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BIRD-WINDOW COLLISIONS

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ABSTRACT. — Collisions of birds with windows were studied by reviewing the literature, collecting data from museums and individuals, monitoring man-made structures, and conducting field experiments. Approximately 25% (225/917) of the avian species in the United States and Canada have been documented striking windows. Sex, age, or residency status have little influence on vulnerability to collision. There is no season, time of day, and almost no weather condition during which birds elude the window hazard. Collisions occur at windows of various sizes, heights, and orientations in urban, suburban, and rural environments. Analyses of experimental results and observations under a multitude of conditions suggest that birds hit windows because they fail to recognize clear or reflective glass panes as barriers. Avian, manmade structural, or environmental features that increase the density of birds near windows can account for strike rates at specific locations. A combination of interacting factors must be considered to explain strike frequency at any particular impact site. *Received 28 Oct. 1988, accepted 17 April 1989.*

The earliest account of a bird hitting a window in North America is by Nuttall (1832:88). He described a Sharp-shinned Hawk (*Accipiter striatus*) which, in the pursuit of prey, flew through two panes of greenhouse glass only to be stopped by a third. Townsend (1931) described a series of five fatalities of the Yellow-billed Cuckoo (*Coccyzus americanus*). His paper was the first to suggest that avian vulnerability to windows may be more marked in some species than in others and that specific windows claim a succession of victims. He termed the victims "tragedies" and apparently regarded them as rare, self-destroying incompetents. Picture windows were relatively uncommon through the end of World War II, and there was little reason for concern about their threat to birds. In the postwar period, a building boom stimulated the rapid expansion of the sheet glass industry, and large glass windows were incorporated into the designs of new and remodeled structures. Today, it is not uncommon to find modern buildings that are entirely surfaced with glass.

I found 88 papers reporting bird-window collisions, primarily after the mid-1940s (Klein 1979). They document strikes in North America, South America, West Indies, Europe, and Africa, and, with few exceptions are cited in annotated bibliographies on man-caused mortality to birds (Weir 1976, Avery et al. 1980). However, most textbooks and encyclopedia treatments of ornithology present little, if any, description of the fatal hazards that windows pose to birds. The sheet glass industry and its commercial allies appear to be unaware of the problem. On the other hand, I found avian fatalities resulting from window strikes to be common knowledge among the general public.

Birds have been reported to strike two general types of windows as classified according to their visual effects on the human eye. These are transparent windows which appear invisible and reflective windows which mirror the facing outside habitat. Two general types of collisions have been described (Wallace and Mahan 1975:456) and both reveal the ability of glass to misinform and misguide at least some birds. One primarily involves birds such as Northern Cardinal (*Cardinalis cardinalis*) that commonly flutter against picture windows and harmlessly peck the glass during the spring and summer. These birds seldom, if ever, stun or injure themselves or shatter the glass and usually are males defending their territories against their reflected images. In the second type, birds fly into transparent or reflective windows as if unaware of their presence. These collisions often have fatal consequences, and are the subject of this paper.

In this paper my objectives are: (1) to propose an explanation for why birds collide with windows, (2) to describe and analyze species, environmental and manmade structural characteristics associated with bird-window collisions in the United States and Canada, and (3) to suggest how these select characteristics account for the differential frequency with which birds strike windows in various man-made structures.

