Preventing Bird Collisions with Glass: A Solutions Handbook

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The federal government cannot endorse any product, service or enterprise. The products and companies listed in this handbook are those that are known to create useful window retrofit options. NPS does not recommend one of these products or companies over any other.

Introduction

Bird collisions with glass are one of the most significant sources of anthropogenic mortality (Table 1, Loss et al. 2015), second only to free-roaming cats (including pet cats that are allowed outdoors, stray cats, and feral cats). However, it is also a problem with many easy and readily available solutions. Because the problem is so widespread, with nearly 50% of mortality taking place on home windows, National Parks have a chance to address their own glass, while also providing information and models for visitors that allow visitors to take immediate action at home.

Table 1. Annual US bird mortality rates from anthropogenic causes (Loss et al. 2013; Loss et al. 2014)

Mortality Cause	Mortality Estimate
Buildings/Glass	0.4 - 1 billion
Outdoor Cats	1.5 - 4 billion

Figure 1. Birds disperse seeds, helping habitat regenerate. Cedar Waxwing. Photo: Stan Lupo

Figure 2. Birds may eat their weight in insects daily. Black-throated Green Warbler. Photo: Andy Reago and Chrissy McLarren

Birds are essential components of ecosystems and humans are generally unaware of how birds contribute to human comfort. In addition to their intrinsic and cultural value, birds disperse seeds, helping to regenerate habitats (Figure 1).

They contribute billions to agriculture, controlling insect pests (Figure 2) and providing pollination services. Bird-watching, as hobby and industry, is an economic engine exceeding forty billion dollars a year, and involving transportation, lodging, equipment, feed and feeders, communications platforms and more. While there will always be questions to answer, luckily research over the last 15 years has provided the information needed to stop collisions mortality (Figure 3).

Figure 3. Display of birds collected by Fatal Light Awareness Program monitors in Toronto. Photo: Kenneth Herdy

Seeing Glass

Most people don't realize that they can't actually see glass. Early in life, they were able to learn the concept of glass, as a solid material that can both be transparent and can create realistic reflections of surroundings. Humans learn cues that tell them where glass is likely to be found, and every year, people still bump into glass doors and walls (Figure 4). Unfortunately, birds don't understand glass as a concept – a solid material that can be both transparent and reflective. Nor can birds use the cues we do to tell where glass may be. A row of decals on a glass door warns humans – but to birds are just obstacles they can fly around (Figure 5).

Figure 4. Sign warning of presence of glass. Photo: Christine Sheppard

Figure 5. Door with rows of decals required by code. Photo: Christine Sheppard

In Figure 6, below, we cannot determine whether the image is a photo of a tree, a tree seen through a window, or the reflection of a tree, because we lack the cues that would help us. With the information in Figure 7— mullions, a crack, and right angles— we know glass is involved, but it is only with the information added in Figure 8— the edges of the glass wall, 'trees' without trunks— that we can confirm that the image is a reflection and that we are not looking out the window.

Figure 6. Photos: Christine Sheppard

Figure 7.

Figure 8.

Birds take what they see literally, and this is the cause of most collisions (Figure 9). That is not to say that birds have poor vision – birds have excellent vision, but their eyes and brains evolved to deal with flight and other challenges people and other mammals don't have to face.

Figure 9. Even transparent glass can be highly reflective, obscuring everything behind the outer surface. Photo: Christine Sheppard

Figure 10. Snow Monkey. Photo: Mark Grundland

Humans and other primates have eyes that are close together (Figure 10). Their eyes see similar views, providing depth perception, three-D vision. Humans tend to experience the world as something in front of them that they are moving into – as witnessed by people often telling each other to watch where they are going.

Most birds have eyes on the sides of their heads (Figure 11) – they see different things with each eye, have relatively little depth perception and presumably see the world as something they are immersed in. Birds use other strategies to determine their flight speed and trajectory, with three-D vision often limited to the end of their beak. Especially if they believe they are flying in an open, uncluttered environment, what's in front may be less important than what they see to the side and even behind. Birds' ability to resolve objects at a distance is poorer than that of humans, making it difficult to create markers visible to birds but not humans.

Figure 11. Pine Warbler. Photo: Vicki DeLoach

Where Are All the Carcasses?

Figure 12. American Robin. Photo: Christine Sheppard

Virtually anyone you ask has seen or heard a bird hit glass, yet most believe that it was a rare event (Figure 12). Most collisions take place during the day; many birds collide in early morning, as birds become active at dawn, seeking food. These carcasses may be swept up by building maintainers, fall into foundation plantings or gratings or injured birds may flutter off, landing away from the glass. Many of these birds die later, from internal injuries. A large fraction of carcasses is taken by scavengers like raccoons, crows, outdoor cats, opossums and rats, with some scavengers checking 'good' windows multiple times a day. This means it can

be difficult to know how many collisions take place on a given piece of glass. Scientists studying collisions often do 'persistence studies', observing carcasses left in known locations, to estimate how long it takes for them to disappear.

