AVIAN MORTALITY AT COMMUNICATION TOWERS: A REVIEW OF RECENT LITERATURE, RESEARCH, AND METHODOLOGY

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Executive Summary

A review of the recent literature and research in progress on bird collisions with communication towers was contracted by the U. S. Fish and Wildlife Service. In the five year period 1995 through 1999, very little research was published or conducted that is relevant to the bird-communication tower collision problem. It seems that since the major reviews of the late 1970s and early 1980s, few researchers and others have been interested in researching the problem. Before 1985, there was an enormous body of literature, mostly anecdotal that has not been examined analytically.

For the current review, a standard literature search was conducted along with a search of the world wide web. In addition, all state fish and game agencies (nongame programs), state ornithological organizations (and their publication editors), bird observatories and organizations, and listserves were canvassed via email, as were representatives of conservation organizations of more than 25 countries. Finally, about a dozen of the world's leading researchers on the topic were interviewed to determine whether they were conducting research or whether they knew of anyone who was. Questionnaires were designed and tailored to each of the groups canvassed.

Although there is little research now being conducted or results published within the past five years, several researchers are now conducting studies of towerkills in Kansas, West Virginia, and New York. These studies, in addition to studies of towerkills at recently developed wind turbine sites, suggest that shorter towers do not kill as many birds as taller towers (no major mortality events have been reported at the shorter towers), although this conclusion should not be considered definitive.

With respect to research on the influence of magnetic radiation and radio frequencies in the range of those emanating from towers on migrating birds, there is little research. Experts canvassed did not feel that these waves are as strong as the earth's magnetic field and are not likely to cause disruption of night migrating birds' orientation or navigation systems. One potentially promising technique involves the impacts of infrasonic (low-frequency acoustic) shock waves on birds, particularly Homing Pigeons, which may – following research into its efficacy – provide a means for warning birds of tower presence and resultant bird avoidance, even in inclement weather.

There have been no studies documenting the difference in risk of various lighting systems, although several researchers stated that white strobes are likely to be less risky than white or red blinking lights.

Several research reports documented the usefulness of various technologies for studying bird flight. Radar (tracking, marine surveillance, and NEXRAD), infrared, and acoustical methods will prove useful for studying the behavior of birds migrating near communication towers. For determining fatalities at communication towers, there have been no standard methods or metrics adopted so it will be very difficult to compare results from different researchers. Recommendations are made herein for designing research and assisting researchers conducting research: 1) standardizing metrics and methods for assessing mortality at towers, 2) establishing a database of existing towers including ownership and characteristics of towers, 3) streamlining/relaxing permit requirements for researchers collecting birds at towerkills, 4) providing access to more towers for towerkill research, and 5) analytically examining the existing towerkill database.

Introduction

The recent proliferation of communication towers across the United States has sparked a renewed interest in avian mortality that results from collisions of night migrating birds with these towers. With more than 50,000 lit communication towers greater than 199 feet above ground level (AGL) existing and thousands more proposed or planned – and perhaps, tens of thousands more less than 200 feet AGL – the number of obstacles to night migrating and other birds is increasing rapidly (see www.towerkill.com and http://migratorybirds.fws.gov). These towers, used mostly by the wireless telephone, radio, and television industries, range in height from less than 100 feet (31 m) to more than 2,000 feet (615 m). With high definition television (HDTV) on the horizon**,** some in the communication industry project that 1,000 new 1,000 foot tall (308 m) towers will be erected.

Our knowledge regarding tower kills is rudimentary, despite more than 50 years of history documenting the problem (first reported by Aronoff in 1949; for reviews see Avery et al. 1978, 1980**;** Banks 1979; Hebert et al. 1995; Kerlinger in press; Trapp 1998**;** and Manville 2000). Basically, we know that birds collide with tall towers and that on some occasions – particularly, but not necessarily always, during inclement weather – these towers kill large numbers of birds. The species impacted most seem to be night migrating songbirds (warblers, thrushes, vireos, tanagers, cuckoos, sparrows, etc.), although smaller numbers of waterfowl, shorebirds, and other species have also been documented**.** Current estimates of the numbers of birds killed annually by communication towers range between 4 and 10 million (www.towerkill.com).

This report is a review of the most recent literature, research, and other efforts to understand the avian-communication tower collision issue from 1995 to the present. It was commissioned by the U. S. Fish and Wildlife Service as part of their new Communication Tower Working Group (Working Group or CTWG) initiative. The report summarizes the literature, as well as research that is now in progress and reports that may soon be published. It also identifies the most active researchers working on the towerkill issue. Research topics included in this review are avian fatality studies at communication towers, the role of lighting and electromagnetic radiation and radio frequencies in avian collisions with communication towers, orientation and navigation behavior of migrants around communication towers, and methodologies used to study the towerkill problem. In addition, it summarizes recent studies from the wind power industry that are relevant.

Methods

An examination of previous literature reviews and bibliographies by Avery *et al.* showed that in the period between the early 1950s, when reports first started to emerge on towerkills, and into the early 1990s, very little was being published in the peer reviewed ornithological or ecological literature. Instead, most reports were from smaller, state ornithological journals or the "gray" literature (*i.e.*, popular articles, unpublished reports and other documents, and some internet [non-journal] materials). Because these reports were not in the mainstream literature and because work in progress and unpublished recent reports were the focus of this review, alternative sources of information were examined. The information sources examined included:

- Primary scientific literature from 1995 to the present from the U. S., Canada, Central and South America, Australia, New Zealand, and Europe including ornithology journals, conservation journals, and wildlife journals;
- Secondary literature from 1995 to the present including state ornithological journals, newsletters, and publications of various ornithological type organizations;
- Keyword searches of the world wide web;
- Questionnaires sent to all nongame programs from state fish and game agencies via email addresses supplied by the International Association of Fish and Wildlife Agencies;
- Questionnaires sent to state ornithological society/club representatives in the U. S.;
- Questionnaires sent to all viable bird observatories and observatory type organizations across the U. S.;
- Questionnaires sent to ornithological journal editors and contacts in foreign countries – via several sources including email addresses found in BirdNet, BirdLife and International partners in 20 countries;
- Questionnaires circulated on various listserves (NEOORN-L for the neotropics) and passed along via numerous avenues, also sent to representatives of conservation organizations in Mexico (Pronatura), Nicaragua, and other countries in Central and South America; and
- Experts in the field interviewed by telephone.

The questionnaires were tailored to each of the above types of publications, organizations, observatories, state fish and game agencies, ornithological publication editors, etc. The format for these questionnaires can be found in Appendix I.

Interviews of experts on towerkills, bird migrations, techniques for observing/monitoring birds in darkness (various radars, ceilometer, infrared, and image intensification), and others were conducted using a standard device (see Appendix II). The following researchers were

interviewed: Kenneth Able (State University of New York at Albany), Michael Avery (National Wildlife Research Center, U.S. Dept. of Agriculture**,** Florida), Robert Beason (State University of New York at Geneseo), Ronald Canterbury (Concord College, West Virginia), Arthur Clark (Buffalo Museum of Science, New York), Francesca Cuthbert (University of Minnesota), Todd Engstrom (Tall Timbers Research Station, Florida), William Evans (independent acoustical ornithologist, New York), Sidney A. Gauthreaux (Clemson University, South Carolina), T. Adam Kelly (Geo-Marine, Inc., Florida), Ronald Larkin (Illinois Natural History Survey, University of Illinois), Hugh McIsaac (University of Denver, Colorado), and Eugene A. Young (Southwest College, Kansas). In addition, several other knowledgeable parties were consulted, primarily to ask who might be doing research or who might know of others conducting research on the bird towerkill issue.

Annotated Bibliography of Published and Unpublished Reports, and Research in Progress on Communication Towers and Birds, 1995-2000

The list of references that follows is arranged alphabetically by principal investigator. Each includes the author's name(s), the date published, the title, the journal or other publication, volume number, page numbers, a brief synopsis, and a code. The codes are:

U = unpublished report; P1 = published in peer reviewed journal; P2 = published in an unreviewed or quasi reviewed journal/periodical; P3 = published in other (gray) literature/website; SC = synopsis of work that has been completed; and SI = synopsis of work that is in progress.

❒ Allred, M. 2000. Tower sitings, co-location - one industry's creative approach to antenna placement. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Discussion of creative ways to eliminate the need for new towers and need for less dangerous towers including placement on existing structures (buildings, billboards, etc.), co-location (placement on existing towers of other companies), monopole construction (no guy wires) and industry recognition of the towerkill problem.

