Bird Strikes and Electrocutions at Power Lines, Communication Towers, and Wind Turbines: State of the Art and State of the Science – Next Steps Toward Mitigation[1]

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Abstract

Migratory birds suffer considerable human-caused mortality from structures built to provide public services and amenities. Three such entities are increasing nationwide: communication towers, power lines, and wind turbines. Communication towers have been growing at an exponential rate over at least the past 6 years. The U.S. Fish and Wildlife Service is especially concerned about growing impacts to some 836 species of migratory birds currently protected under the Migratory Bird Treaty Act of 1918, as amended. While mortality estimates are often sketchy, and won't be verified until nationwide cumulative impact studies are conducted, current figures are troubling. Communication towers may kill from 4-50 million birds per year. Collisions with power transmission and distribution lines may kill anywhere from hundreds of thousands to 175 million birds annually, and power lines electrocute tens to hundreds of thousands more birds annually, but these utilities are poorly monitored for both strikes and electrocutions. More than 15,000 wind turbines may kill 40,000 or more birds annually nationwide, the majority in California. This paper will address the commonalities of bird impacts among these industries; those bird species that tend to be most affected; and research (completed, current, and proposed) intended to reduce bird collisions and electrocutions nationwide. The issues of structure location (siting), lighting, guy supports, lattice or tubular structures, bird behavior, and habitat modifications are reviewed. In addition, this paper reviews the respective roles and publications of the Avian Power Line Interaction Committee and the Wildlife Workgroup of the National Wind Coordinating Committee, the roles of the Service-chaired Communication Tower Working Group and Wind Turbine Siting Working Group, and the Fish and Wildlife Services' voluntary tower and turbine siting and placement guidelines. An update on recent Communication Tower Working Group research initiatives will also be discussed along with promising research findings and needs.

Key words: APLIC, avian impacts, avian mortality, BGEPA, bird strikes, collisions, communication towers, CTWG, electrocutions, ESA, MBTA, mitigation measures, NWCC, power lines, transmission and distribution lines, wind turbines.

Introduction

Acquiring reliable estimates of avian population mortality is difficult, even under controlled circumstances, and the threats to birds from human development continue to increase in the United States and elsewhere globally. As the U.S. human population grows – now the third largest in the world – human structures and the services needed to meet population demands continue to increase. Unfortunately, the impacts of these structures and services on birds, bats, and other species are generally unaccounted for, unknown, or only roughly estimated. This paper will address three of these structural impacts, those from power lines, communication towers, and wind turbines.

To better understand the impacts of human-caused mortality on landbirds – and recently on bats, attempts have been made not only to estimate these mortality factors, but also to assess the spring and fall populations of breeding landbirds in North America to determine rough mortality percentages. While bird hunting mortality has been documented back to at least Biblical times, mortality caused by structures was first documented in the United States in 1874 at lighthouses and lamps (Forest and Stream 1874) and in 1876 at telegraph wires (Coues 1876). The first U.S. Fish and Wildlife Service (USFWS or Service) attempt to estimate nationwide human-caused annual mortality was published by Banks (1979) where he estimated 196 million bird deaths caused by human activity. This estimate represented 1.9 percent of the then existing estimated bird population in North America. Of the 196 million estimated deaths, 61 percent were from hunting, 32 percent from collisions with structures, and 2 percent from pollution and poisoning. To assess the nationwide status of breeding bird populations, Aldrich et al. (1975) used the 1973 Breeding Bird Survey, which averaged 1,284 birds/km^2 (3,325 birds/mi^2), to

[1]A version of this paper was presented at the **Third International Partners in Flight Conference, March 20-24, 2002, Asilomar Conference Grounds, California.**
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estimate 9.975 billion breeding landbirds in the United States exclusive of Alaska and Hawaii. They concluded that the autumn landbird population was probably twice that figure – 20 billion. Banks (1979) used the figure of 10 billion breeding birds in the contiguous United States and assumed an average annual mortality of 10 billion birds. J. Trapp (unpubl. data), of the USFWS' Division of Migratory Bird Management, examined Breeding Bird Censuses for 1991 and 1992, extrapolated from these figures, and concluded that it was probably safe to talk about minimum breeding populations on the order of 10 billion birds, and minimum fall populations on the order of 20 billion birds in North America north of Mexico. While there are far more birds than people generally realize, population impacts can be sizable and most human-caused avian mortality factors are not systematically monitored or assessed.

The USFWS is currently responsible for the conservation and management of 836 species of migratory birds in the United States; these birds are killed by myriad non-hunting-related factors. These include collisions with communication towers, power lines, wind turbines, buildings and windows, smokestacks and monuments, automobiles, and aircraft; electrocutions at power lines; predation by domestic cats; poisoning from pesticides, oil and contaminant spills; drowning in oil and wastewater pits; entanglement, strangulation, and drowning in fishing gear; and loss or degradation of habitat.

Of the 836 migratory bird species managed by USFWS, at least 223 are in trouble. These include 92 listed on the Federal Endangered Species Act (ESA; 16 U.S.C. 1531 et seq.: 77 are endangered and 15 are threatened), and 131 on the USFWS's National List of Birds of Conservation Concern 2002 (USFWS 2003). Populations are declining precipitously for some of these species. To add yet another challenge to managing birds, we essentially lack data on the status of fully one-third of all North American bird populations. These challenges make management difficult. Recent extrapolations from various databases indicate that human-caused mortality could account for billions of bird deaths per year (Klem 1990, Corcoran 1999, Erickson et al. 2001, Manville 2001a, Manville 2001b). Based only on estimates of annual mortality from vehicles strikes (60- 80 million), building and window collisions (98- 980 million), smoke stack casualties (tens to hundreds of thousands), power line electrocutions (tens to hundreds of thousands), power line impacts (hundreds of thousands to perhaps 175 million), communication tower accidents (4-5 to 40-50 million), and wind turbine impacts (~ 34,000), Erickson et al. (2001) estimated from 100 million to well over one billion birds killed annually. The extent to which cumulative mortality from all human-caused factors affects bird populations, and measures that can be taken to reduce these events, are matters of considerable interest and concern to the Service and others (Manville 2001b).

