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Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds

Lesley J. Evans Ogden

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A special report for
World Wildlife Fund Canada
and the Fatal Light
Awareness Program

September 1996

WWF

FLAP

The Author
This report was written by Lesley J. Evans Ogden
for World Wildlife Fund Canada (WWF)
and the Fatal Light Awareness Program (FLAP).
Lesley received her M.Sc. in Biology from York University
and her B.Sc. in Zoology from the University of Toronto.
She specializes in the behaviour, ecology and conservation
of neotropical migrant birds. She currently works as a
research consultant and freelance writer and has been
involved in a wide range of conservation projects with
World Wildlife Fund Canada.

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For more information or to obtain additional copies
of this report at a cost of $10 each, please contact:
World Wildlife Fund Canada
90 Eglinton Avenue East, Suite 504
Toronto, Ontario M4P 2Z7
tel: (416) 489-8800
fax: (416) 489-3611

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Preface

In an annual ritual observed for millennia, hundreds of millions of birds arrive each spring in Canada to choose their breeding grounds, only to return to warmer climes in autumn. Covering return flight distances of up to 25,000 kilometres, migratory birds make a truly extraordinary effort.

Only in this century, and therefore suddenly in evolutionary time-scales, have migrating birds faced collisions with artificial obstacles along their flight paths: buildings and other towering structures covered in glass and lit at night. In the dark, and especially in foggy or rainy weather, the combination of glass and light becomes deadly. Confused by artificial lights, blinded by weather, and unable to see glass, birds by the hundreds and even thousands can be injured or killed **in one night at one building**. Over 100 different species of birds have collided with buildings in Toronto alone. One expert estimates that across North America, up to 100 million birds die in collisions each year. Many species that collide frequently are known to be in long-term decline and some are already designated officially as threatened.

For these reasons, World Wildlife Fund Canada (WWF) and the Fatal Light Awareness Program (FLAP) have formed a new partnership, and jointly published *Collision Course: The Hazards of Lighted Structures and Windows to Migrating Birds*. Formed in 1993, FLAP continues a 30-year tradition in Toronto of rescuing birds trapped in the city's downtown core following late-night collisions with tall buildings: in the wee hours of the morning, volunteers scour plazas and sidewalks beneath skyscrapers for dead, injured or disoriented birds, and later release the survivors back to the wild. WWF, dedicated to wildlife conservation in both the temperate and tropical worlds, seeks to identify emerging issues and advocate practical solutions for the long-term protection of wildlife at risk.

Compared to habitat loss, pollution, and over-hunting, the issue of building collisions is neither well-known nor adequately understood. Yet across North America, more birds die from collisions **each year** than succumbed to the Exxon Valdez oil spill. As author Lesley J. Evans Ogden points out in *Collision Course*, bird collisions is a continent-wide issue affecting millions of birds. Her research experience with migratory species, combined with a commitment to conservation, show us what lessons can be learned and applied. In principal, it is delightfully simple to prevent collisions: by night, turn out the lights; by day, make windows visible to birds. In practice, solutions require commitment and action from building owners, managers and tenants in the short-run, and new approaches to office environments by architects, engineers and designers in the long-run.

Responding to the call to action in *Collision Course*, FLAP and WWF will campaign to make Toronto the first "bird-friendly" city in North America. Royal Bank of Canada, which generously sponsored publication of *Collision Course*, is leading the reform of building management practices in Toronto, with the goal of minimizing escaped light at night and thus bird collisions at the Royal Bank Plaza office towers. When we consider that a bird flying north from the Gulf of Mexico to eastern Canada stands a 70 percent chance of encountering at least one urban area, it is clear that other buildings and other cities must take up the challenge, too. Those who do will find *Collision Course* their starting point.

Steven Price
Director, International Program
World Wildlife Fund Canada

Michael Mesure
Founding Member
Fatal Light Awareness Program

Toronto, Canada *September, 1996*

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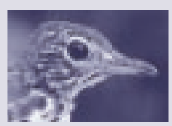
Executive summary

The collision of migrating birds with human-built structures and windows is a world-wide problem that results in the mortality of millions of birds each year in North America alone. Birds killed or injured at such structures are due to two main factors. The first of these is the lighting of structures at night, which "traps" many species of nocturnal migrants. The second factor contributing to the hazard is the presence of windows, which birds in flight either cannot detect, or misinterpret. In combination, these two factors result in a high level of direct anthropogenic (human-caused) mortality. Bird mortality at human-built structures receives relatively little public attention, but structural hazards are actually responsible for more bird kills than higher profile catastrophes such as oil spills. The purpose of this report is to summarize what is currently known about migratory bird collisions, to investigate the seriousness of the threat, to present data on migratory bird mortality in central Toronto, and finally to make preliminary recommendations on how to help eliminate the problem.



The collision of migrating birds with human-built structures and windows is a world-wide problem that results in the mortality of millions of birds each year in North America alone.

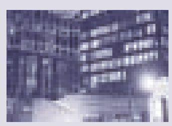
A large proportion of migrating birds affected by human-built structures are songbirds, apparently because of their propensity to migrate at night, their low flight altitudes, and their tendency to be trapped and disoriented by artificial light, making them vulnerable to collision with obstructions. In many species of songbirds known to be undergoing population declines, extra anthropogenic mortality may be an important conservation issue.

A group of volunteers known as the Fatal Light Awareness Program (FLAP) have been collecting birds killed and injured by nocturnal collisions during migration seasons in the downtown district of Toronto since 1993. FLAP has recorded an average annual total of 1,818 birds adversely affected by artificial light, and an average annual mortality rate of 732 birds. These figures are minimum estimates only, since collection does not occur every day and only a small portion of central Toronto is searched. During 1993-95, 100 different species were recorded by FLAP. This phenomenon is not an isolated one, with bird kills

page 2 photo: WWF / Edgar T. Jones; page 3 photo: Ted Almond reported at various types of structures across North America and worldwide. A single tall building in Chicago checked daily during migration seasons has caused an average of 1,478 bird deaths annually, and over a period of 14 consecutive years, the cumulative kill amounted to 20,697 birds.

Further research is necessary to clearly determine why nocturnal migrants are trapped by sources of artificial light. However, birds rely heavily on vision during nocturnal migration and artificial lights apparently interfere with their ability to see the landscape clearly.

With respect to tall office buildings, the obvious solution to migratory bird mortality from collisions is to turn out the lights at night during migration seasons. Where lights are required at structures for the safety of air or marine traffic, the use of flashing white lights (rather than continuous light, red light,



The obvious solution to migratory bird mortality from collisions is to turn out lights at night during migration seasons.

or rotating beams) will reduce the danger to migrating birds. There is no evidence that coloured lights are more effective than white lights at reducing the degree of threat to birds. With respect to windows, the only effective way to prevent bird strikes is to make the glass more visible from the outside with the use of external window coverings. Modifications to make panes of glass tinted and non-reflective, or to incorporate non-reflective interference zones, are additional possibilities.

Migration exposes birds to many natural hazards, but the degree of anthropogenic mortality incurred at artificial obstacles, in concert with other factors such as degradation of breeding, stopover, and wintering habitats, necessitate serious consideration of this world-wide problem and the initiation of effective solutions.

Introduction to the problem

Human-built structures have been recognized as a hazard to birds for more than a century (Cooke, 1888; Kumlien, 1888). However, the accelerated rate of urban development in recent years has seen the proliferation of radio and television towers, office buildings, power lines, cooling towers, emission stacks, and residential housing, all of which represent an increasing threat to flying birds. The major factors contributing to the perilous nature of human-built structures are: (1) the presence of artificial lights at night; and (2) the presence of windows, which are potentially hazardous both day and night. Power lines pose both an electrocution and collision hazard to birds, particularly to raptors, but this issue has been widely studied (e.g. Bevanger, 1994) and will not be dealt with in this report.

Birds migrating at night are trapped by sources of artificial light and become vulnerable to collisions with lit structures.


Ted Almond

Birds migrating at night are strongly attracted to, or at least trapped by, sources of artificial light, particularly during periods of inclement weather (e.g. Verheijen, 1958, 1985). Approaching the lights of lighthouses, floodlit obstacles, ceilometers (light beams generally used at airports to determine the altitude of cloud cover), communication towers, or lighted tall buildings, they become vulnerable to collisions with the structures themselves. If collision is avoided, birds are still at risk of death or injury. Once inside a beam of light, birds are reluctant to fly out of the lighted area into the dark (Graber, 1968), and often continue to flap around in the beam of light until they drop to the ground with exhaustion (Weir, 1976, and references therein). A secondary threat resulting from their aggregation at lighted structures is their increased vulnerability to predation (e.g. Stoddard and Norris, 1967; this study). The difficulty of finding food once trapped in an urban environment may present an additional threat.

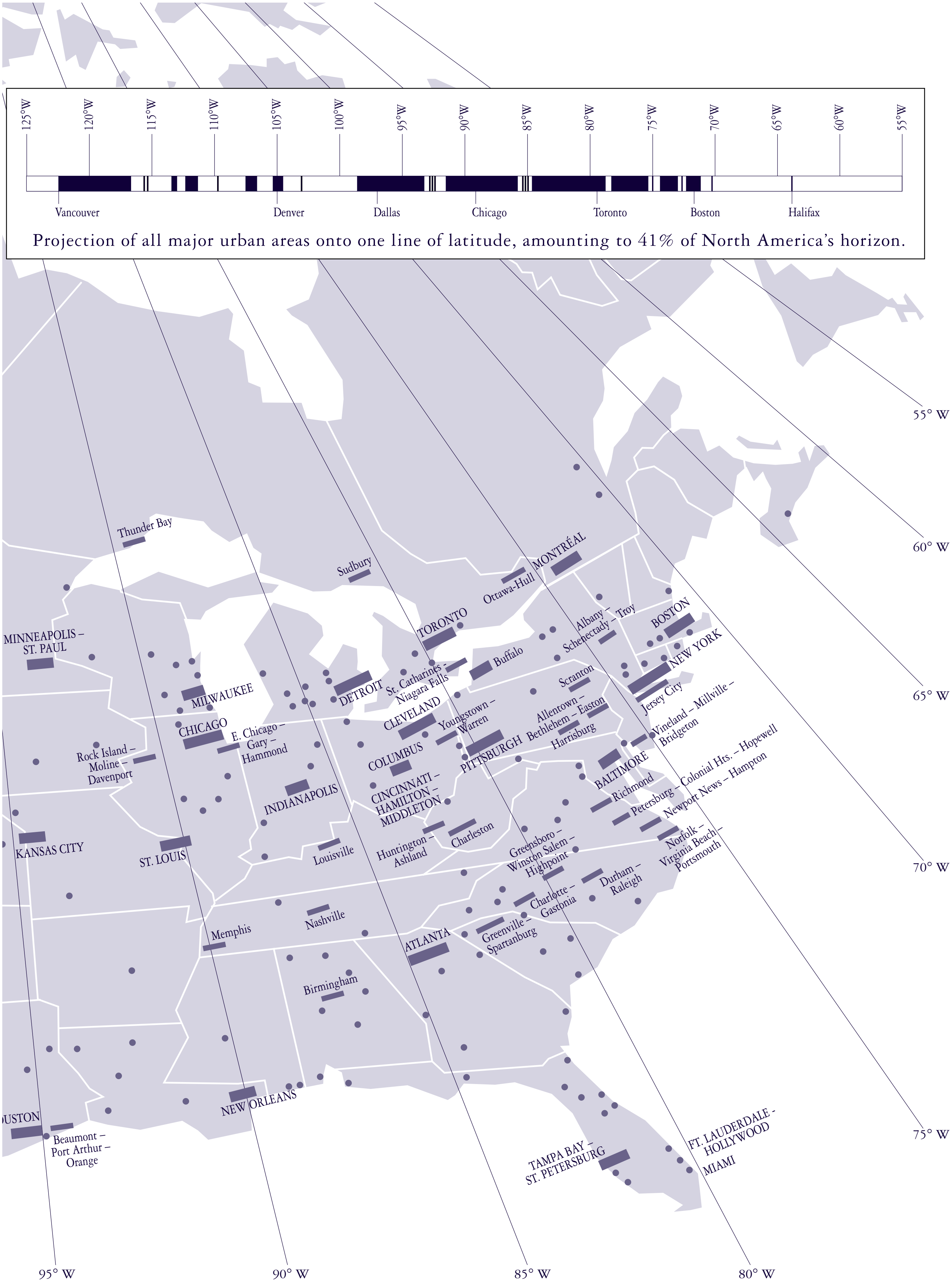
Windows are the second major factor rendering structures potentially lethal to birds. Available evidence suggests that windows are not visible to birds (e.g. Klem, 1989), and thus the presence of either reflective or clear plate glass in the flight path of a bird causes death or injury due to impact at high velocity. Windows represent not only a day-time collision hazard for birds, but are the medium through which light is transmitted at night from office towers and other buildings. Window invisibility and light thus compound the potential danger of night-time collisions.

Resident bird species living alongside humans face a constant threat from human-built structures, and it has been suggested that while rare, some individuals may actually learn to avoid such threats through experience (Klem, 1989). Migrating birds, however, face such risks wherever human-built structures occur along their migratory flight path, and are likely more vulnerable than resident birds to collisions and potentially fatal disorientation. The entrapment of nocturnally migrating birds by areas of artificial light sources is a particularly serious problem, and light is probably the single most important factor in rendering a structure a potent killer to such species (K. P. Able, personal communication). The unnatural threat of human-built structures to such migrants, with reference to both nocturnal and diurnal hazards, constitutes the focus of this paper.

To understand the threat posed by human-built structures to migrating birds, it is necessary to first understand some basic concepts about migration.

Figure 1

Major urban areas of Canada and the U.S. – A threat to migrating birds



Projection of all major urban areas onto one line of latitude, amounting to 41% of North America’s horizon.

WWF / Edgar T. Jones

Migratory bird mortality resulting from collisions with buildings probably occurs in every major city throughout North America. The presence of urban areas along the routes of migrating birds in flight can be imagined in the following way: If the east-west width of all Canadian and American cities over 100,000 in population is projected onto one line (i.e. a single imaginary "horizon" from a bird's-eye view), then the aggregate width of these large urban areas is equivalent to 41 percent of the total east-west width of North America measured from its most easterly and westerly points (see figure 1 inside).

Migration

Bird migration is a world-wide phenomenon. During migration, some 50 million birds passing over the coast of the southern United States can be seen on radar screens over the course of a few hours (Gauthreaux, 1994). In southern Ontario, a long-term study of migration over the Toronto area found that southbound migration traffic rates in autumn are highly variable, ranging from zero to almost 30,000 birds per kilometre of migration front per hour (Richardson, 1982).

Migration in North America is mainly south to north during spring, and north to south during fall, as birds make their way to their breeding and wintering grounds, respectively. In North America, peak migration occurs between March and May in spring, and between August and October in autumn (Weir, 1976). Migration distances vary widely, with some species or populations traveling relatively short distances, and others migrating from nearly pole to pole (Alerstam, 1994). Some birds make a series of short flights, while others fly huge distances without stopping. For example, certain populations of the northern wheatear (*Oenanthe oenanthe*) make non-stop 24-hour journeys across the Atlantic Ocean (Martin, 1990), whereas species such as the Swainson's thrush (*Catharus ustulatus*) apparently adopt a "feed-by-day, fly-by-night" strategy, making numerous stop-overs en route (Winker et al., 1992). Migration behaviour is thus highly variable.

Physiology and feeding behaviour probably determine whether a particular species migrates by day or by night (Alerstam, 1994; Kerlinger and Moore, 1989). Birds able to feed on the wing, such as swallows and swifts, may travel by day and feed while migrating. Songbirds (order Passeriformes) require daylight in order to forage for food, and largely migrate at night (Weir, 1976; Alerstam, 1994). Waterfowl can feed by either day or night, and thus their migration occurs at either time. With respect to physiology, cooler temperatures and less turbulent air at night may also suggest why many birds are nocturnal migrants, since daytime temperatures can cause overheating and enormous loss of body water through evaporative cooling (Kerlinger and Moore, 1989). Nocturnal migration may also reduce the risk of predation for small birds. Categories of night-time and day-time migrants are not necessarily mutually exclusive at either the species or population level (Martin, 1990), with some individuals migrating at different times than others.

Physiological preparation for migration is crucial for an individual's survival through a period of extreme physical exertion, particularly for long-distance migrants that make non-stop flights. Prior to migration, birds spend considerable time gorging to build up fat reserves (e.g. Alerstam, 1994). Fat deposits are stored subcutaneously and in the body cavity (Meier and Fivizzani, 1980). Deposits of fat, a highly concentrated and lightweight form of energy, allow birds to fly for long periods of time without having to stop to "refuel." Different species use different physiological migration strategies. Some species store small fat reserves and migrate in short stages. Others, particularly those species that must traverse inhospitable terrain such as deserts or open ocean, store large fat reserves. To compensate for the weight of additional fat, some species also build up their flight muscles prior to migration (Bibby and Green, 1981).

Entrapment in urban areas during migration has potentially dangerous physiological consequences for migrants. Migrants lose weight quickly during migration (Alerstam, 1994, p. 286), and may continue to lose weight during the first several days at a stopover site before regaining their fat reserves (e.g. Rappole and Warner, 1976). Therefore, trapped birds which avoid collision but remain within the concentration of buildings are potentially at risk of starvation from lack of resources such as seeds and insects. This lack of food may be an important secondary cause of mortality for exhausted migrants trapped in a sterile environment.

