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Review

Landscape, Legal, and Biodiversity Threats that Windows Pose to Birds: A Review of an Important Conservation Issue

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Abstract: Windows in human residential and commercial structures in urban, suburban, and rural landscapes contribute to the deaths of billions of birds worldwide. International treaties, federal, provincial, state, and municipal laws exist to reduce human-associated avian mortality, but are most often not enforced for bird kills resulting from window strikes. As an additive, compared to a compensatory mortality factor, window collisions pose threats to the sustainability and overall population health of common as well as species of special concern. Several solutions to address the window hazard for birds exist, but the most innovative and promising need encouragement and support to market, manufacture, and implement.

Keywords: bird-window collisions; collision prevention; building and landscape architecture; conservation

1. Introduction

Clear and reflective windows in human structures of all sizes in urban, suburban, and rural settings are unintentionally killing vast numbers of birds the world over [1–3]. The annual toll of bird deaths from striking windows range from 100 million to 1 billion (latest quantitative estimate based on available data is 365–988 million) in the United States (U.S.), from 16 to 42 million in Canada [4–7]. Forty years of detailed observation and experimentation reveal that birds behave as if sheet glass and plastic are invisible to them [4,8,9]. Birds strike clear panes while attempting to reach habitat seen through corridors (linkways) or where windows join in the corner or are oriented one behind the other to create an illusion of a passageway through a dwelling. In addition, for installed clear, as well as tinted, panes light levels are most often lower inside a room than outside, which creates a reflection of

the facing habitat and sky that deceives a flying bird who attempts to reach it. Birds kill themselves flying into windows of all sizes, buildings of different shapes and sizes, throughout the day and seasons of the year, and during all types of weather conditions. Fatal strikes are possible wherever birds and windows coexist.

For their aesthetic, recreation, and scientific value and utility birds are admired and studied by people everywhere. Because windows are a lethal threat to birds and are a result of human construction, we must accept the responsibility to protect this exquisitely useful natural resource for future generations. Clearly, the dead and dying resulting from bird-window collisions are unwanted and unintended. However, no reasonable person would likely argue for a windowless world to protect birds, and I have never advocated for using less glass in human residential or commercial buildings. What I have strongly and consistently advocated for is making all sheet glass and plastic exposed to the environment safe for birds. The short-term means of doing so requires the retrofitting of existing windows; the long-term solution is bird-safe sheet glass and plastic specifically manufactured for remodeling and new construction. Relying on encouraging people to voluntarily implement short and long-term measures to protect birds from windows is a monumental struggle with only limited success. Iconic historic federal bird protection laws and recent legislation at local, state, and provincial levels have addressed protecting birds from windows; these acts in turn have effectively incited action among building professionals and conservationists to make windows safe for birds. At least one law firm dedicated to environmental protection in Canada has brought suit against building managers who have a long standing record of overseeing buildings at which birds have been consistently killed, year after year, fatalities that are foreseeable and preventable given current knowledge and the availability of practical solutions. Universally changing building codes to require the use of bird safe glass and plastic will ensure the future protection of wild bird life in the human built environment. Like other measures enacted to ensure a healthier environment for all life, such as prohibiting the use of the pesticide DDT in North America or substituting unleaded for leaded gasoline, requiring bird safe windows will not prove to be cost prohibitive given their value for saving countless innocent bird lives that in turn provide utilitarian and aesthetic services to humans. What follows is a brief review of the landscape, legal, and avian biodiversity threats that windows pose to birds and how to effectively address them.

2. Discussion

Because birds behave as if windows are invisible to them the best predictor of what species are killed, at what location, in what numbers, depends on the density of individuals in the immediate vicinity of the lethal hazard. Various landscape features can influence the density of birds near windows, such as location of a dwelling, the amount of glass exposed to the environment, the immediate and surrounding vegetation, the presence of water as an attractant, and artificial lighting conditions.

