National Wind Coordinating Committee (NWCC) Resource Document*

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Avian Collisions with Wind Turbines:

A Summary of Existing Studies and Comparisons to Other Sources of Avian Collision Mortality in the United States

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EXECUTIVE SUMMARY

It has been estimated that from 100 million to well over 1 billion birds are killed annually in the United States due to collisions with human-made structures, including vehicles, buildings and windows, powerlines, communication towers, and wind turbines. Although wind energy is generally considered environmentally friendly (because it generates electricity without emitting air pollutants or greenhouse gases), the potential for avian fatalities has delayed and even significantly contributed to blocking the development of some windplants in the U.S. Given the importance of developing a viable renewable source of energy, the objective of this paper is to put the issue of avian mortality associated with windpower into perspective with other sources of avian collision mortality across the U.S.

We have reviewed reports indicating the following estimated annual avian collision mortality in the United States:

- Vehicles: 60 million - 80 million
- Buildings and Windows: 98 million - 980 million
- Powerlines: tens of thousands - 174 million
- Communication Towers: 4 million - 50 million
- Wind Generation Facilities: 10,000 - 40,000

The large differences in total mortality from these sources are strongly related to the differences in the number (or miles) of structures in each category. There are approximately 4 million miles of road, 4.5 million commercial buildings and 93.5 million houses, 500,000 miles of bulk transmission lines (and an unknown number of miles of distribution lines), 80,000 communication towers and 15,000 commercial wind turbines (by end of 2001) in the U.S. However, even if windplants were quite numerous (e.g., 1 million turbines), they would likely cause no more than a few percent of all collision deaths related to human structures.

There are also other sources that contribute significantly to overall avian mortality. For example, the National Audubon Society estimates avian mortality due to house cats at 100 million birds per year. Pesticide use, oil spills, electrocution, disease, etc. are other significant sources of unintended avian mortality. Due to funding constraints, the scope of this paper is limited to examining only fatalities resulting from collisions with human-made obstacles. Recognize that the cumulative impacts of all mortality factors on birds continue to increase as the human population climbs and resource demands grow. Every effort by all industries to reverse avian mortality trends and minimize the number of bird deaths is important.

Many of the studies of buildings, communication towers, and powerlines were conducted in response to known or perceived problems with avian collisions, and therefore may not be representative of all structures in the United States. As a consequence, using averages of these estimates to project total avian fatalities in the U.S. would be biased high. The estimates provided for the sources of avian mortality listed above, except wind generation facilities, are based on subjective models and are very speculative.

In contrast to other sources of avian collision mortality, avian hazards at most windplants have been evaluated using more standardized methods, and studies have often been conducted without regard to a known or perceived risk. Fatality estimates from wind generation facilities, especially new facilities, have typically considered adjustments for scavenging and observer detection biases. These biases were generally not considered or calculated in studies estimating avian mortality due to collisions with communication towers, vehicles, and buildings and windows. Therefore, the data available to project overall windplant fatalities are generally more accurate than most available data for other collision sources.

Data collected to date indicate an average of 2.19 avian fatalities per turbine per year in the U.S. for all species combined and 0.033 raptor fatalities per turbine per year. Based on current projections of 15,000 operational wind turbines in the U.S. by the end of 2001, the total annual mortality was estimated at approximately 33,000 bird fatalities per year for all species combined. This estimate includes 4,500 house sparrows, European starlings and rock doves, and 488 raptor fatalities per year. We estimate a range of approximately 10,000 to 40,000 bird fatalities. The majority of these fatalities are projected to occur in California where approximately 11,500 operational turbines exist, and most are older smaller turbines (100- to 250-kW machines). Data collected outside California indicate an average of 1.83 avian fatalities per turbine per year, and 0.006 raptor fatalities per turbine per year. Based on current projections of 3,500 operational wind turbines in the U.S. by the end of 2001, excluding California, the total annual mortality was estimated at approximately 6,400 bird fatalities per year for all species combined. This estimate includes 400 house sparrows, European starlings, and rock doves, and 20 raptor fatalities per year. While there have been numerous single mortality events recorded at communication structures that document several hundred avian fatalities in one night, the largest single event reported at a wind generation facility was fourteen nocturnal migrating passerines at two turbines at the Buffalo Ridge, Minnesota, Windplant during spring migration. Based on current estimates, windplant-related avian collision fatalities probably represent from 0.01% to 0.02% (i.e., 1 out of every 5,000 to 10,000 avian fatalities) of the annual avian collision fatalities in the United States. While some may perceive this level of mortality as small, all efforts to reduce avian mortality are important.

Making projections of the potential magnitude of windpower-related avian fatalities is problematic because of the relative youth of the wind industry and the resulting lack of long-term data. For example, of the existing windplants, only the Altamont Pass, Buffalo Ridge and Foote Creek Rim wind resource areas(WRA) have been studied for more than two years, and most of the studies at Altamont focused on raptor mortality. The data collected at Altamont and other older-generation windplants may not be representative of avian mortality of future wind developments. Newer generation windplants incorporate improvements in site planning and changes in the design of the wind turbines. For example, turbines at the Foote Creek Rim Windplant were moved back away from the rim edge because baseline data detected a pattern of raptor use along the edge of the rim (Johnson *et al.* 2000a). Also, many of the newer generation turbines are designed to provide little perching and no nesting structure (tubular towers, enclosed nacelle). Although it's not clear that perching increases risk of collision, the lack of perching and nesting opportunities may discourage some bird species from using the WRA. Furthermore, some efforts have been made in Altamont to remove turbines associated with higher raptor mortality, and re-powering efforts may result in the replacement of many of the older, smaller turbines with fewer larger, newer generation turbines. If these efforts effectively reduce raptor mortality at Altamont, our raptor mortality projections would also be reduced. Finally, most wind plant developers are required to carry out site evaluations at proposed wind plant sites to determine impacts on birds and other wildlife. While newer generation turbines may be considered more representative of future developments, they have only been in operation in the recent past (i.e. <10 years), and less information on avian collision hazards is available for these turbines.

INTRODUCTION

Wind has been used to commercially produce energy in the United States since the early 1980's (AWEA 1995) and is considered an important source of renewable energy. Recent advances in wind turbine technologies have reduced costs associated with windpower production, improving the economics of wind energy (Hansen *et al.* 1992). As a result, commercial wind energy plants have been constructed in 22 states, and additional projects are planned in another four states as of September 30, 2000 (AWEA 2000). Until recently, most windpower development in the U.S. occurred in California; however, more than 90% of the windpower potential in the U.S. exists within 12 mid-western and western states (Weinberg and Williams 1990).

It has been estimated that from 100 million to well over 1 billion birds are killed annually in the U.S. due to collisions with human-made obstacles, including vehicles, aircraft, buildings and windows, powerlines, communication towers, smokestacks, and other structures (Klem 1990, Manville 2000). Although generally considered environmentally friendly, windpower has been associated with the death of birds colliding with turbines and other windplant structures, especially in California (Orloff and Flannery 1992). Early wind energy facilities in the U.S. were often constructed in areas without an understanding of the level of avian use at those locations. Consequently some of these facilities are located where birds are abundant and the risk of turbine collisions is relatively high (AWEA 1995). High raptor mortality documented at Altamont, California (Howell and Didonato 1991, Orloff and Flannery 1992) has resulted in a great deal of scrutiny of other windplant developments. Wind projects have been delayed and sometimes stopped at new wind sites across the country due in part to avian collision concerns. Significant effort has been devoted to developing standardized methods for siting windplants (NWCC 1999) and monitoring for avian impacts resulting from the windplants (Anderson *et al.* 1999, Erickson *et al.* 2000a). Primarily due to these efforts, many of the new developments have implemented site evaluation and monitoring programs that provide standardized data useful for understanding the impacts of windplants on birds (Johnson *et al.* 2000b, Johnson *et al.* 2001, Erickson *et al.* 2000a, Kerlinger and Curry 2000, Walla Walla County Regional Planning Department 2000, Howe 2001 pers. comm., URS and WEST 2000).

The purpose of this paper is to provide a detailed summary of the mortality data collected at windplants and put avian collision mortality associated with windpower development into perspective with other significant sources of avian collision mortality across the United States. We provide a summary of data collected at many of the U.S. windplants and provide annual bird fatality estimates and projections for all wind turbines in the U.S. For comparison, we also review studies of avian collision mortality from other major human-made structures and report annual bird fatality estimates for these sources. Other sources also significantly contribute to overall avian mortality. For example, the National Audubon Society estimates avian mortality due to house cats at 100 million birds per year. Pesticide use, oil spills, disease, etc., are other significant sources of unintended avian mortality. Due to funding constraints, the scope of this paper is limited to examining only avian mortality resulting from collisions with human-made obstacles.

METHODS

Literature Review

We conducted an extensive literature review to gather information on bird collisions with vehicles and stationary artificial structures. A combination of methods were used including searches on the world wide web, library searches, contacting ornithological societies, contacting experts in the field (Appendix A), and searches of raptor powerline collision/electrocution databases. Published and unpublished articles were found using several existing literature reviews, including Trapp (1998), Kerlinger (2000), Shire *et al.* (2000), and California Energy Commission (1995).

Other methods included searching the National Information Services (NISC) Wildlife Worldwide DISCover (National Information Services Corporation 2000) and the NREL Avian Literature Database (2000), and gathering citations while reviewing articles. Most published articles were obtained through the University of Wyoming Science Library and through inter-library loan. Authors and experts were contacted directly when articles or information could not be obtained through the University of Wyoming. The data form used for recording information from reviewed articles is found in Appendix B.

Data Reporting and Analysis Methods

Summary results from many studies of avian collisions with various human-made structures include species type or group composition, total numbers of bird fatalities observed, and projections of total fatalities. Obtaining reasonable projections on an annual or a seasonal basis from a short-term study of a single structure or a small group of structures is difficult in itself. It is even more difficult to attribute projections to all structures of a particular type. Some factors affecting projections include the method by which structures are selected for search, the interval between carcass searches (e.g., daily searches, weekly searches), the proportion of bird fatalities detected by searchers (searcher efficiency rates), and the rates of carcass removal by scavengers (scavenging rates). Accounting for searcher efficiency and scavenging rates is particularly important for an unbiased estimate of mortality. Nearly all of the studies that report estimated avian collision mortality on a seasonal or annual basis for vehicles, communication towers, buildings and windows did not account for scavenging and searcher efficiency. In addition, the structures studied often do not represent the population of structures (i.e. the number of structures studied is small relative to the whole "population" of structures, or the studies are conducted at structures with high observed fatalities), and/or the studies are of relatively short duration. Using these studies as a basis for projections for all structures of a particular type is problematic and not likely to be highly accurate due to the many sources of bias.

Projections for Wind Turbine Collision Mortality

We provide independent projections of avian mortality for all bird species and for raptors. Projections of wind turbine caused raptor mortality are based on data collected at windplants in Altamont, California (Howell and DiDonato 1991, Howell *et al.* 1991a, Orloff and Flannery 1992), Montezuma Hills, California (Howell and Noone 1992), San Gorgonio, California (McCrary *et al.* 1986a), Vansycle, Oregon (Erickson *et al.* 2000b), Foote Creek Rim, Wyoming (Johnson *et al.* 2001), Buffalo Ridge, Minnesota (Higgins *et al.* 1996, Osborn *et al.* 2000, Johnson *et al.* 2000b), Algona, Iowa (Demastes and Trainer 2000), Searsburg, Vermont (Kerlinger 1997), and in Pennsylvania (Kerlinger 2000, pers. comm.). Estimates for the total number of bird fatalities were obtained for all studies except those that did not estimate scavenging and searcher efficiency for small birds (e.g., most passerines); this eliminated the Altamont and Montezuma Hills studies (Howell and DiDonato 1991, Howell *et al.* 1991a, Orloff and Flannery 1992, Howell and Noone 1992).

We obtained an average fatality per turbine per year estimate for each applicable Wind Resource Area (WRA, e.g., Altamont) by averaging the estimates across studies of the corresponding WRA. The averaged estimates for each applicable WRA were again averaged (among all applicable WRA's), weighted by the number of turbines expected in the WRA by the end of 2001. We then extrapolated this estimate to the total number of operational wind turbines expected in the United States by the end of 2001 from data obtained by the American Wind Energy Association (AWEA). We make all bird and separate raptor fatality projections for wind turbines in California, outside California, and throughout the entire United States. We report a lower and upper range for the all bird estimates using the lower and upper range of fatality estimates from studies that have documented fatalities and have incorporated scavenging and searcher efficiency estimates for small birds.

Projections for Other Sources of Collision Mortality

Bird collisions with artificial structures and associated fatalities have been documented in the U.S. since the late 1880's (Crawford and Engstrom 2000). A large amount of published and unpublished literature exists on avian collisions with artificial structures and vehicles. However, calculating accurate numbers of bird fatalities associated with all human-made obstacles is difficult due to limitations in the scope of most studies. Most of the studies lack standardized methods for searching and are limited to documenting avian collisions at a particular season or location. For example, many of the studies are limited to fall migration periods. The studies usually report the total number of carcasses and species type, without adjustment for scavenging and searcher efficiency, and this information is insufficient to accurately estimate the total number of bird deaths. Difficulties also arise due to the large number of human-made obstacles that exist. Making accurate estimates of fatalities from any of these sources requires a random or at least representative sample of experimental units (e.g., buildings, communication towers, miles of road) with information replicated across time. There are very few studies relative to the vast number of buildings and communication towers and the extensive miles of powerline and roads that exist in the U.S. Furthermore, many of the studies were conducted in response to suspected or actual large mortality events, and focus on areas where the number of fatalities may be unusually high. For example, many powerline studies involved monitoring fatalities associated with powerlines near wetlands with high waterfowl use. Therefore, fatality estimates derived from data reported in the available studies would most likely be an over-estimate of the true mortality.

