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Scientists struggle to make windows safer for birds

By Susan Milius

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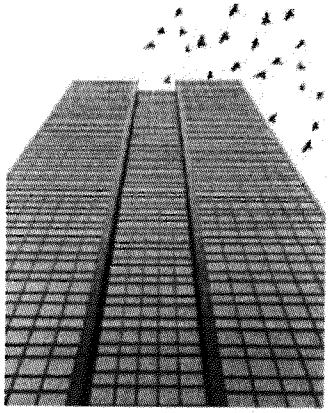
Ornithologist Christine Sheppard, frowning as if she's lost something, squints into the darkness of a 30-foot-long contraption. It looks like a stretch-limo version of a garden shed, but one end sports high-tech glass available only from an industrial R&D lab. From a hole at the other end dangles a child's pajama leg.



Credit: Building: labsas/iStockphoto; Birds: Blackred/iStockphoto

What Sheppard has lost is a song sparrow. She is using the tunnel contraption to test whether birds will fly into the piece of glass at the end. Since birds often don't see glass and fly right into it, Sheppard hopes to test whether stripes or other markings on the glass can warn birds away from a fatal impact. The pajama leg provides a soft chute to slip a sparrow or other bird into at the dark end of the tunnel. The bird flies toward the light-filled windows at the other end, and at the last instant a hair-fine net in front of the glass prevents a collision.

This setup, at Powdermill Avian Research Center in Rector, Pa., is one of three in the United States testing ways to prevent birds from flying into glass. According to one oft-quoted estimate, window crashes account for up to a billion bird deaths a year in the United States alone.

Creating no-crash glass has turned out to be much trickier than it sounds. The researcher behind the first U.S. glass-testing setup for birds, ornithologist Daniel Klem Jr., has been working on the issue for about four decades. His is a tale of the perils of applied science, from "aha" moments to entrenched public resistance and commercial disinterest. Basic research on bird vision has flourished, shedding light on what birds can and can't see, but translating neuroscience into safer window designs and getting them adopted is not so easy.

Ironically, the green building movement of recent years has made landscapes even more dangerous, Sheppard says. Efforts to shave energy costs by letting in more natural light have meant more glass for birds to collide with. But now she's working with architects and glass companies in ways that may at last hatch a market for bird-safe products. Tests show that opaque stripes or dots on windows can reduce bird kills, if people are only willing to use them.

But both Sheppard and Klem have been searching for the Holy Grail of bird safety: windows with patterns that birds can see but that are invisible to people. It is not an exact science. So far this morning at Sheppard's tunnel, one test subject darted out an uncapped observation hole instead of completing the test flight. A crow

just walked down the tunnel. The lost song sparrow has caused a temporary halt in tunnel operations. The bird is free to fly through the open door, but it's lingering inside in the cozy darkness. Sheppard grabs a long-handled net and is preparing to clamber into the tunnel herself when — whoop! — the sparrow flies.

View larger image | Above are a few U.S. bird species often found dead after flying into glass, according to surveys by wildlife groups in Washington, D.C., and Chicago.

Credit: Top row, from left: StevenRussellSmithPhotos/Shutterstock; Steve Byland/Shutterstock; Steve Brigman/Shutterstock; Bottom row, from left: WilliamSherman/iStockphoto; PaulReevesPhotography/Shutterstock; Gerald Marella/Shutterstock

Population unknown

It's hard to find a good number for just how many birds die in window collisions. Klem is the source of the numbers stating that U.S. windows kill 100 million to 1 billion birds a year. "I blatantly and openly tell you they're estimates," he says.

Klem's numbers are based on his 1990 estimates of the number of birds a typical building kills annually (between one and 10) and the number of buildings in the United States (based on 1986 data). Now Scott Loss of Oklahoma State University in Stillwater and colleagues are creating a new estimate using data on per-building mortality rates from 23 studies.

Whatever the new estimate is, there will be debate over what it means for total bird populations. Many species of North American birds are declining in numbers, but they also face degraded habitat, pollutants, invasive species, wind turbines and other hazards. The scale of the hazard windows pose won't be clear without comparable studies of local populations, Loss and colleagues argued in 2012 in *Frontiers in Ecology and the Environment*.