❒ Avery, M. L., P. F. Springer, and N. S. Dailey. 1978. Avian mortality at man-made structures: an annotated bibliography. U. S. Fish and Wildlife Service. FWS/OBS-78/58. (P3)

❒ Avery, M. L., P. F. Springer, and N. S. Dailey. 1980. Avian mortality at man-made structures: an annotated bibliography (revised). U. S. Fish and Wildlife Service. FWS/OBS-80/54. (P3)

This and the previous source have the largest set of references on bird-tower collisions and electrocutions of any of the reviews. Reports are indexed by subject, taxonomic entity, and geography. The report summaries come from a variety of sources.

❒ Ball, L. G., K. Zyskowski, and E. S. Griselda. 1995. Recent bird mortality at a Topeka television tower. Kansas Ornithological Society Bulletin 46:33-35. (P1)

Four towerkills totaling 2,808 birds of 91 species are reported from autumn 1985, 1986, and 1994 at a 943-foot-tall (290 m) guyed and lighted television tower near Topeka, KS. On all 4 evenings, visibility was limited with low ceilings and little precipitation, with the exception of 1 night with rain and snow.

❒ Banks, R. C. 1979. Human-related mortality of birds in the United States. U.S. Department of Interior, Fish and Wildlife Service, Special Scientific Report – Wildlife No. 215. (P3)

This short overview provides rough numbers of birds killed by various sources in the early 1970s. In particular, Banks estimates annual mortality from tower strikes. Based on 50% of the then existing (1979) 1,010 television transmitting towers in the U.S., Banks estimated annual mortality at nearly 1.3 million birds. He made no accounting of mortality from the radio transmitting towers and airport ceilometers nor for mortality from the other one-half of the existing television towers.

❒ Bayley, D. T. 2000. Obstruction marking (lights) - recommendations from the FAA. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Tower lighting procedure, visible marking (lights), environmental concerns, visual nuisance to neighbors, basis for color of lighting, insurance liability, and FAA authority are discussed in relation to bird kills and lighting.

❒ Beason, R. C. 2000. The bird brain: magnetic cue, visual cues, and radio frequency (RF) effects. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

The paper provides an introduction and technical discussion of avian visual physiology as it relates to tower lighting (colors), orientation of migrants, oil droplets in the eye, and disorientation at communication towers. Many questions remain unanswered that could, if answered, potentially provide means of reducing or eliminating towerkills.

❒ Bruderer, B. 1997. The study of bird migration by radar. Part 2. Naturewissenschaften 84:45-54. (P1)

A techniques paper about tracking radar. Methodological applications to studying tower situations.

❒ Bruderer, B., and A. Boldt. 1994. Homing pigeons under radio influence. Naturwissenschaften 81:316-317. (P1)

Although published prior to the time frame of this review, this is one of the few papers that addresses the radiowave question. Homing Pigeons were released near a 7.5 to 21.8 MHz, 150-kW (shortwave) radio-transmitter near Bern, Switzerland. Some effects - difference in

direction of movement - were reported, although the Pigeons did seem to detect the electromagnetic fields. Birds were apparently not disoriented, but visual cues were available.

❒ Bruderer, B., D. Peter, and T. Steuri. 1999. Behaviour of migrating birds exposed to X-band radar and a bright light beam. J. of Experimental Biology 202:1015-1022. (P1)

Tracking of single nocturnal migrants with radar (X-band, tracking radar, and a strong searchlight during autumn in Israel**)** was done to determine if light or radiation from a radar would disorient migrants. No disorientation was detected when birds were in the radar beam, although light profoundly changed the migrants' behaviors. In the light beam, migrants flew more slowly, increased climb rate, and deviated from migration direction. There was zero reaction beyond one kilometer. Confirmation of some earlier work on aircraft lights disorienting birds. Not necessarily applicable to blinking lights on towers. The radar used by Bruderer *et al*. might be ideal for tracking birds around towers with experimental lighting.

❒ Berland, A. H. 2000. Licensing concerns, NEPA, sitings, Telecommunications Act mandates - the FCC perspective. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Perspective on bird kills and tower lighting from staff attorney from FCC. Summary of Telecommunications Act, lighting requirements, proximity to airports, cost of lighting, enforcement by the agency, and other issues are discussed.

❒ Burger, A. E. 1997. Behavior and numbers of Marbled Murrelets measured with radar. Journal of Field Ornithology 68:208-223. (P1)

Flights between forest nests and ocean feeding areas were tracked with radar. This methodology should be useful to researchers for monitoring movements of birds around communication towers, especially in forested areas.

❒ Cooper, B. A., and R. J. Ritchie. 1995. The altitude of bird migration in east-central Alaska: a radar and visual study. Journal of Field Ornithology 66:590-608. (P1)

Results of this paper show that bird migration flight behavior can be studied nicely with this type of mobile radar.

❒ Crawford, R. C., and R. T. Engstrom. 2000. Lights, towers, and avian mortality: where is the science? Transcripts of Proceedings of the Workshop on Avian Mortality at Communications Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Summary of early examination of towerkills and work done at a TV tower in Talahassee, FL, from about 1960 to the present. In 25 years, 42,000 fatalities of 189 species were found, mostly in autumn migration. Species composition, average numbers, weather factors, and other aspects of kills at this tower are discussed, as was the impact of scavenging on the numbers of bird found.

❒ Crawford, R. C., and R. T. Engstrom. Manuscript in prep. Characteristics of avian mortality at a north Florida television tower: a 28-year experience. To be submitted for publication. (U)

Review of tens of thousands of kills at a northern Florida television tower, 1955-1983, and analysis of changes resulting from change in height of tower (reduced from 600/1000 feet to 300 feet in height) and effects of scavenging. Numbers of fatalities decreased from 257 kills per year with the taller structure to only 8 kills in the year after the tower was shortened. Variation was great among years, a result of natural variation, scavenging, and, possibly, reduction in numbers of birds migrating over the site.

❒ Deutschlander, M. E., J. B. Phillips, and S. C. Borland. 1999. The case for light-dependent magnetic orientation in animals. J. Experimental Biology 202:891-908. (P1)

This complex, theoretical/review type paper discusses several hypotheses attempting to resolve the differences observed in the wavelength-dependent effects of light on magnetic orientation in birds, amphibians, and dipterans. The effects of light on magnetic orientation in birds may be a result of direct effects on magnetoreception or to a different effect of light on orientation. The mechanism may be different among salamanders. The applicability of light effects on magnetic orientation of migrating birds may be important to ameliorating towerkills because most birds seem to be attracted to lights when visibility is poor. If light color can impact on magnetic orientation, the mechanisms by which disorientation at towers operates may be understood. However, it would seem that this and other studies that focus on understanding the relationship between light and magnetoreception are a long way from helping with the towerkill problem.

❒ Ellis, C. D. 1997. Back to the tower: tower-killed birds at a Putnam County, West Virginia television transmission tower. The Redstart: 64:112-113. (P2)

A single search at a 999-and a 1,552-foot-tall television tower in September 1995 revealed 275 specimens of about 27 species.

❒ Evans, W. R. 2000. Avian mortality at communications towers: background and overview. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Introduction to workshop, background information on towerkills, and statement of the problem of tower proliferation and bird kills.

❒ Evans, W. R. 2000. Applications of acoustic bird monitoring for the wind power industry. Proceedings of National Avian - Wind Power Planning Meeting III, San Diego, CA, May 27-29 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by Resolve Inc., Washington, D.C. and LGL Ltd., King City, Ont. (P2)

A description of the methodology for acoustically determining species composition of nocturnal migration over a given site.

❒ Evans, W. R. 2000. Applications of avian night flight call monitoring for towerkill mitigation. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Description of acoustical monitoring technique and how the technique was used in a study to determine species composition along a transect through central New York State. The method is useful for studying broad-front species distributions in migration as well as more focused work at specific sites. If an endangered species has a narrow migration path, acoustical monitoring can determine that and signal that towers could be dangerous there.

❒ Evans, W. R., and D. K. Mellinger. 1999. Monitoring grassland birds in nocturnal migration. Studies in Avian Biology 19:219-229. (P1)

A description of the use of acoustical recording equipment to detect and identify different species of grassland birds as they migrate overhead. The acoustical device permits species specific identification of night migrants, which cannot be done with any other technology.

❒ Evans, W. R, and K. V. Rosenberg. 1999. Acoustic monitoring of night-migrating birds: a progress report. In Strategies for bird conservation: creating the Partners in Flight planning process. R. Bonney, D. N. Pashley, R. J. Cooper, and L. Niles. (eds.), Cornell Laboratory of Ornithology, http://birds.cornell.edu/pifcapemay/evans_rosenberg.htm (P1)

Summary of system that records calls of night-migrating songbirds. This system provides a taxonomic and somewhat quantitative overview of migration at a particular location. It has been used by Evans and his team around communication towers.