In North America, peak migration occurs between March and May in spring, and between August and October in autumn. Some birds make a series of short flights, while others fly huge distances without stopping.

Migration altitude is an important causal component affecting the likelihood of mortality at human-built structures. Heights of migration vary enormously, depending on species, location, geographic feature, season, time of day and weather conditions (Cooper and Ritchie, 1995). Birds have been recorded migrating at heights up to 9,000 metres above sea level (just over the Himalayas) (Berthold, 1993). There are many gaps in our knowledge of migration altitude, particularly for nocturnal migrants. However, some generalizations can be made based on what we know thus far:

(1) nocturnal migrants migrate at higher altitudes than diurnal migrants;
(2) very low migration close to the Earth's surface is almost completely non-existent at night;
(3) in head winds, birds withdraw to lower altitudes with lower wind velocities;
(4) lower altitudes are used over mainland and small bodies of water than during transoceanic migrations;
(5) marshes, lowlands, etc. are usually crossed at relatively high altitudes, whereas migrants often cross mountainous regions at relatively low height, sometimes using mountain passes;
(6) faster flyers may prefer higher altitudes than do slower species (Berthold, 1993: p. 82, and references therein);
(7) in North America, birds migrate at higher altitudes in fall than in spring (Richardson, personal communication; Cooper and Ritchie, 1995).

Radar, infrared, and visual observations have provided much useful information on the altitudinal distribution of species groups (e.g. Able, 1970; Cooper and Ritchie, 1995; Liechti and Bruderer, 1995). In general, swans, geese, ducks and cranes fly at higher levels than do raptors, shorebirds and songbirds (Cooper and Ritchie, 1995). Cooper and Ritchie's study (1995), which combined radar and visual observations to study both diurnal and nocturnal flight, was able to determine flight altitudes for individual species flying during the day. Identifying flight altitudes for individual species at night has thus far proved difficult. However, a new technology using audio equipment to identify species-specific flight calls during migration is currently being developed, which may allow future research in this area (Bill Evans, personal communication).

While obtaining species-specific data has proven elusive, radar studies on nocturnal bird migration have provided relatively consistent results on flight altitude for migrants (Able, 1970; Gauthreaux, 1968; Eastwood and Rider, 1965). Cooper and Ritchie (1995) indicated that a large proportion of birds tracked by radar (98 percent in spring and 77 percent in fall) flew at heights below 500 metres above ground level (agl). Several other studies also report that nocturnal migration usually occurs below 500 metres agl (e.g. Bellrose, 1971; Bruderer and Steidinger, 1972; Gauthreaux 1972, 1978, 1991). Others found flight altitudes extending over a broader altitudinal range below approximately 2,000 metres agl (e.g Able, 1970; Eastwood and Rider 1965; Nisbet 1963; Richardson 1971a,b, 1972). Research indicates that after take-off, small birds climb rapidly to their migrating altitude. Maximum numbers of birds in flight and maximum migration altitudes are achieved around midnight. (Lowery and Newman, 1966; Richardson, 1971b; Bruderer et al., 1995). While general ranges of migrational altitude have been defined, a high degree of geographic variability in flight altitudes cautions that site-specific studies are necessary to assess the impact of tall structures at particular locations (Cooper and Ritchie, 1995).

Despite the variability in migration altitudes, songbirds have been consistently identified as a group of species flying at relatively low levels (e.g. ibid; Able, 1970). This makes these species particularly vulnerable to mortality at human-built structures from collisions or from secondary causes such as exhaustion, predation, starvation and dehydration. The low flight altitudes of migratory songbirds are reflected in the high incidence of their representation amongst the kills reported in the literature (e.g. this study).

Weather conditions have a pronounced effect on the mortality of migrating birds at human-built structures. While significantly fewer birds are aloft in conditions of rain or snow (e.g. Gauthreaux 1977; Alerstam, 1978; Zalakevicius 1984; Richardson, personal communication), significantly greater numbers of kills at human-built structures occur on nights of overcast or inclement weather conditions (e.g.

Trapped birds which avoid collision are potentially at risk of starvation in downtown areas where resources such as seeds and insects are scarce.

Kemper, 1964; Aldrich et al., 1966; Verheijen, 1981). Precipitation and cloud cover therefore clearly do not suppress migration altogether. In fact, many studies indicate that some birds migrate even in heavy overcast conditions, with little or no detectable disorientation, since most of these migrants fly either below or above the cloud cover (Able, 1982; Richardson, 1990, and references therein). However, those individuals flying within the cloud are often less well oriented, particularly when unfavourable weather conditions last several days (Able, 1982). In general, "overcast is unfavourable for migration, no doubt partly because it reduces the number of cues available for orientation" (Richardson, 1990).

The higher incidence of birds killed and injured at human-built structures in unfavourable weather conditions probably results from the combination of two factors: (1) the reduced number of navigational cues available; and (2) the lower altitude of individuals flying below the cloud cover. Both factors appear to make them more vulnerable to fatal disorientation and collision with sources of artificial light. The largest kills appear to occur when birds take off in favourable weather conditions but later encounter stormy weather, which forces them down to the ground or to lower altitudes (e.g. Herbert, 1970). While weather is an important influence on the overall numbers of fatalities at human-built structures, mortality occurs to some degree under all weather conditions, necessitating the adoption of preventative measures implemented consistently throughout the migration seasons.

A popular but perhaps misunderstood notion holds that bird migration occurs in a concentrated manner along specific routes, called "flyways." The concept of the migratory flyway was introduced by F. C. Lincoln in the 1930s, and used mainly with reference to waterfowl (e.g. Lincoln, 1935; Ens et al., 1994). While the idea of flyways may indeed have some limited validity for waterfowl and shorebirds, there is much overlap among flyways, and most species use more than one flyway during migration. The term flyway is occasionally applied to other groups of birds, including songbirds. However, at least in continental areas, the application of such an idea is misleading, since songbird migration overland occurs along a broad front with little evidence of concentration along particular routes (J. Richardson, personal communication). During spring and fall migration, birds migrate to and from geographically diverse locations, and thus the visual perception of "highways of birds" is probably neither a useful nor a valid concept. The idea of a flyway for land birds is only appropriate in special geographic situations, such as along the narrow parts of Central America and Mexico.

Songbirds have been consistently indentified as a group of species flying at relatively low levels. This makes them particularly vulnerable to mortality at human-built structures.

WWF / Edgar T. Jones

The wood thrush is one of the ten most frequently killed species in Toronto's downtown core.

This is not to say that all locations are equally hazardous for migrating birds. Structures located at key points along migratory routes may represent a greater hazard than those in other locations. For example, cities or structures located along the shores of the Great Lakes and along the Florida and Louisiana coasts, where birds congregate before or after crossing a large expanse of water, constitute a particularly dangerous threat (e.g. Dunn and Nol, 1980, and references therein). Toronto, located on the northern shore of Lake Ontario, is presumably a hazard to birds setting out over the lake in fall and reaching land after crossing the lake in spring (this study). In Chicago, located on the southern shore of Lake Michigan, mass bird mortality during migration is also a serious problem (Willard, personal communication). While certain locations thus represent more critical migration danger zones, bird migration is a continent-wide and world-wide phenomenon, and all human-erected structures pose a potential threat to birds. All forms of urban development should therefore take this issue into consideration.

FLAP – Toronto case study

Various interested individuals have been collecting dead or injured migrating birds at the base of downtown Toronto buildings at least as early as the 1960s, and some 40 of Toronto's buildings are reported to be responsible for bird deaths (Whelan, 1976). FLAP, the Fatal Light Awareness Program, is a volunteer organization founded in April 1993 by a group of individuals concerned about the large numbers of migrating birds killed or injured by collisions with city buildings in the downtown core of Toronto during spring and fall migration. The group began collecting, identifying and recording their findings in 1993, and rescuing, rehabilitating and releasing as many birds as possible. The purpose of this case study is to illustrate the relative magnitude of the problem of bird mortality during migration in a large urban centre.

FLAP, the Fatal Light Awareness Program, is a volunteer organization founded in April 1993 by a group of individuals concerned about the large numbers of migrating birds killed or injured by collisions with city buildings in the downtown core of Toronto.

Migratory bird collisions in Toronto

It is important to point out that the mandate of FLAP volunteers is primarily to capture uninjured birds trapped in the city centre and transport them to be released in a more natural setting. A secondary goal is to increase the chance of survival for injured birds by transporting them to wildlife rehabilitation centres. An additional FLAP goal is to increase public awareness about the problem of lit buildings during the migration season and to encourage building tenants and owners to turn off lights at night. Given their mandate for rescue, FLAP's information on the total numbers of birds and species composition was therefore not collected as part of a scientific study, and collection did not employ a strict scientific protocol using consistent time of day, duration, effort, and collection routes.

Ted Almond

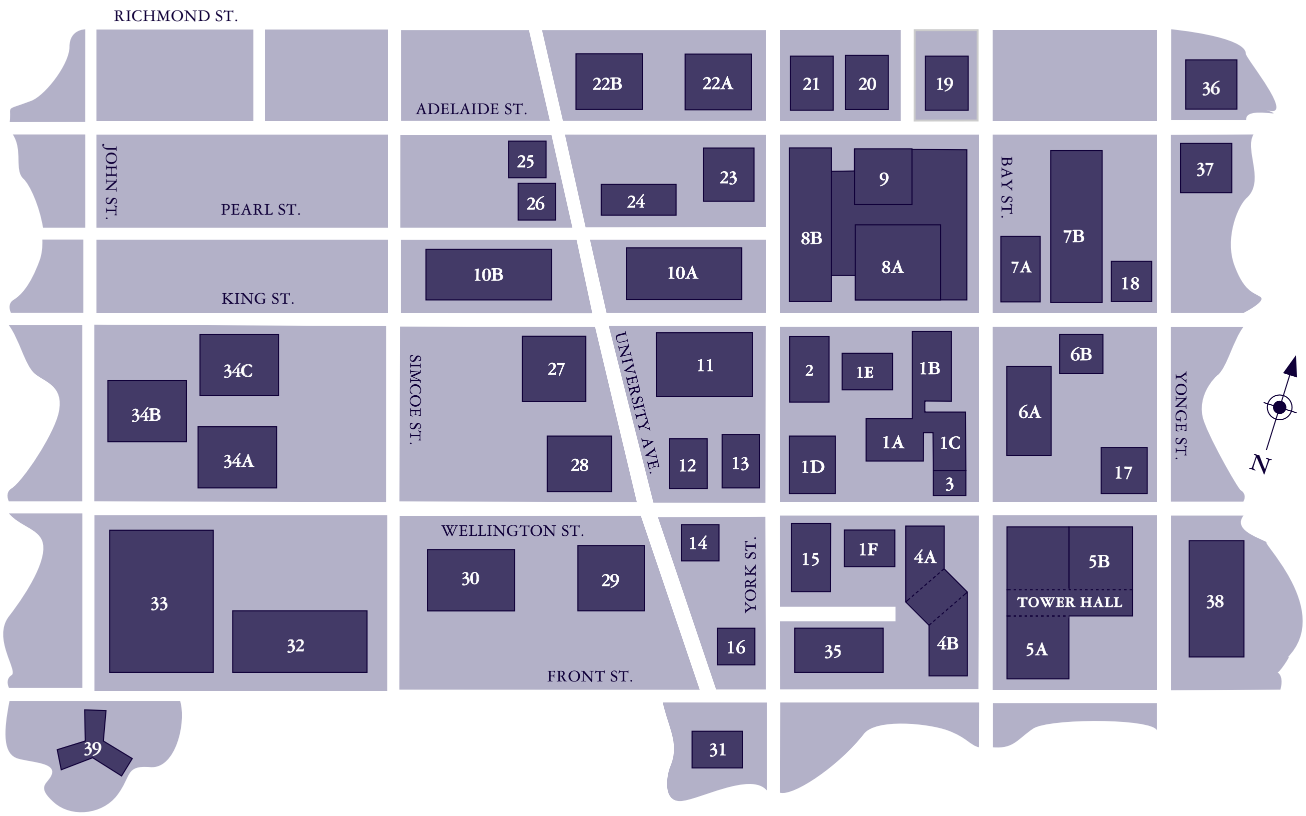
Rescued birds that are uninjured or have recovered are released in natural areas far from buildings.

During the migration season (in spring, from early April to early June; in autumn, from mid-August to mid-November), a group of volunteers from FLAP search the downtown core of Toronto. This district is an area of numerous tall office buildings, many of which are faced entirely with glass. The boundaries of the area searched by FLAP are Front Street to the south, Yonge Street to the east, Richmond Street to the north, and John Street to the west (see Figure 2), an area of approximately 0.7 square kilometres and comprising approximately 40 skyscrapers and numerous small buildings (see Figure 3). A central core area consisting of buildings known as the Toronto-Dominion Centre, Royal Bank Plaza, Commerce Court, BCE Place and First Canadian Place, is checked regularly, with more distant buildings checked less frequently when collisions in the core have been few. Collectors search only the most easily accessible sides of buildings, since some sides of some buildings are difficult to reach. (Above-ground ledges are thought to harbour injured or dead birds, but these are not normally searched.)

Volunteers begin their search in the early hours of the morning, usually between 3:00 a.m. and 9:30 a.m., but searching sometimes begins as early as 11:00 p.m. if the weather is ominous, and on these nights collection may continue into late morning or early afternoon. The time spent collecting varies widely, usually from 30 minutes to three hours. Volunteer availability determines whether or not collection takes place on any given day, and thus collection is not possible every day. Volunteers record information concerning species and location on paper or with the use of a hand-held tape recorder. Birds are captured by hand or with the aid of a hand-held net. Volunteers occasionally administer Dexamethasone to injured birds to reduce brain swelling. Uninjured birds are individually housed in paper bags and released away from the city, injured birds are taken to wildlife rehabilitation centres, and dead birds are donated to scientific institutions (M. Mesure, personal communication). As outlined above, collection methods employed by FLAP volunteers are in

Figure 2

Area monitored by the Fatal Light Awareness Program in Toronto's downtown core

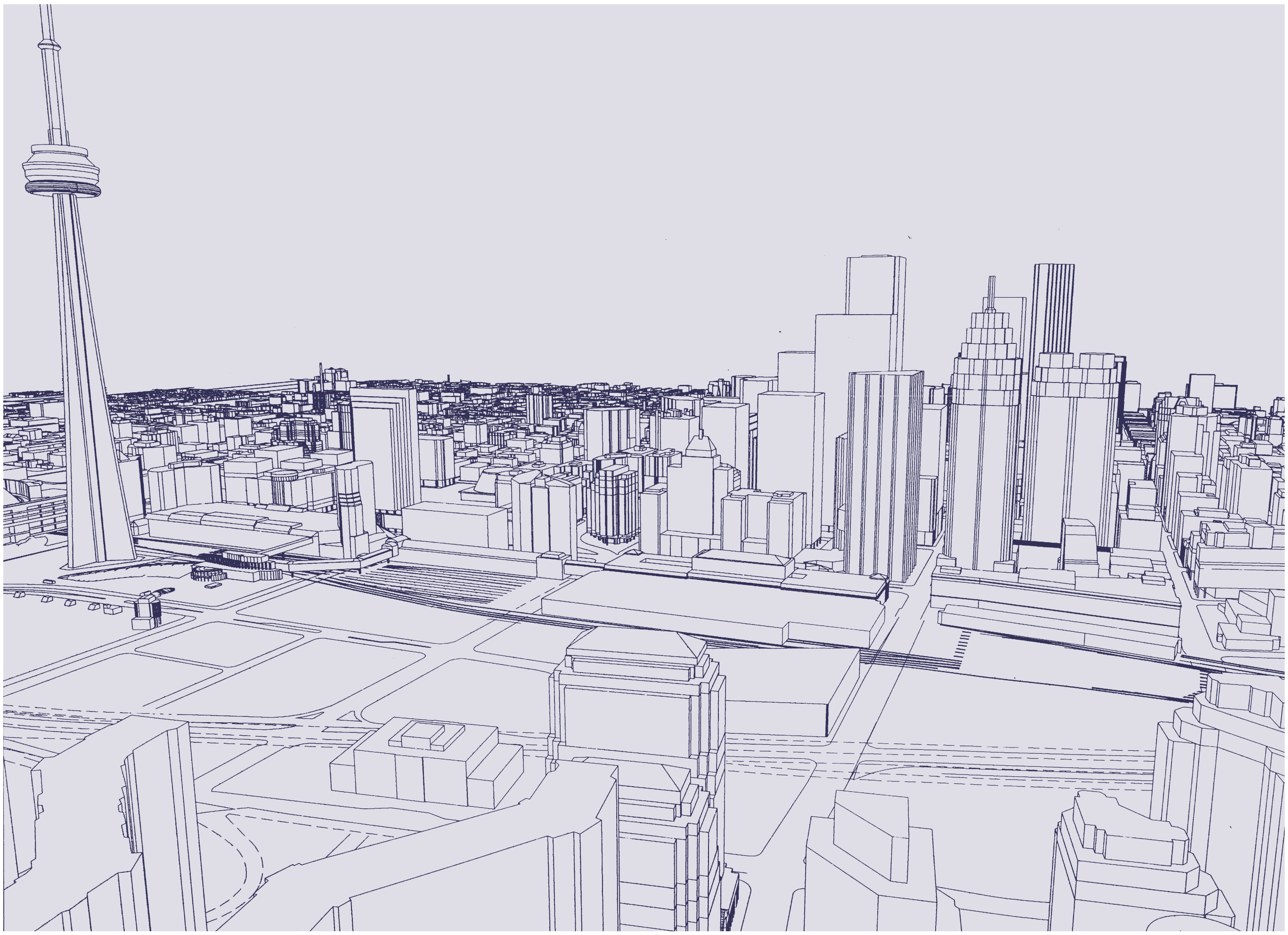


Buildings:

1A TORONTO – DOMINION TOWER
1B TORONTO – DOMINION BANK
1C ERNST & YOUNG
1D COMMERCIAL UNION
1E ROYAL TRUST
1F AETNA
2 STANDARD LIFE CENTRE
3 220 BAY STREET
4A ROYAL BANK PLAZA NORTH
4B ROYAL BANK PLAZA SOUTH
5A CANADA TRUST
5B BAY WELLINGTON
6A CIBC TOWER
6B OLD CIBC BANK
7A OLD SCOTIA BANK
7B SCOTIA PLAZA
8A BANK OF MONTREAL
8B EXCHANGE TOWER
9 105 ADELAIDE STREET WEST
10A SUN LIFE CENTRE
10B MERRILL LYNCH CANADA TOWER
11 145 KING STREET WEST
12 55 UNIVERSITY AVE
13 HONG KONG BANK OF CANADA
14 33 UNIVERSITY AVE
15 DELOITTE & TOUCHE
16 METROPOLITAN PLACE
17 SUN ALLIANCE BUILDING
18 4 KING STREET WEST
19 BELL CANADA
20 RICHMOND ADELAIDE CENTRE
21 130 ADELAIDE STREET WEST
22A NATIONAL BANK BUILDING
22B GUARDIAN OF CANADA TOWER
23 141 ADELAIDE STREET WEST
24 155 UNIVERSITY AVE
25 170 UNIVERSITY AVE
26 UNION BANK OF SWITZERLAND
27 100 UNIVERSITY AVE
28 70 UNIVERSITY AVE
29 40 UNIVERSITY AVE
30 145 WELLINGTON STREET WEST
31 CITIBANK PLACE
32 WORKERS' COMPENSATION BOARD
33 CBC CENTRE
34A UNITEL
34B METRO HALL
34C SUN LIFE TRUST
35 ROYAL YORK
36 YONGE RICHMOND CENTRE
37 1 FINANCIAL PLACE
38 33 YONGE STREET
39 CN TOWER

Figure 3

A bird's eye view of Toronto's downtown core



This figure has been provided by the City of Toronto – Planning and Development, Architecture and Urban Design Division.

