Chapter 20

Impacts to Birds and Bats Due to Collisions and Electrocutions from Some Tall Structures in the United States: Wires, Towers, Turbines, and Solar Arrays—State of the Art in Addressing the Problems

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Introduction

Air and airspace as habitats are relatively new concepts (Kunz et al. 2008; Diehl 2013) for many individuals, academics, scientists, and agencies, including federal agencies such as the U.S. Fish and Wildlife Service (hereafter FWS); action agencies that implement FWS guidelines, rules and regulations such as the Bureau of Land Management and the U.S. Forest Service; and state agencies. Tall structures such as communication towers, power transmission lines, commercial wind turbines, solar power towers, and buildings extend into the airspace, in some cases to great heights (e.g., 229 m above ground level [AGL; 750 ft] for some wind turbine rotor swept areas, 610 m AGL [2000 ft] for some digital television (DTV) communication towers, and 442 m AGL [1451 ft] for Chicago's Willis high-rise tower). These tall structures can have deleterious direct effects and impacts to flying wildlife, not to mention indirect effects caused by air and facility disturbance from infrasound noise and lighting, barriers, and fragmented habitats. The overall goal for developers of tall structures and the agencies that regulate them should be to do no harm to protected wildlife species and minimize impacts to their habitats such as the U.S. Interior Department's "smart from the start" initiative (2011 doi.gov) for renewable energy development calling for minimal impacts from development. Attention is focused here toward that overall goal. Several industries whose efforts

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have recently been implemented to minimize harm to birds and to a lesser extent to bats are also assessed. These include the electric utility and the communication tower industries. Several other industries that could significantly reduce harm and impact to both bird and bat species and their habitats are discussed, but the majority of companies are not doing so, in major part based on the assessment of this author due to lack of regulations. These include the commercial, land-based wind industry in the U.S. and the industrial solar energy industry, currently in the Southwest U.S.

Status of and Impacts to Avifauna and Bats in North America

Avian Status and Legal Protections

Migratory birds—i.e., by federal legislative definition those that migrate across U.S., Canadian and/or Mexican borders, of which 1027 species are currently protected in the United States (50 Code of Federal Regulations [C.F.R.] 10.13), are a public trust resource, meaning they belong to everyone. Almost all North American continental birds are protected by the Migratory Bird Treaty Act of 1918, as amended (MBTA;16. U.S.C. 703 et seq.), which implements and regulates bilateral protocols with Canada, Mexico, Japan, and Russia. The Act is a strict liability statute; proof of criminal intent in the injury or killing of birds is not required by authorities for cases to be made.

The Statute and its regulations protect migratory birds, their parts, eggs, feathers, and nests from un-permitted "take" (migratory bird nests are protected during the breeding season while eagle nests are protected year-round), although efforts are currently underway by FWS to develop a permit where "take" could be allowed under MBTA. A Federal permit is required to possess a migratory bird and its parts, and the MBTA currently provides no provision for the accidental or incidental "take" (causing injury or death) of a protected migratory bird, even when otherwise normal, legal business practices or personal activities are involved. The U.S. Congress noted the "take" of even one protected migratory bird to be a violation of the Statute, with fines and criminal penalties that can be extensive. For example, Moon Lake Electric Cooperative was fined $100,000 (U.S.) in 1999 for electrocuting migratory birds; and PacifiCorp was fined $10,500,000 (U.S.) for electrocuting birds in 2009 (the final 2014 settlement agreement included $400,000 (U.S.) in fines, $200,000 restitution to the State of Wyoming, and $1,900,000 to the National Fish and Wildlife Foundation for eagle conservation). A Duke Energy Wind Facility was fined $1,000,000 (U.S.) in 2013 for killing protected birds in wind turbine blade collisions. All the cases involved several years probation for the company executives and all required significant improvements and upgrades to facilities. Companies can also be fined under the criminal misdemeanor provisions of MBTA which can occur when steps to avoid or minimize "take" are not implemented and "take" subsequently results. This occurs after field staff and agents from the FWS's Office of

Law Enforcement have advised a proponent of concerns and suggested measures to avoid or minimize “take” and such recommendations have been ignored or only minimally implemented. It is important to note that the vast majority of “take” by industry goes un-investigated let alone unenforced due to lack of funding, staff, and other priorities.

Bald (*Haliaeetus leucocephalus*) and Golden Eagles (*Aquila chrysaetos*) are also protected by the Bald and Golden Eagle Protection Act (BGEPA; 50 C.F.R. 22.3, 22.26 and 22.27). “Take” under BGEPA is more expansive than under MBTA and includes pursuit, shooting, poisoning, capturing, killing, trapping, collecting, molesting, and disturbing both species (50 C.F.R. 22.3). Permits are required for disturbance take and take resulting in mortality (50 C.F.R. 22.26), and for take of nests (50 C.F.R. 22.27).

The overall objective of the FWS is to maintain bird populations at stable or increasing numbers. This is a daunting challenge due to the direct and indirect impacts of all of the structural issues discussed in this chapter, plus many others briefly mentioned below. As a result, there are growing numbers of Birds of Conservation Concern (BCCs; USFWS 2008)—species in decline but not yet ready for federal listing as threatened or endangered. Currently, there are 273 species and subspecies on the national BCC, Service Regional BCC and Bird Conservation Region BCC lists (USFWS 2008), providing an early warning of likely peril unless the population trends are reversed. These BCC lists require periodic reviews and updates under provisions of the Fish and Wildlife Conservation Act (16 U.S.C. 2901–2912).

Federally listed bird species are those designated and protected under the Endangered Species Act (ESA; 7 U.S.C. 136, 16 U.S.C. 1531 et seq.). Listed species include 78 endangered and 15 threatened bird species on the List of Threatened and Endangered Species. An endangered species faces a significant risk of extinction in the near, foreseeable future throughout all or a significant portion of its range. A threatened species is at risk of becoming endangered in the near future. Collectively, BCC and ESA-listed birds represent at least 366 bird species (36 %) in decline, some seriously, with numbers of both listed and BCC species growing (Manville 2013a). Additionally, the FWS is also tasked to maintain stable or increasing breeding populations of Bald and Golden Eagles under implementing regulations of BGEPA and compliance with the National Environmental Protection Act (NEPA, 42 U.S.C. 4321 et seq.).

Birds are critically important to us all. Birds provide key ecosystem services that fuel a multi-billion dollar (U.S.) industry through pollination, insect, and weed-seed control efforts in the agribusiness and forest products industries. Without migratory birds, there would be untold additional problems requiring more pesticide, herbicide, and other chemical use. Feeding, photographing, and watching migratory birds also fuel a $32 billion/year (U.S.) recreation industry in the U.S., representing an estimated 20 % of the U.S. adult population involved in these endeavors. It is asserted that more adults in the U.S. feed, photograph, and watch birds than play golf (Carter 2013; MountainNature.com 2015).

A number of migratory bird species—notably Bald and Golden Eagles, Common Ravens (*Corvus corax*), American Crows (*C. brachyrhynchos*), hawks, falcons, doves, owls, and hummingbirds—are revered by and protected by Tribal law of some Native American Tribes and Canadian First Nations Peoples. Some of these very species are also at considerable risk from habitat disturbance, habitat fragmentation, injury, and death from land-based wind turbine blade collisions (Erickson et al. 2014), communication tower and guy wire collisions (Gehring et al. 2009), and heating/array impacts with solar facilities (Kagan et al. 2013).

Problems and Challenges for Migratory Birds

In an attempt to roughly assess the annual status of breeding bird populations in North America, several FWS biologists estimated a minimum of ten billion breeding landbirds in the United States exclusive of Alaska and Hawaii, and a minimum fall population of 20 billion migratory birds in North America north of Mexico based on Breeding Bird Survey data (Manville 2005, citing Aldrich et al. 1975; Banks 1979; J. Trapp 2001 pers. comm.). It is difficult to reliably quantify the total annual spring and fall breeding landbird populations in North America. The number of imperiled/declining North American birds continues to increase, the number of imperiled populations continues to grow continent-wide, and the numbers of birds on bird conservation, species of concern, watch lists, state-endangered, and federal-endangered species lists are growing in North America—in some cases at troubling, rapidly declining population rates (Manville 2013a).