❒ Evans, W. R., and A. Manville, II. 2000. Avian mortality at communication towers. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Symposium proceedings of the first conference on communication towerkills. Papers summarize state of the science, methodology, as well as agency and industry representation and concerns. Each of the presentations is summarized in this report at the website given above.

❒ Evans Ogden, L.J. 1996. The hazards of lighted structures and windows to migrating birds. Fatal Light Awareness Program and World Wildlife Fund Canada. (P2)

A short book summarizing the problem of night migrants colliding with lighted buildings in urban centers. Numbers of carcasses summarized, and a description of the Fatal Light Awareness Program (FLAP) given, which seeks to turn building lights out during migration season to reduce avian fatalities, starting in Toronto, Canada.

❒ Federal Highway Administration. 1999. Bird-tower collision literature. (P3)

List of references on the bird-towerkill issue indexed in various ways: observations, mitigation, lighting, etc. Most of references were published before 1995; nicely organized.

❒ Fortin, D., F. Liechti, and B. Bruderer. 1999. Variation in the nocturnal flight behavior of migrating birds along the northwest coast of the Mediterranean Sea. Ibis 141:480-488. (P1)

Use of infrared sensing device (LORIS - IRTV-445L) to monitor night migration. This paper illustrates how infrared technique can be used and is applicable to tower situations.

❒ 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 Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

The flight behavior or migrating songbirds was studied in spring and fall at communication towers; one with white-strobe and one with red flashing lights, and a control area with no tower to determine whether behavioral differences were evident. A greater proportion of birds showing curved, circling, or hovering at red lighted towers than white lighted towers or the control area. More convoluted flight was also found with white lights than in the control area. The findings suggest white-strobe lights are less dangerous than red lights on towers. A hurricane blew the towers down before the results could be replicated.

❒ Gauthreaux, S. A. 2000. Summary of scientific session. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Comments about the first scientific panel presentations of this meeting.

❒ Hagstrum, J.T. 2000. Perspective: infrasound and the avian navigational map. J. Exper. Biology. Apr. 2000 galley proof: 9 pp. (P1)

How birds, such as Homing Pigeons, are able to select the correct homeward bearing over hundreds to even thousands of miles still remains a mystery. Also mysterious are rare disruptions of Pigeon races in which the birds are substantially delayed and large numbers are lost in what appears to be the birds encountering infrasonic (low-frequency acoustic) shock waves from the Concorde supersonic transport. The paper suggests the presence of infrasonic cues radiated from steep-sided topographic features whose source is microseisms continuously generated by interfering oceanic waves that may be used by birds for navigation. The author suggests the use of a speaker around communication towers radiating infrasound, such as that of thunder, to deter birds and bird collisions. The hypothesis needs testing.

❒ Harmata, A.R., K.M. Podruzny, J.R. Zelenak, and M.L. Morrison. 1999. Using marine surveillance radar to study bird movements and impact assessment. Wildlife Society Bulletin 27:44-52. (P1)

A techniques paper on the use of marine surveillance radar for monitoring movements of birds and assessing potential impact in areas where wind turbines or towers are proposed for development. Use at a site in Montana and technical information is reported. Objects farther away were detected more easily with radar than human eye.

❒ Hebert, E., E. Reese, and L. Mark. 1995. Avian collision and electrocution: an annotated bibliography. California Energy Commission, Sacramento, CA. (P3)

468 references on towerkills and electrocution issues. Annotation does not include tower height on many references (perhaps a result of original papers not always reporting height). All references included were dated prior to the present review.

❒ Herron, J. 1997. Television transmission tower kills in Lewis County, West Virginia. The Redstart 64:114-117. (P2)

A 529-foot-tall television tower was searched during autumn migration, 1978 through 1986, during which 841 birds were found representing 58 species (almost entirely songbirds). Seven visits during fall 1996 revealed 13 dead birds of 8 species.

❒ Kelly, T. A. 1999. Seasonal variation in birdstrike rate for two North American raptors: Turkey Vulture (*Cathartes aura*) and Red-tailed Hawk (*Buteo jamaicensis*). Raptor Research 33:59-62. (P1)

Bird Avoidance Model (BAM) methodology using records of raptor-aircraft strikes. Model may be useful for towerkill problem.

❒ Kelly, T. A., and R. White. 1999. Avian hazard advisory system (AHAS). Report to U.S. Army Corps of Engineers, Fort Worth, TX and U.S. Air Force Air Combat Command. Geo-Marine, Inc., Avian Laboratory, Panama City, FL. (P3)

Use of technology to detect migrants and avoid strikes with aircraft. Sophisticated detection equipment such as NEXRAD Doppler weather radar may be useful to tower work for examining large-scale and medium-scale geographic patterns of migration.

❒ Kelly, T. A., R. Merritt, and R. L. White. 1999. The avian hazard advisory system. Bird Strike '99 - Proceedings, Vancouver, BC, pages 215-218. (P2)

Use of NEXRAD Doppler weather radar, weather forecasts, and known bird distributions to identify bird hazards to military aircraft is described. Technology may be useful for plotting migratory patterns in relation to towers.

❒ Kelly, T. A., R. Merritt, and R. L. White. 2000. NEXRAD Doppler weather radar, other applications for bird monitoring. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Avian Hazard Advisory System, in which NEXRAD weather radar is used, is described along with suggestions for its applications to the bird-communication tower problem. The system is used to detect birds that could strike Air Force planes. Combining NEXRAD with GIS systems can provide both fine and macro scale distributions of migrants. Other methods for monitoring migrants are discussed including image intensification, other types of radars, thermal imagery (TI, also called forward looking infrared [FLIR]), as are the complexities of monitoring with such technology.

❒ Kelly, T. A., E. Zakrajsek, and A. Smith. 1996. Bird avoidance modeling at Dare County Bombing Range, NC, and Moody Air Force Base/Grand Bay Weapons Range, GA. International Bird Strike Committee Europe (IBSC 23) Proceedings and Papers 539-542. (P2)

Summary of effort to quantify risk of bird-aircraft strikes using radar, radio telemetry, satellite telemetry, and acoustics to monitor bird movements at the bombing range. Technology will be useful for studying birds near towers.

❒ Kemper, C. 1996. A study of bird mortality at a west central Wisconsin TV tower from 1957-1995. Passenger Pigeon 58:219-235. (P2)

During 38 autumn and spring migration seasons, conducted for the most part on a "daily basis," 121,560 carcasses representing 123 species were collected through1994 – with Neotropical songbird migrants being most represented. Also reviewed were seasonal dates of migration passage. Carcasses were found only after the tower height was increased from 500' to 1,000' in height. Height, guy wires, and weather were implicated as the causes for major kill events with taller towers being more dangerous, guy wires being dangerous, and poor visibility caused by low ceilings, precipitation, or fog.

❒ Kerlinger, P. 2000. An assessment of the impacts of Green Mountain Power Corporation's Searsburg, Vermont, wind power facility on breeding and migrating birds. Proceedings of the National Wind Coordinating Meeting, San Diego, CA, 1998. (P2)

June through October 1997 carcass searches under 11 192-foot-tall wind turbines on a forested hilltop in southern Vermont yielded no evidence of mortality of migrants. Scavenger and efficiency studies were conducted. The study suggested that towers less than 200 feet in height without lighting do not pose a significant risk to birds.
❒ Kerlinger, P. 2000. An assessment of the impacts of Green Mountain Power Corporation's wind power facility on breeding and migrating birds in Searsburg, Vermont. In press. National Renewable Energy Laboratory, DOE. (P2)

Although this report is about a wind-power facility, one section of it contains a review and analysis of the literature on tower kills from the eastern U. S. This is one of the only reports that examines the role of tower height as a factor in towerkills. Little evidence was found implicating towers less than about 300-450 feet in towerkills that involved anything greater than a few birds.

Kerlinger, P. 2000. Standardizing methods and metrics for quantifying avian fatalities at communication towers: lessons from the wind power industry. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

A system of standardized methods and metrics for finding and reporting fatalities has been developed in the wind power industry. For statistical inferences to be made regarding how many birds are killed at different towers, estimating overall numbers of fatalities, and determining what type of measures may be taken to prevent collisions with towers, standard metrics and methods must be devised for communication tower fatalities. Birds per tower per year is a metric used to summarize fatalities at different wind power sites and could be used for communication towers.

❒ Kingery, U., and H. Kingery. 1999. Northern harrier killed at radio tower. Journal of the Colorado Field Ornithologists 33:174-175. (P2)

Title summarizes paper. Interesting in light of Osprey found by Evans' group under a New York State tower.