Looking north from the Toronto waterfront, this oblique view of the downtown skyline shows the maze of buildings which may confront migrating birds.

no way standardized or consistent. The numbers given therefore provide a rough estimate only, since FLAP does not have the human resources to fully search the entire area and all sides of buildings. The nature of the collection precludes any comparison between individual buildings or the effects of architectural design. However, the data collected at least provide a minimum estimate of the degree of mortality incurred and the types of bird species affected at night by Toronto's tall lighted buildings during the migration season.

Predation also suggests that the number of birds recorded by FLAP indeed represents a minimum. By dawn, gulls (especially ring-billed gulls, *Larus delawarensis*) are scavenging Toronto's downtown core. The search area must therefore be examined before dawn in order to minimize competition with these marauding gulls for access to the dead and injured birds. FLAP's President, Michael Mesure, describes the gulls as appearing to follow particular scavenging routes around Toronto buildings, apparently a behaviour learned in response to the discovery of a reliable food source during migration. Klem (1981) stated that avian predators are unlikely to be capable of learning to use windows as tools to capture their prey, since the predators themselves can collide with the windows around which they hunt. However, gulls observed by FLAP members not only prey on the dead birds, but apparently have learned to scare injured or disoriented birds towards windows, apparently causing collisions that stun or kill the individual, allowing its easy retrieval. Mesure has also observed that an increased number of gulls appears to be present on nights of particularly heavy migration. While FLAP volunteers reduce the number of birds taken by predatory gulls, the gulls may capture the majority of birds, acting as an efficient "clean-up crew," and thus remove most of the evidence of mass bird kills. The counting of gulls in various sectors of the city during migration seasons may in fact be a future method by which FLAP could assess the geographical extent of bird mortality within Toronto (E. Dunn, personal communication). In addition to gulls (the main predators in the Toronto study), predation by raccoons, feral cats, and rats also occurs to a lesser extent.

1993-1995 data

Table 1 illustrates the total number of deaths and the total number of birds collected (including those killed, injured, caught and sighted), thus giving approximate minimum and maximum numbers of birds affected by the lights of tall structures in Toronto during nocturnal migration in spring and fall. The significant increase in numbers during autumn in comparison with spring presumably reflects the increased number of juvenile birds in the population following the breeding season, similar to the findings of other authors (e.g. Klem, 1989). Factors such as the use of different migration routes in spring and fall, and seasonal differences in the speed of migration may also be involved (e.g. Avise and Crawford, 1981). The level of mortality that would occur without FLAP's intervention would be somewhat higher than the figure reported here, since approximately 25 percent of the injured birds die or are euthanized at wildlife rehabilitation centres. Many of the injured birds that survive and are later released would not do so without human intervention. In addition, the actual survival rate of birds released following successful rehabilitation is unknown, since these individuals are not banded. The possibility exists that some individuals may be left with permanent brain damage due to

Volunteers from FLAP begin their search for injured birds in the early hours of the morning, usually between 3:00 a.m. and 9:30 a.m. Birds are captured by hand or with the aid of a hand-held net.

Ted Almond

About one-half of all birds rescued by FLAP can be released away from buildings.

Table 1: Numbers of birds found near tall Toronto buildings during migration (1993-95)[1]

	Spring April – May		Fall August – November		Annual Totals	
Year	*deaths*	*total*[2]	*deaths*	*total*[2]	*deaths*	*total*[2]
1993	301	666	305	639	606	1305
1994	350	972	578	1296	928	2268
1995	250	907	414	974	664	1881
Average	300	848	432	970	733	1818
Total	901	**2545**	1297	**2909**	2198	**5454**

[1]Data collected in Toronto by FLAP members. Number of collection days: 101, 124, 116 for 1993, 1994, and 1995 respectively.
[2]Total number of birds recorded as dead, injured, captured, escaped and sighted.

Table 2: Ten most frequent species found near tall Toronto buildings during migration (1993-1995)[1]

	Spring			Fall			Overall		
Rank of Abundance	*Species*	*Individuals*[2]	*% of total (2545)*[3]	*Species*	*Individuals*[2]	*% of total (2909)*[3]	*Species*	*Individuals*[2]	*% of total (5454)*[3]
1	White-throated sparrow	707	27.8	White-throated sparrow	425	14.6	White-throated sparrow	1132	20.8
2	Ovenbird	504	19.8	Ovenbird	399	13.7	Ovenbird	903	16.6
3	Brown creeper	181	7.1	Common yellowthroat	265	9.1	Common yellowthroat	378	6.9
4	Common yellowthroat	113	4.4	Magnolia warbler	166	5.7	Brown creeper	237	4.3
5	Hermit thrush	97	3.8	Hermit thrush	133	4.6	Hermit thrush	230	4.2
6	Dark-eyed junko	88	3.5	Black-throated blue warbler	90	3.1	Magnolia warbler	203	3.7
7	Wood thrush	52	2.0	Black-and-white warbler	90	3.1	Black-throated blue warbler	132	2.4
8	Magnolia warbler	37	1.4	American redstart	68	2.3	Dark-eyed junco	128	2.3
9	Yellow-bellied sapsucker	37	1.4	Brown creeper	56	1.9	Black and white warbler	124	2.3
10	Black-and-white warbler	34	1.3	Song sparrow	49	1.7	American redstart	85	1.6

[1]Data collected in Toronto by FLAP members. Number of collection days: 101, 124, 116 for 1993, 1994, and 1995 respectively.
[2]Total number of birds recorded as dead, injured, captured, escaped and sighted.
[3]Percent of total number of individuals found, including unidentified birds.

the impact of collision, which may interfere with a variety of crucial skills or behaviours, among them the ability to navigate successfully during migration.

Table 2 depicts the 10 most abundant species collected. Of the 100 species recorded by FLAP, several species stand out as being highly abundant. White-throated sparrows (*Zonotrichia albicollis*) and ovenbirds (*Seirus aurocapillus*) are the most numerous species in spring, comprising 28 percent and 20 percent of the total, respectively. White-throated sparrows and ovenbirds are also the two most common species in fall, comprising 15 percent and 14 percent, respectively. These two species frequently rank the highest in other reports of bird mortality at human-built structures (Klem, 1989; D.E. Willard, unpublished data).

FLAP's data on species composition were also compared to data compiled by the Toronto Ornithological Club (TOC) during 1993-95 (Fairfield, 1993, 1994, 1995). The TOC collected data from several observers who made daily visual and auditory counts of migrating birds at 11 study areas in Metropolitan Toronto. For the May 1 to June 5 period, the species composition of the two studies differed markedly. Ovenbirds, for example, comprise 64 percent of the warblers in the FLAP data, but only six percent of those in the TOC data. Similarly, common yellowthroats (*Geothlypis trichas*) comprise 14 percent of the FLAP data but only three percent of the TOC data. Conversely, yellow-rumped warblers (*Dendroica coronata*) comprise 12 percent of the TOC sample, and only 0.4 percent of the FLAP data. The TOC species composition data is affected by visibility, since some species are more conspicuous than others, and thus comparison between TOC and FLAP data is a relatively crude one. However, the observed trends suggest that the propensity for certain species to be over-represented in collision deaths is not simply a factor of their relative abundance in the composition of migration traffic. Rather, their nocturnal attraction to lighted buildings would appear to be due to some species-specific behaviour that makes them more vulnerable than other species to light entrapment.

Similar to other reports of migration mortality at human-built structures, certain sub-families of birds are also more prevalent than others (see Table 3). The largest proportion of species overall belong to the warbler (Parulinae) sub-family (41 percent). Next most common are sparrows (Emberizinae), which comprise 32 percent of the total overall. Thrushes (Turdinae) and brown creepers (Certhiidae: *Certhia americana*) are also highly represented. The apparent proclivity of certain

Table 3: Ranking of abundance of birds found near tall Toronto buildings during migration (1993-1995), categorized by sub-family[1]

	Spring			Fall			Overall		
Rank of Abundance	*Sub-family*	*Individuals[2]*	*% of total (2545)[3]*	*Sub-family*	*Individuals[2]*	*% of total (2909)[3]*	*Sub-family*	*Individuals[2]*	*% of total (5454)[3]*
1	Sparrow (Emberizinae)	1065	41.8	Warbler (Parulinae)	1438	49.4	Warbler (Parulinae)	2249	41
2	Warbler (Parulinae)	811	31.9	Sparrow (Emberizinae)	697	24	Sparrow (Emberizinae)	1762	32
3	Other	317	12.5	Other	541	18.6	Other	858	16
4	Brown creeper (family Certhiidae)	181	7.1	Thrush (Turdinae)	173	5.9	Thrush (Turdinae)	346	6.3
5	Thrush (Turdinae)	173	6.8	Brown creeper (family Certhiidae)	56	1.9	Brown creeper (family Certhiidae)	237	4.3

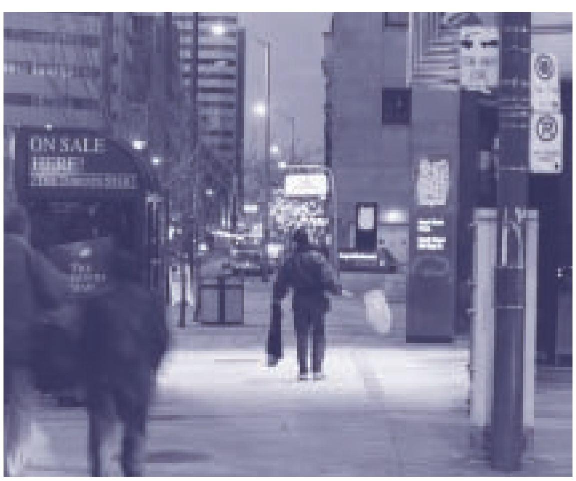
[1] *Data collected in Toronto by FLAP members. Number of collection days: 101, 124, 116 for 1993, 1994, and 1995 respectively.*
[2] *Total number of birds recorded as dead, injured, captured, escaped and sighted.*
[3] *Percent of total number of individuals.*

species and sub-families to be more vulnerable than others to fatal light entrapment is corroborated by many other studies (Appendix 1) and the potential causes and implications of this phenomenon will be discussed later in this report.

The FLAP data for downtown Toronto may be summarized as follows: the total number of species recorded for all years and seasons combined is 100 (see Appendix 2). The average annual total of birds killed or injured by artificial light is 1,818. The average annual number of deaths from 1993 to 1995 is 732, with 300 deaths resulting in spring and 432 in fall. Due to the many additional threats (predation, the day-time hazards of windows for those that survive the night, and the difficulty of finding food in a built-up area), the actual number of deaths in central Toronto prior to FLAP's intervention was likely to be much higher, perhaps closer to 1,000 per year. This figure is almost certainly an underestimate, since bird collections at only two buildings in downtown Toronto have caused the death of 157 birds during fall migration alone (Ranford and Mason, 1967).

Representing only a small section of the potential danger zone in Toronto for migrating birds, these numbers are disturbing. Light entrapment represents a significant and real threat for migrating birds, and for songbirds in particular. This degree of mortality is not an isolated occurrence. In fact, at just one lake-side building in Chicago checked every day during both migration seasons since 1982, the average number of birds killed annually is 1,478, and the total number killed over the past 14 years is 20,697 (D.E. Willard, unpublished data). Cities located on the Great Lakes, such as Toronto and Chicago, may have higher collision mortality rates than cities further inland, since migrating birds (young birds in particular) are known to aggregate along coasts (e.g. Dunn and Nol, 1980, and references therein).

Migrant mortality of varying degrees of severity probably occurs in every major city throughout North America and wherever bird migration and urban centres coincide worldwide. The presence of urban areas along the routes of migrating birds in flight can be imagined in the following way: If the east-west width of all Canadian and American cities over 100,000 in population is projected onto one line (i.e. a single imaginary "horizon" from a bird's-eye view), then the aggregate width of these large urban areas is equivalent to 41 percent of the total east-west width of North America measured from its most easterly and westerly points. In this projection, cities of the same longitude overlap one another; a calculation of all such urban widths is equivalent to 84 percent of the total width of North America. Between Chicago and Boston (i.e. most of eastern North America), urban areas block 70 percent of the horizon and their combined total width is equivalent to 215 percent of the Chicago-Boston horizon.



Alan Cairns / The Toronto Sun

Alan Cairns / The Toronto Sun

Rescue work begins before dawn and may continue through the morning rush-hour. Office workers, largely unaware of the threat of buildings to migrating birds, hold the key to their survival.

The broader picture

While a complete analysis of the existing data is beyond the scope of this study, a partial compilation of data amassed by Avery et al. (1980), a number of recently published works, and several unpublished studies, provide some useful insight into the past and present severity of the problem (see Appendix 1).

FLAP's Toronto case study represents merely one example of a problem which occurs throughout Canada and the world. The problem of avian mortality at human-built structures is a long-standing one, with documentation of incidents occurring as early as the 1880s (Cooke, 1888; Kumlien, 1888). Weir (1976) documented 471 reports of bird kills at human-built obstacles, including lighthouses, ceilometers, chimneys, cooling towers, communication towers, buildings, gantries, bridges, trains, telephone lines and power lines. The origins of Weir's references included North America, the Caribbean, Europe, Malaysia, and the Pacific Ocean. Many of the 471 references were reports documenting multiple incidents.

The annotated bibliography produced for the United States Fish and Wildlife Service (Avery et al., 1980) lists 1,042 references to avian mortality at human-built structures, with many of these references also referring to multiple incidents. More than 15 years later, documentation of the problem continues (e.g. Willard, unpublished data; Klem, 1990; Dunn, 1993), but a comprehensive bibliographic update has not been produced. It is important to consider that formal documentation of avian mortality at human-built structures represents only the tip of the iceberg. The vast majority of kills remains undocumented and presumably largely unnoticed. Avian mortality at human-built structures is thus a large but often covert problem. Wherever there are human-built structures, migrating birds are potentially at risk.

Considerable information exists on bird losses at human-built structures, however most of this information consists of sporadic reports of kills rather than organized and coordinated monitoring. There is a dire need for a comprehensive and co-ordinated effort at national and international levels. Nevertheless, useful information can still be gleaned from the myriad of existing bird collision reports.

Kills of more than one hundred ovenbirds in one night have been documented in multiple reports, and if this degree of mortality prevails across the continent, such losses may have a significant impact on population sizes.

Alan Cairns / The Toronto Sun

Volunteer rescues an ovenbird, the species that collides most often with buildings in North America.

Significance of the problem

While it is difficult to determine an exact numerical figure for the proportion of overall migration mortality incurred by human-built structures, it is important to consider that many songbirds, the group of species that experience the heaviest mortality at human-built structures, are undergoing serious population declines (e.g. Robbins et al., 1989). Therefore, any type of anthropogenic mortality which contributes to their population declines is cause for concern. Mortality at human-built structures may in fact play a larger role in the diminishing numbers of songbirds than previously recognized. Kills of more than one hundred ovenbirds in one night have been documented in multiple reports (cited in Avery et al., 1980), and if this degree of mortality prevails across the continent, such losses may have a significant impact on population sizes.