Structural Review

The U.S. Power Grid

Since the U.S. power grid was first constructed in the late 1880s, power line expansion has increased tremendously. With a growing U.S. population, industrial expansion, and public demand for more electricity as exemplified by energy challenges in California in 2001, more power lines are being installed. The most recent nationwide estimates indicate that there are more than 804,500 km (500,000 mi) of bulk transmission lines in the U.S. (transmission lines in the U.S. carry ≥115,000 volts/115 kV, with conductors attached to either tall wood, concrete or steel towers; APLIC 1996, Harness 1997, Edison Electric Institute 2000). Much of the problem with bird collisions is associated with transmission lines. Distribution lines (those in the U.S. carrying ≤69,000 v/69kV) are constructed on 11- 15 m (36- 49 ft) wooden, steel, or concrete poles, typically configured with one, two, or three energized (phase) wires and one neutral (grounded) wire. Raptor electrocutions, especially in the western United States, are most frequently associated with distribution lines. Distribution lines have phase-to-phase and phase-to-ground wire clearances which place birds perching on the supporting poles at much greater risk of completing a circuit and suffering electrocution, often resulting in a power outage (Boeker and Nickerson 1975, Harness 1997). Because of rapid expansion, new development, and jurisdictional issues, no good accounting of the total amount of distribution line is available for the United States; it is certainly in the millions of kilometers. Williams (2000) cites the figure of 116,531,289 distribution poles in the United States but lists no figure for wire length.

Power Line Electrocutions

Birds have been subject to electrocutions and collisions in the United States since the first overhead telegraph wires were strung in the late 1860s, initially reported by Coues (1876) in rural Colorado. Electrification of the United States and development of the U.S. power grid began by the late 1880s and has rapidly expanded since. Not surprisingly, by 1922, eagle electrocutions were first reported at transmission lines, followed in 1933 by hawk electrocutions at distribution lines, and in 1940 by power outages on Idaho Power lines which subsequently were retrofitted with a deterrent device intended to discourage eagles from landing (R. Harness, EDM International, pers. comm.). By the early 1970s the electric utility industry had become acutely aware of bird electrocutions – especially to eagles, hawks, and owls. Reports of significant bird mortality during the winter of 1970-1971 in Colorado and Wyoming drew the attention of state and Federal law enforcement agents and the industry; nearly 1,200 eagle deaths were reported resulting from poisoning (N = 30+), shooting from aircraft (N = 800+) and electrocution or shooting along a power line (N = 300+) (Olendorff et al. 1981; L. Suazo, USFWS, pers. comm.). M.W. Nelson's 1980 film "Silver Wires, Golden Wings" followed, which was one of the first public relations efforts designed to help prevent eagle electrocutions and to encourage use of nesting platforms on power poles (Lehman et al. 1999). Nelson filmed trained Golden Eagles (*Aquila chrysaetos*) during take-offs and landings on un-energized mock-up power poles to determine how electrocutions occurred and how they might be prevented. His and other research led to an update to the Suggested Practices document (Olendorff et al. 1981).

In an attempt to begin addressing both collision (specifically Whooping Cranes [*Grus americana*]) and electrocution problems, an ad hoc committee represented by several investor-owned electric utilities (IOUs), the National Audubon Society (NAS), and the Service was created in 1983. By 1989, a more formal relationship was established with the creation of the Avian Power Line Interaction Committee (APLIC) composed then of nine IOUs and the FWS (Lewis 1997) – with technical advice from staff of NAS, Clemson University, and the University of Idaho. APLIC was housed in the IOU trade association Edison Electric Institute (EEI), Washington, DC (Huckabee 1993). Following research and earlier publications in 1975 and 1981, Suggested Practices for Raptor Protection on Powerlines (APLIC 1996) became the first definitive work on raptor electrocutions. It was reprinted in 2000 in Spanish. That same year the instructional video, Raptors at Risk (North American Falconers' Association et al. 2000) was released to the public, documenting raptor electrocutions and illustrating inexpensive avoidance techniques. Copies can be obtained from R. Harness at EDM International, <rharness@edmlink.com>.

While the efforts of APLIC to reduce bird electrocutions and collisions have been key, many in the electric utility industry may still not be getting the message that human-caused bird deaths are unacceptable (Williams 2000). At present, APLIC is composed of 18 IOUs (out of 186-some IOUs within this country); one IOU trade association (EEI); some 960 cooperatives represented by the National Rural Electric Cooperative Association (NRECA; out of approximately 1,056 cooperatives housed under the U.S. Department of Agriculture [USDA]); one research organization (Electric Power Research Institute); and three Federal agencies (including USFWS, the Bonneville Power Administration, and the Western Area Power Administration) (L. Suazo, USFWS, pers. comm.; R. Loughery, Edison Electric Institute, pers. comm.; www.APLIC.org). To be a more effective arm of the overall industry, APLIC still needs to recruit additional utility membership. However, many of the cooperatives are small companies, and the $5,000 APLIC initiation fee and $2,500 annual dues are viewed by many as better spent on mitigation or for other purposes.

NRECA – somewhat like APLIC – is the not-for-profit national service organization representing most of the USDA cooperatives which provide electricity to more than 30 million consumer-owners primarily in sparsely population rural areas in 46 states. NRECA published a definitive manual for their industry, Animal Caused Outages (Southern Engineering Company 1996), which addresses wire configurations and situations unique to this segment of the industry. APLIC and NRECA are working to integrate guidance in Suggested Practices for Raptor Protection on Power Lines (APLIC 1996) that conforms to both types of utility structures and needs. USDA cooperatives, for example, now must construct distribution lines using non-conducting wooden braces and cross arms, and install ground wires that are raptor safe.