❒ Kreithen, M. L., and E. Davis. 1995. Development of a pulsed microwave warning system to reduce avian collisions with obstacles. Abstract only, Bird Strike Committee, USA. (U)

Referenced in Bruderer et al. 1999 (abstract not seen). Report not released from Electric Power Research institute (EPRI). Kreithen had done sensory work previously. Upon Kreithen's death, his research materials on this topic were given to Dr. Hugh McIsaac at the University of Denver.

❒ Kleinhaus, S., B. Pinshow, and R. Frumkin. 1995. Thermal effects of short radio waves on migrating birds. Ecological Applications 5:672-679. (P1)

A computer model was used to evaluate the thermal effects of short-wave electromagnetic radiation on migrating birds. Small to medium-sized birds would not be in thermal danger while in the station's radiation canopy. Large birds might incur increased heat load while taking off through that canopy, but normal heat dissipation mechanisms should be available to avoid such loads. Large birds landing on antennas might be vulnerable to overheating. The research was done to determine if the Voice of America station planned for the Arava Valley in Israel would impact migrating birds.

❒ Kruse, K. 1996. A study of the effects of transmission towers on migrating birds. M.S. Thesis. University of Wisconsin-Green Bay, Green Bay, WI. (U)

Although based only on one spring migration season of carcass searches at three communication towers (384, 317, and 110 m; 1,248, 1,040, and 358 feet), this thesis includes the most detailed analyses of factors influencing fatalities at such towers. The shorter tower accounted for 3 birds as opposed to 30 and 50 found at the taller towers. Surveys of live birds conducted on the same days in adjacent habitats showed that the species killed were killed in proportion to their presence. Fog, haze, and other weather factors were correlated with greater incidence of kills.

❒ Larkin, R. P. 2000. Investigating the behavioral mechanisms of tower kills. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

The author described research on behavior of birds at a 1,000 foot communication tower studied in Illinois with tracking radar. Birds displayed circular flight paths around the tower with low ceiling and cloud cover. This behavior suggests that birds fly into guy wires after becoming attracted to lights on towers when there is poor visibility. The author also suggested that birds became stressed as they flew continually in the lights of a tower.

❒ Liechti, F., B. Bruderer, and H. Paproth. 1995. Quantification of nocturnal bird migration by moon watching: comparison with radar and infrared observation. Journal of Field Ornithology 66:457-468. (P1)

Tracking radar and infrared (LORIS) technologies were compared with moon watching. Biases were detected and reported. Radar and infrared (IR) see birds at considerable distances and both are useful for tracking birds near communication towers.

❒ Manville, A.M., II. 2000. Avian mortality at communication towers: background and overview. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Introduction to workshop, statement of the problem, U. S. Fish and Wildlife Service involvement, introduction of speakers, and some preliminary recommendations for tower safety.

❒ Manville, A.M., II. 2000. The ABC's of avoiding bird collisions at communication towers: the next steps. Proceedings of the Avian Interactions Workshop. Dec. 2, 1999, Charleston, SC, Electric Power Research Institute, Palo Alto, CA. (P2)

This overview provides known and suspected causes of bird collisions with communication towers, assesses gaps in the information base, discusses current attempts to fill the gaps, discusses the role of the U. S. Fish and Wildlife Service in the process, and reviews activities that prompted the recent Fish and Wildlife action. Nocturnally migrating songbirds are most susceptible to collisions with lit towers when visibility is poor (low ceiling, fog, precipitation). Preliminary recommendations are made to minimize collisions and a review of recent partnerships (Avian Power Line Interaction Committee and National Wind Coordinating Committee) that are working to resolve bird kills in related industries.

❒ Manville, A.M., II. 2000. Panel Discussion. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Summary of panel discussion at end of communication tower-birdkill conference with comments from all participants included.

❒ Mesure, M. 2000. Buildings, lights, findings applicable to towers, cumulative effects - the Canadian perspective. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY.
http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

The Fatal Light Awareness Program (FLAP) is a program first started in Toronto in which the lights in tall buildings are turned off to prevent birds from colliding with buildings. After discovering that thousands of birds collide with tall buildings, efforts to get lights turned off (both room lights and spot-lights) have been successful at some tall buildings. Bird-Friendly Buildings receive a gold seal to identify them as such. By extinguishing lights, birds are no longer killed at some tall buildings in Toronto and elsewhere.

❒ Meyers, J. M. 2000. Communication towers, avian mortality, and research needs. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

The need for studying towers and birds as a result of collisions is discussed. Studies should include factors involved in fatalities as well as mechanisms of bird migration that relate to the problem. The implication made was that lots of tedious, empirical work will be required to solve the problem, and a large amount of funding will be necessary.

❒ Moss, S. 2000. The wireless industry perspective. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Review of problem from wireless industry including Telecommunications Act of 1996, Congressional mandates for state-of-the-art national telecommunications infrastructure, proportion of towers taller than 200 feet, expansion of industry, and recent nature of problem from the communication industry perspective.

❒ Nehring, J. D. 1998. Assessment of avian population change using migration casualty data from a television tower in Nashville, Tennessee. MS. Thesis. Middle Tennessee State University, Murfreesboro, TN. (U)

Summary of numbers and species of kills from 1960 to 1997 at a 1,368 foot tall television tower (with lights and guy-wires) near Nashville, Tennessee. 19,880 birds of 112 species were collected. Ovenbird, Tennessee Warbler, Magnolia Warbler, and Red-eyed Vireo accounted for 58% of all fatalities found. Kills on two nights accounted for 45% of all fatalities found. Between the 1960s and 1997, the numbers of birds killed dropped from more than 11,000 in the 1960s, to 6,000 in the 1970s, to 1,000 in the 1980s, and to about 600 in the 1990s. As the title states, the reduction may be a result of population declines of some birds.

❒ Rappi, R., R. Wiltschko, P. Weindler, P. Berthold, and W. Wiltschko. 2000. Orientation behavior of Garden Warblers (*Sylvia borin*) under monochromatic light of various wavelengths. Auk 117:256-260. (P1)

Cage orientation experiments using birds reared under controlled light and electromagnetic conditions were conducted during autumn on 12 individuals. Birds raised in altered light environments performed differently than birds raised in a "control white" light regime. This study shows a wave-light dependent orientation with red light (630 nm) not permitting magnetic orientation, while green (565 nm) light does. Birds tested with red lights were disoriented whereas birds tested with green could orient accurately. This has now been found for birds of different orders and among passerines of three different families. Applicability to towerkill situations is not immediately apparent, but such work may eventually shed light on disorientation at lighted towers. If light coloration does inhibit electromagnetic orientation ability, could tower lighting change this ability?

❒ Raynor, L., K. Wilson, E. Snell-Rood, and D. Cristol. 1999. Unpublished project. William and Mary College, Dept. of Biology. Attraction of sparrows to light of differing colors in a Y-maze (title composed by author of this report to describe project). (SC)

Student project focused on how light influenced nine White-throated Sparrows in Y-maze. They tested duration of light flashing (24 vs. 64 flashes per minute), color of the light, etc. Birds were attracted to light over darkness, white over colored light, constant light over flashing light. Future work is planned.

❒ Rogers, K. 2000. Research and policy overview: a critique and needs analysis. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Public policy and implications for research are discussed, including Telecommunications Act of 1996, local regulations about towers, case law, NEPA interpretation by FCC, inclusion of other groups in process, money for FCC to review permits, and ultimate responsibility for towers after they are no longer used.

❒ Rimmer, C. C., K. P. McFarland, and T. S. Redman. 1998. An assessment of migrant bird stopover and collisions with transmission towers on Mt. Mansfield, Vermont, fall 1997. (U)

The Vermont Institute of Natural Science studied avian collisions at 4 towers (television and police communication towers - no heights given) on the Mt. Mansfield ridgeline in Vermont during a single autumn migration season. Searches were made on 39 mornings (and on 12 late afternoons) for periods ranging from 5 to 20 minutes. Flight calls on the previous night were recorded and birds were captured and banded on the following morning nearby using mist nets. No carcasses were found beneath the towers.

❒ Shire, G.G., K. Brown, and G. Winegrad. 2000. Analysis of 50 years of towerkill studies. 1949-1999. American Bird Conservancy Report. (SC)

Review of 140+ publications concerning communication tower kills revealed a significant number of species involved in towerkills are Extremely High Priority on the Partners In Flight Watch List and U. S. Fish and Wildlife Service Species of Management Concern. Analysis differs from others in that it is a synthesis that looks at the species composition of fatalities over a large geographic area and several decades.

