A REVIEW OF FACTORS INVOLVED IN BIRD-TOWER KILLS AND MITIGATIVE PROCEDURES

by

Bernard N. Jaroslow

Prepared for

The Mitigation Symposium

Ft. Collins, Colorado

July 16-20, 1979

ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Operated under Contract W-31-109-Eng-38 for the
U. S. DEPARTMENT OF ENERGY
DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.
The facilities of Argonne National Laboratory are owned by the United States Government. Under the terms of a contract (W-31-109-Eng-38) among the U.S. Department of Energy, Argonne Universities Association and The University of Chicago, the University employs the staff and operates the Laboratory in accordance with policies and programs formulated, approved and reviewed by the Association.

MEMBERS OF ARGONNE UNIVERSITIES ASSOCIATION

The University of Arizona
Carnegie-Mellon University
Case Western Reserve University
The University of Chicago
University of Cincinnati
Illinois Institute of Technology
University of Illinois
Indiana University
Iowa State University
The University of Iowa
Kansas State University
The University of Kansas
Loyola University
Marquette University
Michigan State University
The University of Michigan
University of Minnesota
University of Missouri
Northwestern University
University of Notre Dame
The Ohio State University
Ohio University
The Pennsylvania State University
Purdue University
Saint Louis University
Southern Illinois University
The University of Texas at Austin
Washington University
Wayne State University
The University of Wisconsin

NOTICE

This report was prepared as an account of work sponsored by the United States Government. Neither the United States nor the United States Department of Energy, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness or usefulness of any information, apparatus, product or process disclosed, or represents that its use would not infringe privately-owned rights. Mention of commercial products, their manufacturers, or their suppliers in this publication does not imply or connote approval or disapproval of the product by Argonne National Laboratory or the U.S. Department of Energy.
Between 5 million and 80 million birds are killed annually from collisions with man-made structures, with the largest kills occurring to passerine species on overcast nights during fall migration. An understanding of avian physiological and behavioral factors conducive to collision helps in development of methods for mitigation. Mitigating factors involve structure siting, light-source type and frequency of the signal, and precautionary measures for overcast weather and bird migration seasons.

INTRODUCTION - THE PROBLEM

Records of bird kills from collisions with man-made structures were made before the turn of the century. Lighthouse keepers early recognized the positive correlation between foul weather and the number of birds killed. They also recognized that the beacon light served as an attractant for birds in overcast weather, and attempted to mitigate the attraction by using colored filters and varying the flashing rates (Avery et al., 1978).

According to Banks (1979), an estimated 1.25 million birds are killed each year from collisions with towers, tall buildings, monuments and lighthouses, and 3.5 million die from collision with windows (Banks, 1976). According to the newsletter "Ecology USA" (May 7, 1979), this total is closer to 80 million birds.

One of the more thorough investigations of the problem of bird collisions is an 11-year study conducted at a TV tower in Leon County, Florida (Stoddard and Norris, 1967). The largest single-night kill was estimated as between 4000 and 7000 birds in October 1955, with a 2500-bird kill recorded in October 1957. Over the 11-year period, about 30,000 carcasses were examined, although the number actually killed is probably several-fold higher because many birds were not found in the weeds or had been taken by scavengers.

The nightly toll during migration is highly variable. In 12 nights of bird collection at a TV tower in Topeka, Kansas, in the fall of 1954, the nightly kills ranged from 3 to 585, with a median of 25 (Tordoff and Mengel, 1956). Finches and warblers composed about 70% of the victims; ovenbirds, vireos and thrushes made up another 25%. These proportions vary from one report to another, but the groups listed are consistently the major victims of bird-kills by collision. Hassler et al. (1963), using radar, found that some birds elected to fly under the overcast and others flew above. This is likely to be species- or group-specific behavior which might account for the preponderance of passerine birds that are victims of collision with towers and skyscrapers.