We did not attempt to develop our own estimates of avian mortality from sources other than wind turbines due to the lack of standardized information. We feel that the available data cannot be used to make projections based on averages of individual estimates. Instead, we have updated previous estimates provided in the literature based on increases in the number (e.g., buildings) or extent of collision sources.

RESULTS

Avian Mortality due to Collisions with Vehicles

Although several studies have been conducted in Europe (e.g., Dunthorn and Errington 1964, Hodson 1962, Finnis 1960, Hodson and Snow 1965, Hugues 1996), we found relatively few documents that reported vehicle-related avian mortality in the United States (Appendix C). In Illinois, Decker (1987) traversed a 4.4-mile (7 km) stretch of road daily and documented a mean mortality estimate of 33 birds per mile per year (21 birds/km/year). The most common fatalities were passerines or other small birds, including yellow-billed cuckoo, blue jay, red-winged blackbird, and indigo bunting. In Ontario, Canada, Ashley and Robinson (1996) searched a 2.2 mile (3.6 km) stretch of road located near wetlands three days a week and calculated that 223 birds were killed per mile per year (139 birds/km/year), most of which were passerines. No adjustments were made for searcher efficiency or scavenger removal in either of these studies.

From 1969 to 1975, Case (1978) searched the entire length of Interstate 80 in Nebraska (458 miles, 732 km) and documented a total of 7,195 ring-necked pheasant vehicle collision fatalities. Based on finding 562 dead ducks over a 10-year period, Sargeant (1981) estimated that vehicles killed 13,500 ducks each year in the prairie pothole regions of North and South Dakota. Mean annual mortality of ducks was estimated to be 0.250 ducks per mile (0.156 ducks/km) of interstate, 0.008 ducks per mile (0.005 ducks/km) of unsurfaced roads, and 0.042 ducks per mile (0.026 ducks/km) for all road types combined. Although the number of fatalities appears high, it was estimated to represent less than 0.2% of the breeding population in the study area. Much lower mortality was documented during other studies. McClure (1951) documented only four road-killed ducks while driving 76,250 miles (122,000 km) of road in Nebraska. In Minnesota, Sargeant and Forbes (1973) found only three road-killed ducks along 17 miles (27 km) of roads driven almost daily for an 18-month period. Raptors also appear susceptible to vehicle collisions in some areas. Based on driving surveys over a 10-year period in New Jersey, Loos and Kerlinger (1993) estimated that 25 raptors were killed per year within a 90-mile (145 km) survey route. Most of the fatalities were owls; however, six species of hawks were also found among road fatalities.

Banks (1979) summarized several studies and reported estimates of avian fatality rates ranging from 2.7 to 6.1 deaths per mile of road per year to 60 to 144 bird fatalities per mile per year. From U.S. studies reported in Banks (1979), use of the minimum (2.7) and maximum (96.25) reported values for bird deaths per mile yields estimates of 10.7 million to 380 million annual bird deaths on U.S. roads. Banks (1979) estimated a total annual avian road mortality rate of 57.2 million. This figure was acquired using the estimate of 15.1 bird fatalities per mile reported by Hodson and Snow (1965), who conducted a fairly extensive study in England, although no scavenging or searcher efficiency bias was considered which would contribute to an underestimate of true fatality rates. According to the U.S. Census Bureau (Statistical Abstract of the United States 1999), in 1997 there was an estimated 3,944,597 miles of road in the U.S. Using this number to update Banks' estimate yields a current (1997) estimate of approximately 60 million avian fatalities on U.S. roadways annually. The number of registered vehicles has increased 35% from 1980 to 1998 alone, so an alternative estimate would be 1.35 times 60 million, or approximately 80 million avian fatalities. Klem (1991) reports that vehicles make up 19.7% of the total human-caused bird fatalities (includes collision, pesticide, cats and other sources), which he estimated at approximately 300 million birds per year.

Although most avian fatalities caused by vehicles occur on roadways, avian collisions also occur with trains (Spencer 1965) and airplanes. Avian collisions with airplanes present a significant hazard to both military and commercial aircraft. The Federal Aviation Administration (FAA) keeps records of avian collision strikes involving aircraft in the U.S. In 1998, the U.S. Air Force reported over 3,500 bird strikes by planes, and it is estimated that civil aircraft strike over 25,000 birds per year. Data collected from 1990 to 1999 indicate that gulls (31%), waterfowl (31%) and raptors (15%) comprise 77% of the reported bird strikes causing damage (Bird Strike Committee USA 2000). No estimates for train caused avian mortality were found in the literature. It is likely that train collisions also result in several thousand bird deaths annually in the United States.

Avian Mortality due to Collisions with Buildings and Windows

Numerous studies have documented extensive avian collision mortality associated with buildings and similar structures such as smokestacks (Appendix D). Fatalities associated with buildings are usually the result of collisions with tall buildings and collisions with windows at residential houses. Studies may be divided into 2 categories, studies of short-term or episodic mortality events, and longer-term studies. Some mortality events at tall buildings have involved extensive numbers of birds (Appendix D1). At one oil flare stack in Alberta, 1,393 dead birds comprised of 24 species of passerines were found over a 2-day period in May 1980 (Bjorge 1987). Over a 3-day period in October 1964, Case *et al.* (1965) searched several buildings in Florida and recovered 4,707 dead birds, most of which were passerines. Also in Florida, Maehr *et al.* (1983) searched the base of four smokestacks over a 2-day period in September and recovered 1,265 dead passerines. The authors estimated that 5,000 birds might have collided with the structures during this period. In the fall of 1970, 707 dead birds were documented below the Empire State Building in New York (Bagg 1971). Extensive numbers of nocturnal migrant fatalities have also been documented at the Washington Monument in Washington, D.C. (Overing 1936). From October 5-8, 1954, 9,495 dead birds (mostly passerines) were documented at 25 tall buildings in the eastern and southern U.S. following a cold front during fall migration, and it was estimated that 106,804 birds were actually killed (Johnston and Haines 1957).

Several long-term studies have documented the chronic nature of collision mortality associated with some buildings (Appendix D2). Over a 3-year period in Toronto, Ontario, Ogden (1996) counted 5,454 dead birds at 54 tall glass buildings and estimated that 733 birds (mostly passerines) were killed per building per year. Following nights with inclement weather conditions, Taylor and Kershner (1986) searched one building in Florida from 1970 to 1981 and documented 5,046 avian fatalities comprised of 62 species, the majority of which were passerines. Two smokestacks in Citrus County, Florida, were searched 5 times per week from 1982 to 1986, and 2,301 dead birds were found (Maehr and Smith 1988). From this, the authors estimated that 541.4 birds were killed per year. Fatalities included 50 species, most of which were neotropical migrant passerines. Daily searches of two smokestacks in Ontario, Canada, over a 4-year period yielded 8,531 dead birds. Again, most of these were passerines (Weir 1976).

Klem (1990) searched single houses in Illinois and New York daily from 1974 to 1986. A total of 100 dead birds were found at the two houses, and the author estimated that 55% of window collisions result in death. Over the 1989-1990 winter, 5,500 residential houses in the U.S. were searched for dead birds using a standardized procedure, and a total of 995 dead birds were found (Dunn 1993). The author estimated that an average of 0.85 birds are killed per house each winter based on actual mortality ranging from 0.65 to 7.7 birds per house per year. The fatalities were comprised of 66 species, most of which were passerines commonly found at feeders during the winter.

In 1995 there were an estimated 4,579,000 commercial buildings (warehouse, religious/worship, public assembly, offices, mercantile/services, lodging, health care, food sales, education) in the United States (Statistical Abstract of the United States 1999). Klem (1990) reported there were 93.5 million houses in 1986. Due to the large number of structures in this class, and only a few good studies, it is difficult to obtain very accurate fatality estimates for the U.S. There are no requirements to conduct regular searches of homes or other buildings for dead birds. As a result, most of the building and window collision data comes from studies of known or suspected problem structures. Accurately predicting the number of building-related avian fatalities would require random selection of numerous buildings of all types and sizes, followed by long-term standardized and systematic searches for dead birds. In the absence of such data, obtaining accurate, defensible estimates of building-related avian collision mortality is difficult.

Banks (1979) acknowledged a lack of information on building and window collision mortality, and estimated 3.5 million avian fatalities per year based on an arbitrary estimate of 1 bird fatality per square mile in the U.S. Klem (1990) reported estimates of 97.6 to 976 million bird deaths per year due to collisions with windows based on an estimated 1 to 10 bird deaths per structure per year in the U.S. These estimates were based primarily on best professional judgement (Klem 1990).

Avian Mortality due to Collisions with High Tension Lines

Concern over avian collisions with high-tension lines has existed at least since 1876, when Coues (1876) counted approximately 100 avian carcasses (primarily horned larks) beneath a 3-mile long (4.8 km) section of telegraph wire between Denver, Colorado, and Cheyenne, Wyoming. Since then, there have been numerous studies of powerline collisions involving birds (Appendix E). Faanes (1987) searched 6 miles (9.6 km) of powerlines in North Dakota in the spring and fall of 1977 and 1978. Based on a total of 633 dead birds found, he estimated that 200 avian fatalities per mile per year (125 birds/km/yr) were occurring at those sites. The powerlines included in the study were located near wetlands or lakes and most of the fatalities consisted of waterbirds (46%) and waterfowl (26%), followed by shorebirds (8%) and passerines (5%).

For some types of birds, powerline collisions appear to be a significant source of mortality. Waterfowl band recovery data collected prior to 1967 indicated that powerline strikes were responsible for 65% of the collision fatalities involving 3,015 banded birds (Stout 1967). Of 75 trumpeter swan deaths recorded from 1958 to 1973, 19% of the fatalities were due to powerline collisions (Weaver and St. Ores 1974). During a 2-year study of mute swans in Rhode Island, Willey (1968) found that 26.7% of adult fatalities were due to collisions, mostly with powerlines.

The U.S. electrical energy system includes more than 500,000 miles (800,000 km) of bulk transmission lines (Kappenman *et al.* 1997, Edison Electric Institute 2000). A total of 157,810 miles (252,496 km) are comprised of the larger 230 kV transmission lines (North American Electric Reliability Council 2000). Estimates for the length of distribution line could not be found in the literature, but are likely to be much greater than for bulk transmission lines. Estimates of avian fatalities due to collisions with high-tension lines are lacking due to minimal monitoring efforts on a large-scale basis. As with most other sources of collision mortality, most monitoring and/or studies are conducted in response to a known or perceived problem, and little data collected at randomly chosen sites are available. The U.S. Fish and Wildlife Service reports tens of thousands of avian fatalities per year (Manville 2000) due to collisions with power transmission and distribution lines, but there are very few quantitative studies relative to the length of powerlines in the U.S. Based on the limited studies, waterfowl including ducks, geese, swans, and cranes appear to be most susceptible to powerline collisions when powerlines are located near wetlands. In upland habitats away from wetlands, raptors and passerines appear most susceptible to collision.

In the Netherlands, where approximately 2,875 miles (4,600 km) of high-tension lines are present, Koops (1987) estimated that 750,000 to 1 million birds are killed annually by collisions. Extrapolating this estimate to the 500,000 miles (800,000 km) of bulk transmission lines in the United States would lead to a fatality estimate of 130 million to 174 million birds per year. A range using the estimate by Manville (2000) and this extrapolation based on Koops (1987) would yield an annual fatality estimate of >10,000 to 174 million. Given the large number of miles of transmission lines, and the unknown but very large number of miles of distribution lines, we believe the low end of this range is very conservative (too low).

Avian Mortality due to Collisions with Communication Towers

Substantial concern over the recent proliferation of communication towers in the U.S. has arisen in response to large fatality events, such as an estimated kill of 5,000 to 10,000 birds, mostly Lapland Longspurs, at 3 associated communication towers and a natural gas pumping facility in western Kansas on the night of January 22, 1998 (Evans 1998). Large, single-night fatality events are not new. Kemper (1996) counted and identified species for over 12,000 birds killed one night in 1963 at a television tower in Wisconsin. As a result of this concern, avian collision mortality associated with communication towers has received more study and review than other sources of collision mortality, with the possible exception of wind turbines. During our review we located numerous studies covering avian collision mortality with communication towers in 25 states (Appendix F). The vast majority of the studies were one-day searches at single towers following nights of substantial avian mortality (Appendix F1). Most avian fatalities at communication towers involve nocturnal migrant passerines, especially warblers, vireos, and thrushes.

We found 17 studies where collision mortality was measured for periods of time ranging from one to 38 years (Appendix F2). For studies conducted over a period of at least two years and employing searches on a daily or almost daily basis, the estimated mean number of annual collisions per tower ranged from approximately 82 birds per year at an 825-ft (250-m) tall television tower in Alabama (Bierly 1968, 1969, 1972; Remy 1974, 1975; Cooley 1977) to 3,199 birds per year at a 1,000-ft (305-m) tower in Eau Claire, Wisconsin (Kemper 1996). Very few of the studies measured scavenging removal and searcher efficiency. The research at Eau Claire, Wisconsin, was the longest study conducted at any one tower and covered the period from 1957 to 1994 (38 years). Two other continuous studies at individual communication towers include a study that took place from 1960 to 1997 (37 years) at a 1,368-ft (417-m) tower in Nashville, Tennessee (Nehring 2000), and another study that took place at a 1,010-ft (308-m) tower from 1955 to 1983 (28 years) at Tall Timbers Research Station in Tallahassee, Florida (Crawford and Engstrom 2000).

