An Assessment of Factors Associated with Avian Mortality at Communications Towers – A Review of Existing Scientific Literature and Incidental Observations

Technical Comments prepared in response to the August 20, 2003, Notice of Inquiry Issued by the Federal Communications Commission (FCC)
WT Docket No. 03-187

November 2003

Prepared by

Woodlot Alternatives, Inc.
30 Park Drive
Topsham, ME 04086

Prepared for

Cellular Telecommunications & Internet Association
PCIA: The Wireless Infrastructure Association
The National Association of Broadcasters

EXECUTIVE SUMMARY

The Federal Communication Commission (FCC) issued a Notice of Inquiry (NOI) on August 20, 2003, to gather comment and information on the impact communications towers may have on migratory birds. In response to the NOI, a review of the published literature was conducted by Woodlot to determine what is, and is not, known about the effects of communications towers on avian mortality, and to determine how significant this mortality may be to bird populations.

The literature review largely included peer-reviewed scientific journals, ornithological publications, and regional wildlife society bulletins and newsletters. This volume of available literature was then segregated into two distinct bodies of work based on the scientific strength of the presented data or observations. These segregated bodies of work included incidental reports and observations, and peer-reviewed studies. Further analysis of the incidental reports and peer-reviewed studies was then supported through the development of separate matrices. The following is a summary of the findings:

- Estimates of avian mortality attributed to human causes vary widely. It is not currently well understood what overall influences this mortality may be having on bird populations. Avian mortality due to domestic cats, buildings, windows, transmission lines, pesticides and vehicle collisions are all thought to have a much greater impact on the avian population than collisions with communications towers.

- There have been many incidental reports of avian mortality at certain communications towers. The quality of information in these reports varies widely, with no standard methodology used in collection of data. Due to the incidental and biased nature of these reports it is not possible to examine specific factors that have contributed to avian mortality. These reports, however, provide some documentation of bird mortality at communications towers at many locations in the eastern and central United States.

- Very few in-depth studies on avian mortality at communications towers have been conducted. The majority of studies have examined only single towers and made no comparisons between different towers in different sites. These studies primarily focus on mortality trends and species composition at towers. No published research has systematically examined the host of specific factors that may contribute to mortality at towers sites.

- Certain factors that are reported to be more significant than others are weather, lighting, and seasonal migration patterns. For example, it has been reported in the literature that large kills are almost entirely restricted to nights with cloudy and foggy conditions, when the cloud ceiling is low. However, because there are few studies that have examined specific factors related to avian mortality at communications towers and due to the limited, selective, and sporadic nature of the incidental reports it is unclear how most factors associated with towers contribute to avian mortality.

- Several studies have documented a decline in avian mortality at communications towers over the last several decades. No research has examined the factors involved in this decrease, but researches have hypothesized that it may be due an increase in light pollution in the vicinity of the towers, a general decline in the migratory bird population, and/or scavenger impact on the killed birds before collection.

The most important conclusion reached after reviewing the current literature on avian mortality at communications towers is that there is a need for further research. The occurrence of some avian mortality at communications towers is well documented, but the extent of the effect of this mortality on migrating bird populations is unknown. While several well-conducted studies have been completed in this field, they primarily focus on individual towers and the trends and species composition involved with mortality at those

towers. No published research has specifically examined the factors associated with communications towers that contribute to mortality.

TABLE OF CONTENTS

Executive Summary i

1 Introduction 1

1.1 Background 2
1.1.1 Incidental Reports and Observations 3
1.1.2 Peer-reviewed Scientific Studies 3

2 Methods 4

2.1 Literature Review 4
2.2 Matrix 1 – Peer-reviewed Scientific Studies 4
2.3 Matrix 2 – Incidental Reports and Observations 5
2.4 Data Quality Review 6
2.5 Web Search 6
2.6 Researcher Contacts 6

3 Results 7

3.1 Sources of United states Avian Mortality and Population Estimates 7
3.1.1 Windows and Buildings 8
3.1.2 Vehicle Collisions 9
3.1.3 Wind Turbines 9
3.1.4 Transmission Lines 10
3.1.5 Pesticides and Oil Pollution 10
3.1.6 Cat Predation 11
3.1.7 Hunting 12
3.1.8 Communications Towers 12
3.1.9 Human-caused Mortality in the Context of the Total Avian Population 13
3.2 Overview of Peer-Reviewed Scientific Studies and Incidental Reports and Observations 15
3.3 Factors Affecting Mortality 16
3.3.1 Tower Location 17
3.3.2 Topographic Location 18
3.3.3 Elevation 19
3.3.4 Year 20
3.3.5 Season 21
3.3.6 Weather 23
3.3.7 Years of Study/Search Frequency/Survey Effort 24
3.3.8 Tower Height and Guy Wires 25
3.3.9 Tower Lighting 27
3.3.10 Tower Signal 29
3.3.11 Scavenger Impact 29
3.4 Fatalities and Species Composition 30
3.4.1 Total Fatalities and Mean Annual Fatalities 30

3.4.2 Mass Mortalities....32
3.4.3 Number of Species and Common Species/Percent Neo-tropical Migrants....33
3.4.4 Data Quality Review of Scientific Studies....33

4 Current Research....35

4.1 Michigan Study Review....35
4.2 Other Ongoing Research....37

5 Summary....38

6 Conclusion....39

7 Literature Cited....41

1 INTRODUCTION

The Federal Communication Commission (FCC) issued a Notice of Inquiry (NOI) on August 20, 2003, to gather comment and information on the impact communications towers have on migratory birds. Specifically, FCC was interested in information that is supported by evidence concerning numbers of migratory bird collisions with communications towers, as well as the role specific factors associated with communications towers may have on avian mortality.

In response to the NOI, Cellular Telecommunications & Internet Association (CTIA), PCIA: The Wireless Infrastructure Association (PCIA), and The National Association of Broadcasters (NAB) contracted Woodlot Alternatives, Inc. (Woodlot) to prepare technical comments to the FCC regarding the possible impact of communications towers on avian mortality. Woodlot's own technical expertise in the avian tower collision arena was developed over the last decade through a variety of research and study methods, including marine and NEXRAD radar, acoustic, and ceilometer studies of bird migrations in the northeast, as well as a series of field assessments of communication tower sites. An important component of these previous studies has included reviews of research associated with potential avian/tower collision factors throughout North America.

Technical comments presented in this document were prepared by Woodlot's professional staff, including Principal Biologist Steve Pelletier, who has particular expertise in evaluating wildlife impacts and developing avoidance and mitigation measures for projects ranging from wind power developments to commuter rail lines. Woodlot President and Certified Wildlife Biologist John Lortie is an avian expert with special expertise in migratory bird studies. Senior Avian Ecologist Robert Roy is considered to be one of the top ornithologists in northern New England. Mr. Roy has led avian species evaluations at multiple projects and recently designed and conducted migratory bird surveys and avian impact evaluations for a Federal Energy Regulatory Commission (FERC) wind power project in northern New England, utilizing both standard bird survey field protocols and radar surveys. Dr. Peter Vickery, a Woodlot

Associate and one of the foremost bird experts in the country, also assisted in the preparation of this document. Dr. Vickery is avian ecologist and president of Ecological Research, a non-profit organization in Richmond, Maine. He received his PhD from the University of Maine and is an adjunct professor at the University of Massachusetts.

Technical comments presented in this document were primarily derived from a review of the existing scientific literature concerning avian mortality, with a particular focus to provide a scientific basis for response to the questions posed in the NOI. In summary, these questions were:

1. *What is, and is not, known about the effects of communications towers and avian mortality;*
2. *How significant is overall avian mortality*; *and*
3. *Are there specific, identifiable factors associated with communications towers that cause collisions and lead to avian mortality?*

This document details how these questions were used to analyze previously reported research and information gathered to date and includes comments regarding the relative significance of those data. It also provides a brief assessment of other ongoing studies, including current avian/collision research efforts underway in Michigan (Gehring 2003).

1.1 BACKGROUND

Available scientific data on the effects of communications towers on migrating avian populations is currently limited and mostly based on a relatively large volume of incidental reports and observations and a few peer-reviewed, scientific research studies.

This deficiency in scientifically based data has resulted in a lack of understanding of those factors potentially associated with avian tower collisions. Differences between the two types of information are briefly explained below.

1.1.1 Incidental Reports and Observations

The first report of avian mortality due to collisions with communications towers was in 1949 (Arnoff 1949). Since that time, reports of avian mortality at communications towers have been published in a range of literature (from newspapers to local birding newsletters to scientific publications). Despite the amount of incidental reports and observations on this phenomenon, there have been relatively few scientific studies of the causes or factors of this mortality, or of the overall significance of this particular type of impact on the migrating bird population. In addition, the quality of available information contained in the incidental reports varies widely, with no standard methodology used in collection of data. Regardless, the collective volume of these incidental reports and observations are recognized as having some value in that they document avian mortality in a number of eastern and midwestern states since the 1950s, thereby providing some general indications of trends.

1.1.2 Peer-reviewed Scientific Studies

Those scientific, peer-reviewed avian mortality studies that have been published to date largely focus on mortality numbers at individual towers and the species composition of those kills. No large-scale studies have been conducted on potential factors that may affect mortality at these sites. The longest continuous study on avian mortality at a communication tower began in 1955 at the Tall Timbers Research Station in Leon County, Florida (Crawford and Engstrom 2001). Most other studies have occurred over a much shorter time period and have not been conducted in a scientifically rigorous manner. These studies often provide useful information on species composition of tower kills, weather associated with kills, and seasonality associated with mortality. Collectively, these studies do not, however, provide sound data on the specific factors associated with the tower that may affect mortality, nor do the towers studied necessarily provide an unbiased, representative sample.

2 METHODS

2.1 LITERATURE REVIEW

A review of the published literature was conducted by Woodlot to determine what is, and is not, known about the effects of communications towers on avian mortality. The literature review largely included peer-reviewed scientific journals, ornithological publications, and regional wildlife society bulletins and newsletters. This volume of available literature was then segregated into two distinct bodies of work based on the scientific strength of the presented data or observations: 1) incidental reports and observations; and 2) peer-reviewed studies. Further analysis of the incidental reports and peer-reviewed studies was then supported through the development of separate matrices. Following is a description of each.

2.2 MATRIX 1 – PEER-REVIEWED SCIENTIFIC STUDIES

A matrix was developed to categorize the peer-reviewed scientific studies conducted at individual towers (Appendix A). The reviewed studies, in general, contain more detailed information of the factors involved in mortality. Use of the matrix allowed the opportunity for some general trends or conclusions to be drawn from these factors. It was not possible to conduct a statistical analysis of various potential factors reported in the scientific studies due to the relatively small number of studies on this subject and the varying ways in which studies were conducted and data reported. The following factors were recorded for avian mortality studies, when reported:

- State – As reported.
- Tower/City – As reported.
- Topographic Location – Physical location of the tower, whether it was located on a hill, mountain, ridgeline, plateau, agricultural field, or plain.
- Tower Elevation – Elevation of the base of the tower above sea level (ASEL) and/or above the surrounding landscape (ASUL).
- Number of Towers in Study – As reported.
- Tower Height – Total tower height in feet (ft), including the antenna.
- Presence of Guy Wires – As reported, Yes or No.
- Tower Lighting – Lighting scheme of the individual tower.
- Years of Study – See specific year(s) that the study was conducted.
- Number of Years – Total number of years the study was conducted.

- Search Frequency – Frequency that the tower area was searched for avian mortality.
- Scavenger Impact – Details on the impact of scavengers on the numbers of birds collected and whether efforts were made to control the removal of carcasses by predators or scavengers.
- Number of Birds Collected –Total number of avian fatalities over the length of the study.
- Mean Annual Fatalities – Average number of fatalities per year. When not provided in the report, this number was calculated by Woodlot by dividing the total number of fatalities by the number of years the study was conducted.
- Number of Species – Total number of bird species collected.
- Percent Neo-tropical Migrants – Percentage of neo-tropical migrants among the total number of species collected. Woodlot calculated this percentage, if not reported in the study.

2.3 MATRIX 2 – INCIDENTAL REPORTS AND OBSERVATIONS

A second matrix was developed to categorize the large volume of incidental mortality reports that allowed an examination of individual factors that may contribute to avian mortality (Appendix B). This listing includes a series of specific factors cited in the August 20, 2003, NOI (Section III), as well as potential factors encountered during the course of this analysis. As with the Matrix 1 assessment, a statistical analysis of individual factors was not possible due to the limited data available in many of these publications and the biased nature of reporting. General comparisons were made, however, between the different factors. The following factors were recorded for avian mortality incidents, when reported:

- State – As reported.
- Tower/City – As reported.
- Topographic Location – Refers to the reported physical location of the tower, whether it was located on a hill, mountain, ridgeline, plateau, agricultural field, or plain.
- Tower Elevation – Elevation of the base of the tower above sea level (ASEL) and/or above the surrounding landscape (ASUL).
- Date – Date(s) of the incidental report of avian mortality.
- Year – Year of the incidental report.
- Season – Season of the year associated with the incident of avian mortality (i.e., winter, spring, summer, or fall).
- Weather – Observed weather conditions the night of the avian mortality incident.
- Survey Effort – Total hours of search effort and/or the area beneath the tower that was searched.

- Tower Height – Total tower height in feet (ft), including the antenna.
- Presence of Guy Wires – As reported, Yes or No.
- Tower Lighting – Lighting scheme of the individual tower.
- Years of Study – Specific year(s) that the study was conducted.
- Number of Years – Total number of years the study was conducted.
- Search Frequency – Frequency that the tower area was searched for avian mortality.
- Scavenger Impact – Impact of scavengers on the numbers of birds collected, and whether efforts were made to control the removal of carcasses by predators or scavengers.
- Number of Birds Collected – As reported.

2.4 DATA QUALITY REVIEW

An evaluation of methods used to collect data and to analyze results was made for the most relevant and scientifically sound journal publications (Appendix C). This analysis included an evaluation of study objectives, hypothesis, standard operating procedure, statistical analysis, results, and conclusions. This analysis was the basis for determining the overall significance of each study reviewed. Each of the studies was then evaluated, on their face, in terms of satisfying aspects of the Data Quality Act (particularly, the requirements of transparency and reproducibility), as administered by the Office of Management and Budget (PL 106-554; H.R 5658, Sec. 15) and the Information Quality Guidelines published by the FCC (FCC 02-227).

2.5 WEB SEARCH

To supplement gathered literature references, keyword searches targeting avian collisions with communications towers were conducted on the World Wide Web. Information obtained off the web included incidental reports, avian collision studies, and general comments and information on factors affecting mortality.

2.6 RESEARCHER CONTACTS

Based on the literature and web searches, a list of researches in this field was created. These researchers were directly contacted in regards to their ongoing studies to determine how those studies investigate avian mortality and transmission towers (Section 4.2)

3 RESULTS

3.1 SOURCES OF UNITED STATES AVIAN MORTALITY AND POPULATION ESTIMATES

Birds migrating through North America face a landscape that has become increasingly altered by humans since the Industrial Revolution. In addition to naturally occurring sources of mortality such as predation and starvation, birds are subject to mortality from numerous human-caused forces (Bevanger 1994). Human-caused sources of bird mortality addressed in this section of the report comprise the majority of documented sources of avian mortality and include window/building collisions, vehicle collisions, wind turbine collisions, mortality associated with transmission lines, pesticide/oil pollution, domestic cats, and hunting (Banks 1979, Coleman and Temple 1995).

Estimates of avian mortality for the entire country are generally made by extrapolating the results of area-specific studies. As a result, these estimates can have extremely large ranges, making accurate comparisons of the relative impact of each source of mortality difficult to determine. In order to accurately assess the impact of human-caused bird mortality on overall bird populations within a certain geographic range, the total bird population within that range, including migrants, would need to be known. To date, the few estimates of total bird populations that exist for any geographic region are speculative and vary widely. A direct means of assessing impacts of human-caused bird mortality is to compare various sources of mortality to get a sense of relative impact, and to then compare the sum total of human-caused mortality to the existing estimates of the total bird population. These comparisons must be made cautiously and with an understanding of the limitations and potential inaccuracy of the estimates of total bird mortality and population.

Attempts were made by Woodlot to review and compare all available avian mortality-related literature to limit ranges of mortality estimates. When possible, articles published in peer-reviewed journals were used to generate bird mortality estimates presented in this

report. Nonetheless, all estimates presented in this section are subject to inaccuracies caused by extrapolation and must be viewed in that context.

This section of the report summarizes what is known about each documented human-caused source of bird mortality and evaluates the accuracy of the existing information. It also contextualizes various sources of mortality by comparing them to one another and by estimating their relative impact on the estimated total bird population.

3.1.1 Windows and Buildings

Windows and buildings pose danger to birds for several reasons. Evidence suggests that birds are unable to perceive glass as an obstacle (Klem 1989, 1990). Although certain bird species are killed by window collisions more often than others, individuals representing 25 percent of all bird species in the United States have been reported killed in this manner. The remaining 75 percent of the species are those typically not found in developed areas (Klem 1991).

In addition to not being able to see glass, according to some researchers birds tend to be attracted to artificial lights at night and may have difficulty leaving lit areas (Ogden 1996). These factors, combined with local weather patterns, locations and designs of buildings, window types, and illumination types, make certain buildings especially likely locations for bird collisions.

Mortality associated with window and building collisions ranges from regularly occurring, small scale collisions with houses and small buildings, to episodic mass mortality events in which large numbers of birds are killed by colliding with large buildings (Klem 1990, Johnston and Haines 1957). Because of this range, and the site-specific nature of studies documenting mortality due to collisions with windows and buildings, estimating the total amount of this type of mortality is difficult (NWCC 2001). Nevertheless, this issue has received considerable attention, and window-associated mortality estimates that exist are in similar ranges.

As a means of predicting the total mortality associated with windows and buildings in the United States, Klem (1990) estimated that between 1 and 10 birds were killed per building per year. At the time of the Klem study, there were 93.52 million houses and 4.04 million commercial buildings in the United States, resulting in a total mortality estimate from 97.6 million to 975.6 million avian deaths per year (Klem 1990). In 2000, there were 115.91 million houses and 4.66 million commercial buildings in the United States (U.S. Bureau of Census 2002). Therefore, using Klem's estimate of 1 to 10 deaths per building per year, current estimates of avian mortality due to collisions with windows and buildings would range from 120.6 million to 1.21 billion. In a study focusing on residential houses, Dunn (1993) used data obtained from the Project Feeder Watch program and estimated possible window-kill mortality ranges to be from 0.65 to 7.70 per building, yielding mortality estimates slightly lower than those proposed by Klem. Multiplying Dunn's mortality estimates by the number of buildings in the United States yields total mortality values ranging from 78.4 million to 928.3 million deaths per year.