❒ Steiner, I., and B. Bruderer. 1999. Anfangsorientierung und Heimkehrverhalten von Brieftauben unter dem EinfluB von Kurzwellen. Journal fur Ornithologie 140:165-177. (P1)

Homing Pigeons in the vicinity of a short wave transmitter were tested. These birds can detect short wave radiation, but it did not interfere with their initial orientation. Birds habituated to the radiation.

❒ Trapp, J. L. 1998. Bird kills at towers and other man-made structures: an annotated partial bibliography (1960-1998). U. S. Fish and Wildlife Service web report: www.fws.gov/r9mbmo/homepg.html. (P3)

Some 125 publications are listed and annotated focusing primarily on communication tower kills and to a lesser extent on glass windows, tall buildings, and other structures. Now at http://migratorybirds.fws.gov/issues/towers.html.

❒ Willis, R. 2000. FCC permitting, NEPA, endangered species, refuge issues: the role of the Fish and Wildlife Service. Transcripts of Proceedings of the Workshop on Avian Mortality at Communication Towers, August 11, 1999, Cornell University, Ithaca, NY. http://migratorybirds.fws.gov/issues/towers/agenda.html (P3)

Summary and discussion of the role of the U. S. Fish and Wildlife Service in the towerkill issue including comments on NEPA, Migratory Bird Treaty Act (MBTA), federal licensing, towers in refuges, tower permits and Service staff limitations, interaction with other agencies (FCC), and more relating to the towerkill problem.

❒ Wiltschko, R., and W. Wiltschko. 1995. Magnetic orientation in animals. Springer-Verlag, Heidelberg, Germany. (P1)

Volume summarizes state of art up until publication date regarding electromagnetic orientation and navigation. The role of electromagnetic radiation in the orientation and navigation of animals is difficult to study and results are difficult to interpret. Evidence suggests that animals have the ability to detect magnetic fields comparable to fields found in natural circumstances and that some animals can use these fields to orient and navigate. Basics may be applicable to towerkill research.

❒ Wiltschko, R., and W. Wiltschko. 1998. Pigeon homing: effect of various wavelengths of light during displacement. Naturwissenschaften 85:164-167. (P1)

Color of light interacts with electromagnetic orientation/navigation in a nonmigrant bird. Pigeons held in different color light on the outgoing route performed differently. Variation in performance was small. Marginally applicable - perhaps not applicable - to towerkill research.

❒ Wiltschko, W., and R. Wiltschko. 1995. Migratory orientation of European Robins is affected by the wavelength of light as well as by a magnetic pulse. Journal of Comparative Physiology A 177:363-369. (P1)

European Robins were tested in cages to determine if magnetic pulses and light of various wavelengths influenced orientation. Robins submitted to a brief magnetic pulse (designed to alter the magnetization of single domain magnetite) after being tested with different wavelength light regimes. The magnetic pulse changed migration orientation with birds tested in white and green light being able to orient accurately but birds tested in red light (633 nm) could not orient. Individual variation was found. Thus, there seems to be a light-dependent compass and a magnetite-based map among migrants, although many questions are unanswered. Because lighted towers seem to attract birds and disorient them, these types of tests may be applicable to towerkill research.

❒ Wiltschko, W., and R. Wiltschko. 1999. The effect of yellow and blue light on magnetic compass orientation in European Robins, *Erithacus rubecula*. Journal of Comparative Physiology A 184:295-299. (P1)

Robins tested during spring in migration cages with magnetic fields shifted 120 degrees oriented well with green and blue light, but under yellow light these birds could not orient. The reason for the abrupt change observed between 565 and 590 nm is unclear. There is no simple relationship between magnetic orientation/navigation and color receptors.

❒ Young, E. A., and B. M. O'Brien. 1995. Bird mortality at several transmitting towers in south-central Kansas, spring 1995. unpublished report to U. S. Fish and Wildlife Service, Ecological Services, Tulsa, OK. (U)

Four television towers (653 to 1253 feet in height) were searched March-May 1995, once per week, during which time 79 birds of 16 species were collected. Height of tower, location, habitat, and color of light were not associated with the number of fatalities. Moon phase and number of guy wires may have been associated with increased collision rates. It should be noted that Young has several other unpublished manuscripts and has worked for several years on these towers. His data set may be an excellent one to test hypotheses about towerkills. Young has searched at other towers and has more data.

Summary and Conclusions from Recent Literature and Current Research

The results of the literature and current research review are divided into sections, each pertaining to a different aspect of the problem or how the problem has or is being examined.

Fatality Studies

There have been few systematic or quantitative towerkill studies in the past 5 years that have focused solely on determining the numbers of fatalities at given towers. There are, however, promising areas where there is strong interest among qualified researchers who wish to pursue the towerkill issue. These researchers (reference Appendix III) are now collecting information on bird kills at towers. This information can be used to test hypotheses that have or are being proposed. These researchers are currently managing projects in West Virginia, New York, and Kansas in which several towers are searched for fatalities. Search schedules vary greatly among the studies, with some towers being searched only when weather conditions suggested a mortality event (low ceiling and poor visibility due to rain or fog). Other studies in this group used more frequent sampling with a relatively constant interval between sampling.

Though they have not been published, studies now being conducted in 3 states (Appendix III) suggest that towers less than 400 to 500 feet in height are not as dangerous to migrating songbirds, especially neotropical species, as towers greater than 500 feet in height. The basis for this statement is a small database from West Virginia (Canterbury, personal communication), New York (Evans, personal communication and data on the <www.towerkill.com> website), Kansas (Young, personal communication), Florida (Engstrom personal communication), and Minnesota (Cuthbert, personal communication). See Appendix III for details of these studies in progress. In these situations, towers less than 500 feet have generally experienced very few kills, while under taller towers larger numbers of dead birds were found. There is 1 notable exception. On Jan. 22, 1998, a kill of between 5-10,000 Lapland Longspurs and a few other birds occurred at a series of 3 communication towers and a natural gas pumping facility tower near Rochester, KS. The tallest of these towers is 420 ft. AGL. In most of the studies there generally has not been what many call a mortality event or large kill involving more than a several dozen or one hundred birds in a single night.

The fact that between an estimated 5,000- 10,000 Lapland Longspurs and others were killed at a series of 3 communication towers and a natural gas pumping facility tower – the tallest tower 420 feet AGL – in mid- winter is problematic because this species has rarely been reported from towerkills. This event may be an anomaly in some ways and should be treated differently from the mortality events involving Neotropical and North American migrants that are normally found in the literature, although the mechanisms or circumstances may be the similar.

Another seemingly important result from some researchers is the fact that the number of fatalities seems to be declining. Arthur Clark (Appendix III) reports that in recent years, the numbers of birds under the towers he searches has dropped precipitously. Mr. Clark has been studying towerkills at several communication towers in the Buffalo, NY, area for well over 33 years. There is speculation among several other researchers that towerkills in general decline a few years after a new tower is erected. Explanations of this phenomenon range from the fact that Neotropical migrants have declined in number over the past 40 years, to the fact that there are more towers – numbers currently increasing at an exponential rate the past 3 years or so – and that the kills may be more dispersed. All explanations are speculative, although many years ago researchers noticed that fatalities decreased at towers, particularly several years after initially large kills.

Lighting Studies

In the past 5 years there have been no definitive or suggestive studies regarding how or if lights disorient or attract songbirds to towers. At least one study was published (Bruderer et al. 1999) in which a spotlight trained on migrating birds disoriented them, but this may not be comparable to towerkill issue. Bruderer was attempting to find ways to haze birds away from aircraft, not attract them to towers. Information that is forthcoming from the few studies now being conducted may help us understand the role of lights of different color in attracting birds, but it is more likely that specific research is needed to address this problem.

Despite a lack of empirical evidence or studies, there seems to be a degree of consensus among experts, based on past data collection or experience that white strobes are less hazardous to migrating songbirds than are white or red blinking lights. The fact that several researchers believe strongly enough to suggest or recommend strobe over other tower lighting types, suggests that research efforts focus on the difference. This promises to be fruitful research that could have direct impact on numbers of birds killed at towers. To date, however, there very few or no published papers or recent databases that substantiate the fact that white strobes are less dangerous than other color or type of lights, other than what was presented at the August 11, 1999, workshop at Cornell University on "Avian Mortality at Communication Towers," transcripts of which are currently available at <www.towerkill.com> and at <http://migratorybirds.fws.gov/issues/towers/agenda.html>. No data were presented in that paper and the results should be considered speculative.