A very crude estimate of the proportion of birds killed by structures in central Toronto versus overall numbers migrating overhead can be made by comparing the number of those known to be killed and injured with known mean migration traffic rates for the Toronto area (Richardson, 1982). This method of estimation has many sources of uncertainty, but at least provides an order of magnitude estimate of the significance of this source of mortality. Assuming an average migration traffic rate (MTR) for the whole autumn migration season of 1,500 birds per kilometre of migration front per hour, averaged over a 90-night migration period, with an average of eight hours of migration per night, an estimated 1,500 x 90 x 8, or approximately one million migrants fly across a one kilometre east-west front over the course of fall migration (W.J. Richardson, personal communication). Multiplying this one kilometre front of birds by 40 km – the approximate east-west breadth of Metropolitan Toronto – gives us a total of approximately 40 million birds passing over Toronto each autumn. FLAP covers an area approximately 0.5 kilometres wide (from east to west), and thus an estimated 500,000 birds fly over this area each fall, of which approximately 500 are killed due to collision with lighted buildings. This estimate assumes that migrating birds are evenly distributed over the Toronto air space, and that there is no focussing effect over the downtown district. Thus, acknowledging once again that this gives a very crude order of magnitude estimate, approximately one in 1,000 birds that fly over Toronto's downtown district in autumn are killed due to collision. Migration traffic data are unavailable for spring, and thus a corresponding estimate of the proportion of spring migrants killed is not possible.

Banks (1979) estimates that approximately 1.25 million birds are killed in North America each year in collisions with tall structures. He bases this estimate on the assumption that approximately half of the 1,010 television transmission towers in the United States (in 1975) incur a mortality rate of 2,500 per year (based on averages of three independent studies on TV tower mortality). This estimate is therefore based on the impact of television towers alone, and does not include other tall structures such as cooling towers, radio towers, and tall office buildings. Weir (1976) gives the number of TV towers in Canada in December 1975 as 189, and using the same assumptions and method of calculation as Banks, an estimated 236,250 birds were killed at Canadian TV towers in 1975.

Klem (1989) has estimated that the number of birds killed by day-time window collisions at low-level structures (such as individual residences) ranges from approximately 100 million to close to one billion per year in the United States alone. This estimate is based on year-round kills, and thus includes the mortality of resident species as well as those involved in migration. Klem's annual window-kill mortality estimate has been supported by a similar, independent estimate (Dunn, 1993). Thus, while lighted structures result in large numbers of avian injured or dead birds, windows may represent an even greater problem for migrants.

Until widespread and standardized reporting of bird kills is implemented, estimating continent-wide mortality incurred by structural hazards is unavoidably speculative. In the case of lighted structures, estimates of collision mortality are likely to represent minimums, since documentation of kills is scant. As Avery et al. (1980) points out, the number of kills reported in the literature is probably more closely related to the waxing and waning of public interest in the phenomenon rather than the frequency of its actual occurrence. In urban areas, concern over bad publicity may result in many office

Many songbirds, the group of species that experience the heaviest mortality at human-built structures, are undergoing serious population declines.

tower managers instructing maintenance workers to remove bird carcasses prior to the arrival of employees. In rural and remote areas, infrequent human attendance and automation, such as that implemented at many Canadian lighthouses in recent years, probably results in large numbers of unrecorded avian deaths (e.g. Weir, 1976).

In addition, the kills themselves are often masked by the fact that local predators have learned to exploit this occasional food source. A host of mammalian and avian predators have been documented scavenging birds killed and injured at human-built structures. In an eleven-year study at a Leon County TV tower in Florida, Stoddard and Norris (1967) reported a host of predators preying on dead and injured birds, including: domestic cats, opossums, foxes, skunks, raccoons, great horned owls (*Bubo virginianus*), loggerhead shrikes (*Lanius ludovicianus*), crows (*Corvus* sp.), and insects. One study reported losses due to scavenging as 76 percent, determined experimentally with tagged carcasses (Williams et al., 1975). Another estimated that half of the dead specimens were removed by nocturnal mammalian scavengers before searches by the investigator in the morning (Rybak et al., 1973). Predation by gulls in FLAP's Toronto study necessitates pre-dawn collecting. Predation is likely to reduce reported numbers to some degree in every study, and most of the evidence of mass bird mortality at unstudied structures may disappear without a trace.

While it is well established that structurally-mediated bird mortality is a considerable problem, the proximate causes of this problem are less clear. What causes the fatal attraction of birds to light sources during nocturnal migration? And, what causes birds to collide with windows? In order to address these questions it is necessary to: (1) understand the mechanisms by which birds navigate during migration; (2) investigate the behaviour of birds at human-built structures; and (3) examine what is known about avian vision with respect to both light and plate glass.

Even if collision with a lit structure is avoided, birds are still at risk of death or injury as they are reluctant to fly out of the area into the dark, and often continue to flap around in the beam of light until they drop to the ground with exhaustion.

Robert McCaw

Eight of the hundreds of different species of birds that have had fatal encounters with buildings lit at night.

Effects of light on nocturnal migrants

Migratory bird navigation

Bird navigation has been a vigorous area of research in recent years, and has revealed that birds use a variety of orientational cues, including the position of the sun, the Earth's magnetic field, the patterns of the stars, the moon and topographical features (e.g. Berthold, 1993; Martin, 1990). The Earth's magnetic field is a constantly available directional reference, available to both diurnal and nocturnal migrants. Diurnal migrants have the additional reference of the sun. Nocturnal migrants use the stars, the setting sun and the correlated pattern of polarized light in the sky, as directional cues (Moore, 1987).

Despite the multiple cues available, we cannot assume that all of these cues are available at any given time, or even that all species use these cues in a similar fashion. Evidence suggests that orientational cues are used in a hierarchical fashion (Emlen, 1975; Moore, 1985). That is, species or populations are opportunistic with respect to which orientation mechanism is used depending upon weather conditions or geographic location.

The orientation and navigation mechanisms of nocturnal migrants are of particular interest, since it is these species which are predominantly affected by fatal entrapment by lighted structures. While evidence suggests that nocturnally migrating birds make use of magnetic cues (e.g. Presti, 1985), there is much evidence that cues based on vision are at least as important as, and maybe more important than, magnetic cues. Documentation of this evidence is found in a number of experimental findings and field observations compiled by Martin (1990):

(1) *The majority of nocturnal migration takes place in weather which provides the ideal conditions of calm, light or following winds with little cloud cover and good visibility, both prior to the time of departure and during the actual flight (Richardson, 1978; Elkins, 1983; Kerlinger and Moore, 1989).*

(2) *Prior to their nocturnal migratory journey, passerine birds usually cease their normal daytime activities and start to roost around dusk in the usual way (Palmgren, 1944; Hebrard, 1971). It is thought that it is during this flightless period that migrant birds make the decision of whether to migrate and in which direction. Just what birds do at this time is unclear but the primary importance of visual cues associated with detecting the position of the sun or the pattern of polarized light in the sky (which is a direct correlate of the sun's position) has been demonstrated (Moore, 1987).*

(3) *There is considerable evidence that visual cues are of primary importance not only in initiating the direction of orientation but also in maintaining it throughout the migratory journey. These visual cues may be associated with the stars and moon and also involve the use of topographical landmarks as guides or beacons.*

When migrating at night, birds are able to detect only the grossest detail.

The disorientation of birds in low cloud or fog suggests that the Earth's magnetic field alone is not sufficient for successful navigation. Visual cues derived either from the celestial cues above or from the ground below would seem necessary for the correct nocturnal orientation of birds. The fact that migrating birds "caught out" by bad weather conditions are trapped, often fatally, by illuminated structures, suggests strongly that at night these birds may be dominated by visual cues from below them but that they are easily confused (Martin, 1990). The attraction of birds to lighthouses has been hypothesized to be due to their confusing the artificial light source with the moon, which they would normally use as an orientational reference. (Baker, 1984, p.94). If this is the case it suggests that avian visual discrimination at night of even large, bright objects is relatively poor (Martin, 1990).

Even in the absence of bad weather, nocturnally migrating birds have been observed to be confused by artificial lights below them. Songbird species migrating through East Africa are attracted at night to artificial lights when there is no moon combined with fog or mist at ground level in the area illuminated by the lights. When these two conditions are fulfilled, birds apparently passing in the clear, starlit sky above the low cloud are attracted down through the mist to the lights. The presence of a moon at any phase appears to nullify the effects of the artificial lights (D. Pearson, personal communication, cited by Martin, 1990). A similar effect has been observed at a lighthouse in Wales, where birds are attracted to the light in the absence of the moon, under overcast conditions, and when there is low cloud and a clear starlit sky above (Durman, 1976).

The effect of the moon on the incidence of fatal attraction to artificial sources of light has been the subject of some debate. Verheijen (1980) found a strong correlation between large tower kills and moonless nights. Crawford (1981b) rejected Verheijen's hypothesis, citing evidence that the numbers of birds killed were not dependent upon moon phase. Nevertheless, Crawford's analysis determined that the frequency distribution of bird-kill nights was non-random, with two peaks occurring: one at the new moon, and one at the full moon, suggesting that while the relationship is not simple, the presence or absence of the moon does indeed have an effect on nocturnal migrants. A study on Hawaiian seabirds (Telfer et. al., 1987) also showed a strong relationship between moon phase and bird attraction to lights.

These observations on lunar and meteorological effects suggest that passerines have a limited ability to make visual discriminations at night, and songbirds are influenced by visual cues from the ground beneath them even when there is a clear starlit sky above. Visual cues from below may therefore dominate over both magnetic and star-based cues during actual migratory flight, even though these latter cues may be used to determine direction of flight at the time of departure (Martin, 1990). Nocturnal migrants may therefore use a similar process to humans when orienting through unfamiliar terrain; that is, they may determine their compass direction from some other cue but then project this direction for migratory flight onto the landscape, thereafter using topographical features to stay on course.

Given that most nocturnal migrants are generally diurnally active outside of the migration period, it is important to consider just how much these species can see at night. While absolute visual thresholds are known for only a few bird species, enough is now known about the theoretical limits to visual sensitivity in vertebrate eyes in general (Snyder et al., 1977; Barlow, 1981; Martin, 1985) to determine what is not possible for an animal to detect visually at a given light level (Martin, 1990).

Visual thresholds are known for humans (Pirenne et al., 1957), the tawny owl (*Strix aluco*) (Martin, 1977) and the rock dove (or city pigeon, *Columba livia*) (Blough, 1955). Human vision in very low light levels extends to a level close to that of the owl, with vision possible even on moonless overcast nights. The minimum threshold for vision in the pigeon, however, is reached at much higher light levels. Given that the owl is nocturnal and the pigeon diurnal, the sensitivity of many diurnal birds is assumed be similar to that of the pigeon (Martin, 1985).

Prior to the erection of tall human-built structures, a high level of visual acuity at night was of no adaptive value to nocturnally migrating species.

We can determine the extent of nocturnal vision possible by birds by comparing the known thresholds of vision with luminance levels of the Earth's surface when viewed from above and illuminated by various natural light sources. At the light levels produced by starlit nights, diurnal birds are likely to have some kind of vision. However, on nights of minimum starlight, no vision will be possible at all for many species. Spatial resolution is also likely to be very limited (Fite, 1973; Snyder et al., 1977), and Martin (1990) thus concludes that "when migrating at night, even under light levels in the maximum moonlight/maximum starlight range, birds are able to detect only the grossest detail and are unlikely to achieve the degree of spatial resolution that the human visual system is capable of under the same circumstances. Therefore on both theoretical grounds and by extrapolation from current data on bird vision, it seems safe to conclude that nocturnally migrating birds cannot be guided by fine detail."

Compared to the kind of fine spatial detail which is assumed to guide their flight when completing the day-time component of their life cycle, night migrants must be flying nearly blind. Such poor resolution of detail during nocturnal migration does not pose a problem for birds migrating in open air space well away from obstacles. Under clear skies, major topographical features such as water surfaces and tree canopies will be detectable on the ground and silhouetted against the sky. And the horizon will always be visible except on moonless nights with overcast skies (Martin, 1990). Prior to the erection of tall human-built structures, a high level of visual acuity at night was therefore of no adaptive value in nocturnally migrating species. And prior to widespread use of artificial lights, there would have been few if any bright light sources from below. Diurnal bird species migrating at night may therefore not have evolved any visual mechanism by which to cope with the detection of human-built hazards encountered during flight.

Flight mobility of strictly nocturnal birds in complex environments probably combines a detailed knowledge of their environment with the limited visual cues available. Songbirds migrating nocturnally are not afforded the luxury of such a behavioural strategy. Although flying in a spatially simple air space, correct orientation for nocturnal migrants depends on correct interpretation of minimal visual cues. However, learning may play a role if the ability to correctly interpret minimal sensory information increases with experience of both the general nature of the night environment and that of a specific migratory route. One study indeed suggests that immature songbirds are influenced more than adults by extraneous lighting cues during night-time tests of migratory orientation (Gauthreaux, 1982). Learning requires that an individual survives the experience about which it is to learn, and is obviously not possible for those birds killed outright by collisions.

Approaching the edge of the illuminated area, migrants are hesitant to fly into the darkness beyond and instead fly back toward the obstruction, where inevitably some are killed or injured in collisions.

Light attraction behaviour

The phenomenon of bird aggregation at artificial lights is commonly termed "attraction." However, while a convenient descriptive term, there is as yet insufficient evidence to determine whether birds are in fact attracted to artificial light from a distance, or whether birds flying in the vicinity of a light source become trapped by the light and are reluctant to leave. The term light attraction in this paper therefore refers to the phenomenon of aggregation and entrapment at artificial light, without implying that such behaviour is the result of "attraction" per se. Avery et al.'s (1976) experimental work in fact suggests that light entrapment is a more accurate description of the phenomenon, since birds are apparently not attracted from a distance but rather enter the lighted area by chance and are then trapped by the artificial light.

Attraction to artificial light at night is a phenomenon not restricted to birds. Artificial light adversely affects sea turtles. Emerging hatchlings proceed inland toward artificial light sources instead of toward the sea, and in doing so face the risks of desiccation or collision with traffic on coastal roads (Verheijen, 1985). Migrating bats such as the North American silver-haired bat (*Lasionycteris noctivagans*) have also been reported as fatally colliding with the lights of buildings (Banfield, 1981), although bats are probably attracted by swarms of insects at lights rather than the lights themselves. The nocturnal attraction of insects and fish to light is also widely reported and used to the advantage of entomologists and fishermen (Southwood, 1971; Ben-Yami, 1976). There are numerous accounts in the literature of the behaviour of birds at sources of artificial light. In the district of Toronto monitored by FLAP, those birds that are not killed outright by impact with lit windows are disoriented by the light and continue to fly around the light source, often to the point of exhaustion (M. Mesure, personal communication). Once trapped by walls of lighted windows, the survivors often exhaust themselves fluttering up and down the window panes. Since energy levels are at a premium for migrating birds, those which survive the night, escape predation, and avoid day-time collision with a sea of windows, then face the challenge of finding sufficient food within the concentration of buildings to replenish their fat stores and continue their migratory journey.

Lighthouses were the first human-built structures responsible for large migratory bird kills in North America, particularly during weather conditions of low visibility such as rain or fog (Weir, 1976). The rotating beams typical of traditional light stations "result in birds circling the tower, flying up the beams and dashing themselves against the glazing, cowling, etc." (Baldwin, 1965, and references therein).

Nocturnal light attraction behaviour of migrant birds appears to be quite stereotyped, and is virtually identical at all types of lighted structures. Birds flying in the vicinity of artificial light are attracted to the source of light "like iron filings to a magnet" (Weir, 1976). Death or injury result from the birds colliding with lighted obstructions or with each other. If collision is avoided, exhaustion often occurs after birds have fluttered in the light beam for long periods.

A number of theories have been put forward as to why birds are attracted to artificial light sources. Verheijen (1958) described the phenomenon of avian attraction to artificial light as a "trapping effect," since the behaviour seems to be a "forced movement." He suggested that the "low illumination intensity of the environment around such a light source interferes with normal photic orientation resulting in a drift of the animal towards the light source." Verheijen's later work suggests that birds are drawn to light due to the differences in the properties of natural versus artificial light.

One belief holds that nocturnal migrants are attracted to lit structures because the lights are mistaken for stars. However, the credibility of this theory is questionable. Experimental studies have revealed that various non-passerines have the ability to distinguish between lights of different wavelengths, flash rates, and intensities (Hailman, 1967; Oppenheim, 1968; Granit, 1955; Mentzer, 1966). In addition, Emlen (1967) demonstrated that star patterns, not individual stars, are sufficient for correct orientation in the indigo bunting (*Passerina cyanea*), a migrant songbird.

While visual capacities have been determined for only a few avian species, it appears improbable that all types of lights appear identical to nocturnally migrating songbirds, and equally improbable that tower lights or beams are confused with stars (Avery et al., 1976). One study on non-passerine birds suggests that not only are there species differences in light perception, but also that individual differences are highly variable (Belton, 1976).

While few studies have looked at age as a factor in mortality at lit structures, this susceptibility may be particularly relevant in Autumn, when large numbers of young are migrating for the first time.

Avery et al. (1976) performed an experiment at a 336-metre-tall radio tower using a portable ceilometer to observe bird behaviour at night around the tower's lights. Their experiment demonstrated the significant effect of weather conditions on the number of birds congregating around tower lights. On overcast nights during both spring and fall migration, significantly greater numbers of birds were observed at the study tower than were observed at the control location. On clear nights, the reverse was true, indicating that migrants were not attracted to the tower under clear conditions. This study also suggested that birds flying around the tower lights in overcast conditions were disoriented, since they did not exhibit a significant mean direction in comparison with birds observed at the same time away from the tower.