The large, estimated annual loss of birds is due to a number of factors. Natural mortality can decimate some bird populations (e.g., starvation, disease, predation, parasitism, stress, nutrient deficiencies, and accidents), recognizing that some of these factors can also be human-related. Additionally, the direct and indirect impacts from humans are extensive. According to the theory, natural mortality tends to decrease to compensate for reduced density, but when mortality such as from structures exceeds a threshold, it can become additive to natural mortality, becoming exploitive (Allen et al. 2006). The mortality factors related to our human footprint include collisions with structures (e.g., building windows, power lines, communication towers and guy wires, wind turbine blades, solar power towers and mirrors, monuments, and bridges)—several of which are discussed in this chapter. Birds are also killed or injured by domestic and feral cats, illegal shootings, collisions with vehicles and aircraft, poisoning from pesticides and contaminants, drowning in oil and wastewater pits, impacts from oil and chemical spills, electrocutions at power line infrastructure, entanglement and drowning in fishing gear, drowning in stock tanks, “take” from hunting and crippling loss (i.e., birds injured but not killed by licensed hunters which subsequently die), poaching, poisoning from lead and other metals, direct loss of breeding habitat, and documented impacts to birds from climate change, among others (Manville 2013a, b). Individually and collectively, these impacts may become additive and all should be assessed cumulatively.

Frequently, proponents from one industry sector, concerned citizens, politicians, and conservationists supporting a specific type of industry will compare estimated levels of mortality from their sector of industry to another. For example, building windows are estimated to kill upwards of 1 billion birds/year in the U.S. (Klem and Saenger 2013; Loss et al. 2013b)—probably the greatest single source of structurally caused bird mortality in the U.S. Compare this to the estimated impacts to birds from power line collisions in the U.S., which may number from 8 to 57 million bird deaths annually based on sensitivity analysis and a meta-review of studies (Loss et al. 2014). Electrocutions, meanwhile, may kill from 0.9 to 11.6 million birds annually in the U.S. (Loss et al. 2014). However, collisions with communication towers may "take" *only* 6.8 million birds/year in North America, most of which are in the U.S. (Longcore et al. 2012). Proponents of the communication tower and cellular telephone industries will frequently make these comparisons to favor their own sector from further scrutiny as does the wind generation industry.

A recent estimate by Loss et al. (2013a) suggests a median estimate of 2.4 billion birds killed annually in the U.S. by domestic and feral cats—the largest projected source of human-related mortality to birds yet published in North America. Using this estimate for comparison is misleading since cats tend to concentrate on smaller birds. By comparing mortality from cats to the most recent estimates of mortality caused by commercial land-based wind turbines, the wind energy estimates are several orders of magnitude smaller, resulting in what might at face value be interpreted as insignificant. For several reasons, this comparison is very misleading. Some birds may have evolved adaptions to cat predation (e.g., sparrows and starlings), but behaviors for avoiding rotating blades and structures that appear as water have not evolved (USFWS 2015 pers. comm). Mortality must be cumulatively assessed for all known and projected causes, including for wind generation. Arguing that wind-generation-caused bird mortality is small by comparison may fail to include it among cumulative effects. Some bird species are more vulnerable to "take" which was acknowledged by Erickson et al. (2014) when concerns were raised about the mortality to 13 species of BCC (USFWS 2008) by the wind industry based on available data.

Collisions with land-based, wind energy turbine blades were recently estimated to kill 440,000 birds/year based on a 2008 estimate of some 22,000 operating turbines (Manville 2009) and have more recently been estimated to kill 573,000 birds/year in the U.S., of which an estimated 83,000 are raptors, based on a 2012 estimate of some 34,400 operating monopole and lattice-constructed turbines (Smallwood 2013). Loss et al. (2013c) attempted to estimate bird mortality at monopole-constructed turbines in the U.S., projecting an average of 234,000 bird deaths/year. Erickson et al. (2014) conservatively estimated annual bird mortality in the U.S. and Canada at 368,000 for all bird species killed. In the opinion of this author and some FWS biologists, field staff, wind energy leads, and law enforcement agents (FWS 2014 and 2015 pers. comm., FWS 2014 confidential internal memos), there continues to be a problem with the transparency, reliability, consistency, and rigor of many of the reports evaluated and subsequent mortality estimates published. These concerns are discussed beyond. Loss et al. (2013c) acknowledged the need for the public release of industry reports and a further evaluation of risk to birds before proceeding with a widespread shift to taller and larger turbines. Those recommendations are essentially being ignored. However, as wind generation grows exponentially, impacts to birds and bats are elevated. As of December 31, 2014, 65,879 megawatts (MW) of installed capacity (more than 48,000 utility scale turbines) were operating in the U.S. (DOE WINDExchange 2015, American Wind Energy Association 2015).

From the perspective of commercial, land-based wind energy, there is yet another problem with these mortality comparisons. The relatively low level of estimated wind energy mortality does not account for the current disproportionate take of Golden Eagles (GOEAs) by wind turbines in the Western U.S. Of approximately 67–75 GOEAs killed/year at Altamont Pass Wind Resource Area, California (Smallwood 2013), there are additional records of more than 79 GOEAs and six Bald Eagles (BAEAs) that have been documented killed in the West at other commercial wind energy facilities from 1997 to 2012 (Pagel et al. 2013), contrary to assertions by some wind energy proponents that eagle mortality is only a problem at Altamont Pass, California. These figures represent a substantial underestimation of the number of GOEAs killed at wind facilities in the Western U.S. (Pagel et al. 2013) since records continue to be collected by FWS staff detailing more eagle mortalities (FWS 2014 and 2015 confidential unpublished data). The Pagel et al. (2013) discoveries were not based on any systematic mortality or monitoring surveys. The growing "take" of eagles and the effects to eagle territories and eagle use areas are growing concerns as more wind facilities are built and become operational. Additionally, there is a growing—but still low—level of take of BAEAs nationwide at wind energy facilities, but more records exist of eagle fatalities from both species at wind energy facilities which have not been released by wildlife agencies since the publication of Pagel et al. (2013; FWS 2015 pers. comm., FWS 2014 and 2015 confidential unpublished data).

There is also a disproportionately large but still poorly substantiated level of take of passerines at wind facilities nationwide (Smallwood 2013; Erickson et al. 2014). A proportion of the migratory birds killed at wind facilities which are Birds of Conservation Concern (BCCs; USFWS 2008) continues to grow (Manville 2009, 2013a; Erickson et al. 2014). These BCC species are already in decline and in some cases in significant peril, but not yet listed under the Endangered Species Act. The current status of BCC species is a growing concern and not easily rectified by lack of federal and state agency resources to address these issues. Yet proponents of the wind generation industry will frequently cite other larger estimated sources of mortality to estimated mortality from wind turbines (AWEA 2015) rather than focusing on addressing the problems of wind turbines indiscriminately killing multiple bird species.

The bottom line, when trying to understand the dynamics of bird (and for that matter bat) populations, all impacts of tall structures and alternate energy sources should be assessed through cumulative effects analyses under the National Environmental Policy Act (NEPA). However, not all projects (i.e., from single turbines to large wind facilities) require NEPA review unless proponents want and apply for a BGEPA or ESA “take” permit, are located on public/federal property, or are receiving federal funding (Manville 2013a). Performing a NEPA review can be challenging, especially given data gaps, unknowns, and uncertainties. However, cumulative effects analysis can best be performed by coordination between the project proponent’s consultant and the FWS NEPA specialist/coordinator for the FWS Region where the project is being proposed. This will help determine the need for a NEPA Environmental Assessment, an Environmental Impact Statement, or possible categorical exclusion.

