# Eagles and Wind Energy: Identifying Research Priorities

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# Identifying Research Priorities

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The American Wind Wildlife Institute (AWWI) brings together wind energy industry, national conservation organization and wildlife agency leaders in a shared mission: to facilitate the timely and responsible development of wind energy while protecting wildlife and wildlife habitat. To accomplish this mission, AWWI advances research that addresses priority wind-wildlife issues, and develops tools and strategies that have impact on the ground. More information about AWWI is available at www.awwi.org.

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AWWI is ultimately responsible for the paper's contents.

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# Abstract

The Bald and Golden Eagle Protection Act prohibits the taking (killing, wounding, or disturbing) of bald and golden eagles without a permit. Eagles can be killed by wind turbines, yet, as the most commercially viable and scalable form of renewable energy, wind power is critical to addressing climate change, a major threat to eagles and other wildlife. The U.S. Fish and Wildlife Service (Service) has developed a framework for permitting lawful take and conserving eagles and has recently proposed regulations for the issuance of eagle take permits where the take is associated with an otherwise lawful activity, such as wind energy. Helping to reconcile the goals of wind energy development and eagle conservation is an urgent priority of the American Wind Wildlife Institute (AWWI) and its partners. This white paper and the November 2011 AWWI Eagle Workshop at which an earlier working draft was discussed draw on input from scientific experts on bald and golden eagles to define the technical issues around wind energy development and eagles, and to identify research that would improve implementation of and compliance with the Service's Eagle Guidance.

We summarize information about the population status and trends of bald and golden eagles and discuss "take" threshold in terms of eagle management units. We review anthropogenic sources of eagle mortality along with estimated magnitude of take from wind energy and from leading sources such as electrocution, collision, shooting, and poisoning. Potential mitigation options are identified. Research topics considered include: a) identifying and addressing information gaps on demography and status relevant to calculating take thresholds; b) developing unbiased estimates of eagle mortality; c) creating models for siting and operational strategies that avoid or minimize eagle fatalities at wind energy facilities; d) expanding options for compensatory mitigation; and e) coordinating and enhancing existing collaborative eagle research.

Because bald eagle populations appear to be thriving, Eagle Workshop participants recommend that AWWI emphasize research on golden eagles that is directly relevant to wind energy development. The white paper concludes that AWWI should focus over the next 12 months on expanding options for compensatory mitigation while continuing to identify, support, and collaborate with other research initiatives, as appropriate.

# Preface

The purpose of the AWWI Eagle Workshop held November 15-17, 2011 in Denver, CO was to define the science needs most directly relevant to AWWI's mission: promoting wind energy development that minimizes impacts to wildlife – in this case, to eagles. The Bald and Golden Eagle Protection Act prohibits the taking (killing, wounding, or disturbing) of bald and golden eagles without a permit. Wind energy facilities have "taken" eagles in the course their operations. Through its 2009 Eagle Rule and 2011 Eagle Guidance, the U.S. Fish and Wildlife Service (Service) has developed a framework for permitting lawful "take" and conserving eagles, which are protected under the Bald and Golden Eagle Protection Act. Given the broad potential range of eagles and the gaps in our understanding of eagle wind energy interactions, which make it difficult to predict possible risk to eagles, accomplishing the dual objective of permitting lawful take and conserving eagles creates a challenge for developing and operating wind energy projects where eagles occur.

To address this challenge, support the Service's implementation of the Eagle Guidance, and assist wind industry compliance with the Eagle Rule and Eagle Guidance, AWWI convened the November 2011 Eagle Workshop in collaboration with stakeholders from state and federal agencies, eagle experts, and AWWI Partners from the wind energy industry and the conservation community. The goals of the workshop were to describe the current state of knowledge of bald and golden eagles and to identify research that would improve implementation of and compliance with the Eagle Guidance for wind energy. There is an urgent need to define the research that will enable us to meet this challenge within the next five to ten years.

AWWI Partners came together in recognition that climate change is a looming threat of potentially enormous magnitude to all wildlife, including eagles. Many climate experts state that emissions reductions in the next five to ten years will have major consequences for the amount of climate change that will occur over this century. To meet a broad range of pollution as well as climate change emissions reduction goals, many states and regions have established targets for renewable and emission-free electricity production, and wind energy is the most commercially viable form of renewable electricity.