Prior to 1999, only two fines had been levied by law enforcement agents against electric utility companies for electrocuting birds protected under the Migratory Bird Treaty Act (MBTA; 16 U.S.C. 703-712) and the Bald and Golden Eagle Protection Act (BGEPA; 16 U.S.C. 668-668C), one in 1993 and the other in 1998. MBTA is a strict liability statute; the killing of any protected migratory bird is not technically allowed under law unless a permit is obtained, and the Service does not issue "incidental or accidental take" permits. The landscape changed in August 1999 with the District Court's decision against the Moon Lake Electric Association in western Colorado and eastern Utah. Beginning in 1997, agents of the Service's Office of Law Enforcement (LE) in the West investigated bird mortalities from electrocutions and strikes, and found to their dismay that the statistics rivaled those from the 1970s. As a result of this investigation, the Department of Justice prevailed in its first criminal prosecution of a utility under BGEPA and MBTA. Moon Lake pleaded guilty and agreed to pay $100,000 in fines and restitution, serve 3 year's probation, sign a memorandum of understanding (MOU) with the Service, implement an avian protection plan, and retrofit poles that were killing raptors. The message was a powerful one, sending shock waves through the electric utility, wind generation, and communication tower industries. In addition to fines as high as $500,000, company officers could be convicted of felonies, lose their right to vote, pay personal fines as high as $250,000, and be jailed for up to two years (Williams 2000).

Following release of the Moon Lake MOU, LE was inundated with requests for other MOUs. In 2002, an historic MOU was signed with Xcel Energy and the USFWS Denver, Colorado, Regional Office in concurrence with the Department of Justice. The proactive agreement presently covers Colorado and Wyoming. The USFWS is currently finalizing the template for an avian protections plan (APP) with APLIC These voluntary, proactive agreements will call for the development of comprehensive APPs which are intended to reduce electrocutions and bird strikes by participating companies.

Looking specifically at the problem of electrocutions, eagles are the most commonly reported electrocuted birds, Golden Eagles reported 2.3 times more frequently than Bald Eagles (*Haliaeetus leucocephalus*) by Harness (1997) in the West, with juveniles more frequently reported killed than adults. Red-tailed Hawks (*Buteo jamaicensis*) and Great Horned Owls (*Bubo virginianus*) were the most commonly reported hawk and owl species by Harness (1997) and Harness and Wilson (2001). Power outages can result in damaged equipment, safety problems, brush and forest fires, and loss of service to customers. Nationwide, animals are the third leading identifiable cause of all power outages, with birds causing more outages than any other animal (Southern Engineering Company 1996). Of 4,300 eagle mortalities investigated by the Department of Interior from the early 1960s to 1995, electrocution was reported as the second greatest cause of mortality to Golden Eagles and the third greatest cause to Bald Eagles (LaRoe et al. 1995). Electrocution is now rated the fourth leading cause of death for Bald Eagles, following accidental trauma, poisoning, and shooting (Lehman 2001).

Where vegetation is low and terrain is flat, power poles are particularly attractive to raptors in the West since they provide structures from which to hunt and roost (Boeker 1972, Benson 1981). Eagles and buteos (soaring hawks) actively seek out poles, especially where prey is abundant and few other perches exist, increasing their range of vision, allowing greater attack speed when hunting, and advertising territorial ownership (Olendorff et al. 1981, Colson and Associates 1995). It was commonly believed in the 1980s that a very small percentage of distribution poles was actually electrocuting raptors. These were designated as "preferred poles," situated in good habitat or near high prey concentrations (Olendorff et al. 1981). Nelson and Nelson (1976) even estimated that 95 percent of electrocutions could be prevented by modifying 2 percent of the poles. Conventional wisdom indicates that these assessments were probably unrealistic due, in part, to lack of a nationwide reporting system and systematic nationwide studies, and observational and data-collection biases (Lehman 2001).

Twelve North American raptor species are known nesters on utility structures. In the East, Osprey (*Pandion haliaetus*) is frequently seen nesting on power poles (Blue 1996). Due to lack of staff and funding, very little of the U.S. power grid is assessed – if even infrequently – for bird electrocutions. The estimates of tens of thousands to hundreds of thousands or more birds killed each year are only very rough approximations based on very limited data. True mortality could be much higher. Recent information suggests that raptor electrocutions may be under-reported, possibly larger by several orders of magnitude (Lehman 2001).

Mitigation measures can vary in cost, depending on whether or not they are required for new construction or are retrofitted. Sufficient phase-to-phase and phase-to-ground wire spacing is critical for large-winged birds. This can be costly if wires have to be re-strung for wider separation. Three-phase transformers can be especially deadly where bare energized jumper wires connect transformers, protective cutouts, and surge arresters. These can be deadly to small and large raptors (Negro and Ferrer 1995). Jumper wires on all electrical equipment should be insulated, including at tap and dead-end locations. Existing transformers can be retrofitted by replacing bare wire with either 600 v insulated jumpers or by sliding insulating material over bare jumpers; new jumpers should contain 600 v insulated jumpers and be insulated with bushing covers (Harness 1997, Harness and Wilson 2001). Specifications are provided by APLIC (1996) and Southern Engineering Company (1996). With the use of cost-effective new or replacement steel distribution poles – steel has been used on transmission towers for years – we see a new electrocution challenge. The mitigation measures used on wooden poles are not effective on metal ones. In a European study, insulating cross-arm braces on steel distribution poles proved most effective, while perch guards were less effective (Janss and Ferrer 1999). Harness and Wilson (2001) call for more research to attempt to qualify the relationships between raptor electrocutions and different types of electrical power structures. The Service strongly agrees.