In addition to the impacts from causes due to natural mortality, additive mortality, or a continuum between compensatory mortality and additivity (Peron 2013), project proponents should also include cumulative impacts from cats, windows, power lines, wind turbines, solar facilities, lighting, communication towers, and all other anthropogenic structures including bridges and airports. The impacts should be assessed over the lifetime of all the structures and other impact sources. Additionally, the growing effects of climate change should be incorporated in any cumulative effects analysis (Manville 2013a).

The situation makes for a complicated review with many dynamics involved in assessing the status of bird and other populations. The good news: as scientifically validated, peer-reviewed, and published best-management practices, best available technologies, proven conservation measures, and other tools become publicly available, they should be systematically and consistently implemented. This approach makes the best conservation sense, provides the most bang for the buck, and may help reverse declining populations trends.

Status and Impacts to Bats in North America

Among some of the most maligned yet important animals in the world, insectivorous bats (Microchiroptera) play critical roles and provide key ecosystem services to humanity. Unfortunately, the roles bats play are hugely misunderstood by the public. In the U.S., bats alone save billions of dollars each year by protecting the forest products and agricultural industries. The estimated savings range from $4 billion–$53 billion/year (U.S. dollars, averaging $22.9 billion; Boyles et al. 2011). For example, a single big brown bat (*Eptesicus fuscus*) can consume from 3000 to 7000 mosquitoes/night, some of which may be carrying West Nile virus, malaria, and chikungunya virus, among other diseases. A colony of 20 million Mexican free-tailed bats (*Tadarida brasiliensis*) in Central Texas can consume ≥113,398 kg (0.25 million pounds) of insects/night (Cryan et al. 2014). Insectivorous bats consume June beetles (subfamily Melolonthinae), leafhoppers (family Cicadellidae), spotted cucumber beetles (*Diabrotica undecimpunctata*), green stink bugs (*Chinavia hilaris*), corn ear worm larvae (*Helicoverpa zea*), gypsy moths (*Lymantria dispar dispar*), spotted budworms (*Heliothis* spp.), and many other pests.

Of the 45 species of bats found in the contiguous 48 United States, six are federally listed under the ESA (FWS.gov). These include the gray (*Myotis grisescens*), Indiana (*M. sodalis*), Ozark big-eared (*Corynorhinus townsendii ingens*), Virginia big-eared (*C. t. virginianus*), lesser long-nosed (*Leptonycteris yerbabuenae*), and the Mexican long-nosed (*L. navies*) bats. Highly troubling are recent deleterious impacts to cave-dwelling bats, especially those in the genus *Myotis* (e.g., little brown [*M. lucifugus*] and Indiana bat), from the fungal disease known as White-nosed Syndrome (WNS; *Pseudogymnoascus destructans*). To date, WNS is conservatively estimated to have killed more than seven million hibernating bats in 25 U.S. States and six Canadian Provinces. Population declines of >80 % of the bats in the Northeastern United States have recently been reported (Reynolds et al. 2015). All efforts to protect bats and reverse population declines are critically important and any efforts that can reduce or eliminate additional compensatory and/or additive mortality should be employed.

Addressing Problems Through Stressor Management

One approach being used by wildlife agencies, specifically the FWS in addressing direct, indirect, and cumulative impacts to migratory birds—and other fauna including bats—is through stressor management. A stressor is defined as any alteration or addition to the environment that when applied to a resource becomes a threat to the individual bird and/or its population. Stressors can be both anthropogenic and natural. For example, dissecting a project's construction and operational schedule can delineate each stressor. Common avian stressors that impact breeding, foraging, migration, migration corridors, and wintering areas include artificial lighting, noise, human/habitat disturbance, the addition of structures to the landscape, and the removal and manipulation of vegetation. The principle behind stressor management is to focus on the *cause* of the impact (e.g., installation of lighting) rather than its *effect* (e.g., nighttime bird attraction). Previously, managing project effects had focused on fixing the consequences of an action such as marking communication tower guy-support wires with bird deterrent devices to reduce bird collisions—admittedly costly, often difficult, and not necessarily effective. By constructing an un-guyed, monopole, or lattice-support tower, guy wire collisions are avoided. Stressor management today aims to deconstruct a project, providing a more tangible impact analysis by identifying the full spectrum of avian stressors associated with the lifecycle of a project. The stressors produced by each individual activity (e.g., brush clearing, dredging, using heavy machinery, or installing structural lighting), within each phase of a project (i.e., pre-construction, construction, post-construction/operation, and decommissioning), helps the project proponent realistically anticipate the problems that might be associated with their project and identify cost-effective ways to avoid or minimize the individual stressors at their source before they become realized threats to migratory birds (Morris and Kershner 2013; E. Kershner 2013 pers. comm.).

Discussion: Projected Impacts to Birds and Bats from Specific Industry Sectors

Direct and Indirect Effects of Transmission and Distribution Powerline Collisions and Electrocutions

The impacts of transmission and distribution powerlines on migratory birds have not been carefully or systematically monitored, even though dozens of peer-reviewed studies have been published in scientific journals assessing impacts to birds from powerless (e.g., APLIC 2006, 2012). This is in part due to the millions of kilometers (miles; APLIC 2012; Manville 2013a) of distribution lines and nearly 1.207 million km (0.75 M miles; APLIC 2012; Manville 2013a) of transmission lines in the U.S.; lack of adequate utility and agency staff to systematically survey them for dead birds; lack of pressure by the regulatory agencies on the industry; lack of recognition of the problem; and lack of adequate agency funding (Manville 2009, 2011). For purposes of comparison, distribution lines in rural and urban areas generally carry from 2.4 kilovolts (kV) up to 60 kV of electricity, using transformers to step down the voltage going into homes, offices, and other structures. Distribution lines are often placed above ground as undergrounding increases the cost. High voltage transmission lines carry from 60 to >700 kV and are generally located on tall pylon power towers, or other platforms. Transmission lines can be placed underground, but the challenges to maintain them can be significant, plus the costs range from three to 20 times that of above-ground placement, which are significant increases (APLIC 2006; B. Bolin 2013 pers. comm.).

Collisions and electrocutions are both important avian problems, but each has different impacts and rates of mortality vary between species (Manville 2013a). Although different species have different vulnerabilities, other than BAEA, GOEAs, and buteos (i.e., soaring hawks; APLIC 2006), there generally are not enough data to generate a clear quantitative picture of how vulnerable different species are to electrocutions. Vulnerability, time of day/night, weather conditions, visual acuity, disturbance, and issues still not well understood about avian vision all affect collision impacts (Martin 2011, 2014), but all need further quantitative testing, peer review, and publication.

Bird collisions occur primarily with energized transmission wires and the smaller, static (lighting arresting) wires generally located on top of the transmission towers which are not as visible to birds in flight (APLIC 2012). Visual acuity can be critically important since birds must depend on eyesight to see and avoid obstacles such as static wires close-up (Martin 2011, 2014).

Electrocutions, however, occur primarily at distribution lines and their infrastructures, although flashovers (contact between two energized wires, or an energized and grounded structure) have been occasionally documented from raptor “streamers” (streams of liquid fecal waste) which contact energized transmission wires (APLIC 2006). Distribution power lines supplying alternating current are frequently constructed in three, energized (hot) phases, with an additional ground wire separate from them. Because each energized phase is different, electrocutions can occur between them, or between a hot and the ground wire. For birds which touch phased distribution lines placed too close together, electrocutions can result from phase-to-phase line contact (often between fleshy parts of a bird's anatomy, e.g., wrist to foot, or wrist-to-wrist); phase-to-ground contact; or when feathers are wet (resulting in electrocutions and not infrequently power outages). Uninsulated power pole infrastructure can cause bird electrocutions by touching equipment such as exposed wire bushings, bare jumper wires, unprotected fused cutouts, unprotected switches, and by other means. Even small birds such as passerines can be at risk of electrocution (APLIC 2006).