3.1.2 Vehicle Collisions

In a special report to the U.S. Fish and Wildlife Service (USFWS), Banks (1979) predicted the number of birds killed each year by direct collisions with vehicles by estimating a number of birds killed per mile of road and multiplying this estimate by the total road mileage in the United States in 1972, yielding an estimate of 57.2 million deaths. Banks used an estimate of 15.1 birds killed per mile that was generated in a study of approximately 350 miles of roads in Great Britain (Hodson and Snow 1965). He also predicted low and high estimates, ranging from about 10.2 million to 374.5 million deaths, based upon several studies done in the United States (Banks 1979). Using the estimate of 15.1 birds killed per mile and multiplying by the number of miles of roads in the United States in 1998, the National Wind Coordinating Committee (NWCC) estimated the number of birds killed by vehicle collisions to be 80 million (NWCC 2001).

3.1.3 Wind Turbines

Avian mortality caused by wind turbines has been evaluated in several newly constructed wind generation facilities. In a report on the relative mortality caused by wind power

facilities, the NWCC estimated that wind generators account for approximately 2.19 deaths/turbine/year. Multiplied by the approximately 15,000 wind generators in the United States in 2001, they reported a total bird mortality of approximately 33,000 deaths per year. Another document prepared for the Technical Advisory Committee of the Oregon Office of Energy by Western EcoSystems Technology, Inc. (2001) reported a total of 2.991 deaths/turbine/year, which would yield a total mortality of approximately 45,000 when multiplied by 15,000 generators in the United States.

3.1.4 Transmission Lines

Mortality associated with transmission lines mainly consists of mortality from collisions and mortality from electrocution (Bevanger 1994). In a study of the effects of medium-tension transmission lines on raptors in a national park in Spain, Ferrer *et al.* (1991) concluded the majority of large-bird fatalities were due to electrocution and that 2.8 percent of these fatalities were associated with collisions. Collision mortality is higher in smaller birds and in those that tend to fly closer to the ground (Bevanger 1994).

Most of the information available regarding bird mortality associated with transmission lines has been collected by private companies, and published in industrial reports pertaining to specific geographic locations (Bevanger 1994), so few estimations of nationwide mortality exist. The NWCC used the results of several area-specific studies and multiplied the results by the total amount of documented high-tension transmission lines in the United States yielding annual mortality estimates in the tens of thousands to 174 million. Because the amount of smaller distribution lines in the United States is not documented and most likely far exceeds the amount of high-tension lines, the upper-end of the estimated range is probably more accurate, according to the NWCC (NWCC 2001).

3.1.5 Pesticides and Oil Pollution

Pesticides are used heavily for agriculture in the United States, and also by homeowners. Partners in Flight, an organization that focuses on the conservation of birds, estimates that 67 million birds die each year from direct exposure to pesticides on farmlands, and

that an additional 7 million birds die from direct exposure to pesticides on household lawns (Partners in Flight 2003). The USFWS reported a total estimate of 72 million deaths per year caused by direct exposure to pesticides (USFWS 2003), while Pimintel *et al*. (1992) reported 67 million deaths per year. Oil spills range from large-scale catastrophes such as the Exxon Valdez spill that may cause as many as 300,000 avian deaths (Piatt *et al.* 1990) to smaller spills resulting in much lower mortality. Between 1997 and 2000, approximately 8,000 oil spills occurred in United States waters annually, resulting in approximately 800,000 to 1,400,000 gallons of spilled oil (U.S. Bureau of Census 2002). Banks (1979) estimated an annual mortality rate from oil spills of about 15,000, with catastrophic events such as the Exxon Valdez spill causing much higher mortality. In addition to mortality associated with oil spills, Banks (1979) conservatively predicted that 1.5 million birds are killed in oil sumps in the United States each year. The total annual mortality associated with direct exposure to pesticides and oil, yielded by combining the above estimates, ranges from approximately 67 million to 76 million.

3.1.6 Cat Predation

Estimates vary greatly regarding the number of birds killed each year by cats in the United States. A study conducted in rural Wisconsin (Coleman and Temple 1995) estimated 23 percent of the diet of free-ranging cats consisted of birds (with other studies not cited by Coleman and Temple reporting between 20 and 30 percent). They further reported that various studies estimated that the average cat killed between 28 and 365 animals per year, resulting in a projection that cats kill between 7.8 million and 219 million birds per year in Wisconsin alone, with 38.7 million being an intermediate estimate (Coleman and Temple 1995).

According to the U.S. Bureau of Census (2002), approximately 31.6 percent of households had pet cats in 2001, with the average number of cats per household being 2.1. Multiplied by the 105.48 million households in the United States, these numbers yield an estimate of 70 million domestic cats in the United States. The number of feral cats was not recorded by the census. While the estimate of 70 million domestic cats does not discriminate between indoor and outdoor cats, neither does it account for feral cats.

Using the low estimates for kill rates presented by Coleman and Temple (1995) and the population of 70 million domestic cats reported by the U.S. Bureau of Census, the estimate for total annual mortality caused by cats in the United States would be approximately 450 million.

Another study performed in Great Britain estimated that 9 million cats killed between 25 and 29 million birds between April 1 and August 31, 1997 (Woods *et al.* 2003). Extrapolating to the United States cat population, this would translate to between 194 and 226 million birds in the same 5-month time period. In addition to having a direct effect on birds through predation, cats have been implicated in indirectly endangering raptor populations through food supply competition during winter months. Cats consume large numbers of the small mammals upon which raptors rely, especially during winter (George 1974). Taking into account the various estimates on cat-related bird mortality, a likely annual range in mortality is from 300 and 500 million.

3.1.7 Hunting

Hunting has been implicated by Banks (1979) and Klem (1991) as one of the largest human-caused sources of avian mortality, accounting for approximately 120 million deaths per year. However, hunting focuses almost exclusively on waterfowl and game birds and does not cause mortality in other migratory passerines and raptors, which are the primary types of birds involved in most collision and cat-related mortality. Nevertheless, hunting represents a large source of mortality for waterfowl and game species. Unlike most other sources of avian mortality, the estimates of hunter-associated mortality are likely to be relatively accurate, because the number of hunters and the numbers of birds harvested is documented by the USFWS.

3.1.8 Communications Towers

Much caution must be used when estimating the number of birds killed at communications towers. Too little is known about mortality rates at towers and the many factors that may potentially influence these rates. The observed decline in avian mortality at communications towers, scavenger impact of the number of birds collected,

and regional differences in migration and weather patterns all influence estimates of mortality. Until further research is completed, no estimate of mortality can be considered very accurate.

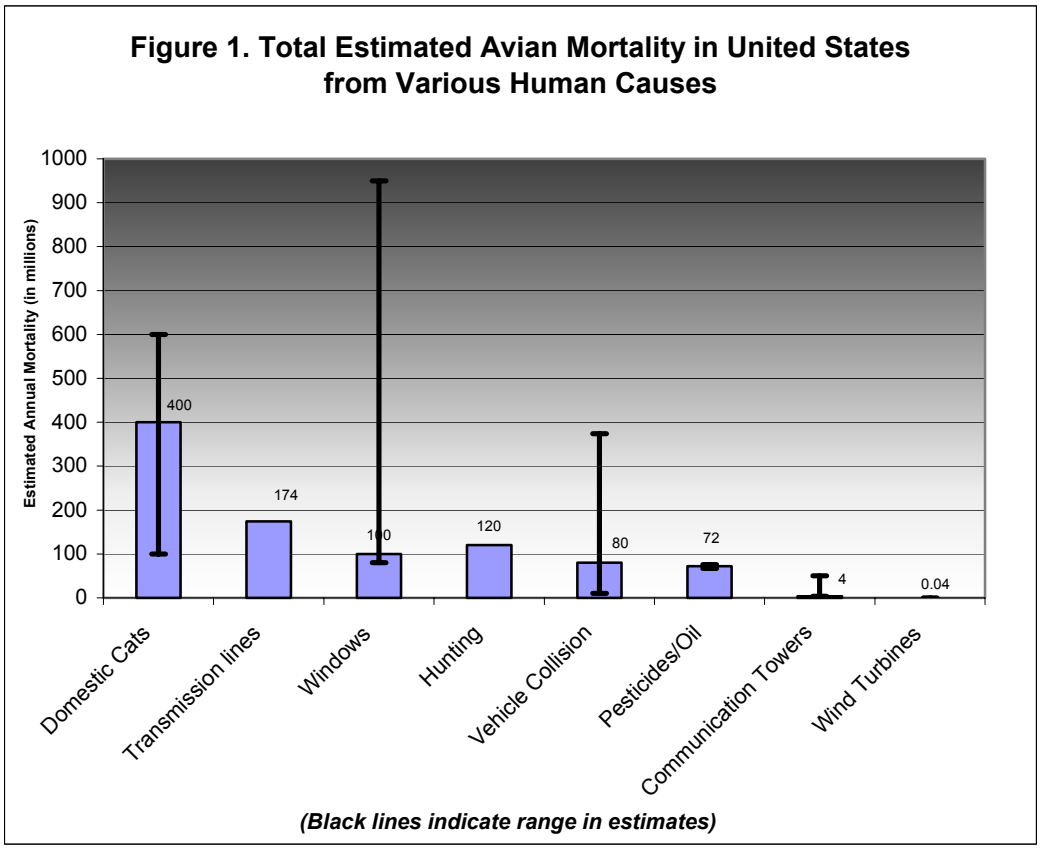
Very few estimates of annual bird mortality at communications towers have been made. Because so little is known about the differences in mortality between towers, and tower locations, it is impossible to make an accurate estimate. Banks (1979) estimates that approximately 1.25 million birds are killed annually in the United States at television transmitting towers. His estimate is based on mortality rates from tower studies by Stoddard (1962), Avery *et al.* (1975) and Taylor and Anderson (1973). At the time of his estimate, these studies estimated kill rates of approximately 2,500 birds per tower per year. The FCC provided him with the number of television transmitting towers in 1975 as 1,010, but no statistical breakdown on height, location, power, or other factors was provided. He concluded that if half of these 1,010 towers had similar mortality rates to the towers in the 3 studies, than an estimate of annual mortality would be 1.25 million birds. The number of communications towers has increased dramatically since the time of Banks' estimate. Erickson *et al*. (2001) reports that based on Banks' estimates and models developed by the Tall Timbers Research Institute and Bill Evans, estimates likely range from four to five million birds a year. Some experts believe this estimate could be off by an order of magnitude.

3.1.9 Human-caused Mortality in the Context of the Total Avian Population

An accurate evaluation of the relative impacts to bird populations caused by various sources of human-caused mortality would require species-specific population information and species-specific risk assessments for each type of mortality. To date, neither type of information exists. Breeding Bird Surveys and migration studies have tracked population changes in specific geographic areas, but little effort has been made at assembling all of this information together to create nationwide population estimates. The American Ornithologists' Union (AOU) (1975) estimated a breeding bird population of 10 billion in the United States in 1975, with the fall population estimate being 20 billion. Bird populations fluctuate dramatically depending on the season, and because many common

bird species are relatively short-lived, the survival of young from a particular year can be very important to the overall population. Therefore, it is important to consider the potential effects that human-caused mortality may have on the stability of bird populations. There is no evidence in the literature that we have been able to identify that states that communications towers are having a statistically significant impact on migratory bird populations.

Each individual source of mortality mentioned in this report represents a relatively small percentage of the total bird population as estimated by the AOU (Figure 1), with communications towers being one of the smallest of all the factors identified. Adding together the most likely estimates of annual bird mortality due to the major human-caused components yields a total mortality estimate of about 950 million, with lower and upper estimates ranging from between 381 million to 2.3 billion deaths per year. Using the 1975 AOU estimates of total bird population, these numbers represent a potential mortality estimate of about six percent. Accordingly, the avian mortality attributable to towers would be approximately 0.42 percent of human caused mortality and only 0.05 percent of total bird populations (based on an estimated bird population of 10 billion birds). Because so little is known about the overall bird population in the United States, caution should be employed when assessing the potential impact of human-caused mortality sources on bird populations.



3.2 OVERVIEW OF PEER-REVIEWED SCIENTIFIC STUDIES AND INCIDENTAL REPORTS AND OBSERVATIONS

The majority of the information documenting avian mortality at communications towers comes from non-peer-reviewed publications that issue incident reports of relatively large "kills" at individual towers. The peer-reviewed journals contained a mix of incidental mortality reports and scientific studies concerning avian mortality and towers.

The matrix analysis of studies published in peer-reviewed journals focuses on 21 journal articles. Seven of these articles were published in regional journals and are generally weaker scientifically. Most often these studies focused on a limited number of collection days over one or two seasons or did not have a detailed description of methods and results. The remaining 14 journal articles were published in nationally distributed scientific publications and were part of 7 main studies of mortality at communications

towers. The quality of these studies varies. The percentage of studies containing information used in the scientific study matrix is contained in Table 1.

For this analysis, 173 incidental reports of avian mortality at communications towers were also reviewed. As expected, the amount and quality of data provided in these reports varies widely. The percentage of incidental reports containing specific information used in the incidental mortality matrix is documented in Table 1.

Table 1. Percent Available Data for Incidental Reports and Scientific Studies

Categories	Incidental Reports (Percentage)	Scientific Studies (Percentage)
Topographic Location	16	38
Tower Elevation	13	69
Weather	45	NA
Survey Effort	0	15
Tower Height	40	100
Guy Wires	18	92
Tower Lighting	10	77
Total Fatalities	99	100
Number of Species	73	100
Scavengers	NA	85

3.3 FACTORS AFFECTING MORTALITY

An evaluation of each of the individual factors assessed by Woodlot during the analysis is presented below. Included in the evaluations are findings for the peer-reviewed scientific studies and the incidental reports and observations, as well as a general discussion of these results.

3.3.1 Tower Location

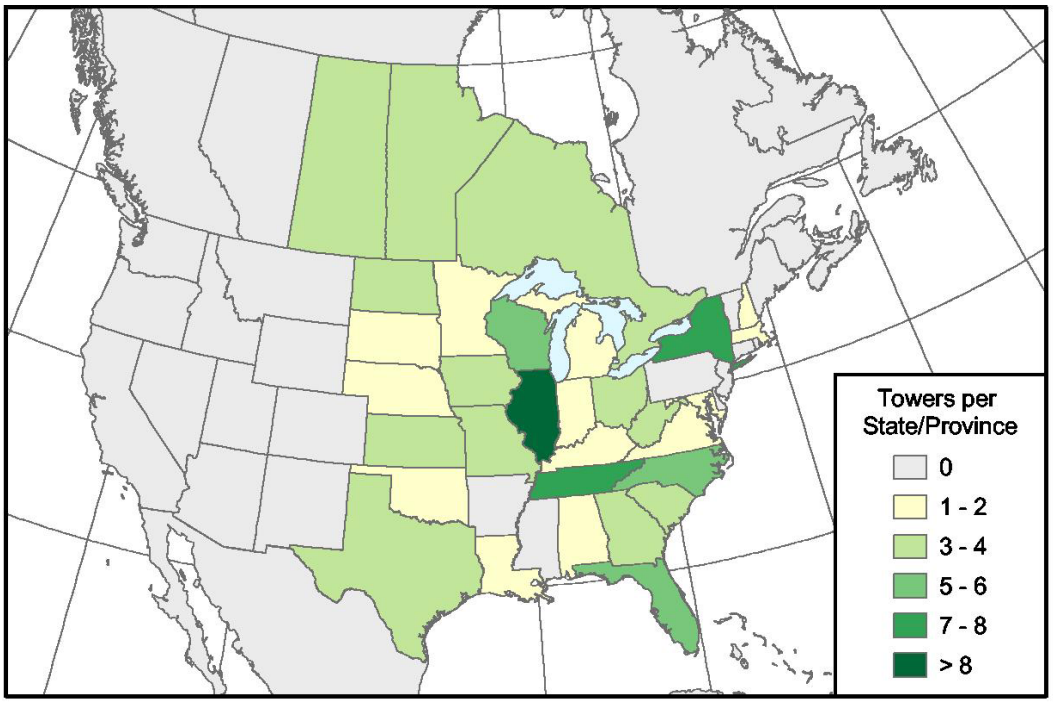
Peer-reviewed Scientific Study Findings

Studies involving avian mortality at communications towers have been limited to nine states, primarily east of the Mississippi River. There are no indications that tower selections made for these studies were randomized or that they are representative of similar towers in other states. Rather, the potential exists that these tower locations were specifically studied because of a documented mortality incident. Consequently, findings relevant to this factor are likely biased.

Findings on Incidental Reports and Observations

A significant degree of geographic bias also exists among the incidental reports, with only 26 states and 3 Canadian provinces documenting incidents of mortality (Figure 2). No State west of Kansas, Nebraska, and Texas reported tower related avian kills. Again, it is important to note that these reports are not scientific studies. Sites were not randomly selected and no control was established. While the geographic location of incidental reports may be influenced by the number of tower kills associated with certain regions, these reports may also be heavily biased by proactive individuals or groups that occasionally monitor towers in their home state.

Figure 2. Number of Towers Per State/Province With Documented Avian Mortality.



Discussion

The lack of reports of tower kills in the western United States is an interesting finding. Too little is currently known about the specific regional factors that contribute to tower kills to make any conclusions on this geographic bias. Factors that may contribute to this phenomenon could include: a lack of cloudy/foggy conditions at towers in the west during spring and fall migration; differences in overall abundance of migrating birds in the west; and the species composition of western migrations. The two most common species found in eastern tower kills are the ovenbird (*Seiurus aurocapillus*) and the red-eyed vireo (*Vireo olivaceus*), both birds having an eastern distribution.

3.3.2 Topographic Location

Peer-reviewed Scientific Study Findings

Of the 12 main studies on avian mortality at communications towers, 8 (67%) provide specific information of topographic position. Towers were located primarily on hills or in agricultural fields. No studies analyzed topographic location as it relates to avian mortality. The limited numbers of studies combined with the lack of reporting in this

field does not allow for analysis of this factor in the matrix. None of the studies reported being within five miles of the coast.

Findings on Incidental Reports and Observations

Only 28 of 173 (16%) incidental reports contained information on the topographic location of towers. Tower locations included hilltops, ridgelines, mountains, plateaus, and agricultural fields. The incidental reports provided no information on the proximity of tower locations to coastlines. Due to the limited amount of data in this field, no trends were observed between topographic location and avian mortality at communications towers.

Discussion

Waterfowl migration is often categorized into specific routes called flyways. The flyway concept does not apply to the same degree to neo-tropical migrants. Songbird migration generally occurs across broad fronts in continental areas and not along specific routes (W.J. Richardson, pers. comm. in Odgen 1996). However, neo-tropical migrants have been shown to congregate in certain areas. During autumn passerine migration, a greater percentage of immature birds have been noted in coastal areas. It is hypothesized that these birds are more likely to stop in coastal areas after migrating over a body of water, where adult birds tend to land further inland (Murray 1966 in Ogden 1996). Dunn and Nol (1980) conclude that immature birds migrating south are more likely to hesitate at flying over the Great Lakes and often turn back and land on the shore towards the end of a migratory flight. This phenomenon has also been observed over the east coast of North America, where birds have been observed flying back to the coast near dawn at the end of the nights migratory flight (Richardson 1972).

3.3.3 Elevation

Peer-reviewed Scientific Study Findings

Of the 12 main studies, 8 (67%) report on tower elevations above sea level. No correlation is made in any of the studies between tower elevation and avian mortality. None of the studies report on the elevation of the tower in relation to the surrounding

landscape. This factor is important in that a 1,000-ft tower in an agricultural field in Kansas is substantially lower than a 1,000-ft tower located on a 1,000-ft hill on the east coast.