Power Line Collisions

Birds of a much greater variety strike power transmission and distribution lines. Coues (1876) was the first to report over 100 dead birds, mostly Horned Larks (*Eremophila alpestris*), along a 4.8-km (3-mi) section of telegraph line, and even witnessed the deaths of three birds. Cohen (1896) reported 14 Red Phalaropes (*Phalaropus fulicaria*) and a Ruddy Duck (*Oxyura jamaicensis*) verified by necropsies as telegraph wire kills. Emerson (1904) reported shorebirds and a Black Rail (*Laterallus jamaicensis*) colliding with electrical wires over a salt marsh and evaporation ponds – representing the first reported power line strikes. Large, less maneuverable birds are more vulnerable to collisions with power lines, including Great Blue Herons (*Ardea herodias*), cranes (*Grus* spp.), swans (*Cygnus* spp.), and pelicans (*Pelicanus* spp.; Huckabee 1993). Line collisions resulted in 36 percent of the known mortality to fledged Greater Sandhill Cranes (*G. canadensis tabida*) in the Rocky Mountains (Drewien 1973), 44 percent mortality of fledged Trumpeter Swans (*C. buccinator*) in Wyoming (Lockman 1988), and 40 percent of the know mortality of endangered fledged Whooping Cranes in the Rocky Mountains (Lewis 1993). In a study near wetlands in North Dakota, Faanes (1987) found that waterbirds (based on 46 percent documented mortality), waterfowl (26 percent), shorebirds (8 percent), and passerines (5 percent) were most vulnerable to strikes with transmission lines. In habitats away from wetlands, raptors and passerines appear to be most susceptible to collisions with power lines. Collisions from many other species have also been reported (Erickson et al. 2001).

On Kaua'i, Hawaiian Islands, studies by Podolsky et al. (1998) and Ainley et al. (2001) documented rather unique lighting and power line impacts to Newell's Shearwaters (*Puffinus auricularis newelli*). During the first nocturnal flights of fledglings from nests to the ocean, a high percentage (≥2 to ≥10 percent) of fledglings were reported blinded by man-made lighting, disoriented, and killed while colliding with lights, utility poles, wires, buildings, and automobiles (Ainley et al. 2001). Contrary to recommendations by APLIC, wide spacing of power transmission lines appeared to increase collisions of summer nesting season adults and subadults during their nocturnal and crepuscular flights to and from bird colonies (Podolsky et al. 1998). It was hypothesized that the wide spacing increased the incidence of collisions as birds attempted to avoid hitting one line, only to hit another. In experimental areas, light shielding was shown to reduce attraction by as much as 40 percent while reducing light intensity also lowered deaths significantly (Ainley et al. 2001). Burying power lines was also recommended for particular hot spots.

Estimates of mortality from avian collisions with power lines have varied considerably and have frequently been based on extrapolations. Faanes (1987) estimated 124 avian fatalities/km/yr (200 fatalities/mi/yr) near prairie wetlands and lakes in North Dakota. Koops (1987) examined 4,666 km (2,900 mi) of bulk transmission line in the Netherlands, estimating 0.75 - 1 million birds killed there per year. U.S. mortality could range from hundreds of thousands up to perhaps 175 million birds per year, based on extrapolations by Erickson et al. (2001) and Koops (1987). Very little of the power grid, however, is currently being examined so these estimates are not particularly meaningful.

In an attempt to comprehensively address the collision problem, APLIC (1994) provided voluntary guidance to the industry on avoiding power line strikes. The document will be updated once research being conducted by the Electric Power Research Institute and others at the Audubon National Wildlife Refuge, North Dakota, is completed, and results of tests on a Bird Strike Indicator and Bird Activity Monitor can be published. Other research findings will also likely be included. For example, marker balls, bird diverters, and paint have been shown to reduce collisions, sometimes significantly. Strikes were reduced by 53 percent at a South Carolina transmission line outfitted with yellow marker balls (Savereno et al. 1996). In southwestern Colorado, polyvinyl chloride plastic dampers reduced collisions of cranes and waterfowl by 61 percent while yellow fiberglass square plates reduced mortality to the same species by 63 percent (Brown and Drewien 1995).

Communication Tower Collisions and Related Problems

Communication towers, whether monopole cellular telephone, or tall, lattice structured digital television (DTV) antennas, are an increasingly familiar sight in neighborhoods, near highways, and along ridge tops. For at least the past 6 years, the number of communication towers (including but not necessarily limited to radio, television, cellular, microwave, emergency broadcast, national defense, paging, and related) constructed across the landscape has been growing at an exponential rate. Based on the July 2002 statistics from the Federal Communication Commission's (FCC) Antenna Structure Registry Database (FCC 2002), more than 138,000 towers were listed with the Commission – of which some 106,000 were lighted. Revised published statistics (FCC 2003) may have indicated some double-counting of the 2002 numbers, since nearly 93,000 towers were reported registered in June 2003. Due to an under-reporting to the FCC of up to some 35 percent, the actual number of existing towers is likely higher (Manville 2001b).

While this is positive news for the communications industry, it is decidedly problematic for migrating birds. Towers today pose a likely significant impact on migratory birds, especially some 350 species of passerines. The earliest known report of a bird-tower kill in the United States took place in September 1948 at a 137-m (450-ft) radio tower in Baltimore, Maryland, although no details about the incident were available (Aronoff 1949). The first long-term study of the impact of a television tower on birds was begun in 1955 by the