Collisions: The Basics

Figure 13. Baltimore Oriole. Photo: David Strickland

Highest collision peaks occur during spring and fall migration, with songbirds the most frequent victims. However, in late spring, another peak corresponds with local birds fledging young and another peak in winter, reflects resident birds leaving territories to search for food. Almost every type of bird – 1,358 species reported so far – has been recorded as a collision's victim.

Repeatedly, studies have shown that more glass, both absolutely and relatively, and larger pane size correlate with more collisions (Klem et al. 2009; Parkins et al. 2015; Ocampo-Peñuela et al. 2016; Loss et al. 2019). In 2014, the Smithsonian published a meta-analysis of collisions monitoring data – estimating that 365 million to 988 million (nearly a billion birds) are killed annually in the U.S. (Loss et al. 2014). The higher figure is more likely, given that the data used were from 2012 and earlier, the amount of glass in the built environment has steadily increased, and recent studies have shown that monitors find fewer carcasses than had been previously assumed.

When and Where Do Collisions Take Place?

The Smithsonian study showed that nearly half of collisions take place on homes (Figure 14) and other structures up to three floors tall, partly because there are so many buildings this size. Most of the remainder occur on low rise buildings (4-11 stories tall, Figure 15), and only a fraction on high rises. This is because there are few skyscrapers, relative to lower structures, but also because the majority of collisions happen in 'bird activity zone' – from the ground up to tree top height.

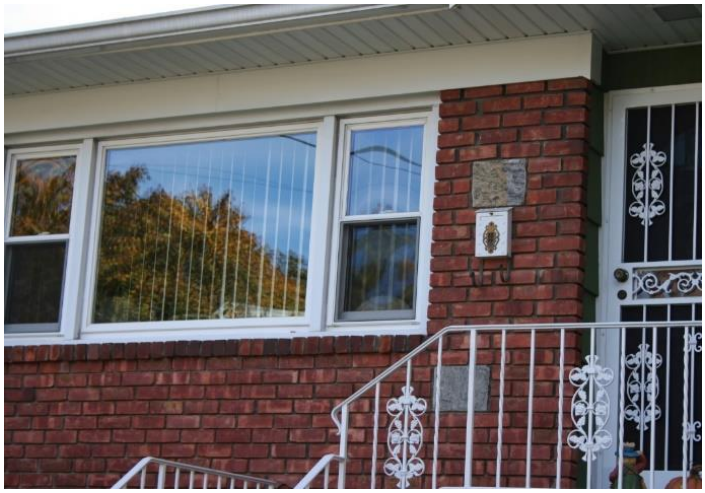

Figure 14. Home windows. Photo: Christine Sheppard

This is where birds find the vegetation they need for food and shelter. Most collisions on tall buildings take place on the lower floors, although there is some increment with increasing height. Most collisions take place during the day, especially in the morning, as birds search for vegetation, search within vegetation and collide with glass that reflects vegetation.

Figure 15. U.S. Bank Stadium, Minneapolis, MN. Photo: Jim Teter

What is Bird-friendly Glass?

Most bird-friendly glass incorporates two-dimensional visual markers that are visible to birds. This pattern can be made of ceramic frit, ceramic ink, etch, enamel, vinyl, a UV coating or other material integral to the glass (Figure 16).

Figure 16. Bird-friendly glass with a frit pattern. Photo: Lila Kakut

Figure 17. Sunshade at Stephen A. Levin building, University of Pennsylvania. Photo: Gregory Benson

Three dimensional structures like louvers, sunshades and screens can also make glass safe for birds (Figure 17). The pattern of markers is what *we* notice, but it is the empty spaces in the pattern that are meaningful to birds. If spacing is too tight to fly through, they'll avoid it.

To be effective, patterns of visual markers must have appropriate spacing, be visible to birds, and show up against reflections or habitat seen through the glass.

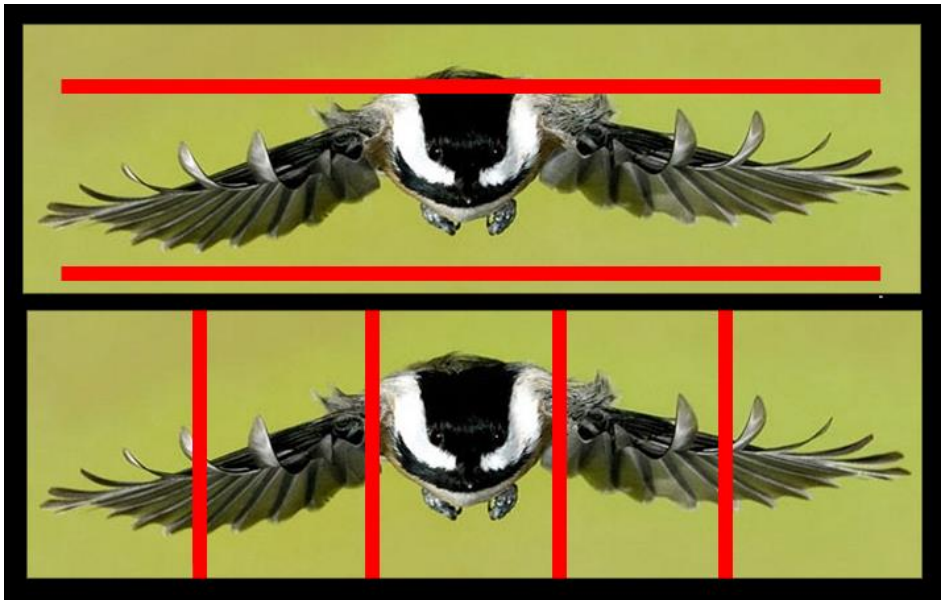

Figure 18. Diagram of recommended spacing for bird-friendly visual markers.