Currently, the Federal Communications Commission has registered over 80,000 towers, of which at least 52,000 are lighted and generally greater than 199 feet (60 m) in height. Since an undetermined number of towers are not registered with the FCC, the total number of communication towers likely exceeds 100,000. Numerous types of towers are being built, including radio, television, cellular, microwave, paging, messaging, open video, public safety, wireless data, government dispatch, and emergency broadcast towers (Manville 2000). Due to the recent proliferation of cellular phones and the advent of digital television, approximately 5,000 to 10,000 new towers are being added each year (6-8% increase annually). Some have estimated there will be a total of 600,000 towers in the United States within the next 10 years, creating a potentially catastrophic impact on avian migrants (Manville 2001, pers. comm.). Avian mortality appears to increase with tower height. Taller towers also tend to have more guy wires and more lights, often more solid or pulsating red lights, which may increase the potential for collision mortality. Most lighted towers are lit due to FAA pilot warning regulations. On foggy or low cloud-ceiling nights, these lighted towers appear to attract neotropical nocturnal migrants (Manville 2000), increasing the risk of collision. Lighting appears to be the single most critical attractant, and preliminary research indicates that solid and pulsating red lights seem to be more attractive to birds at night during inclement weather conditions than are white strobe lights. During low cloud conditions, migrating birds fly at lower altitudes, below the cloud ceiling. It is speculated that the birds are attracted to the lighted towers, become disoriented and fly around them in a spiral, colliding with the tower, the guy wires, other birds, or falling to the ground in exhaustion (Manville 2001, pers. comm.).

There are very few long-term studies of avian mortality at communication towers, although there are concerted efforts by both the industry and other interested parties to begin collecting standardized data and using standardized metrics following the methods and metrics recommended and used at many windplants (Anderson *et al.* 1999). Currently, much of the published and unpublished information regarding avian fatalities at communication towers is based on single observations of carcasses found at the base of the towers. Because of the lack of standardized information, it is difficult to make accurate predictions of avian mortality attributable to collisions with communication towers and associated support wires. Based on estimates of Banks (1979) and models developed by Tall Timber Research and Bill Evans (Manville 2000, pers. comm.), conservative estimates range from 4 million to 5 million avian fatalities per year due to collision with communication towers (Manville 2000). Some experts believe these estimates could be off by an order of magnitude, especially as the number of towers increases exponentially each year, and that annual mortality may be closer to 40 million to 50 million birds (Manville 2001, pers. comm.). Further studies are needed to ascertain the true impact.

Avian Mortality due to Collisions with Wind Turbines

Many of the early avian/windpower interaction studies involved examining impacts associated with single, large experimental turbines. The first study of avian/windpower interactions took place in Sandusky, Ohio, where a single large turbine was monitored for avian mortality during four migratory seasons. Two dead birds were found during this period (Gauthreaux 1994). Two large experimental turbines and a meteorological tower in Wyoming were monitored for avian mortality in the early 1980's. Twenty-five fatalities were found over a one-year period, most of them involving passerines that had collided with guy wires on the meteorological tower (U.S. Bureau of Reclamation 1984). At a single, 60-m tower wind turbine in Solano County, California, seven fatalities were documented from September 1982 to January 1983, and the total fatality estimate with adjustments for scavenger removal and searcher efficiency was estimated at 54 birds (Byrne 1983, 1985).

The first large-scale wind energy development took place in California. In response to several reported incidents of avian collisions, the California Energy Commission (CEC) obtained data on bird strikes at the Altamont and Tehachapi windplants through interviews and review of unpublished data collected over a 4-year period from 1984 to 1988 (CEC 1989). This study documented 108 raptor fatalities of seven species. Collisions with windplant structures accounted for most of the avian fatalities (67%), including 26 golden eagles and 20 red-tailed hawks. Several subsequent studies were initiated to further examine windplant-related fatalities at California windplants. Many of these studies have been conducted at Altamont Pass, where more than 5,000 turbines exist within the WRA. In general, these studies focused on obtaining raptor fatality estimates with other bird fatalities recorded coincidentally. An early 2-year study documented 182 bird deaths on study plots, 68% of which were raptors and 26% of which were passerines. The most common raptor fatalities were red-tailed hawk (36%), American kestrel (13%), and golden eagle (11%). Causes of raptor mortality included collisions with turbines (55%), electrocutions (8%), and wire collisions (11%) (Orloff and Flannery 1992). Based on the number of dead birds found, the authors estimated that as many as 567 raptors may have died over the 2-year period due to collision with wind turbines.

Further investigations at Altamont continued to document levels of raptor mortality sufficient to cause concern among wildlife agencies and others. During a study at Altamont, Howell (1997) found 72 fatalities over an 18-month period, of which 44 were raptors. Most of the remaining fatalities were passerines. Other avian groups with some mortality at Altamont included waterfowl, waterbirds, and doves, especially rock doves. During a one-time search of turbines included in the original 1992 Altamont study, Orloff and Flannery (1996) found 20 carcasses, including 15 raptors, two ducks, two rock doves, and one common raven. From 1998 to 2000, Thelander (2000, pers. comm.) documented 256 fresh bird carcasses at Altamont. Most (54.3%) of the fatalities were raptors, 25.0% were passerines, 18.0% were doves, and the remaining 2.8% were waterfowl and waterbirds. Many of the fatalities at Altamont have been golden eagles, and annual golden eagle mortality at this facility has been estimated to range from 25 (Howell and Didonato 1991) to 39 (Orloff and Flannery 1992). Population modeling suggests that the local golden eagle population may be declining in the Altamont region, at least in part due to windplant mortality (Hunt *et al.* 1999), with other sources (e.g., expanded housing developments and landfills, road and industrial park development and a new reservoir) also considered possible contributors. Not all studies have documented high relative proportions of raptor fatalities compared to other avian groups (e.g., passerines) at Altamont. During an experiment to assess effects of painting turbine blades in an effort to reduce collisions, Howell *et al.* (1991b) found 10 dead birds, of which only one was a raptor; however, this study was of short duration and was based on small sample sizes.

Avian mortality has also been documented at other California windplants. Researchers estimated 6,800 birds were killed annually at the San Gorgonio wind facility based on 38 dead birds found while monitoring nocturnal migrants. McCrary *et al.* (1983,1984) estimated that 69 million birds pass through the Coachella Valley annually during migration; 32 million in the spring and 37 million in the fall. The 38 avian fatalities were comprised of 25 species, including 15 passerines, seven waterfowl, two shorebirds, and one raptor. Considering the high number of passerines migrating through the area relative to the number of passerine fatalities, the authors concluded that this level of mortality was biologically insignificant (McCrary *et al.* 1986a). During a more recent 15-month study at San Gorgonio, Anderson (2000a, pers. comm.) documented 42 fatalities including nine waterfowl, five owls, six passerines, six rock doves, two waterbirds, two diurnal raptors and one shorebird, during quarterly searches of approximately 360 turbines. The waterfowl and shorebird mortality generally occurred when water was present in the vicinity of the wind resource area, attracting large numbers of waterfowl and shorebirds. At Montezuma Hills, field surveyors identified 13 confirmed collision fatalities, 9 of which were raptors during the 10-month period from November 1994 to September 1995 in a study that included 76 turbines (Howell 1997). Howell and Didonato (1991) searched 359 turbines in Alameda and Contra Costa Counties over a 1-year period and found 42 avian fatalities, of which 25 were assumed turbine strikes. Seventeen of the 25 fatalities were raptors, with the other fatalities consisting primarily of passerines and rock doves. In Solano County, Howell and Noone (1992) studied 237 turbines (178 from April 1990 to December 1990) from the spring of 1990 to the spring of 1992, and found a total of 22 fatalities, 14 of which were raptors. At Tehachapi Pass, Anderson (2000b, pers. comm.) documented 147 avian fatalities including 50 passerines, 28 diurnal raptors, and 18 owls during quarterly searches of approximately 700 of the 3,000 turbines at the windplant.

Some studies at California windplants have documented apparently very low avian mortality. No avian fatalities were found during a one-time survey of 156 turbines at Tehachapi Pass in 1991 (Orloff 1992), and nine raptor fatalities were reported over a 6-year period (1984-1989)(CEC 1989). No raptor fatalities were found during a two-year study at SeaWest's Mojave Park windplant, Tehachapi Pass (Colson and Associates 1995). The high levels of raptor mortality associated with some California windplants have not been documented at windplants constructed in other states. No avian fatalities were documented during a 9-month study of three wind turbines near Algona, Iowa (Demastes and Trainer 2000). Similarly, no avian fatalities were found during a 4-month study of 11 turbines at Searsburg, Vermont (Kerlinger 1997). No fatalities were found during a 6-month study of 8 turbines in Somerset County, Pennsylvania. During a 2-year study of 29 turbines in northern Colorado, nine avian fatalities, comprised of eight passerines and one duck, were documented (Kerlinger and Curry 1999, Kerlinger *et al.* 2000b). At the 73-turbine Phase I windplant on Buffalo Ridge, Minnesota, eight collision fatalities were documented during the initial two-year period of operation (Higgins *et al.* 1996). The fatalities consisted of one ruddy duck, one Franklin's gull, one American coot, one yellow-bellied sapsucker, and four passerines. The estimated total number of annual fatalities for the entire windplant was 36 (Osborn *et al.* 2000), equivalent to an annual mean of 0.49 collisions per turbine per year. A more extensive study of this windplant plus two additional windplants on Buffalo Ridge totaling over 350 turbines was conducted from 1996 through 1999. Total annual mortality was estimated to average 2.8 birds per turbine based on the 55 fatalities found during the study. Only one raptor, a red-tailed hawk, was found during the 4-year monitoring period. Most of the fatalities were passerines (76.4%), followed by waterfowl (9.1%), and waterbirds and upland gamebirds (5.5% each) (see Appendix G for species composition). Many of the fatalities documented were nocturnal migrants (Johnson *et al.* 2000b). Radar studies at Buffalo Ridge (Hawrot and Hanowski 1997) indicate that as many as 3.5 million birds per year may migrate over the wind development area (Johnson *et al.* 2000b). The largest single mortality event reported at a U.S. windplant was fourteen nocturnal migrating passerines at two turbines at the Buffalo Ridge, Minnesota Windplant during spring migration. We are not aware of any other mortality events greater than a few birds at single or adjacent turbines found during a single search.

At a windplant recently completed in Carbon County, Wyoming, total mortality associated with the 69 turbines and 5 meteorological towers was estimated to be approximately 159 birds per year based on the 95 turbine collision fatalities actually found during the first two years of operation (Johnson *et al.* 2001). Mean annual mortality was estimated to be 1.75 birds per turbine and 0.036 raptors per turbine per year. Of the 95 fatalities found during the first year of operation, raptors comprised only 5.2%, whereas passerines comprised 91%. Furthermore, while many of the fatalities at this location were nocturnal migrant passerines (Johnson *et al.* 2001), the largest number of carcasses detected at a turbine during one search was two. At a 38-turbine windplant recently completed on Vansycle Ridge, Oregon, 12 avian fatalities were located during the first year of operation. The 12 avian casualties were comprised of at least six species, and most of the fatalities (58%) were passerines. Total estimated mortality was 24 birds per year, or 0.63 birds per turbine per year. No raptors were among the fatalities (Erickson *et al.* 2000a).

We summarize the species composition of avian fatalities from most windpower studies reported above (Appendix G). Composition of fatalities is most likely biased towards larger birds, since small birds are more difficult to detect and scavenging of small birds can be expected to be higher (e.g. Johnson *et al.* 2000b). Table 1 contains a description of the studies included in the species composition analysis as well as those used in the fatality projections. Of 841 avian fatalities reported in Appendix G from California studies, 41.5% were diurnal raptors, 20.1% were passerines (excluding house sparrows and European starlings), and 11.1% were owls. Non-protected birds including house sparrows, European starlings, and rock doves comprised 16.6% of the fatalities. Other avian groups generally made up <10% of the fatalities. Outside of California, diurnal raptor fatalities comprised only 2.7% of the windplant-related fatalities. Passerines (excluding house sparrows and European starlings) were the most common collision victims, comprising 78.0% of the 192 fatalities documented (Table 2). Other groups each comprised <10% of the fatalities. Low and high range percentages of nocturnal migrant fatalities are reported in Table 2. Ranges are reported due to difficulty in determining whether a fatality found during migration is a resident breeder or a nocturnal migrant passing through the area, and whether the fatality occurred during the night. The low range includes known migrants; the high range includes fatalities that could possibly be migrants (e.g., unidentified passerines, resident breeders found during early/late breeding period during migration). Unlike California, where less than 11% (range 3% to 10%) of the number of fatalities were classified as nocturnal migrant passerines, as many as 59.9% (range 34.4% to 59.9%) of the avian collision victims elsewhere are likely nocturnal migrants (Table 2). The percentage of the total number of fatalities comprised of likely nocturnal migrants has ranged from a low of 19.0% at the Wisconsin windplant to a high of 48.0% at the Foote Creek Rim, Wyoming, windplant.

These data suggest that while turbines are generally below the flight altitude of most nocturnally migrating birds, weather and other factors that reduce migrating bird flight altitudes may result in collisions with wind turbines as well as other artificial structures. This appears to be more likely outside of California, although as stated previously, we are aware of only one mortality event of more than a few fatalities found below wind turbines during a single search. There are not many reports of single mortality events (greater than a few birds) at communication structures less than 500 feet (150 m) in height (Kerlinger 2000; Manville 2000, pers. comm.). Most new wind turbines are less than 350 feet to the tip of the blades and do not have guy wires. Guy wires associated with communication towers have been considered a major source of the mortality problem. The largest single event reported at a wind generation facility was fourteen nocturnal migrating passerines at two turbines at the Buffalo Ridge, Minnesota Windplant during spring migration. Therefore, although some nocturnal migrants have been killed by wind turbines, we believe large mortality events at windplants are unlikely. Fatality data collected at many of these newer windplants with large turbines will continue to provide information regarding this issue.

Summary of Windpower Fatality Estimates

For all avian species combined, estimates of the number of bird fatalities per turbine per year from individual studies have ranged from 0 at the Searsburg, Vermont (Kerlinger 1997) and Algona, Iowa sites (Demastes and Trainer 2000) to 4.45 on the Buffalo Ridge, Minnesota Phase III site (Johnson *et al.* 2000b) (Table 3). The Phase III Buffalo Ridge site estimate was based on one field season (1999) and was greatly influenced by a fatality event involving 14 warblers, vireos and flycatchers observed during a May 17 carcass search of two turbines (Johnson *et al.* 2000b). Avian fatality rates were much lower at the Buffalo Ridge Phase I and II sites, where several years of data were collected (Osborn *et al.* 2000, Johnson *et al.* 2000b).