Findings on Incidental Reports and Observations

Information on tower elevation varied between incidental reports. Of the 23 studies reporting on elevation, five (22%) gave elevations of the base of the tower in relation to the surrounding landscape and the remaining gave the tower elevation above sea level. This limited reporting did not provide significant data to observe any trends in tower mortality and elevation.

3.3.4 Year

Peer-reviewed Scientific Study Findings

Twenty studies were reported during the period from 1955 to 1999.

Findings on Incidental Reports and Observations

Dates of incidental reports reviewed for the matrix ranged from 1954 to 1999. Table 2 summarizes the number of incidents and incidents of mass mortality per decade. In general there has been a decrease in published accounts of incidents of avian mortality and incidents of mass mortality at towers since the 1970s. This trend corresponds to observed decreases in numbers of bird mortalities at towers (Crawford and Engstrom 2001, Morris *et al.* 2003, and Nehring and Bivens 1999) and discussed in Section 1.13.1. This general trend in the incidental reports may, however, be biased by factors such as public interest in monitoring and reporting on tower kills.

Table 2. Incidental Reports of Avian Mortality by Decade

Decade	Total Incidents	Mass Mortality (>100)	Mass Mortality (>1000)
1950s	24	15	2
1960s	96	44	4
1970s	37	23	4
1980s	7	5	0
1990s	8	2	1

3.3.5 Season

Peer-reviewed Scientific Study Findings

Three studies specifically examined seasonal (spring versus fall) mortality at communications towers. Several others studies discussed the seasonal pattern of mortality in regards to their findings. In Florida, approximately 70 percent of the fatalities occurred in fall migration (Sep – Nov) (Crawford and Engstrom 2001). In North Dakota, approximately 54 percent of the fatalities occurred during fall migration and 46 percent occurred in spring. Most of the fall fatalities were vireos and warblers (Avery *et al.* 1978). Kemper (1996) looked specifically at the dates associated with spring and fall migration tower fatalities in Wisconsin and the differences in species composition between these seasons. He did not give percentages for the mortality in spring versus fall. In Illinois, Brewer and Ellis (1958) report that mortality was 10 times greater in the fall than in the spring. Studies by Morris *et al*. (2003) and Nehring (1999) were limited to the fall months after initial results determined that this was the only season when significant mortality was observed.

Though Crawford and Engstrom (2001) document that avian mortality occurs primarily during spring and fall migration, small kills are reported throughout the year. Avian mortality was documented on 3,579 days of the approximately 10,585-day (29-year) study at the WCTV tower in Tallahassee, Florida. On average, some mortality was observed approximately every third day.

Findings on Incidental Reports and Observations

One-hundred-fifty-seven of the incidental reports occurred during the fall migration. Thirteen reports were from the spring and the other two were from the winter. This trend in tower kills during the fall months corresponds to fall mortality documented in a number of long-term studies (Crawford and Engstrom 2001, Avery *et al.* 1978). Again, much bias is introduced here because of many tower observers visiting tower sites only during fall migration when tower kills are most frequently documented to occur. The large kill of Lapland longspurs in Kansas during the winter (Evans 1998) can be considered an abnormality. These birds were not migrating at the time of the kill. Apparently a heavy snowstorm caused the birds to fly at night in search of bare ground and a dense fog caused the birds to become disoriented around a Kansas tower (Evans 1998). A similar kill occurred during a snowstorm on March 28, 1965, at a 1,117-ft tower in South Dakota when 578 horned larks were killed. Many of these birds were killed hitting the lighted windows of the transmitter building (Pierce 1969).

Discussion

Stoddard (1962) examines some factors that may contribute to the seasonal variation in mortality at communications towers. He reports that the tendencies of larger and more frequent kills in the fall are partly due to the large number of young birds making their first migration south. Older, more experienced birds that return in the spring may also be better prepared for dangers that may confront them. Certain species in this region also have elliptical migration patterns, traversing the western part of the Gulf of Mexico in the spring and the eastern part in the fall (Rappole *et al.* 1979 in Crawford and Engstrom. 2001).

The work of Avery *et al.* (1975) in North Dakota supports the hypothesis that certain species migration patterns shift seasonally, affecting tower mortality numbers. They found several species exhibited greater mortality in the spring than fall though overall mortality for all species was higher during the fall migration. Avery also reports that other factors that may affect the seasonal pattern of mortality could include weather patterns during spring and fall migrations and altitudes at which various species migrate.

After continued work at the same tower in North Dakota, Avery *et al.* (1978) goes on to hypothesize that some species of migrants that breed locally in that area are more susceptible to tower kills during the spring as they search for breeding habitat. He based this hypothesis on the greater proportion of locally breeding birds in the spring kills.

3.3.6 Weather

Peer-reviewed Scientific Study Findings

Many observers have reported that most nocturnal fall migrants are killed when the winds are from the north and there is substantial cloud cover. In Florida, Crawford's study (1981b) lends strong support to this general view. In a 5-year study, he found that 83 percent of the mortality occurred with north winds. He also found that 82.3 percent of the fatalities occurred on cloudy nights, despite the fact that cloudy conditions occurred 50.9 percent of the time. Not surprisingly, the greatest rate of mortality occurred after a cold front when it was cloudy and winds were from the north (Crawford 1981b).

In North Dakota, large numbers of fall fatalities occurred following a cold front under cloudy conditions with northerly winds, consistent with other studies (Avery *et al.* 1977). Additional behavioral research at this site revealed that birds congregated near the tower on cloudy nights and were killed near the tower (Avery *et al.* 1976). However, spring losses were not generally characterized by large kills. Spring fatalities were more regular and often occurred on clear nights (Avery *et al.* 1977). The proportion of birds killed by guy wires further away from the tower was much greater in spring than in the fall (Avery *et al.* 1976).

Findings on Incidental Reports and Observations

Seventy-seven of the incident reports contained some weather information. The detail of this information varies widely; with some reports documenting a number of weather factors and others reporting only that a cold front had passed. All of the incidental reports occurred during conditions of either clouds, low ceiling, rain, fog, cold fronts, and/or hurricanes. This trend is well supported by studies of avian mortality at communications towers (Crawford 1981b, Avery *et al.* 1977). Bias is again introduced

here because the general trend of avian mortality at communications towers is documented to occur during periods of inclement weather during fall and spring migration and most tower visits occurred primarily during these time periods.

Discussion

There is general agreement that most fall bird fatalities occur following a cold front with cloudy or foggy conditions and northerly winds. This is well documented by several studies (Crawford 1981a; Avery *et al.* 1976, 1977) and is widely reported in the incidental reports. The behavioral research in North Dakota (Avery *et al.* 1976) demonstrated that under cloudy conditions birds congregated near the tower, presumably attracted to the lights. Lights were turned off for a short period and the number of birds and call notes declined markedly when it was dark. Once the lights were switched on the number of birds increased rapidly (Avery *et al.* 1976). The reasons why birds become disoriented and are attracted to light are unclear.

3.3.7 Years of Study/Search Frequency/Survey Effort

Peer-reviewed Scientific Study Findings

The duration, sampling frequency, and survey effort varied substantially among the published studies reviewed. The length of these studies varied from 1 to 38 years. Search frequency varied from intensive daily searches to infrequent survey effort, sometimes as few as four times in a fall. Actual survey effort also varied substantially and was usually not fully described.

Only 4 studies continued for more than 10 years (Appendix A). In Florida, a 29-year study used daily surveys (e.g., 270 survey days in 1956) starting at dawn on a 20-acre (8-ha) area that was mowed weekly (Crawford and Engstrom 2001). In Tennessee, a study was conducted for 38 years, and the tower was checked daily in September and October (Nehring and Bivens 1999). Two long-term studies in New York (30 years) and Ohio (19 years) were conducted; however, these studies averaged only 11 visits per fall (range, 4 – 33) (Morris *et al.* 2003).

Findings on Incidental Reports and Observations

Search effort was not documented in any of the incidental reports of mortality. There were no descriptions of the area searched or the amount of time spent searching.

Discussion

Because these studies vary so widely in duration, sampling frequency, survey effort, and seasonality, it is very difficult to use them collectively to try and determine underlying causes of avian mortality. Despite these wide differences, the fact that so many studies identified the major mortality factor for fall migrants as cloudy weather coinciding with northerly winds lends strong support to the generality of the importance of this finding.

3.3.8 Tower Height and Guy Wires

Peer-reviewed Scientific Study Findings

No studies have specifically analyzed the role of tower height on avian mortality in relation to different towers and tower locations. Most towers studied (91%) in the analysis of peer-reviewed studies were found to be greater than 900 ft tall (21 of 23 towers) and with guy wires. No general trend was observable in regards to tower height and guy wires when analyzing the peer-reviewed studies, which may be due to the limited number of towers that have been studied and the bias towards taller towers. The Florida study (Crawford and Engstrom 2001) was the most interesting study relevant to tower height. When the original 670-ft tower was replaced by a 1,010-ft tower in 1960, they detected no statistically significant difference in the numbers of birds killed in September and October between the two tower heights. In this analysis they controlled for weather conditions, knowing that cloud ceiling heights had been shown to influence mortality at this tower. In 1989, the tower was shortened from 1,008 ft to 284 ft. Based on data collected in 1999 and 2000, the shorter tower resulted in a decrease in the number of avian fatalities (Crawford and Engstrom 2001).

There is little evidence of a threshold of tower height that is more dangerous to birds. Seets and Bohlen (1977) found kill numbers from towers of comparable heights in central Illinois varied widely on a single night. Avery and Clement (1972) also report on a wide

range of avian mortality numbers on a single night from towers of similar height and location in North Dakota. Kemper's work in Wisconsin demonstrated that the 505-ft tower he was studying had little impact on birds until the height was increased to 984 ft. He estimated the lethal tower height threshold to be approximately 400 ft (Kemper 1996). It is unclear why Kemper chooses the 400-ft threshold of tower height, when he saw little mortality at the 505-ft tower he was observing.

Findings on Incidental Reports and Observations

Sixty-nine of the 170 incidental reports reported on tower height. No general trend in tower height is observable when analyzing tower height versus number of avian mortalities at each of these towers. However, when looking at just the towers that have documented occurrences of mass mortality (i.e., over 100 fatalities), the tallest towers have the greatest incidents of large kills (Table 3). Towers in these reports were not randomly sampled so a large amount of bias may occur here. People reporting on tower kills are also likely to visit a taller tower over a shorter one when time is limited.

Table 3. Tower Height Compared to Number of Mass Mortality Events

Tower Height	Number of Mass Mortality Events (>100 fatalities)
0-500 feet	5
500-1000 feet	12
Over 1000 feet	16

Thirty-two of the incidents of avian mortality reported on the presence of guy wires. No observable trend can be reported due to the limited reporting on this factor and the likelihood that most of the towers reported on have guy wires.

Discussion

The effects of tower height on avian mortality have yet to be studied in depth. Conclusions by Crawford and Engstrom (2001) indicate towers less than 295 ft may not present a serious threat to migrating birds. It is unclear whether these findings would be

applicable to other towers or other sites. Manville (2000) asserts, "The taller the tower, the more likely it will be to kill birds." He doesn't cite specific evidence or studies when making this claim, but speculates there may be a correlation because the taller the tower the greater likelihood of guy wires and the subsequent risk of avian collision. However, due to the current lack of available data or research, a 1,000-ft tower in an agricultural field in the mid-west cannot be realistically compared to a 1,000-ft tower on a 1,000-ft hill on the east coast. Until research is completed that examines a range of tower heights in different geographic and topographic locations, no specific conclusions can be made.

3.3.9 Tower Lighting

Peer-reviewed Scientific Study Findings

Several studies explore the effects of tower lighting on migrating birds during cloudy and foggy weather (Avery *et al*. 1976, Crawford 1981b, Cochran and Graber 1958). No studies, however, have been published on the particular effects of different tower light schemes on avian mortality.

Observations of avian attraction to communications tower lights has been reported by Cochran and Graber (1958) and Avery *et al*. (1976). Cochran and Graber (1958) examined the frequency of call notes in the vicinity of a lighted tower during nights with low cloud ceilings. They found that the frequency of call notes decreased when tower lights were turned off and increased again when the lights were turned on. This effect was not observed on clear nights. Avery *et al.* (1976) used a portable ceilometer to examine the behavior of birds in the vicinity of a lighted communications tower. Their results showed that on overcast nights, nocturnal migrants congregated around red warning lights of the tower in their study. On clear nights, significantly fewer birds were observed at the tower. They hypothesize that the lights of the tower do not draw birds from a distance, but birds passing close by on cloudy nights enter the illuminated area and are reluctant to leave.

Findings on Incidental Reports and Observations

Seven of the 173 incidental reports (4%) provide information on the specific lighting scheme and colors of tower lights involved in avian fatalities. Since all but one of the towers in the incidental reports is over 200 ft, the FAA requires that they be lit. The low incidents of reporting here do not allow for any analysis of trends.

Discussion

On cloudy and foggy nights, tower lights create a lighted area as light reflects off water particles in the air. Graber (1968) hypothesizes that when birds enter a lighted area they are hesitant to fly into the dark beyond. His hypothesis was based on observation of birds in a lighted room that will not fly into a darker one. Birds trapped in the lighted area of the tower often fly around until they collide with guy wires or become exhausted. This hypothesis is supported by limited radar work completed by Larkin and Frase (1988), in which they found that on cloudy nights some birds circled (at least partly) a tower at altitudes below the towers top. This circling affect was not observed on clear nights at the same tower. Graber's hypothesis, however, is yet to be systematically studied.

At the "Avian Mortality at Communications Tower" workshop held in 1999, Dr. Sidney Gauthreaux presented some unpublished work on tower lighting. He examined the influences of red light and white strobe lighting on the flight and orientation of nocturnally migrating birds. He found that circling and hovering behavior was exhibited more at red-lighted towers than at towers with white strobes and a control site. The specific methods used to determine this finding were not available in this abstract (Gauthreaux 2000). Until this work is published it is not possible to comment on his findings.

The USFWS's interim guidelines in regards to tower lighting are based largely on the above published and unpublished studies. Several studies document the effects of tower lighting on migrating birds during cloudy and foggy weather (Avery *et al*. 1976, Crawford 1981b, Cochran and Graber 1958). No studies have been published, however, on the effects of particular lighting schemes and colors as they relate to avian mortality.

3.3.10 Tower Signal

Peer-reviewed Scientific Study Findings

No published studies have been conducted looking at the specific role of tower signals on avian mortality. Cochran and Graber (1958) and Avery *et al.* (1976) both note that no differences in birds behavior were observed at the towers in their studies when the signal was turned on and when it was turned off. Taylor and Anderson (1973) report that major tower kills occurred at the tower in their Florida study, both when the signal was turned on and when it was off.

3.3.11 Scavenger Impact

Peer-reviewed Scientific Study Findings

Scavenger activity was reported from almost every study. This is a significant issue because scavengers can have a strong effect on the number of birds remaining beneath a tower long enough to be collected by a researcher. Despite the number of incidental observations of scavenger activity at communications towers, only two studies calculated the rate of bird carcass removal by scavengers. In Florida, Crawford (1971) placed marked birds beneath the tower on five different nights. He found that approximately 93 percent of these birds were removed or damaged by 9:00 am the following day. In North Dakota, scavenger rates were 7.4 percent (range: 2.4 in spring 1972 and 17.6 in spring 1973) (Avery *et al.* 1978).

Discussion

Crawford (1971) and Crawford and Engstrom (2001) provided convincing evidence of the need to document the effects of scavengers on avian mortality numbers from communications towers. Crawford made substantial efforts to control scavengers for much of the study. When scavenger control efforts were terminated, there was a 71 percent decline in birds found under the tower, suggesting a strong scavenger effect. Avery *et al.* (1978) found a lower scavenger rate (7.2%), which suggests that there could be regional differences, or other contributing factors, determining the number of carcasses removed by scavengers. These findings have very important implications for

any study of tower kills. Adequate documentation of avian related mortality will require better estimates of scavenger removal rates.

Scavenger rates are calculated by placing bird carcasses out at night and calculating the rate at which they are removed over time. Gauthreaux (1999) comments that this method of calculating scavenger rate may be inaccurate because predators such as the great horned owl, may cue in of the motion of the bird hitting the ground. This factor should be further analyzed in any future studies on scavenger impacts.

3.4 FATALITIES AND SPECIES COMPOSITION

3.4.1 Total Fatalities and Mean Annual Fatalities

Peer-reviewed Scientific Study Findings

Only two studies were conducted in both spring and fall; these are the only studies to provide convincing data relating to annual mortality rates. Total reported fatalities were strongly affected by study length and search frequency. Not surprisingly, long-term studies account for a greater number of fatalities.

In Florida, a total of 44,007 individuals of 186 species were found under the tower during the 29-year period (Crawford and Engstrom 2001). Days when a single bird was killed (3,579, approximately 33% of the days when birds were found) accounted for only 2.7 percent of the total fatalities (Crawford and Engstrom 2001). In North Dakota, a total of 937 individuals of 102 species were found under and near the tower during the 3-year period. Six separate studies provided sufficient data and had sufficient sampling effort to give a reasonable estimate of annual fatalities (Appendix A). In Florida, annual mortality was estimated to be 1,517 individuals (Crawford and Engstrom 2001). In North Dakota, annual mortality was estimated to be approximately 1,075 individuals (Avery *et al.* 1978). Three long-term studies all noted a decline in mortality in more recent decades (Nehring and Bivens 1999, Crawford and Engstrom 2001, Morriss *et al.* 2003).

Findings on Incidental Reports and Observations

Total number of fatalities for the 173 incidents of avian mortality is approximately 53,000. This averages to approximately 300 fatalities per incident.

Discussion

Because so few (only two) studies have surveyed towers during spring and fall migrations, it is very difficult to get a clear sense of total mortality and annual mortality. This is compounded by the problem of scavengers removing dead birds. Thus, all of these studies provide a glimpse at the magnitude of avian mortality, but actual numbers should be viewed as minimal.

A number of long-term studies have documented a general decline in avian mortality at communications towers in the last several decades. Nehring and Bivens (1999) observed a significant decline in both the number of birds collected and the number of species observed at the WSMV tower in Nashville, Tennessee, from the 1960s through 1997. A contributing factor to this decline is that no large-scale mortality events have occurred since 1970. The two largest bird kills, which occurred in 1968 and 1970, make up 45 percent of the total birds killed at this tower. A lack of large bird kills and general decline of mortality overall has been observed at this tower over the last 30 years.

Nehring and Bivens discuss several factors that may be affecting this decline. They comment that scavengers have been well documented under the tower and may be removing a large number of birds before they can be collected. No effort has been made to calculate scavenger impact or control scavengers at this site. Crawford and Engstrom (2001) believe a significant proportion of the decline in avian mortality at the WCTV tower in Florida is related to scavengers. Nehring and Bivens also report that the long-term decline of mortality at the Nashville tower may also be related to the growth of Nashville. Since the tower was first constructed, there has been significant development in that area. They hypothesize that light pollution from the surrounding city may have made the towers lights less attractive to migrating birds or that migrants may be adjusting their migratory route overall to avoid the Nashville area. Goodpasture (1984) also was

involved with this study and notes that the overall decline in avian mortality could be related to a general decline in the migrating bird population.