Spacing Guidelines for Visual Markers

Early research (Klem 1990, 2009; Rössler 2004, 2005; Rössler et al. 2007) indicated that visual markers with 2" horizontal spacing, as well as markers with 4" vertical spacing, reduced collisions significantly, leading to a common recommendation for spacing, the '2x4' rule. Post remediation monitoring, however, showed that 4-inch vertical spacing was not effective in stopping hummingbirds from colliding. **Spacing no greater than 2" vertically or 2" horizontally is the current recommendation to deter most collisions** (Figure 18). To be visible to birds, a dot should have a minimum dimension of ¼". Lines should be at least ⅛" wide.

Choosing Retrofit Solutions for Remediation of Existing Glass

Existing glass can be made bird-friendly by application of film, decals, paint, screens, external cords and other materials *on the outside surface*.

Visual markers work best when applied to the outside surface of the glass, as reflections on the outer surface can obscure or even obliterate the view of markers on inside surfaces.

Examples of the different options available for retrofitting glass follow and information about them is summarized in Table 2 (following page).

- Solutions range from cheap to expensive, easy to apply to those needing professional installation, short term to long term.
- All the options described in this document can be effective at reducing bird collisions with glass.
- All of the options on the following table are included in American Bird Conservancy's searchable database of products and solutions, and products for new construction are also included here: Products & Solutions to Stop Birds Flying Into Windows | ABC (abcbirds.org)

Summary Table of Retrofit Solutions

Table 2: Comparison of retrofit options. Choosing the right retrofit option to stop collisions on your glass can be trying, because there are many different but effective solutions for glass, each with its own pros and cons. We've included only materials costs, not added costs for shipping or installation.

Table Codes			
Cost/Square Foot	$ = <$1.00	$$ = $1-$5.00	$$$ = >$5
Installation	MIN = minimal tools, easiest application	DIY = few tools, moderate ease of application	PRO = professional installation
Longevity	SEASONAL = can't be reused if removed	LONG TERM = permanent installation	REUSABLE = remove and reuse seasonally

Product	Cost/Square ft.	Installation	Longevity	Page
Paint, freehand	$	MIN	seasonal	13
Paint, with template	$	MIN	seasonal	14
Paint, with stencil roller	$	MIN	seasonal	15
Acopian Birdsavers	$-$$	DIY	long term	16
Bird crash preventers	$$	DIY	long term	17
Decals	$$	MIN	seasonal	18
Tape	$$	MIN	long term	19
Feather Friendly (DIY)	$$	DIY	long term	20
Insect screen	$$	PRO	long term	21
CollidEscape	$$	PRO	long term	22
Feather Friendly (commercial)	$$	PRO	long term	23
Bird Divert	$$	PRO	long term	24
Solyx Window film	$$$	PRO	long term	25
Netting	$$$	PRO	long term	26
Shades, solar, motorized	$$$	PRO	long term	27

Paint: Free-hand

Available at craft stores and on line; less than $1/square foot; minimal tools; can't be reused if removed

Figure 19. Seasonal painted window. Photo: Christine Sheppard

Paint, applied to the outside surface of the glass, can be used as an effective and inexpensive collisions' deterrent. Depending on the paint, this solution can be temporary, making it an excellent seasonal option (Figure 19), or long lasting.

Designs can be applied free-hand (Figures 20-21), using a guide like a stencil taped to the other side of the glass or with a patterned roller, so it is easy to customize patterns or change them seasonally. Tempera paint is non-toxic and lasts surprisingly well, while being easy to remove. Acrylic or oil-based paints are harder to take off.