Table 4 contains the average fatality estimates for each wind resource area, the overall estimate of bird collisions per turbine per year for all sites, and total fatality projections based on the approximate estimate of 15,000 operational wind turbines in the U.S. by the end of 2001. The average number of avian collision fatalities per turbine is 2.19 per year. Therefore, on average, we estimate approximately 33,000 birds (range 10,000 to 40,000) die annually from collision with wind turbines in the United States (assuming 15,000 turbines). Species composition data indicate that approximately 14.0% of the projected fatalities are non-protected birds (house sparrows, European starlings and rock doves), and excluding these non-protected species yields an estimate of approximately 28,500 (protected) birds. We estimate approximately 6,400 birds will die annually outside California at the 3,500 turbines estimated to be in operation by the end of year 2001 (Table 4). Species composition data outside California indicate 3.3% of the projected fatalities are non-protected birds; excluding these non-protected species yields an estimate of approximately 6,200 avian fatalities per year.

Because much attention has been given to the issue of raptor/windpower interaction, we also developed separate fatality estimates for raptors. Estimates of raptor fatalities per turbine per year from individual studies ranged from 0 at the Vansycle, Oregon; Searsburg, Vermont; Ponnequin, Colorado; Somerset County, Pennsylvania; and Buffalo Ridge, Minnesota, Phase II and Phase III sites, to 0.10 per turbine per year at the Altamont, California site (Thelander 2000, pers. comm.) (Table 3). Based on these statistics and the estimated total number of operational turbines by the end of 2001, we estimate that approximately 488 raptors are killed annually by turbines in the United States, nearly all in California. We project raptor mortality at windplants outside California to be 20 per year based on 1 raptor found at Buffalo Ridge, Minnesota over a 6-year period and 5 raptors found at the Phase I Foote Creek Rim, Wyoming facility during a two-year study of 69 turbines (Table 4).

DISCUSSION

Using the annual avian collision mortality estimate of 200-500 million, we estimate that at the current level of development, wind turbines constitute 0.01 percent to 0.02 percent (1 out of every 10,000 to 2 out of every 10,000) of the avian collision fatalities. Communication tower fatality estimates make up 1-2 percent (1 out of every 100 or 2 out of every 100) using the conservative estimates of 4 million annual avian fatalities due to collisions with these structures. The low range estimate from buildings/windows of 98 million (Klem 1991) would comprise approximately 25 to 50 percent of the collision fatalities. The low range estimate of 60 million vehicle collision fatalities comprises 15-30% of the total estimated collision fatalities. Our very wide range for estimates of powerline collision fatalities (>10,000 – 174 million) makes it extremely difficult to quantify the percentage of total fatalities due to this source. Nevertheless, we expect the total collisions with powerlines to be much higher than the total collisions with wind turbines given the number of miles of high-tension lines that exist across a wide range of habitats in the U.S. Given the uncertainty in the estimates, the true avian mortality, especially for communication towers, buildings and windows, powerlines and roads, could easily be different by several orders of magnitude.

Many of the collision mortality studies for other sources were conducted in response to a known or perceived risk and therefore are probably not appropriate for extrapolation in the same manner we extrapolated for wind turbines. However, it has been argued by several researchers making mortality projections that their estimates are probably conservative (underestimates), given that scavenging and searcher efficiency biases have generally not been incorporated into the estimates. For example, Banks' (1979) estimate of vehicle mortality was based on the Hodson and Snow (1965) estimate of 15.1 birds per mile (9.4 bird/km), which was based on weekly surveys that did not adjust for scavenging and searcher efficiency.

Several potential biases may also exist with windpower-related fatality estimates. We have assumed the fatality estimates provided for individual studies are representative of the true fatality estimates of other windplants that were not sampled. We currently do not have any data from Texas, where a relatively large number of turbines are present. If bird mortality is large (or small) relative to mortality at the windplants we used in our estimates (~2 birds per turbine per year which includes European starling and rock doves), we may be underestimating (or overestimating) the total number of avian fatalities due to wind turbines in the United States. Furthermore, bird fatality estimates are primarily based on studies conducted outside of California, since the focus of most studies in California has been on raptors. The estimate of approximately 2 birds per turbine per year was applied to all 15,000 turbines expected to be in operation throughout the United States at the end of 2001. A relatively high level of uncertainty exists in these estimates due to the lack of detailed fatality monitoring of small birds at Altamont and Tehachapi Pass. Distance between search transects for most studies at Altamont (e.g., Howell and Noone 1992, Howell *et al.* 1991) was greater than the 10 to 20 feet distances used in many of the more recent studies at Altamont and at other windplants outside California (Johnson *et al.* 2000b, Johnson *et al.* 2001, Erickson *et al.* 2000b, Thelander 2000, pers. comm). All studies at Altamont including Thelander (2000, pers. comm.) documented fewer small bird/passerine fatalities relative to raptor fatalities when compared to results from most studies at other windplants The lack of scavenging and searcher efficiency data and other experimental design factors (e.g., number of weeks between searches, width between transects) currently make it difficult to make all bird fatality projections for California windplants. If actual fatality rates at Altamont and Tehachapi Pass are significantly less than 2 birds per turbine per year, we may be overestimating the true total number of fatalities per year. Likewise, if actual fatality rates at Altamont and Tehachapi Pass are greater than 2 birds per turbine per year, we may be under estimating the true total number of fatalities per year. Based on species composition from past studies at Altamont and recent work by Thelander (2000, pers. comm.), we believe it is more likely our estimates are accurate or a slight overestimate of the true fatality rates.

Furthermore, turbines at the new windplants are larger than the majority of turbines at the older windplants, such as Altamont. Newer turbines are typically 600-kW – 1.5-MW machines, with tower heights ranging from 200-350 feet (60-100 m) and rotor diameters of 30 m to 70 m. Layouts of turbines at newer generation facilities are very different than the large windplants in California. Turbines at the newer windplants are typically spaced farther apart than turbines at older windplants. There is currently limited data available to understand potential differences in fatality rates for small, older generation turbines compared to the large, newer generation turbines. Based on information to date, siting of windplants appears to be the most significant factor related to bird mortality, with the effects of other factors such as turbine designs (e.g., lattice towers versus tubular towers, small versus large turbines) less understood. The range for bird mortality estimates was based on a study at the 38-turbine windplant in Vansycle (0.63 birds per turbine per year), and the bird mortality estimate at the Buffalo Ridge Windplant (highest estimate, 2.83 bird fatalities per turbine per year). Acknowledging the potential biases, we still believe using this range as a basis for the range of annual avian mortality is reasonably and likely accurate.

Scavenging and searcher efficiency estimates need to be incorporated to accurately estimate true fatality rates, especially for small birds. We feel this is especially important when fatality rates are compared between Wind Resource Areas and studies, since the habitats (and subsequent estimates of searcher efficiency), search interval, and scavenging all can influence the actual number of birds recorded by searchers. In many of the studies that report fatality estimates for all bird species and have measured scavenging and searcher efficiency rates, large adjustments are made to the observed number of carcasses for scavenging and searcher efficiency bias (Johnson *et al.* 2000b, Johnson *et al.* 2001). These adjustments, although necessary to accurately estimate true fatality rates, add uncertainty into the estimates. Nevertheless, we have reported a range of estimates for wind turbines that we believe is a reasonable range to represent true current annual avian mortality (10,000 – 40,000 fatalities).

Even with the potential biases, most of the avian collision data from windplants (especially the newer generation windplants) have been collected using standardized methods and regardless of perceived avian risk. In addition, the proportion of windplants studied is quite high relative to any other source of avian collision mortality. Therefore we believe our avian mortality estimates due to collisions with wind turbines are more accurate than the collision fatality estimates attributable to other sources. The low mortality rates of wind turbines compared with communication towers can probably be attributed to the fact that the majority of wind turbines range from 200-350 feet (60-100 m) in height, whereas television and radio communication towers are generally much taller. However, wireless cellular towers are also generally shorter and the massive current tower growth is occurring primarily within the cellular communication arena. Many of the communication towers are guyed structures, whereas nearly all of the newer-generation wind turbines are unguyed structures. There are relatively few reports of single mortality events (greater than a few birds) at communication structures less than 500 feet (150 m) in height (Kerlinger 2000; Manville 2000, pers. comm.) or at windplants.

We are unaware of any studies that directly compare communication tower mortality to wind turbine mortality; although, we do have limited information on guyed meteorological (met) tower mortality compared with wind turbine mortality at the Foote Creek Rim, Wyoming windplant. At this site we searched both wind turbines (600-kW, approximately 200-ft (60-m) towers) and guyed met towers (200 ft (60 m) in height) once a month during the study. During this period of study, the met towers had estimates of 7.5 bird fatalities per tower per year, whereas the turbines had estimates of 1.8 bird fatalities per turbine per year (Johnson *et al.* 2001).

Most of the studies at communication towers were the result of an episodic event at a single tower, although a few long-term studies have been conducted. It appears that the collision mechanisms at wind turbines and communication towers may be different. Most bird collisions at communication towers occur during migration and during nights of inclement weather. In addition, communication tower fatalities have mainly been reported east of the Rocky Mountains. It is unclear whether lower reported mortality in the West is the result of a lack of studies, or fewer collisions. Many of the communication towers in the western United States occur in isolated locations, where dead birds are less likely to be "discovered"; such discoveries are most frequently the stimulus for communication tower studies in the East. In May 1972, 57 birds of five species were killed at the Cape Scott Lighthouse, Vancouver Island, British Columbia. Because inclement weather including low cloud ceiling and fog do occur along the Pacific Coast and other areas of the West, the potential for bird mortality due to collisions with communication towers during periods of inclement weather may exist, in spite of the lack of studies or reported occurrences in this area.

While the majority of bird fatalities reported at communication towers are comprised of nocturnal migrating passerines, bird fatalities associated with wind turbines are composed of a variety of different groups including waterfowl, seabirds, shorebirds, passerines, and raptors. Vulnerability to collisions is species- and habitat- specific; therefore, siting issues must be assessed accordingly. For example, raptor collisions with wind turbines may be more likely to occur while the raptor is concentrating on foraging, or stooping towards a prey item. A dense or abundant prey base within a wind resource area may attract a greater number of raptors within the vicinity of wind turbines, and subsequently increase the potential for collision fatalities among raptor species. Water within the vicinity of wind turbines may attract waterfowl, seabirds and shorebirds, increasing the collision potential for water bird species, although other factors such as adjacent habitats and movement patterns would also greatly influence mortality near these water sources.

SUMMARY

Our review indicates that avian collision mortality associated with windplants is much lower than other sources of collision mortality in the United States. We believe there are reasons for the relatively low mortality rates at most windplants. The primary reason is that there are far fewer windplants and that many of the windplants are located in areas with relatively low bird and raptor use. However, even if windplants were quite numerous (e.g., 1 million turbines), they would likely cause no more than a few percent of all collision deaths related to human structures. It appears from the available data that siting windplants in areas with low bird and raptor use is currently the best way to minimize collision mortality. The apparently high raptor mortality levels at Altamont can mostly be attributed to high prey base for raptors, large populations of raptors, topography and the large size of the windplant. Other factors such as older turbine designs may also contribute to the raptor mortality levels, but such factors are less understood. Windplants sited in areas of high bird use can expect to have higher fatality rates than many of those reported in this document although other factors such as topography, prey abundance, and species composition also likely influence mortality. For example, in the Netherlands, where turbines are often sited near coastal areas, estimates of collision rates have been as high as 37 birds per turbine per year (Winkelman 1994).

The results of our review and updated estimates indicate that avian collision mortality attributable to windpower at the current level of production in the U.S. is minor in comparison to other sources of collision mortality. The current levels of mortality caused by windplants do not appear to be causing any significant population impacts (except possibly for golden eagles at Altamont (Hunt *et al.* 1999), although several possible contributors to this decline have been proposed). Due to recent declines in many species of birds, especially some raptors and many neotropical migrants, however, any additional mortality may be a cause for concern. Monitoring programs in place at many of the newer generation windplants will continue to provide information to better understand avian mortality levels and to continue to determine factors important for siting windplants. Because the cumulative impacts of all mortality factors on birds continue to increase as the human population climbs and resource demands grow, efforts by every industry are important to reverse avian mortality trends and to minimize bird deaths.

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Table 1. Description of studies of avian mortality used for species composition or fatality estimates.

WRA	Turbine Types	Dates of Study	# of Turbines Searched	Search Interval	Total # Observed Fatalities[a]	# of Raptor Fatalities	Reference
Buffalo Ridge, MN Phase I	Kenetech Model 33-MVS	4/94-12/95	50	7 days	12	0	Osborn *et al.* 2000.
Buffalo Ridge, MN Phase I	Kenetech Model 33-MVS	3/96-11/99	21	14 days	13	1	Johnson *et al.* 2000b.
Buffalo Ridge, MN Phase II	Zond Z-750	3/98-11/99	40	14 days	22	0	Johnson *et al.* 2000b.
Buffalo Ridge, MN Phase III	Zond Z-750	3/99-11/99	30	14 days	20	0	Johnson *et al.* 2000b.
Foote Creek Rim, WY Phase I	Mitsubishi 600 kW tubular	11/98-10/99	69	28 days	95	5	Johnson *et al.* 2001.
Green Mountain Searsburg, VT	Zond Z-40	6/97-10/97	11	Weekly/ monthly	0	0	Kerlinger 1997.
IDWGP Algona, IA	Zond Z-50	10/99-7/00	3	14 days	0	0	Demastes and Trainer 2000.
Ponnequin, CO	NEG/MICON 750 Kw	11/98-11/00	29	3 days-1.5 mo.	9	0	Kerlinger *et al.* 2000.
Somerset County, PA		6/00-1/00	8	Weekly-monthly	0	0	Kerlinger 2000, pers. comm.
Vansycle Ridge, OR	660 kW Vestes	1/99-12/99	38	28 days	12	0	Erickson *et al.* 2000b.
Wisconsin (MG&E and PSC)	Vestes 660 kW	3/99-12/00	31	Daily-weekly	21	0	Howe 2001, pers. comm.