Tall Timbers Research Station in northern Florida. After the first 25 years of the study, 42,384 birds representing 189 species were tallied (Crawford and Engstrom 2000). On average, 1,517 birds were killed per year over the 29-year period of this study, 65 percent of the mortalities documented in the fall and 20 percent in the spring (Crawford and Engstrom 2001). The longest study yet conducted – over 38 years – was performed by physician C. Kemper, beginning in 1957. He collected nearly 121,560 birds representing 123 species and he still holds the all-time record for most birds collected and identified from a single-night tower strike: more than 12,000 birds were retrieved in 1963 from the base of a television tower in Eau Clair, Wisconsin, not accounting for almost certain scavenging by wild and domestic predators (Kemper 1996). Able (1973) reported single night kills exceeding 1,000 birds at television towers in Tennessee and Florida during the fall 1972. While published accounts of kills at short towers are limited, Herndon (1973) reported 1,801 birds of 44 species killed during two foggy nights in the fall 1972 at 38-m (125-ft) and 26-m (85-ft) towers and floodlit buildings. In bad weather, bird strikes have been recorded near or at ground level, usually associated with lighting. James (1956) retrieved 2,421 dead birds of 39 species (mostly warblers) beneath light poles on a coastal island following a single stormy spring night in 1951. Lord (1951) reported 200 birds of 23 species killed after apparently being confused by floodlights and striking a lodge on the Blue Ridge Parkway during a foggy night in the fall 1950. In 1975, Wylie (1977) reported 73 birds of 21 species killed by striking an unlit, 30-m (100-ft) tall fire tower during a night of rain and fog. Until more research is conducted on the effects of short towers on birds, we cannot assume that they are not having an impact on populations of songbirds.

To assess tower mortality, Banks (1979) estimated that 1.25 million birds were killed per year in strikes with towers, basing this estimate on 505 tall towers likely to impact birds in 1975. Evans (1998) reassessed mortality based on increased numbers of tall towers, estimating 2-4 million bird deaths per year. Manville (2001a, from a December 1999 evaluation) estimated annual mortality at 4-5 million birds, while Manville (2001b, based on a December 2000 assessment) again cited the 4-5 million figure but indicated that mortality could range as high as 40-50 million. He cautioned that only a cumulative impacts study would assess the true magnitude of the problem and again raised concerns over impacts on already imperiled bird species.

A recently discovered and potentially troubling problem for birds is the impact of low-level, non-thermal radiation emitted from towers. Several studies have recently been conducted using standard 915 MHz cell phone radio frequency microwave radiation on domestic chicken embryos for either 4 days of continuous exposure or at timed intervals twice daily for 4 days (Farrel et al. 1998, data published in DiCarlo et al. 2002; T. Litovitz, Catholic University, pers. comm.). Radiation levels in one study (T. Litovitz, Catholic University, data, published in DiCarlo et al. 2002) were far below current FCC-approved and permissible human health radiation standards (i.e., 1.6 W/kg of whole body tissue). With exposures of 30 minutes or more of radiation per day, embryos developed deformities (e.g., induced DNA damage at 1/600th [0.0024 W/kg] the current permissible level) and in some cases died (e.g., due to affected calcium levels in the heart at 1/10,600th [0.00015W/kg] the permissible level under hypoxic conditions). While extended low doses of microwave cell-phone radiation are being shown to be a distinct risk to human health through enhanced probabilities of cancer (Hardell and Mild 2001) and Alzheimer's disease (Sobel et al. 1996), what effects tower-emitted radiation have on nesting and roosting wild birds on or next to towers are only now being studied. Preliminary research in Valladolid, Spain, has shown strong negative correlations with levels of tower-emitted microwave radiation and bird breeding, nesting, and roosting in the vicinity of these electromagnetic fields. In the House Sparrow (*Passer domesticus*), White Stork (*Ciconia ciconia*), Rock Dove (*Columba livia*), Magpie (*Pica pica*), Collared Dove (*Streptopelia decaocto*), and other species, nest and site abandonment, plumage deterioration, locomotion problems, and even death were reported among those species found close to cellular phone antennas (A. Balmori, 2003 unpubl. ms). Laboratory mice were treated with radiation to replicate conditions found close to an "antenna park" by Magras and Xenos (1997) in Greece. After five generations of newborns, irreversible infertility occurred. What similar effect antennas may have on birds is unknown.

From a collision perspective, the towers that cause the most problems are tall (especially those exceeding 305 m [1,000 ft]), illuminated at night with solid or pulsating incandescent red lights, guyed, near wetlands, in major songbird migration pathways or corridors, and with a history of inclement weather during spring and fall migrations (Manville 2001a). All towers, however, have the potential to kill birds. Light appears to be a key attractant for night-migrating songbirds, especially on nights with poor visibility, low cloud ceilings, heavy fog, or various forms of precipitation associated with either passing or stationary cold fronts (Tordoff and Mengel 1956, Ball et al. 1995). Its attractant effects were first reported in Forest and Stream (1874) and later Allen (1880, cited in Cochran 1959) reported birds killing themselves by flying against lighthouse lights. Cochran and Graber (1958) and Cochran (1959) reported that songbirds were heavily attracted to red incandescent lights at a television tower during inclement weather. In two studies where lighted towers attracted songbirds, and the lights were extinguished, birds continued on their migrations leaving previously lit, cloud enshrouded towers (Cochran and Graber 1958, Avery et al. 1976). In both studies, when the lights were turned back on, within minutes birds began circling the towers in large numbers. Gauthreaux and Belser (1999) showed a greater proportion of bird attraction to red flashing incandescent lights than to white strobes; strobes still attracted some birds compared to unlit controls that attracted none. When nighttime weather conditions and visibility improved, in all cases reported in the literature, the birds left the lighted towers, apparently continuing on their migrations. While tall lighted towers appear to be a major problem, lights can draw birds close to or at ground level, as James (1956) reported on South Padre Island, Texas, when several thousand carcasses were retrieved following a one-night storm.