Paints must be applied to clean surfaces. Remove dirt and any residue from cleaner. Free-hand application can be done with a sponge or a brush, or even a finger

Figure 20. Freehand tempera paint. Photo: Gail Walter

Figure 21. Freehand tempera paint. Photo: Christine Sheppard

Paint: Stencils, Templates and Other Guides

Available at craft stores or online; less than $1/square foot; minimal tools; can't be reused if removed

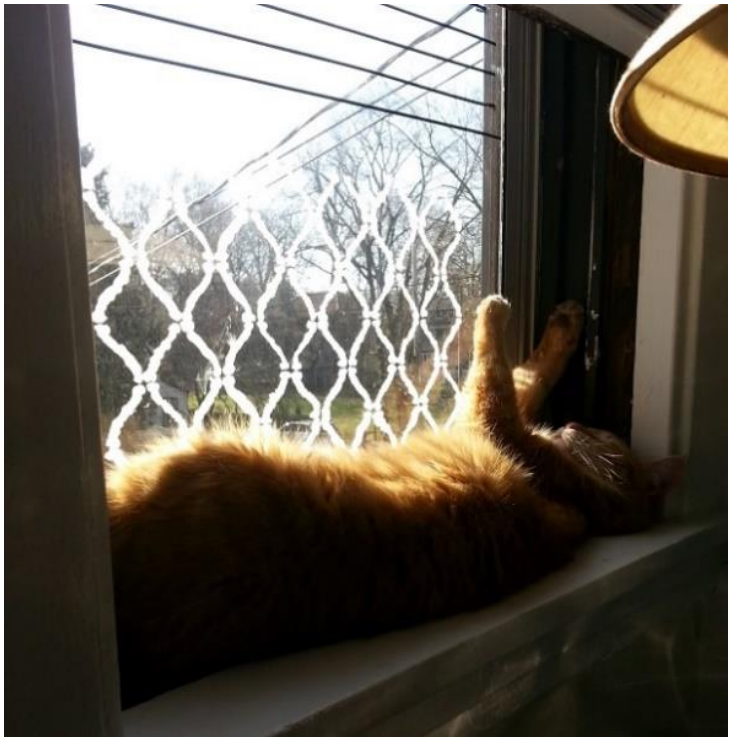

Figure 22. Indoor cat admires tempera paint applied with brush and template. Photo: Christine Sheppard

Stencils can be adhered to the front of the glass and used with spray paint, or attached to the back of the glass and used as a guide, with the design traced with a brush or other tool on the front (Figure 22). Paint should be applied to the outside surface of clean glass. It is important to ensure that there is no residue from any product used to clean the glass or the paint may not stick.

At the Beaty Biodiversity Museum at the University of British Columbia, paper was applied to the inside of the windows, and a design was projected onto the paper. Volunteers then traced the design on the outside of the glass, using white oil-based pens (Figure 23).

Figure 23. Painted design using oil-based markers. Photo: University of British Columbia

Paint: Patterned Paint Rollers and Stencil Rollers

Available at craft stores or online; less than $1/square foot; minimal tools; can't be reused if removed

- https://www.artisticpaintingstudio.com/
- Bueer 7" DIY Patterned Paint Roller Decorative Rubber Roller - Amazon.com

Stencil rollers speed coverage of large areas of glass, as shown here at the North Carolina Zoo's Education building (Figures 24-26).

Some practice is required to master the techniques, but the manufacturers provide good video tutorials.

Figures 24 - 25. Tempera pattern applied with stencil roller and stencil roller. All photos this page: North Carolina Zoo

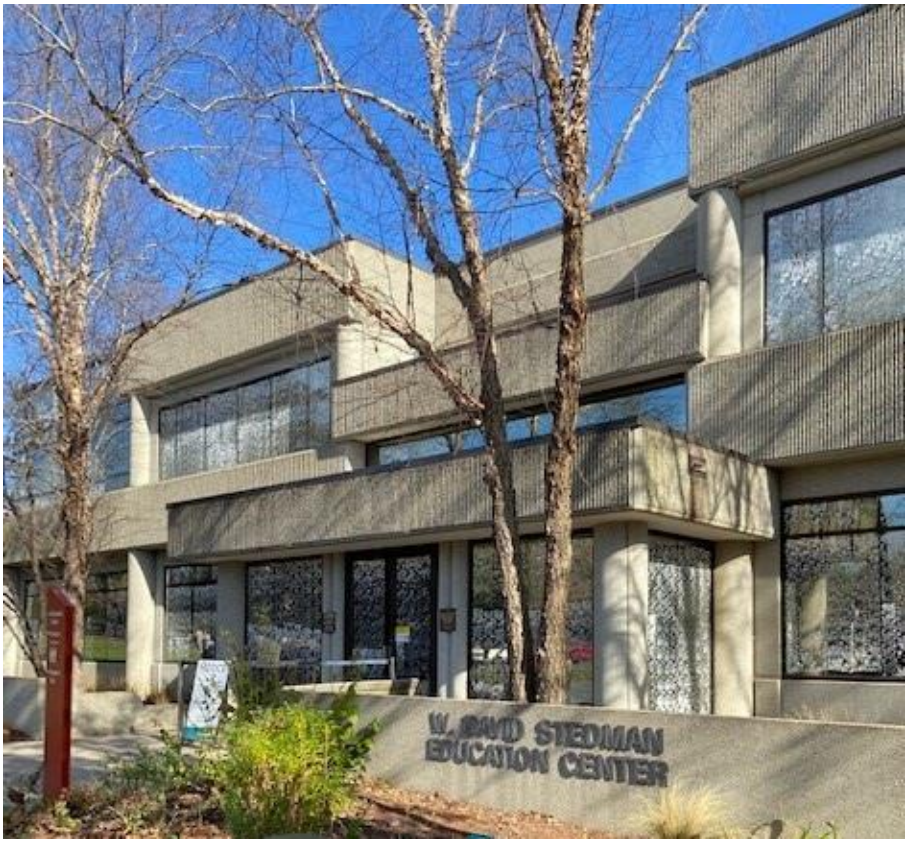

Figure 26. Education Center, North Carolina Zoo, with stenciled windows.