[a] types of fatalities included often varies by study. For example, in some studies, feather spots are included or electrocutions are included. In other studies only fresh carcasses that are likely turbine kills are included. Sometimes incidental discoveries are included, other times they are not.

Table 1 (*cont.*). Description of studies of avian mortality used for species composition or fatality estimates.

WRA	Turbine Types	Dates of Study	# of Turbines Searched	Search Interval	Total # Observed Fatalities[a]	# of Raptor Fatalities	Reference
Altamont Pass and Tehachapi Pass, CA	<250 kW turbines	1984-1988	Incidental discoveries	Incidental discoveries	Raptor reports	63 (Alt) 9 (Teh)	California Energy Commission 1989.
Altamont Pass, CA	<250 kW turbines	9/88-8/89	359	2/week	42	18	Howell and DiDonato 1991.
Altamont Pass, CA	<250 kW turbines	4/90-3/91	150	2/week	10	1	Howell *et al.* 1991b.
Altamont Pass, CA	<250 kW turbines	1989-1991	1169	1-2/week	182	74	Orloff and Flannery 1992.
Altamont Pass, CA	<250 kW turbines	1/1994	1169	one time search	20	15	Orloff and Flannery 1996.
Altamont Pass, CA	KVS –33 & 56-100	12/93-8/95	165	2/week	72	44	Howell *et al.* 1997.
Altamont Pass, CA	mostly <250 kW turbines	4/98-3/00	785	1/5 weeks	256	117	Thelander 2000, per. comm.
Montezuma Hills, CA	<250 kW turbines	4/90-5/92	237	Weekly	22	14	Howell and Noone 1992.
Montezuma Hills, CA	KVS –33 & 56-100	11/94-9/95	76	2/Week	13	10	Howell *et al.* 1997.
San Gorgonio, CA	<250 kW turbines	1985	Not available	not available	38	1	McCrary *et al.* 1986a.
San Gorgonio, CA	mostly <250 kW turbines	3/97-5/98	~360	Quarterly	42	7	Anderson 2000a, pers. comm.
Tehachapi Pass, CA	mostly < 250 kW turbines	5/95-5/98	640-760	Quarterly	147	46	Anderson 2000b, pers. comm.

[a] types of fatalities included often varies by study. For example, in some studies, feather spots are included or electrocutions are included. In other studies only fresh carcasses that are likely turbine kills are included. Sometimes incidental discoveries are included, other times they are not.

Table 2. Composition of observed avian collision fatalities at U.S. windplants.

WRA	% Composition by Avian Group											
	Water-birds	Water-Fowl	Shore-birds	Diurnal Raptors	Owls	Fowl-like birds	Protected Passerines	Other	Non-protected birds	# Carcasses	% Nocturnal Migrants Low[j]	% Nocturnal Migrants High[k]
California												
Altamont[a]	1.6	1.1	0.0	47.6	11.3	0.0	18.6	2.0	17.8	613	1.4	6.4
Montezuma Hills[b]	0.0	4.8	0.0	61.9	7.1	0.0	11.9	7.1	7.1	42	7.1	9.5
San Gorgonio[c]	4.8	21.4	2.4	4.8	11.9	0.0	9.5	16.7	28.6	42	0	9.5
Tehachapi Pass[d]	0.0	0.0	0.0	20.1	3.5	11.1	31.9	22.2	11.1	144	8.3	27.1
Subtotal	1.2	2.2	0.1	39.1	11.5	0.7	18.9	10.8	15.5	841	2.6	10.2
Outside California												
Buffalo Ridge, MN[e]	5.5	9.1	1.8	1.8	0.0	5.5	72.7	0.0	3.6	55	18.2	45.5
Foote Creek Rim, WY[f]	1.1	0.0	0.0	4.2	1.1	0.0	90.5	3.2	0.0	95	3.2	48.4
Ponnequin, CO[g]	0.0	11.1	0.0	0.0	0.0	0.0	88.9	0.0	0.0	9	22.2	33.3
Vansycle, OR[h]	0.0	0.0	0.0	0.0	0.0	25.0	66.7	8.3	0.0	12	33.3	50.0
MG&E and WPSC, WI[i]	4.8	9.5	0.0	0.0	0.0	0.0	66.7	4.8	14.3	21	19.0	19.0
Subtotal	3.3	5.3	0.7	2.7	0.5	4.0	78.0	2.7	3.3	192	34.3	59.9
Grand total	1.6	2.5	0.2	34.3	9.1	1.1	31.5	5.7	14.0	1033	8.5	19.5

[a] Howell and Didonato (1991), Orloff and Flannery (1992), Orloff and Flannery (1996), Howell (1997), Howell *et al.* (1991b), Thelander (2000) pers. comm.

[b] Howell and Noone (1992), Howell (1997).

[c] Anderson (2000a) pers. comm., McCrary *et al.* 1986a not used because species composition unavailable

[d] Anderson (2000b) pers. comm.

[e] Johnson *et al.* (2000b).

[f] Johnson *et al.* (2001) (includes meteorological tower and wind turbine fatalities).

[g] Kerlinger and Curry (2000), Kerlinger *et al.* (2000b).

[h] Erickson *et al.* (2000b).

[i] Howe (2001) pers. comm.

[j] includes only observations known to be nocturnal migrants.

[k] includes nocturnal migrants and birds that could be either migrants or residents (breeders found during migration period).

Table 3. Wind turbine mortality estimates from studies conducted in the U.S.

Study Area	State	Reference	Seasons	Dates	Turbines In study	Turbines In WRA	# bird fatalities /turbine/yr.	# raptors /turbine/yr.
California								
Altamont Pass	CA	Howell and Didonato (1991)	All	9/88-8/89	359	7340	na[a]	0.050
Altamont Pass	CA	Howell and Didonato (1991)	All	9/90-8/91	150	7340	na[a]	0.007
Altamont Pass	CA	Orloff and Flannery (1992)	All	89-90	1169	7340	na[a]	0.058
Altamont Pass	CA	Orloff and Flannery (1992)	All	90-91	1169	7340	na[a]	0.023
Altamont Pass	CA	Thelander (2000) pers. comm.	All	99-2000	685	5400	na[a]	0.100
Montezuma Hills	CA	Howell and Noone(1992)	All	89-90	237	600	na[a]	0.048
San Gorgonio	CA	McCrary *et al.* 1986a	All	1985	Not available	2947	2.307	na[a]
Outside California								
Buffalo Ridge (Phase I)	MN	Osborn *et al.* (2000)	All	1/95-12/95	50	73	0.493	0.000
Buffalo Ridge (Phase I)	MN	Johnson *et al.* (2000b)	all but winter	3/96-11/99	21	73	0.980	0.012
Buffalo Ridge (Phase I)	**MN**				**Weighted average (by years)**		**0.883**	**0.010**
Buffalo Ridge (Phase II)	MN	Johnson *et al.* (2000b)	all but winter	3/98 –11/99	40	143	2.270	0.000
Buffalo Ridge (Phase III)	MN	Johnson *et al.* (2000b)	all but winter	3/99-11/99	30	138	4.450	0.000
Buffalo Ridge Overall	**MN**				**Weighted average (by turbines)**		**2.834**	**0.002**
Foote Creek Rim (Phase I)	WY	Johnson *et al.* (2001)	All	11/98-10/00	69	69	1.750	0.036
Green Mt, Searsburg	VT	Kerlinger(1997)	Summer, fall	6/97-10/97	11	11	0.000	0.000
IDWGP, Algona	IA	Demastes and Trainer (2000)	Fall,winter, spring	10/98-6/99	3	3	0.000	0.000
Ponnequin	CO	Kerlinger (2001) pers. comm.	All	11/98-11/00	29	29	nc[b]	0.000
Somerset County	PA	Kerlinger (2001) pers. comm.	All	6/00 – 1/01	8	8	0.000	0.000
Vansycle	OR	Erickson *et al.* (2000b)	All	11/98-10/99	38	38	0.630	0.000
MG&E and WPSC	WI	Howe (2001) pers. comm.	All	3/99-12/00	31	31	nc[b]	0.000

[a] although all bird estimates reported, no scavenging or searcher efficiency conducted for small birds (e.g., passerines).

[a] not calculated

Table 4. Estimates of avian collision mortality by Wind Resource Area.

Wind Resource Area	Turbines in WRA Expected 2001	Turbines in WRA during study	# birds/ turbine/year	# raptors /turbine/year
Outside California				
Buffalo Ridge, MN	~450	~400	2.834	0.002
Foote Creek Rim, WY	133	69	1.750	0.036
Green Mountain, Searsburg, VT	11	11	0.000	0.000
IDWGP, Algona, IA	3	3	0.000	0.000
Ponnequin, CO	44	29	na[b]	0.000
Somerset County, PA	8	8	0.000	0.000
Vansycle,OR/Stateline OR,WA	~338	38	0.630	0.000
MG&E and WPSC, WI	31	31	na[b]	0.000
Subtotal	1,018	589	1.825	0.006
California				
Altamont, CA	~5,400	~7,340	na[b]	0.048
Montezuma Hills,CA	600	600	na[b]	0.048
San Gorgonio, CA	~2,900	~2,947	2.307	0.010
Grand Total	9,148	11,106	2.19	0.033

Total Fatality Projections[a]	**Overall**	**Outside California**
Projected annual bird fatalities	33,000	6,400
Projected annual bird fatalities (excluding house sparrows, rock doves, and European starlings)	28,400	6,200
Raptor fatalities	488	20

[a] assumes 15,000 turbines in 2001.

[b] not applicable since scavenging and searcher efficiency data not available and some fatalities were observed.

APPENDIX A - LIST OF PEOPLE CONTACTED FOR INFORMATION

Dick Anderson, California Energy Commission
Kathy Belyeu, American Wind Energy Assocation
Todd Engstrom, Tall Timbers Research Station
Bill Evans, Old Bird, Inc.
Monte Garrett, Pacific Corp.
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Rick Thompson, Xcel Energy
Steve Ugoretz, Wisconsin Department of Natural Resources
Eugene Young, Cowley College, KA

APPENDIX B - INFORMATION RECORDED FOR EACH STUDY IF ESTIMATES ARE MADE OF AVIAN MORTALITY

Reviewer initial:
Date:

1. Full Citation:

2. Do we have the document (Y N)?
3. Location of Study:

4. Type of Structures:
A. roads
B. turbines
C. meteorological towers
D. communication towers
E. powerlines
F. buildings
G. fences
H. other

5. For 4, describe the structures (height ranges, guyed versus unguyed, etc.)

6. How many structures/miles of road/miles of powerline etc.?

7. When did the study take place (years, seasons)?

8. How often was the area searched? (daily, weekly)

9. Was scavenging and/or searcher efficiency evaluated?

10. How many dead birds found?

11. Were extrapolated estimates made? If so, what were the estimates (total number, total number/season, total number/year) Please standardize to #/mile of road/year or /fall season, #/mile of powerline/year or season, #/building/year or season, #/tower/year or season).

12. Composition of fatalities (mainly raptors, migrating passerines (group, warblers, sparrows, etc., local passerines? waterbirds)

13. General remarks?

APPENDIX C - STUDIES OF AVIAN COLLISIONS WITH VEHICLES ON ROADS

Location	Years of Study	Season	#Years	Length of Road (KM)	Length of Road (MILES)	Total Fatalities	Primary Bird Type Killed	Search Frequency	Estimates/ Comments	Study Type	Reference
Southern New Jersey	1980-1990	Annual	10	145	90	250	Raptors	Searched 5 times/week	Average 25 raptor kills per year.	Raptor	Loos and Kerlinger 1993.
North Dakota, South Dakota	1969-1979	Annual	10	132,767	82,500	562	Waterfowl (75% Dabbling ducks)	Irregular	13,500/yr;0.042 duck/mile; 0.156 ducks/km of I 80; 0.005 ducks/km of unsurfaced roads.	Ducks	Sargeant 1981.
Nebraska	1969-1975	Annual	7	732	455	7,195	Nonpasserine (Ring-necked pheasant)	Searched Daily	*	General Study Pheasant Results	Case 1978.
Ontario	1979-1980, 1992-1993	Apr-oct	4	3.6	2.2	1,302	Passerines	Searched 3times/week	325.5 birds/yr; 101.72/km/yr; 0.51/km/day.	General	Ashley and Robinson 1996.
Northeast of France	1991-1995	Annual	4	517.8 (258.9 x 2 sides of motorway)	321.6 (160.8 x 2 sides of motorway)	1,598	Raptors (81.5%)	Searched 3 times/day	*	General	Hugues 1996.
Wiltshire England	1957-1960	Annual	3.25	11.3	7	1,279	Passerines	9 two-way journeys, fortnight	426.3/yr; 60.9/mi/yr.	General	Dunthorn and Errington 1964.
Minnesota	*	*	1.5	27	17	3	Waterfowl	*	*	*	Sargeant and Forbes 1973.
Tennessee	1981-1982	Annual	1	State Route 29	*	13	*	*	*	General	Rice 1983. (Abstract)
Illinois, Iowa	1986-1987	Annual	1	7.1	4.4	146	Passerines	Searched Daily	33/mi/yr (50% of birds hit may have been thrown into the ditch and were uncounted).	General	Decker 1987.

* Information not provided in report.