In planning the Eagle Workshop, AWWI recognized that understanding the status of eagles and the threats to eagles, especially golden eagles, from the development and operation of wind energy facilities and other anthropogenic activities has been a major focus of research scientists at government agencies, wildlife consulting firms, and at academic institutions and non-governmental conservation organizations. Among recent efforts to define research priorities for golden eagles, the 2010 Colloquium and Science meetings and the 2011 Research Roundtable (GOEA Colloquium 2010; GOEA Science Meeting 2010) have resulted in the initiation of several collaborative research efforts between the Service and scientists at the U.S. Geological Survey (USGS). These efforts inform AWWI's investment in wind energy and eagle research, which is intended to complement and support the research of the Service and the USGS.

AWWI staff prepared a version of this white paper prior to the workshop to help AWWI better understand the technical issues around wind energy development and eagles. Although much of the recent concern has focused on golden eagles and wind energy, the workshop and white paper included a review of bald eagles because interactions between wind energy production and bald eagles are likely to increase as wind energy development continues to expand, especially at coastal and nearshore locations. The white paper also was intended to help identify areas of remaining uncertainty and to create a framework for defining a research agenda to reduce these uncertainties. The principal outcome of the workshop was a set of priorities which AWWI would implement to fill the knowledge gaps identified and to support the permitting of lawful take while conserving eagles.

The first draft of this white paper was provided on October 17, 2011 to the more than 20 technical experts invited to participate in the mid-November Eagle Workshop. Invited technical experts were asked to provide comments to AWWI by October 31. A second draft of the white paper was prepared by AWWI staff on the basis of comments received, and on November 4, this draft was distributed to all workshop participants and discussed during a webcast open to all AWWI Sustaining Partners and Friends. The final pre-workshop draft of the white paper, incorporating comments from the webcast discussion, was distributed to invited participants and AWWI Sustaining Partners and Friends on November 9.[1] The workshop took place in Denver, CO, November 15-17, 2011. Results from the workshop were incorporated into a post-workshop draft, which was shared with invited technical participants for further comment. This white paper reflects this additional input.

[1] AWWI gratefully acknowledges the input of workshop participants that improved the style and substance of the white paper. AWWI assumes all responsibility for the white paper's content.

# I. Introduction

Eagles are protected under the Bald and Golden Eagle Protection Act (BGEPA), the Migratory Bird Treaty Act (MBTA), and various state laws. BGEPA states that it is unlawful for anyone to “take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import, at any time or in any manner, any bald eagle . . . or any golden eagle, alive or dead, or any part, nest, or egg thereof . . . .”[2] BGEPA further defines “take” as "[to] pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, molest or disturb individuals, their nests and eggs."[3] In delisting the Bald Eagle from the Endangered Species Act (ESA) in 2007, the Service issued a rule to further define disturb as “to agitate or bother a bald or golden eagle to a degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior."[4] In September 2009, the Service published a Final Rule (50 CFR 22.26) under BGEPA authorizing limited issuance of permits to “take” bald and golden eagles during otherwise lawful activity.

Generating electricity from wind can wound or kill eagles when they collide with turbine blades, and can also disturb eagles during construction and operation of the wind energy facility resulting in nest abandonment or displacement from breeding territories. In February 2011, the Service released “Proposed Guidance for Eagle Conservation Plans Module 1: Wind Energy Development” (Eagle Guidance; USFWS 2011b) to provide recommendations for the development of Eagle Conservation Plans (ECPs) for the issuing of programmatic take permits for wind energy facilities. The Eagle Guidance proposed procedures for applicants and biologists to assess potential risk to eagles and to implement conservation practices and adaptive management. Public comment on the Eagle Guidance was received by the Service until May 2011, and a revised version of the Eagle Guidance has been completed and is undergoing internal review; publication is anticipated in summer 2012 (Brian Millsap, U.S. Fish and Wildlife Service, personal communication).