METHODS

I collected data for this study from 1974 to 1986 from personal observations, records of cooperating individuals, and a series of field experiments. A form letter was sent to 466 curators of museums and I I individuals in the United States and Canada. They were asked to identify birds salvaged as window-kills or noted as surviving window strikes in 1975 and 1976; a few respondents included additional data from 1963 to 1977. Of those surveyed. 208 responded: 125 listed species known or reported to have collided with windows and 13 estimated the number of collision casualties brought to them each year, although they did not indicate the species. I obtained data from: (1) salvaged window-kills that were placed in the Dept. of Zoology Bird Collection at Southern Illinois University at Carbondale (SIUC) between 1971 and 1974 (currently in the Dept. of Biology bird collection at Muhlenberg College, Allentown, Pennsylvania), (2) Jack and Muriel Hayward's house in the Union Hill community located 5.7 km southwest of Carbondale, Jackson County, Illinois, and (3) several private homes and university and commercial buildings within a 52,300-h area in and around Carbondale, Illinois. The Hayward house was the only building at which bird strikes were recorded systematically in southern Illinois. The home was checked by the occupants, often several times a day, from September 1974 through December 1976. The house stands on a slope and is surrounded by shrubs, mixed conifer and deciduous trees, fields and lawn. It has 52 windows ranging in size from 0.6 m wide by 0.9–2.2 m high with a total outer glass surface area of 114.3 m^2. Each window was individually numbered to accurately register the location of bird strikes. As with the Hayward home, detailed data were obtained from the residence of Polly Rothstein in southeastern New York, 1.6 km southeast of Purchase, Westchester County. Except for short periods, a few hours to 1-2 days, she collected data from August 1975 through December 1976. The Rothstein house is located in a suburban setting on level ground and is surrounded by trees, shrubs, and lawn. Bird collisions were documented whenever a strike was heard or seen, or a specimen was found beneath a window. Although most reports lacked some information, the data recorded were species, temporal, and habitat variables. Specimens salvaged at the Rothstein house were given to the Bruce Museum, Greenwich, Connecticut.

Four field experiments were conducted to determine if birds can recognize transparent obstructions or reflections. All experiments were conducted on the farm of W. G. George in the Shawnee Hills, 1.7 km north of Cobden, Union County, Illinois. Typical of small farms in this area, the land has patches of woods and fields, a small apple orchard, a sizeable lawn around the farmhouse, a corn field, and two water impoundments. Two preliminary experiments, conducted over 8- and 13-day periods (8-15 November and 19 November-1 December 1976), were designed to determine if birds would strike clear and reflective glass not associated with man-made structures. A strike was registered when a specimen was found beneath a window or a feather, body smudge or blood smear was found on the glass. In the first experiment, six clear storm windows, 0.4 m wide by 1.2 m high, having a combined surface area of 2.9 m^2 were placed on the ground adjacent to one another (separated by 0–15.2 cm) and on the periphery of a woody thicket facing an old field habitat. When viewed from the field or the thicket, habitat was visible behind each pane. In the second experiment, a mirror, 0.6 m x 1.7 m high, simulated a reflective glass pane. It was placed in the same locality as the clear panes and appeared to reflect perfectly the field habitat and sky. During both experiments the glass was checked daily. The third experiment, conducted over a 20-day period (19 March-7 April 1977), was designed to determine if birds would strike clear picture windows simulating those in new houses and erected in a habitat where no other man-made structure previously existed. Five identical wood-framed windows, 1.4 m x 1.2 m high, with their bases 1.2 m above ground, having a combined surface area of 8.5 m^2 were constructed on the edge of a wooded area and corn field (Fig. 1). Windows were placed along a tree line running east to west and facing north-south. Distance between windows from cast to west (right to left in Fig. 1) were 12.9 m, 16.5 m, 15.7 m, and 23.8 m. Depending on the light conditions and angle of view, habitat was seen behind or reflected from the glass, or a combination of these effects was visible. Trays were placed under each window to catch collision casualties. Each window was checked daily.

Fig. 1. Field experiment study site in Cobden, Union County, Illinois.

The fourth experiment, conducted over a 1-year period (21 February 1977-21 February 1978), was designed to determine if birds would strike clear and reflective windows that were placed in an existing structure (a century-old barn) that previously had no windows. Two clear and two gray-tinted panes, 1.4 m wide by 1.2 m high, having a combined surface area of 6.8 m^2, were installed with their bases 3.8 m above the ground on the north and east sides of the barn. From outside, wooded habitat was visible on the other side of the barn when looking through both clear panes. When viewed from an angle that did not permit a view through both panes, the clear windows reflected the facing wooded habitat. The tinted panes were adjacent to the clear panes, and they appeared to reflect perfectly the facing wooded habitat. Trays were placed under each window to catch collision casualties. Each window was checked daily.