Morris *et al.* (2003) documents declines of avian mortality at three towers in New York and one in Ohio from 1970 to 1999. Regression analysis of her results showed declines at all four towers was statistically significant. In addition to the potential factors that may contribute to this decline, she suggests that both changes in weather patterns and an evolutionary decrease in the attraction of tower lights to birds may be factors. Specifically a decrease in foggy nights, fog density, and nights with low cloud ceiling, which have been shown to cause large mortality at towers, may be a contributing factor in the decline of overall mortality.

3.4.2 Mass Mortalities

Peer-reviewed Scientific Study Findings

Mass fatalities appear to be very infrequent events. In Florida, large kills (>100 individuals) occurred on <0.1 percent (less than 1 in a 1,000) of the days but accounted for approximately 15 percent of the total mortalities (Crawford and Engstrom 2001). In Tennessee, two very large kills occurred during the 38-year study period; 5,399 birds were found on 26 Sep 1968 and 3,487 birds were collected on 28 Sep 1970 (Nehring and Bivens 1999). In Kentucky, Elmore and Palmer-Ball (1991) reported 5 large kills (>100 individuals), the largest (1,576) on 17 Oct 1990. In North Carolina, 3,487 individuals were found dead on 28 Sep 1970 (Carter and Parnell 1976). No large kills (>500 birds) were reported in North Dakota, but the study was only 3 years long (Avery *et al.* 1978).

Findings on Incidental Reports and Observations

Eighty-three (48%) of the 173 incidents of avian mortality included kills of over 100 birds. Eleven (6%) on these incidents involved kills of over 1,000 birds.

Discussion

Although mass mortality events appear to be rare events, they can have a substantial impact on the total number of birds killed. The deaths of several thousand Lapland

longspurs in a single incident suggest that large kills could impact sub-populations of a particular species.

3.4.3 Number of Species and Common Species/Percent Neo-tropical Migrants

Peer-reviewed Scientific Study Findings

Most papers (8 of 10) reported that neo-tropical migrants accounted for >70 to 99 percent of the total tower-associated mortalities (Appendix A). For example, in Tennessee, neo-tropical migrants accounted for >90 percent (Nehring and Bivens 1999) and in Florida, more than 94 percent were neo-tropical migrants (Crawford and Engstrom 2001). Results from North Dakota were quite different, where approximately 46 percent of the kills were neo-tropical migrants (Avery *et al.* 1978).

Findings on Incidental Reports and Observations

The number of species comprising the kills was documented in 173 of the incidental reports. The greatest species diversity was 75 from 2 separate kills in North and South Carolina. In general, Tennessee had the largest number of kills with the greatest diversity.

One-hundred-three incidental reports document common species from tower kills. The majority (~80%) of the common species are neo-tropical migrants. Warblers and vireos were the most common groups of birds in the incidental reports, with ovenbirds and red-eyed vireos being the two most common species.

3.4.4 Data Quality Review of Scientific Studies

Understanding the scientific protocols and methods used by researchers in their studies was a key component of the literature assessment. Most of the literature cited, particularly those involving observations and incidental reports, was found to be of limited scientific value. Referring to some aspects of the FCC's Data Quality guidelines (transparency and reproducibility), we used these criteria to assess the 27 peer-reviewed studies used in this review. In accordance with these guidelines, published papers were required to 1) have a research protocol with a clearly described methods section; 2)

maintain sufficient metrics for statistical analyses; 3) have clearly stated results; and 4) have reproducible results. The studies that appeared to meet these criteria were published in peer-reviewed scientific journals. We found that 19 studies met the above criteria as discussed in the guidelines and 8 studies were doubtful in this regard (Table 4). None of the 173 incidental reports of avian mortality met the FCC Data Quality guidelines for transparency and reproducibility.

Table 4. Assessment of Data Quality for Transparency and Reproducibility

Study	Meets Criteria (Y/N/Doubtful)
Avery and Clement 1972	Y
Avery *et al.* 1975	Y
Avery *et al.* 1976	Y
Avery *et al.* 1977	Y
Avery *et al.* 1978	Y
Brewer and Ellis 1958	Y
Crawford 1971	Y
Crawford 1978	Y
Crawford 1981a	Y
Crawford 1981b	Y
Crawford and Engstrom 2001	Y
Goodpasture 1984	Y
Howell *et al.* 1954	Y
Larkin and Frase	Y
Morris *et al.* 2003	Y
Nehring and Bivens 1999	Y
Seets and Bohlen 1977	Y
Stoddard 1962	Y
Taylor and Anderson 1973	Y
Boso 1965	Doubtful
Carter and Parnell 1976	Doubtful
Carter and Parnell 1978	Doubtful
Cochran and Graber1958	Doubtful
Elmore and Palmer-Ball 1991	Doubtful
Herron 1997	Doubtful
Kemper 1996	Doubtful
Strnad 1975	Doubtful

4 CURRENT RESEARCH

4.1 MICHIGAN STUDY REVIEW

In the FCC's August 20, 2003, NOI a request is made for comments on the need for and scope of additional study. As already discussed in this report, there are few scientifically rigorous studies on the impacts of communications towers on migratory birds. Recognizing this, the State of Michigan Departments of State Police and Information

Technology developed an avian collision study plan for the Michigan Public Safety Communications System (Gehring 2003). This plan was developed in conjunction with P. Kerlinger (Curry and Kerlinger) and A. Manville (USFWS). The study contains a provision for implementing a pilot study in the fall of 2003 to collect data expected to be useful in bolstering the main study design. The primary objectives of the full study are to assess the role of lighting, height, and guy wires on avian mortality associated with several types of towers. A study of this nature, if successful in segregating out the effect of each of these factors, would add greatly to the understanding of avian collisions. Regardless, the regional limitations of the study, the regulated two-year time period, and overall limited number of tower types will likely continue to constrict researchers in developing a full and comprehensive understanding of the potential effects communications towers may have on avian mortality.

The following comments were generated following a review of the full and pilot study plans. Comments are presented following the order of sections in the study plan.

- Overall this appears to be a solid research proposal, especially with the adjustments of a pilot study and power analysis of preliminary data.
- It is unclear whether a 2-year study will be long enough to answer the questions raised in the proposal.
- It is unknown whether results from the Michigan study will be applicable to other parts of North America. There are many species of migratory birds that will not be observed by the Michigan study. Possible results regarding tower height might be applicable to other areas, but differences in topography could mean that the Michigan results would not be applicable to areas of different landscape context. It is also unclear whether birds migrate in the same manner in different parts of the country, so factors such as height, geographic location, and response to topography may differ in different areas.

Proposal and Scope of Work

Summary of Hypotheses to be Tested

- Two of the three independent variables, guy wires and height, may not be truly independent. The study plan would benefit from a discussion on how these variables will be treated statistically *a priori*.
- "taller towers" and "shorter towers" should be defined.
- It will be beneficial to test the hypothesis of differences in collision based on tower proximity near and away from shorelines; however, a discussion on the rationale for using the 5-mile range distance would enhance the study plan.
- The hypotheses are clearly written and applicable.

Design Methodology

- This section provides a foundation for a potentially robust statistical design; however, the details of the statistical design need to be presented in much greater detail. A drawback with matched-pair design is that as the number of features requiring matching increase, the size of the required sample pool increases. It is unclear whether the proposed sample design will be able to address this factor.
- A power analysis should be conducted *a priori* using expected variability in mortality from published avian studies to estimate sample sizes needed to achieve the desired power. The pilot study discusses the need to perform such an analysis, but does not describe the mechanics of the analysis or present a draft analysis. Data from the pilot study, however, should help determine whether the sample sizes are sufficient for the major study.
- A quality assurance/quality control (QA/QC) plan should be developed for each phase of the study, including project management, data generation and acquisition, assessment and oversight, and data validation and usability.
- The work plan should discuss in detail the data quality objectives and how the standards of precision, accuracy, completeness, representativeness, comparability, and sensitivity will be met. The work plan would benefit from the inclusion of a table showing the type of field or office activity, each specific measurement endpoint, the minimum frequency of check by the field survey lead or principal scientist, and acceptance criteria.

Constraints and Caveats

- The study plan would benefit from a more detailed discussion of how weather data will be specifically collected and recorded and how it will be treated in the statistical analysis.

4.2 OTHER ONGOING RESEARCH

The following researchers were contacted regarding current research in the field of avian mortality and communications towers: Dr. Ronald Canterbury, Arthur R. Clark, Bill Evans and Dr. Sidney Gauthreaux. At the time of this publication, only Arthur Clark and

Bill Evans had responded to email and phone requests for information. Extensive conversations with Clark and Evans indicated little additional research had been completed on bird collisions with towers. Neither researcher was aware of ongoing research that was near completion or publication. Bill Evans is presently working on several projects in New York. Arthur Clark indicated he expected to collaborate with researchers from Canisius College to analyze the long-term data set from the Buffalo, New York, region (Morris *et al.* 2003).

5 SUMMARY

- Estimates of avian mortality attributed to human causes vary widely. It is not currently well understood what overall influences this mortality may be having on bird populations. Avian mortality due to domestic cats, buildings, transmission lines, pesticides and vehicle collisions are all thought to have a much greater impact on the avian population than collisions with communications towers.

- There have been many incidental reports of avian mortality at certain communications towers. The quality of information in these reports varies widely, with no standard methodology used in collection of data. Due to the to the incidental and biased nature of these reports it is not possible to examine specific factors that have contributed to avian mortality. These reports, however, provide some documentation of bird mortality at communications towers at many locations in the eastern and central United States.

- Very few in-depth studies on avian mortality at communications towers have been conducted. The majority of the studies have examined only single towers and made no comparisons between different towers in different sites. These studies primarily focus on mortality trends and species composition at towers. No published research has examined the host of specific factors that may contribute to mortality at towers sites.

- Several studies have documented a decline in avian mortality at communications towers over the last several decades. No research has examined the factors involved in this decrease, but researches have hypothesized that it may be due to an increase in light pollution in the vicinity of the towers, a general decline in the migratory bird population, and/or scavenger impact on the killed birds before collection.

- Weather is believed to be the most important environmental factor contributing to large bird kills at communications towers. Large kills reported in the literature are almost entirely restricted to nights with cloudy and foggy conditions, when the cloud ceiling is low.

- Lighting is believed by most researchers to be an important factor contributing to avian collisions with towers. There have been numerous recommendations regarding lighting scheme and colors, but no published research has determined which lighting factors are significant to migrating birds.

- Avian mortality at communications towers occurs primarily during the spring and fall nocturnal migrations of neo-tropical birds. Most birds are killed during the fall months. Small kills can occur throughout the year.

- Scavengers can have a large impact on the number of birds that are collected at towers. This impact appears to vary depending on tower location.

6 CONCLUSION

The most important conclusion reached after reviewing the current literature on avian mortality at communications towers is that there is a need for further research. The occurrence of some avian mortality at communications towers is well documented, but the extent of the effect of this mortality on migrating bird populations is unknown. While some well-conducted studies have been completed in this field, they primarily focus on

individual towers and the trends and species composition involved with mortality at those towers. No published research has specifically examined the factors associated with communications towers that contribute to mortality.

7 LITERATURE CITED

Able, K.P. (1963). Television tower mortality in the Niagara Frontier during fall 1962. Kingbird 13(4): 192-195.

Able, K. P. (1966). Television tower mortality near Louisville. Kentucky Warbler 42:27-28.

Able, K. P. (1968). Connecticut Warblers in the Louisville [Kentucky] area in autumn. Kentucky Warbler 44: 3-4.

Alsop, F.J., III and G.O. Wallace. (1969). Spring tower-kill in Knox County. Migrant 40(3): 57-58.

AOU (American Ornithologists' Union). (1975). Report of the American Ornithologists' Union ad hoc committee on the scientific and educational use of wild birds. Auk 92(3, Suppl.): 1A-27A.

Arnoff, A. (1949). The September migration tragedy. Linnaean News-Letter 3(1): 2

Avery, M. and T. Clement. (1972). Bird Mortality at 4 Towers in Eastern North Dakota: Fall 1972. *Prairie Naturalist.* 4:87-95.

Avery, M. L., P. F. Springer and J.F. Cassel. (1975). Progress report on bird losses at the Omega tower, southeastern North Dakota. North Dakota Academic Science 27(2): 40-49.

Avery, M. L., P.F. Springer and J.F. Cassel. (1976). The effects of a tall tower on nocturnal bird migration – a portable ceilometer study. Auk 93(2): 281-291.

Avery, M. L., P.F. Springer and J.F. Cassel. (1977). Weather Influences on nocturnal bird mortality at a North Dakota tower. Wilson Bulletin 89(2): 291-299.

Avery, M.L., P.F. Springer, and J.F. Cassel. (1978). The composition and seasonal variation of bird losses at a tall tower in southeastern North Dakota. American Birds 32(6): 1114-1121.

Bagg, A.M. (1957). The changing seasons. Audubon Field Notes 11(4): 312-325.

Bagg, A.M. (1971). The Changing Seasons. American Birds 25(1): 16-23.

Baird, J., R.I. Emery, and R. Emery. (1959). Fall migration: northeastern maritime region. Audubon Field Notes 13(1): 11-13.

Banks, R.C. (1979). Human related mortality of birds in the United States. United States Fish and Wildlife Service, Special Scientific Report—Wildlife No. 215: 16.

Barbour, R. W. (1961). An unusual bird mortality at Lexington [Kentucky]. Kentucky Warbler 37: 55.

Bartolo, B. (1976). Bird kill at [Ohio] TV tower. Redstart 43: 109.

Belcher, M., A. Binnie, and B. Binnie. (1966). The 1965 Fall Warbler Migration at Regina. Bluejay 24: 10-15.

Bevanger, K. (1994). Bird interactions with utility structures: collision and electrocution, causes and mitigation measures. Ibis 136:412-425.

Bierly, M.L. (1969). 1968 Birmingham [Alabama] tower casualties. Alabama Birdlife 17: 46-49.

Bierly, M.L. (1972). Spring 1969 tower casualties in Birmingham. Alabama Birdlife 20(1-2): 3.

Bierly, M.L. (1973). 1971 fall television tower casualties in Nashville. Migrant 44(1): 5-6.

Boso, B. (1965). Bird Casualties at a Southern Kansas TV tower. Transactions of the Kansas Academy of Science 68(1): 131-136.

Breckenridge, W.J. (1959). Spring migration: western Great Lakes region. Audubon Field Notes 13(4): 371-373.

Brewer, R and J.A. Ellis. (1958). An Analysis of migrating birds killed at a television tower in east central Illinois. Auk 75(4): 400-414.

Carter, J.H. III and J.F. Parnell. (1976). TV tower kills in eastern North Carolina. Chat 40(1) 1-9.

Carter, J. H. III and J. F. Parnell. (1978). TV tower kills in eastern North Carolina: 1973 through 1977. Chat 42: 67-70.

Chamberlain, B.R. (1957). Fall Migration: southern Atlantic Coast region. Audubon Field Notes 11(1): 15-18.

Chamberlain, B.R. (1961). Fall Migration: southern Atlantic Coast region. Audubon Field Notes 15(1): 23-26.

Churcher, P.B., and J.H. Lawton. (1987). Predation by domestic cats in an English village. Journal of Zoology 212: 439-455.

Cochran, W.W. and R.R. Graber. (1958). Attraction of Nocturnal migrants by lights on a television tower. Wilson Bulletin. 70(4): 378-380

Coffey, B.B., Jr. (1964). Two bird kills at WMC-TV, Memphis. Migrant 35(2): 53.

Coleman, J.S., and S.A. Temple. (1995). How many birds do cats kill? Wildlife Control Technology 44.

Cooley, C.D. (1977). Television tower casualties at Huntsville [Alabama]: fall, 1976. Alabama Birdlife 25(3-4): 14-15.

Crawford, R.L. (1971). Predation on birds killed at TV tower. Oriole 36(4) 33-35.

Crawford, R.L. (1978). Autumn bird Casualties at a northern Florida TV Tower: 1973-1975. Wilson Bulletin 90(3): 335-345.

Crawford, R.L. (1981a). Bird kills at a lighted man-made structure: often on nights close to a full moon. Am. Birds 35: 913-914.

Crawford, R.L. (1981b). Bird Casualties at a Leon County, Florida TV Tower: A 25 year migration study. Bulletin of Tall Timbers Research Station 22: 1-30

Crawford, R.L. and R.T. Engstrom. (2001). Characteristics of avian mortality at a north Florida television tower: A 29-year study. J. Field Ornithol 72(3): 380-388.

Cunningham, R.L. (1965). Fall Migration: Florida Region. Audubon Field Notes 19(1): 28-33.

Dinsmore, S., E. Munson, J. J. Dinsmore and G. M. Nelson. (1987). Two television tower kills in Iowa. Iowa Bird Life 57: 5-8.

Dunn, E. (1993). Bird mortality from striking residential windows in winter. Journal of Field Ornithology 64(3): 302-309.

Dunn, E.H. and E. Nol. (1980). Age-related migratory behavior of warblers. J. Field Ornithol. 51(30): 254-269

Eaton, S.W. (1967). Recent tower kills in upstate New York. Kingbird 17(3): 142-147.

Elder, W.H. and J. Hansen. (1967). Bird Mortality at KOMU-TV tower, Columbia, Missouri, fall 1965 & 1966. Bluebird 34(1): 3-7.

Elder, W.H. (1982). Television can be hazardous for [Missouri] warblers. Bluebird (St. Louis) 49(4): 9.

Ellis, C.D. (1997). Back to the Tower: Tower Killed Birds at Putnam County, West Virginia. Redstart 64: 112-113.

Elmore, J. B., Jr., and B. Palmer-Ball Jr. (1991). Mortality of migrant birds at two central Kentucky TV towers. Kentucky Warbler 67: 67-71.

Erickson, W.P., G.D. Johnson, M.D. Strickland, D.P. Ypung, K.J. Sernka, and R.E. Good. (2001). Avian collisions with wind turbines: A summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee Resource Document. Western EcoSystems Technology, Inc.

Evans, B. (1998). Telecommunications towers affect avian community. Wave-Guide Information, Tower-Related Bird Kill Rates. http://www.wave-guide.org/archives/waveguide_3/birdkill.html.

Evans, B. (1999). New York State Tower Survey. http://towerkill.com/statereports/NYR/NYsurvey-data99.1.html.

Evans, B. (2003). 1998 New York State Tower Survey. http://towerkill.com/statereports/NYR/NYsurvey-data98.2.html.

Ferrer, M., M. de la Riva, J. Castroviejo. (1991). Electrocution of raptors on power lines in southwestern Spain. Journal of Field Ornithology 62(2): 181-190.

Gauthreaux, S.A. (1999). Panel Discussion. *In* Proceedings of Conference on Avian Mortality at Communications Towers, August, 11 1999, Cornell University, Ithaca, NY. Published on the Internet at www.towerkill.com.