Wind energy is projected to contribute significantly to a national strategy for meeting growing electricity demand while reducing production of greenhouse gases and other forms of air and water pollution, decreasing water consumption for power production (Averyt et al. 2011), diversifying national energy supplies, and reducing dependence on foreign energy supplies. The U.S. Department of Energy (DOE) has developed a scenario for obtaining 20% of U.S. electricity from wind energy by 2030 (DOE 2008). Generation of electricity from wind in 2010 was 2.3% of the total U.S. electricity generation in the U.S.[5] Thus, to achieve the DOE scenario, a substantial increase in installed wind capacity will need to occur in the next 18 years.

Bald and golden eagles are widespread in the contiguous United States, and most wind energy projects will have some overlap with breeding, wintering, or migrating individuals of one or both species. There are large areas of the U.S. where encounters with eagles will be rare or infrequent (e.g., see Good et al. 2007); thus the risk to eagle populations from wind energy development will vary

[2] U.S.Code § 668a
[3] Ibid.
[4] See http://cfr.regstoday.com/50cfr22.aspx; section 22.3 Definitions

[5] http://www.eia.gov/cneaf/solar.renewables/page/wind/wind.html

geographically. Nevertheless, the requirements of the Eagle Rule and Eagle Guidance and the widespread range of eagles in the U.S. represent a significant challenge to meeting the country's energy production goals.

To support the Service's implementation of the Eagle Guidance and to assist wind industry compliance with the Eagle Rule and Eagle Guidance, AWWI in collaboration with stakeholders from the wind industry, state and federal agencies, eagle experts, and the conservation community convened an Eagle Workshop in Denver, CO on November 15-17, 2011. The goals of the workshop were to describe the current state of our knowledge of bald and golden eagles and to identify research that would improve implementation of and compliance with the Eagle Guidance for wind energy development.

Specifically in the context of the Eagle Guidance, research needs were to be articulated under the following premises:

- Operating wind energy facilities may "take" eagles by collision with turbines and possibly by disturbance of eagles that results in nest abandonment or displacement (as further defined in BGEPA) and reduced productivity.
- Allowable eagle take reflects our understanding of the status and trends in eagle populations (or sub-populations), which includes the ability of populations to sustain increased mortality (see sidebar: *Establishing Take Thresholds for Bald and Golden Eagles*).
- Evaluation of the need for take permits will be determined by our ability to predict take, i.e., our ability to predict risk of a specific project to eagles and our ability to avoid and minimize this risk through the implementation of "advanced conservation practices" to the extent practicable (as defined in 50 CFR 22.26).
- When avoidance and minimization are insufficient to eliminate all predicted take, then compensatory mitigation may be required.[6]
- In those situations where compensatory mitigation is required, proposed mitigation must demonstrate a direct numerical offset of predicted take.

### *ESTABLISHING TAKE THRESHOLDS FOR BALD AND GOLDEN EAGLES*

As defined by BGEPA, take involves effects leading to injury, mortality, or reduced productivity. The Final Environmental Assessment for the 2009 Eagle Rule (USFWS FEA 2009) described the modeling methodology used by the Service to define allowable take for bald and golden eagles. The model included parameters estimated from available data on the status and trends in populations, annual productivity and age-specific survival, and existing mortality sources for both species. Model simulations resulted in estimates of sustainable "harvest" or take for each management unit as a small percentage of annual productivity. Detailed information was available on bald eagle nest distribution as a result of this species' delisting review, and this information was used in defining management units for this species. Similar information was not available for golden eagles, and management units for this species corresponded to Fish and Wildlife Service Bird Conservation Regions. Take thresholds are to be reviewed and updated every five years.

[6] Measures to offset eagle take will be required only when take thresholds for a particular eagle management unit are being exceeded.

Prior to the workshop, AWWI staff, with input from invited participants, prepared a synopsis of: 1) the known population status of bald and golden eagles in the contiguous U.S.; 2) sources of eagle mortality from wind energy development and other anthropogenic activities; and 3) potential measures for mitigating potential negative impacts of wind energy development on eagles, focusing primarily on information relevant to reducing take of eagles solely at wind energy facilities. This white paper does not explore the applications of this research and mitigation effort for addressing other related issues, though they may set the stage for such a discussion.