Data were compared and analyzed with binomial and Chi-square tests (Siegel 1956). In some analyses, the data were subdivided to determine if they showed chronological trends.

RESULTS

Species. — My survey revealed 225 species belonging to 42 families are known to have struck windows. This number represents 25% of the 917 species that occur in the two countries (A.O.U. 1983). Table 1 lists the 20 most frequently reported species in the survey. In general, the diversity of collision victims include species that occupy every major habitat type. Absent from the fist are birds that rarely occur in habitats containing man-made structures. They include most waterbirds, soaring hawks, and terrestrial species occupying unpopulated or sparsely populated desert, grassland, and forest. Species accounting for most strikes at single residences were similar to those in the survey. Exceptions were relatively large numbers of Yellow-billed Cuckoo collisions at the Hayward house and Blue Jay (*Cvanocilta cristata*) and House Sparrow (*Passer domesticus*) strikes at the Rothstein house.

TABLE 1

SPECIES[a] MOST FREQUENTLY REPORTED STRIKING WINDOWS IN UNITED STATES AND CANADA

American Robin (*Turdus migratorius*)	White-throated Sparrow (*Zonotrichia albicollis*)
Dark-eyed Junco (*Junco hyemalis*)	Ruby-throated Hummingbird (*Archilochus colubris*)
Cedar Waxwing (*Bombycilla cedrorum*)	Tennessee Warbler (*Vermivora peregrina*)
Ovenbird (*Seiurus aurocapillus*)	Yellow-bellied Sapsucker (*Sphvrapicus varius*)
Swainson's Thrush (*Catharus ustulalus*)	Purple Finch (*Carpodacus purpureus*)
Northern Flicker (*Colaptes auratus*)	Common Yellowthroat (*Geothlvpis trichas*)
Hermit Thrush (*Catharus guttatus*)	Rose-breasted Grosbeak (*Pheucticus ludovicianus*)
Yellow-rumped Warbler (*Dendroica coronata*)	Gray Catbird (*Dumatella carolinensis*)
Northern Cardinal (*Cardinalis cardinalis*)	Wood Thrush (*Hvlocichla mustalina*)
Evening Grosbeak (*Coccothraustes vespertinus*)	Indigo Bunting (*Passerina cyanea*)

[a] Species reported most often in a survey of 125 museum curators and individuals: most frequent is listed first.

Age and sex. — Window casualties were analyzed for age and sex differences by comparing pooled species data for all of southern Illinois, at a single residence (Hayward house), and for select species with sample sizes of ten or more (Table 2). Passerine ratios of immature (hatching-year, HY) to adult (after-hatching-year, AHY) birds were expected to be 3:1 if the samples were representative of populations immediately after the breeding season (Lack 1954, Peterson 1963). Except for the Purple Finch (*Carpodacus purpureus*), there were no significant differences from the expected ratio (Binomial test, $P > 0.05$). Counts for the Purple Finch differed significantly from the 3:1 ratio (Binomial test, $P < 0.03$), but adults and immatures were killed with equal frequency; adults of this species may be more vulnerable than immatures or they may have occurred in proportionately greater numbers at this particular site. These data suggest that adults and immatures are at least equally vulnerable to windows. Male and female strike rates did not differ significantly from the expected 50:50 ratio for pooled or individual species data (Binomial test, $P > 0.24$).