APPENDIX C (*continued*) - STUDIES OF AVIAN COLLISIONS WITH VEHICLES ON ROADS

Location	Years of Study	Season	#Years	Length of Road (KM)	Length of Road (MILES)	Total Fatalities	Primary Bird Type Killed	Search Frequency	Estimates/ Comments	Study Type	Reference
Britain	1960-1961	Annual	1	562	349	5,269	Passerines	Varied	15.1/mi; est annual mortality of 2.5 million birds in Britain.	General	Hodson and Snow 1965.
Corby, Northants, England	1961-1962	*	1	3.2	2	644	Passerines (50% house sparrows)	*	10.0-55.2 deaths per 100yards of road for the range of veg types present for all species. 1.3-28.9 deaths/100 yards house sparrows.	General	Hodson 1962.
Meade, Colorado	1998	Spring	0.5	98.2	61	9	Raptors	1 survey date: 3/3/98.	1 individual per every 6.78 miles.	Barn Owl	Rivers 1998.
Southern England	1995	Fall	0.5	50	31	154	Raptors	Searched 3 times per week.	*	General results, barn owl study	Dixon *et al.* 1996.
New Zealand	1990	Summer	0.25	1,803	1,120	53	Passerines (young magpies)	Occasional	*	Magpies	Burger and Gochfeld 1992.
England	1935-1956	Annual	*	160,930	100,000	4,600	Passerines	Hiking and bike tours by birders.	1.5-563/mile; 11 estimates in paper.	General	Finnis 1960.
Britain	1964-1980	Annual	*	*	*	341	Raptors	Recovered ringed specimens.	2% die by vehicle collision; 48% died from collisions.	Raptor	Newton 1979.
Nebraska	*	*	*	122,000	76,250	4	Waterfowl	*	*	*	McClure 1951.
Rhode Island	1966-1968	*	*	*	*	*	Waterbirds	Band Recoveries.	13.3% of mortality due to auto collisions.	Mute Swan	Willey 1968.
Montana	1986-1995	*	*	*	*	37	Raptors	*	Found during powerline study.	Raptor	Harness 1997.
Connecticut	1962-1993	Annual	*	*	*	312	Passerines	Bird Recoveries.	312 of 650 specimens, auto & window collisions only.	General	Codoner 1995.

* Information not provided in report.

APPENDIX D1 - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH BUILDINGS/WINDOWS

Location	Date	Structure Type	Total Birds Collected	Primary Bird Type Killed	Fatality Estimates	Reference
Alabama	October 8, 1954	Ceilometer	1,283	Passerines	Total kill est. at 1,600 birds.	Velie 1963.
Florida	Oct 6-8,1964	Many buildings	4,707	Passerines	Birds collected represent only small fraction of total kill.	Case *et al.* 1965.
Florida	Sept 23-24,1982	4 chimneys	1,265	Passerines	Total kill est. at 5,000 birds.	Maehr *et al.* 1983.
Florida	May 9-14, 1960	4 shopping centers with large windows	156	Passerines	Total kill est. at over 200 birds.	Velie 1963.
Georgia	October 8, 1954	Ceilometer	2,552	Passerines	Total kill est. at 50,000 birds – largest on record.	Velie 1963.
Maine	September 9, 1954	Hanger doors of airport	*	Passerines	Est. 500-1,000 birds.	Velie 1963.
Minnesota	September 12, 1961	Store windows, 4 blocks Main Street, downtown section	200+	Passerines	Total kill est. at over 400 birds.	Velie 1963.
Minnesota	September 12, 1961	Duluth Ceilometer	440	Passerines	Total kill est. at 1,000 birds.	Velie 1963.
Minnesota	September 19, 1963	Duluth Ceilometer	92	Passerines	After 10-20 minutes the light was turned off.	Green 1963.
Nevada	December 13, 1928	Buildings/Houses	*	Waterfowl	Est. Several Thousand Eared Grebe fatalities.	Cottam 1929.
New York	Sept 27-28, 1970	Empire State Building (1,454 ft)	707	Passerines	Numerous bird kills in eastern U.S. at comm. towers same night and following night.	Bagg 1971.
South & East USA	Oct 5-8, 1954	25 locations	9,495	Passerines	106,804 fatalities estimated.	Johnston and Haines 1957.
South Dakota	October 25, 1951	Buildings/Obstacles	*	Waterfowl	Est. 500 duck fatalities.	Schorger 1952.

* Information not provided in report.

APPENDIX D1 (*continued*) - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH BUILDINGS/WINDOWS

	Date	Structure Type	Total Birds Collected	Primary Bird Type Killed	Fatality Estimates	Reference
Tennessee	October 7, 1954	12 acre parking lot, with powerlines, streetlights and buildings	575	Passerines	Total kill est. at 1,000 birds.	Dunbar 1954.
Tennessee	September 25, 1955	Ceilometer	*	Passerines	Total kill est. at 1,400 birds.	Velie 1963.
Washington, D.C.	September 12, 1937	Washington Monument (555 ft)	576	*	24 species.	Velie 1963.
West Virginia	October 20, 1975	1 fire tower	73	Passerines	*	Wylie 1977.
Wisconsin	September 21-26, 1887	Old Milwaukee Exposition Building (0ver 200 ft)	*	*	40+ species.	Velie 1963.
Alberta	May 26-28,1980	Oil Flare Stack	2,318	Passerines	Total kill est. at 3,000 birds.	Bjorge 1987.
Canada	September, 1961	Airport Hanger	58	Passerines	Blackburnian Warblers	Herbert 1970.

* Information not provided in report.

APPENDIX D2 - STUDIES OF AVIAN COLLISIONS WITH BUILDINGS/WINDOWS

Location	Year	Season	# Years	Structure Type	Search Frequency	Total Birds Collected	Fatality Estimates	Reference
Illinois & New York	1974-1986	Annual	12	2 houses	Daily	100	97.6-975.6 million/yr in the U.S.[a]	Klem 1989, 1990.
Florida	1970-1981	Annual	9	1 building	Occasional	5,046	0.0054 birds/m2 building profile/year.	Taylor and Kershner 1986.
Washington	1968-1974	Annual	6	667m2 glass	*	266	0.0067 birds/m2/yr.	Johnson and Hudson 1976.
Florida	1982-1986	Annual	4	4 chimneys	5 times/wk	2,301	541.4/year.	Maehr and Smith 1988.
Ontario	1972-1976	Annual	4	2 chimneys	Daily	8,531	*	Weir 1976.
Toronto	1993-1995	Annual	2	54 Buildings	Most days	5,454	733/year.	Ogden 1996.
California	1982-1983	Annual	1	49m2 mirrors	2-3 times/wk	70	0.000016 birds/m2/week; 1.54-1.78 birds/week.	McCrary *et al.* 1986b.
Washington, D.C.	1932-1933	Annual	2	Washington Monument	*	655	*	Overing 1936.
Washington, D.C.	1935	Fall	0.5	Washington Monument	Daily	246	*	Overing 1936.
Washington, D.C.	1936-1937	Fall	1.0	Washington Monument (555 ft tall)	*	1,468	*	Velie 1963.
Connecticut	1962-1993	Annual	*	Window strikes	Recoveries	338	338 of 650 birds, comparing auto & window collisions.	Codoner 1995.
North America	1989-1990	Winter	0.5	5,500 Residential Houses	1-2 times every 2 weeks	995	0.85 birds/house in winter; .65-7.7 birds/house/year.	Dunn 1993.

* Information not provided in report.

[a] 55% of collisions with glass result in death.

APPENDIX E - STUDIES OF AVIAN COLLISIONS WITH HIGH TENSION LINES

	Year	Season	Size of Powerline	Length of Powerline (km)	Length of Powerline (Miles)	Total Fatalities	Top Bird Types Killed	Comments/ Estimates	Reference
Alaska	1986-1987	May-September	13.8 kV	12.5	7.8	31	Waterbirds	1 collision per 1020-7692 flights across. Collision Rate: .017-.098% and .013-.046%.	Anderson and Murphy 1988.
California	1898, 1903	Sept 8&9, Nov *and May 11	Telephone line	6.4	Approx. 4 miles	Approx. 115	Shorebirds	3 dates in 1898, and May 11, 1903.	Emmerson 1904.
Canada	1995	July-November	822 wood poles and steel towers	81	50	35 birds	Waterbirds Passerines	No scavenging or search efficiency bias.	Curtis 1997.
Colorado	1988-1990	Fall (3) Spring (3)	7.2 kV distribution	13.2	8.2	474	Waterbirds Waterfowl	Half of each length was marked w/ color markers; 284 of the fatalities were confirmed powerline collision deaths.	Brown and Drewien 1995.
Colorado and Utah	1996-1998	*	*	*	*	17 raptors	Raptors	Court found that at least 17 raptors were electrocuted along MLEA powerlines.	Melcher and Suazo 1999.
Colorado-Wyoming	1876	October	Telegraph wire	4.8	3	100 birds	Passerines Waterfowl	100 birds per 3 miles	Coues 1876.

* Information not provided in report.

APPENDIX E (*continued*) - STUDIES OF AVIAN COLLISIONS WITH HIGH TENSION LINES

Location	Year	Season	Size of Powerline	Length of Powerline (km)	Length of Powerline (Miles)	Total Fatalities	Top Bird Types Killed	Comments/ Estimates	Reference
Denmark	1952-1954	*	*	*	*	*	White storks	35% fatalities due to collisions with high tension lines.	Johansen and Bjerring 1955; Koops 1987.
Nebraska	1988-1990	Spring (3)	69 kV - 345 kV	13.8	8.6	36; 25 of which were collisions w/ unmarked lines	Sandhill Cranes Shorebirds	Half of each length was marked w/ color markers.	Morkill and Anderson 1991.
Netherlands	1944-1963	*	*	*	*	400,000 birds/yr	*	750,000 to 1,000,000 bird killed annually due to high tension wire collisions.	Koops 1987.
North Central States	1958-1973	*	*	*	*	75 trumpeter swans	Waterbirds	19% mortality due to powerlines.	Weaver and St. Ores 1974.
North Dakota	1977-1978	Sept-Oct & April-May	230kV	5.2 km old line 8.7 km new line	3.2 mi old line 5.4 mi new line	105 birds	Passerines Waterfowl	Approx. 5 birds/mile.	Cassel *et al.* 1979.
North Dakota	1980-1982	Spring (2), Fall (2)	12, 230, and 400 kV	9.6	6	633	Waterfowl, Gulls, Cranes, Shorebirds	Estimated total fatalities: 1,333, Collision rate 1 per 86 flights.	Faanes, C.A. 1987.
Oregon	1977	Winter - Spring	115 & 230 kV	1.4 km (2 parallel lines)	0.87	60	Seabirds Waterfowl	Bird flight observations and collision rates provided in report.	Lee *In* Avery 1978.
Oregon and Washington	1977-1978	Oct-Jan&Feb-May	500kV, 230kV and 115kV	5.9	3.7	31 birds	Waterfowl Shorebirds	Bird flight observations and collision rates provided in report.	Meyer 1978.

* Information not provided in report.

APPENDIX E (*continued*) - STUDIES OF AVIAN COLLISIONS WITH HIGH TENSION LINES

Location	Year	Season	Size of Powerline	Length of Powerline (km)	Length of Powerline (Miles)	Total Fatalities	Top Bird Types Killed	Comments/ Estimates	Reference
Oregon and Washington	1978-1979	Fall, Winter	115 and 500 kV	4.4	2.7	30, 13 "feather spots"	Waterfowl passerines	estimated total collisions: 609 day, 86 night.	James and Haak 1979.
Oregon and Washington	1977-1978	Winter	115, 230, & 500 kV	5	3.1	19; 10 of which were near a 0.6 km section of line	Waterfowl Passerines	Estimated 1 collision per every 2,233 flights during good visibility.	Lee *In* Avery 1978.
Oregon and Washington	1980 & 1981	Fall (1980) Spring (1981)	230 - 500 kV line	Approx. 1 km	0.6	7	Passerines Waterfowl	Study objective to test collision rate with no ground wire.	Beaulaurier 1981.
Rhode Island	1966-1968	Annual	*	*	*	*	Waterbirds	26.7% of mute swan adult mortality due to collisions - powerlines were the most freq. object collided with.	Willey 1968.
United States	Pre-1967	Annual	*	*	*	3,015 waterfowl	Waterfowl	Publ & Unpub data, band recoveries. Wire strikes: 1487 (65%). Waterfowl Study.	Stout 1967.
Utah	2 years, ~1970	*	*	*	*	56 eagles	Raptors	Electrocution.	Smith and Murphy 1972.
Western United States	1986-1996	Annual	Various - Info. From 58 utilities	*	*	1,558 birds. Mostly raptors	Raptors Shorebirds Seabirds	Wire collision: 13; Wire entanglement: 6; Electrocution: 1525; Plus 22 electrocution falconer records, and 8 non-raptors.	Harness 1997.

* Information not provided in report.