The most spectacular bird-kills have been the kill estimated at 15,000 to 30,000 birds at a 1000-foot TV tower, on the night of September 18, 1953, near Eau Claire, Wisconsin (Kemper, 1964), and the kill estimated at 50,000 birds at a ceilometer on the Warner Robins Air Force Base near Macon, Georgia, on the night of October 7-8, 1954 (Johnston and Haines, 1957).

Given this problem, the objectives of this paper will be to examine: 1) the conditions that lead to bird kills via collisions;
CONDITIONS THAT LEAD TO BIRD-KILLS WITH STRUCTURES

Three major factors that lead to bird collisions with stationary objects are:
- "Invisibility" of the Object--A raptor in pursuit of prey, and waterbirds taking off in panic, may collide with transmission lines; low-flying nocturnal migrants often collide with tall, unilluminated structures such as buildings, stacks, and towers.
- Deception--The bird sees a continuation of air space beyond a reflecting window and strikes it at full flying speed.
- Confusion--Discrete sources of light attract, confuse, and disorient night migrants on overcast nights (for example TV towers or lighthouses).

Analysis

Invisibility

When birds strike wires, it is probably because the object has become "invisible" owing to inattentiveness of the bird. A falcon pursuing a pigeon or a flock of ducks taking off in panic may be too intent upon what it is doing, and, consequently, does not see wires. In transmission line corridors carrying more than one powerline, e.g., a 345-kV and a 765-kV system in the same corridor, the wires provide a formidable obstacle course for a panic-stricken flock of birds.

Transparent walls (windows) or glass-walled corridors which provide a view of an open outdoor space have been a source of constant, low-level kills of resident and migrating birds (Banks, 1976).

Birds flying at night may not see a structure in their flight path. The occasional large bird-kills that take place on clear nights during migration (Taylor and Anderson, 1973) may, conceivably, occur when an atmospheric temperature inversion with a low-level jet stream (<2000 ft. altitude) develops (Taylor, 1954). The migrating birds may descend to take advantage of the tail wind and large numbers collide with obstacles projecting into their air space (Hansler et al., 1963).

Deception

Birds that fly into windows are deceived by the reflections. A straight-on view reflects the clear flight path that the bird is using; from an angle, some other clear path may appear. This type of problem could occur either by day or by night.

Confusion

The most dramatic bird kills recorded are probably those that result from confusion. They occur when the sky is overcast (with and without rain, drizzle, or fog) and when light sources are present to attract the migrating birds. The light appears to serve as an attractive super stimulus in the absence of light from celestial objects.

Cochran and Graber (1958) graphically described how the area around a TV tower was occupied by a heavy concentration of birds circling around, and fluttering about in confusion. They suggested that the illuminated area around the TV tower served as a lighted room which many birds were reluctant to leave. Birds repeatedly circled the tower until they collided with guy wires or the tower frame, or finally fell exhausted to the ground. The behavior of the birds, and the numbers killed, were unaffected by whether the tower was or was not transmitting.

BEHAVIORAL FACTORS

There are several questions that must be answered before we can understand why the birds are killed in such large numbers and before we can develop methods for mitigating the magnitude of the problem. First, why are the birds attracted to the lights on overcast nights? Second, why do they fly around the lights until they are exhausted? Third, why do they seem to be so disoriented that they fly into the ground or into large, illuminated structures such as monuments and cooling towers?

To answer the first question we might examine the method by which birds navigate at night. The explanation for the large tower kills on overcast nights probably does not reside with a single behavioral response associated with migration; instead, it is the result of the relative strengths of different behavioral patterns at different stages of the migration.

It is now generally accepted that long-distance migrants primarily use celestial
navigation (Emlen, 1975). The first phase of setting out on a migratory flight is to determine the direction of the goal. According to the experimental data of Wiltschko and Wiltschko (1976, 1978), the initial orientation is determined from the geomagnetic field. The birds then take a bearing on the stars and use celestial navigation during the actual flight. The ability to navigate by the sun and stars during migratory flight includes the ability to compensate for the movement of the stars during the night (Emlen, 1975; Sauer, 1958).