In addition to direct impacts (e.g., Bevanger and Broseth 2004—in an empirical study in Norway), birds, bats, and other fauna are also impacted by the indirect effects of transmission and distribution lines, powerline utility poles, solar power towers and solar mirrors, and their infrastructure. These include the introduction of barriers to movement, habitat fragmentation, site avoidance/abandonment, disturbance, loss of population vigor, behavioral modification, creation of sub-optimal or marginal habitats, loss of refugia, and intraspecific and interspecific competition for resources (Manville 2013a). It is important to note that most of these indirect effects are difficult to quantify, difficult to separate from other impacts, and for the most part have not been quantitatively tested, critically reviewed, and published in refereed journals.

To better understand and address these issues, considerable research has and continues to be conducted on understanding the indirect effects of transmission and distribution lines, among other tall structures. Power lines, wind energy facilities, communication towers, and oil pumping facilities have been suspected of causing negative effects to some bird species, notably some species of grouse (Manville 2004). The imperiled status of many of these species better explains the research focus. For example, the Attwater's Prairie-chicken (*Tympanuchus cupido attwater*) is Federally ESA-listed as endangered, the Gunnison Sage-grouse (*Centrocercus minimus*) is threatened, the Lesser Prairie-chicken (*T. pallidicinctus*) is threatened, and the Greater Prairie-chicken (*T. cupido*) has been petitioned for federal listing. Research on the direct and indirect effects of tall structures on prairie-chickens, sage-grouse, and Sharptail-grouse (*T. phasianellus*) has been extensive (e.g., Connelly et al. 2000; Braun et al. 2002; Hagen 2003; Wolfe et al. 2003a, b; Pitman 2003; Hagen et al. 2004; Patten et al. 2004; Connelly et al. 2004—all summarized in Manville 2004). Research and studies continue with more recent advances discussed in APLIC (2012). Winder et al. (2014) and Winder et al. (2015 in press) empirically tested the recommendation by FWS (Manville 2004) for avoiding development within an 8-km (five mile) buffer from leks by wind energy facilities affecting Greater Prairie-chickens. Both studies showed negative effects on both males and females of this species within eight km, supporting FWS's previous buffer recommendation. Evaluation and proper power line routing continue to be assessed and implemented to address direct and indirect effects on federally endangered Whooping Cranes (*Grus americana*; APLIC 2012).

Bats have been found incidentally in bird mortality searches in both transmission and distribution powerline corridors. While the recommendations from the Avian Power Line Interaction Committee (APLIC 2006, 2012) have been primarily focused on avoiding and minimizing impacts to protected migratory birds, the recommendations and best practices may also benefit bats, especially where bird-wire marking devices are installed. However, until research is conducted on the etiology of bat-wire collisions, the benefits of APLIC recommendations for bats will continue to remain speculative.

Addressing Problems and Attempting to Resolve Impacts to Birds from Powerline Collisions and Electrocutions: An Electric Utility-FWS Partnership

The North American partnership between members of the electric utility industry, including investor-owned utilities, electric cooperatives, electric administrations, several federal agencies, the Edison Electric Institute, Electric Power Research Institute, FWS, and some Canadian (e.g., Canadian Wildlife Service and Environment Canada) and Mexican partners (e.g., Semarnat and the Mexican Institute of Ecology), is noteworthy and deserves closer examination. Called the Avian Power Line Interaction Committee (APLIC), the group's proactive approach in addressing effects from avian impacts as well as dealing with threats associated with electric utility infrastructure has become well-known.

Begun as an ad hoc collaborative in the early 1970s to specifically address Whooping Crane-powerline collisions and GOEA electrocutions at distribution line infrastructure, the APLIC partnership has been significantly expanded and was codified in 1989 with the creation of the committee housed within and managed by the Edison Electric Institute where records are maintained. It has grown to more than 55 members today (www.aplic.org).

While APLIC's initial and early focus centered on avoiding raptor electrocutions and Whooping Crane collisions, its orientation has expanded to all birds, including much more involvement among company members, other stakeholders including vendors, members of academic and research communities, and the interested general public. Similarly, the FWS's involvement with electric utilities—as well as other industries which it regulates—has focused, in descending order of priority, on education, exchange of information, and lastly enforcement—the three "E's" (J. Birchell 2012 pers. comm.). While APLIC has been touted as one of the longest and possibly most productive partnerships FWS has had with any industry sector to date, the partnership between the electric utility industry and FWS has not been without some controversy. FWS law enforcement agents and prosecuting attorneys at the Department of Justice made two criminal cases against the industry, with multi-million dollar (U.S.) penalties, including against the Moon Lake Electric Cooperative in 1999 and PacifiCorp in 2009—previously referenced. While APLIC members are sensitive to the cases and the media surrounding them, in the opinion of this author the cases have served to garner the undivided attention of some of the industry, resulting in more proactive cooperation with FWS and the other regulators. The same cannot be said for the wind generation industry where only one criminal case, previously referenced, has been prosecuted.

APLIC has set the industry standard for a proactive approach to addressing stressors *prior* to wire and infrastructure placement and operation. These include the development and release of APLIC's 2005 *Avian Protection Plan (APP) Guidance* (APLIC 2005), a collaborative effort between APLIC and FWS.[1] The *APP Guidance* lays out 12 principles for companies, cooperatives, public service and utility districts, and electric administrations to follow, while developing and implementing a proactive plan to address potential impacts from wire collisions and electrocutions. By developing and implementing an APP, a utility is ideally focused on the *cause* of a problem (e.g., wire collision and infrastructure electrocution, disturbance to nesting GOEAs due to excessive noise, or removal of vegetation negatively affecting birds) and taking steps to address it proactively, including throughout any new construction. As a result, the APP becomes a business and operational tool and better protects the utility against prosecution from FWS. There are, to date, more than 100 APPs already developed or under development by electric utilities and cooperatives, exclusive of any additional APPs required under court order (e.g., Moon Lake and PacifiCorp).

To proactively deal with stressors as well as deal with existing threats, APLIC periodically publishes best management practices and best operational technologies based primarily on peer-reviewed, published scientific studies to address electrocutions (most recently, *Suggested Practices for Avian Protection on Power Lines: the State of the Art in 2006*)[2] and collisions (most recently, *Reducing Avian Collisions with Power Lines: the State of the Art in 2012*).[3] These documents and their recommendations are designed for use on existing power line infrastructure (e.g., retrofits—focused on addressing threats) and for all new construction (i.e., anticipating and avoiding potential stressors, where possible). Both documents, in part, deconstruct the powerline/infrastructure projects, focusing on the true problems, helping to identify other activities that may produce stressors, and suggesting cost-effective ways to identify and avoid or minimize the stressor component of an activity while still allowing the activity to proceed. Included in the APLIC (2006) document are chapters on regulations and compliance, biological aspects of avian electrocution, power line design and avian safety (in considerable detail), and the development of an APP, among others. Similarly, in APLIC (2012), there are chapters on progress in dealing with collision issues (in North America, internationally, with the need for future research priorities), avian regulations and compliance, understanding bird collisions, minimizing collision risks, powerline marking to reduce collisions, and APPs.

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[1] A document this author helped craft and negotiate.

[2] Coauthored by this author.

[3] Coauthored by this author.

APLIC also teaches short courses and other training modules dealing with avian-wire interactions, funds bird-utility research, and holds bi-annual meetings open to the public—including 1.5-day avian interaction workshops. The work of APLIC and its members has resonated in Canada, Mexico, Europe, Asia, Australia, and elsewhere. Fundamentally, APLIC has set the benchmark for other industries to follow in enabling a means to proactively address two significant threats to birds by identifying, avoiding, and minimizing the primary avian stressors associated with that activity. This still allows the activity to proceed in an effective and efficient way by enhancing reliable electrical energy delivery. In June 2014, APLIC and FWS celebrated their 25th anniversary working collaboratively since the committee was formed, while previously working in an ad hoc capacity since the 1970s (aplic.org).