Gauthreaux, S.A. (2000). The behavioral responses of migrating birds to different lighting systems on tall towers. Transcripts of Proceedings of the Workshop on Avian Mortality at Communications Towers, August 11, 1999, Cornell University, Ithaca, NY.

George, W. (1974). Domestic cats as predators and factors in winter shortages of raptor prey. Wilson Bulletin 86(4): 384-396.

Gehring, J. (2003). Avian collision study plan for the Michigan Public Safety Communications System (MPSCS): Assessing the role of lighting, height, and guy wires in avian mortality associated with wireless communications and broadcast towers. Project underwritten by the State of Michigan Department of State Police and the Department of Information Technology.

Goodpasture, K.A. (1974a). Fall 1972 television tower casualties in Nashville. Migrant 45(2): 29-31.

Goodpasture, K.A. (1974b). Fall 1973 television tower casualties in Nashville. Migrant 45(3): 57-59.

Goodpasture, K.A. (1975). Nashville tower casualties, 1974. Migrant 46(3): 49-51.

Goodpasture, K.A. (1976). Nashville television tower casualties, 1975. Migrant 47(1): 8-10.

Goodpasture, K.A. (1984). Television tower casualties, Nashville, Tennessee 1976-1983. Migrant 55: 53-57.

Goodpasture, K.A. (1986). Nashville, Tennessee, television tower casualties, 1984. Migrant 57: 70-72.

Goodwin, C.E. and R.C. Rosche. (1971). The fall migration: Ontario. American Birds 25(1): 49-54.

Graber, R.R. (1962). Fall Migration – Middle western prairie region. Audubon Field Notes 16: 35.

Graber, R.R. (1968). Nocturnal migration in Illinois: different points of view. Wilson Bulletin 80(1): 36-71.

Gregory, H. (1975). Unusual fall tower kill. Bluebird 42(4): 9-10.

Hall, G.A. (1968). Fall migration: Appalachian region. Audubon Field Notes 22(1): 37-40.

Hall, G.A. (1975). The Fall Migration: Appalachian Region. American Birds 29(1): 57-61.

Herndon, L.R. (1973). Bird kill on Holston Mountain. Migrant 44(1): 1-4.

Heron, J. (1997). TV Transmission Tower Kills in Lewis County, West Virginia. Redstart 64: 114-117.

Heye, P.L. (1963). Tower fatalities. Bluebird 30(1): 7.

Hodson, N. L. and D. W. Snow. (1965). The road deaths enquiry, 1960-61. *Bird Study* 12(2): 90-99.

Hoskin, J. (1975). Casualties at the CKVR-TV tower, Barrie. Nature Canada 4(2): 39-40.

Houston, C.S. and M.I. Houston. (1975). Fall Migration- Northern Great plains Region. Audubon Field Notes 26: 76.

Howell, J.C., A. R. Laskey and J.T. Tanner. (1954). Bird mortality at airport ceilometers. Wilson Bulletin 66: 207-215.

Janssen, R.B. (1963). Destruction of bird life in Minessota- Sept 1963. Birds killed at the Lewisville television tower. Flicker 35(4): 110-111.

Johnston, D. (1955). Mass bird mortality in Georgia, October 1954. Oriole 20(2): 17-26.

Johnston, D.W. (1957). Bird Mortality in Georgia, 1957. Oriole 22(4): 33-39.

Johnston, D.W. and T.P. Haines. (1957). Analysis of mass mortality in October, 1954. Auk 74(4): 447-458.

Kale, H.W.,II, M.H. Hundley and J.A. Tucker. (1969). Tower-killed specimens & observations of migrant birds from Grand Bahama Isl. Wilson Bltn. 81(3): 258-263.

Kale, H.W.,II. (1971). The spring migration: Florida region. American Birds 25(4): 723-725, 730-735.

Kemper, C.A., D.G. Raveling, and D.W. Warner. (1966). A comparison of the species composition of two TV tower killed samples from the same night of migration. Wilson Bulletin 78(1): 26-30.

Kemper, C.A. (1996). A Study of Bird Mortality at a Central Wisconsin TV Tower from 1957-1995. Passenger Pigeon 58:219- 235

Kleen, V.M. and L. Bush. (1973). The Fall Migration: middle western prairie region. American Birds 27(1): 66-70.

Kleen, V.M. (1975). The fall migration: middlewestern prairie region. American Birds 29(1): 64-68.

Klem, D. (1989). Bird-window collisions. Wilson Bulletin 101(4): 606-620.

Klem, D. (1990). Bird-window collisions: mortality and prevention. Journal of Field Ornithology 61(1): 120-128.

Klem, D. (1991). Glass and bird kills: an overview and suggested planning and design methods of preventing a fatal hazard. In: Adams, L.W., and Leedy, D.L. eds. Wildlife Conservation in Metropolitan Environments: Proceedings of a National Symposium on Urban Wildlife. Published by the National Institute for Urban Wildlife, Columbia, MD. pp 99-104.

Lahrman, F.W. (1959). TV Tower Casuality List. Blue Jay 17: 142-143.

Lahrman, F.W. (1962). Fall Migration TV tower Kills, 1962. Blue Jay 20: 152.

Larkin, R. P., and B. A. Frase. (1988). Circular paths of birds flying near a broadcasting tower in cloud. J. Comp. Psychol. 102: 90-93.

Laskey, A.R. (1962). Migration data from television tower casualties at Nashville. Migrant 33(1): 7-8.

Laskey, A.R. (1963a). Casualties at WSIX TV tower in autumn, 1962. Migrant 34(1): 15.

Laskey, A.R. (1963b). Mortality of night migrants at Nashville TV towers, 1963. Migrant 34(4): 65-66.

Laskey, A.R. (1964). Data from the Nashville TV Tower casualties. Migrant 35(4): 95-96.

Laskey, A.R. (1968). Television tower mortality at Nashville, autumn 1967. Migrant 29(2): 25-26.

Laskey, A.R. (1969a). TV tower casualties at Nashville in autumn 1968. Migrant. 40(2): 25-27.

Laskey, A.R. (1969b). Autumn 1969: TV tower casualties at Nashville. Migrant 40(4): 79-80.

Laskey, A.R. (1971). TV tower casualties at Nashville: spring and autumn, 1970. Migrant 42(1): 15-16.

Lister, R. (1965). Fall Migration: Northern Great Plains Region. Audubon Field Notes 19(1): 48-53.

Manville, A.M. (2000). The ABCs of avoiding bird collisions at communication towers: the next steps. Proceedings of the Avian Interactions Workshop, December 2, 1999, Charleston, SC. Electric Power Research Institute.

Mollhoff, W. J. (1979). [Nebraska] tower kills. Nebraska Bird Review 47: 58.

Mollhoff, W. J. (1983). [Nebraska] tower kills. Nebraska Bird Review 51: 92.

Morris, S.R., A.R. Clark, L.H. Bhatti, and J.L. Glasgow. (2003). Television tower mortality of migrant birds in western New York and Youngstown, Ohio. Northeastern Naturalist 10(1): 67-76.

Mumford, R. E. (1960). Fall migration: middlewestern prairie region. Audubon Field Notes 14(1): 38-41.

Mumford, R. E. (1961). Fall migration: middlewestern prairie region. Audubon Field Notes 15(1): 44-46.

National Wind Coordinating Committee (NWCC). (2001). Avian collisions with wind turbines: a summary of existing studies and comparisons of avian collision mortality in the United States. Washington D.C.

Nehring, J. and S. Bivens. (1999). A study of bird mortality at Nashville's WSMV television tower. Migrant 70: 1-8.

Nero,R.W. (1962). Regina TV tower mortality May 11-12, 1962. Blue Jay 20: 151-152.

Newman, R.J. (1957). The Changing Seasons. Audubon Field Notes 11(1): 4-6.

Newman, R.J. (1958). The Changing Seasons. Audubon Field Notes 12(1): 4-9.

Nicholson, C. P. (1984). September 1984 tower kill in Knox County, Tennessee. Migrant 55: 86.

Niles, D.M., S.A. Rohwar, J.A. Jackson and J.D. Robbins. (1969). An observation of midwinter nocturnal movement and tower mortality of tree sparrows. Bird Banding 40(4): 322-323.

Norman, J. L. (1982). The Coweta [Oklahoma] TV tower kill. Bull, Oklahoma. Ornithol Soc. 15: 19-22.

Ogden, L.J. (1996). Collision Course: The hazards of lighted structures and windows to migrating birds. A special report for the World Wildlife Fund Canada and the Fatal Lights Awareness Program. Published on the web at www.flap.org.

Parmalee, P.W. and B.G. Parmalee. (1959). Mortality of Birds at a television tower in central Illinois. Bulletin of the Illinois Audubon Society 11(1): 1-4.

Parmalee, P.W. and M.D. Thompson. (1963). A Second Kill of Birds at a television tower in central Illinois. Bulletin of the Illinois Audubon Society 12(8): 13-15.

Partners in Flight. (2003). Perils Past and Present. Online PDF report accessed 11/5/03. http://birds.fws.gov/documents/PastandPresent.pdf

Peterson, P.C., Jr. (1959). TV tower mortality in western Illinois. Bulletin of the Illinois Audubon Society 11(2): 14-15.

Peterson, P.C., Jr. (1964a). Fall migration: middle western prairie region. Audubon Field Notes 18:42.

Peterson, P.C., Jr. (1964b). Spring migration: middle western prairie region. Audubon Field Notes 18: 455.

Peterson, P.C., Jr. (1965). Fall migration: middle western prairie region. Audubon Field Notes 19: 44.

Peterson, P.C., Jr. (1966a). Fall migration: middle western prairie region. Audubon Field Notes 20: 53.

Peterson, P.C., Jr. (1966b). Fall migration: middle western prairie region. Audubon Field Notes 20: 514.

Peterson, P.C., Jr. (1967). Fall migration: middle western prairie region. Audubon Field Notes 21(1): 44-45.

Peterson, P.C., Jr. (1968). Fall migration: middle western prairie region. Audubon Field Notes 22(1): 48-50.

Peterson, P.C., Jr. (1969). Fall migration: middle western prairie region. Audubon Field Notes 23(1): 64-65.

Peterson, P.C., Jr. (1971). Fall migration: middle western prairie region. American Birds 25(1): 64-66.

Piatt, J.F., C.J. Lensink, W. Butler, M. Kendziorek, D.R. Nysewander. (1990). Immediate impact of the 'Exxon Valdez' oil spill on marine birds. Auk 107(2): 387-397.

Pierce, M.E. (1969). Tall Television tower and bird migration. South Dakota Bird Notes 21(1): 4-5.

Pimintel, D., H. Acquay, M. Biltonen, P. Rice, M. Silva, J. Nelson, V. Lipner, S. Giordano, A. Horowitz, and M. D'Amore (1992). Environmental and economic costs of pesticide use. BioScience 42(10):750-760.

Pulich, W.M. (1961). A Record of the Yellow Rail from Dallas County, Texas. Auk 78: 639-640.

Richardson, W.J. (1972). Fall migration and weather in eastern Canada: A radar study. American Birds 26(1): 10-17

Roberts, R. E., and C. V. Tamborski. (1993). Blackpoll Warbler mortality during fall migration at a tower in southeastern Florida. Florida Field Nat. 21: 118-120.

Sawyer, P.J. (1961). Bird Mortality at the WENH-TV Tower in Deerfield, New Hampshire. New Hampshire Audubon Quarterly 14(2): 46-49.

Scott, F.R. and D.A. Cutler. (1965). Fall migration: middle Atlantic coast region. Audubon Field Notes 19(1): 21-24.

Scott, F.R. and D.A. Cutler. (1972). Fall migration: middle Atlantic coast region. American Birds 26(1): 41-45.

Seets, J.W. and H.D. Bohlen. (1977). Comparative Mortality of birds at television towers in central Illinois. Wilson Bulletin 89(3): 422-433.

Sharp, B. (1971). Heavy Mortality of migrating birds at Madison's TV towers. Passenger Pigeon 33(4): 203-204.

Shire, G.G., K. Brown, and G. Winegrad. (2000). Communication Towers: A Deadly Hazard to Birds. American Bird Conservancy. Published on the Internet at www.abcbirds.org.

Smith, L.B. (1966). Bird mortality at a radio and TV towers near Winnipeg, September 1965. Blue Jay 24: 172-176.

Stevenson, H.M. (1956). Fall Migration: Florida region. Audubon Field Notes 10(1): 18-22.

Stevenson, H.M. (1958a). Fall Migration: Florida region. Audubon Field Notes 12(1): 21-26.

Stevenson, H.M. (1958b). Spring Migration: Florida region. Audubon Field Notes 12(4): 344-348.

Stevenson, H.M. (1962). Fall migration: Florida region. Audubon Field Notes 16(1): 21-25.

Stoddard, H. L., Sr. (1962). Bird casualties at a Leon County, Florida, TV tower: 1955-1961. Bull. Tall Timbers Res. Sta. 1: 94.

Strnad, F. (1975). More Birds at KROC-TV Tower, Ostrander Minnesota. Loon 47: 16-21.

Taylor, W.K. and B.H. Anderson. (1973). Nocturnal Migrants killed at a south central Florida TV tower, autumn 1969-1971. Wilson Bulletin 85(1): 42-51.

Taylor, W.K. and B.H. Anderson. (1974). Nocturnal Migrants killed at a south central Florida TV tower, autumn 1972. Florida Field Naturalist 2(2): 40-43.

Taylor, W. K. (1981). No longer a bird killer. Florida Naturalist 9: 4, 5, 10.

Teulings, R.P. (1972). The fall migration: southern Atlantic Coast Region. American Birds 26(1): 45-50.

Teulings, R.P. (1974). The Fall Migration: southern Atlantic Coast Region. American Birds 28(1): 37-40.

Teulings, R.P. (1975). The fall Migration: Southern Atlantic coast region. American Birds 29(1): 40-43.

Tomkins, I.R. (1963). Fall Migration- southern Atlantic coast region. Audubon Field Notes 17: 22.

Turner, L., and M. Davis. (1980). Birds killed at television towers in Knox County [Tennessee]. Migrant 51: 27-29.

United States Bureau of the Census. (2002). Statistical Abstract of the United States: 2002. Washington, D.C.

USFWS (United States Fish and Wildlife Service). (2003). Migratory Bird Mortality. Online PDF report accessed 11/5/03. http://birds.fws.gov/mortality-fact-sheet.pdf

Western EcoSystems Technology, Inc. (2001). Stateline Wind Project Wildlife Monitoring Annual Report. Prepared for FPL Energy Technical Advisory Committee of the Oregon Office of Energy.

Williams, F.C. (1967). Fall migration- south central plains region. Audubon Field Notes 21: 51.

Williams, F.C. (1975). Fall migration- south central plains region. Audubon Field Notes 29: 77.

Williams, F.C. (1976). Fall migration- south central plains region. Audubon Field Notes 30: 90.

Woodford, J. and D.E. Burton. (1961). Fall Migration- Ontario- Western New York Region. Audubon Field Notes 15: 35-36.

Woodford, J. and J. Lunn. (1962). Fall Migration- Ontario- Western New York Region. Audubon Field Notes 16: 25-27.

Woods, M., R.A. McDonald, and S. Harris. (2003). Predation of wildlife by domestic cats Felis catus in Great Britain. Mammal Review 33(2): 174-188.

Wylie, B. (1977). Bird kill at Chestnut Ridge. Redstart 44: 65.

Appendix A

Peer-Reviewed Scientific Studies

Scientific Research Involving Avian Collisions with Communication Towers

Study	Number Towers in Study	Reference	State	Tower/City	Topographic Location	Elevation (ft)	Tower Height (ft) Including Antenna	Guy Wires (Y/N)	Tower Lighting	Years of Study	Number of Years	Search Frequency	Search Effort (Area/Time)	Searcher Efficiency	Scavenger Impact	Number of Birds Collected	Mean Annual Fatalities	Number of Species	Neotropical Migrants (%)	Mass Mortalities Date (No. of fatalities) [c]	Comments
Mortality Studies																					
1	1	Crawford and Engstrom 2001	FL	WCTV/Leon County	near gulf coast	290 ASEL	669/1,010/295	Yes	steady and flashing	1955-1983	29	almost daily	14 hectares	NR	scavengers removed from 1955-1967, also 1974-1976	44,007	1,517 [b]	186	94	NR	High quality.
	1	Crawford 1981a	FL[1]	WCTV/Leon County	near gulf coast	290 ASEL	1,008	Yes	steady and flashing	1962-1966	5	almost daily	14 hectares	NR	NR	8,123	NR	NR	NR	NR	Compares weather to tower mortality.
	1	Crawford 1978	FL[1]	WCTV/Leon County	near gulf coast	290 ASEL	1,008	Yes	steady and flashing	1973-1975	3	almost daily	14 hectares	NR	scavengers regularly removed	3,223	1,074 [b]	57	NR	17 Oct 1973 (133); 5 Sep 1974 (134); 23 Sep 1974 (220); 17 Oct 1974 (971); 14 Sep 1975 (636); 15 Sep 1975 (486)	OK, most birds killed following cold fronts.
	1	Stoddard 1962	FL[1]	WCTV/Leon County	near gulf coast	290 ASEL	673/1,008	Yes	steady and flashing	1955-1961	7	almost daily	14 hectares	NR	scavangers removed	15,251	2,178 [b]	149	NR	4 April 1956 (190); 5 April 1956 (135); 26 April 1956 (201); 2 April 1957 (131), 4 April 1958 (228); 6 April 1958 (102); 11 April 1958 (220); 27 Sep 1957 (111); 30 Sep 1957 (146); 1 Oct 1957 (222); 2 Oct 1957 (126); 5 Oct 1957 (2,325); 9 Oct 1955 (4,000-7,000)	Detailed methods section, most rigorous collection.
2	1	Taylor and Anderson 1973	FL	WDBO/ Orange County	central FL	65 ASEL	1,481	Yes	red, steady and flashing	1969-1971	3	unclear, but not daily (after large kills)	1 acre	NR	no scavengers mentioned	7,782	2,594 [b]	82	NR	29 Sep 1970 (1,592); 30 Sep 1970 (859)	Area surveyed limited to 1 acre
3	4	Morris et al. 2003	NY	WRGZ/Wales	NR	1352 ASEL	961	Yes	red beacon	1970-1999	30	mean = 11 visits annually (range 4-33), nights with overcast conditions	NR	NR	scavengers noted, but no calculation of scavenger removal	8,011	267 [ab]	106 (all 3 NY towers)	NR	NR	OK, nothing special in analysis, general decline in mortality over time.
			NY	WKBW/Colden	NR	1735 ASEL	1,076	Yes	red beacon	1970-1999	30	mean = 11 visits annually (range 4-33), nights with overcast conditions	NR	NR	scavengers noted, but no calculation of scavenger removal	11,092	370 [a]	106 (all 3 NY towers)	NR	NR	
			NY	WIBV/Colden	NR	1640 ASEL	1,059	Yes	red beacon	1970-1999	30	mean = 11 visits annually (range 4-33), nights with overcast conditions	NR	NR	scavengers noted, but no calculation of scavenger removal	1,043	35 [a]	106 (all 3 NY towers)	NR	NR	
			OH	WFMJ/ Youngstown	NR	1033 ASEL	1,084	Yes	red beacon	1974-1992	18	varies from daily during fall 1974 to only after kills and cloudy weather thereafter	NR	NR	scavengers noted, but no calculation of scavenger removal	4,310	144 [a]	80	NR	NR	
4	1	Brewer and Ellis 1958	IL	WCIA/ Champaign County	flat	720 ASEL	981	Yes	red flashing and steady	1955-1957	3	only 7 times in 3 years, after major kills	NR	NR	no calculation of scavenger removal	486	N/A	51	80		Mortality generally with >80% cloud cover, ceiling of 400-1,600 ft. Only 7 visits, study of limited use.
5	7	Seets and Bohlen 1977	IL	Bluffs	NR	NR	1,587	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	328	N/A	43	NR	2 Sep 1972 (221); 29 Sep 1972 (107)	Only 13 visits, mortality generally followed cold fronts, low clouds.
			IL	Springfield	NR	NR	1,458	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	1,680	N/A	61	NR	2 Sep 1972 (735); 27 Sep 1972 (391); 29 Sep 1972 (319)	