All species may be potentially vulnerable to window strikes, but past and current studies clearly reveal that not all species have been documented as window strike casualties [6–12]. Ruffed grouse (*Bonasa umbellus*, American woodcock (*Scolopax minor*), *Accipiter* hawks, hummingbirds, *Catharus* and *Hylocichla* thrushes, and ovenbird (*Seiurus aurocapilla*) are suspected to be deceived by clear and reflective panes more often because of their habits of swiftly flying through restricted passageways

through dense vegetation [8,9,13,14]. Tropical hermit hummingbirds (*Phaethornis* spp.) are thought to be especially susceptible to window collisions because of their habit of traplining [15]. Predators and their pursued prey often become collision victims when raptors hunt near windows [8,9,16,17]; collisions occur when predator is engage in a concentrated chase following prey performing erratic evasive flights, frequently but not exclusively at feeding stations near windows. American robin (*Turdus migratorius*) and cedar waxwing (*Bombycilla cedrorum*) are suspected to be more vulnerable to flying into windows after becoming intoxicated on fermented fruits [8,9,18]; accounts indicate that birds behave similar to humans when under the influence of alcohol and as such those that "drink" and fly are apt to be more vulnerable than those that do not. Addressing differential species vulnerability to windows, recent detailed studies have found North American and Neotropical migrants, those flying long distances or at night, to be killed more often than diurnal migrants or non-migratory residents [6,7,10–12]. Those species known to occur in large numbers around buildings, especially in urban areas, such as rock pigeon (*Columba livia*), European starling (*Sturnus vulgaris*), and house sparrow (*Passer domesticus*) are known collision casualties [3,8], but at most study sites they have been recorded infrequently or not at all as window fatalities [6–12]. This seeming immunity to windows is likely the result of their behavior flying to perches such as sills and ivy or other vegetation that are near glass surfaces where, like feeders close to windows, if they strike the glass they do so with a force below which is needed to injure or kill themselves, but enough to learn to avoid the space thereafter [3,19]. Resident northern cardinals (*Cardinalis cardinalis*) may similarly gain protection when discovering their reflected image and responding to it as a rival in their territory [3,8,11,12]. Hager and his colleagues reported little or no support for bird density near windows explaining the species and number of fatal strikes at the buildings they studied [11,12]. Their measure of density included counting the number of birds within 50 or less meters from the windows they monitored, but density is a meaningful explanation of the number of strikes if measured within 10 or less meters of a window surface, a vulnerable contact zone, where individuals of any species can be deceived attempting to reach habitat seen behind clear or reflected in mirrored panes. Although clear and reflective glass may be invisible to birds, the results of recent experiments reveal that alterations to the outside surface of windows, even with clear external films, offer enough visual cues to reduce the risk of a strike by 59% or more [20,21].

If birds are a welcome addition around human dwellings, it is imperative to transform windows into barriers that birds will see and avoid rather than modifying landscape features to reduce their presence.

The vertebrate eye, and among them, the bird eye even with its astounding abilities, in many ways greater than human vision is most likely not capable of seeing clear and reflective windows. I interpret what we know about avian vision and behavior to conclude that clear and reflective sheet glass is an indiscriminate killer, taking the fittest as well as the less fit members of species populations. Notwithstanding claims that window collisions represent a compensatory mortality factor for bird populations in general [10,22,23], the inability of any individual of a species to see clear and reflective glass as a barrier to be avoided is reasonable justification to believe all individuals of a population are potentially vulnerable. Therefore, I interpret avian mortality resulting from collisions with clear and reflective windows to be an addition to the more expected compensatory factors of disease, predation, starvation, adverse weather, and others. The consequence of this type of attrition is that it is potentially damaging to the health of the abundant as well as species of conservation concern.

We have the means to protect birds by using retrofit methods on existing windows, and a growing number of novel panes prepared for remodeling and new construction. Most preventive techniques currently available are unacceptable to most homeowners and building managers because of aesthetics, practical application, and cost. Nevertheless, an increasing number of preventive methods are finding acceptance because of more effective education which in turn incites volunteerism or through the threat of legal action for inaction.

2.1. Landscape

Windows the size of a few centimeters (cm) like those in garage doors to those covering and making up entire walls of multi-story buildings are known to kill birds. But just as the density of individual birds in the vicinity of windows increases the chance of a fatal strike, the more glass surface the greater probability of providing an illusion resulting in a strike [7,8]. Attractants such as immediate and surrounding vegetation that guide birds to the vicinity of windows, water containers, baths, or impoundments, and bird feeders contribute to increasing fatalities because of greater numbers of individuals in the immediate vicinity of the hazard [6,7,12,24–26].

Hager and his colleagues [12] found bird kills at windows in an urban environment were related positively to window area and negatively to development. They reported that season of the year, development, and distance to vegetation best explained the number of birds killed at windows. They concluded that patchy environmental resources and the amount of window area create special variation in window mortality in an urban setting; finding that more birds are killed when attracted to vegetation that offers cover and food near buildings with greater glass facades.