While Loss et al. (2014) attempted to refine nationwide estimates for wire collisions and electrocutions, they did not attempt to summarize the overall efficacy of APLIC recommendations. Instead, they called for more information on the proportion of utilities implementing new best practices and retrofits, the degree with which these practices are reducing mortality, and the need for a consistent, peer-reviewed monitoring protocol. APLIC has yet to publish a nationwide meta-review of how best practices and suggested mitigation measures have worked to date. However, both APLIC documents (2006, 2012) do summarize empirical findings of mortality reduction based on some specific studies reported in these documents. FWS agents and field biologists routinely request the use of APLIC standards (2006, 2012) as benchmarks for addressing wire collisions and electrocutions, even though the recommendations are voluntary (FWS 2014 pers. comm.). In this author's opinion, one notable example of success should be credited to Puget Sound Energy, in western Washington. Where collision issues are identified as problems, this company has reduced to near-zero additional distribution wire collisions from Trumpeter Swans (*Cygnus buccinator*) by marking wires with bird diverter devices where birds are feeding at adjacent potato fields and may collide with the lines (M. Walters 2014 pers. comm.; pse.org/environment).

Collisions and Radiation Effects from Communication Towers: Addressing Problems to Birds

Tower Collision Mortality

Communication towers, which vary from short (<61 m AGL [200 ft]) monopole cellular telephone towers and antenna arrays to tall (>610 m AGL [2000 ft]) radio, television, and emergency broadcast towers, have two impacts on migratory birds, and to a lesser extent on bats since mortalities are reported only anecdotally to bird deaths. Information was first published in the late 1940s of a large, single night bird collision with a radio tower in Baltimore, Maryland (Aronoff 1949). More recently, information has been published on the suspected etiology of avian-tower collisions.

Frequently during nighttime migrations, birds are overwhelmed by inclement weather events, forcing bird fall-out, significant reductions in flight heights, and resultant attraction to lighted structures and confusion (Manville 2007, 2009, 2014a). Mortality has previously been conservatively estimated at 4–5 million birds killed in the U.S. annually (Manville 2002, 2005, 2009) based on limited, empirical data, and extrapolation from Banks' (1979) estimate. Current estimates of 6.8 million birds/year in the U.S. and Canada (Longcore et al. 2012) are based on a meta-review of 38 studies for which mortality data were available and corrected for sampling error, searcher efficiency, and scavenging. The vast majority of these bird deaths are in the U.S. (Longcore et al. 2012). In another review, at least 13 species of Birds of Conservation Concern were estimated to suffer annual mortality of 1–9 % of their estimated total population based solely on tower collisions in the U.S. or Canada (Longcore et al. 2013). These include estimated annual mortality of >2 % for the Yellow Rail (*Cocturnicops noveboracensis*), Swainson's Warbler (*Limnothlypis swainsonii*), Pied-bill Grebe (*Podilymbus podiceps*), Bay-breasted Warbler (*Setophaga castanea*), Golden-winged Warbler (*Vermivora* chrysoptera), Worm-eating Warbler (*S. discolor*), Prairie Warbler (*S. discolor*), and Ovenbird (*Seiurus aurocapilla*). Up to 350 species of birds have been documented killed at communication towers (Manville 2007, 2014a).

Radiation Effects

The much less documented but growing concern to birds and other wildlife involves effects of non-thermal, nonionizing microwave (and other) radiation from communication towers on nesting and roosting wild birds, an impact yet unstudied in the U.S. In Europe, impacts have been well-documented. Balmori (2005) found strong negative correlations between levels of tower-emitted microwave radiation and bird breeding, nesting, and roosting in the vicinity of electromagnetic fields in Spain. He documented nest and site abandonment, plumage deterioration, locomotion problems, and death in House Sparrows (*Passer domesticus*), White Storks (*Ciconia ciconia*), Rock Doves (*Columba livia*), Magpies (*Pica pica*), Collared Doves (*Streptopelia decaocto*), and other species. While these species had historically been documented to roost and nest in these areas, Balmori (2005) did not observe these symptoms prior to construction of the cellular phone towers. Balmori and Hallberg (2007) and Everaert and Bauwens (2007) found similar strong negative correlations among male House Sparrows. Under laboratory conditions in the U.S., T. Litovitz (2000 pers. comm.) and DiCarlo et al. (2002) raised troubling concerns about impacts of low-level, non-thermal radiation from the standard 915 MHz cell phone frequency on domestic chicken embryos (*Gallus gallus*)—with lethal results (www.healthandenvironment.org/wg_emf_news/6143). Given the findings of the studies mentioned above, and an extensive meta-review of the published studies by Panagopoulos and Margaritis (2008), field studies should be conducted in North America by third-party, independent research entities with no vested interest in the outcomes to validate potential impacts of communication tower radiation—both direct and indirect—to birds and other animals. However, to date, these have yet to be performed.

Efforts to Reduce Bird Collisions at Communication Towers

The FWS's Division of Migratory Bird Management became actively involved in the avian-tower collision issue in early 1998 with a large, single-night bird kill of up to 10,000 mostly Lapland Longspurs (*Calcarius lapponicus*) at a lighted, gas pumping facility and three surrounding communication towers in western Kansas (Manville 2001). To begin addressing the issue, the FWS published *Voluntary Guidelines for Communication Tower Design, Siting, Construction, Operation, and Decommissioning* in September 2000.[4] It developed and chaired the Communication Tower Working Group, focusing on the science surrounding bird attraction to lights, the dynamics of bird collisions, and efforts focused on dealing with stressors and their threats. The interim, voluntary *Guidelines* published in 2000 were updated in 2013 based on FWS recommendations provided on the record to the Federal Communications Commission (FCC) in 2007, 2011, 2012, and 2013 (Manville 2013a, b, 2014a). Changes in lighting and reductions in tower height and guy-support wires (Manville 2007; Gehring et al. 2009, 2011; Longcore et al. 2012) appear to preliminarily be reducing bird deaths, but a systematic review of these changes is recommended to determine empirically if the FWS guidelines, FCC licensing, and Federal Aviation Administration (FAA) lighting updates are reducing bird mortality. The FAA is finalizing updates to their 2007 lighting circular (FAA 2007), which incorporates new changes to steady-burning, red pilot warning obstruction lights generally placed on tall structures >61 m AGL (200 ft) in height (Manville 2013a; J. Gehring 2015 pers. comm.). Birds are particularly sensitive to the color red at night, especially if the red lights burn continuously rather than flashing or strobed (Gehring et al. 2009).

This development is highly noteworthy given the coordination, research, and work done by J. Gehring (Gehring et al. 2009, 2011). Specifically, new breakthroughs in better understanding the roles of lighting (especially steady-burning, red incandescent L-810 lights), tower height, and the use of guy support wires could—once fully implemented by the FCC and the FAA—reduce bird attraction and collision mortality by more than 50 % based on recent research and meta-reviews (Gehring et al. 2009, 2011; Longcore et al. 2012, 2013). That projected reduction in mortality still needs to be empirically assessed and verified, strongly suggesting the need in the opinion of this author for systematic mortality monitoring based on accepted monitoring protocols (e.g., Gehring et al. 2009).

Meanwhile, the vast majority of the FWS's voluntary recommendations are intended to proactively address the effects of stressors and their threats *before* tower

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[4] Coauthored by this author.

siting and construction occur. These includes recommendations for collocation of antennas, use of a lattice or monopole construction, avoiding wetlands and other important bird areas, building in already degraded sites, eliminating L-810 lighting, keeping towers unlit and unguyed, following APLIC (2006, 2012) recommended standards for wire infrastructure, minimizing habitat footprints, down-shielding security lighting using only motion or heat-sensitive types, decommissioning inactive towers, and other steps (Manville 2013b). The efficacy of each of these recommendations will need, in the opinion of this author, to be systematically monitored and assessed to see how well each is working and modified or adapted as necessary to make them most effective. Since lighting changes will ultimately result in energy cost savings for tower owners and lessees, it is hoped that the majority of communication tower construction projects will comply with the suggested lighting practices and other best practice recommendations, and that re-licensing, existing retrofits, and new construction will collectively result in significant reductions in both "take" and habitat alteration and fragmentation. While no similar partnership like APLIC exists among the communication tower operators and FWS, that industry is represented by a consortium of trade associations. These include CTIA, PCIA, the National Tower Erectors Association, and the National Association of Broadcasters. Members of the consortium are beginning to acknowledge, appreciate, and address the benefits of constructing and maintaining bird-friendly communication towers.