For ornithologists and bird lovers, though, buildings that kill wildlife are disturbing regardless of total population impact. Architect Anne Lewis leads City Wildlife project volunteers who get up before dawn to walk through downtown Washington, D.C., documenting birds that have crashed against glass. Sometimes she picks up stunned birds, placing them in paper bags to rest before being released in leafy parks far from dangerous glass. "Sometimes they die in your hand," she says. "It makes a believer out of you."

Daniel Klem (left) has been trying for decades to convince people to use simple bird-safe methods like the decoratively coated glass behind him. Christine Sheppard (right) tests birds' reactions to new kinds of glass in her testing tunnel.

Credit: From left: Bill Uhrich/Hawk Mountain; S. Milius

Bird safety basics

Witnessing bird collisions made a believer out of Daniel Klem while he was still a graduate student. One day in 1974, he sat down on a bench in front of the mirrored-glass chemistry building at Southern Illinois University Carbondale. "It only took about 20 minutes," he remembers. A mourning dove thumped against an upper story of the building so hard that feathers scattered, and the bird dropped to die on the ground.

At the time, no one knew why birds fly into glass. A 1931 scientific report on yellow-billed cuckoo crashes treated the deceased as "rare, self-destroying incompetents," says Klem, now at Muhlenberg College in Allentown, Pa. As the building boom after World War II fed demand for picture windows and glass walls, accounts of birds crashing into windows surged. So did speculations on the cause. Perhaps the birds just didn't understand glass. Or their eyes were bad. Or sun glare, mist or smoke temporarily blinded them. One report even suggested the birds were drunk on fermented fruit.

Klem began to set up experiments. He propped panes of clear and mirrored glass against tree trunks at the edge of the woods on his adviser's property, and he built a 12-foot Masonite tunnel, the first ever for testing windows. Birds flew toward a pane of clear glass as readily as through an empty window frame, showing no sign they could tell glass from air.

"It's the glass, stupid," is Klem's sloganized conclusion. Birds just don't see clear glass as an obstacle. Reflections may even lure them toward what appear to be trees, grass or other shelter that actually lie behind them.

Reflections not only cause collisions but also affect behavior. This cardinal crashed repeatedly, though not fatally, into a window, defending its territory from a reflection.

Credit: John Scherr

To see how people might warn birds away from glass, Klem began testing bird-deterrence markings in his tunnel. He compared a plain pane with glass adorned with something: stripes, silhouettes of predators or even blinking lights. (A lone predator decal is useless.)

His results helped establish what's now known as the two-by-four rule. Most birds won't fly through a space less than 4 inches wide between vertical stripes or 2 inches high between horizontal stripes.

This finding has had conspicuously little impact on offices, homes, airports, bus shelters and the rest of the increasingly glassy world. The failure has little to do with the birds or the experiments. "People told me time and time again, 'You know, Dan, you go mucking around with the way people look through their windows, and you're going to lose,' " he says. Any pattern obscuring a view means counterintuitive marketing for anything but bathrooms.

Then came a *Nature* paper in 1978 from prominent ecologist Thomas Eisner of Cornell and a colleague reporting evidence that homing pigeons react to real-world ultraviolet light. "From the very instant I read about it, I was excited," Klem says. "I was beside myself, thinking this could be the Holy Grail."

People can't see the very short wavelengths, from 100 to 400 nanometers, that make up ultraviolet light, but it turns out that pigeons and many more birds can. In theory, window patterns that show up only in UV could warn birds of a no-fly zone while giving humans a clear view.

But after the initial thrill, Klem says, "I realized there wasn't any way for me to test this." He contacted glass companies, people who might know product developers, people who might know people, searching for a material that reflects UV wavelengths but not others. He found a lot of UV absorbers, but no useful UV-only reflectors. He refers to this period as a "time when I was in this frustration — which was most of the '80s and the '90s."

Eventually a chemist who developed window films for cars happened to hear a radio interview with Klem, and as a side project devised a UV film that reduced bird crashes. The chemist's company deemed the project financially untenable, though, and yet another attempt to finance it has fallen through within the last year. A few other companies are now testing and even marketing UV-reflecting products such as decals and glass.

As for testing the effectiveness of such products, Klem argues that tunnels are "informative but not completely reliable," because they are not very accurate mimics of windows in actual buildings. Instead, he mounts glass to be tested and clear glass for comparison in frames, shuffling positioning to counteract quirks of lighting or location. He scores effectiveness by comparing numbers of carcasses or smudges on each pane. He omits nets, he says, because they can be visible from some angles and in some lighting, distorting results.