Avery et al. support the explanation given by Graber (1968), who theorized that migrants are not attracted to towers in the sense of being drawn from a distance, but rather those passing nearby on a cloudy night enter an illuminated area that they are reluctant to leave. Approaching the edge of the illuminated area, migrants are hesitant to fly into the darkness beyond and instead fly back toward the obstruction, where inevitably some are killed or injured in collisions (Avery et al., 1976). Crawford's (1981a) study of bird mortality at a television tower resulted in a similar conclusion: "The attraction to the lighted area is limited to the immediate vicinity of the tower: the birds are not drawn from a considerable distance." Artificial light may interfere with dark adaptation, similar to the phenomenon experienced by humans entering darkness after leaving a brightly lit area.

Telfer et al. (1987) studied the fatal attraction to light by several species of Hawaiian seabirds. Their study suggests that inexperience is probably a major factor, and that phototropism is likely an innate behaviour. While few studies have looked at age as a factor in mortality at lit structures (Gauthreaux, 1982), this susceptibility may be particularly relevant in the autumn, when large numbers of young are migrating for the first time.

While several theories have been put forward, the key question of what causes birds to congregate at tall lighted structures (particularly under overcast conditions), remains unanswered. To fully understand this phenomenon, a series of controlled experiments on the reactions of birds to lights of various intensities, wavelengths (colours), and flash rates, is necessary. One useful method with which to observe the effects of tall lit structures on bird behaviour would be to track birds fitted with radio transmitters (Avery et al., 1976).

Since energy levels are at a premium for migrating birds, those which survive the night, escape predation, and avoid day-time collision with a sea of windows, then face the challenge of finding sufficient food in downtown areas to replenish their fat stores and continue their migratory journey.

Ted Almond

Falling to street level after hitting a skyscraper, dazed birds must contend with the confusion of lights and reflections.

Windows as an avian hazard

Perhaps no birds are immune to the hazard of windows, and approximately 25 percent (225/917) of all North American bird species have been documented as killed or injured by collisions (Klem, 1991). The most comprehensive studies on day-time bird collisions with windows have been performed by Dr. Daniel Klem, Jr. (1979, 1981, 1989, 1990, 1991), who estimates that approximately one hundred million to one billion birds are killed annually by day-time window collisions at low-level structures in the U.S. alone. This estimate for the number of window kills is based on year-round deaths, and thus includes the mortality of resident species as well as those involved in migration. Contrary to the popular notion that birds killed from colliding with windows die from a broken neck, Klem (1990) determined that such fatalities are largely due to hemorrhaging of the brain resulting from impact. His studies elucidate that window strikes by birds are a year-round problem. Klem's 1989 study revealed no evidence of an age or gender bias in window collisions, with adults, juveniles, males and females equally likely to strike windows. His data indicate that, at least for residential homes, birds strike windows almost exclusively during the day, with collisions occurring at a higher frequency during the morning. Strike rates were found to be considerable under both sunny and overcast weather conditions. During migration seasons, the orientation of windows with respect to compass direction was found to have no significant effect, with windows facing south or north no more hazardous than windows facing other directions (Klem, 1989).

Approximately one hundred million to one billion birds are killed annually by day-time window collisions at low-level structures in the U.S. alone.

FLAP

Glass – misinterpreted or invisible to birds – can be lethal.

Several hypotheses attempt to explain how windows are rendered functionally invisible to birds (Klem, 1989). Birds have been speculated to hit windows as a result of: defective eyes (Willet, 1945); impaired vision due to smoke (Langridge, 1960); blinding glare (Sinner, unpublished data); mist (Konig, 1963); alcohol from fermented fruits (Rogers, 1978); and diverted attention (Dunbar 1949; Giller; 1960, Bent, 1968:231; Raible, 1968; Valum, 1968, all cited by Klem, 1989). However, Klem's experimental study, in which he tested the degree of hazard of clear and reflective windows, does not support any of these explanations. His results demonstrate that neither windows alone nor windows installed in human-built structures are recognized as obstacles by birds.

A second group of hypotheses invoke perception. Many authors have conjectured that inexperienced birds strike windows (Bauer, 1960; Giller, 1960; Morzer-Bruijns and Stwerka, 1961; Löhrl, 1962; Raible, 1968; Valum, 1968; Schmitz, 1969; Harpum, 1983; all cited in Klem, 1989). However, Klem's (1989) study demonstrated that immatures and adults are equally vulnerable to the hazards of glass. Klem concluded that deficiencies and inexperience do not make birds more susceptible to collisions; rather, the available evidence, while indirect, supports the hypothesis that "the avian visual system is incapable of perceiving clear and reflective glass" or perhaps visually misinterprets it. Glass is thus a potentially lethal hazard for all birds in flight.

Factors influencing the frequency and species of birds involved in window collisions include: season, time of day, weather, the density of birds in the vicinity of windows, flight habits, window type, size, placement of glass, and the presence of bird attractants such as feeders or fruiting trees. Windows are equally deadly to birds migrating at night when they act in conjunction with interior lights, transmitting light to the outside and thus attracting birds. Attraction to the lighted windows causes disorientation, fatal or injurious collisions, or eventual exhaustion. The critical concept with respect to windows is that glass is not perceived as an obstruction to birds in flight, and thus the key to reducing window collision mortality is to make plates of glass visible as obstructions.

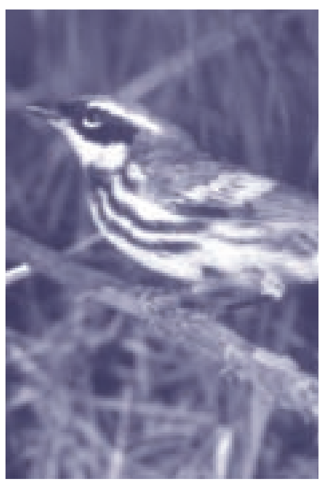
Species-specific vulnerability

Species-specific vulnerability to mortality caused by human-built structures is a further unstudied but potentially important phenomenon. A compilation of some of the available literature on bird kills at different types of structures reveals some interesting species trends. Reported kills at both tall structures and residential windows show remarkable consistency in species composition despite the varied geographic locations of the studies (see Appendix 1; also Klem, 1989). Certain species of warblers, thrushes, vireos and sparrows consistently head the list as those most prevalent to collide with building windows. Notable among these are the ovenbird, bay breasted warbler (*Dendroica castanea*), red-eyed vireo (*Vireo olivaceous*), and blackpoll warbler (*D. striata*), with reported kills for a single season at some structures often numbering in the hundreds (e.g. Appendix 1, reference numbers 7, 8, 34, 60).

Available information suggests that at least among songbirds, individual species are not restricted to exclusive altitudinal ranges during migration (Bill Evans, personal communication). Flight altitude alone therefore cannot explain the predominance of certain species as those most abundantly killed. It would appear, therefore, that certain species are more vulnerable to collisions due to their species-specific behaviour. Ovenbirds, thrushes, and other birds that "habitually make swift flights through restricted passages in heavy cover" are probably guided in their flights by a view of the light ahead of them (Snyder, 1946). This flight behaviour has been speculated to explain why these species are among the most commonly killed by striking windows (ibid; Ross, 1946; Willet, 1945). In a survey across North America, species whose activities occur on or near the ground, such as several species of thrushes, wood warblers, and finches, were found to suffer a greater vulnerability to window deaths (Klem, 1991). Likewise, certain nocturnal migrating species appear to be more prone than others to attraction and disorientation at sources of light. At the Washington Monument on October 20, 1935, hundreds of field sparrows (*Spizella pusilla*) were described as "resting on benches and other perches at the base of the monument, while warblers were flying overhead and crashing into the floodlit monument" (Overing, 1936, 1937).

When species undergoing significant population declines coincide with those appearing as the most abundant individuals in structurally-related kills, we should be particularly concerned. Any factor contributing to the decline of such species is a potentially important one. Some of the species collected by FLAP are among those undergoing population declines (see Appendix 2). Combining both migration seasons, five of the 20 most abundant species recorded by FLAP are experiencing significant long-term population declines according to either the Canadian Breeding Bird Survey (BBS) (Downes and Collins, 1995), or the Forest Bird Monitoring Program (FBMP) (Cadman, 1996) (see Appendix 2).

Five of the 20 most abundant species recorded by FLAP are experiencing significant long-term population declines.



WWF / Edgar T. Jones

The magnolia warbler is the fourth most frequent species on Toronto's list of birds that die from building collisions.

Few continent-wide analysis of species trends in collision mortality have been conducted. One notable exception is a study on the ovenbird. Taylor (1972) states that "few fall disasters at tall structures and airport ceilometers in eastern North America have lacked ovenbirds," and cites that "of 59,032 warblers representing 37 species reported killed in the last 20 years during autumn migration...in eastern Canada and the United States, 11,236 (19 percent) were ovenbirds."

While the Canada-wide analysis (BBS, 1966-1994) for ovenbird populations shows no population trend (Downes and Collins, 1995), surveys within Ontario forests show this species to be declining (Cadman, 1996). Given the high numbers of ovenbird kills across the continent, and that ovenbirds also constitute 17 percent of FLAP's data, this species may be one of several that warrant special attention. Analysis of existing data for other species trends would be worthwhile and informative. While it is premature to suggest that a direct relationship exists between population declines and collision mortality for such "collision-prone" species, this possibility merits immediate attention and research.

The hazards of human-built structures may already have been partially responsible for the extinction, or near extinction of one species. According to one ornithologist, a large proportion of the museum specimens of Bachman's warbler (*Vermivora bachmanii*) (now probably extinct) came from a single fixed-beam lighthouse at Sombrero Key, Florida (Chandler S. Robbins, personal correspondence). Many of the bird species classified as endangered, threatened or vulnerable in Canada and the United States show up on the lists of species killed by human obstructions (e.g. Weir, 1976; Avery, 1980). Documented window deaths for species of special concern include the Kirtland's warbler (*Dendroica kirtlandii*), and peregrine falcon (*Falco peregrinus*) (Klem, 1991, and references therein). While collisions with human-built structures may have only a small impact on most relatively abundant species, those with already small or declining populations cannot afford any unnecessary source of mortality. It is certainly hard to ignore the impact on white-throated sparrows and ovenbirds. These species alone account for 20 percent and 17 percent of the overall mortality in FLAP's data, respectively.

Of 59,032 warblers killed in the last 20 years during autumn migration in eastern Canada and the United States, 11,236 (19 percent) were ovenbirds. This species may be one of several that warrant special attention.

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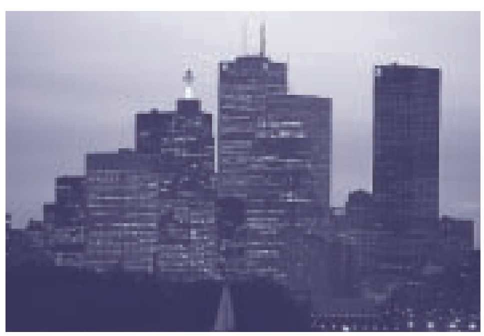
What can be done – solutions and recommendations

Lights and nocturnal migrants

The simple answer to the problem of night-time migratory bird mortality at lighted structures is to turn out the lights. This is especially crucial after midnight, when birds begin to descend from their peak migration altitudes (Lowery and Newman, 1966; Richardson, 1971b; Bruderer et al., 1995). In office buildings, turning out the lights is an achievable solution, since the vast majority of offices do not operate during the night. Another structural possibility is the use of shielding to direct light downward and thus prevent its visibility from above. Such a technique has been successfully employed to prevent collisions of endangered Hawaiian seabirds (Reed et al., 1985). Vegetation planted between beaches and adjacent roads to shield the dispersal of light has also been an effective conservation measure for sea turtles (Verheijen, 1985). Shielding the upward radiation of light is obviously not an option when the purpose of the light is to serve as an aviation beacon. However, the shielding of low level lighting such as street lights may help to reduce the overall amount of light emanating upwards from an urban area, which may help reduce the attraction of migrants.

The simple answer to the problem of night-time migratory bird mortality at lighted structures is to turn out the lights. Another possibility is the use of shielding to direct light downward and thus prevent its visibility from above.



FLAP

If light does not have to be perceived by humans, as in the case of ceilometers (used to determine the height of cloud cover for air traffic), a filter transmitting only ultra-violet light is an effective measure (Terres, 1956). While songbirds can detect ultra-violet light (e.g. Finger and Burkhard, 1994), they are apparently not trapped by it. Where illumination is unavoidable, the installation of perches on the sides of tall, glass-faced buildings may also reduce the number of birds flapping themselves to exhaustion and then falling to their death. Structures such as cooling towers and communication antennae require some lighting for the safety of air traffic, and likewise, lighthouses are specifically designed for the safety of marine traffic. However, not all types of lighting are equally hazardous, and it is worthwhile to discuss different types of lights and lighting regimes with reference to their effect on the safety of migrating birds.

With respect to lighthouses, a lighting regime employed at the Dungeness Lighthouse in Kent, England considerably reduces the level of bird mortality (Baldwin, 1965). The former white paraffin lamp at Dungeness was replaced with a xenon-gas-filled bulb in 1961, following successful experiments for two years with the new light. The new light, emitting an "ice white" (bluish) light, has been found to be highly effective at reducing migratory bird kills. The xenon light is intermittent in form, flashing once every ten seconds. It is likely that the intermittent nature of the Dungeness Lighthouse, rather than its bluish colour, is what reduces its attraction to migrants.

After the experimental period with the new light, floodlighting of the lighthouse was begun to provide a navigational beacon for pilots. Lighthouse personnel claim that no birds were killed once the xenon light was installed, even after permanent floodlighting began. However, the use of floodlighting to illuminate an obstacle has not proven successful in reducing mortality at other locations. Floodlighting of the lighthouse at Long Point, Ontario (Baldwin, 1965); of the Washington Monument in the United States (Weir, 1976); and of the CN Tower in Toronto (McAndrew, 1994), have resulted in mass bird mortality. Removal of floodlighting at the CN Tower during migration seasons has virtually eliminated bird kills there (M. Mesure, personal communication). Verheijen (1985) suggests that the variability in the effect of floodlighting is dependent on the direction of the beam and the degree of its divergence, with a broad beam directed downwards less likely to cause a trapping effect. While Transport Canada regulations (1987) offer floodlighting as an option for the lighting of structures such as buildings under construction, moored balloons, chimneys, and church steeples, other types of lighting regimes are also acceptable, and thus the use of floodlighting should be discouraged.

An alternative to the use of floodlighting is the use of strobe or flashing lights. Changing to this type of lighting regime could reduce or perhaps eliminate bird kills at lighthouses and other structures which are presently floodlit. The conversion to strobe lighting at lighthouses in Great Britain was undertaken due to the impetus of the Royal Society for the Protection of Birds, and has been very successful (Baldwin, 1965). A recent move to automate Canadian lighthouses has seen the replacement of the traditional rotating beam with less intensive strobe lighting, which should reduce the danger to migrating birds. Since the removal of floodlighting from Long Point Lighthouse in Ontario and its replacement with white strobe-lighting, there has been a dramatic decline in the number of avian collisions, with migrant mortality now a rare phenomenon at this location (Jon McCracken, personal communication). However, many of the remaining attended Canadian lighthouses continue to use a rotating beam (Steve Lear, personal communication), and an effort should be made to promote the change to strobe lighting at all light stations. It has been suggested in the past that the use of foghorns at lighthouses was another method by which to reduce migratory bird collisions (e.g. Bretherton, 1902; Dixon, 1897). However, there is insufficient evidence to suggest that this method is effective, and the use of loud noise as a deterrent would unlikely be acceptable except in remote locations (Jon McCracken, personal communication).

Communication towers are not as brightly lit as many other structures, but are generally very tall (up to almost 500 metres) and often situated on high points of land, thus encroaching into the airspace of migrating birds. Some suggestion has been made that in addition to lights, the signal from radio or television antennae may contribute to the disorientation of migrating birds. However, Avery et al.'s (1976) study indicated that migrants were found at a communication tower both when it was transmitting and when it was not, indicating that the signal itself had very little, if any, role in the migrants congregating there.

Communication towers often use red obstruction lighting, and in Canada such usage must combine both steady burning and flashing red lights (Transport Canada, 1987). Such a lighting regime for communication towers is not mandatory, however, and these towers may instead employ a medium intensity white flashing light system. While "white" light is generally associated with major migratory bird kills, there is little evidence that the colour of the light itself has an effect on bird collisions. Several studies have suggested that red lighting reduces the level of bird mortality (e.g. D. Broughton, unpublished report). However, red lights used at communication towers are probably less deadly than white lights not because of their colour but because they are relatively weak in intensity (Verheijen, 1985). One study suggests that red light may actually disrupt the magnetic orientation of migrating birds (Wiltschko et al., 1993). Experiments on a number of non-passerine species demonstrate a wide spectral sensitivity (Graf and van Norren, 1974; van Norren, 1975; Finger and Burkhardt, 1993, all cited in Verheijen, 1985), and it is likely that in general any light source visible to humans, whether "coloured" or not, will also be visible to birds, and thus constitute a potential hazard (Verheijen, 1985).