The impacts of tower radiation, especially on nesting birds, are still unstudied in the U.S. Until independent, third-party research can be conducted and results analyzed, no recommendations can yet be provided on this issue—other than to proceed using the precautionary approach and to keep emissions as low as reasonably achievable. The precautionary approach, based in part on Article #15 of the 1992 Rio Conference (unep.org), recommends that where serious harm may result, lack of scientific certainly is not a reason for postponing implementation of cost-effective measures. Aside from the field and laboratory studies referenced above, there remains much uncertainty about effects from nonionizing radiation on migratory birds and other wildlife.

Collisions and Habitat Impacts from Commercial, Land-Based Wind Turbines: Addressing Bird and Bat Impacts

The Effects

Land-based commercial wind energy electrical-generating facilities are relatively new structures on the landscape, only operating in the U.S. since the 1980s at Altamont Pass Wind Resource Area, California (Righter 1996; Smallwood and Thelander 2004). However, from the 1980s to the present, commercial wind generation in the U.S. has grown explosively (DOE 2015). The U.S. Department of

Energy's 2015 WINDExchange (DOE 2015) indicates that 65,879 MW of installed capacity (more than 48,000 utility-scale turbines) were operating by the end of 2014. It is not at all surprising that estimated bird mortality has grown from what was first presented as an average of 34,000 bird deaths/year in 2000 (Erickson et al. 2001, estimating mortality based on a review of only 12 projects). In 2008, as the industry continued to grow exponentially and mortality monitoring protocols by consultants remained inconsistent between nearly every project, Manville (2009) estimated 440,000 bird deaths/year by correcting for six major biases inadequately addressed in then existing project review. These included in decreasing order of bias concern (1) variability in the duration and intensity of carcass searches (including observer bias and lack of credible levels of detection), (2) failure to address carcass searches during some migration and most nesting, (3) effects of inclement weather, (4) size of the search areas, (5) unaccounted crippling loss incidents, and (6) impacts from wind wake and blade wake turbulence. Manville (2009) did not include the formula and actual calculations he used to develop his estimate, in major part due to a lack of space in the peer-reviewed Proceedings. He took the industry's 2008 estimate of 58,000 annual bird deaths, attempting to update it reflective of biases still inadequately addressed by industry consultants. Using conceptual models developed by Huso (2008, later published in 2010), he attempted to address concerns over estimators (Huso 2008), especially where biases remained very large between projects and continued to be unaddressed by many industry consultants. Finally, Manville (2009) weighted the inconsistencies addressed by Huso (2008) in a decreasing order of bias concerns listed above. By selecting decreasingly weighted percentages for the six biases, he roughly calculated a range of annual bird mortality from 440,000 to 690,000, selecting the lowest estimate. Due to the numerous biases in the industry's 2008 cumulative mortality estimate, Manville made no attempt to apply any statistical rigor to his estimate (Manville 2012). By 2012, Smallwood (2013) estimated 573,000 bird deaths, of which some 83,000 were raptors, from wind facilities nationwide based on closer review and analysis. His estimate included a correction for inadequate survey and assessment of passerines killed based on approximately 34,400 then operating turbines across the U.S. in 2012. Loss et al. (2013c) estimated 234,000 birds killed at monopole-constructed wind turbines in the U.S. (excluding lattice turbine structures), while Erickson et al. (2014) estimated 368,000 birds killed at turbines in the U.S. and Canada. There continues to be some disagreement regarding the methodologies and rigor used to assess mortality.

Others (e.g., Sovacool 2009) have published comparisons of bird mortality from wind energy to fossil fuel, nuclear energy, and other sources. While these comparisons can be instructive, the analytical methods used to develop the estimates are often highly variable, duration and intensity of monitoring may differ greatly, scientific peer review may not have been conducted (Ferrer et al. 2012; Smallwood 2013), and reporting mortality in the aggregate (i.e., number of birds estimated killed) fails to detect species-level effects necessary to make conservation assessments and decisions (Longcore et al. 2013).

Impacts especially to Golden Eagles continue to be especially troubling. To date, only the Shiloh IV Wind Project, Solano Country, California, a 102-MW facility, has a pending eagle "take" (50 C.F.R. 22.26) permit to injure and/or kill up to five GOEAs over a 5 year period (http://www.fws.gov/cno/press/release.cfm?rid=628). The pending permit is not without controversy as at least two retired FWS law enforcement agents have spoken out against the project and its permit (Wiegand 2014) as have several environmental groups (Associated Press 2014).

Smallwood (2013) estimated at least 888,000 insectivorous bats killed/year at U.S. commercial wind energy facilities, which was based on 51,630 MW of installed wind capacity in 2012, now at more than 65,879 MW by late December 2014, and growing (DOE 2015). Bats are currently being lost in unprecedented numbers from blade collisions and barotrauma, most susceptible of which are the tree roosting bats including the hoary (*Lasiurus cinereus*), Eastern red (*L. borealis*), and silver-haired bats (*Lasionycteris noctivagans*; Cryan et al. 2014). Why these bats remain more susceptible to collisions with turbine blades, especially at low blade speeds, remains yet unknown. It appears that bat behaviors that evolved at tall trees are now proving maladaptive to flying around turbine blades (Cryan et al. 2014).

Like the impacts from other industry sectors, commercial wind energy projects cause direct and indirect effects on birds and bats. Due, however, to the massive footprint of some of these projects—i.e., hundreds of km^2—effects can be accentuated. The direct effects of turbines and their projects include bird and bat collision mortality, and barotrauma in bats and anecdotally reported in small birds (Manville 2009). Direct habitat loss, creation of barriers, loss of grasslands, direct fragmentation of habitat, increase in habitat edge, increase in nest parasitism and predation, and impacts on water quality can also be problematic (e.g., Sovacool 2009). From the perspective of indirect effects, numerous concerns have also been raised. These include reduced nesting and breeding densities, loss of population vigor and overall densities, habitat and site abandonment, loss of refugia, attraction to modified habitats including suboptimal ones, effects on behavior (e.g., stress, interruption, and modification), displacement, avoidance, and habitat unsuitability (Manville 2004; Gillespie 2013; Winder et al. 2014, 2015 in press). Indirect effects can be incredibly difficult to quantify, with further difficulties teasing out specific effects from others.

Beginning to Address the Problems

The FWS went through a long and detailed, multi-year process (2007–2010), coincident with the process to develop an eagle "take" permit mechanism, working through the Wind Energy Federal Advisory Committee (FAC) to develop and update the FWS's 2003 interim, voluntary land-based wind energy guidelines. This author served as one of two technical scientific advisors to the FAC. The 2003 document[5]

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[5] Cowritten by this author

was open to 2 years of public comment. The resultant product was the *2012 Service Wind Energy Guidelines* (WEG) available on the FWS's website at www.fws.gov. While the specific guidelines are not prescriptive and only provide recommendations, they do recommend a detailed, tiered process for addressing stressors and their threats—notably Tiers 1, 2, and 3 focused on pre-construction landscape and site review. *If* a wind developer does perform its due diligence and properly sites wind facilities in bird, bat, and habitat-friendly locations, the project is unlikely to impact trust resources including birds in a significant way—i.e., negatively affecting their populations. However, there still is no permitting mechanism for "take" of migratory birds, and the permitting mechanism for eagle "take" requires important data on adult survivorship, territorial and foraging range integrity, adult breeding viability, recruitment, and disturbance to justify proposed levels of "take." The permitting process continues to remain a work in progress within FWS.