Study	Number Towers in Study	Reference	State	Tower/City	Topographic Location	Elevation (ft)	Tower Height (ft) Including Antenna	Guy Wires (Y/N)	Tower Lighting	Years of Study	Number of Years	Search Frequency	Search Effort (Area/Time)	Searcher Efficiency	Scavenger Impact	Number of Birds Collected	Mean Annual Fatalities	Number of Species	Neotropical Migrants (%)	Mass Mortalities Date (No. of fatalities) [c]	Comments
			IL	Argenta	NR	NR	1,063	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	969	N/A	55	NR	2 Sep 1972 (110); 27 Sep 1972 (807)	
			IL	Monticello	NR	NR	1,047	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	1,176	N/A	57	NR	27 Sep 1972 (992); 31 Oct 1972 (184)	
			IL	Seymour	NR	NR	981	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	130	N/A	22	NR	27 Sep 1972 (127)	
			IL	Fithian	NR	NR	1,338	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	942	N/A	63	NR	2 Sep 1972 (266); 27 Sep 1972 (634)	
			IL	Gibson City	NR	NR	605	Yes	NR	1972	1	13 dates between 2 Sep and 12 Nov 1972, following cloudy weather	NR	NR	scavengers noted, but no calculation of scavenger removal	206	N/A	27	NR	27 Sep 1972 (206)	
6	1	Avery et al. 1978	ND	Omega/west of LaMoure, se ND	marshy and grassland	NR	1,197	Yes	red, steady and flashing	1971-1973	3	nightly	NR	NR	measured scavenger effort, estimated to be 7.3% nightly	937, partial sample	approx 1,075	102	NR	NR	Consistent sampling effort. Measured scavenger effort, estimated to be 7.3% nightly.
	1	Avery et al. 1977	ND[2]	Omega/west of LaMoure, se ND	marshy and grassland	NR	1,197	Yes	red, steady and flashing	1972-1973	2	nightly	NR	NR	NR	approx 1,064	approx 563 [b]	NR	NR	NA	Consistent sampling effort, major fall kills followed cold fronts.
	1	Avery et al. 1975	ND[2]	Omega/west of LaMoure, se ND	marshy and grassland	NR	1,197	Yes	red, steady and flashing	1971-1972	2	nightly	NR	NR	measured scavenger effort, estimated to be between 2.5 and 4.9%	633, partial sample	approx 1,000	87	NR	NR	This is an interim report, ignore.
	4	Avery and Clement 1972	ND[2]	KXJB/ Galesburg	agricultural field	NR	2,060	Yes	red, steady and flashing	1972	1	Irregularly (Sep through Oct)	NR	NR	scavengers loss expected to be greater than Omega tower	163	N/A	51	NR	N/A	Search effort and area differed between towers.
			ND[2]	KTHI/ Blanchard	agricultural field	NR	2,063	Yes	red, steady and flashing	1972	1	Irregularly (Sep through Oct)	NR	NR	scavengers loss expected to be greater than Omega tower	82	N/A	28	NR	N/A	Search effort and area differed between towers.
			ND[2]	WDAY/ Amenia	agricultural field	NR	1,206	Yes	red, steady and flashing	1972	1	Irregularly (Sep through Oct)	NR	NR	scavengers loss expected to be greater than Omega tower	90	N/A	39	NR	N/A	Search effort and area differed between towers.
			ND[2]	Omega/ LaMoure	marshy and grassland	NR	1,197	Yes	red, steady and flashing	1972	1	daily (Aug to Nov)	NR	NR	scavenger losses of birds estimated at under 5%	226	N/A	67	NR	N/A	Search effort and area differed between towers.
7	1	Nehring and Bivens, 1999	TN	WSMV/ 3 miles sw of Nashville, TN	hill	2702 ASEL	1,364	Yes	red, steady and flashing	1960-1997	38	daily, Sep and Oct only	4700 m2	NR	scavengers noted, but no calculation of scavenger removal	19,880	523 [b]	112	99	26 Sep 1968 (5,399); 28 Sep1970 (3,487)	Effort only in Sep and Oct, several large kills, 5,399 killed on 26 Sep 1968, 3,487 killed on 28 Sep 1970, general decline in mortality over period of study.

Study	Number Towers in Study	Reference	State	Tower/City	Topographic Location	Elevation (ft)	Tower Height (ft) Including Antenna	Guy Wires (Y/N)	Tower Lighting	Years of Study	Number of Years	Search Frequency	Search Effort (Area/Time)	Searcher Efficiency	Scavenger Impact	Number of Birds Collected	Mean Annual Fatalities	Number of Species	Neotropical Migrants (%)	Mass Mortalities Date (No. of fatalities) [c]	Comments
	1	Goodpasture 1984	TN	WSMV/ 3 miles sw of Nashville, TN	hill	2702 ASEL	1,364	Yes	red, steady and flashing	1976-1983	8	daily, Sep and Oct, less regular 1982/83	NR	NR	scavengers noted, but no calculation of scavenger removal	2,126	266 [b]	73	NR	NR	Study of limited value, subset of previous, long-term study
Studies published in Regional Journals. Generally weaker scientifically.																					
8	2	Carter and Parnell 1976	NC	WECT/ Bladen County	42 miles from coast	NR	1,994	Yes	red, steady and flashing	1971-1972	2	after cold fronts and cloudy nights in 1971 and 1972	NR	NR	scavengers noted, but no calculation of scavenger removal	3,070 (both towers)	1535 [ab]	84 (both towers)	NR	NA	In 1971, 2,683 birds found, only 387 in 1972; predation noted as a problem.
			NC	WWAY/ Brunswick County	10 miles from coast	NR	1,188	Yes	red, steady and flashing	1971-1972	2	after cold fronts and cloudy nights in 1971 and 1972	NR	NR	scavengers noted, but no calculation of scavenger removal	3,070 (both towers)	1536 [ab]	85 (both towers)	NR	4 Oct 1971 (Approx. 1,000)	Large kill associated with low ceiling and northerly winds. Dense vegetation around towers limited searching.
	2	Carter and Parnell 1978	NC	WECT/Bladen County	42 miles from coast	NR	1,994	Yes	red, steady and flashing	1973-1977	4	WECT tower checked more regularly than WWAY	NR	NR	scavengers noted, but no calculation of scavenger removal	4,208	approx 1,403 [ab]	65	NR	1 Oct 1973 (660+); 5 Sep 1974 (3,240+); 28 Oct 1975 (306+)	Study of limited value, checks too infrequent. Many birds lost to predation and dense vegetation.
				WWAY/ Brunswick County	10 miles from coast	NR	1,188	Yes	red, steady and flashing	1973-1977	4	WECT tower checked more regularly than WWAY	NR	NR	scavengers noted, but no calculation of scavenger removal	NR	NR	NR	NR	NR	
9	2	Elmore and Palmer-Ball 1991	KY	WGRB/Adair County	hill	900 ASEL	1,000	Yes	NR	1983-1990	8	infrequent, not immediately after cold fronts	NR	NR	scavengers noted, but no calculation of scavenger removal	NR	NR	approx 72	>80	11 Oct 1986 (113); 17 Oct 1990 (1,576+)	Study of limited value, checks very infrequent.
			KY	WAVE/Oldham County	hill	800 ASEL	1,739	Yes	NR	unclear	NR	NR	NR	NR	NR	NR	NR	NR	NR	20 Oct 1990 (133)	Tall grass limited searching at both towers.
10	1	Kemper 1996	WI	Eau Claire	NR	NR	1,000	Yes	NR	1957-1995	38	almost daily since 1959, after large kills before that	NR	NR	no scavengers mentioned	9,496	250[b]	123	>80	29 Aug 1957(300-500)	Study appears to be significant effort, but the way the methods and results are reported decrease this studies value.
11	1	Boso 1965	KS	KOAM/ Cherokee County	agricultural field	940 ASEL	1,200	Yes	steady and flashing, red	1963-1964	1	12 fall trips, 21 Sep - 30 Oct 1963; 14 spring trips, 15 Mar - 23 May 1964	NR	NR	scavengers noted, but no calculation of scavenger removal	125	N/A	49	>70	NR	Limited study, 12 fall visits, 14 spring visits, no information on whether these were dawn trips; not much use.
12	1	Herron 1997	WV	Lewis County	hill	2173 ASEL	529	NR	red flashing lights	1978-1986	9	infrequent, from 1 to 21 times annually	NR	NR	scavengers noted, but no calculation of scavenger removal	841	N/A	58	>90	NR	Limited study, too few visits annually to provide meaningful data. Collection efforts varied between visits.
13	1	Strnad 1975	MN	KROC/Fillmore County	NR	2642 ASEL	approx 1,314	Yes	flashing lights	1961-1974	5	infrequent, not quantified	NR	NR	scavengers noted, but no calculation of scavenger removal	3,507	N/A	84	>85	12 Sep 1972 (183); 30 Sep 1973 (860); 12 Sep 1974 (1,500)	Limited study, too few visits annually to provide meaningful data. Collection efforts varied between visits.

[a] Mean based on limited number of collection days per year.
[b] Mean not reported in article and was calculated by Woodlot (total collected / # years).
[c] Mass mortality is over 100 birds
NR= Not Reported

[1] Previously published article associated with Crawford and Engstrom 2001 long-term study
[2] Previously published article associated with Avery et al. 1978 long-term study

Appendix B

Incidental Reports and Observations

Incidental Reports Involving Avian Collisions with Communication Towers

Number	State	Tower/City	Topographic Location	Elevation (ft)	Date	Year	Season	Weather	Survey Effort (Hours/ Area)	Tower Height (ft)	Guy Wires (Y/N)	Tower Lighting	Total Fatalities	Daily Range of Mortalities	No. of Species	Common Species	Comments	Reference
1	Alabama	Birmingham, WAPI and WBRC	Mountain	NR	March 15 - May 22	1969	Spring	NR	NR	NR	Yes	NR	44	NA	17	Red-eyed vireo	Tower details can be found Alabama Birdlife 16:4(34)	Bierly 1972
2	Alabama	Huntsville, WHNT	Mountain	1600 ASEL	Sept. 30 - Oct. 31	1976	Fall	NR	NR	1000	Yes	NR	42	NA	18	Bay-breasted warbler (9)	Oct 1 was the biggest kill, with 15 birds of 9 species.	Cooley 1977
3	Alabama	Birmingham, WAPI and WBRC	Mountain	NR	March 15 - May 22	1968	Spring	NR	NR	NR	Yes	NR	36	NA	16	Red-eyed vireo (14)	NA	Bierly 1969
4	Alabama	Birmingham, WAPI and WBRC	Mountain	NR	Sept. 5 - Nov 15	1968	Fall	NR	NR	NR	Yes	NR	47	NA	21	Red-eyed vireo (14)	NA	Bierly 1969
5	Florida	Martin County LORAN	NR	NR	Oct. 8	1991	Fall	Cloudy, wind	NR	626	Y	White and red lights	617	NA	9	Blackpoll warbler (586)	NA	Roberts and Tamborski 1993
6	Florida	Bithlo, WDBO-WFTV	NR	NR	Aug. 16 - Nov. 30	1972	Fall	NR	NR	NR	NR	NR	1347	NA	49	Common yellowthroat	NA	Taylor and Anderson 1974
7	Florida	Jacksonville	NR	NR	Sept. 29	1970	Fall	Cold front	NR	NR	NR	NR	70	NA	11	Black throated blue warbler	NA	Bagg 1971
8	Florida	Jacksonville	NR	NR	Oct. 6-8	1964	Fall	Cloudy, rain, ceiling 900' to 2000'	NR	NR	NR	NR	2000	NA	NR	Warblers were the bulk of the kill	These numbers are from two towers.	Cunningham 1965
9	Florida	Near Georgia line	NR	NR	Oct. 9	1955	Fall	Cloudy, low ceiling	NR	660	NR	NR	2000	NA	NR	NR	Estimate of fatalities.	Stevenson 1956
10	Florida	Jacksonville	NR	NR	Oct. 5	1957	Fall	NR	NR	NR	NR	NR	700	NA	NR	NR	NA	Stevenson 1958
11	Florida	Jacksonville	NR	NR	Apr. 21	1958	Spring	NR	NR	NR	NR	NR	297	NA	NR	NR	The reports from the two towers in Jacksonville.	Stevenson 1958
12	Florida	Jacksonville	NR	NR	Sept. 17	1961	Fall	NR	NR	NR	NR	NR	1100	NA	NR	NR	The report says between 1,100 and 1,200 fatalities at the two towers.	Stevenson 1962
13	Georgia	North Augusta, WRDW-TV	NR	NR	Oct. 6	1957	Fall	Cloudy, rain	NR	NR	NR	NR	12	NA	NR	NR	NA	Johnston 1957
14	Georgia	Okefenokee, Camp Cornelia	NR	NR	Oct. 4-7	1957	Fall	Cloudy, rain	NR	200	NR	Red lights	86	NA	17	Yellowthroat	NA	Johnston 1957
15	Georgia	Atlanta, WSB	NR	NR	Oct. 5	1957	Fall	Cloudy, rain	NR	1062	NR	NR	423	NA	34	Red-eyed vireo	Most birds fatalities found just southeast of tower.	Johnston 1957
16	Georgia	Atlanta, WAGA	NR	NR	Oct. 5	1957	Fall	Cloudy, rain	NR	NR	NR	NR	23	NA	12	Yellow-breasted chat	NA	Johnston 1957
17	Georgia	Atlanta, WSB-TV	NR	NR	Oct. 6-8	1954	Fall	Cold front	NR	1062	NR	NR	327	NA	28	Magnolia warbler (62)	Estimate of 600 fatalities, only 327 collected.	Johnston 1955
18	Georgia	Okefenokee Camp Cornelia	NR	NR	Oct. 6-8	1954	Fall	Cloudy	NR	200	Y	Lights present	883	NA	31	Yellowthroat (225)	Estimate of 900 fatalities, only 883 collected.	Johnston 1955
20	Illinois	Springfield, WICS	NR	NR	Sept. 16 (birds not picked up until Sept. 20)	1959	Fall	Cloudy, rain	NR	865.9	Y	Red lights flashing and steady	827	NA	40	Gray-cheeked thrush (145)	Estimated 1,000-1,500 dead birds, only 827 collected.	Parmalee et al. 1959
21	Illinois	Orion, WHBF	NR	NR	Oct. 7	1959	Fall	Cloudy, fog	NR	983	Y	Lights present	88	NA	32	Tennessee warbler (7), Swainson's thrush (7), ovenbird (7)	NA	Petersen 1959
22	Illinois	Springfield, WICS	NR	NR	Sept. 13	1963	Fall	Cloudy, rain	NR	865.9	Y	Red lights flashing and steady	219	NA	31	Ovenbird (53)	45 of the birds were picked up on Sept 14.	Parmalee and Thompson 1963
23	Illinois	Champaign	NR	NR	Sept. 15-17	1958	Fall	NR	NR	983	NR	NR	147	NA	17	Swainson's thrush	NA	Graber 1968
24	Illinois	Champaign	NR	NR	Sept. 28-29	1959	Fall	NR	NR	983	NR	NR	465	NA	29	Swainson's thrush	NA	Graber 1968
25	Illinois	Champaign	NR	NR	Sept. 19-20	1960	Fall	Cloudy	NR	983	NR	NR	478	NA	32	Ovenbird	NA	Graber 1968
26	Illinois	Champaign	NR	NR	Sept. 24-25	1962	Fall	NR	NR	983	NR	NR	296	NA	29	Swainson's thrush	NA	Graber 1968
27	Illinois	Decatur	NR	NR	Sept. 14	1962	Fall	Cold front	NR	NR	NR	NR	36	NA	NR	NR	NA	Graber 1962
28	Illinois	Rockford	NR	NR	Sept. 24	1962	Fall	NR	NR	NR	NR	NR	233	NA	25	NR	NA	Graber 1962
29	Illinois	Rockford	NR	NR	Sept. 24	1962	Fall	NR	NR	NR	NR	NR	87	NA	NR	NR	NA	Graber 1962
30	Illinois	Springfield	NR	NR	Sept. 22-23	1970	Fall	NR	NR	NR	NR	NR	212	NA	28	NR	NA	Peterson 1971
31	Illinois	Springfield	NR	NR	Oct. 13-14	1970	Fall	NR	NR	NR	NR	NR	37	NA	16	NR	NA	Peterson 1971
32	Indiana	WHAS-TV	NR	976 ASEL	Sept. 14	1965	Fall	Cloudy, rain, fog	NR	973	Y	NR	8	NA	8	Eight fatalities-eight species	NA	Able 1966
33	Indiana	WHAS-TV	NR	976 ASEL	Sept. 25	1965	Fall	Cloudy, rain, wind	NR	973	Y	NR	9	NA	6	Gray-cheeked thrush	NA	Able 1966
34	Indiana	WHAS-TV	NR	976 ASEL	Oct. 1	1965	Fall	Cloudy, rain	NR	973	Y	NR	1	NA	1	Bay-breasted warbler	NA	Able 1966
35	Indiana	WHAS-TV	NR	976 ASEL	Oct. 3	1965	Fall	Cold front	NR	973	Y	NR	5	NA	5	Five fatalities-five species	NA	Able 1966
36	Indiana	WHAS-TV	NR	976 ASEL	Oct. 23	1965	Fall	Cloudy, low ceiling	NR	973	Y	NR	2	NA	2	Two fatalities-two species	NA	Able 1966
37	Indiana	WHAS-TV	NR	976 ASUL	Oct. 6-7	1967	Fall	Cloudy, low ceiling	NR	973	Y	NR	78	NA	NR	NR	NA	Able 1968
38	Indiana	Floyd Knobs, WHAS	NR	NR	Oct. 7	1967	Fall	NR	NR	NR	NR	NR	78	NA	NR	NR	NA	Peterson 1968
39	Indiana	South Bend	NR	NR	Sept. 27	1959	Fall	Cloudy, rain, wind	NR	NR	NR	NR	49	NA	NR	NR	NA	Mumford 1960
40	Indiana	Floyd County	NR	NR	Sept. 23	1966	Fall	NR	NR	NR	NR	NR	123	NA	NR	NR	NA	Peterson 1967
41	Iowa	Alleman towers	Agricultural Field	NR	Sept. 21-22	1985	Fall	Cloudy, rain	NR	2000	NR	NR	515	NA	39	Ovenbird (110)	Group of several towers.	Dinsmore et al. 1987
42	Iowa	Hinton towers	Hill	NR	Sept. 21-22	1985	Fall	Cloudy, rain	NR	NR	NR	NR	469	NA	39	Nashville warbler 228	NA	Dinsmore et al. 1987
43	Iowa	Davenport	NR	NR	Sept. 20	1960	Fall	NR	NR	NR	NR	NR	281	NA	25	NR	NA	Mumford 1961
44	Iowa	Des Moines	NR	NR	Sept. 11-12	1974	Fall	NR	NR	NR	NR	NR	1500	NA	NR	Red-eyed vireo	The report states "over 1500 bird " fatalities.	Kleen 1975
45	Kansas	Lawrence, KANU	NR	NR	Jan. 29	1969	Winter	Cloudy, snow	NR	600	Y	NR	21	NA	1	Tree sparrows	This report only deals with tree sparrows.	Niles et al, 1969
46	Kansas	KCMO	NR	2049 ASEL	Oct. 15	1975	Fall	Cloudy, ceiling 5000' to 10000'	NR	Over 1000	N	NR	55	NA	13	Mourning dove (32)	NA	Gregory 1975
47	Kansas	Lawrence	NR	2049 ASEL	Oct. 15	1975	Fall	Cloudy, ceiling 5000' to 10000'	NR	500-600	NR	NR	25	NA	8	Mourning dove (8)	NA	Gregory 1975
48	Kansas	WDAF	NR	2049 ASEL	Oct. 15	1975	Fall	Cloudy, ceiling 5000' to 10000"	NR	Over 1000	NR	NR	2	NA	2	NR	NA	Gregory 1975
49	Kansas	KCPT	NR	2049 ASEL	Oct. 15	1975	Fall	Cloudy, ceiling 5000' to 10000'	NR	Over 1000	NR	NR	4	NA	3	Lincoln's sparrow	NA	Gregory 1975