Acopian Birdsavers

Available at https://www.birdsavers.com; $1 - $5/square foot; tools needed; permanent installation

Figure 27. Birdsaver constructed in frames. Photo: Ellen K. Rudolph

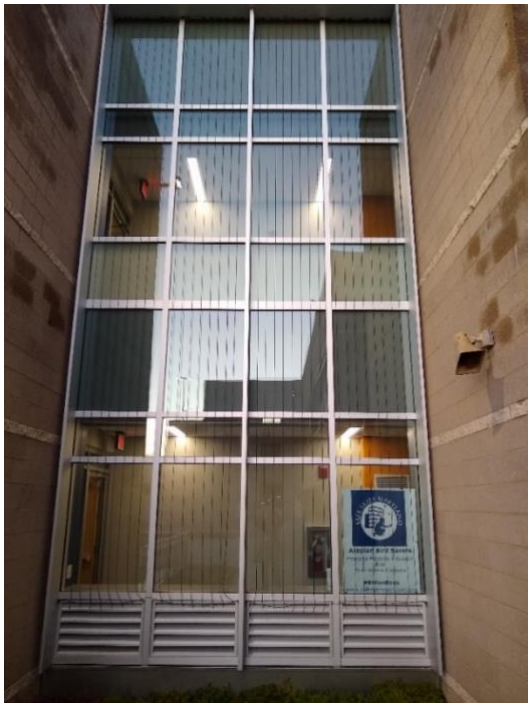

Figure 28. Multi-story birdsaver. Photo: SafeSkies Maryland

Acopian Birdsavers, aka Zen Windcurtains, are a highly effective collisions solution, in addition to being very cost effective and quite unobtrusive. They are a three-dimensional solution, paracord hung in front of glass, spaced 4" apart. Cords are attached at the top and may be attached at the bottom. They may combine a visible signal with a physical barrier. Initially used as a home retrofit, as in Figure 27, they can also be applied at larger scales (Figure 28) and even planned as part of new construction. They can be purchased pre-made or they can be handmade for a lower cost following instructions on the website. The birdsavers website has instructions for installation but many have used the concept with different materials or installation types (Figure 29).

Figure 29. Cord Birdsaver at Organ Pipe Cactus National Monument. Photo: Danny Martin

Bird Crash Preventers

Available at birdcrashpreventers.com; $1 - $5/square foot; tools needed; permanent installation

Monofilament lines spaced three inches apart, attached at top and bottom to rods, mounted with brackets above the glass. Available as kits, in white (Figure 30) or brown (Figure 31), 36 or 48” wide x up to 84” tall. Lines are attached to bars at top and bottom. There is no data to show whether white outperforms brown, but more visible strings will be more effective.

Figure 30. White bird crash preventer. Photo: Santa Rosa National

Figure 31. Brown bird crash preventer. Photo: Santa Rosa National

Decals

Available online and in some bird specialty stores; $1 - $5/square foot; minimal tools; some can be removed and re-used

- https://abirdseyeview.com
- https://windowalert.com
- find more at Amazon.com

Figure 32. Single and widely spaced decals don't deter collisions. Photo: Christine Sheppard

Decals are the collisions solution familiar to most people and they can be effective when properly used. Unfortunately, this depends strongly upon applying multiple decals with correct spacing and one frequently hears people say 'I tried a decal but it didn't work' (Figure 32). The problem is a combination of a persistent myth, lack of understanding why spacing is important (page 10) and often misleading or no guidance provided when decals are purchased and on packaging.

Decades ago, it was proposed that birds interpret silhouettes as predators and that the silhouette of a diving raptor applied to glass would cause birds to avoid windows. The research on which this was based was not substantiated, and installing a single raptor decal has repeatedly been found not to work (Schleit et al. 2011), but the idea has had a life of its own. To some extent, it has become confused with the fact that a single row of decals can warn humans to avoid glass walls and doors. Because birds never understand the concept of glass as a transparent barrier, a single decal or a row of decals does not warn birds.

Figure 33. Window Alert decals with correct spacing. Photo: Christine Sheppard

In order to be effective, decals must be spaced to cue birds that the spaces between them are too narrow to fly through, as in Figures 33 and 34 below. Birds do not recognize decals as birds, or leaves or butterflies. These shapes are pleasing to humans, but it is the spacing between them is critical for deterring collisions. **Decals must be spaced no more than 2" by 2" apart.** Decals are often larger than necessary for visibility and will work when cut into smaller pieces, which can reduce window coverage while remaining effective.