TABLE 2
AGE[a] AND SEX[b] OF WINDOW CASUALTIES

	Age			Sex		
Pooled[c]/individual[d]	N	AHY	HY	N	M	F
Southern Illinois	72	17	55	191	91	100
Hayward House	22	8	14	56	25	31
American Robin				10	7	3
Northern Cardinal				is	7	11
Dark-eyed Junco	11	4	7	12	5	7
Purple Finch	18	9	9	18	6	12

[a] Age was determined by skull pneumatization and limited to AHY (after hatching year) and HY (hatching year) passerines killed in fall (September to December).

[b] M = male; F = female.

[c] Southern Illinois data obtained from casualties at several buildings around Carbondale, Jackson County; Hayward house data obtained from single residence.

[d] Species with sample sizes of 10 or more.

Seasons.— Strike data from several buildings in southern Illinois and at single residences of the Hayward and Rothstein houses were analyzed by season (Fig. 2). The frequency of strikes per month were not uniformly distributed for southern Illinois in 1975 ($x^2 = 27.6$, $P < 0.01$) or 1976 ($x^2 = 50.0$, $P < 0.001$), for the Hayward house in 1975 ($x^2 = 35.5$, $P < 0.001$), or the Rothstein house in 1976 ($x^2 = 32.9$, $P < 0.\ 00\ 1$). Seedeaters; attracted to feeders near windows accounted for high numbers of strikes in winter (December-February). Migrants, especially nocturnal migrants, active around dwellings during the day, accounted for high strike rates in spring (March-May) and fall (September-November). Breeding birds, especially the Yellow-billed Cuckoo, accounted for summer (June-August) strikes. These data suggest that birds strike windows in every season of the year, that collision rates may vary greatly from month to month, and except for a reduction during summer breeding, no marked seasonal differences are evident.

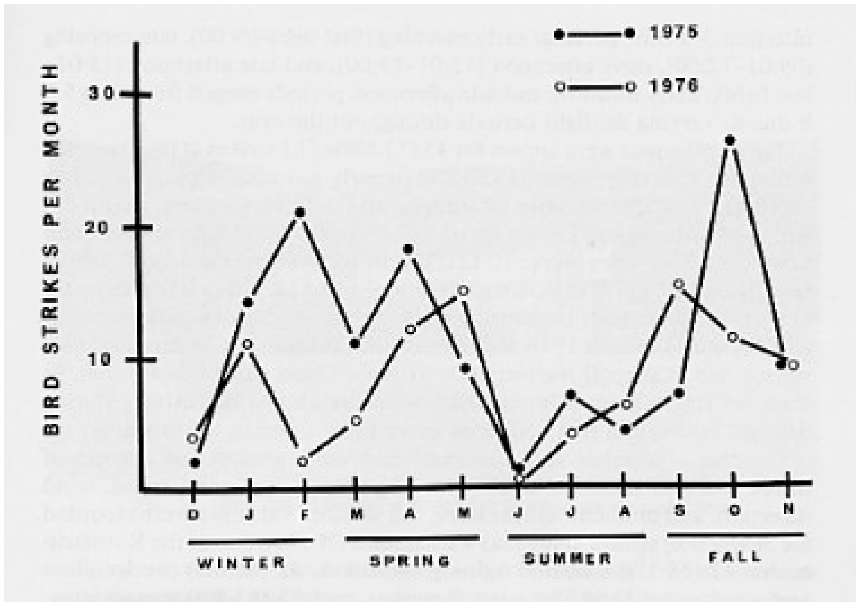

Fig. 2. Seasonal distribution of frequency of bird strikes at windows in southern Illinois.

Times of day. — To compare diurnal collision rates, a day was divided into four 3-h time periods: early morning (first light-09:00), late morning (09:01-12:00), early afternoon (12:01-15:00), and late afternoon (15:01-last light). Early morning and late afternoon periods ranged from 2 to 5.5 h due to varying daylight periods throughout the year.