As discussed earlier, migrating birds are capable of orienting by means of polarized light (Moore, 1987). However, at least in the case of seabirds, experimentation on the use of po-

While the problem of migratory bird mortality has been widely reported, a mere handful of experimental studies has been performed on the effectiveness of various lighting regimes as deterrents. In the meantime, it is important to apply what effective measures are known to minimize this unnecessary slaughter of migrating birds.

larizing filters determined that they were ineffective in deterring collisions with human-built obstructions (Telfer, 1987).

Recommendations regarding lighting

The simple solution to the problem of nocturnal migratory bird mortality in urban centres is to extinguish the internal lights of buildings, at least from midnight to dawn, and avoid the use of external floodlighting. Towers and similar obstructions which must be lit according to Transport Canada regulations should be strongly encouraged to use strobe or flashing white lights as warning beacons to aircraft rather than floodlighting or red lights. Flashing light is preferable to a constant beam because the interruption of light appears to allow any birds caught in the beam to disperse (Baldwin, 1965; Avery et al., 1976). Studies at the Nanticoke Thermal Generating Station, and the Wesleyville and Thunder Bay Hydro sites (all in Ontario), have demonstrated that those killed and injured at stacks and towers are virtually eliminated by switching from floodlighting to strobe lighting (Broughton, 1977; Chubbuck, 1983). Intermittent lighting appears to be the only lighting regime that reduces bird kills while satisfying Transport Canada's (1987) regulations regarding obstruction lighting. The use of sound in conjunction with stroboscopic lights may also act as a deterrent, although further research is necessary (Belton, 1976). Auditory deterrents would obviously only be appropriate in remote locations where noise pollution would not be a concern.

While the problem of migratory bird mortality at human-built structures has been widely reported, a mere handful of experimental studies has been performed on the effectiveness of various lighting regimes as deterrents. The undertaking of such studies would be a huge asset in the engineering and implementation of effective solutions. In the meantime, it is important to apply what effective measures are known to minimize this unnecessary slaughter of migrating birds.

Windows

A number of recommendations for preventing collisions at windows have been presented by Klem (1991). The only effective way to prevent collisions with existing windows is to ensure that birds recognize the area covered by glass as a space to be avoided. For relatively small windows in residential buildings, netting erected close to the window can prevent birds from reaching the glass surface. Although of questionable practicality, an option for larger buildings faced with continuous glass is the covering of the external glass surface with opaque or translucent window coverings. Experimental studies indicate that outside window coverings must be separated by no more than five centimetres horizontally or 10 centimetres vertically in order to prevent collisions. Klem (ibid) has suggested the development and manufacture of an external roll-up window covering that completely or partially covers the glass surface.

The only effective way to prevent collisions with windows is to ensure that birds recognize the area covered by glass as a space to be avoided.

Despite their continued use and promotion, silhouettes of falcons, owl decals, large eye patterns, decoys, and other pattern designs, do not significantly reduce collision rates (Klem, 1990). These objects fail to prevent most strikes because they cover only a small portion of the glass and are applied in insufficient numbers to alert the birds to the glass barrier. In order to be effective as deterrents, such objects would have to be placed every five to 10 centimetres on the external surface, as described above.

The use of interior window coverings such as blinds or curtains is also of limited efficacy at reducing bird collisions. Except when in direct light, curtains or blinds on the inside of a window are not visible from the outside. When it is darker inside a building and lighter outside, a clear or tinted pane of glass reflects like a mirror. Direct sunlight shines onto any given window for only a short period of time each day, and thus interior blinds or curtains are only effective at deterring collisions for a brief period of time each day (D. Klem, personal communication).

The development of modifications in glass itself provides another potential solution. The use of non-reflective tinted glass would be one method by which windows could be transformed into visible objects for birds. A second method would be the creation of non-reflective or interference zones on or inside the glass (Klem, 1991). Analagous to one-way glass, interference zones would be visible only from one side. Such a window would therefore appear as a clear pane of glass when looking out, but from the outside a pattern or design would be visible to both birds and humans. Patterns or designs would need to conform to the five to 10 centimetre configuration, but such designs could be aesthetically pleasing to people and protective to birds. As yet, no move toward the development of such windows has been made. Until a market is created for glass windows that are not hazardous to birds, this situation is unlikely to change. In the meantime, the use of non-reflective stained glass and windows with decorative grids may reduce collisions somewhat. And use of window films such as those used to advertise in the windows of public transportation is another technique worthy of investigation.

The downward angling of windows so that they reflect the ground was thought to be another potential solution to the window kill problem (Klem, 1991). However, recent experiments indicate that windows would have to be oriented at angles of 20-40 degrees, which is likely to be impractical for most human-built structures (Klem, unpublished data).

The careful placement of bird feeders in the vicinity of windows is one method to reduce bird kills, although this applies mainly to resident species, since most migrants are unlikely to make use of bird feeders. Placing a feeder four to 10 metres from a glass surface creates a hazardous zone from which 70 percent of window strikes is likely to be fatal. If feeders are placed within one metre or less of the window, birds alighting from the feeder will be unable to generate sufficient velocity to injure themselves on the glass (Klem, 1991, and unpublished data). Other bird attractants such as bird baths and certain types of vegetation increase the hazard of birds strikes, and it is recommended that such items be carefully placed (see above), removed, or that nearby windows be covered with netting. Even indoor plants visible from outside may be potentially hazardous to birds flying in the vicinity of windows. Such vegetation is thought to contribute to window collisions as a result of its attractiveness to birds trapped in urban areas (C. Parke, personal communication). As Klem (1991) points out, "A willingness to modify or incorporate alteration to building and landscape designs can save millions of birds."

The use of non-reflective tinted glass would be one method by which windows could be transformed into visible objects for birds.
A willingness to modify or incorporate alteration to building and landscape designs can save millions of birds.

Summary of recommendations

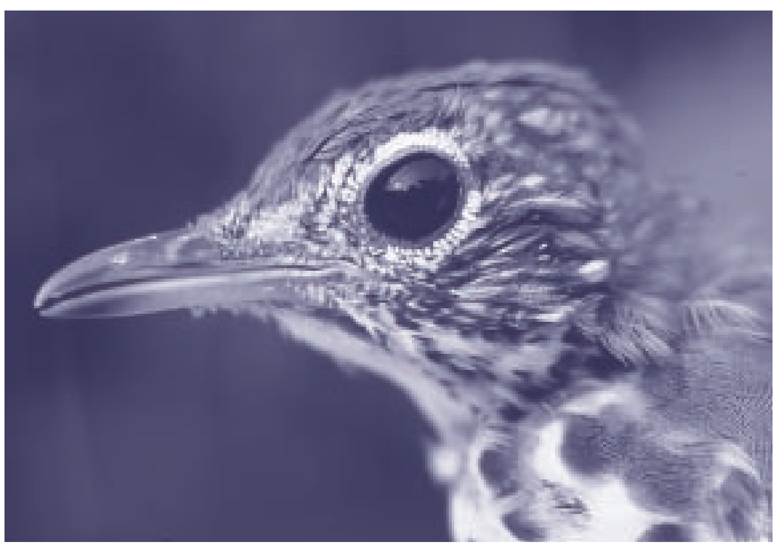
Lights

1. *Extinguish interior lights at night to avoid illumination from windows, and avoid the use of exterior floodlighting.*

2. *Use strobe or flashing lights in place of continuously burning lights for obstruction lighting.*

3. *Install shields on light sources not necessary for air traffic to direct light towards the ground.*

4. *Conduct further research into the degree of attraction of various types of lighting regimes, the use of sound as a deterrent, and the use of perches in areas where illumination at night is unavoidable.*



WWF / Edgar T. Jones

The single most important step to save this immature wood thrush from a building collision is to ensure that lights are out at night, especially in spring and fall.

Conclusions

Windows

1. *Install exterior window coverings or netting at existing windows, or replace clear glass with non-reflective glass (such as stained or frosted glass) where possible.*

2. *Develop plate glass which incorporates non-reflective interference zones, and develop non-reflective tinted glass.*

3. *Investigate the use of window films to make windows visible to birds from the outside.*

4. *Place bird attractants such as bird feeders and baths within one metre or beyond 10 metres from windows in order to reduce collision mortality.*

Collision of migrating birds with human-built structures and windows is a continent-wide, and probably world-wide problem. Since the majority of such bird injuries and kills goes unreported, one can only speculate as to the magnitude of this mortality across North America. However the sheer numbers of kills which are reported, often numbering hundreds of birds in a single night, and the fact that certain species are particularly vulnerable, suggest that this source of mortality may be having a detrimental impact on some migratory songbird species, especially on those which are known to be declining. A crude order of

It must be emphasized that this is a preventable source of mortality.

magnitude estimate for the proportion of migrating birds killed in fall by nocturnal collisions with lighted buildings in the downtown core of Toronto is one in 1,000, or 0.1 percent. While this level of mortality may appear insignificant, it must be emphasized that this is a preventable source of mortality which could be minimized by simply extinguishing interior lights at night during migration seasons. Coupled with avian window mortality, these two sources of anthropogenic mortality are a conservation concern.

The most effective and realistic solutions to minimize migratory bird mortality at night in urban centres are to: (1) extinguish all interior lights in buildings, particularly after midnight; (2) attach shields to streetlights and other external lights to prevent unnecessary upward radiation of light; and (3) install white strobe lighting in place of red light, continuous light, rotating light, or floodlighting, to comply with federal safety regulations for air and marine transport. Extinguishing non-essential interior lights and installing more efficient, shielded exterior lights would not only significantly reduce bird mortality during migration, but would be cost-saving in the long term. It is estimated that poorly designed or badly installed outdoor lighting wastes more than one billion dollars in electricity annually in Canada and the United States, with most of that light going aimlessly up into the sky (Dickinson, 1988). Prompted by the adverse effects of light pollution on astronomers, rather than on migrating birds, the State of Arizona has legislated strict laws on lighting. Since 1972 in Arizona, all lights installed or replaced must be shielded to prevent upward glare, all advertising and non-security parking lot and building illumination must be turned off at 11 p.m., and high-glare mercury-vapour outdoor home

Author's acknowledgements

light fixtures cannot legally be sold in many parts of the state. The implementation of similar legislation in Canada would greatly reduce nocturnal migratory bird mortality at lighted structures.

With respect to windows, the solutions to bird collisions are less simple. While the installation of exterior blinds or netting on residential housing may be a feasible solution, such a solution would be prohibitively expensive for glass-faced office buildings. The research and development of alternative solutions, such as glass which is non-reflective on the exterior, or windows which incorporate permanent or stick-on interference zones, is a priority. The greatest challenge will be to find a solution by which windows can be made acceptable to humans and less harmful to birds.

Further research is necessary into many aspects of migrant collision mortality. The creation of a centralized database and reporting centre for North America would facilitate accurate monitoring of this problem and provide a less speculative and more quantitative indication of its effect on migrating songbird populations. Experimental research is necessary to provide insight into various components of the problem, including the effects of building height, lighting types, light shielding, and the effectiveness of other potential deterrents. Further research is needed not only on the collisions themselves, but also into the causes and mechanisms of songbird population regulation. Experimental investigation of the effect of different lighting regimes on bird migration behaviour is also urgently needed. Techniques such as the fitting of radio-transmitters to birds could prove useful in such studies (Avery et al., 1976).

Priorities for conservation action to minimize migratory bird collisions with human-built structures and windows are: (1) to promote public awareness and education about the problem; (2) to lobby for the extinguishing of non-essential interior lights at night during the migration season, which may or may not include pressing for legislation on lighting, such as that in the state of Arizona; and (3) to conduct further research into causes and prevention of avian collision mortality, and to investigate its impact on those songbird species identified as particularly vulnerable.

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Appendix 1

Bird collision literature summary table

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
Chicago building, Illinois, USA	b	Spring, Fall	1982-95	20697		Song Sparrow, Dark-eyed Junco, Swamp Sparrow, White-throated Sparrow, Hermit Thrush, Fox Sparrow, Ovenbird, Lincoln's Sparrow, American Tree Sparrow, Tennessee Warbler	
3 Mile Isle, PA, USA	4s	July-May	1973	64		Vireo, Kinglet, Warbler	504
WJBF-TV, Aiken, SC, USA	t	Sept 7	1962	400	32	Red eyed Vireo	766
Albany, NY airport ceilometer, USA	c	Sept 15-16	1956	313	25	269 (86%) Warbler, 128 (41%) Bay-breasted Warbler, 44 (14%) Magnolia Warbler, Vireo	77
Alleman, Iowa, USA	t	Sept 7-8	1972	726		406 (40%) Warbler	420
Atlanta & Marietta, GA, USA	c	Sept	1955	500		Warbler, Swainson's Thrush, Red-eyed Vireo	158
Baltimore, MA, USA	t	Sept 11-12	1964	1032	37	300 (29%) Ovenbird	669
Barrie, ON, CAN	t	Fall	1974	4900		1000 (20%) Bay-breasted Warbler, 900 (18%) Ovenbird	337
Bay of Fundy, Northeastern maritime, CAN	l	Fall	1963	488		Warbler	53
Beverly, Ohio, USA	s	Fall	1970	68		Warbler	309
Blue Ridge Park Lodge, NC, USA	b	Sept 7	1950	200	23	44 (22%) Ovenbird	Chat (1951) 15(1)
Boston, USA	2t	Sept 19-20	1958	300		Warbler, Vireo	63
Boylston, MA, USA	t	Sept	1971	158	29	134 (85%) Warbler, 95 (60%) Blackpoll Warbler	62
Boylston, MA, USA	t	Fall	1970	350	29	266 (76%) Warbler	61
Brunswick, USA	o	Sept 8-9	1954	500-1000	13	Swainson's Thrush	621
Buffalo, NY, USA	3t	Aug 25-Nov 12	1978	359	51	44 (15%) Blackpoll Warbler, 36 (10%) Ovenbird, 35 (10%) Swainson's Thrush, 25 (7%) Red-eyed Vireo	892
Buffalo, NY, USA	3t	Sept 21-Sept 30	1974	651		Warbler	169
Buffalo, NY, USA	b	Fall	1973	15		Yellow-bellied Sapsucker	651
Buffalo, NY, USA	3t	Oct 11	1970	534	46	105 (20%) Yellow-rumped Warbler, 63 (12%) Black-throated Blue Warbler	775
Cape Scoh, Vancouver Is, BC, CAN	l	May 2-3	1972	57	5	30 (35%) Savannah Sparrow, 19 (33%) Fox Sparrow	324
Carolinas, USA	4t,2c	Sept 6-8	1962	4189	61	American Redstart, Ovenbird, Vireo	5
Cedar Rapids, IA, USA	t	Aug	1963			Thrush, Warbler	585
Chapel Hill, NC, USA	t	5 days in Fall	1956	2500	40	Warbler, Thrush	Chat (1957) Mar
Chapel Hill, NC, USA	t	Sept 28-29	1956	2500		Warbler	159
Charleston, NC, USA	c,t	Oct 7	1954	1000+E18	24	Warbler, Common Yellowthroat	Chat (1954) 18(4)
Charleston, SC, USA	t	Sept 7-8	1962			Red-eyed Vireo, Ovenbird, American Redstart	766
Charlotte, NC, USA	c	Sept 25	1955	114	23	23 (20%) Ovenbird, 20 (17.5%) Red-eyed Vireo	Chat (1956) Mar
Charlotte, NC, USA	c	Sept	1955	112		Swainson's Thrush, Red-eyed Vireo, Warbler	158
Atlanta & Marietta, GA, USA	c	Sept	1955	500		Swainson's Thrush, Red-eyed Vireo, Warbler	158
Charlotte, NC, USA	c	Sept 25	1956	114	24	Red-eyed Vireo, Ovenbird	553
CHRE-TV, Regina, SK, CAN	t	Aug 30-31	1965	172		Warbler	90
CKCK-TV, Regina, SK, CAN	t	Aug 30-31	1965	227		Warbler	90
CKVR-TV, Barrie, ON, CAN	t	Fall	1975	175		Bay-breasted Warbler, Ovenbird, Red-eyed Vireo, Chestnut-sided Warbler, 414 (10%) Red-eyed Vireo, 313 (8%) Chestnut-sided Warbler	840
CKVR-TV, Barrie, ON, CAN	t		1960-73	4282	75	668 (16%) Ovenbird, 437 (10%) Bay-breasted Warbler	841
Columbia, MN, USA	t	Sept 20-21	1963	941		Red-eyed Vireo, Ovenbird	585