However, other than proper site location—i.e., siting turbines in low risk, degraded habitats, developed sites, or other locations where birds and bats will be minimally impacted—options are very limited. These low-risk sites still need to be clearly documented using accepted, scientific protocols that that can tie in low risk to factors that reduce rates of bird collision and minimize impacts from habitat alteration. These efforts continue to be a work in progress. There are no best practices or best available technologies for birds yet available for large-scale, wind energy developers. Such practices and technologies need to be independently peer-reviewed, scientifically validated, and acknowledged by independent experts as accepted tools to avoid or minimize "take" and/or affect habitats. In short, no silver bullet exists. Blade feathering (i.e., changing the pitch of the blades so they no longer cut into the wind), seasonal shutdowns, and electronic monitoring with automated Supervisory Control and Data Acquisition (SCADA) radar systems tied to feathering—which incidentally emit large quantities of radio frequency radiation—have only been reported to show limited success. Additionally, setbacks from ridge edges and turbine alignment have also shown some promise, but only with limited success (e.g., Smallwood and Thelander 2004). SCADA, for example, is very expensive to operate and companies using the system are finding it to be ineffective due to issues of sensitivity, response time to feathering, and verification of approaching targets (FWS 2015 pers. comm.). Mortality data are generally not shared with FWS or other agencies, or made available for third party data collection or independent peer review. This makes the efficacy of mitigation measures unclear, unknown, and difficult to verify (e.g., Wiegand 2014; Associated Press 2014). The smaller and shorter, vertical axis helix, flow-through turbines are far more efficient but more expensive than current technologies. They do have some promise in being more bird- and bat-friendly (FWS 2015 pers. comm.). Economies of scale suggest that higher blade heights with larger rotor swept areas are more efficient, overall less expensive per megawatt produced, but at a growing cost to wildlife and their habitats (Loss et al. 2013c). Rotor-swept areas now exceed 2.8 ha (seven acres) in area, larger than the entire area of three modern 747 jets. This is a situation quite different from what APLIC published through its 2006 and 2012 *Suggested Practices* documents that contain quantified and scientifically validated best practices and best available technologies. Many of these practices have been shown to significantly reduce wire collisions, electrocutions, and habitat alterations.

Hoary, Eastern red, silver-haired, and little brown bats are being heavily impacted by turbine blades. Whether these impacts are compensatory, additive, or represent a continuum between compensation and additivity (Peron 2013) still remains unclear and needs much more assessment. However, for insectivorous bats, there may be a conservation measure that could significantly deter blade collisions. Insectivorous bats tend to forage for insects when wind speeds are low (e.g., ~0.5 to 3.5 m/s) and the insects are present and readily available. Insectivorous bats remain highly susceptible to collisions and even barotrauma at these low wind speeds. By increasing the cut-in speed of turbine blades—i.e., the speed of the wind at which the blades begin to rotate—from ~3.0 to 6.0 or 6.5 m/s, bat mortality in a Pennsylvania study was reduced by up to 93 % (Arnett et al. 2011). While this change results in a loss of only a small fraction of energy production, it could significantly reduce bat mortality and therefore deserves careful consideration (Arnett et al. 2011; Arnett and Baerwald 2013). However, because the recommendation in the FWS's WEG is only voluntary, few companies are currently implementing this or other useful mitigation measure (Williams 2014; Manville 2014b).

Based on public comment, review, and internal assessment, the FWS published its updated, *Eagle Conservation Plan Guidance, Module 1, Land-based Wind Energy, Version 2* (ECPG), in April 2013. Like the WEG, it recommends approaches to avoiding and minimizing eagle "take" and impacts to eagle territories and eagle use areas based on a tiered protocol using the stressor management approach—i.e., identifying the stressors, their threats, and the consequences. While following the ECPG is voluntary, where disturbance "take" and/or "take" resulting in mortality are likely to occur, a permit (50 C.F.R. 22.26 or 22.27) is strongly recommended as un-permitted "take" may have legal consequences (Associated Press 2014). The goal of the ECPG is to ensure that the breeding population of both species of eagles remains stable or increasing. While the FWS published the authorization for the take permits in 2009 (50 C.F.R. 22.26 for eagle "take" and 22.27 for nest "take") along with the required NEPA documentation, the implementation of the regulations and permitting are a work in progress.

Studies are beginning to be published on the indirect effects of commercial wind energy facilities including on grassland bird density, nest survival, bird avoidance and attraction, and bat presence at turbines, turbine pads, and the generation facilities in Iowa (Gillespie 2013). As previously discussed, Winder et al. (2014) and Winder et al. (2015 in press) are validating a FWS recommendation (Manville 2004) of an 8-km (five-mile) buffer between Greater Prairie-Chicken leks and wind facilities. Research into indirect effects continues.

For numerous reasons, it has become increasingly clear that independent, third-party monitoring of wind facilities and site studies, and solar facilities briefly discussed next, must also be implemented. Unfortunately, with FWS's voluntary WEG guidance, that currently seems unlikely. Instances of data falsification and obfuscation of data; data release limitations through confidentiality agreements signed by project biologists, contractors, and cooperators; submission of fraudulent reporting;

and inadequate monitoring have been reported to FWS's Office of Law Enforcement (e.g., Wiegand 2014). Also reported were concerns about vested consultant interests, spotty reporting, proprietary data, and an unwillingness to work with FWS (FWS 2014 and 2015 pers. comm.)—unlike many of the companies in the electric utility industry. As Williams (2014:67) reminds us, "…some wildlife mortality is inevitable with even the best projects. But nothing will do more harm to the industry than excusing or tolerating wildlife-stupid projects that give it a bad name." If the public remains concerned, their voices need to be heard, and in turn, the industry needs to proactively address these concerns.

Beginning to Address Problems to Birds from Collisions and Heat Impacts at Industrial Solar Facilities in the Southwest

Problems to Birds and Other Wildlife

Industrial-scale solar development is relatively new to the U.S. Not until 1979 was the first industrial solar facility installed and operated in the U.S. in the Mojave Desert, which used a heliostat-power tower-solar receiver boiler generation system. Named Solar One, it had a tower of 86 m AGL (282 ft) in height, and a heliostat field of 765 m (2510 ft) in diameter—small by current power tower standards. At Solar One, McCrary et al. (1986) collected and reported 70 bird fatalities involving 26 species, 57 birds of which died from collisions while 13 died from burning. More recently, Leitner (2009) raised additional concerns and made suggestions for the proper selection of solar sites, including more research and mitigation. However, based on preliminary discoveries, a recent publication with troubling results (Kagan et al. 2013), and specific new recommendations by researchers, the environmental project review for the current solar technologies continues to be sorely inadequate.

There are three types of solar-generating facilities: (1) photovoltaic systems, (2) trough systems, and (3) solar power towers.

(1) Photovoltaics directly convert sunlight into energy (e.g., Desert Sunlight—at 1619+ ha [4000+ acres], with more than eight million panels, is probably the largest solar facility in the world). These flat panel systems can each cover enormous areas, displacing foraging habitats for GOEAs (a species of concern for FWS), their prey, and other species. In California's Imperial County alone, 91 km^2 (35 mi^2) of flat panel photovoltaics have already been and are being proposed for development. In a recent 2013 opportunistic survey conducted by staff of FWS and reported by the National Fish and Wildlife Forensics Laboratory (NFWFL; Kagan et al. 2013), where no pre-determined carcass sampling protocol was used, 61 bird carcasses retrieved from Desert Sunlight were transported to NFWFL to determine cause of death. Birds apparently mistook the shiny mirrored surfaces of the cells for water, resulting in blunt force trauma, predation, and unknown causes. Bird carcasses have

also incidentally been found at other flat panel projects in California's Central Valley, Imperial Valley, and in Nevada. These reports are only incidental to facility operations, not based on systematic surveys—which is a quandary.