APPENDIX F1 - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	City/Tower	Tower Height (Feet)	Date	Year	Season	Total Fatalities	#Species	Comments/ Estimates	Reference
Alabama	WAPI/WBRC	825; 795.2	*	1967	Spring	12	5	2 random days.	Bierly 1968.
Florida	G. B. Island Tracking Tower	400	22-Oct	1966	Fall	99	18		Kale *et al.* 1969.
Florida	G. B. Island TV Tower	200	22-Oct	1966	Fall	37	14		Kale *et al.* 1969.
Florida	LORAN	627	8-Oct	1991	Fall	617	9		Roberts and Tamborski 1993.
Florida	WDBOWFTV	1,500	11-Sep	1969	Fall	356	24		Taylor 1981.
Florida	WDBOWFTV	1,500	28-Sep	1970	Fall	1,592	37		Taylor 1981.
Florida	WDBOWFTV	1,500	29-Sep	1970	Fall	859	31		Taylor 1981.
Georgia	WALB	1,000	13-Sep	1959	Fall	114	10		Crawford 1976.
Georgia	WALB	1,000	8-Sep	1962	Fall	228	20		Crawford 1976.
Georgia	WALB	1,000	18-Oct	1962	Fall	23	13		Crawford 1976.
Illinois	ARGENTA	*	27-Sep	1972	Fall	807	50		Dinsmore *et al.* 1987.
Illinois	FITHIAN	*	27-Sep	1972	Fall	634	42		Dinsmore *et al.* 1987.
Illinois	FITHIAN	*	24-Oct	1979	Fall	283	19		Graber and Graber 1980.
Illinois	GIBSON CITY	*	27-Sep	1972	Fall	206	27		Dinsmore *et al.* 1987.
Illinois	MONTICELLO	*	27-Sep	1972	Fall	992	50		Dinsmore *et al.* 1987.
Illinois	SPRINGFIELD	998	27-Sep	1972	Fall	391	44		Dinsmore *et al.* 1987.
Illinois	SPRINGFIELD	998	29-Sep	1972	Fall	319	44		Dinsmore *et al.* 1987.
Illinois	WHBF	983	7-Oct	1959	Fall	88	32		Petersen 1959.
Illinois	WICS	999	16-Sep	1958	Fall	827	40	Est. 1,500 birds.	Parmalee and Parmalee 1959.
Illinois	WICS	999	13-Sep	1963	Fall	219	31		Parmalee and Thompson 1963.

* Information not provided in report.

APPENDIX F1 (*continued*) - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	City/Tower	Tower Height (Feet)	Date	Year	Season	Total Fatalities	#Species	Comments/ Estimates	Reference
Indiana	WHAS	973	23-Sep	1966	Fall	123	*		Petersen 1967.
Indiana	WHAS	973	5 dates	1966	Fall	24	16	Random survey.	Able 1966.
Indiana	WHAS	973	7-Oct	1967	Fall	78	*		Able 1968.
Iowa	ALLEMAN	2,000	14-Sep	1982	Fall	384	33		Dinsmore *et al.* 1983, 1987.
Iowa	ALLEMAN	2,000	21-Sep	1985	Fall	515	39		Dinsmore *et al.* 1987.
Iowa	HINTON	*	21-Sep	1985	Fall	469	38	Est. 2,000 birds.	Dinsmore *et al.* 1987.
Kansas	KANU	*	29-Jan	1969	Winter	21	1		Niles *et al.* 1969.
Kansas	KLOE	700	30-Aug	1974	Fall	114	12		Barkley *et al.* 1977.
Kansas	KLOE	700	16-Sep	1975	Fall	390	30		Barkley *et al.* 1977.
Kansas	KOAM	1,200	29-Sep	1961	Fall	85	23		Boso 1965.
Kansas	KTKA	1,440	26-Sep	1985	Fall	919	54		Ball *et al.* 1995.
Kansas	KTKA	1,440	1-Oct	1986	Fall	635	49		Ball *et al.* 1995.
Kansas	KTKA	1,440	12-Oct	1986	Fall	834	64		Ball *et al.* 1995.
Kansas	KTKA	1,440	9-Oct	1994	Fall	420	45		Ball *et al.* 1995.
Kansas	SYRACUSE	420	22-Jan	1998	Winter	5,000-10,000	*	Mostly Lapland Longspurs.	Evans 1998.
Kansas	TOPEKA	950	1-Oct	1954	Fall	585	*		Velie 1963.
Kansas	TOPEKA	*	9-Oct	1999	Fall	478	35		Robbins *et al.* 2000.
Kentucky	HENDERSON	1,000	21-Sep	1990	Fall	128	20		Palmer-Ball and Rauth 1990.
Kentucky	LEXINGTON	670	7-May	1961	Spring	82	21		Barbour 1961.
Maryland	WBAL	450	28-Sep	1970	Fall	1,965	43		Bagg 1971; Scott and Cutler 1971.
Minnesota	KEYC	1,116	19-Sep	1963	Fall	924	47		Janssen 1963.
Minnesota	KROC	1314	4-Sep	1961	Fall	526	33	Est. 1,500 birds.	Velie 1963.
Minnesota	KROC	1314	11-14-Sep	1961	Fall	901	43		Velie 1963.
Minnesota	KROC	1314	9-Oct	1961	Fall	111	26		Velie 1963.
Minnesota	KROC	1314	19-Sep	1963	Fall	248	28	Est. 1,500-2,000 birds.	Feehan 1963.
Minnesota	WDSM	800	19-Sep	1963	Fall	29	13	Many birds not collected.	Green 1963.

* Information not provided in report.

APPENDIX F1 (*continued*) - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	City/Tower	Tower Height (Feet)	Date	Year	Season	Total Fatalities	#Species	Comments/ Estimates	Reference
Mississippi	WMAV	1,304	21-Apr	1984	Spring	26	*	Est. 200 birds.	Davis 1987.
Missouri	KFVS	*	27-Sep	1960	Fall	45	16	75 more birds not collected.	Anonymous 1961.
Missouri	KOMU	*	24-Sep	1960	Fall	658	41		Anonymous 1961.
Missouri	KOMU	*	20-Sep	1963	Fall	941	46		George 1963.
Missouri	KOMU	*	20-Sep	1966	Fall	618	32		Petersen 1967; Dinsmore *et al.* 1987.
Missouri	KOMU	*	15-Sep	1982	Fall	34	17		Elder 1982.
Nebraska	KNCA	*	16-Sep	1982	Fall	320	42		Molhoff 1983.
New York	WSYE	843	19-Sep	1975	Fall	800	40		Kibbe 1976.
New York	WSYE	843	20-Sep	1977	Fall	1,817	40		Welles 1978.
New York	WSYE	843	21-Sep	1977	Fall	1,358	28		Welles 1978.
New York	WSYE	843	22-Sep	1977	Fall	375	26		Welles 1978.
New York	WSYE	843	23-Sep	1977	Fall	132	25		Welles 1978.
New York	WSYE	843	24-Sep	1977	Fall	180	27		Welles 1978.
North Carolina	CHAPEL HILL	788	1-Oct	1956	Fall	125	40	Est. 2,500 birds.	Trott 1957.
North Carolina	RALEIGH	1,175	Sept 20 & 28	1969	Fall	2	1		Browne and Post 1972.
North Carolina	WECTWWAY	1,194; 1,188	30-Oct	1970	Fall	*	*	Est. 1,000 birds.	Carter and Parnell 1976.
North Carolina	WECTWWAY	1,194; 1,188	1-Oct	1973	Fall	660+	39		Teulings 1974.
North Carolina	WECTWWAY	1,194; 1,188	5-Sep	1974	Fall	3,240	41+1 hybrid		Carter and Parnell 1978.
North Carolina	WECTWWAY	1,194; 1,188	28-Oct	1975	Fall	306+	21		Carter and Parnell 1978.
North Carolina	WSOC	1,000	Sept 29-Oct 2	1960	Fall	341	34		Chamberlain 1961; Norwoods 1960.
North Carolina	WSOC	1,000	Oct 8,9	1960	Fall	49	17		Norwoods 1960.

* Information not provided in report.

APPENDIX F1 (*continued*) - INCIDENTS/EVENTS OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	City/Tower	Tower Height (Feet)	Date	Year	Season	Total Fatalities	#Species	Comments/ Estimates	Reference
Ohio	WHIO	*	*	1966	Fall	305	49		Petersen 1967.
Ohio	YOUNGSTOWN	*	Aug 24, Sept 17, Oct 9	1976	Fall	200	*		Hall 1977.
Pennsylvania	PITTSBURGH	*	*	1975	Fall	364	*		Hall 1976.
South Dakota	KSOO	1,117	28-Mar	1965	Spring	578	1	Horned Larks.	Pierce 1969.
South Dakota	KSOO	1,117	14-Sep	1965	Fall	102	32	Est. 200 birds.	Pierce 1969.
Tennessee	WATE	1,153	30-Sep	1984	Fall	368	34		Nicholson 1984.
Tennessee	WBIR	*	30-Sep	1984	Fall	393	34		Nicholson 1984.
Tennessee	WMC	*	7-May	1961	Spring	19	11		Coffey 1964.
Tennessee	WMC	*	11-May	1964	Spring	99	21		Coffey 1964.
Tennessee	WSIX	940	Sept-mid Nov	1960	Fall	1,553	*	Random survey.	Newman 1961.
Tennessee	WSM	1,368	28-Sep	1960	Fall	321	30		Ogden 1960.
Tennessee	WSM	1,368	Sept 27-30, Oct 16-17	1960	Fall	2,130	59	Results for 6 dates.	Newman 1961.
Tennessee	WSMV	1,368	26-Sep	1968	Fall	5,408	*		Purrington 1969.
Tennessee	WSMV	1,368	28-Sep	1970	Fall	3,487	*		Nehring 2000.
Texas	WBAP	750	16-Oct	1960	Fall	106	*		Pulich 1961.
Texas	WFAAKRLD	1,520	16-Oct	1960	Fall	500	37		Pulich 1961.
West Virginia	WCHS	999	7-Oct	1967	Fall	274	26		Ellis 1997.
West Virginia	WCHS	999	16-Sep	1995	Fall	5	5	Random survey.	Ellis 1997.
Wisconsin	EAU CLAIRE	1,000	29-Aug	1959	Fall	834	39		Velie 1963.
Wisconsin	EAU CLAIRE	1,000	1-Oct	1959	Fall	821	51	Est. 1,200 birds.	Velie 1963.

* Information not provided in report.

APPENDIX F2 - STUDIES OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	Tower/City	Tower Height (Ft)	Years of Study	#Years	#Birds Collected	Mean Annual Fatalities[a]	Search Frequency	Reference
Wisconsin	EAU CLAIRE	1,000	1957-1994	38.0	121,560	3,199	Daily (after 1959)	Kemper 1996.
Tennessee	NASHVILLE	1,368	1960-1997	37.0	19,880		Daily during migration	Nehring 2000.
Florida	WCTV	1,010	Oct 1955-Dec 1983	28.0	44,007	1,572	Daily	Crawford and Engstrom 2000.
New York	ELMIRA	843	Fall 1963-1983	10.0	7,500		Daily in Fall migration	Anonymous 2000. (USA Towerkill Summary)
West Virginia	WESTON	529	1978-1986	7.0	841		Occasional/ Catastophic	Anonymous 2000. (USA Towerkill Summary)
Minnesota	KROC	1,314	1961-1962, 1972-1974	5.0	3,507		*	Strnad 1975.
Michigan	WPBN	1,125	Fall 1959-1964, Spring 1962-1964	4.5	1,740		Occasional/ Catastophic	Caldwell and Wallace 1966.
Michigan	WWTV	1,281	Fall 1959-1964, Spring 1962-1964	4.5	3,975		Occasional/ Catastophic	Caldwell and Wallace 1966.
Alabama	WAPI, WBRC	825, 795.2	Fall 1967, 1968, Spring 1969, Fall 1974, 1975, Fall 1976	4.0	326	82	Daily	Bierly 1968, 1969, 1972; Remy 1974, 1975; Cooley 1977.
Florida	WDBO-WFTV	1,500	Fall 1969-Spring 1973	4.0	9,331		Occasional/ Catastophic	Taylor 1981; Taylor and Anderson 1973.
North Carolina	WECT-WWAY	1,194; 1,188	1971-1972, Fall 1973-Fall 1975	3.5	7,278		Occasional/ Catastophic	Carter and Parnell 1976, 1978.
Michigan	WKAR, WJIM	983; 1,023	Fall 1959-1964	3.0	355		Occasional/ Catastophic	Caldwell and Wallace 1966.
Michigan	WKZO, WOOD	1,000; 920	Fall 1959-1964	3.0	760		Occasional/ Catastophic	Caldwell and Wallace 1966.
Michigan	WMSB	983	Fall 1959-1964	3.0	199		Occasional/ Catastophic	Caldwell and Wallace 1966.
Illinois	CHAMPAIGN COUNTY	984	Fall 1955-Spring 1957	2.0	486		Occasional/ Catastophic	Brewer and Ellis 1958.
North Dakota	LAMOURE	1,200	1972-1973	2.0	563	282	Daily	Avery *et al.* 1977.

* Information not provided in report.

[a] Scavenging removal or searcher efficiency bias was not included in fatality estimates unless footnoted and some estimates are only seasonal if only migration was studied. Means were calculated only for year round studies with regular search intervals using #birds collected/#years study/tower, unless noted below.

APPENDIX F2 (*continued*) - STUDIES OF AVIAN COLLISIONS WITH COMMUNICATION TOWERS

State	Tower/City	Tower Height (Ft)	Years of Study	#Years	#Birds Collected	Mean Annual Fatalities[a]	Search Frequency	Reference
Indiana	WSJV/WSBT	1961: 650ft 1962: 1,074ft	Fall 1961-Fall 1962	1.5	325		*	Manuwal 1963.
Iowa	ALLEMAN TOWERS	2,000	Fall 1973-Fall 1974	1.5	3,521		*	Mosman 1975.
Kansas	KOAM	*	Fall 1963, Spring 1964	1.0	125		*	Boso 1965.
Massachusetts	BOYLSTON	1,349	Fall 1970, Fall 1971	1.0	508		20 Search Days	Baird 1970, 1971.
Nebraska	KNCA	*	1978	1.0	80		*	Molhoff 1979.
New Hampshire	DEERFIELD	*	1959-1960	1.0	267		Occasional/ Catastophic	Anonymous 2000. (USA Towerkill Summary)
New York	ELMIRA	843	Fall 1969, Fall 1970	1.0	520		Occasional/ Catastophic	Rosche 1970, 1971.
Illinois	7 TOWERS	*	Fall 1972	0.5	5,465		Occasional/ Catastophic	Seets and Bohlen 1977.
Kansas	KFDI	1,154	Spring 1994	0.5	13	672 [b]	1-2/week	Young *et al.* 1994.
Kansas	KSNW	1,079	Spring 1994	0.5	27	912[c]	1-2/week	Young *et al.* 1994.
Kansas	KYQQ	1,253	Spring 1994	0.5	25	408[d]	1-2/week	Young *et al.* 1994.
Kansas	TCI-TV	653	Fall 1993	0.5	30	1,272[e]	1-2/week	Young *et al.* 1994.
Kansas	TCI-TV	653	Spring 1994	0.5	14	384[f]	1-2/week	Young *et al.* 1994.
Kansas	LORAN	700	Fall 1992	0.5	*	1,080[g]	*	Young *et al.* 1994.
Kansas	LORAN	700	Summer 1993	0.5	*	1,032[h]	*	Young *et al.* 1994.
Kansas	WIBW	950	Fall 1954	0.5	1,090		*	Tordoff and Mengel 1956.
Missouri	KFVS	*	Fall 1962	0.5	325		*	Heye 1963.
New York	3 TOWERS	*	Sept 15-mid Nov. 1970	0.5	2,100		20 times	Rosche 1971.
New York	COLDEN	1,000	Fall 1962	0.5	1,400		*	Eaton 1967.
Ohio	YOUNGSTOWN	*	Fall 1975	0.5	1,031		*	Hall 1976.
Oklahoma	CIMARRON	*	Fall 1992	0.5	79		3 times/wk	Young 1993.
Vermont	MOUNT MANSFIELD	*	Aug 4-Oct 10, 1997	0.5	0		51 Search Days	Rimmer *et al.* 1998.