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
Dallas, TX, USA	t	Oct 22	1960	11	1	Yellow Rail	85
Davenport, IA, USA	t	Sept 19-20	1960	281	25	Thrush, Warbler	506
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Sept 1-Oct 22	1976	207	35	118 (57%) Warbler, 54 (26%) Kinglet, 6 (3%) Finch	370
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Spring	1977	48	21	15 (31%) Warbler, 9 (18%) Vireo, 5 (10%) Finch	371
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Fall	1977	151	25	98 (65%) Warbler, 17 (11%) Kinglet, 7 (5%) Finch	371
Davis-Besse Nuclear Power Plant, OH, USA	b,s	Fall	1975	155	35	88 (57%) Warbler, 32 (21%) Kinglet, 15 (10%) Finch	745
Davis-Besse Nuclear Power Plant, OH, USA	b,s,o	Apr 14-Jun 6	1976	62	31	34 (55%) Warbler, 7 (11%) Finch, 5 (8%) Kinglet	746
Davis-Besse Nuclear Power Plant, OH, USA	b,s,o	Apr 27-Jun 1	1974	176	45	121 (69%) Warbler, 14 (8%) Finch, 9 (5%) Vireo	836
Davis-Besse Nuclear Power Plant, OH, USA	b,s,o	Aug-Nov	1975	342	47	178 (52%) Warbler, 92 (27%) Kinglet	837
Davis-Besse Nuclear Power Plant, OH, USA	b,s,o	Apr 6-Jun 1	1975	57	29	20 (35%) Warbler, 9 (16%) Kinglet, 9 (16%) Finch	838
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Apr 10-May 24	1978	78	30	54 (69%) Warbler, 13 (17%) Common Yellowthroat 10 (13%) Red-eyed Vireo, 9 (12%) Black-and-white Warbler	1021
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Sept 15-Oct	1978	71	22	43 (61%) Warbler, 10 (14%) Bay-breasted Warbler, 6 (8%) Ruby-crowned Kinglet, 6 (8%) Common Yellowthroat	1021
Davis-Besse Nuclear Power Plant, OH, USA	s,o		1972-73	157		Warbler, Kinglet	1029
Davis-Besse Nuclear Power Plant, OH, USA	s,o	Fall	1974	342		53 (16%) Golden Crowned Kinglet, 39 (11%) Magnolia Warbler, 38 (11%) Ruby-crowned Kinglet	1029
Dayton, OH, USA	t	Sept 20	1966	305	49	Red-eyed Vireo, Golden-crowned Kinglet, Ovenbird	590
Des Moines, IA, USA	t	Sept 11-12	1974	1500		750 (50%) Red-eyed Vireo	415
Destruction Is, USA	l	Mar 31-Aug 3	1916	149		Leach's storm-petrel	380
Eastern USA	25 (t,c,b)	Oct 5-8	1957	100000	88	Ovenbird, Magnolia Warbler, Red-eyed Vireo, Chestnut-sided Warbler	389
WEAU-TV, Eau Clair, WI, USA	t	Fall	1957	1525	40	Warbler	404
WEAU-TV, Eau Clair, WI, USA	t	Sept 19-20	1957	2972	42	Warbler	116
Elmira, NY, USA	t	Fall	1966	270		Ovenbird	644
Elmira, NY, USA	t	Fall	1969	300		Bay-breasted Warbler	647
Elmira, NY, USA	t	Aug 29-31	1972	540	55	Warbler	649
Elmira, NY, USA	t	Sept 19	1975	800	40	198 (25%) Bay-breasted Warbler, 78 (9.8%) Ovenbird 110 (14%) Magnolia Warbler	411
Empire State Building, NY, USA	b	Oct	1954	100		Blackpoll Warbler	224
Empire State Building, NY, USA	o	Oct 19	1955	156	17	103 (66%) Yellow-rumped Warbler	542
Erie County, NY, USA	3t	Aug 10-Nov 11	1977	1397	50	168 (12%) Bay-breasted Warbler, 154 (11%) Ovenbird, 112 (8%) Magnolia Warbler	172
Fire Is, Long Island, NY, USA	l	Spring	1883	517	27	235 (45%) Blackpoll Warbler	214
Fire Is, Long Island, NY, USA	l	Sept 23	1887	595	25	356 (60%) Blackpoll Warbler	215
FL, USA	b,t,o	Oct	1964	4707	37	4646 (99%) Warbler	154
FL, USA	5t, 3b	Apr-May	1971	2500	42	Warbler	394
FL, USA	t	Fall	1972	1347	49	1199 (89%) Warbler	744
GA, USA	l	Sept 23-24	1924	176	23	Ovenbird	79
Grand Bahama Is, USA	2t	Oct 21-22	1966	136	22	Gray-cheeked Thrush, Blackpoll Warbler	401

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
Great Duck Is, Lake Huron,ON, CAN	l	Sept 17-26	1977	5900	62	3009 (51%) Thrush, 2360 (40%) Warbler, 1947 (33%) Swainson's Thrush, 944 (16%) Gray-cheecked Thrush, 826 (14%) Ovenbird, 354 (6%) Sparrow, 236 (4%) Vireo	FON Letter
Indian River, FL, USA	b, o	Oct 6	1964	4707	37	4613 (98%) Warbler, 1365 (29%) Common Yellowthroat, 329 (7%) Blackpoll Warbler	193
Jacksonville, FL, USA	2t	Oct 6-8	1964	2000		1900 (95%) Warbler, 273 (14%) Blackpoll Warbler	193
Jacksonville, USA	t	Sept 28-Oct 22	1970	146		Warbler	633
Jacksonville, USA	2t	Sept 2-3	1967	174		Ovenbird	635
KCMO-TV, KS, MO, USA	t	Oct 14-15	1975	67		23 (34%) Mourning Dove	289
Knoxville, TN, USA	c	Fall	1954	267		80 (30%) Ovenbird	124
KOMU-TV, Columbia, MO, USA	t	Oct 5	1954	1887	63	354 (19%) Common Yellowthroats, 313 (17%) Gray Catbird	290
KROC-TV, Ostrander, MN, USA	t		1961-62, 1972-74	3507	84	619 (18%) Northern Waterthrush, 516 (15%) Red-eyed Vireo	729
KTOL-TV, Coweta, OK, USA	t	Oct 9	1974	117	28	64 (55%) Nashville Warbler	554
Kupreonof Strait, AK, USA	o	Jan 16	1977	1000	1	Crested Auklet	203
Lawrence, KS, USA	t	Jan	1969	19		19 (100%) Thrush and Sparrow	545
Lennox Power Plant, Barrie, London TV ON, CAN	s, 2t	Fall	1974	7550		1359 (18%) Bay-breasted Warbler, 1129 (15%) Red-eyed Vireo, 1038 (14%) Ovenbird, 920 (12%) Magnolia Warbler	283
Lennox, ON Hydro, ON, CAN	s		1970-77	4656	69	705 (15%) Red-eyed Vireo, 705 (15%) Magnolia Warbler, 553 (12%) Common Yellowthroat, 405 (9%) Ovenbird, 335 (7%) Bay-breasted Warbler	884
London, ON, CAN	t	Sept 13-14	1970			Ovenbird, Warbler	279
Long Point, ON, CAN	l	Fall	1977	1411	48	212 (15%) Blackpoll Warbler, 155 (11%) Bay-breasted Warbler, 127 (9%) Magnolia Warbler, 113 (8%) Common Yellowthroat, 113 (8%) Swainson's Thrush	172
Long Point, ON, CAN	l	Fall and Spring	1960-69	6800	101	1156 (17%) Ovenbird, 1020 (15%) Swainson's Thrush	114
Long Point, ON, CAN	l	May 19-20	1960	56		Warbler	135
Long Point, ON, CAN	l	May 17-18	1977	422	37	Ovenbird, Swainson's Thrush, Veery, Common Yellowthroat	285
Long Point, ON, CAN	l	Apr 12-13	1964			Finch	361
Long Point, ON, CAN	l	Sept 7,9,24-29	1929	2060	55	254 (12%) Common Yellowthroat, 236 (11%) Blackpoll Warbler, 176 (9%)Red-eyed Vireo, 168 (8%) Swainson's Thrush, 153 (7%) Gray-cheeked Thrush, 146 (7%) Ovenbird	656
Long Point, ON, CAN	l	May 17-20	1963	302		Swainson's Thrush, Veery	844
Laughlin Air Force Base, TX, USA	c	Sept 27	1962	6000		4200 (70%) Mourning Dove	328
Laughlin Air Force Base, Del Rio,USA	c	Sept 27	1962	6000		4200 Mourning Dove	792
Madison, WI, USA	4t	Sept 23-24	1968	493	33	Thrush, Warbler, Warbler	677
Magnolia, Larue County, USA	b	Sept 25	1962	270	30	Swainson's Thrush, Ovenbird, Bay-breasted Warbler	144
Maryland State Office Centre Building	b		1976-77	53		Thrush, Warbler, Sparrow	944
Maryville, MO, USA	3 t	Sept 5-Nov 16	1972	71	33	Sparrow	69
MI, USA	7t		1959-64			Thrush, Warbler	141
Mitchell Field, Long Island, NY, USA	o	Oct	1954	230		Blackpoll Warbler	224

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
Moosejaw, SK, CAN	t	Sept 22	1959	33	13	Yellow-rumped Warbler, Orange-crowned Warbler	426
Nanticoke, ON Hydro, ON, CAN	s		1970-77	5088	72	969 (19%) Magnolia Warbler, 616 (12%) Red-eyed Vireo, 499 (10%) Ovenbird, 499 (10%) Common Yellowthroat, 370 (7%) Bay-breasted Warbler	884
Nashville, TN, USA	c	Sept 10	1948	300	33	95 (32%) Red-eyed Vireo	694
NY, USA	2t	Oct 2-3	1959	110		Warbler, Vireo	663
NS, CAN	l	Oct 17-18	1966	115	1	115 (100%) Blackpoll Warbler	24
Olney, IL, USA	t	Sept 22	1978	622	36	498 (80%) Warbler	951
Omega Tower, LaMoure, ND, USA	t	Spring	1973	1417	51	Finch	38
Omega Tower, LaMoure, ND, USA	t	Spring	1972	255	58	Finch	39
Omega Tower, LaMoure, ND, USA	t	Fall	1972	226	66	Warbler	39
Omega Tower, LaMoure, ND, USA	t	Fall and Spring	1971-73	937	102	Warbler, Vireo	42
Omega Tower, LaMoure, ND, USA	t	Fall	1971	152	41	Warbler, Vireo	25
ON, CAN	53(t,l,b)	Fall	1961	1115	57	156 (14%) Ovenbird, 99 (8.9%) Chestnut-sided Warbler, 91 (8.2%) Bay-breasted Warbler, 91 (8.2%) Red-eyed Vireo	64
ON, CAN	7(t,l,b)	Fall	1962	3446	66	Thrush,Warbler,Vireo	65
ON, CAN	7(t,l,b)	Fall	1963	1190	71	Thrush, Warbler, Vireo	66
Orion, IL, USA	t	Oct 6-7	1959	88		Swainson's Thrush, Warbler	505
Pensacola, FL, USA	l	Oct 26-27	1925	29		29 (100%) Yellow-rumped Warbler	134
Philadelphia City Hall, Philadelphia, USA	b	May 21-22	1915	100		Common Yellowthroat	190
Philadelphia,USA	b,t	Sept 11	1948			Warbler	603
Portland, ME, USA	c	Sept 16-17	1958	198	28	American Redstart, Blackpoll Warbler, Bay-breasted Warbler	571
Power Plant, Cheshire, OH, USA	s	Sept 30	1973	2000		Warbler, Vireo	720
Prudential Centre, Boston, MA, USA	b	May 4	1968	100		White-throated Sparrow	227
Prudential Centre, Boston, MA, USA	b	May 2-3	1973	80		White-throated Sparrow	239
S. Atlantic coast, USA	o,t,c,b	Oct	1954			Ovenbird, Red-eyed Vireo	156
S. Erie County, NY, USA	3t	Fall	1967-71	4094	82	450 (11%) Ovenbird, 409 (10%) Golden Crowned Kinglet, 287 (7%) Blackpoll Warbler, 287 (7%) Gray-cheeked Thrush, 246 (6%) Vireo	167
Sherco Stack, Sherburne County, Becker, MN, USA	s	Apr 1-Dec 21	1977	69	26	Warbler, Vireo	Ann. Rpt.
Sherco Stack, Sherburne County, Becker, MN, USA	s	May 5-Nov 1	1978	49	20	28 (57%) Warbler, 17 (35%) Vireo, 3 (6%) Flycatcher	Ann. Rpt.
Sherco Stack, Sherburne County, Becker, MN, USA	s	May 1-Nov 2	1979	72	23	Warbler, Vireo	Ann. Rpt.
South Bend, IN, USA	t	Sept 27	1959	49		Swainson's Thrush, Warbler	505
Springfield, USA	o	Sept 19-21	1958	200		Warbler, Vireo	63
TD Centre, Toronto, ON, CAN	2b	Fall	1967-69	470	64	White-throated Sparrow, Common Yellowthroat	615
TN, USA	o,b	Sept, Oct	1965	1915		Thrush, Ovenbird	659
Three Mile Isle Nuclear Station	4s		1973-74	37		14 (39%) Kinglet, 11 (30%) Warbler, 10 (28%) Vireo	1042
Topeka Tower, KS, USA	t	Oct 7	1967	800	43	240 (30%) Nashville Warbler	152
Topeka, KS, USA	t	Fall	1955	16	2	15 (94%) Mourning Warbler, 1 (6%) Connecticut Warbler	83
Various	26(t,c)			16118		2498 (15.5%) Ovenbird, 1950 (12.1%) Tennessee Warbler, 1418 (8.8%) Red-eyed Vireo, 1418 (8.8%) Magnolia Warbler	259
Vero Beach, USA	t	Sept 28-Oct 22	1970	31		Warbler	633

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
Warner Robins Air Force Base, GA, USA	o	Oct 7-8	1954	50000			Oriole 20: 17-26
Washington Monument, Washington D.C., USA	o	Fall	1935	246	33	Red-eyed Vireo, Warbler	566
Washington Monument, Washington D.C., USA	o	Fall	1938	945	43	Red-eyed Vireo, Common Yellowthroat, Magnolia Warbler	568
WBAL-TV , Baltimore, MD, USA	t	Sept 28	1970	1965	43	489 (25%) Ovenbird, 410 (21%) Red-eyed Vireo	671
WBAL-TV , Baltimore, MD, USA	t	Sept 28-29	1973	180		Warbler	673
WBAL-TV , Baltimore, MD, USA	t	Sept 27-28	1970	1800	41	435 (24%) Ovenbird, 391 (22%) Red-eyed Vireo, 148 (8%) Black and White Warbler, 115 (6%) Common Yellowthroat, 81 (5%) Magnolia Warbler	
WBAL-TV , Baltimore, MD, USA	t	Fall and Spring	1964-66	3595	74	899 (25%) Ovenbird, 468 (13%) Black-and-white Warbler, 395 (11%) Magnolia Warbler	136
WBDO-TV, Orlando, FL, USA	t	Sept 28-Oct 22	1970	2790	51	Warbler	633
WCIX-TV, Homestead, USA	t	Sept 28-Oct 22	1970	300		Warbler	633
WCSH-TV, Sebago, USA	t	Aug 12-13	1973	300		Warbler, Thrush	292
WCTU-TV, Tallahassee,USA	t	Apr 7	1962	249		Red-eyed Vireo	578
WCTV-TV Tower, Leon County, FL, USA	t	Sept	1963	735		81 (11%) Bobolink	191
WCTV-TV Tower, Leon County, FL, USA	t	Mar 12	1964	709		335 (47%) Yellow-rumped Warbler	713
WCTV-TV Tower, Leon County, FL, USA	t		1973-75	3864	109	896 (23%) Red-eyed Vireo, 219 (6%) Ovenbird, 159 (4%) Common Yellowthroat, 140 (4%) Magnolia Warbler	899
WCTV-TV, Tallahassee, USA	t	Sept 28-Oct 22	1960	237	53	Warbler	633
WCTV-TV, Tallahassee, USA	t	Nov	1960	384		230 (60%) Sparrow	637
WEAU-TV, Eau Clair, WI, USA	t	Oct 18-19	1968	145		Kinglet, Warbler	629
WECT & WWAY-TV, SE NC, USA	2t		1971-77	7270		1023 (14%) Common Yellowthroat, 925 (13%) American Redstart, 865 (12%) Ovenbird, 701 (10%) Red-eyed Vireo, 549 (8%) Black-and-white Warbler	888
WECT-TV, NC, USA	t	Fall	1971-72	3070	84	Warbler, Sparrow, Thrush, Vireo, 583 (19%) Common Yellowthroat, 288 (9.4%) Black-throated Blue Warbler, 267 (8.7%) Ovenbird, 218 (7.1%) Yellow-rumped Warbler, 163 (5.3%) Gray Catbird	Chat (1976) 140(1)
WEHN-TV, Deerfield, NH, USA	t	Oct 13-14	1959	130		74 (57%) Ruby-crowned Kinglet	661
West Brands, IA, USA	t	Fall	1970	58	16	Kinglet, 14 (24%) Nashville Warbler, 9 (16%) Ruby-crowned Kinglet, 8 (14%) Yellow-rumped Warbler, 7 (12%) Golden-crowned Kinglet	1022
Westhampton Air Force Base, NY, USA	o	Oct	1954	2000		Blackpoll Warbler	224
Westhampton, Long Island, NY, USA	c	Oct 5-6	1950	2000	49	Blackpoll Warbler	541
WFMJ-TV, Youngstown,OH, USA	t	Sept 18-27	1975	1057	39	Warbler, 317 (30%) Ovenbird	78
WFMS-TV, Youngstown, OH, USA	t	Sept	1977	315		Bay-breasted Warbler, Blackpoll Warbler	873
WHEN-TV, Syracuse, NY, USA	t	Sept 18-19	1959	45		Thrush,Vireo, Warbler	662
WHIO-TV, Dayton, OH, USA	t	Sept 9-Nov 15	1967	348	45	Red-eyed Vireo, Warbler	591
WHNT-TV, Huntsville, USA	t	Sept 30-Oct 31	1976	42	18	27 (64%) Warbler	896
Winston-Salem, NC, USA	c	Oct 7	1954	190	21	57 (30%) Ovenbird, 29 (15%) Tennessee Warbler, 25 (13%) Red-eyed Vireo	Chat (1954) 18 (4)