Times of impact were known for 45 (73.8%) of 61 strikes at the Hayward house in 1975; they were: 31 (50.8%) in early morning, 8 (13.1%) in late morning, 5 (8.2%) in early afternoon, and 1 (1.6%) in late afternoon. Times of impact were known for 41 (87.2%) of 47 strikes at the Rothstein house in 1976. They were: 10 (21.3%) in early morning, 19 (40.4%) in late morning, 8 (17.0%) in early afternoon, and 4 (8.5%) in late afternoon. Only two accounts of impacts at night were recorded. Both occurred at the Hayward house in 1976 and were by Black-throated Green (*Dendroica virens*) and Blackpoll warblers (*D. striata*). These data indicate that, at least for single homes, birds strike windows almost exclusively during daylight hours, and that collisions occur more often in the morning.

Weather. — Weather variables examined were: presence or absence of direct sunlight, presence or absence of precipitation, wind speed, wind direction, and ambient temperature. All weather variables were recorded for 36 (59.0%) strikes at the Hayward house. Of 47 strikes at the Rothstein house, 32 (68.1 %) included lighting condition, 31 (66.0%) precipitation and wind speed, 2 (4.3%) wind direction, and 30 (63.8%) temperature. The percentages used in the weather analysis refer to these documented records.

Strike rates were substantial at both houses during both sunny and overcast conditions; under sunny conditions, 24 (66.7% and 75.0%) collisions were recorded at both the Hayward and Rothstein houses. All but one strike, during rain at the Rothstein home, occurred in the absence of precipitation. In southern Illinois, three additional strikes were documented in rain. During a severe snowstorm approximately 50 non-fatal bird strikes were recorded when a flock of Dark-eyed Juncos (*Junco hyemalis*) flew into a window of a rural home in Makanda, Illinois, in 1976. Birds struck windows under varying wind speeds, but collisions were recorded most often during calm conditions; 33 (91.7%) and 23 (74.2%) collisions occurred in winds of 0-11.3 kph (0-7 mph) at the Hayward and Rothstein houses, respectively. At the Hayward house five or more strikes occurred at windows facing all major compass directions. Similarly, for both houses, collisions occurred in temperatures ranging from -9.4-31.1C (15.1-88.0F). Comparison of the frequency of strikes in four equal categories of the temperature range for each house revealed that three (10.0%) or more occurred in each category. The overall weather data indicate that, with the exception of certain severe conditions affecting visibility, strike rates are higher during favorable weather.

FIG. 3. Clear glass windows of a corridor showing see-through effect.

Windows and man-made structures. — Bird strikes occurred at windows with clear transparent panes and at those with tinted reflective panes. When clear windows are installed one behind the other, such as in corridors, stairways, or rooms, they create an illusion of an unobstructed passageway (Fig. 3). Tinted windows create an illusion of unobstructed habitat which is mirrored on the glass surface. Clear panes mimic tinted mirror-like panes when little or no light is visible behind them (Fig. 4). Except for a seemingly related incident of frightened individuals hitting the side of a home, I found or collected no records of strikes at opaque, translucent, or stained glass windows which present other visual effects. At one site, over a 5-year period (1975-79), one account documented a strike at a reflective glass door but none at the adjacent stained glass windows of a church in Madison, Illinois (V. Lecko pers. comm.).

Strikes occurred at windows of various sizes, in structures of many different sizes and shapes ranging from those installed in stationary motor vehicle doors and telephone booths, to large plate glass walls around multistory buildings. Collisions were documented at windows of buildings located in urban, suburban, and rural environments. These data qualitatively indicate that collisions are likely at any outside clear or tinted window installed in any structure located in any type of habitat.