Number	State	Tower/City	Topographic Location	Elevation (ft)	Date	Year	Season	Weather	Survey Effort (Hours/ Area)	Tower Height (ft)	Guy Wires (Y/N)	Tower Lighting	Total Fatalities	Daily Range of Mortalities	No. of Species	Common Species	Comments	Reference
50	Kansas	Western Kansas	Agricultural Field	NR	Jan. 22	1999	Winter	Cloudy, snow	NR	420	Yes	3 white strobes	5,000-10,000	NA	4	Lapland longspurs	Non-migratory flight during snowstorm. Birds looking for bare ground?	Evans 1998
51	Kentucky	Lexington	NR	NR	May 7	1961	Spring	Cloudy, rain	NR	670	Y	NR	82	NA	21	NR	NA	Barbour 1961
52	Louisiana	Baton Rouge	NR	NR	Sept. 24	1957	Fall	Cold front	NR	NR	NR	NR	400	NA	NR	NR	The report states more then 400 birds.	Newman 1958
53	Maryland	Baltimore, WBAL-TV	NR	NR	Sept. 28	1970	Fall	Cold front	NR	NR	NR	NR	1965	NA	42	Ovenbird (489)	NA	Bagg 1971
54	Maryland	Baltimore	NR	NR	Sept. 12	1964	Fall	NR	NR	NR	NR	NR	1032	NA	37	Ovenbird (331)	The report states that thousands of birds were found.	Scott and Cutler 1965
55	Massachusetts	Boston (two TV towers)	NR	NR	Sept. 20	1958	Fall	NR	NR	NR	NR	NR	300	NA	NR	NR	The number of birds are only estimates.	Baird et al. 1959
56	Massachusetts	Needham	NR	NR	Sept. 24	1957	Fall	Cold front	NR	NR	NR	NR	96	NA	NR	NR	The report states 96 "migrants".	Newman 1958
57	Michigan	Detroit	NR	NR	May 17	1959	Spring	NR	NR	NR	NR	NR	284	NA	NR	NR	NA	Breckenridge 1959
58	Minnesota	Lewisville, KEYC-TV	Agricultural Field	NR	Sept. 18-19 (birds collected Sept 21)	1963	Fall	NR	NR	1116	NR	NR	924	NA	47	Red-eyed vireo (305)	Birds picked up Sept 21, but report states that birds were likely killed on the 18th and 19th.	Janssen 1963
59	Missouri	Columbia	NR	NR	Sept. 25	1962	Fall	NR	NR	NR	NR	NR	77	NA	25	NR	NA	Graber 1962
60	Missouri	Columbia, KOMU	NR	NR	Sept. 21	1963	Fall	NR	NR	NR	NR	NR	971	NA	NR	NR	NA	Peterson 1964a
61	Missouri	Columbia	NR	NR	May 12	1964	Spring	NR	NR	NR	NR	NR	51	NA	22	NR	NA	Peterson 1964b
62	Missouri	University of Missouri-Columbia	NR	NR	Sept. 15	1982	Fall	Cloudy, ceiling 300' to 600'	NR	NR	NR	NR	34	NA	17	Red-eyed vireo	NA	Elder 1982
63	Missouri	Columbia, KOMU	NR	NR	Sept. 22	1965	Fall	NR	NR	775	NR	NR	205	NA	15	Catbird (60)	NA	Elder amd Hansen 1967
64	Missouri	Columbia, KOMU	NR	NR	Sept. 27	1965	Fall	NR	NR	775	NR	NR	28	NA	15	Magnolia and Tennessee warbler (both 3 each)	NA	Elder amd Hansen 1967
65	Missouri	Columbia, KOMU	NR	NR	Sept. 20	1966	Fall	Cloudy, fog, ceiling 400' to 1200'	NR	775	NR	NR	618	NA	32	Yellowthroat	NA	Elder amd Hansen 1967
66	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 20	1962	Fall	NR	NR	NR	NR	NR	1	NA	1	Rose-breasted grosbeak (1)	NA	Heye 1963
67	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 24	1962	Fall	NR	NR	NR	NR	NR	5	NA	4	Rose-breasted grosbeak (2)	NA	Heye 1963
68	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 26	1962	Fall	NR	NR	NR	NR	NR	48	NA	16	Yellowthroat (6)	NA	Heye 1963
69	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 27	1962	Fall	NR	NR	NR	NR	NR	11	NA	7	Red-eyed vireo (4)	NA	Heye 1963
70	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 28	1962	Fall	NR	NR	NR	NR	NR	5	NA	5	Five fatalities-five species	NA	Heye 1963
71	Missouri	Columbia, KFVS-TV	NR	NR	Sept. 29	1962	Fall	NR	NR	NR	NR	NR	5	NA	5	Five fatalities-five species	NA	Heye 1963
72	Missouri	Columbia, KFVS-TV	NR	NR	Oct. 6	1962	Fall	NR	NR	NR	NR	NR	254	NA	45	Yellowthroat (49)	NA	Heye 1963
73	Nebraska	Albion, KCNA-TV	NR	NR	Sept. 20	1978	Fall	NR	NR	NR	NR	NR	36	NA	NR	NR	NA	Mollhoff 1979
74	Nebraska	Albion, KCNA-TV	NR	NR	Sept. 12-16	1982	Fall	Cloudy, rain	NR	NR	NR	NR	320	NA	42	NR	NA	Mollhoff 1983
75	New Hampshire	Deerfield, WENH-TV	Mountain	1100 ASEL	Apr. 14 - May 20	1959	Spring	NR	NR	436	Y	NR	34	NA	16	Yellowthroat (6)	NA	Sawyer 1961
76	New Hampshire	Deerfield, WENH-TV	Mountain	1100 ASEL	Sept. 11 - Nov. 9	1959	Fall	NR	NR	436	Y	NR	190	NA	34	Ruby-crowned kinglet (77)	NA	Sawyer 1961
77	New Hampshire	Deerfield, WENH-TV	Mountain	1100 ASEL	Jan. 1 - May 14	1960	Winter/spring	NR	NR	436	Y	NR	13	NA	8	Ovenbird (4)	NA	Sawyer 1961
78	New Hampshire	Deerfield, WENH-TV	Mountain	1100 ASEL	Sept. 14 - Oct. 10	1960	Fall	NR	NR	436	Y	NR	30	NA	11	Blackpoll warbler (12)	NA	Sawyer 1961
79	New York	WKBW-TV	NR	2224 ASUL	Sept. 27, 29, & Oct. 7	1962	Fall	Cloudy, fog, low ceiling	NR	1076	Y	NR	682	57-381	43	Swainson's thrush	NA	Able 1963
80	New York	Syracuse (10 miles North)	NR	NR	Sept. 22	1999	Fall	Cloudy, rain (hurricane)	NR	1173	NR	NR	63	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
81	New York	Binghamton (Southwest)	NR	NR	Sept. 22	1999	Fall	Cloudy, rain (hurricane)	NR	934	NR	NR	1	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
82	New York	Binghamton (Southwest)	NR	NR	Sept. 22	1999	Fall	Cloudy, rain (hurricane)	NR	553	NR	White Strobed	6	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
83	New York	Syracuse (6 miles SW)	NR	NR	Oct. 10	1998	Fall	Cloudy, rain	NR	1019	NR	NR	4	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
84	New York	Binghamton (Southwest)	NR	NR	Oct. 10	1998	Fall	Cloudy, rain	NR	934	NR	NR	1	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
85	New York	Pompey (North)	NR	NR	Oct. 10	1998	Fall	Cloudy, rain	NR	964	NR	NR	10	NA	NR	NR	NA	Evens, Bill (towerkill.com) 2003
86	New York	Ellicottville, Cattaraugus Co.	Plateau	2140 ASEL	Sept. 12 - Oct. 15	1965	Fall	NR	NR	300	NR	NR	141	NA	NR	NR	NA	Eaton 1967
87	North Carolina	Chapel Hill	NR	NR	Sept. 28	1970	Fall	Cold front	NR	NR	NR	NR	266	NA	23	Yellowthroat (129)	NA	Bagg 1971
88	North Carolina	Raleigh	NR	NR	Sept. 28	1970	Fall	Cold front	NR	NR	NR	NR	145	NA	5	Red-eyed vireo (87)	NA	Bagg 1971
89	North Carolina	Chapel Hill	NR	NR	Sept. 28-29	1956	Fall	Hurricane Flossy	NR	NR	NR	NR	2500	NA	44	NR	NA	Newman 1957 and Chamberlain 1957
90	North Carolina	Charlotte, WSOC	NR	NR	Sept. 28 - Oct. 2	1960	Fall	Cloudy, low ceiling	NR	1000	Y	NR	341	NA	NR	NR	Tower and weather information from Norwoods 1960.	Chamberlain 1961
91	North Carolina	WECT	NR	NR	Fall	1971	Fall	NR	NR	1600	NR	NR	1706	NA	75	NR	NA	Teulings 1972
92	Ohio	Dayton, WHIO-TV	NR	NR	Sept. 9 - Nov. 15	1967	Fall	NR	NR	NR	NR	NR	348	NA	45	NR	NA	Peterson 1968
93	Ohio	Dayton, WHIO-TV	NR	NR	Sept. 27	1968	Fall	NR	NR	NR	NR	NR	72	NA	NR	NR	NA	Peterson 1969
94	Ohio	Dayton, WHIO-TV	NR	NR	Sept. 28	1968	Fall	NR	NR	NR	NR	NR	36	NA	NR	NR	NA	Peterson 1969
95	Ohio	Dayton, WHIO-TV	NR	NR	Sept. 29	1968	Fall	NR	NR	NR	NR	NR	13	NA	NR	NR	NA	Peterson 1969
96	Ohio	Dayton, WHIO-TV	NR	NR	Oct. 1	1968	Fall	NR	NR	NR	NR	NR	12	NA	NR	NR	NA	Peterson 1969
97	Ohio	Dayton, WHIO-TV	NR	NR	Oct. 11	1968	Fall	NR	NR	NR	NR	NR	12	NA	NR	NR	NA	Peterson 1969
98	Ohio	Cincinnati	NR	NR	Sept. 28	1964	Fall	NR	NR	NR	NR	NR	300	NA	NR	NR	Estimate of 300 birds.	Peterson 1965
99	Ohio	Dayton, WHIO-TV	NR	NR	Oct. 10	1966	Fall	NR	NR	NR	NR	NR	25	NA	NR	NR	NA	Peterson 1966a
100	Ohio	Dayton, WHIO-TV	NR	NR	Oct. 23	1966	Fall	NR	NR	NR	NR	NR	66	NA	NR	NR	NA	Peterson 1967
101	Ohio	Dayton, WHIO-TV	NR	NR	Sept. 23	1966	Fall	NR	NR	NR	NR	NR	58	NA	NR	NR	NA	Peterson 1967
102	Ohio	Dayton, WHIO-TV	NR	NR	May 19-21	1966	Spring	NR	NR	NR	NR	NR	23	NA	NR	NR	NA	Peterson 1966b
103	Oklahoma	Coweta	NR	NR	Oct. 9	1974	Fall	NR	NR	NR	NR	NR	177	NA	28	NR	NA	Williams 1975

Number	State	Tower/City	Topographic Location	Elevation (ft)	Date	Year	Season	Weather	Survey Effort (Hours/ Area)	Tower Height (ft)	Guy Wires (Y/N)	Tower Lighting	Total Fatalities	Daily Range of Mortalities	No. of Species	Common Species	Comments	Reference
104	Oklahoma	Coweta, KUTL	NR	NR	Fall months	1975	Fall	NR	NR	NR	NR	NR	89	NA	27	Black and white warbler (13)	Tower call number from Norman 1977.	Norman 1982
105	Oklahoma	Coweta, KUTL	NR	NR	Fall months	1976	Fall	NR	NR	NR	NR	NR	166	NA	47	Ruby-crowned kinglet (16)	Tower call number from Norman 1978.	Norman 1982
106	Oklahoma	Coweta, KUTL	NR	NR	Fall months	1977	Fall	NR	NR	NR	NR	NR	101	NA	29	Dark-eyed junco (26)	Tower call number from Norman 1979.	Norman 1982
107	Oklahoma	Coweta, KUTL	NR	NR	Fall months	1978	Fall	NR	NR	NR	NR	NR	209	NA	41	Red-eyed vireo (31), Nashville warbler (31)	Tower call number from Norman 1980.	Norman 1982
108	South Carolina	Aiken County, WJBF	NR	NR	Oct. 8	1957	Fall	Cloudy, rain, low ceiling	NR	1300	Y	Blinking and non blinking	759	0-444	75	Ovenbird, Red-eyed vireo, Palm warbler over the range of days.	Total # of species calculated from Oct. 4 and 5 only.	Johnston 1957
109	South Carolina	Aiken County, WRDW-TV	NR	650 ASUL	Oct. 6-8	1954	Fall	Cloudy	NR	500	NR	Red lights	81	NA	12	Magnolia warbler (22)	NA	Johnston 1955
110	South Carolina	Aiken	NR	NR	Sept. 7	1962	Fall	Cold front	NR	NR	NR	NR	400	NA	32	Red-eyed vireo (239)	NA	Tomkins 1963
111	South Carolina	Charleston	NR	NR	Sept. 7-8	1962	Fall	Cold fronts	NR	NR	NR	NR	1602	NA	NR	Red-eyed vireo, Ovenbird and Redstart 91% of birds	The report states "about 1602".	Tomkins 1963
112	South Dakota	Flandreau, KSOO-TV	NR	NR	Sept. 14	1965	Fall	NR	NR	1117	NR	Lights present	200	NA	32	Yellowthroat (15)	102 individuals recovered.	Pierce 1969
113	South Dakota	Flandreau, KSOO-TV	NR	NR	March 28	1965	Spring	Cloudy, snow	NR	1117	NR	Lights present	578	NA	1	Horned larks	NA	Pierce 1969
114	Tennessee	Knoxville, WTKV	NR	1285 ASEL	May 8	1969	Spring	Cloudy	NR	1073	Y	NR	20	NA	10	Red-eyed vireo	NA	Alsop et al. 1969
115	Tennessee	Nashville, WSIX	NR	NR	Sept. 1 - Nov. 3	1971	Fall	NR	NR	NR	NR	NR	135	NA	24	Ovenbird (24) (but 38 species no id)	NA	Bierly 1973
116	Tennessee	Nashville, WSIX	NR	NR	Sept. 1 - Oct. 31	1972	Fall	NR	NR	NR	NR	NR	199	NA	40	Ovenbird (38) (but 16 species no id)	69 birds were collected on Sept 5 after a night with fog and rain.	Goodpasture 1974a
117	Tennessee	Nashville, WSIX	NR	NR	Sept.1 - Oct. 31	1973	Fall	NR	NR	NR	NR	NR	109	NA	35	Tennessee warbler (14)	Days not searched: Sept 29 and Oct 20 and 26	Goodpasture 1974b
118	Tennessee	Nashville, WNGE	NR	NR	Aug. 31 - Nov. 11	1974	Fall	NR	NR	NR	NR	NR	56	NA	28	Black and white warbler (5) (but 15 species no id)	NA	Goodpasture 1975
119	Tennessee	Nashville, WNGE	NR	NR	Aug. 31 - Nov. 11	1974	Fall	NR	NR	NR	NR	NR	56	NA	28	Black and white warbler (5) (but 15 species no id)	NA	Goodpasture 1975
120	Tennessee	Nashville, WNGE	NR	NR	Sept. 1 - Oct. 31	1975	Fall	NR	NR	NR	NR	NR	78	NA	32	Ovenbird	No search Oct 10, but included Nov 1, 2, and 7.	Goodpasture 1976
121	Tennessee	Nashville, WNGE or WKRN	NR	NR	Sept. 1 - Nov. 1	1984	Fall	NR	NR	NR	NR	NR	38	NA	19	Tennessee warbler	NA	Goodpasture 1986
122	Tennessee	Elizabethton, WCYB-TV	Mountain	NR	Sept. 30	1972	Fall	Cloudy, rain ceiling 4000	NR	125 (tallest of two)	Y	Flood lights reported	582	NA	NR	NR	NA	Herndon 1973
123	Tennessee	Knox county, WBIR-TV	Ridge	NR	Sept. 30	1984	Fall	Cloudy	NR	NR	NR	NR	393	NA	34	Ovenbird	NA	Nicholson 1984
124	Tennessee	Knox county, WATE-TV	Ridge	NR	Sept. 30	1984	Fall	Cloudy	NR	NR	NR	NR	368	NA	26	Ovenbird	NA	Nicholson 1984
125	Tennessee	Knox county, WBIR-TV	Ridge	NR	Sep. 29	1979	Fall	Clear Sept. 29 but Cloudy, fog on Sept. 28	NR	NR	NR	NR	47	NA	16	Bay-breasted warbler	NA	Turner and Davis 1980
126	Tennessee	Knox county, WATE-TV	Ridge	NR	Sept. 29	1979	Fall	Clear Sept. 29 but Cloudy, fog on Sept. 29	NR	NR	NR	NR	280	NA	33	Ovenbird	NA	Turner and Davis 1980
127	Tennessee	Nashville, WSIX	NR	NR	Late Aug. - Nov. 8	1968	Fall	NR	NR	NR	NR	NR	197	NA	39	Ovenbird	The tower was not surveyed daily.	Laskey 1969a
128	Tennessee	Nashville, WSIX	NR	NR	Autumn	1970	Fall	NR	NR	NR	NR	NR	104	NA	21	Ovenbird	The largest kill was on Sept 25 (78 birds), it was overcast and raining.	Laskey 1971
129	Tennessee	Nashville, WSIX	NR	NR	Autumn	1967	Fall	NR	NR	NR	NR	NR	98	NA	27	Magnolia warbler	NA	Laskey 1968
130	Tennessee	Nashville, WSIX	NR	NR	Aug. 22 - Nov. 16	1969	Fall	NR	NR	NR	NR	NR	307	NA	51	Magnolia warbler	The largest kill was on Oct 15 (139 birds), it was overcast and cold.	Laskey 1969b
131	Tennessee	Nashville, WSIX	Hill	NR	Sept. 12 - Nov. 8	1964	Fall	NR	NR	NR	NR	Lights present	665	NA	58	Tennessee warbler (114)	NA	Laskey 1964
132	Tennessee	Memphis, WMC-TV	NR	NR	May 7-8	1961	Spring	NR	NR	NR	NR	NR	19	NA	11	Magnolia warbler (4)	NA	Coffey 1964
133	Tennessee	Memphis, WMC-TV	NR	NR	May 11	1964	Spring	NR	NR	NR	NR	NR	96	NA	20	Red-eyed vireo (55)	NA	Coffey 1964
134	Tennessee	Nashville, WSIX	Hill	NR	Sept. 6 - Nov. 11	1962	Fall	NR	NR	NR	NR	Lights present	243	NA	46	Tennessee warbler (37)	NA	Laskey 1963a
135	Tennessee	Nashville, WSIX	Hill	NR	Sept. 13 - Nov. 7	1961	Fall	NR	NR	NR	NR	Lights present	228	NA	52	Ovenbird (38)	NA	Laskey 1962
136	Tennessee	Nashville, WSIX	Hill	NR	Sept. 3 - Nov. 7	1963	Fall	NR	NR	NR	NR	Lights present	292	NA	55	Tennessee warbler (31)	NA	Laskey 1963a
137	Tennessee	Nashville, WLAC	NR	870 ASEL	Sept. 15	1963	Fall	Fair weather	NR	1179	NR	NR	17	NA	7	Red-eyed vireo (8)	NA	Laskey 1963b
138	Texas	Ceder Hill, WFAA-TV	NR	NR	Oct. 16	1960	Fall	NR	NR	NR	NR	NR	500	NA	37	NR	NA	Pulich 1961
139	Texas	Meadowbrook, WBAP-TV	NR	NR	Oct. 16	1960	Fall	NR	NR	750	NR	NR	106	NA	NR	NR	NA	Pulich 1961
140	Texas	Dallas	NR	NR	Sept. 16	1966	Fall	NR	NR	NR	NR	NR	200	NA	27	NR	NA	Williams 1967
141	Texas	Dallas	NR	NR	Sept. 14	1975	Fall	NR	NR	NR	NR	NR	NR	NA	25	NR	NA	Williams 1976
142	Virginia	Lynchburg	NR	NR	Sept. 24	1971	Fall	NR	NR	NR	NR	NR	200	NA	NR	NR	The report states "about 200 birds".	Scott and Cutler 1972
143	West Virginia	Putnam County, WCHS-TV	Mountain	1087 ASEL	Oct. 7	1967	Fall	NR	NR	999	Y	NR	275	NA	26	Ovenbird	NA	Ellis 1997
144	West Virginia	St. Albans	Ridge	NR	Oct. 7	1967	Fall	NR	NR	NR	NR	NR	380	NA	42	NR	NA	Hall 1968
145	Wisconsin	Westport, KCMT-TV	Agricultural Field	NR	Sept. 10	1962	Fall	NR	NR	1100	NR	NR	528	NA	24	Swainson's thrush	NA	Kemper et al. 1966
146	Wisconsin	Madison, WKOW	NR	NR	Sept. 24	1968	Fall	Cloudy, rain, ceiling 600-6500 (ft)	NR	NR	NR	NR	317	NA	29	Olive-backed thrush (84)	NA	Sharp 1971