Figure 34. Decals designed by Lynne Parks. Photo: Christine Sheppard

In most cases, decals should be placed on the outside surface of the window. Otherwise, reflections may obscure the decals and make them invisible to birds. The one exception is Birds Eye View decals, which have been shown to work on the inside of single pane plate glass windows. On multi-pane glass or glass with coatings they may be less effective.

Tape

Available online. $1 - $5/square foot; minimal tools; permanent installation

- ABC BirdTape available at https://www.featherfriendly.com/abc-birdtape
- Amazon.com (search on 'chart tape')
- https://www.stripeman.com/1-8-single-line-single-color-vinyl-stripe-roll/

Tape and decals are similar, with decals generally smaller and used over shorter periods of time. It is easier to cover a large area with tape, which should also be installed on the outside surface of the glass. Any tape can work, but tape specifically designed for exterior use will last much longer. Tape should be at least 1/8" wide, (or wider) spaced two inches apart. Horizontal and vertical lines are fine, but diagonals and chevrons can add interest (Figures 35-38). ABC BirdTape is available in both rolls and as 2" by 2" squares.

Figure 35. ABC Birdtape at Estero Llano Grande State Park, TX. Photo: Katherine Sheppard

Figure 36. Tape and decals at Tirimbina Rainforest Lodge, Costa Rica. Photo: Tirimbina Rainforest Lodge

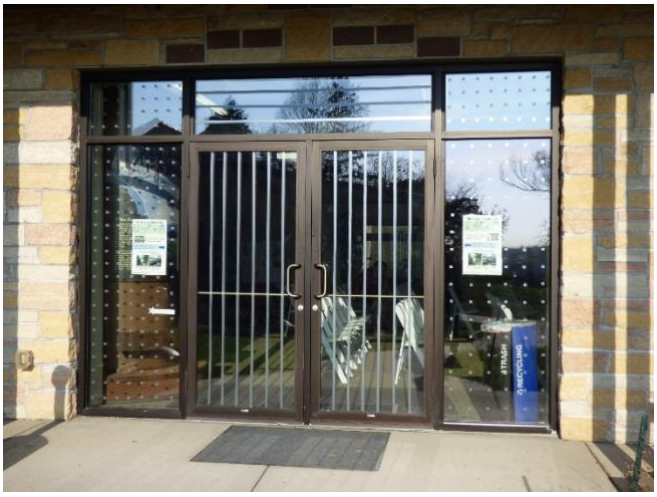

Figure 37. ABC BirdTape at the Carpenter Nature Center, Minnesota. Photo: Joanna Eckles

Figure 38. Chart tape stripes on double hung window section without screen. Photo: Christine Sheppard

Feather Friendly (DIY)

Available at www.featherfriendly.com; $1 - $5/square foot; few tools; permanent installation

Feather Friendly makes a range of standard and custom patterns with appropriate spacing. The material is applied like a window film, but the backing is then pulled off, leaving only the visual markers. Most of their products should be professionally applied, but they also have a 'Do It Yourself' tape, shown here in Figures 39-42. Markers are added one row at a time and a measuring tape is provided to help with spacing. The

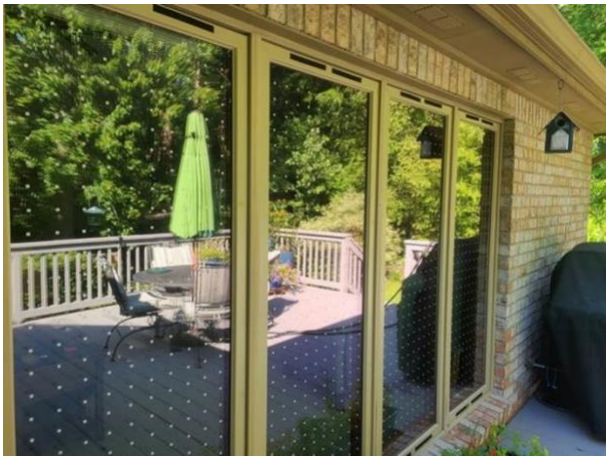

Figure 39. Feather Friendly applied to glass exterior. Photo: Feather Friendly

Figure 40. Feather Friendly, view from inside. Photo: Feather Friendly

markers will last for years, even when windows are cleaned. Windows with Feather Friendly cannot be power-washed, because it will remove the material, but you can wash windows with typical cleaning products such as soap, glass or cleaner and paper towels, sponges and squeegees.

Figure 41. Installing Feather Friendly DIY at the University of Guelph Arboretum. Photo: Chris Earley

Figure 42. View from Interior, University of Guelph Arboretum. Photo: Chris Earley

Insect Screens

Available online and at hardware stores; $1 - $5/square foot; professional installation; permanent installation

- Insect Screening, Sun Shading, Outdoor Fabrics & More | Phifer

Figure 43. External insect screen. Photo: Shutterstock

External insect screens (Figure 43) are an excellent solution for new construction, reducing or eliminating reflections, as seen on the left in Figure 44, and reducing impact if a collision does occur. The home in Figure 45 has screens on all windows. It is possible to add screens to windows without them but a professional installer may be necessary. It is also possible to remediate glass using screens attached by hooks or suction cups (see next section).