Quantitatively, 1975 data from the Hayward house were used to analyze strikes at windows of different sizes, heights from the ground, and orientation. Window size was known for 53 (86.9%) and window height for 49 (80.3%) strikes (Table 3). These data indicate that collisions occur at windows of different sizes and heights from the ground. Collisions may be more frequent at large windows (>2 m^2 [21.6 ft^2]) placed at ground level and above 3 m (10 ft). Window orientation was known for 49 (80.3%) strikes, Strikes per square meter of glass for each facing direction were: 0.5 northeast, 0.1 southeast, 0.9 south, 0.4 southeast, and 0.7 west and northwest. During fall and spring, windows that cut across and faced migratory flightpath directions, north and south respectively, were suspected of posing a greater hazard to migrants than windows facing east or west. To test this hypothesis, only migrants in southern Illinois were considered and consisted of 14 fall and three spring migrants at the Hayward house in 1975 and 1976. As might be expected for fall migrants, eight (57.1%) struck windows oriented northwest, but five (35.7%) hit southwest, and one (7.1%) struck a west facing window (Binomial test, $P = 0.79$). Only one (33.3%) spring migrant hit a window oriented southwest while two (66.7%) others struck windows facing northwest. Comparison of strikes per square meter of glass showed no marked tendency for south or north bound migrants hitting north or south facing windows, respectively. These data indicate that windows facing general migratory directions of north and south are no more hazardous than windows oriented in other directions.

Experiments. — Two experiments tested the hazards of clear and reflective glass not associated with man-made structures. Over an 8-day period, four birds died after colliding with clear windows; they were: two Northern Cardinals, a Red-bellied Woodpecker (*Melanerpes carolinus*), and a White-throated Sparrow (*Zonotrichia albicollis*). Over a 13-day period, two birds died after hitting a mirror simulating a reflective pane, a White-throated

Sparrow and a Dark-eyed Junco. Strikes at the mirror were probably minimal due to ice covering the surface during early morning hours throughout the experiment. These results indicate that windows need not be associated with man-made structures to kill birds.

FIG. 4. Clear glass of Hayward house showing reflective effect.

The third experiment, monitoring five clear picture windows simulating those in new houses, resulted in 13 strikes over a 20-day period. Eight (65%) were fatal, the birds killed were: Northern Cardinals, two; Dark-eyed Juncos, four; Fox Sparrow (*Passerella iliaca*); and Swamp Sparrow (*Melospiza georgiana*). These data further suggest that birds may fail to detect transparent windows in man-made structures.

In the fourth experiment, seven strikes were recorded over a I-year period at clear and reflective windows installed in a century-old barn. Bay-breasted Warbler (*Dendroica castanea*) and three unidentified birds hit clear windows; American Robin, Dark-eyed Junco and one unidentified bird hit reflective windows. These results further document that glass panes become hazardous for birds once installed in man-made structures, regardless of how long the structure may have been a part of the surrounding environment.

TABLE 3
BIRD COLLISIONS[a] AT WINDOWS OF DIFFERENT HEIGHTS[b] AND SIZES

	Size								
	Small (<1 m²)			Medium (1-2 m²)			Large (>2 m²)		
Height (m)	N	Arca(m²)	N/m²	N	Area(m²)	N/m²	N	Area (m²)	N/m²
0.0-0.3	0	0.0	0.00	0	0.0	0.00	22	43.4	0.51
0.3-3.0	2	6.3	0.32	0	8.5	0.00	2	11.7	0.17
>3.0	0	6.9	0.00	0	8.7	0.00	23	29.0	0.79

[a] Data from a single residence, the Hayward house, Carbondale, Jackson County, Illinois

[b] Height is distance from ground to base of pane.