There is a body of information of recent literature from Europe in which migrants of several species and Homing Pigeons were studied in controlled situations in which various color lights were used in an effort to override or disorient birds' magnetic compasses. This literature strongly suggests that birds exposed to red lights in laboratory or controlled conditions may not be able to use magnetic cues as well as birds exposed to green or white lights. The applicability of these studies, at least in the immediate future, is worthy of consideration, especially in light of

speculation that red lights are more dangerous than white strobe lights. However, the underlying mechanisms behind the disorientation of songbirds at lighted communication towers during times of poor visibility (precipitation, fog, low ceiling) may be related to the findings of these studies. If birds are attempting to use magnetic cues in times of poor visibility, red lights may disorient them.

Electromagnetic and other Radiation Studies

The literature on applicable electromagnetic radiation and radio frequency influences on migrating birds is nearly nonexistent. By "applicable," I refer to studies in which radio frequencies or geomagnetic fields that are similar to those created by communication towers were investigated. Only one study really addressed the influence of short-wave radio waves on Homing Pigeons (Bruderer and Boldt 1994), not migrating birds or species of birds that migrate at night.

Interviews with researchers who are knowledgeable about migration or study migration provided little insight into the question. However, most seemed to doubt whether the strength and type of radio frequencies or electromagnetic fields around communication towers could disrupt the orientation/navigation of migrants. They stated that the earth's magnetic field was likely to be much stronger than that of communication towers. Several of the researchers referred to the Project Seafarer study in which electromagnetic pulses, similar to those experienced in nuclear explosions, were investigated by avian researchers. These pulses are so strong as to not be applicable to communication tower situations, according to those interviewed. The behavioral data from migrants tested in cages were so variable as to be inconclusive (F. Moore, personal communication).

Methods for Studying Fatalities and Behavior at Communications Towers

There are currently no standard metrics or metrics being used to evaluate towerkills. Researchers use different methods to search for birds and report their results in different fashions. These differences may lead to different results. For example, some researchers look on mornings after nights in which the visibility was poor. Others search once per week or once per month. Thus, there is no way of comparing results. Similarly, the area searched under towers is not standardized by researchers and in some cases the search area is not even reported.

Regarding the study of behavior of night migrants that is applicable to studying how birds behave around communication towers, several studies appeared between 1995 and 1999. These studies included several methods: radar (tracking, marine surveillance, and NEXRAD), infrared (LORIS) devices, acoustical devices, ceilometers, and moon watching. Very briefly, radar uses microwave radiation that is reflected by the water in the bodies of birds to determine their location over the ground. Tracking radar locks on to individual migrants and provides very

detailed behavioral information. Marine surveillance radar (portable via truck or boat) provides a two dimensional picture (X,Y coordinates) of migrants as they move through a several square mile area. NEXRAD is a weather radar technology that provides a macro image of bird migration over several hundred square miles. Infrared devices track birds by imaging the heat differences between birds and the air they are in. Infrared devices provide a detailed picture of birds migrating by a location at night. Acoustical devices sense birds via their flight calls, enabling researchers to determine the species composition of birds as they fly within the first thousand or so feet overhead. Ceilometers are pencil beam lights that are pointed vertically in the night sky. As birds pass through the beam they are counted and their direction is determined. Moon watching is a means of determining the number migrants and their directions as they pass through the disk of the moon, as observed with a spotting scope.

Each of these methods has advantages and disadvantages. It is likely that the most useful methods, especially for studying the reactions of birds close to towers, and therefore testing hypotheses about how birds react to lighting or other stimuli at towers, will be tracking and marine surveillance radars and infrared devices. Acoustical devices may be useful in some situations and for answering some questions. Moon watching is not likely to prove useful, although ceilometer may be useful if volume of migration at low altitude is the desired measurement. The references provided above will be of use to researchers who wish to investigate or consider various methodologies for studying behavior of migrants in close proximity to towers.

The study of behavior of captive birds, as with the magnetism and light studies (see Wiltschko and other references above), may be useful in situations where the perceptual ability of birds is investigated.

Results of Interviews

Responses of those interviewed were almost uniform. None of those interviewed were currently working on communication tower projects or projects related to communication towerkills. They also knew of very few (almost no) studies that were currently being conducted (or researchers doing studies). Of those questioned, Gauthreaux stated that he planned to publish a paper on lighting and towerkills and Engstrom stated that he would be publishing a paper shortly on the 30+- year towerkill project he is conducting with R. Crawford in northern Florida (Also see Appendix III).

Wind Turbine Kills and Night Migrating Songbirds

During the past decade and especially during the past 5 years, the wind power industry has undergone a rapid expansion both in numbers of operating turbines and locations of those turbines. Wind turbines have been perceived to be dangerous to birds since some early studies reported that Golden Eagles, Red-tailed Hawks, and other raptors sometimes collide with turbines. As a result of these fatalities, systematic studies have been and are being conducted to examine the bird-turbine collision issue. These studies have been general studies to determine what types of birds collide with turbines, how many, and other aspects of collisions.

The interest in turbine-induced bird fatalities has resulted in significant effort on the part of industry and agencies to have standardized methods of study and metrics for measuring impacts (Anderson *et al*. 1999). Though there is disagreement about some methodologies and metrics, there has been a relative degree of consensus regarding how to search for fatalities and estimate the actual numbers of birds involved. There has been no focus directed toward learning specifically about interactions between night migrants and turbines.

Several common methods have been adopted by researchers. First, most studies have conducted carcass searches within about 55- 66 yards (50-60 m) of towers at a rate of once per month during which all turbines in the study area are examined. In at least 2 instances (Kerlinger 2000, Kerlinger *et al*. in preparation), researchers have made additional efforts to detect nocturnal migrants by conducting carcass searches more frequently than the usual monthly schedule. By searching more frequently it was believed that rare events might be detected more easily and carcasses might be detected before they disappeared. In addition to monthly searches, studies done at wind turbines also incorporate efficiency studies to determine what proportion of dead birds are actually detected by observers and scavenging studies in which the rate of carcass removal by scavengers is determined. These methods are also used by researchers who have studied collisions with transmission lines and will undoubtedly become standard procedures in communication tower studies.

Virtually all turbines installed since 1996 stand greater than 200 feet AGL and have FAA-approved lighting. None have guy wires. These studies and publications give some insight into the situation with wind turbines and are in some ways applicable to the bird-communication tower issue.

In the past 10 years a number of studies have been conducted to determine the degree to which birds of all sorts, including night migrants, collide with wind turbines.

The following list of references may be useful to researchers and policy makers examining the bird-communication tower issue. Full references for papers cited in the wind turbine section (above) are provided below.

❒ Anderson, R., M. Morrison, K. Sinclair, D. Strickland, H. Davis, and W. Kendall. 1999. Studying wind energy/bird interactions: a guidance document. Metrics and methods for determining or monitoring potential impacts on birds at existing and proposed wind energy sites. Prepared for National Wind Coordinating Committee Avian Subcommittee. 87 pp.

Complex and detailed volume about monitoring birds at wind plants (pre and post construction). Sections on fatality searches are relevant to communication towerkills, although whether other parts of volume are applicable is arguable.

❒ Colson & Associates. 1995. Avian interactions with wind energy facilities: a summary. Prepared for the American Wind Energy Association.

Summary of early studies of what was known about wind turbine-bird interactions. The review focused primarily on the first commercial wind plants in the United States and, to a lesser extent, Europe. It was conducted before a major wave of studies that commenced in about 1995, so it does not examine research conducted at the new and mostly smaller facilities that use modern wind technology.

❒ Cooper, B. A., C. B. Johnson, and R. J. Ritchie. 1995a. Bird migration near existing and proposed wind turbine sites in the eastern Lake Ontario region. Report to Niagara Mohawk Power Corporation, Syracuse, NY. 71 p.

❒ Cooper, B. A., C. B. Johnson, and E. F. Neuhauser. 1995b. The impact of wind turbines on birds in upstate New York. Windpower '95 Proceedings. American Wind Energy Association, Washington, DC.

Radar and visual observations of migrants at 2, unlighted wind turbines 30 miles east of Lake Ontario, NY. Two migration seasons (spring and fall) of searches under the towers revealed no dead birds.

❒ Leddy, K., K. F. Higgins, and D. E. Naugle. 1999. Effects of wind turbines on upland nesting birds in conservation reserve program grasslands. Wilson Bulletin 111:100-104.

Grassland nesting birds were studied using an impact gradient design along a transect running away from wind turbines. Reduction in nesting results close to turbines in the first years following turbine installation. Not applicable to communication tower issue.

❒ Proceedings of National Avian - Wind Power Planning Meeting, Denver, CO, 20-21 July 1994. 1995. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee. Resolve, Inc. and LGL Ltd., King City, Ont. 145 p.