Number	State	Tower/City	Topographic Location	Elevation (ft)	Date	Year	Season	Weather	Survey Effort (Hours/ Area)	Tower Height (ft)	Guy Wires (Y/N)	Tower Lighting	Total Fatalities	Daily Range of Mortalities	No. of Species	Common Species	Comments	Reference
147	Wisconsin	Madison, WMTV	NR	NR	Sept. 24	1968	Fall	Cloudy, rain, ceiling 600-6500 (ft)	NR	NR	NR	NR	124	NA	24	Olive-backed thrush (43)	NA	Sharp 1971
148	Wisconsin	Madison, WISC	NR	NR	Sept. 24	1968	Fall	Cloudy, rain, ceiling 600-6500 (ft)	NR	NR	NR	NR	36	NA	13	Olive-backed thrush (16)	NA	Sharp 1971
149	Wisconsin	Madison, WHA	NR	NR	Sept. 24	1968	Fall	Cloudy, rain, ceiling 600-6500 (ft)	NR	NR	NR	NR	16	NA	6	Olive-backed thrush (7)	NA	Sharp 1971
150	Manitoba, Canada	Ste. Agatha, CJAY	Agricultural Field	NR	Sept. 23	1965	Fall	Cloudy	NR	1003	NR	NR	77	NA	22	White-throated sparrow (12)	NA	Smith 1966
151	Manitoba, Canada	Starbuck, CBWT	NR	NR	Sept. 23	1965	Fall	Cloudy	NR	1016	NR	NR	77	NA	29	Swamp sparrow (9)	NA	Smith 1966
152	Manitoba, Canada	St. Norbert, CFMW	NR	NR	Sept. 23	1965	Fall	Cloudy	NR	855	NR	NR	24	NA	16	Lincoln's sparrow (4)	NA	Smith 1966
153	Manitoba, Canada	Ste. Agatha, CKY	Agricultural Field	NR	Sept. 23	1965	Fall	Cloudy	NR	320	NR	NR	5	NA	4	White-throated sparrow (2)	NA	Smith 1966
154	Manitoba, Canada	Ste. Agatha, CJAY	NR	NR	Sept. 29	1965	Fall	Cloudy	NR	1003	NR	NR	91	NA	22	White-throated sparrow (14)	NA	Smith 1966
155	Manitoba, Canada	Ste. Agatha, CJAY	NR	NR	Oct. 1	1965	Fall	Cloudy, rain	NR	1003	NR	NR	146	NA	27	Swainson's thrush (44)	NA	Smith 1966
156	Ontario, Canada	Barrie, CKVR	NR	NR	Sept. 10	1974	Fall	NR	NR	1000	Y	NR	409	NA	NR	NR	NA	Hoskin 1975
157	Ontario, Canada	Barrie, CKVR	NR	NR	Sept. 13	1974	Fall	NR	NR	1000	Y	NR	709	NA	NR	NR	NA	Hoskin 1975
158	Ontario, Canada	Barrie, CKVR	NR	NR	Sept. 14	1974	Fall	NR	NR	1000	Y	NR	371	NA	NR	NR	NA	Hoskin 1975
159	Ontario, Canada	Barrie	NR	NR	Sept. 13	1961	Fall	Cloudy, fog	NR	NR	NR	NR	591	NA	31	Ovenbird (126)	NA	Woodford and Lunn 1962
160	Ontario, Canada	Agincourt	NR	NR	Sept. 13	1961	Fall	Cloudy, fog	NR	NR	NR	NR	150	NA	17	NR	150 fatalities is appoximate	Woodford and Lunn 1962
161	Ontario, Canada	Barrie	NR	NR	Sept. 20	1961	Fall	NR	NR	NR	NR	NR	14	NA	11	NR	NA	Woodford and Lunn 1962
162	Ontario, Canada	Agincourt	NR	NR	Sept. 20	1961	Fall	NR	NR	NR	NR	NR	6	NA	6	NR	150 fatalities is appoximate	Woodford and Lunn 1962
163	Ontario, Canada	Barrie	Hill	250 ASUL	Sept. 23-27	1960	Fall	Cloudy	NR	708	NR	NR	936	NA	41	NR	The largest kill on Sept. 24 with 633 dead birds.	Woodford and Burton 1961
164	Ontario, Canada	London TV tower	NR	NR	Sept. 14	1970	Fall	NR	NR	NR	NR	NR	125	NA	NR	NR	NA	Goodwin and Roshe 1971
165	Ontario, Canada	Toronto, WRJ	NR	NR	Sept. 14	1970	Fall	NR	NR	1000	NR	NR	136	NA	NR	NR	NA	Goodwin and Roshe 1971
166	Saskatchewan, Canada	Regina	NR	NR	Aug. 20 - Sept. 4	1964	Fall	NR	NR	NR	NR	NR	490	NA	36	NR	Combination of fatalities from three towers.	Lister 1965
167	Saskatchewan, Canada	Regina	NR	NR	Sept. 12	1974	Fall	NR	NR	NR	NR	NR	67	NA	13	Red-eyed vireo (12)	Warblers and Vireos were the only species listed under fatalities.	Houston and Houston 1975
168	Saskatchewan, Canada	Caron, Moose Jaw TV tower	NR	2400 ASEL, 500 ASUL	Sept. 22	1959	Fall	NR	NR	480	NR	NR	33	NA	13	Myrtle warbler (7)	NA	Lahrman 1959
169	Saskatchewan, Canada	Regina, CKCK-TV	NR	NR	Aug. 31	1965	Fall	Cloudy, rain, wind	NR	NR	NR	NR	188	NA	14	Tennessee warbler (76)	Birds were also picked up on Aug 27, 28, 29; Sept 9, 12, 16, 17, 19, 22, 25, 30; and Oct 2. Birds collected on these days were minor compared to Aug 31.	Belcher et al. 1966
170	Saskatchewan, Canada	Regina, CHRE-TV	NR	NR	Aug. 31	1965	Fall	Cloudy, rain, wind	NR	NR	NR	NR	138	NA	11	Tennessee warbler (49)	Birds were also picked up on Aug 27, Sept. 17, and Sept. 30, but only in small numbers. Since there was no sampling procedure I have only included the collection account for Aug 31.	Belcher et al. 1966
171	Saskatchewan, Canada	Regina, CHRE-TV	NR	NR	May 12-13	1962	Spring	Cloudy, ceiling 200-800 ft	NR	NR	NR	NR	59	NA	6	Gray-cheeked thrush	NA	Nero 1962
172	Saskatchewan, Canada	Regina, CKCK-TV	NR	NR	Sept. 7-8	1962	Fall	NR	NR	NR	NR	NR	54	NA	14	Ovenbird (13)	NA	Lahrman 1962
173	Saskatchewan, Canada	Regina, CKCK-TV	NR	NR	Oct. 6-7	1962	Fall	NR	NR	NR	NR	NR	24	NA	9	Orange-crowned warbler (8)	NA	Lahrman 1962
19	Grand Bahama	USAF 3 miles East of West End	NR	NR	Oct. 22	1966	Fall	Cold front	NR	400	NR	NR	99	NA	18	Gray-cheeked thrush	NA	Kale et al. 1969

ASEL = Above Sea Level
ASUL = Above Surrounding
NR = Not Reported

Appendix C

Scientific Study Review Forms

Title: The Composition and Seasonal Variation of Bird Losses at a Tall Tower in Southeastern North Dakota

Authors: Avery, Michael L, Paul F. Springer, and J. Frank Cassel

Date: 1978

Journal: American Birds

Objectives: To determine the extent and seasonal variation of bird mortality at a 1,200 foot transmitting tower in southeastern North Dakota.

Methods: Surveys began at dawn; these surveys were taken almost daily. The area within 151 feet of the tower was thoroughly monitored. The authors developed a randomized sampling effort in three separate concentric circles, each circle extending further from the tower (radii = 302 feet, 600 feet, and 2,400 feet, respectively). Each of these circles had a total of 8 sampling plots, each 40.7 feet on a side. Finally, the authors assessed scavenger removal rates by placing 296 dead birds at various points in the sampling scheme.

Statistical Analysis: Largely a descriptive study. Authors used chi-square tests to determine if the kill rates of particular species or families changed with the season.

Results: A total of 937 individuals of 102 species were found under and near the tower during the 3-year period. The authors estimated an annual mortality rate of approximately 1,075 individuals. Approximately 46% of the kills were Neotropical migrants. Approximately 54% of the kills occurred in fall migration (September – November), most of these were vireos and warblers. Scavenger rates were 7.4% (range: 2.4% in spring 1972 and 17.6% in spring 1973).

Conclusion: Authors conclude that the annual mortality rate is approximately 1,075 birds and that any study of tower kills must incorporate measures to control scavengers, although it is believed that their scavenger rates were much lower than the rates reported from Florida.

Important points: This study is quite good, nearly 3 years long (actual length was about 2.5 years). The sampling effort was substantial (essentially daily), consistent (dawn starts), quite extensive (clear randomized design), and it included an experimental effort to determine scavengers.

Tower kills did not vary greatly between spring (46%) and fall (54%), unlike the Florida study. There were no large kills (>500 birds), but the study was only 3-years long. The authors provided clear evidence of scavenger effects (7.4% loss).

November 3, 2003

Title: Characteristics of Avian Mortality at a Northern Florida Television Tower: a 29-year Study

Authors: Crawford, Robert L., and R. Todd Engstrom

Date: 2001

Journal: Journal of Field Ornithology.

Objectives: To determine the extent of bird mortality at a transmitting tower in northern Florida.

Methods: Daily surveys (e.g., 270 in 1956) started at dawn of a 20-acre (8-ha) area that was mowed weekly. This mowed area was under the tower and adjoining guy wires. From 1955 to 1967, Stoddard (who initiated this study) made an effort to remove scavengers and predators by trapping and using poison. Scavenger removal was stopped after 1967 except for a 3-year period between 1974 and 1976.

Tower height changed during the course of this study. The tower was 673 feet tall and was in service between 1955 and 1960. A new 1,008 feet tall tower was installed in 1960 and remained in service until 1989. The main part of this study concluded in 1985.

This tower was shortened to 284 feet in 1989 and has been in service since. In October 1999 and 2000 the authors checked this shorter tower to compare kill rates to the same period (October) when the tower was taller.

Statistical Analysis: Essentially a descriptive study. Used ANOVA to determine if kill rates changed when the height of the tower was increased from 673 to 1,008 feet. No effect found.

Results: A total of 44,007 individuals of 186 species were found under the tower during the 29-year period. More than 94% of these individuals were Neotropical migrants. Approximately 70% of the kills occurred in fall migration (September – November). Large kills (> 500 individuals) occurred on < 0.1% of the days but accounted for approximately 15% of the total mortalities. Days when a single bird was killed (3,579, approx 33% of the days when birds were found) accounted for only 2.7% of the total mortalities.

Two factors changed during the course of the study, tower height and predator control. Reduction in predator control corresponded with a 71% decline in birds found under the tower, suggesting a

strong scavenger effect. The number of mortalities declined by a factor of 32 after the tower was shortened in 1989: only 32 birds found October 1999 (27 visits) and 14 birds October 2000 (18 visits).

Conclusion: Authors conclude that shorter towers less than 295 feet may not present a serious threat to migrating birds. Also, any study of tower kills must incorporate measures to control scavengers.

Important points: This is probably the best study on tower kills. The sampling effort was substantial (essentially daily), consistent (dawn starts), extensive (covered 20+ acres that were mowed weekly), and there was a substantial effort to reduce predators for most of the 29-year period.

The authors provide convincing evidence for substantial scavenger effects. Scavengers were controlled (which probably means kept to tolerably low levels) for much of the study and when scavenger control efforts ended kill rates declined substantially. This has implications for every study of tower kills.

It is important to note that large kills (> 500 birds) occurred on very few occasions, < 0.1% of the sampling effort. Although very infrequent, these large kills accounted for approximately 15% of the total mortalities for this 29-year period. The number of days when only a single bird was found (3,579) accounted for 2.7% of the total mortalities.

The markedly lower mortality rate when the tower was checked in 1999 and 2000 suggests that shorter towers kill fewer birds. This is suggestive but needs more study.

October 31, 2003

Title:	Television Tower Mortality of Migrant Birds in Western New York and Youngstown, Ohio
Authors:	Morris, Sara R., Arthur R. Clark, Laura H. Bhatti, and Jamin L. Glasgow
Date:	2001
Journal:	Northeastern Naturalist
Objectives:	To determine the extent and seasonal variation of bird mortality at three towers in NY and a single tower in Ohio.
Methods:	Surveys followed overcast nights when authors thought mortality events were more likely (from 8 to 67 visits annually). Area within 164 to 197 feet of the tower was thoroughly monitored. There was no effort to determine level of scavenger activity.
Statistical Analysis:	Largely a descriptive study. Authors used linear regression analysis to determine whether the number of kills declined during the course of the study.
Results:	A total of 20,148 individuals of 106 species were found under and near the three New York towers during the study period, 1970 - 1999. A total of 4,310 individuals of 80 species were collected beneath the Ohio tower between 1974 and 1992. The annual mortality rate was approximately 672 in New York and 227 individuals in Ohio. The percent of Neotropical migrants was not calculated. There was a statistical decline in the number of birds killed at these towers during the course of the study.
Conclusion:	Authors conclude the mortality rate at these towers have declined over time.
Important points:	Although a long-term effort, this study is quite limited and does not provide a species list. The sampling effort was adequate but uneven so annual mortality rates may not mean very much. The only conclusion the authors make was that mortality rates declined over time. The authors did not explore other facets, nor did they provide sufficient data for others to do so.

November 3, 2003

Title:	A Study of Bird Mortality at Nashville's WSMV Television Tower
Authors:	Nehring, Jennifer, and Sandy Bivens
Date:	1999
Journal:	The Migrant
Objectives:	To determine the extent of bird mortality during fall at a single tower in Tennessee.
Methods:	Daily surveys from September 1 to October 31 for 38 years (1960 - 1997). The start of these visits, the sampling effort, and area studied are not provided. There was no effort to determine level of scavenger activity.
Statistical Analysis:	This is a descriptive study, no statistics provided.
Results:	A total of 19,880 individuals of 112 species were found under and near the Nashville tower during the period, 1960 - 1997. The annual mortality rate was approximately 523. There were two large kills—5,399 birds were found on September 26, 1968, and 3,487 birds were collected on September 28, 1970. Neotropical migrants accounted for > 90% of the total kill. There was a clear decline in the number of birds killed at these towers during the course of the study.
Conclusion:	Authors concluded that the mortality rate at this tower declined over time.
Important points:	Although a long-term effort, this study is quite limited and does not provide a species list. The sampling effort was good but was limited to September and October, so annual mortality rates were certainly underestimated. It seems important that only 2 large mortality events were reported. Unfortunately, the authors did not provide data on kills > 500 individuals and just reported the very large kills. The only real conclusion the authors make was that mortality rates declined over time. They did not explore other facets.

November 3, 2003