Figure 44. Compare reflection on screened window at left, with unscreened window at right. Photo: Christine Sheppard

Figure 45. Bird-friendly home with screened windows. Photo: Christine Sheppard

CollidEscape

Available at collidescape.org $1 - $5/square foot; professional installation; permanent installation

CollidEscape is a perforated vinyl film that permits a view from the inside (Figure 46) while eliminating reflections on the outside of glass. It comes in a range of colors and the external surface can be printed with graphics. We do not recommend 'clear'. CollidEscape will last for years and is in use at a number of Federal sites (Figure 47, 48). At the Cape May campus of Atlantic Cape Community College (Figure 49), CollidEscape stopped collisions and also reduced energy consumption.

Figure 46. Inside view - CollidEscape on right pane at the National Conservation Training Center (NCTC). Photo: NCTC

Figure 47. Installing CollidEscape at the National Conservation Training Center. Photo: NCTC

Figure 48. CollidEscape at Johnson Space Center. Photo: Sandy Parker

Figure 49. CollidEscape at Cape May campus, Atlantic Cape Community College (ACCC). Photo: ACCC

Feather Friendly (Commercial)

Available at featherfriendly.com; $1 - $5/square foot; professional installation; permanent installation

Feather Friendly comes in a range of patterns, as well as custom markers (Figure 50), all spaced according to current recommendations (Figure 51). It is highly effective and lasts for many years (early installations from the 2010s are still in good condition.) The material is installed like a window film, but the backing is pulled off, leaving the visual markers. It can be difficult to obtain a photo that shows both the scale of a building and the Feather Friendly markers installed (Figure 52). The markers are not visually distracting when seen from the interior (Figure 53).

Figure 50. Sport icons used as markers at the Pan Am Sports Center, Toronto. Photo: Feather Friendly

Figure 51. Railings at Liberty Park, NYC. Photo: Stefan Knust

Figure 52. Feather Friendly at the Markham Civic Center, Markham, Ontario. Photo: Christine Sheppard

Figure 53: View from interior, Markham Civic Center. Photo: Christine Sheppard

Bird Divert

Available at birddivert.com; $4.75 per square foot; professional installation; permanent installation; DIY version available.

Bird Divert's commercial product is an array of alternating rows of UV reflecting and absorbing dots (Figures 54 and 55). It is applied like a window film, but the backing is removed, leaving only the dots. A video on their website shows the process. The 12' width of the product makes it problematic for most home applications; a DIY version requires installation of dots individually. Because some bird groups, including songbirds, see into the UV range, but humans do not, this solution has minimal visual impact for humans. However, this means it may not deter collisions by groups like doves and raptors, and it may be less effective early in the morning or on overcast days, when there is less UV light.

Figure 54. Bird Divert, exterior view. Photo: Dan Piselli

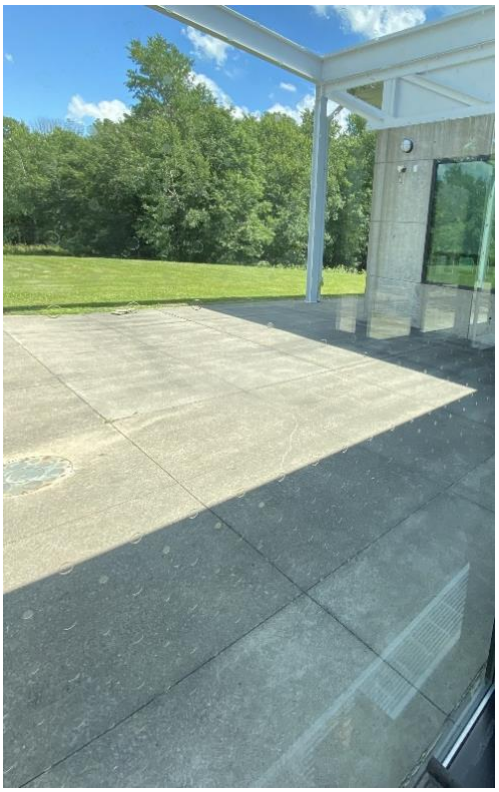

Figure 55. Bird Divert, interior view. Photo: Bird Divert

Solyx Window Film

Available at https://www.decorativefilm.com/specialty-bird-safety; $5 - $10/square foot; professional installation; permanent installation

Figure 56. Horizontal Bird Strike film at Northwestern University. Photo: Bryan Lenz

Most window film with visual markers is intended for use inside buildings, for privacy or decoration. This type of film will not hold up if installed on the outside surface of the glass. Solyx is a window film intended to be installed on the exterior of the glass to reduce bird strikes (Figures 56-59). It must be professionally installed, which can make it expensive, but it will last for years.