The types of human dwellings account for a disproportionate amount of mortality [6,7]. Both Canadian and U.S. studies attribute most annual avian morality at windows occurred in residences (1–3 stories), in low-rise buildings (4–11 stories), and at high-rise buildings (equal or greater than 12 stories); 44% at residences, 56% at low-rises, and <1% at high rises. The amount of mortality at each building type is the consequence of relative representation in the environment; larger more dramatic kills occur at high rise urban skyscrapers, but these multi-story structures are few compared to large numbers of single residence dwellings and low rise commercial buildings.

2.2. Legal

At the federal level in the U.S. the International Migratory Bird Treaty Act (MBTA) of 1918 and the Endangered Species Act (ESA) of 1973, as respectively amended, potentially can be powerful tools to protect birds from windows. Although unintentionally killing a single individual wild bird is theoretically cause for legal action under the MBTA, it seems unreasonable to enforce when every human dwelling containing windows are likely violators. Moreover, given the original purpose of the MBTA to protect over exploitation of birds from the millinery trade, some legal professionals believe that using the MBTA to protect birds from windows may limit rather than enhance environmental protection in general. The ESA is restricted to listed endangered species such as the plain pigeon (*Patagionenas inorata*) and Kirtland's warbler (*Setophaga kirtlandii*) that are known window victims. The results of recent studies have supported and reinforced the potential risk windows pose to species of conservation concern in North America, and by inference worldwide [6,7]. The U.S. General

Services Administration (GSA) is mandated to use sustainable designs in new federal construction, and in so doing plan to incorporate bird-safe features in their structures. An introduced U.S. House of Representative bill titled Federal Bird-Safe Building Act would require all new federal buildings to be built bird-safe remains under consideration. In Canada, the Species at Risk Act and the Ontario Environmental Protection Act have been used in the courts to protect birds from windows. Among a few others, bird-safe window practices have been implemented in the cities of Minneapolis, Oakland, and Toronto. In Toronto, the non-profit environmental law firm Ecojustice brought suit against the building managers Cadillac Fairview under their Species at Risk Act and the provincial law Ontario Environmental Protection Act. The outcome of the case is interpreted as an environmental success because the courts established reflected light radiation to be responsible for creating an illusion that takes the lives of protected birds. The judge dismissed the case against Cadillac Fairview because they showed due diligence in retrofitting their offending windows with external film to mitigate continued bird casualties. The environmental victory is interpreted from the expectation that other building managers will institute bird-safe practices to prevent their properties from being the target of future litigation. Clearly, the use of the legal system is a far more powerful means of stimulating action to protect birds from windows than relying on the voluntary efforts of the many constituencies involved in this important conservation issue for birds and people; among them are the building professionals that include glass manufacturers, architects, developers, building managers, landscape designers, and the conservation community that include government law enforcement, research scientists, and the legion of conservation advocate organizations. Over the long term, to stimulate the creation of new products to retrofit existing buildings and produce novel panes for remodeling and new construction, the introduction, enactment, and enforcement of federal legislation requiring windows be made safe for birds is an ambitious, worthy, and justified goal to protect this useful and valuable natural resource.

2.3. Biodiversity

A survey of North American museums and select individuals has documented 267 (28%) of the 947 species occurring in the continental U.S. and Canada to be window casualties [27]. From additional systematic surveys and contacting select knowledgeable individuals, my records document 868 (9%) of the approximately 10,000 bird species known to be window strike casualties worldwide [3,28]. Window strike victims of conservation concern appearing on the National Audubon Society 2007 WatchList for the U.S. are 6 (9%) of the 67 species on their Red List, 24 (26%) of 94 species on their Yellow List [3]. Red List species are declining rapidly and are of global conservation concern. Yellow List species are declining but at a slower rate and are of national conservation concern. In addition, those species on formal lists of conservation concern, Loss and his colleagues [7] found the following species with declining populations to be especially vulnerable to windows in the U.S.: golden-winged warbler (*Vermivora chrysoptera*), painted bunting (*Passerina ciris*), Canada warbler (*Cardellina canadensis*), wood thrush (*Hylocichla mustelina*), Kentucky warbler (*Geothlypis formosa*), and worm-eating warbler (*Helmitheros vermivorum*).