Compendium of papers and other formatted contributions on wind power and bird issues. Paper by Winkelman from Netherlands is one of few that summarizes fatalities at coastal turbines. Summary of collisions at many European sites showed only small numbers of birds were involved.

❒ Proceedings of National Avian - Wind Power Planning Meeting II, Palm Springs, CA, 20-22 September 1995. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by Resolve Inc., Washington, D.C. and LGL Ltd., King City, Ont. 152 p.

Compendium of papers and other formatted contributions on wind power and bird issue. Several papers on techniques for monitoring bird movements.

❒ Proceedings of National Avian - Wind Power Planning Meeting III, San Diego, CA, May 27-29 1998. Prepared for the Avian Subcommittee of the National Wind Coordinating Committee by Resolve Inc., Washington, D.C. and LGL Ltd., King City, Ont. In press.

Compendium of papers summarizing the results of studies of fatalities, behavior, and other impacts at wind turbine plants in the United States and Europe.

❒ Osborn, R. G., C. D. Dieter, K. F. Higgins, and R. E. Usgaard. 1998. Bird flight characteristics near wind turbines in Minnesota. American Midland Naturalist 139:29-39.

Study of flight patterns of birds around wind turbines and behavior of birds in close proximity to turbines, similar to earlier European studies. Not applicable to night migrants.

The wind power industry offers a perspective that may help understand potential problems at shorter communication towers, especially wireless telephone and microwave towers that are less than 300 feet in height. There are several differences between wind turbines and communication towers that are the same height. These differences include:

- Most communication towers – especially those in excess of 200 feet AGL – have some sort of guy wiring system, whereas virtually no commercial turbines installed recently have such wires;
- Turbines have rotors that move (rotate), whereas there is no comparable movement on communications towers;
- Turbines are primarily situated on tubular towers, which appear solid, whereas communications towers are usually lattice structures;
- Turbines make low frequency noise, presumably very different from the sounds made by communications towers and their guy wires; and
- Lights on turbines are not situated on the top of the highest point of the tower (the turbine), but rather on the supporting tower which is about 100 feet (on many

turbines) below the maximum height to which rotors extend - thus, lights on turbines are lower than lights on communication towers of similar height.

These, and possibly other differences between turbines and communication towers should be considered when comparing bird kills at these very different types of towers.

Appendix IV summarizes the numbers of fatalities from quantitative studies done at wind turbine installations in the United States. Studies in several states indicate that wind turbines rarely kill nocturnal songbird migrants. At most of these sites, scavenger and observer efficiency studies have been done to make sure that large numbers of birds were not disappearing or missed. Yet, with so few kills - virtually none found at many sites - it may be that wind turbines do not experience the large scale fatality events that are known from tall communication towers. The reason has been suggested to be that these towers do not extend high enough for night time migrants to be impacted. Also, the lights are lower than lights on communication towers of equal height because the lights are on the actual tower. For most turbines this is about 200 feet above the ground. It should be noted, however, that few studies have been conducted at wind turbines in the eastern United States where the bulk of communication tower fatalities have been found.

Findings from European wind farm facilities have seen reasonably low mortalities with the possible exception of some sites located in coastal areas (Winkelman 1995 in Proceedings of the National Avian - Wind Planning Meeting in Denver 1994.)

Discussion

Since 1996, very little new information has emerged on the bird-communication collision issue. Part of the reason is that no large-scale, quantitative studies have been published and few are being conducted. The few studies that are now being conducted do show some promise, although the methods are not sufficiently rigorous. The numbers of days of coverage in these studies are small and there is some variation in search methods. Some researchers state that they are only looking for the large-scale events and gear their search methods accordingly. For example, some only search after nights of poor visibility to see how many birds collide with the towers in their studies. Although some of these studies have been done using methods that permit statistical comparison and, therefore, inference regarding causation or correlation, most will not shed much light on the problem. The reason for the lack of rigor is generally that funding was not sufficient and that the studies were mostly exploratory, with a few exceptions. The literature is nearly devoid of information about small (less than 400 feet) towerkills and small tower collision studies. This may be explained by: a lack of funding for such projects, a scarcity of observations and reporting from such towers, or fatalities do not occur or occur in very small numbers at short towers.

Recommendations

From the information examined in this study, the following observations and recommendations are made:

1. Analytical Review of the Communication Towerkill Literature. To date, there has been no analytical review of the entire body of literature on avian collisions with communication towers. The large number of studies that have been conducted since the 1950s, if examined analytically, could provide important insight into the problem and how to design future studies. It is likely that such an analysis could be used to focus research efforts on the most critical problems or provide the most efficient design for future studies. Perhaps the most important analysis that could be done would be to compare towers of different heights. Because there are so many more towers today, especially short towers used by the cellular/wireless telephone industry, there is a need to know if they present a major risk to migrants. The old literature did not provide information that implicates towers less than 400 feet in anything but a very few kills. Similarly, the results from the most recent studies by Young in Kansas, Canterbury in West Virginia, and Evans in New York (See Appendix III), though only suggestive, do not implicate short towers. Information from the wind power industry are consistent with the communication tower studies that short towers (<300 feet) rarely kill migrants.

2. Standard Metric and Method for Comparing Mortality at Towers. The information that will be most helpful in accessing risk at towers should include actual body counts taken at communication towers. What is needed is a standardized metric for comparing towers. It is

recommended that the number of birds killed per night by a tower – a rate – be used as a common metric. In addition, methods for determining these numbers should be the same such that standard areas are searched (larger for taller towers) and a standard amount of time be used for searches. The amount of time may have to be flexible as more search time is needed when carcasses are present. The extra time is needed to bag and tag/record specimens and sort out the odd parts/feathers found so as to accurately determine the number of fatalities. Staff time and extra staff assistance should be considered – and calculated – when employing these methodologies. Until standard metrics and methods are established, no meaningful comparisons will be possible. It is also recommended that observer efficiency and carcass removal rates be determined for all studies conducted to estimate the actual number of fatalities. There are standard methodologies for estimating mortality at wind turbines and transmission lines.

3. Streamlining/Relaxation of Collection Permit Issuance. Phone interviews with at least 3 researchers (who shall remain anonymous) resulted in complaints that securing salvage or other types of permits to pick up dead birds under towers made it difficult to do their research. For research to proceed, the U.S. Fish & Wildlife Service and state agencies should grant special permits to researchers that allow their field staff (volunteers, students, etc.) to pick up dead birds and deliver them to the researcher. Without such permit streamlining/relaxation, these researchers and others involved will be reluctant to participate in future studies.

4. Tower Information Database. Several researchers complained that securing permission to search under towers was problematic as was finding information about towers. Often it was difficult to determine tower ownership to thus then approach the company for permission to search beneath towers. These same researchers also had difficulty finding information about the specifications or characteristics of given towers. Furthermore, they were not always granted access or were severely limited in access so that studies were difficult if not impossible to complete. A central computer database is recommended and should be established using information from both the FAA and FCC computer databases containing the following information: tower owner and manager (address, telephone number, fax, and email address), tower location (lat-long, township, county, state), tower height, tower lighting characteristics, tower guy-wire characteristics, other tower characteristics (number of co-located antennas, types of transmission, size of footprint, outbuilding lighting, etc.), distance to nearby towers, habitat under the tower (rough indication of type of habitat), and, perhaps some other parameters. The parameters and format of the database should be established by the Communication Tower Working Group and its Research Subcommittee. Establishing this database will make it possible to design and implement more efficient and cost effective studies. Such a database would also permit researchers to examine old publications.

Appendix I. Sample questionnaire. The one shown went to editors of state ornithological journals and miscellaneous others.

To: State Ornithological Journal Editors, Societies, and Natural History Groups

Re: U.S. Fish &Wildlife Service's Communication Tower Working Group Initiative (Communication tower collisions and bird kills)

I am under contract with U.S. Fish and Wildlife Service to conduct a literature and research review of the communication tower-bird kill problem (wireless, cellular, radio, television, paging and messaging, two-way dispatch, fixed band and open video, and public safety towers), which may involve 10 million or more bird deaths each year. This contract is part of U.S. Fish and Wildlife Service's new Communication Tower Working Group initiative. The Working Group includes representatives from the wildlife agency; the FAA, FCC, BRD/USGS, NPS, Federal Highway Administration, USDA National Wildlife Research Center, 2 state agencies; university and independent researchers; environmental organizations; and representatives from industry. The USFWS chairs the Working Group. Members of the group are attempting to understand the problem and find solutions. Your assistance will be greatly appreciated.