DISCUSSION

Why birds strike windows. —The literature contains several hypotheses attempting to explain how windows may be rendered functionally invisible to birds. If we exclude the harmless collisions resulting from territorial residents fighting their mirror images, all other hypotheses can be grouped into two causal categories. One group consists of defective, impaired, or deceived hypotheses. Several authors have speculated that birds hit windows because of: (1) defective eyes (Willet 1945), (2) impaired vision due to smoke (Langridge 1960), blinding glare (Sinner unpubl. data), mist (Konig 1963), alcohol (Rogers 1978), or diverted attention (Dunbar 1949, Giller 1960, Bent 1968:231, Raible 1968, Valum 1968). None of these explanations are supported by my results. Field experiments revealed that birds collide with: (1) clear and reflective windows not installed in manmade structures, (2) clear windows installed in structures simulating those in new houses and placed in habitats where no other human dwellings previously existed, and (3) clear and reflective windows installed in an existing structure which had been a part of the habitat for more than a century. Individual accounts further document that birds strike windows of various sizes, heights from the ground, and orientation in man-made structures of various shapes and sizes that are set in urban, suburban, and rural environments. These data suggest that windows are not recognized as obstacles by birds, whether installed in man-made structures or placed in their accustomed haunts.

The second group of hypotheses emphasize perception. A number of authors have speculated that inexperienced birds strike windows (Bauer 1960, Giller 1960, Morzer-Bruijns and Stwerka 1961, Löhrl 1962, Raible 1968, Valum 1968, Schmitz 1969, Harpum 1983). There is no evidence indicating that physical deficiencies of the young or learning in adult or immature solely determines the ability of birds to detect glass barriers. Immatures and adults were found to be equally vulnerable, and the diversity of window-kills suggest no species is immune from the hazards of glass. Although indirect. available evidence supports the interpretation that the avian visual system is incapable of perceiving clear and reflective glass (Gibson and Walk 1960, Walk and Gibson 1961, Emlen 1963, Tallarico and Farrell 1964).

My observational data indicate that there is no exclusive avian vulnerability to windows based on age or sex, season, time of day, weather, window type or setting. Experiments further document that birds do not discriminate between unobstructed habitat and habitat seen behind clear glass or mirrored in reflective panes. Overall, these findings indicate that birds are likely to strike windows wherever they mutually occur. In general, glass is an invisible and potentially lethal hazard for all birds, but especially for those in flight. Other animals (insects, fish, mammals) are known to frequently strike stationary windows or other glass barriers, but the momentum at which they impact usually does not cause serious injury. In contrast, even the smallest flying bird can generate fatal momentum.

Factors influencing collision frequency. — Since glass is invisible to birds, various bird, window, and environmental characteristics may explain the frequency with which certain species become casualties at particular localities. Strike rates at specific sites are unique and require attention to a combination of contributing factors. However, some factors can substantially influence the species and frequency of collisions. Considering the importance of single factors is a means of dealing with a complex problem, and knowing the importance of a factor can help assess and suggest measures to reduce or eliminate strikes at a particular site.

Bird-related factors include density and behavior. Although other factors were examined in their analysis, Graber and Graber (unpubl. data) found that the total number of birds in the area was correlated with the number of collisions at their rural Pope County home in southern Illinois ($r = 0.83$, $N = 10$, $P < 0.005$). Flight habits of birds accustomed to manmade structures may provide some protection by reducing the force with which the strike occurs. House Sparrow, European Starling (*Sturnus vulgaris*), and Rock Dove (*Columba livia*) seem to avoid windows by hovering in front of or slowly flying to nearby perches. However accustomed these species are to human dwellings, they are killed frequently at some sites. R. F. Johnston (pers. comm.) reports Rock Dove flying against small, cave-like windows at the Museum of Natural History, Univ. of Kansas. Hummingbirds learned to avoid the glass sides of cages (Bent 1940:386), and individuals accustomed to living near buildings may benefit from non-fatal collisions by learning to avoid the space that windows occupy. If this type of learning occurs in the wild, it may serve to protect at least some individuals, but it is likely to be of limited consequence for most species. Some birds are reported to be at high risk due to their habit of flying, through restricted passageways in heavy cover (Ross 1946, Snyder 1946); they are killed while attempting to reach lighted areas behind or reflected in glass and often consist of Accipiter hawks, grouse, thrushes, and waxwings. Others habitually fly through open doors and windows, thus increasing their vulnerability (Löhrl 1962). Many accounts document distracted individuals as frequent victims: individuals chasing one another (Dunbar 1949), individuals escaping danger (Valum 1968, Schmitz 1969), predators pursuing prey (Klem 1981), and individuals under the influence of alcohol (Rogers 1978), or spatially disoriented due to a combination of adverse weather and artificial lighting (Herbert 1970).