To my knowledge the only bird species currently known to be adversely affected by window strike mortality at the population level is the swift parrot (*Lathamus discolor*) of Australia, a world threatened species; in 2006 Raymond Brereton (personal communication), Manager of the Swift Parrot

Recovery Program for Parks and Wildlife Service of the State of Tasmania, stated that 1.5% of the 1000 breeding pair population annually succumbing to window collisions [1–3,29]. Documented window casualties and their respective international conservation designations included the following: Critically Endangered—Townsend's shearwater (*Puffinus auricularis*), yellow-crested cockatoo (*Cacatua suphurea*); Endangered—swift parrot and eastern bristlebird (*Dasyornis brachypterus*); Vulnerable—Gould's petrel (*Pterodroma leucoptera*), cape gannet (*Morus capensis*), superb parrot (*Polytelis swainsonii*), cerulean warbler (*Setophaga cerulea*), marsh grassbird (*Megalurus pryeri*); Near Threatened—northern bobwhite (*Colinus virginianus*), copper pheasant (*Syrmaticus soemmerringii*), oriental darter (*Anhinga melanogaster*), black rail (*Laterallus jamaicensis*), bush thick-knee (*Burhinus grallarius*), plain pigeon, whistling green-pigeon (*Treron formosae*), New Zealand pigeon (*Hemiphaga novaseelandiae*), red-headed woodpecker (*Melanerpes erthrocephalus*), olive-sided flycatcher (*Contopus cooperi*), Bell's vireo (*Vireo bellii*), flame robin (*Petroica phoenicea*), diamond firetail (*Stagonopleura guttata*), golden-winged warbler, Kirtland's warbler, Brewer's sparrow (*Spizella breweri*), and painted bunting [3]. Historically conservationist have reminded all who will listen that the time to save a species is when it is abundant, not when it is on the brink of extinction or experiencing troubling declines as all currently designated species of special concern are doing. Given the indiscriminate killing of individuals at all levels of health in species populations, windows adding to natural compensatory attrition can potentially place common as well as species of concern at risk. The biodiversity of the planet is irreparably harmed when a species becomes extinct; the loss or threat of loss of birds as integral parts in the world ecosystems and as useful indicators of environmental health would be devastating. The scale of avian loss from window collisions makes addressing this human-associated mortality factor imperative; to be responsible stewards of the earth humans ideally must eliminate and minimally mitigate the killing of birds at the windows we install in our dwellings, residential and commercial structures that are increasing exponentially over the entire globe as humans increase and eventually spread across every avian breeding and non-breeding areas, and migratory routes.

2.4. Prevention

Architecturally designing the surface of buildings to make their glass more visible to birds is fundamental to reducing bird-window collision mortalities, and the American Bird Conservancy (ABC) has offered several examples to encourage bird-friendly building design [30]. Bird-friendly building guidelines addressing building location, landscaping, lighting, and bird-window collision prevention have been prepared for the state of Minnesota, cities of Calgary, New York, and Toronto [31–34], which have in turn stimulated briefer but meaningful recommendations for, among others, Baltimore, Chicago, and San Francisco. A structural design that has proven to protect birds by deflecting the force with which the bird strikes the pane is angling windows inward by 20 to 40 degrees; the greater the angle the greater the protection [19]. At those sites where feeders are used to attract birds, placing the feeder within less than one meter protects visitors by limiting the ability of a bird to build up enough momentum to injure or kill itself hitting a nearby window [19]. A number of alternatives are available to retrofit existing windows to protect birds, but most require tolerating some limited interference looking out a treated pane from inside a dwelling. Tapes, strings, netting, and

conventional window screening are effective for residential homes. In addition to these options, one-way external films successfully have been used on residential and commercial buildings. These methods and other background information on the general threats windows pose to birds are available at Acopian Bird Savers, ABC, Chicago Ornithological Society, CollidEscape, and Fatal Light Awareness Program (FLAP) websites [35–40].

Few sheet glass products are currently available specifically to prevent bird-window collisions for remodeling and new construction. Those that have been effective also limit viewing, but for those committed to protecting innocent potential victims the obstructed view is acceptable. Line and dot patterns that uniformly cover the entire pane and are applied in the form of ceramic frit or etching to surface #1 (facing outside environment) of a single or multi-pane window are most effective; they are less effective if applied to inner surfaces [20,21]. To completely eliminate collisions the dot and line patterns must be separated at most by 5 cm if oriented in horizontal rows, or 10 cm if oriented in vertical columns [4].