(2) Trough systems consist of parabolic mirrors which are about 9m (30 ft) tall and can be hundreds of meters long. They focus sunlight onto tubes which convert heat to electricity (e.g., Genesis Solar Energy). From the Genesis site, 31 bird carcasses were opportunistically evaluated by NFWFL for cause of death. The results included impact trauma, predation, and unknown causes (Kagan et al. 2013). It is important to note that the number of carcasses found to date far outnumber the 31 reported several years ago by Kagan et al. (2013; FWS 2015 pers. comm.). These carcasses were found opportunistically, with no research study design, based on no third-party monitoring.

(3) Solar power towers are by far the most complex of industrial solar generation and also the most deadly to both birds and bats—based on the preliminary evidence. They consist of thousands of mirrors (e.g., Ivanpah with more than 300,000—the largest industrial solar steam generating system in the world). The mirrors intensely reflect solar energy to a power-generating tower (for Ivanpah, 140 m AGL [459 ft]), producing steam at temperatures of up to 427 °C (800 °F). This, in turn, runs a turbine and has an air-cooled condenser. Ivanpah has been characterized as a "mega-trap" for wildlife by the NFWFL (Kagan et al. 2013). In addition to significant bat and monarch butterfly (*Danaus plexippus*) mortality, the facility has attracted other insects, which in turn have attracted insect-eating birds, which were incapacitated by the solar energy flux, in turn attracting avian and mammalian predators. This has created an entire food chain vulnerable to injury and death. Carcasses collected opportunistically at Ivanpah included 141 birds which died from solar flux ($N=47$), impact trauma ($N=24$), predation ($N=5$), undetermined trauma ($N=14$), and "unknown" ($N=46$; Kagan et al. 2013). Even more troubling is a very recent, preliminary report (FWS 2015 unpublished data) by third-party monitors of 130 birds killed during a 4-h observation period at Crescent Dunes solar steam power project, Nye County, Nevada. Virtually all the birds were vaporized (FWS 2015 pers. comm.).

If just three commercial solar energy facilities are killing $N=233$ protected migratory birds based only on opportunistic and incidental monitoring during a few visits—i.e., information not gathered via pre-determined, robust, and peer-reviewed protocols for mortality monitoring—then how many birds, bats, and imperiled insects (e.g., monarchs) are actually being killed/year? It must be emphasized that the $N=233$ number represents only what FWS opportunistic visits discovered several years ago. Current FWS Special Purpose-Utility (Avian Take Monitoring) Annual Reports (SPUT; FWS Form 3-202-17) indicate that for Desert Sunlight, Genesis, and Ivanpah alone, more than 1000 birds killed representing almost 160 different species have been reported to FWS (2015 unpublished FWS data; also reported on www.kcet.org). This is far greater than the Kagan et al. (2013) preliminary reporting. While no GOEA carcasses have yet been found, solar facilities are displacing thousands of hectares of breeding and foraging habitat. One estimate suggests that up to 28,000 birds, including rapidly declining populations of Western Grebes (*Aechmophorus occidentals*; a BCC species), Common Loons (*Gavia mimer*), Peregrine Falcons (*Falco peregrinus*), Burrowing Owls (*Athene cunicularia*), Short-eared Owls (*Asio flames*), and others, are being killed each year in commercial solar arrays now operating only in Southern California, with a focus on Ivanpah (Center Biological Diversity 2014). However, until reporting is consistent, systematic, robust, and scientifically credible, the direct, indirect, and cumulative effects of industrial solar development on resident and wintering/migrant birds will remain uncertain. The lack of peer-reviewed data and a push by the current administration to fast-track renewable energy only complicates the situation.

These developments clearly do not bode well for industrial solar development. Apparently a number of FWS biologists raised major concerns before projects were even approved, let alone constructed, but their concerns did not resonate (FWS 2014 and 2015 pers. comm. and internal communications).

Beginning to Address the Problems

It is time to go back to the basics, using sound science and accepted protocols for monitoring as the drivers for developing industrial solar energy. These protocols should be scientifically credible, sufficiently robust, field tested, peer-reviewed, and accepted as valid by the scientific community—e.g., Gehring et al. 2009, as modified to apply to solar monitoring. Agencies need to maintain the leadership willing to stand up to the powerful industries and not be swayed by “green washing” (i.e., industry touting its actions as environmentally friendly and responsible, when in fact they can be very impactful). Because it is so challenging, enacting change within the agencies can be incredibly difficult. For example, on Bureau of Land Management public lands where the focus is on the development of solar facilities, thorough pre-construction risk assessment must be implemented, along with a full NEPA review of proposed projects, including citizen participation in the process (e.g. testimony, peer review, and litigation). Meanwhile, here is a preliminary list of some suggested mitigation for wildlife impacts at industrial solar facilities—which is far from exhaustive. All should be further tested using empirical field studies and published in refereed scientific journals, indicating which techniques are most effective. Bird and bat mortality can be reduced through fencing, nets, perch deterrents, exclusionary measures, UV-reflective glass, suspended operations during peak bird presence, use of video cameras and trained dogs for detection of carcasses, at least 2 years of daily bird and bat mortality searches—adjusting for scavenger removal including by Common Ravens, and addressing observer bias—and other measures as suggested by Kagan et al. (2013). Independent peer review of the agencies and contractors’ statistics is also critical. How these projects were approved without sufficient oversight is very troubling. In this author’s opinion, this same concern also applies to land-based wind development.

Conclusion

The issues discussed above present huge challenges, especially since we still know so little about the overall, cumulative impacts of powerlines, communication towers, commercial wind projects, and commercial solar arrays on birds, bats, and their habitats. If electric transmission, electronic communication, and renewable energy development are to be bird-, bat-, and habitat-friendly, changes must take place. This suggests a complete paradigm shift in assessing sites, adequately predicting pre-construction risks, validating risks during post-construction monitoring and assessment, and reversing ongoing very troubling trends.

To begin making this shift, this author recommends the development of an accepted monitoring protocol for each industry sector. Each protocol should be empirically based, scientifically valid, sufficiently robust—of the appropriate duration and intensity, with a consistent study design, field tested, peer-reviewed, and published in a refereed scientific journal. Post-construction monitoring should ideally include empirically driven, field-tested, and validated conservation and mitigation measures. Where such measures currently do not exist (e.g., industrial solar arrays and wind energy projects), research should continue to try to find them. Mitigation replacement/compensation measures for "take" and impacts to wildlife habitats should also be developed, empirically evaluated, peer-reviewed, published, and adopted, where most effective.

The guidelines for avoiding or minimizing impacts to migratory birds at communication towers, electric utilities, and commercial wind turbines have, for the most part, been voluntary—generally left up to the discretion of the industry proponents. This has often resulted in huge inconsistencies in monitoring (e.g., this author recounts a consultant providing four days of bird monitoring data at a proposed wind energy site to represent an entire migratory season of three months). As a result, a regulatory (e.g., implemented through the U.S. Code of Federal Regulations) versus voluntary approach has been suggested, including by this author, but under the current political climate in the U.S., that is highly unlikely. If regulations were developed, the suggested, empirically based monitoring protocols mentioned above should be incorporated as part of them. Also important, the agencies required by law and statute to manage wildlife and wildlife habitats need to acknowledge and implement their trust and statutory responsibilities regarding the wildlife they are entrusted to protect and conserve. Based on this author's experiences, politics rather than sound science seem to drive many current decisions. The Department of Interior and Department of Energy might be good places to begin the shift.

Based on the experiences of this author, there is some good news. With collaborative efforts such as those of APLIC long in place—and generally working well—the bar has been set high for other industries and agencies to follow. Where companies and their consultants are working with FWS, other agencies, and the public to better understand and minimize the impacts from human structures, their efforts should be applauded. This is a very good, but still too rare a thing.

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