Window-related factors influencing strike rate include type, size, placement of glass, and the presence of bird attractants. I found birds more vulnerable to clear or reflective large (>2 M^2) windows at ground level and at heights above 3 m. With respect to location, birds hit windows wherever they occur, but strike rates were highest in suburban and rural environments, which, in most cases, typically contain the largest densities.

Similarly, bird attractants were found to influence the frequency of strikes by increasing bird density near windows. Attractants are feeders, fruiting trees and shrubs, water supplies in the form of bird baths and impoundments, nesting or perching sites in vegetation, and areas that offer protection from adverse weather conditions. The frequency with which finches, blackbirds, chickadees, titmice, nuthatches, woodpeckers, and hummingbirds were reported as victims is probably best explained by their regular and abundant occurrence at feeders.

Environmental factors influencing strike rate include season, time of day, and weather. The frequency of strikes in different seasons is probably best explained by the seasonal abundance of birds in human-modified environments. I found seasonal strike rates to be highly variable in southern Illinois and New York. Higher winter collision rates at single houses in these regions, compared to those reported elsewhere, are probably best explained by local site differences, the major one being the presence of feeding stations which attract large numbers of winter residents. Seedeaters predominated as strike casualties during the winter in both regions and included: Dark-eyed Junco, White-crowned (*Zonotrichia leucophrys*), and White-throated sparrow, and Northern Cardinal. Strikes in fall and spring consisted mainly of migrant warblers, thrushes, waxwings, and finches. Few birds hit windows in summer, probably because their movements are largely restricted to breeding territories. Southern Illinois species killed in summer were Ruby-throated Hummingbird (*Archilochus colubris*), fledgling White-eyed Vireo (*Vireo griseus*), Nashville Warbler (*Vermivora ruficapilla*, an early migrant), and Yellow-billed Cuckoo. The cuckoos were known breeders, determined by eggs in the oviduct. Although few in number, summer window-kills may result in the added loss of dependent eggs and young. Those species which occur in the greatest numbers during any one season will most likely comprise the greater number of window casualties for a particular site.

In Indiana, strike rates during daylight hours of sunrise to 13:00 were reported to be four times greater than at any other time of the day (Witzler et al. unpubl. data). In this study, most strikes occurred in early and late morning. Graber and Graber (unpubl. data) reported collisions throughout the daylight hours (06:0017:00) in southern Illinois, but more strikes occurred between 10:01-12:00 and 13:01-14:00 than at other times. At some localities strikes probably occur more often in early morning because birds are actively searching for food, and as most feeder watchers will testify, the largest concentration of birds at feeding stations usually occurs in early morning. Alternatively, during winter when large numbers of birds congregate at feeding stations, high strike rates can be expected throughout the day as local flocks periodically visit specific feeding stations.

Various weather conditions have been hypothesized to increase strikes by enhancing the deceptive effects of glass, hampering visibility, or accounting for the increased abundance of birds in the vicinity of manmade structures (Valum 1968, Konig 1963, Carpenter and Lovell 1963, Hall 1972). Most strikes occur under generally favorable weather, and probably are due to the clarity with which habitat is visible behind or reflected in glass. As my data further support, under conditions of poor visibility, during day or night, birds may experience spatial disorientation and become especially vulnerable if they descend to the vicinity of manmade structures and are attracted to lighted areas behind windows.

In summary, it is clear that: (1) birds fail to see windows as barriers and are vulnerable to them wherever they mutually occur, (2) any factor that increases the density of birds near windows will account for strike frequency, and (3) for any specific collision site, a combination of interacting factors must be considered to explain strike rates.

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