* Information not provided in report.

[a] Scavenging removal or searcher efficiency bias was not included in fatality estimates unless footnoted and some estimates are only seasonal if only migration was studied. Means were calculated only for year round studies with regular search intervals using #birds collected/#years study/tower, unless noted below.

[b] Est. 111 fatalities, 56 /mo.

[c] Est. 151 fatalities, 76 /mo.

[d] Est. 86 fatalities, 34 /mo.

[e] Est. 424 fatalities, 106 /mo.

[f] Est. 80 fatalities, 32 /mo.

[g] Est. 226 fatalities, 90 /mo.

[h] Est. 215 fatalities, 86 /mo.

APPENDIX G -SPECIES COMPOSITION OF FATALITIES

ALTAMONT

(Howell and Didonato (1991), Orloff and Flannery (1992), Orloff and Flannery (1996), Howell (1997), Howell *et al.* (1991), Thelander (2000) pers. comm.)

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]	Species/Group	Status[a]	# Fat.	% Fat.
Waterbirds				**Passerines**			
black crowned night heron		1	0.2	Brewer's blackbird		8	1.3
brown pelican		1	0.2	cliff swallow	M	3	0.5
California gull		2	0.3	common raven		9	1.5
unidentified gull		4	0.7	horned lark		14	2.3
unidentified waterbird[d]		2	0.3	house finch		3	0.5
Subtotal		10	1.6	loggerhead shrike		1	0.2
Waterfowl				mountain bluebird	M	2	0.3
mallard		5	0.8	red-winged blackbird	M	2	0.3
unidentified duck		2	0.3	unidentified passerine[d]	R-M	29	4.7
subtotal		7	1.1	violet-green swallow	R-M	1	0.2
Diurnal Raptors				Western bluebird	R-M	2	0.3
American kestrel		49	8.0	Western meadowlark		40	6.5
ferruginous hawk		2	0.3	Subtotal		114	18.6
golden eagle		30	4.9	**Others**			
northern harrier		2	0.3	mourning dove		1	0.2
prairie falcon		2	0.3	unidentified bird	R-M	11	1.8
red-tailed hawk		181	29.5	Subtotal		12	2.0
Swainson's hawk		1	0.2	**Non-protected Birds**			
turkey vulture		4	0.7	European starling		17	2.8
unidentified buteo		9	1.5	rock dove[d]		92	15.0
unidentified raptor		12	2.0	Subtotal		109	17.8
Subtotal		292	47.6				
Owls							
barn owl		25	4.1				
burrowing owl		27	4.4				
unidentified owl		10	1.6				
great horned owl		7	1.1				
Subtotal		69	11.3				

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)

[b] # fatalities

[c] species composition (%)

[d] a total of 48 birds were grouped as unidentified waterbirds, passerines, and rock doves in Orloff and Flannery (1996). Based on discussions with S. Orloff, we assigned 2 to unidentified waterbirds, 23 to unidentified passerines and 23 to rock doves.

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
MONTEZUMA HILLS
(Howell and Noone (1992), Howell (1997))

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Waterfowl			
mallard		2	4.8
Subtotal		2	4.8
Diurnal Raptors			
American kestrel		11	26.2
golden eagle		1	2.4
prairie falcon		1	2.4
red-tailed hawk		13	31.0
Subtotal		26	61.9
Owls			
barn owl		1	2.4
great horned owl		2	4.8
Subtotal		3	7.1
Passerines[d]			
American pipit	M	1	2.4
common raven		1	2.4
red-winged blackbird	M	2	4.8
Western meadowlark		1	2.4
Subtotal		5	11.9
Others			
mourning dove		1	2.4
northern flicker		1	2.4
unidentified bird	R-M	1	2.4
Subtotal		3	7.1
Non-protected Birds			
rock dove		3	7.1
Subtotal		3	7.1

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)
[b] # fatalities
[c] species composition (%)
[d] all passerines excluding house sparrows and starlings

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
SAN GORGONIO
(Anderson 2000a, pers. comm.)

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Waterbirds			
unidentified egret		1	2.4
unidentified grebe		1	2.4
Subtotal		2	4.8
Waterfowl			
American coot		6	14.3
mallard		2	4.8
unidentified duck		1	2.4
Subtotal		9	21.4
Shorebirds/Rails			
sora		1	2.4
Subtotal		1	2.4
Diurnal Raptors			
golden eagle		1	2.4
red-tailed hawk		1	2.4
Subtotal		2	4.8
Owls			
barn owl		3	7.1
burrowing owl		1	2.4
great horned owl		1	2.4
Subtotal		5	11.9
Passerines[d]			
common raven		2	4.8
Western meadowlark		1	2.4
white-throated swift		1	2.4
Subtotal		4	9.5
Others			
greater roadrunner		1	2.4
mourning dove		2	4.8
unidentified bird	R-M	4	9.5
Subtotal		7	16.7
Non-protected Birds			
European starling		2	4.8
rock dove		10	23.8
Subtotal		12	28.6

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)

[b] # fatalities

[c] species composition (%)

[d] all passerines excluding house sparrows and starlings

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
TEHACHAPI PASS
(Anderson 2000b, pers. comm.)

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]	Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Diurnal Raptors				**Passerines**[d]			
American kestrel		11	7.5	Brewer's blackbird		1	0.7
ferruginous hawk		1	0.7	chipping sparrow	M	1	0.7
prairie falcon		1	0.7	common raven		8	5.4
red-tailed hawk		15	10.2	dark-eyed junco	M	1	0.7
Subtotal		28	19.0	hermit thrush	M	1	0.7
Owls				horned lark		4	2.7
barn owl		4	2.7	loggerhead shrike		1	0.7
flamulated owl		1	0.7	rock wren		1	0.7
long-eared owl		1	0.7	Scott's Oriole	M	1	0.7
great horned owl		12	8.2	scrub jay		2	1.4
Subtotal		18	12.2	Swainson's thrush	M	4	2.7
Fowl-like Birds				unidentified passerine	R-M	6	4.1
California quail		4	2.7	unidentified sparrow	R-M	1	0.7
chukar		3	2.0	Western meadowlark		10	6.8
Subtotal		7	4.8	Western tanager	M	3	2.0
				yellow-rumped warbler	M	1	0.7
				Subtotal		46	31.3
				Others			
				greater roadrunner		3	2.0
				mourning dove		6	4.1
				northern flicker		3	2.0
				unidentified bird	R-M	20	13.6
				Subtotal		32	21.8
				Non-protected Birds			
				European starling		4	2.7
				rock dove		12	8.2
				Subtotal		16	10.9

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)

[b] # fatalities

[c] species composition (%)

[d] all passerines excluding house sparrows and starlings

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
BUFFALO RIDGE
(Osborn *et al.* 2000, Johnson *et al.* 2000b)

Species/Group	# Fat.[b]	% Comp.[c]	Species/Group	Status[a]	# Fat.	% Comp.
Waterbirds			**Passerines**[d]			
herring gull	1	1.8	barn swallow		4	7.3
pied-billed grebe	2	3.6	black and white warbler	M	3	5.5
Subtotal	3	5.5	blackpoll warbler	M	1	1.8
Waterfowl			chipping sparrow		1	1.8
American coot	2	3.6	common grackle		1	1.8
blue-winged teal	1	1.8	common yellowthroat	R-M	5	9.1
mallard	2	3.6	common yellowthroat		2	3.6
Subtotal	5	9.1	dickcissel		1	1.8
Shorebirds			empidomax flycatcher	R-M	2	3.6
killdeer	1	1.8	gray catbird		1	1.8
Subtotal	1	1.8	least flycatcher	R-M	1	1.8
Diurnal Raptors			Lincoln sparrow	R-M	1	1.8
red-tailed hawk	1	1.8	magnolia warbler	M	1	1.8
Subtotal	1	1.8	orange-crowned warbler	M	4	7.3
Fowl-like Birds			purple martin		1	1.8
gray partridge	1	1.8	ruby-crowned kinglet	R-M	1	1.8
ring-necked pheasant	2	3.6	sedge wren	R-M	1	1.8
Subtotal	3	5.5	sedge wren		1	1.8
			unidentified passerine		1	1.8
			vesper sparrow	R-M	1	1.8
			vesper sparrow		1	1.8
			warbling vireo	M	1	1.8
			Western meadowlark		1	1.8
			yellow warbler	R-M	2	3.6
			yellow-rumped warbler	R-M	1	1.8
			Subtotal		40	72.7
			Non-protected Birds			
			European starling		1	1.8
			house sparrow		1	1.8
			Subtotal		2	3.6

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)
[b] # fatalities
[c] species composition (%)
[d] all passerines excluding house sparrows and starlings

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
FOOTE CREEK RIM (Johnson *et al.* 2001)

Species/Group		# Fat.[b]	% Comp.[c]
Waterbirds			
western grebe		1	1.0
Subtotal		1	1.0
Diurnal Raptors			
American kestrel		3	3.1
northern harrier		1	1.0
Subtotal		4	4.2
Owls			
short-eared owl		1	1.0
Subtotal		1	1.0
Passerines[d]			
American pipit	M	1	1.0
American robin		1	1.0
Brewer's sparrow	R-M	3	2.1
Brewer's sparrow		2	3.1
brown creeper	M	2	2.1
chipping sparrow	R-M	5	5.2
cliff swallow		1	1.0
dark-eyed junco	R-M	1	1.0
green-tailed towhee	R-M	2	2.1
hermit thrush	R-M	1	1.0
horned lark		28	29.2
house wren	R-M	2	2.1
lark bunting	R-M	1	1.0
Macgillivray's warbler	R-M	1	1.0
mountain bluebird		2	2.1
rock wren	R-M	4	4.2
ruby-crowned kinglet	R-M	1	1.0
sage thrasher	R-M	1	1.0
Townsend's warbler	R-M	3	3.1
tree swallow		1	1.0
unidentified blackbird		2	2.1
unidentified passerine	R-M	5	5.2
unidentified swallow		1	1.0
vesper sparrow	R-M	7	7.3
warbling vireo		1	1.0
Western meadowlark		1	1.0
Western tanager		1	1.0
white-crowned sparrow	R-M	2	2.1
Wilson's warbler	R-M	3	3.1
yellow-rumped warbler	R-M	1	1.0
Subtotal		87	90.6
Others			
common nighthawk		1	1.0
common poorwill	M	1	1.0
mourning dove		1	1.0
Subtotal		3	3.1

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)

[b] # fatalities

[c] species composition (%)

[d] all passerines excluding house sparrows and starlings

APPENDIX G (*continued*)
SPECIES COMPOSITION OF FATALITIES
VANSYCLE, OR, PONNEQUIN, CO, AND WISCONSIN
(Erickson *et al.* 2000a, Kerlinger and Curry 2000, Kerlinger 2000b, Howe 2001, pers. comm.)

VANSYCLE, OR

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Fowl-like Birds			
chukar		1	9.1
gray partridge		2	18.2
Subtotal		3	27.3
Passerines[d]			
unidentified passerine	R-M	1	9.1
unidentified sparrow	R-M	1	9.1
white-crowned sparrow	M	4	36.4
white-throated swift		1	9.1
Subtotal		7	63.6
Others			
Lewis woodpecker	M	1	9.1
Subtotal		1	9.1

PONNEQUIN, CO

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Waterfowl			
unidentified teal		1	11.1
Subtotal		1	11
Passerines[d]			
white-throated swift	M	2	22.2
McCown's longspur	R-M	1	11.1
horned lark		5	55.6
Subtotal		8	89.0

Species/Group	Status[a]	# Fat.[b]	% Comp.[c]
Waterbirds			
herring gull		1	4.8
Subtotal		1	4.8
Waterfowl			
mallard		1	4.8
mallard		1	4.8
Subtotal		2	9.5
Passerines[d]			
American goldfinch		1	4.8
barn swallow		1	4.8
chimney swift		1	4.8
Eastern kingbird		1	4.8
golden-crowned kinglet	M	2	9.5
grasshopper sparrow		1	4.8
horned lark		1	4.8
red-winged blackbird		1	4.8
savannah sparrow		2	9.5
snow bunting	M	1	4.8
tree swallow	M	2	9.5
Subtotal		14	66.7
Others			
yellow-bellied sapsucker	M	1	4.8
Subtotal		1	4.8
Non-protected Birds			
European starling		3	14.3
Subtotal		3	14.3

[a] status of species (M=nocturnal migrant, R-M=possible resident or nocturnal migrant)
[b] # fatalities
[c] species composition (%)
[d] all passerines excluding house sparrows and starlings