He's far from the only scientist to sacrifice animals in a study. "It's a part of the work that I grimace at," he says.

He tells his students that when extraterrestrial scientists finally reach Earth, it's only fair that he volunteer as their specimen. But unless he can trust that his results are realistic, he says, he runs the risk of "sanctioning something that is continuing to kill animals."

For decades, mainstream ornithology wasn't exactly ignited by Klem's interest in window glass, and a 2003 magazine profile called him "the Rodney Dangerfield of ornithology." As far as a widespread awareness of collision hazards that fuels a broad resolve to change windows, "we're still quibbling," he says. "I'm an educational failure."

Bird's-eye view

While Klem struggled with window treatments, basic research on avian vision flourished, with ever more precise analyses of eye structure, nerve responses and which genes turn on when. These scientists haven't been talking to people like Klem who work on practical problems, says Graham Martin of the University of Birmingham in England.

And if they were to talk, it's not clear what they could say except that designing a UV pattern to warn a bird about glass could be difficult.

For one thing, most birds' eyes are on the sides of their heads. "Birds have got this fantastically comprehensive visual field," Martin says, "but the best vision for most birds is actually out sideways."

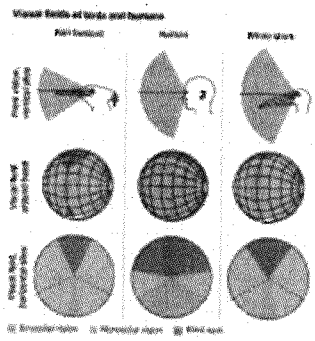
In some big birds, such as eagles, bustards and the two vulture species Martin reported on in *Ibis* in 2012, a gap between the left and right visual fields creates a blind spot to the upper front. "As soon as they start to look down, they're effectively flying blind," Martin says.

This gap means these birds may not see an obstacle ahead, nor would they see warning patterns ahead. "They're flying with the assumption — that has been a pretty good one for the last God knows how many millions of years — that there won't be anything sticking up in the way," Martin says.

Songbirds, which are more often killed by windows than are the big scavengers and birds of prey that Martin studies, do not have this big frontal blind spot. But even for them, "forward vision is not so good," Martin says. Birds, like people, typically get their sharpest view in the center of the eye's field of view. For side-eyed birds, that's to the side. Martin predicts that patterns to the front probably need to be extra bold for birds to notice them.

Another problem in creating bird-visible patterns is that birds are not as sensitive to contrast as people are. For a typical bird to pick out a grayscale pattern, the contrast between grays has to be about 10 times greater than it would for a human observer, says Almut Kelber of Lund University in Sweden.

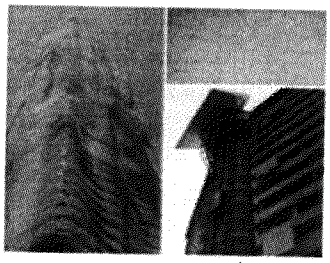
There are other problems specific to developing UV-reflecting patterns. Even one of the commonly repeated examples of birds seeing UV signals in nature may not be true, Kelber and her



Where birds see

View larger image | With eyes on the sides of their heads, birds have a different field of view than humans. Africa's Kori bustards have a narrower vertical range of binocular vision than people or storks. If a bustard looks 25 degrees down, it has a blind spot to its front. The middle row shows areas of each vision type surrounding each animal's head, facing the center of the yellow binocular zone. The bottom row shows a slice through the equator of those spheres, showing humans' large rear blind spot compared with birds.

Credit: Modified from G.R. Martin; adapted by S. Egts



View larger image | Bird-safe can be beautiful, advocates say. Chicago's Aqua Tower (left) has textured (or fritted) glass and balconies limiting birds' view of windows. Other strategies include UV-reflecting patterns (Ornilux glass, top right) and window shades (bottom right).

Credit: Clockwise from top left: Chicagogeek/Flickr; Ecombetz/Wikimedia Commons; Sali Sasaki/Flickr

colleagues argued in May in the *Journal of Experimental Biology*. A 1995 paper had proposed that birds of prey track voles in Finland by catching the UV glimmer of their urine dribbled across the landscape. Kelber found that lenses and fluids in the eyes of kestrels filter out much of the UV. And in any case, the voles Kelber's team tested didn't pee in ultraviolet. This doesn't mean that other birds have trouble seeing in UV. But Kelber cautions against generalizing about bird vision based on the small number of species that have been tested.