I propose that, under overcast skies, the dominant orienting stimulus of celestial objects is lost; then, the dominant stimulus becomes the geomagnetic field. Leak (1977) suggests that the signal is associated with the optic apparatus and that the weak radiation of the geomagnetic field is amplified by a mechanism in the eye which is capable of "optical pumping." Whatever the mechanism is for sensing the geomagnetic field, the strength of this stimulus appears to be weak. The geomagnetic orientation may be maintained and strengthened by "consensus" of the flock, i.e., Graber (1968) reports "...migrants flying under complete overcast were extremely vociferous. As the cloud layer broke, calling declined, but as the overcast closed again about 2200 CST, calling began to increase again...."

In any case, the strength of the orienting stimuli, in some night-migrating birds, is less than the stimulus produced by a point source of light when the sky is overcast. Kemper (1964) suggests that birds flying under overcast conditions orient on tower lights as they would on stars. As they approach the light, their direction of flight relative to the tower light changes, and they are no longer in conformance with the celestial orientation established at or before take off. To make navigation corrections on what has become their "guiding star," the birds begin a spiral around the light. This terminates in collision with the tower or its guy wires, or with exhaustion and collapse on the ground.

Sometimes the point source of light is a ceilometer or an illuminated structure. When the birds enter the illuminated area, they appear to be confused and circle inside and around the illuminated area until they fly into a nearby structure or fall exhausted to the ground (Howell et al., 1954; Johnston and Haines, 1957) while in the beam of a ceilometer; and there is a report of many birds, on a rainy night, flying into the ground around a recreation area that was illuminated with tall light poles (James, 1956).

Herbert (1969) gives a convincing argument in explanation of the confusion and disorientation of birds when they fly into an illuminated area, particularly in rainy or misty conditions. He suggests that, in night flights, the birds stabilize themselves on a horizontal horizon, with lighter areas above and darker masses below the horizon. In the illuminated areas of a light source, they become disoriented and may suffer vertigo when their sense of gravity is at variance with their sense of vision. As a result, birds in the light beam are seen to flutter in a confused manner. Some of the birds are apparently so visually confused that in these situations they appear to accept the edge of light and darkness as the horizontal horizon, and fly into the ground; other birds refuse to leave the cone of light, flying round and round until they fall to the ground exhausted (Cochran and Graber, 1958; Howell et al., 1954; James, 1956; Johnston and Haines, 1957). In his discussion, Herbert points out that pilots have shown the same disorientation when confronted by bright lights on dark nights.

**MITIGATION**

Collisions resulting from "invisibility" of an object involve wires (e.g., transmission lines, telephone wires), transparent walls (glass-walled corridors between buildings), and tall structures not visible on dark nights.

Mitigation of kills by overhead wires and cables could be accomplished by conscientiously avoiding, where possible, the stringing of wires across flight corridors, for example, near lakes and ponds used by water birds, or across major migration corridors such as the Mississippi flyways (Goddard and Richardson, 1974). Silhouettes of raptors on windows have been used with success to reduce bird losses from collision with windows or window walls (National Wildlife, 1976). Tall, dark structures could be illuminated on clear nights but left darkened on overcast nights, when they would serve as an attraction and hazard.

Collisions resulting from deception occur when birds see a reflection of open air space and fly into the reflective surface, a frequent problem with modern architecture, which uses large areas of glass. In many instances, reflectivity is enhanced because the windows are covered with heat reflectors which can serve effectively as mirrors. This hazard primarily affects diurnal residents and migrants.

Mitigative procedures are several, but the easiest way to decrease the fidelity of the reflected image is to have white-lined drapes
in the room, or have the room lights on in the
daytime whenever bird-strikes are likely to
become frequent. Any method that would
decrease the fidelity or the brightness of the
reflected image would be helpful.

Collisions resulting from disorientation,
with subsequent confusion, are associated with
night migration on overcast nights. The dis-
orientation results from stationary lights on
the ground or on towers.