The Service's Division of Habitat Conservation and our 78 Ecological Services field offices have been involved, to varying degrees, for decades in assessing towers and their impacts on species listed under ESA and required consultations under Section 7 of the Act. However, not until 1998 did the Division of Migratory Bird Management become actively involved in the tower collision issue when in January 1998, up to 10,000 Lapland Longspurs (*Calcarius lapponicus*) and several other species died in a one-night multi-tower accident in western Kansas (Manville 2000). In response to pressure from the environmental community to address this growing problem, the Service developed a tower risk model in late 1998 (the key points of the model referenced in Manville 2001a) and in June 1999 chaired a meeting facilitated by the environmental dispute resolution group, RESOLVE. The most noteworthy outcome of the RESOLVE meeting was the formation of the multi-stakeholder group, the Communication Tower Working Group (CTWG) – made up of more than 14 Federal and several state agencies; most of the communication industry trade associations and several companies; radar, acoustical and physiological ornithologists; consultants; and a number of conservation organizations. The purpose of the CTWG is to develop research protocols, seek funding, and implement pilot studies and a strategic nationwide tower monitoring and cumulative impacts study. Specific details of Working Group developments and related tower challenges are referenced in Manville (2001a, 2001b; see also http://migratorybirds.fws.gov/issues/towers/abcs.html).

In 1999, the USFWS co-sponsored a workshop on "Avian Mortality at Communication Towers" at Cornell University (complete transcripts available at http://migratorybirds.fws.gov/issues/towers/agenda.html). Following meetings in 1999 and 2000, the CTWG developed protocols for conducting pilot studies; approved the framework for a nationwide monitoring study; and prioritized research needs for pilot studies on lighting attraction, behavior effects of lighting, dead bird searches, a critique for dangerous towers, and Geographic Information System needs. Three pilot studies were peer-reviewed by members of the Ornithological Council of which one on lighting has been funded and implemented in the spring 2003.

In 2001, Florida-based Richland Towers funded and implemented the first avian mortality study west of the Rocky Mountains in Sacramento County, California. Avian mortality was small; researchers discovered some ten dead birds during the one-month spring migration study. No bad weather events occurred during the research.

In February 2002, the CTWG met to discuss developing a public-private partnership. Since that meeting, the National Fish and Wildlife Foundation (NFWF) has contributed $50,000 in funding to be matched 1:1 by industry or another source. At the February 2004 meeting of the CTWG, NFWF continued to commit the $50,000. The monitoring of NFWF funding will likely be used to match a portion of $200,000 in funding from the state of Michigan for a lighting study now under way.

Like the voluntary Suggested Practices used by the electric utility industry, the Service developed voluntary tower siting and placement guidelines for the communication tower industry in September 2000 (http://migratorybirds.fws.gov/issues/towers/comtow.html) – based on two years of comments and concerns from the industry, key scientists, and conservationists, and based on the best science available. As new research findings are discovered, for example through pilot studies, the guidelines will be updated with this information.

The U.S. Forest Service is to be commended for using the USFWS's siting guidelines for companies proposing to site short, unguyed cellular phone towers in Arizona National Forests, and for requiring the companies to fund and implement three-year tower monitoring studies in Coconino, Prescott, and Kaibab NF s. They have also adopted the Migratory Bird Division's suggested monitoring protocol for these studies that should yield needed data on the magnitude of avian mortality at short towers in the West. The U.S. Coast Guard is also to be commended for signing a memorandum of understanding with the Service, in which they will use the Service's voluntary communication tower guidance to collocate existing and some proposed new antennas on other towers, buildings, or similar structures; and they will fund and implement a joint Service-USCG research study at a select number of new towers around the U.S. coastline and the Great Lakes. Lighting will be a key component of the research.

Wind Generation

Wind-generated electrical energy is renewable, produces no emissions, and is a generally environmentally clean technology that is becoming competitive with electricity produced from fossil fuels and nuclear power (American Wind Energy Association [AWEA] unpubl. data, http://www.awea.org). However, like so many technologies, "there is no free lunch." Wind generation has one significant downside: rotor blades kill birds – especially raptors – and bats; birds can strike the towers; electrocutions can occur if designs are poor; and wind farms may impact bird movements and habitat use. Wind turbine technology is not new to the United States. In the late 1930s, Vermont boasted the world's then-largest turbine that was likely disabled by high winds due to design flaws, and Cape Cod supported over 1,000 working windmills in the 1800s (Ferdinand 2002). But wind turbine 'farms' and their impacts to birds are a recent phenomenon, as compared to power lines and communication towers where mortality has been documented for decades or longer. The problem in the United States surfaced in the late 1980s and early 1990s at the Altamont Pass Wind Resource Area – a facility then containing some 6,500 turbines on 189 km^2 (73 mi^2) of gently rolling hills just east of San Francisco Bay, California (Davis 1995). Orloff and Flannery (1992) estimated that several hundred raptors were killed each year due to turbine collisions, guy wire strikes, and electrocutions. The most common fatalities were those of Red-tailed Hawks, American Kestrels (*Falco sparvarius*) and Golden Eagles, with less mortality of Turkey Vultures (*Cathartes aura*), Common Ravens (*Corvus corax*), and Barn Owls (*Tyto alba*). The impacts of this wind farm were of most concern to the population of Golden Eagles which was showing a "disturbing source of mortality" to a disproportionately large segment of the population (Southern Niagara Escarpment [WI] Wind Resource Area unpubl. ms). Of the variety of wind turbines at the site, the smaller, faster moving, Kenetech-built, lattice-supported turbines caused most of the mortality at Altamont Pass. As part of a re-powering effort, these turbines are now being replaced with slower moving, tubular-supported turbines. While mortality has declined, an average of 40-60 Golden Eagles and several hundred Red-tailed Hawks and American Kestrels are still estimated to die annually (Hunt 2002) – a continuing concern to the Service. While Europeans have used tubular towers almost exclusively, the United States has almost solely used lattice support – at least until recently (Berg 1996).

Wind farms can also disturb and fragment habitats and disrupt birds (Manes et al. 2003). A 6-year ongoing radio telemetry study of Lesser Prairie-Chickens (*Tympanuchus pallidicinctus*) in the Midwest (R. Robel, unpubl. data, Kansas State University) raises serious questions about turbine impacts to breeding grassland birds that use leks. Because of habitat fragmentation, prairie chickens and Sage Grouse (*Centrocercus urophasianus*) are already in serious trouble.