What's more, perceiving ultraviolet patterns while in motion "might be impossible for birds," says Daniel Osorio, a color vision expert at the University of Sussex in England. The part of the bird's midbrain that analyzes motion receives information from cells in the eye that aren't sensitive to ultraviolet, current evidence suggests.

Neither Osorio nor Martin is optimistic about UV-reflecting patterns after attending a symposium on birds and glass at a September meeting of European ornithologists. Birds may not sensitive enough to UV to detect a warning pattern on an actual window, researchers suggested at the meeting.

Glass houses

View larger image | Researchers in Austria tested nearly 800 bird flights toward windows covered with stripes, dots or no marks (listed above with distance between markings). The results are grouped from most bird-safe (A) to least (C). Acrylic panes, or Plexiglas, containing thin black horizontal filaments were the top performer. In other tests (D), birds were at least as likely to fly toward unmarked acrylic as toward an empty window frame.

Credit: Source: M. Rössler et al/Boku Vienna 2009

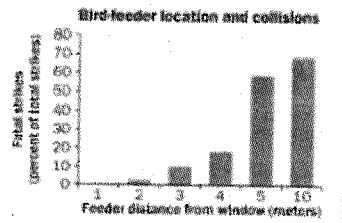
Build it

Experiments on birds won't do any good if there's no market for the results, though. So Sheppard is taking her case to architects and glass manufacturers. Her testing tunnel results are now what some companies rely upon to rate the safety of new kinds of glass for birds.

For the first two decades of Sheppard's ornithology career, she didn't bother with experiments since she had an obviously successful device: soap.

When she finished her Ph.D. and went to work for the Wildlife Conservation Society's Bronx Zoo, the staff routinely smeared soap on any expanses of glass surrounding a new bird on exhibit. The newcomer would avoid the solid-looking windows. Once it learned its way around, the staff would wash off the soap.

Then the zoo planned to build a new Center for Global Conservation and turned to Sheppard for advice on keeping the building from becoming a bird killer. The moment she found an Internet reference to a nonlethal contraption in Austria for testing glass, she decided to build one.



Feeding bird deaths

Bird feeders can draw birds toward windows, but are less deadly if placed within a meter of glass. Birds may be drawn to the feeder instead of windows and are not flying as fast if they hit a window while flying away.

Credit: D. Klem et al/Wilson Bulletin 2004

She now has one testing tunnel at Pennsylvania's Powdermill Nature Reserve and a new one at the Bronx Zoo. She also has what may be the only job in the world devoted to making buildings safe for birds, at the American Bird Conservancy. She has made trade-offs in experimental design different from those in Klem's work. Sheppard's controlled flights in tunnels give results from a large number of test birds of known species, without harming any. But the birds fly from a dark tunnel toward a light-filled window, which isn't what usually happens in real life. "I'm not trying to be realistic," she says. "I'm testing patterns."

Opaque dots and stripes covering as little as 5 percent of glass surface can prevent 90 percent of collisions, she

says (see sidebar). What architects dream about, though, are patterns invisible to humans, and those are harder to develop. Ornilux, made by Arnold Glas in Germany, carries subtle, irregular crisscross bands that reflect UV. This glass tested as bird-visible in Sheppard's Powdermill tunnel. For Klem, the protection worked only if there was less light behind the window than in front of it, he and a colleague report in the June *Wilson Journal of Ornithology*. Though Sheppard and Klem emphasize different elements of experimental design, both acknowledge that lighting and other conditions vary in real life. "Architects need to take our results, along with what we know about reflections, and make informed decisions," Sheppard says.

In another of Sheppard's tests, panes with tiny white dots on the glass surface didn't seem to alert birds to an obstacle. Birds were almost as likely to veer toward a panel as away from it. Increasing the density of the dots — which made more of the glass opaque — helped. It looked like a simple case of covering more surface area.

But then Sheppard tested glass panes with eighth-inch-wide lines instead of dots. Glass marked with either vertical or horizontal lines scored much better than the dotted panels — even though the lines covered about the same small fraction of the surface. "It became very clear it's not simply the coverage," Sheppard says. Within certain limits, stripes appear to be more effective for their size than dots as practical warning signs on buildings.