The study by Cochran and Graber (1958)
provides information useful in understanding
the causes of disorientation and in develop-
ing mitigative procedures to decrease colli-
sions. By counting the number of bird calls
per minute, they found that the numbers were
much higher when the lights were on and
decreased rapidly as soon as the lights were
extinguished. They used different on/off
sequences for tower lights and found that the
number of bird calls increased about two min-
utes after lights were switched on, and by
four minutes after illumination the frequency
was at or close to maximum. Immediately after
the lights were extinguished, the birds left
the vicinity of the tower, as evidenced by the
diminishing volume, as well as number, of bird
calls. In support of the mitigative efficacy
of intermittent illumination on the size of
bird kills is a reference to an experiment at
Dungeness Lighthouse in which the newly in-
 stalled lighthouse beacon was flashed for one
second in every ten-second period (Avery et al.,
1976, citing Baldwin, Ontario Naturalist 3:3-11,
1965), and the numbers of birds killed declined
from previous years when the illumination had
been constant.

Mitigative procedures for aircraft warn-
ing lights on towers and tall structures should
provide for a lighting sequence in which the
lights are on for no more than two minutes and
off for less than one minute on overcast nights
during the migration season. Further research
might show that a ten-second cycle, such as
used at the Dungeness Lighthouse, is both fea-
sible and effective. The light intensity
should be decreased as much as is compatible
with its function as a warning light. This
would limit the zone of attraction and the
intensity of the stimulus.

Illumination of tall structures such as
monuments and cooling towers (Kryak et al.,
1973), which are used for aesthetic purposes, should
be stopped during the danger period. The
lights in skyscrapers should be extinguished,
if possible, or drapes should be drawn at
those times.

Many experiments have been conducted to
determine cause-effect relationships between
different colored lights and bird collisions
with illuminated structures, but the results
are inconclusive. 4 This is not surprising.
Studies of color vision in birds (review by
Stillman, 1973) show that color sensitivity is
highly variable among different families. Most
unfortunately, few of these studies were
concerned with passerines, due, in part, to
the difficult technical problems in working
with these small birds. A thorough study
(Donner, 1953) of spectral sensitivity in
pigeons showed that they have good vision over
the entire region that humans call "visible
light."

Ceilometers, because of their intense
beam, provide a super stimulus, and attract
migrants from many miles. Fortunately, miti-
gation of the problem is simple — use of
ultraviolet light (Terres, 1956; Tordoff and
Mengel, 1956) or infrared light (Donner,
1953). Both are invisible to birds but easily
detected with instruments. According to Mr.
Donald Whitman, Chief of Data Acquisition,
National Weather Service, Central Division
(Personal Communication), all U.S. airports
use rotating beam ceilometers with continuous
recording. Rotating beam ceilometers give
light in the infrared range. (For example,
the light source advertised by Weathertronics,
Inc., is described as a laser diode that emits
400 W, peak power, at 900 nm.) A fixed-beam
ceiling light is sometimes used with a five-
minute on-off cycle. I am unaware of any
bird-kills associated with the use of either
system.

SUMMARY

Between 5 million (Banks, 1979) and
80 million (Ecology USA, 1979) birds are
killed annually by collision with man-made
structures. They collide with objects that
are poorly visible, such as wires strung across
their flight path; objects that deceive by
reflecting a free flight path; or, on overcast
nights, structures with point sources of illu-
mination which act as super stimuli that
attract, disorient, and confuse.

Mitigation can be achieved by better
siting of wires, decreasing the reflectivity
of surfaces, substituting ultraviolet or infa-
red light in ceilometers, and using an appro-
 priate on-off cycle for warning lights and
ceilometers on overcast nights during migra-
tion (further research is required to deter-
mine the optimum cycle). Illumination for

4See the annotated bibliography of Avery
et al. (1978) for references to these studies.
esthetic or advertising purposes should be extinguished, whenever possible, during danger periods.

ACKNOWLEDGMENTS

I wish to thank Ms. P. Merry, Dr. L. Soholt, and Dr. E. Pentecost of Argonne National Laboratory for their helpful contributions and discussions during the preparation of this manuscript. I am grateful to the Nuclear Regulatory Commission and the Department of Energy for support.

LITERATURE CITED