Colson (1995) indicated that some 16,000 wind turbines operated in California, making the State the largest concentration of wind energy development in the world. Since 1995, that statistic has changed. While California still boasts the greatest number of turbines in the United States, many smaller turbines are being replaced by fewer but larger models. Worldwide, an estimated 50,000 turbines are generating power (Ferdinand 2002; AWEA unpubl. data), of which over 15,000 are currently in 29 states in the United States Turbine numbers are often difficult to track since statistics are generally presented in megawatts (MW) of electricity produced, rather than number of turbines present – the latter statistic is of greater concern to ornithologists. In 1998, for example, Germany was the greatest producer with 2,874 MW of electricity produced by turbines, followed by the United States (1,884), and Denmark (1,450; AWEA unpubl. data). While some project that the number of wind turbines in the United States may increase by another 16,000 in the next 10 years, current trends indicate an even greater potential growth. While the United States presently produces less than 1 percent of its electrical energy from turbines – compared, for example, to Norway's 15 percent – 2001 was a banner year for U.S. turbine technology, doubling the previous record for installed wind production. Companies installed 1,898 turbines in 26 states, which will produce nearly 1,700 MW, at a cost of $1.7 billion for the new equipment (J. Cadogan, U.S. Department of Energy, pers. comm.). Over the past decade, wind power has been the fastest growing energy industry in the world. By 2020, the AWEA (unpubl. data) predicts that wind will provide 6 percent of this nation's electricity to as many as 25 million households. Enron Wind Corporation constructed some 1,500 of the 1,898 turbines installed in the United States in 2001. Although Enron is now bankrupt, General Electric purchased the company and is now producing wind turbines.

In 2002, President Bush signed the Job Creation and Worker Assistance Act, extending the production tax credit to the wind industry for another two years. However, the race to meet the tax credit deadline is forcing the industry to rush turbine development without critical pre-construction site evaluation. Extending the reauthorization period for this Act for more than two years would partially solve this problem. Even with a bright future for growth, and with low speed tubular-constructed wind turbine technology now being stressed, larger and slower moving turbines still kill raptors, passerines, waterbirds, other birds, and bats. Low wind speed turbine technology requires much larger rotors, blade tips often extending more than 128 m (420 ft.) above ground, and blade tips can reach speeds in excess of 320 kph (200 mph) under windy conditions (J. Cadogan, U.S. Department of Energy, pers. comm.). When birds approach spinning turbine blades, "motion smear" – the inability of the bird's retina to process high speed motion stimulation – occurs primarily at the tips of the blades, making the blades deceptively transparent at high velocities. This increases the likelihood that a bird will fly through this arc, be struck by a blade, and be killed (Hodos et al. 2001).

What cumulative impact these larger turbines will have on birds and bats has yet to be determined. Johnson et al. (2002) raised some concerns about the impacts of newer, larger turbines on birds. Their data indicated that higher levels of mortality might be associated with the newer and larger turbines, and they indicated that wind power-related avian mortality would likely contribute to the cumulative impacts on birds. Since little research has been conducted on the impacts of large land-sited and offshore turbines on birds and bats, this newer technology is ripe for research.

Howell and Noone (1992) estimated U.S. avian mortality at 0.0 to 0.117 birds/turbine/yr., while in Europe, Winkelman (1992) estimated mortality at 0.1 to 37 birds/turbine/yr. Erickson et al. (2001) reassessed U.S. turbine impact, based on more than 15,000 turbines (some 11,500 in California), and estimated mortality in the range of 10,000 to 40,000 (mean = 33,000), with an average of 2.19 avian fatalities/turbine/yr. and 0.033 raptor fatalities/turbine/yr. As previously mentioned, this may be a considerable underestimate. As with other structural impacts, only a systematic turbine review will provide a more reliable estimate of mortality. While some have argued that turbine impacts are small (Berg 1996), especially when compared to those from communication towers and power lines, turbines can pose some unique problems especially for birds of prey and mortalities must be reduced especially as turbine numbers increase. In addition to protections under the MBTA, Bald and Golden Eagles are afforded protections under the ESA for the former and the BGEPA for both raptors. As strict liability statutes, MBTA and BGEPA also provide no provisions for un-permitted "take." Wind farms can affect local populations of Golden Eagles and other raptors whose breeding and recruitment rates are naturally slow and whose populations tend to have smaller numbers of breeding adults (Davis 1995). Large raptors are also revered by Native Americans as well as by many others within the public, they are symbolic megafauna, and they provide greater emotional appeal to many than do smaller avian species. Raptors also have a lower tolerance for additive mortality (Anderson et al. 1997). In the eastern United States, recent and proposed installations of hundreds of turbines on Appalachian Mountain ridges raise new concerns for raptors and songbirds. Environmentalists are calling for a systematic area-wide preconstruction review of these sites. As with all other human-caused mortality, we thus have a responsibility to reverse mortality trends at wind farms.

Until very recently, U.S. wind turbines have mostly been land-based. Perhaps following the European lead of siting wind turbines in estuarine and marine wetlands (van der Winden et al. 1999, van der Winden et al. 2000), and perhaps due to an assessment of a large number of potential offshore turbine locations in the U.S. (based on Weibull analyses of "good, excellent, outstanding, and superb" wind speed potentials [National Renewable Energy Laboratory 1987]), a new trend is evolving in North America. Several proposals for huge offshore sites are being submitted for locations on both Atlantic and Pacific coasts. These, at the very least, should require considerable research and monitoring to assess possible impacts to resident and migrating passerines, waterfowl, shorebirds, and seabirds. One site at Nantucket Shoals, offshore of Nantucket Island near Cape Cod, Massachusetts, is proposed by the Cape Wind Association to contain 170 turbines, many over 128 m (420 ft.), within a 65 km^2 (25 mi^2) area (Ferdinand 2002, AWEA unpubl. data). What impacts will this wind farm have on wintering sea ducks and migrating terns, especially the Federally endangered Roseate Tern (*Sterna dougallii dougallii*), and on Northern Gannets (*Morus bassanus*)? The Long Island Power Authority is proposing a site offshore of Long Island, New York's south shore, covering as much as 813 km^2 (314 mi^2). Other sites are being proposed for Portland, Maine, and Lake Erie. The largest proposed wind farm in North America is being planned for a 130 km^2 (50 mi^2) area between Queen Charlotte Island, BC, and Alaska. It is being designed to contain 350 turbines, many exceeding 122 m (400 ft.) in height. While the potential for significant offshore turbine impacts on waterbirds is great, virtually no research has been conducted in the United States to quell these concerns, and finding carcasses at sea is very challenging.