I have repeatedly described the most elegant solution to be one that transforms windows into barriers that birds see and humans do not. This method uses ultraviolet (UV) signals in the form of adjacent and contrasting UV-reflecting and UV-absorbing elements separated by the same 5 and 10 cm pattern elements visible to humans. One German glass manufacturer has produced and sold a supposedly bird-safe pane using UV signals but reliable experimental testing of their windows revealed that they are ineffective, even more hazardous to birds than conventional glass. The interpretation of the inability of these panes to alert birds to their presence is that the UV signal is too weak (7%–22%) over the too narrow UV wavelength (300–400 nanometers) range, reaching above 20% UV-reflection only at 397 nm [21]. In comparison, previous studies found external films with UV-reflecting components of 20%–40% over 300–400 nm to effectively deter bird-window collisions [20,21]. Remarkably, although known for some time, no external film company has produced a product for retrofitting offending windows, nor has any glass manufacturer produced an effective bird-safe window using UV signals. A federal government mandate coupled with effective enforcement requiring bird safe windows in all human built structures would stimulate product development and expedite bird protection.

3. Conclusions

Bird-window collisions and the extravagant toll they exact on birds is still an underappreciated human-associated avian mortality factor. For a topic that is an extremely important conservation issue for birds and people, educating the general public and through them stimulating those who can enact effective means to mitigate, or ideally eliminate, these unwanted and unintended deaths is still an essentially unfulfilled need, even a desperate one for those of us who have worked so hard for so long to protect birds from a preventable senseless death. From the first modern reports and annual estimates of the carnage birds experience at windows, speculating 3–5 million annual deaths in the U.S. to a more objective assessment of 1 billion a year, the topic continues to receive periodic but brief attention in broadcast media and popular and professional publications [4–7,41,42]. One dramatic example of the scale of attrition exacted by windows is that if one accepts the lowest contemporary estimate of 100 million annual kills at glass in the U.S. you need 333 Exxon Valdez oil spills each year to match the

level of this tragedy. Yet the 100,000 to 300,000 marine birds estimated to be killed by the 1989 Exxon Valdez oil spill in Alaska is still, along with the more recent Gulf oil spill, cited by various media as an example of a world-class environmental disaster while the exponentially higher toll from window strikes is relatively ignored. Arguably windows also play a role in the toll that domestic cats exact on birds, estimated to be the greatest human-associated source of attrition on wild birds in the U.S. and Canada [43–45]. But what cats take is connected and confounded in that unknown numbers of birds preyed upon by cats were first victims of window strikes, having been injured or killed outright. Studies have documented that cats among other predators and scavengers regularly patrol the areas below and in the vicinity of windows to capture the dead and dying [16,19]. Moreover, windows are invisible to birds and therefore birds are at risk whenever they confront clear and reflective panes, and almost certainly there are exponentially far more windows present and passively threatening birds in the environment than there are cats to do so. Detailed continuous monitoring of a single home revealed one out of two strikes results in an outright fatality, half of those that strike fly away with some trauma and injury [46]. Those that survive often appear debilitated and likely succumb to their injuries or predators that find them relatively easy prey. The dead and surviving suffer head trauma, resulting in blood in the brain, and thought to be the cause of death or debilitation; injured and initially surviving birds that were monitored after striking a window and then captured and cared for exhibited increased paralysis over time that eventually ended their life [46,47]. Moreover, detailed monitoring of field experiments have revealed the minimally one out of four bird strikes leave no evidence of a collision, such as a feather, feather or body imprint, blood or other fluid on the window surface [20]. Consequently, the number of deaths may be even far greater than our most objective and sophisticated methods permit us to determine.

Irrespective of the potential species population effects, preventing the deaths of innocent victims that have no voice and no ability to prevent killing themselves because of an attractive realistic illusion created by humans is justified for ethical and legal reasons. Ethically we humans should require that the environment we build causes no unintended harm to what we judge to be other valuable and useful life. Legally, there are international treaties and national acts, and a growing number of regional and local laws and other legislation specifically written to protect the killing of protected birds. To prevent bird-window collisions and all their consequences, windows in the form of sheet glass and plastic must be transformed into barriers that diverse bird species will see and avoid. Notwithstanding skeptics [48,49], the most elegant solution, using UV signals that birds see and we humans do not has been shown to be an effective prevention method [20,21]. External films with effective prevention are not being manufactured because those with the know-how will not commit to production because they cannot factor in unconventional consumer interest into their business plan to determine if it merits their investment. Glass manufacturers currently seem technically incapable of offering a strong enough UV signal to produce an effective bird-safe pane for remodeling and new construction. Both these building industry constituents must be convinced to commit to producing bird-safe products to ensure we humans will be able to save more bird lives from windows.

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Conflicts of Interest

The author declares no conflict of interest.

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