To get any of these solutions in place, "you have to get to the architects," Sheppard says. She helped the Green Building Council develop a way to calculate a building's lethality to birds. In 2011 they began a pilot program to add a collision-deterrence credit to the LEED program, or Leadership in Energy & Environmental Design, which certifies buildings as environmentally responsible. To get the credit, architects have to minimize clear panes, and their see-through acreage can expand in proportion to how well the glass performs in Sheppard's tunnel test.

One spring day at the Powdermill bird-banding station, a pane with a UV pattern (Sheppard can't say more about the proprietary material) sits in the testing slot beside regular glass. At this time of year, the bird-banding crew starts at 5 a.m. six days a week, trooping through shrubbery every half hour to check the nets that capture birds to be banded and tested. Birds hang in dark clots of tangled threads. In dozens of quick miracles, banders unsnarl them and fit each bird into its own beige cloth bag. To keep their hands free, the banders clip each bag to a cord around their necks, creating broad necklaces that occasionally twitch.

Thus dressed, the crew strides back to a snug room. Hands slide into anonymous beige bags and emerge with delicate creatures, the technicians working with the intensity of a surgical team to measure birds as quickly as possible.

Sheppard and technician Matthew Webb, hovering on the edges of the controlled rush, accept a bag and step across the station's yard to the glass-testing tunnel. Webb pulls out a yellow warbler, brilliant as a daffodil and only somewhat bigger. Webb squints at the numbers on its leg band, reads them into the video recorder and slips his handful of bird into the tunnel. Seen from outside, there's just a man with one arm down a pajama leg.

The actual test is so fast, just two or three seconds, that it's almost anticlimactic. Webb, watching the small screen of the video recorder aimed into the tunnel, suddenly pronounces "indirect right," and it's over. The warbler has swerved and ended up on the right, flying away from the UV-treated glass. Sheppard opens a large door, and in seconds a yellow dot of warbler blurs off toward the shrubs.

Across the yard, windows in the banding station carry fleets of translucent tape, with admirable two-by-four spacing. They shouldn't be a menace to the warblers, sparrows, kinglets, wrens, flycatchers and literally hundreds of other travelers darting through the woods. But after starting to think about glass, it's hard to stop. Just down the road in the town of Donegal, more windows loom in the houses, the Dairy Queen, the turnpike tollbooths. So many windows, and still so few stripes.

Bird-safe by law

In some places, regulations are beginning to encourage or require more bird-safe architecture. Minnesota mandates that buildings that receive state funds include certain bird-safety features in plans for environmental friendliness. Since 2011, buildings in San Francisco's bird-rich areas near parks or water must meet avian safety requirements, and Oakland, Calif., this year added a layer to its building permit process requiring feasible improvements in protective measures for birds.

Toronto has been a center of activity for bird-safe buildings, with pioneering regulations, and this year an unusual lawsuit. A major property company, Cadillac Fairview, ended up in court because the massive glass facades on its Yonge Corporate Centre were killing birds.

The company was acquitted this year after, the decision noted, installing window-taming treatments that cost about $100,000. The judge stated that emissions of reflected light from windows causing bird crashes should be considered violations of Canada's environmental laws. — *Susan Milius*

Bird safety dos and don'ts

Even small panes of glass can trick a bird into a fatal crash, and some products sold for bird safety may not work, warns Christine Sheppard of the American Bird Conservancy. Here are some solutions that Sheppard recommends:

Recommended

- **Window screens** reduce bird collisions by reducing reflections and providing a softer surface.
- **Washable tempura paints** can provide a simple warning and can be changed seasonally as decoration.
- **Shutters or exterior shades** can be closed when no one is looking out a window or during high-risk seasons for collisions, such as spring and fall migration.
- **Stripes or dots on the outside of glass** can break up reflections. Ideally, vertical lines should be spaced no more than 4 inches apart, horizontal lines no more than 2 inches apart.
- **Fritted glass,** which has a rough surface, reduces reflections and collisions as long as the fritting is on the outside surface.

Not recommended or problematic

- **A single predator decal** such as a hawk silhouette is not recognizable to birds as a dangerous predator. Arranging multiple decals could deter birds by reducing a window's transparent area, but decal shape does not matter.
- **Light-colored blinds or shades** inside windows may be better than nothing, but depending on the lighting, birds can still see deceptive reflections.
- **Overhangs or awnings** can block a window from sight for birds above but can leave birds with views of reflected plants and sky.

- **Glass slanted** at least 20 degrees from the vertical reduced deaths in tests near feeders, but Sheppard says this may work only when birds fly parallel to the ground.