LOCATIONS	TYPE*	DATE(S)	YEAR(S)	No. KILLED	No. SPECIES	PREDOMINANT SPECIES/GROUPS	REFERENCE**
WIS-TV Tower, Columbia, SC, USA	t	Sept 29, Oct 2	1969	**500**	20	Warbler, Thrush, Vireo, Common Yellowthroat, Magnolia Warbler	165
WJBF-TV, Aiken, SC, USA	t	Sept 6-7	1962	200	32	48 (24%) Swainson's Thrush	Chat (1963), Mar.
WJBF-TV, Aiken, SC, USA	t	Sept 6-7	1962	400	32	239 (60%) Red-eyed Vireo	601
WMC-TV, Memphis, TN, USA	t	May 7-8	1961	19	11	Warbler,Vireo	176
WMC-TV, Memphis, TN, USA	t	May 11	1964	99	21	58 (58%) Red-eyed Vireo	176
WPSK-TV, Clearfield Co, PA, USA	t	Oct 8-Nov 8	1969	75		Brown Creeper, Kinglet, Warbler	1039
WSM & WNGE-TV, Nashville, TN, USA	2t	Fall	1976	406	43	63 (16%) Ovenbird, 61 (15%) Tennessee Warbler, Magnolia Warbler, Bay-breasted Warbler	920
WSM & WSIX-TV, Nashville, TN, USA	2t	Sept 28	1971	3560		Warbler, 845 (24%) Tennessee Warbler, (18%) 631 Ovenbird, 429 (12%) Black-and-white Warbler, 420 (12%) Magnolia Warbler	452
WSM-TV, Nashville, TN, USA	t	May 14-15	1967	160	12	115 (72%) Blackpoll Warbler	448
WSM-TV, Nashville, TN, USA	t	Sept 25-26	1968	5408		4380 (81%) Warbler	450
WSYE-TV, Elmira, NY, USA	t	Sept 29-Oct 4	1963	200	36	Warbler	342
WSYE-TV, Elmira, NY, USA	t	Fall	1968	260	30	Warbler	346
WSYE-TV, Elmira, NY, USA	t	Sept 27-29	1973	465	39	Warbler	351
WSYE-TV, Elmira, NY, USA	t	Sept 21-22	1974	844		246 (29%) Bay-breasted Warbler	352
WSYE-TV, Elmira, NY, USA	t	Fall	1977	3874	48	1227 (32%) Bay-breated Warbler, Magnolia Warbler, 311 (8%) Ovenbird, 218 (6%) Swainson's Thrush	353
Youngstown, OH, USA	t	Fall	1975	1050		305 (29%) Ovenbird	27

Bold indicates where number given is an estimate or a minimum
**Type refers to type of structure: s = stack (no windows), t = TV tower, b = building with windows, c = ceilometer, l = lighthouse, o = other structure.*
*** Numbered references refer to Avery et. al (1980) bibliography.*

Appendix 2

List of species recorded by FLAP (1993-1995) and their population status in Ontario and Canada according to the Canadian Breding Bird Survey (BBS), the Forest Bird Monitoring Program (FBMP) and the Committee on the Status of Endangered Wildlife in Canada (COSEWIC)[1]

		SPRING		FALL		SPRING & FALL		Status (BBS) 1966-94[2]	Status (BBS) 1966-94[2]	Status (FBMP) 1988-1994[2]	Proportion of total	Proportion of total spring & fall
SPECIES	**SCIENTIFIC NAME**	**Dead**	**Total[3]**	**Dead**	**Total[3]**	**Dead**	**Total[3]**	**S. Ont.**	**Canada**	**Ontario**	**deaths**	**recorded**
Ovenbird	*Seiurus aurocapillus*	232	504	203	399	435	903	+		*	0.20	0.17
White-throated Sparrow	*Zonotrichia albicollis*	233	707	193	425	426	1132		*		0.19	0.21
Common Yellowthroat	*Geothlypis trichas*	36	113	82	265	118	378				0.05	0.07
Magnolia Warbler	*Dendroica magnolia*	18	37	96	166	114	203				0.05	0.04
Hermit Thrush	*Catharus guttatus*	36	97	48	133	84	230	+	+	ND	0.04	0.04
Black-throated Blue Warbler	*Dendroica caerulescens*	6	27	69	105	75	132	ND		+	0.03	0.02
Brown Creeper	*Certhia americana*	48	181	17	56	65	237	ND			0.03	0.04
Black-and-white Warbler	*Mniotilta varia*	13	34	44	90	57	124	+			0.03	0.02
American Redstart	*Setophaga ruticilla*	8	17	40	68	48	85				0.02	0.02
Wood Thrush	*Hylocichla mustelina*	27	52	13	23	40	75				0.02	0.01
Golden-crowned Kinglet	*Regulus satrapa*	10	19	25	42	35	61	ND		*	0.02	0.01
Dark-eyed Junco	*Junco hyemalis*	21	88	12	40	33	128	ND			0.02	0.02
Song Sparrow	*Melospiza melodia*	8	21	20	49	28	70		*		0.01	0.01
Yellow-bellied Sapsucker	*Sphyrapicus varius*	20	37	8	23	28	60				0.01	0.01
Chestnut-sided Warbler	*Dendroica penslyvanica*	4	5	21	38	25	43				0.01	0.00
Nashville Warbler	*Vermivora ruficapilla*	4	5	20	40	24	45				0.01	0.00
Northern Flicker	*Colaptes auratus*	12	22	12	21	24	43	*	*		0.01	0.00
American Woodcock	*Scolopax minor*	18	30	6	10	24	40			ND	0.01	0.00
Lincoln's Sparrow	*Melospiza lincolnii*	8	21	12	42	20	63	ND	+	ND	0.00	0.01
Swamp Sparrow	*Melospiza georgiana*	10	17	10	18	20	35				0.00	0.00
Ruby-crowned Kinglet	*Regulus calendula*	12	31	7	18	19	49	ND		ND	0.00	0.00
Northern Waterthrush	*Seiurus noveboracensis*	7	20	11	25	18	45				0.00	0.00
White-crowned Sparrow	*Zonotrichia leucophrys*	5	10	13	20	18	30	ND		ND	0.00	0.00
Yellow-rumped Warbler	*Dendroica coronata*	3	5	14	21	17	26		+		0.00	<0.01
Blackburnian Warbler	*Dendroica fusca*	0	2	15	22	15	24	ND			0.00	<0.01
Black-capped Chickadee	*Parus atricapillus*	1	1	14	15	15	16	+	+		0.00	<0.01
Gray Catbird	*Dumetella carolinensis*	5	18	9	23	14	41		*		0.00	0.00
Swainson's Thrush	*Catharus ustulatus*	5	12	9	14	14	26	ND			0.00	<0.01
Ruby-throated Hummingbird	*Archilochus colubris*	0	1	14	18	14	19				0.00	<0.01
Winter Wren	*Troglodytes troglodytes*	3	16	10	30	13	46			+	0.00	0.00
Mourning Warbler	*Oporornis philadelphia*	2	3	11	29	13	32	+		+	0.00	0.00
Wilson's Warbler	*Wilsonia pusilla*	1	2	11	25	12	27	ND		ND	0.00	<0.01
Bay-breasted Warbler	*Dendroica castanea*	0	4	12	22	12	26	ND		ND	0.00	<0.01
Red-eyed Vireo	*Vireo olivaceus*	1	1	10	16	11	17		+		0.00	<0.01
Rose-breasted Grosbeak	*Pheucticus ludovicianus*	7	10	4	5	11	15				0.00	<0.01
Canada Warbler	*Wilsonia canadensis*	4	6	5	15	9	21				<0.01	<0.01
Pine Warbler	*Dendroica pinus*	1	1	8	19	9	20	ND		+	<0.01	<0.01

		SPRING		FALL		SPRING & FALL		Status (BBS) 1966-94[2]	Status (BBS) 1966-94[2]	Status (FBMP) 1988-1994[2]	Proport-ion of total	Proport-ion of total spring & fall
SPECIES	**SCIENTIFIC NAME**	**Dead**	**Total[3]**	**Dead**	**Total[3]**	**Dead**	**Total[3]**	**S. Ont.**	**Canada**	**Ontario**	**deaths**	**recorded**
Black-throated Green Warbler	*Dendroica virens*	2	4	6	15	8	19	+		+	<0.01	<0.01
Fox Sparrow	*Passerella iliaca*	3	5	4	6	7	11	ND		ND	<0.01	<0.01
White-breasted Nuthatch	*Sitta carolinensis*	0	0	7	7	7	7				<0.01	<0.01
Eastern Wood-Pewee	*Contopus virens*	4	6	2	5	6	11		*		<0.01	<0.01
Red-breasted Nuthatch	*Sitta canadensis*	0	1	6	9	6	10		+		<0.01	<0.01
Brown Thrasher	*Toxostoma rufum*	5	20	0	1	5	21	*	*	ND	<0.01	<0.01
Virginia Rail	*Rallus limicola*	0	5	4	10	4	15	ND		ND	<0.01	<0.01
Connecticut Warbler	*Oporornis agilis*	0	2	4	8	4	10	ND		ND	<0.01	<0.01
Cape May Warbler	*Dendroica tigrina*	1	2	3	4	4	6	ND	+	ND	<0.01	<0.01
Palm Warbler	*Dendroica palmarum*	0	0	7	10	7	10	ND		ND	<0.01	<0.01
Grasshopper Sparrow	*Ammodramus savannarum*	3	3	1	2	4	5			ND	<0.01	<0.01
Blue Jay	*Cyanocitta cristata*	0	0	4	4	4	4	+			<0.01	<0.01
Mourning Dove	*Zenaida macroura*	3	3	1	1	4	4	+	+		<0.01	<0.01
Philadelphia Vireo	*Vireo philadelphicus*	0	1	3	8	3	9	ND		ND	<0.01	<0.01
Eastern Phoebe	*Sayornis phoebe*	0	0	3	8	3	8				<0.01	<0.01
Least Flycatcher	*Empidonax minimus*	2	3	1	1	3	4			*	<0.01	<0.01
Veery	*Catharus fuscescens*	1	8	1	1	2	9		*	*	<0.01	<0.01
Northern Parula	*Parula americana*	0	0	2	6	2	6	ND		ND	<0.01	<0.01
American Tree Sparrow	*Spizella arborea*	0	1	2	4	2	5	ND		ND	<0.01	<0.01
Orange-crowned Warbler	*Vermivora celata*	0	0	2	5	2	5	ND		ND	<0.01	<0.01
Blackpoll Warbler	*Dendroica striata*	0	0	2	4	2	4	ND	*	ND	<0.01	<0.01
Chimney Swift	*Chaetura pelagica*	1	2	1	1	2	3		*	ND	<0.01	<0.01
Scarlet Tanager	*Piranga olivacea*	1	2	1	1	2	3				<0.01	<0.01
Yellow-bellied Flycatcher	*Empidonax flaviventris*	0	1	2	2	2	3	ND			<0.01	<0.01
Eastern Meadowlark	*Sturnella magna*	2	2	0	0	2	2	*	*	ND	<0.01	<0.01
Yellow Warbler	*Dendroica petechia*	1	1	1	1	2	2	+	+	+	<0.01	<0.01
Whip-poor-will	*Caprimulgus vociferus*	0	3	1	9	1	12	ND		ND	<0.01	<0.01
Tennessee Warbler	*Vermivora peregrina*	0	2	1	9	1	11	ND		ND	<0.01	<0.01
House Wren	*Troglodytes aedon*	0	4	1	3	1	7		+		<0.01	<0.01
American Robin	*Turdus migratorius*	1	4	0	0	1	4	+	+		<0.01	<0.01
Cedar Waxwing	*Bombycilla cedrorum*	0	0	1	4	1	4	+	+	*	<0.01	<0.01
Rufous-sided Towhee	*Pipilo erythrophthalmus*	0	0	1	3	1	3			*	<0.01	<0.01
Savannah Sparrow	*Passerculus sandwichensis*	1	1	0	2	1	3	*		ND	<0.01	<0.01
Field Sparrow	*Spizella pusilla*	1	1	0	1	1	2			*	<0.01	<0.01
Gray-cheeked Thrush	*Catharus minimus*	0	0	1	2	1	2	ND		ND	<0.01	<0.01
Great Crested Flycatcher	*Myiarchus crinitus*	1	1	0	1	1	2				<0.01	<0.01
Indigo Bunting	*Passerina cyanea*	0	0	1	2	1	2				<0.01	<0.01
Purple Finch	*Carpodacus purpureus*	0	1	1	1	1	2	+	*		<0.01	<0.01

SPECIES	SCIENTIFIC NAME	SPRING Dead	SPRING Total[3]	FALL Dead	FALL Total[3]	SPRING & FALL Dead	SPRING & FALL Total[3]	Status (BBS) 1966-94[2] S. Ont.	Status (BBS) 1966-94[2] Canada	Status (FBMP) 1988-1994[2] Ontario	Proportion of total deaths	Proportion of total spring & fall recorded
American Goldfinch	*Carduelis tristis*	0	0	1	1	1	1				<0.01	<0.01
Blue-winged Warbler	*Vermivora pinus*	1	1	0	0	1	1	ND	ND	ND	<0.01	<0.01
Eastern Screech-Owl	*Otus asio*	1	1	0	0	1	1	ND	ND	ND	<0.01	<0.01
Evening Grosbeak	*Coccothraustes vespertinus*	0	0	1	1	1	1	ND			<0.01	<0.01
American Black Duck	*Anas rubripes*	0	2	0	0	0	2			ND	<0.01	<0.01
Pied-billed Grebe	*Podilymbus podiceps*	1	1	0	0	1	1		*	ND	<0.01	<0.01
Red-winged Blackbird	*Agelaius phoeniceus*	0	0	1	1	1	1				<0.01	<0.01
House Sparrow	*Passer domesticus*	0	2	0	1	0	3		*	ND	0	<0.01
Baltimore Oriole	*Icterus galbula*	0	2	0	0	0	2				0	<0.01
Sora	*Porzana carolina*	0	0	0	2	0	2	ND		ND	0	<0.01
Brown-headed Cowbird	*Molothrus ater*	0	0	0	1	0	1	*	*		0	<0.01
Chipping Sparrow	*Spizella passerina*	0	1	0	0	0	1				0	<0.01
Clay-colored Sparrow	*Spizella pallida*	0	1	0	0	0	1	ND	*	ND	0	<0.01
Golden-winged Warbler	*Vermivora chrysoptera*	0	1	0	0	0	1	ND	+	ND	0	<0.01
Hairy Woodpecker	*Picoides villosus*	0	1	0	0	0	1		+		0	<0.01
Hooded Warbler	*Wilsonia citrina*	0	0	0	1	0	1	T/ND	ND	ND	0	<0.01
House Finch	*Carpodacus mexicanus*	0	1	0	0	0	1	+	+	ND	0	<0.01
Killdeer	*Charadrius vociferus*	0	1	0	0	0	1		*	ND	0	<0.01
Le Conte's Sparrow	*Ammodramus leconteii*	0	0	0	1	0	1	ND		ND	0	<0.01
Mallard	*Anas platyrhynchos*	0	1	0	0	0	1	+		ND	0	<0.01
Marsh Wren	*Cistothorus palustris*	0	0	0	1	0	1	ND	+	ND	0	<0.01
Rock Dove	*Columba livia*	0	1	0	0	0	1			ND	0	<0.01
Solitary Vireo	*Vireo solitarius*	0	1	0	0	0	1	ND	+	+	0	<0.01
Yellow-breasted Chat	*Icteria virens*	0	0	0	1	0	1	V/ND	ND	ND	0	<0.01
Northern Saw-whet Owl	*Aegolius acadicus*	1	1	0	0	1	1	ND	ND	ND	<0.01	<0.01
Total number of species = 100												
Column total		866	2243	1221	2562	2075	4847					

[1] *Nine bats were also recorded, of which several were identified as silver-haired bats (Lasionycteris noctivagans), a species known to be migratory.*

[2] ** Denotes species with significant declining population trends.*

+ denotes species with significant increasing trends.

(source: Downes, C..M, and Collins, B.T. 1996. The Canadian Breeding Bird Survey, 1996-1994. CWS Progress Notes no.210. and the Forest Bird Monitoring Program, 1988-1994, Mike Cadman, personal communication).

T *Denotes a species which is threatened according to The Committee on the Status of Endangered Wildlife in Canada (COSEWIC). "Threatened" is defined as a species likely to become endangered in Canada if the factors affecting its vulnerability are not reversed.*

V *Denotes a species which is vulnerable according to COSEWIC. "Vulnerable" is defined as a species particularly at risk because of low or declining numbers, small range or for some other reason, but not a threatened species.*

ND *No data is available for these species.*

[3] *Total represents the total number of birds recorded as dead, injured, captured, and sighted.*

ROYAL BANK

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WWF

World Wildlife Fund Canada (WWF) is part of an international network of 29 organizations around the world, dedicated to saving the diversity of life on Earth. Since its founding in 1961, WWF has supported more than 7,000 projects worth $800 million in 130 countries. Charitable number: 0308270-54

World Wildlife Fund Canada
90 Eglinton Ave. East, Suite 504
Toronto, Ontario M4P 2Z7
tel (416) 489-8800

FLAP

The Fatal Light Awareness Program (FLAP) was formed in 1993 to protect night-migrating birds from the dangers posed by lighted, human-built structures. FLAP offers emergency rescue for birds injured during collisions with Toronto's lit towers, provides advice and assistance to concerned individuals and groups in other metropolitan centres, and works towards a permanent, lights-out solution to the problem. Charitable number: 0983114-54

FLAP
1 Guelph Rd.
Erin, Ontario N0B 1T0
tel (416) 831-FLAP

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