I am specifically interested in:

- Studies of avian mortality at communication towers.
- The influence of lights (color, blinking frequency, etc.) on mortality and behavior of migrating birds - especially at towers.
- The effect of electromagnetic radiation and radio frequencies on birds near towers.

Needs include:

- Published and unpublished reports from 1995 to the present - your society's journal or other publications within your state.
- Research in progress within your state.
- Names, phone numbers, email addresses of people currently conducting research or in the process of writing reports on the problem within your state.
- Information on state agency research or other initiatives.

Please contact me if you have information about this topic. With respect to your society journal or publications, please ask the editor and others whether articles have appeared about any of these topics from 1995 to the present. Information is needed by January 28, 2000. If you cannot respond by this date, please inform me when you can respond.

For information on the Communication Tower Working Group and towerkills in general see www.towerkill.com.

Thank You,

Paul Kerlinger, Ph.D. - 609-884-2842
Curry & Kerlinger, L.L.C.
pkerlinger@aol.com

Appendix II. Questionnaire and procedure for interviewing experts about recent research and publications or reports about birds and communication tower research.

The procedure for interviewing respondents included the following:

Interviewer identified himself, his firm, and stated that he was conducting a review of the recent literature, research, and study techniques and methodologies regarding collisions of birds with communication towers. The interviewer stated to respondents that the contract was from the United States Fish and Wildlife Service and that all contributors of information would be credited by name and firm, agency, or educational institution.

The interviewer then asked the respondent the following questions**:**

1. Are you or anyone you work with studying avian collisions at communication or other tall towers, buildings, and/or other structures including tall buildings?

2. Are you or anyone you work with studying lighting as it relates to collisions with towers, attraction of birds, disorientation of birds (including migrants)?

3. Are you or anyone you work with studying electromagnetic radiation and radio frequencies (such as those associated with or generated by radio, telephone, and television towers) as they relate to collisions at communication towers or as they relate to attraction or (dis)orientation of birds (including migrants)?

4. Are you or anyone you work with developing methodological or technological approaches to studying avian collisions/fatalities at communication towers or the lighting and radiation questions asked earlier?

5. Do you or anyone you work with know of other pertinent information or do you know of any researchers or projects focusing on any of the previous questions?

Appendix III. List of researchers (names, institutional affiliation, addresses, phone numbers, and email address) who are currently working on communication tower projects involving bird kills in the United States. Also included is what they are currently doing or have recently completed. Because of their recent interest and activity, these researchers might be ideal for conducting research recommended by the Communication Tower Working Group and the Research Subcommittee. Note the diverse geographic distribution of those listed and their project sites.

Dr. Ron Canterbury, Associate Professor
Biology Department
Concord College
Athens, WV 24712
304-384-5214
canterburyr@concord.edu

Starting in the fall 1999, Canterbury has monitored several towers and plans to monitor up to 21 towers ranging in height from 300 to 1,200 feet in West Virginia using students and volunteers to search for carcasses. More than 100 birds were found after one foggy night. He is interested in teasing out differences in numbers of kills at towers with different lighting, guy wire configuration, topography, and height. His study was funded by WV Department of Natural Resources and the local U. S. Fish and Wildlife Office is aware of his work. His crew searches twice per week and compares fatality numbers with the numbers of birds banded at his long-term banding station nearby. This is one of the few studies where a researcher has attempted to link numbers of birds making stopovers with numbers of fatalities. His data will also provide information on what species may be most susceptible to colliding with towers because he has species composition information from banding data.

Arthur R. Clark
Associate Curator - Vertebrate Zoology
Buffalo Museum of Science
1020 Humboldt Parkway
Buffalo, NY 14211-1293
716-896-5200, x372
aclark@sciencebuff.org

Clark has monitored three tall (~1,000 foot) television towers near Buffalo for 33 years as of 1999. He has meticulously recorded information on more than 20,400 kills of 110 species found and is attempting to put those data in a computer file for analysis. He has continued to collect specimens and has many in the Museum's freezers. Numbers of fatalities have dropped in recent years from > 1,000 kills per autumn before 1982 to <100 per season since 1990. The reason(s) for these declines is(are) unknown.

Bill Evans
Independent acoustical ornithologist
P.O. Box 46
Mecklenberg, NY
607-272-1786
wrevans@clarityconnect.com

Evans is conducting studies at up to 30 towers across New York State ranging in height from a few hundred feet to more than 1,000 feet AGL. He supervises a collaborative group of several volunteers who check under the towers mostly when weather conditions suggest that a kill may have occurred (*i.e.*, low visibility from precipitation, fog, low ceiling, or light snow). From information he has made available through his website – www.towerkill.com – it appears that the taller towers (>500 feet) are responsible for a larger number of fatalities. He has yet to find a mortality event that exceeds a few dozen birds per night. Evans has been using acoustical devices to study night migrants via their vocalizations (chip calls) for nearly a decade. His methodology shows great promise in identifying the species composition of migrants over a particular site.

Dr. Eugene A. Young
Biology Department
Southwestern College
100 College St.
Winfield, KS 67156-2499
316-221-4150
young@sckans.edu

Young has been collecting information on bird kills at several towers in Kansas for more than 5 years. His work involves the use of students and volunteers who systematically search beneath towers of different heights and with different guying and lighting characteristics. He has published several papers on the issue and has enlisted the assistance of academics from other universities and museums in Kansas.

Appendix IV. Summary of fatalities of night migrating birds at wind turbines.

- Vermont - Searsburg (near Green Mountain National Forest) - 11 modern turbines (unlit**;**192 feet) at forested site. Surveys conducted June-October, 1996; zero fatalities recorded (Kerlinger, 2000, in press, National Wind Coordinating Committee **v**olume)

- Massachusetts - Princeton Windfarm (Watchusett Mountain State Forest and Hawkwatch) - 8 older turbines (< 150 feet, unlit) at forested site. Surveys conducted in autumn & winter, 1993; zero avian fatalities recorded (Jacobs, 1995, paper presented at Windpower '94, Minneapolis, MN)

- Minnesota - Buffalo Ridge (near Lake Benton) - 200+ modern turbines (< 200 feet, unlit) at farmland site. Surveys conducted 1997-1999; about 24 avian fatalities recorded - zero raptors or endangered/threatened species (Strickland, paper presented to National Wind Coordinating Committee, San Diego, CA, May 1998)

- New York - Copenhagen (30 miles east of Lake Ontario) - 2 modern turbines (< 200 feet, unlit) at farmland site. Surveys conducted in spring and autumn migration seasons, 1994; zero avian fatalities recorded (Cooper and Johnson, 1995, Proc. American Wind Energy Association Conference 1996 and report to Niagara Mohawk Power Corporation)

- Colorado - Ponnequin - 29 modern turbines (275 feet, red lighting) at rangeland site (cattle and bison). Surveys conducted 1998-September 1999 (ongoing); 5 songbird fatalities recorded (none of which seemed to be migrants) - zero raptors or endangered/threatened species; Curry & Kerlinger unpublished data provided to National Audubon Society and U.S. Fish & Wildlife Service)

- California - Altamont - 5,400+ mostly older turbines (<200 feet, unlit) at grassland site. Significant raptor mortality recorded (exceptionally high raptor and prey density); small numbers of other species involved (Orloff & Flannery, 1992, 1996, California Energy Commission Reports, other reports)

- California - San Gorgonio Pass (Palm Springs area) - 2,700 modern and older turbines (<200 feet, unlit) at desert site (or 3,500 in area). Recent studies indicate very few raptor or songbird fatalities (Anderson, California Energy Commission, paper presented to the National Wind Coordinating Committee, May 1998, San Diego)

- California - Tehachapi Pass - 3,750 modern and older turbines (<200 feet, unlit) in study (of 5,000 in area) at rangeland/arid grassland site. Recent surveys indicate low (perhaps moderate) level of avian mortality - small numbers (<24) of raptors and fewer than 10 night migrating songbirds (Anderson, California Energy Commission, paper presented to the National Wind Coordinating Committee, May 1998, San Diego).

- Wisconsin - Door County Peninsula - 18 (now 35) modern turbines (~ 250 feet, lit) in farmland; 2 songbird fatalities in first year (S. Puzen report from Wisconsin Public Service Corporation).

- Oregon - Vansycle, near Columbia River - 35 modern turbines (~280 feet, lit) in farmland; 8 songbirds (some may have been night migrants), 4 gamebirds (alien species) in 1999 (Report to Umatilla County Department of Resource Services and Development, Pendleton, OR).

Other Sites - Wyoming, Texas, Iowa - studies in progress - very few or no reports of night migrants being killed