be killed by collisions with windows every year in the United States,

WHEREAS, reducing light pollution has been shown to reduce bird deaths from collisions with windows,

WHEREAS, new buildings can be designed to reduce bird deaths from collisions without additional cost,

WHEREAS there exist strategies to mitigate collisions on existing buildings,

WHEREAS, bird-friendly practices often go hand-in-hand with energy efficiency improvements,

And **WHEREAS** [any additions specific to the particular location]

NOW, THEREFORE, BE IT ORDAINED,
by [acting agency]

[title of legislation and other necessary language]

(a) In this section the term "Leadership in Energy and Environmental Design (LEED)" means a green building rating system promulgated by the United States Green Building Council (USGBC) that provides specific principles and practices, some mandatory but the majority discretionary, that may be applied during the design, construction, and operation phases, which enable the building to be awarded points from reaching present standards of environmental efficiency so that it may achieve LEED certification from the USGBC as a "green" building,

(b) [acting agency] does hereby order [acting department] to take the steps necessary to assure that all newly constructed buildings and all buildings scheduled for capital improvement are designed, built, and operated in accordance with the standards and requirements of the LEED Green Building Rating System Pilot Credit #55,

(c) The USGBC releases revised versions of the LEED Green Building Rating System on a regular basis; and [acting department] shall refer to the most current version of the LEED when beginning a new building construction permit project or renovation.

(d) New construction and major renovation projects shall incorporate bird-friendly building materials and design features, including, but not limited to, those recommended by the American Bird Conservancy Guidelines for Bird-friendly Design.

(e) [acting department] shall make existing buildings bird-friendly where practicable.

The U.S. Census Complex in Suitland, Maryland, designed by Skidmore, Owings, Merrill, features a *brise soleil* that shades the curtain wall. Wavy vertical fins of marine-grade, white oak reduce sun glare while eliminating glass reflections. Photo: Esther Langan

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The World Trade Center of New Orleans, designed by Edward Durrell Stone, uses a simple bird-friendly strategy – almost all windows have exterior shutters. Photo: Christine Sheppard, ABC

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The steel mesh enveloping Zurich's Cocoon in Switzerland, designed by Camenzind Evolution Ltd, provides privacy and protects birds, but still permits occupants to see out. Photo: Anton Volgger

External shades, as shown here on the Batson Building in Sacramento, California, designed by Sym Van der Ryn, are a simple and flexible strategy for reducing bird collisions, as well as controlling heat and light.
Photo courtesy of MechoShade

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American Bird Conservancy Authors and Editors

Written by Dr. Christine Sheppard, Bird Collisions Campaign Manager
Additional contributions by: Michael Fry, Michael Parr, Anne Law
Edited by: George Fenwick, Leah Lavin, Darin Schroeder, Gavin Shire, David Younkman
Designed by: Gemma Radko

Recommended Citation:

Sheppard, C. 2011. *Bird-Friendly Building Design*. American Bird Conservancy, The Plains, VA, 60 pages.

Acknowledgements

American Bird Conservancy (ABC) would like to thank the following for their help in bringing this document to fruition: Susan Elbin, Glenn Phillips, and the staff of New York City Audubon; The Wildlife Conservation Society; Bird-safe Glass Foundation; International Dark Skies Association; Fatal Light Awareness Program; Joanna Eckles; and Dr. Dennis Taylor.

We are especially grateful to the Leon Levy Foundation for their ongoing support for ABC's Collisions Program.

This document is based on guidelines published by: New York City Audubon Society, Inc., May 2007: Project Director: Kate Orff, RLA, Columbia University GSAPP; Authors: Hillary Brown, AIA, Steven Caputo, New Civic Works; NYC Audubon Project Staff: E.J. McAdams, Marcia Fowle, Glenn Phillips, Chelsea Dewitt, Yigal Gelb; Graphics: Benedict Clouette, Nick Kothari, Betsy Stoel, Li-Chi Wang; Reviewers: Karen Cotton, Acting Director, Bird-Safe Working Group; Randi Doeker, Birds & Buildings Forum; Bruce Fowle, FAIA, Daniel Piselli, FXFOWLE; Marcia Fowle; Yigal Gelb, Program Director, NYC Audubon; Mary Jane Kaplan; Daniel Klem, Jr., PhD., Muhlenberg College; Albert M. Manville, PhD., U.S. Department of the Interior, Fish and Wildlife Service; E. J. McAdams, Former Executive Director NYC, Audubon; Glenn Phillips, Executive Director, NYC Audubon

Disclaimer

The Institute Arabe du Monde in Paris, France provides light to the building interior without using glass. Photo: Joseph Radko, Jr.

The Orange Cube, a commercial and cultural complex, was designed by Jacob + McFarlane Architects as part of redevelopment of the harbor in Lyons, France. The external skin virtually eliminates threats to birds while permitting natural illumination of the interior and sightlines for those inside. Photo © Nicolas Borel

(BACK COVER) The Wexford Science and Technology Building in Philadelphia, designed by Zimmer, Gunsul, Frasca, uses opaque glass to provide light without glare, making it safe for birds. Photo courtesy of Walker Glass

ISBN 978-1-4675-2159-8
$11.99
51199>
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