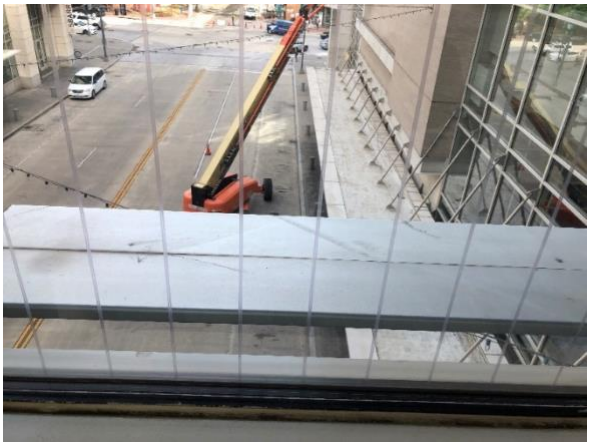

Figure 57. Vertical Bird Strike film at D.C. Convention Center. Photo: Anne Lewis

Figure 58. Horizontal Bird Strike film at the Wildlife Conservation Society. Photo: Christine Sheppard

Figure 59. Vertical Bird Strike Film at Smith College. Photo: Glenn Phillips

Netting

Available online; $5 - $10/square foot; professional installation; permanent installation

- http://birdmaster.com/permanet.html
- https://www.birdcontroladvisory.com/
- birdbgone.com

Figure 60. Netting at Chicago Botanical Garden. Photo: Stuart Koch

Netting can be a good solution, but must be selected and installed carefully (Figures 60-62). Mesh size should be no larger than 1" to ensure that birds can't slip through and become trapped, and netting should be taut, to prevent entangling. Netting should be checked regularly to make sure no birds have become trapped.

Figure 61. Home installation. Photo: Sherri Smith

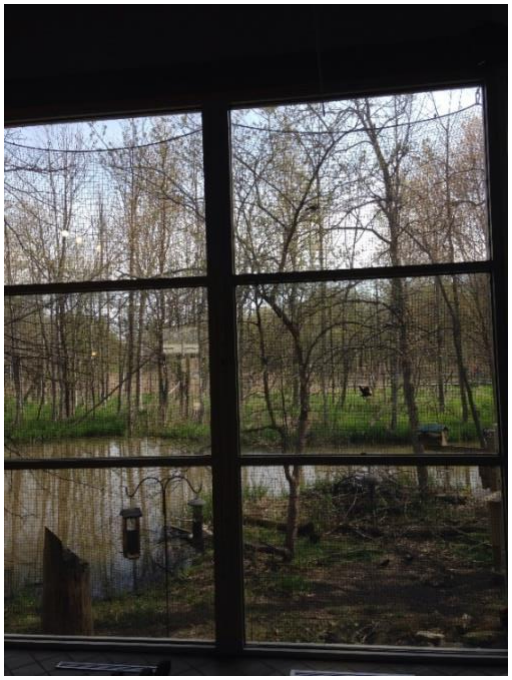

Figure 62. Maumee Bay State Park. Photo: Heidi Trudel

External Motorized Shades

Available from blinds companies; >$10/square foot; professional installation; permanent installation

- http://www.blinds.com (see 'outdoor solar shades')
- https://www.blindsgalore.com (see 'outdoor shades)

Figure 63. Motorized external solar shades on a private residence. Photo: Donaldson Motorized Shades

External motorized solar shades, often solar powered and operated by a remote control, eliminate reflections completely (Figures 63-65). This system requires that the operator open and close the shades, but in some cases, it is possible to program shades to open and close on a schedule. External shades provide more flexibility than other collisions solutions that are always on the glass. Highest risk to birds is the very early morning, when facilities and windows are often not in use. It is important to evaluate when birds are hitting windows in each individual location in order to determine an ideal schedule to prevent collisions.

Figure 64. External motorized solar shades on a private residence. Photo: Christine Sheppard

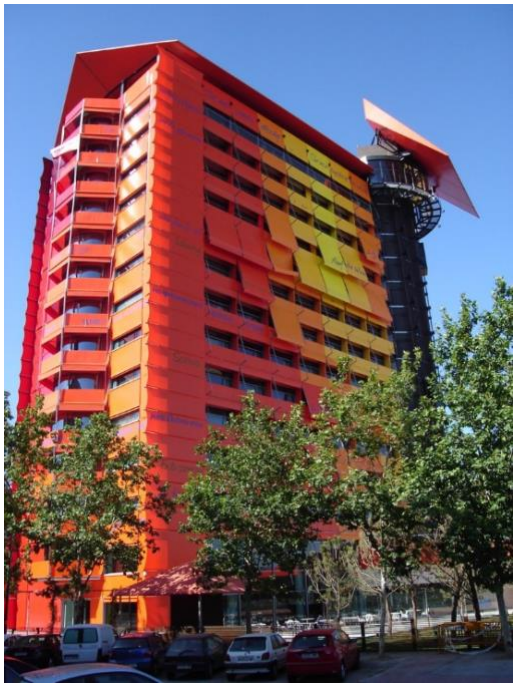

Figure 65. External shades on Hotel Puerta Americas, Madrid, Spain. Photo: Spanaut (Flickr Commons).

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