In an attempt to begin addressing the bird mortality issue – and ancillary to this the issue of ESA-listed bat strikes also of concern to the USFWS – the National Wind Coordinating Committee was created in 1994 as part of President Clinton's Global Climate Change Action Plan (Colson 1995). Shortly following the creation of the Committee, the Avian Subcommittee – now called the Wildlife Workgroup – was formed, co-founded by the Service. In 1999, the Avian Subcommittee published a Metrics and Methods document to study turbine impacts on birds (Anderson et al. 1999). The document provides an excellent resource for conducting research on proposed and existing turbines and wind farms.

To address the turbine collision and habitat fragmentation problems in-house, the Service's Wind Turbine Siting Working Group developed interim voluntary site evaluation, siting, placement, and monitoring guidelines for the wind industry, much like those that exist in the Suggested Practices for power companies, or the tower guidelines for the communication tower industry. We encourage use of this guidance and are soliciting input from industry, other experts, and the public for a 2-year period since the guidance was released to the public in July 2003. Once the public comment period closes in 2005, we will reassess and update this voluntary guidance, based on input. The guidance is intended to assist the wind industry in avoiding or at least minimizing wildlife impacts by evaluating potential wind development sites, properly siting and designing turbines within these areas, and conducting pre- and post-construction research and monitoring to identify impacts to wildlife and their habitats. The guidance also contains a detailed protocol for evaluating and ranking a site before it is developed.

Based on the efforts of a team of Federal, state, university, and wind industry biologists in Montana, a protocol was developed to evaluate and rank potential sites proposed for wind development. The process is designed to identify and evaluate so-called "reference sites" – areas where wind development would result in a maximum negative impact to wildlife and habitats – then use these reference sites to rank sites proposed for actual development. Ranking a site results in an index score for that location. The protocol is intended to be used nationwide.

Based on considerable published information from the Wildlife Workgroup and from other sources, the Service's Working Group also agreed to a number of recommendations under the categories listed below. Some of these include:

Site development:

- avoid siting turbines in major bird migration corridors or in areas where birds are highly concentrated;
- avoid placing turbines in areas that attract raptors; specifically, consider setbacks from cliff/rim edges, avoid dips or passes along ridges, and avoid turbine sites in or near prairie dog and ground squirrel colonies;
- avoid attracting high densities of prey animals consumed by raptors, reduce carrion availability, and avoid creating wetlands adjacent to turbines;
- in known prairie grouse habitat, avoid siting turbines within at least 8 km (5 mi) of documented lek breeding areas;
- where rotor swept area is a risk to wildlife, adjust turbine tower height where feasible to reduce or eliminate the risk from turbine strikes;
- avoid siting turbines near bat hibernation and breeding colonies, migration corridors, and in flight paths; and
- avoid siting turbines in areas with Federally ESA-listed plants, animals, and designated critical habitat.

Turbine design and operation:

- use tubular supports with pointed tops rather than lattice supports to minimize bird perching and nesting opportunities;
- avoid using guy support wires for turbines and meteorological study towers. Where guys must be used, mark them with recommended bird deterrent devices (APLIC 1994);
- for turbines whose rotor-swept area exceeds 61 m (199 ft) above ground level, use white strobe lighting with the minimum number, minimum intensity, and minimum number of flashes per minute allowed by the Federal Aviation Administration during nighttime operations. Avoid lighting all turbines but flash lights simultaneously on lighted structures. Avoid solid red or pulsating red incandescent lighting;
- where feasible, place electric power lines underground to avoid electrocuting birds and use the Suggested Practices (APLIC 1996, Southern Engineering Company 1996) for aboveground lines, transformers, and conductors;
- in areas of high seasonal bird concentrations, where feasible, shut down turbines during periods when birds are highly concentrated at those sites; and
- when retrofitting, specifically where studies indicate high levels of mortality, follow the above guidance as closely as possible.

The Working Group also included a monitoring and dead-bird-search protocol that is being used by the Forest Service to study communication towers; this should easily be modified to study wind turbines. The Group also identified these additional research needs:

- assess the effects of inclement weather in attracting birds – especially passerines – and bats to lighted turbines and their rotor-swept areas;
- monitor and assess local impacts of turbines on wildlife, including habitat loss and fragmentation, effects of noise, and habituation;
- assess turbine string configuration and its potential for mortality, including end-of-row, dip and pass, and setback placements;
- determine the effectiveness of deterrents including blade colors (black/white and UV gel coatings to reduce the "smear effect"), lighting, infrasound, and visual markers;
- assess acoustic, infrared, and radar technologies to detect bird presence, movement, flight level, and position in relation to turbines;
- assess mortality estimates, including the number of lost carcasses (especially passerines) fragmented by the blades and lost to the wind, review the size and shape of dead-bird-search areas, and review possibilities of recording collisions through acoustic, radar, or infrared monitoring;
- determine the utility of GIS as a tool to assess migratory pathways and stopovers, particularly for passerines, bats, and butterflies;
- assess the effectiveness of time-specific or seasonal shutdowns to prevent mortalities; and
- compare the impacts of newer larger turbines to their smaller counterparts.

In conclusion, the challenges posed by power lines, communication towers and wind turbines are daunting and our avian friends need all the help we can provide them. This will require the collective minds of many individuals and interest groups.

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