In preparing this synopsis it was readily acknowledged that there has been a longstanding and intensive focus on the conservation of both eagle species. Comprehensive species accounts were prepared and published for the Birds of North America series on bald eagles (Buehler 2000) and golden eagles (Kochert et al. 2002), and an update on the status of both species was prepared as part of the Final Environmental Assessment in support of the development of the Eagle Rule (USFWS FEA 2009a). In 2010 two workshops involving federal research scientists and wildlife managers reviewed the state of knowledge about golden eagles, including population status and threats, and defined research priorities (GOEA Colloquium 2010; GOEA Science Meeting 2010). This white paper relies heavily on the substantial body of knowledge for both species reflected in these efforts.

# II. Status and Trends of Bald and Golden Eagle Populations in North America

The population status and trends of bald and golden eagles are key elements in the application of the Eagle Rule and Eagle Guidance, as applied to eagle management units (see sidebar*: Establishing Take Thresholds for Bald and Golden Eagles* for the definition). The Service has stated (50 CFR 22.26) that programmatic permits will be issued when take is compatible with the preservation of eagles defined as consistent with the goal of stable or increasing populations. If the estimated take from a proposed project exceeds the established take thresholds for the relevant eagle management unit, the proposed activity must completely offset predicted take resulting in no net mortality increase.

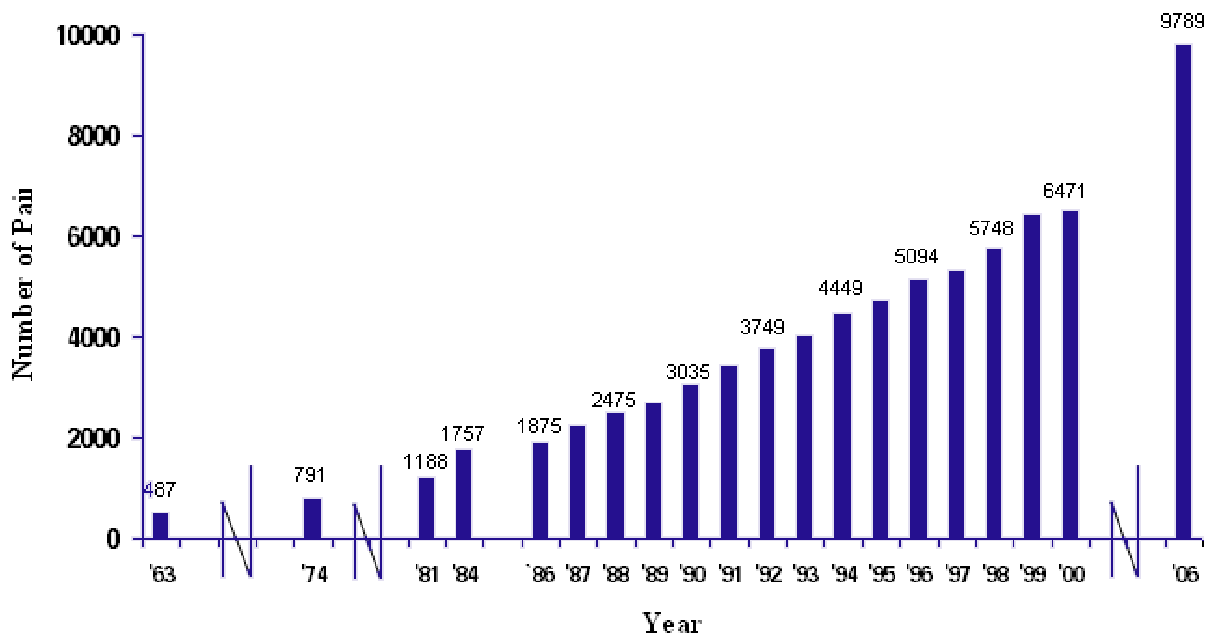
## A. Bald Eagle

Bald eagles were listed under the Endangered Species Act (ESA) in 1978. Prior to listing, population estimates in the contiguous U.S. comprised approximately 400 breeding pairs in the early 1960s (Figure 1), and the species had been extirpated from much of the eastern and southern U.S. (Buehler 2000). Low bald eagle numbers reflected centuries of persecution and, in the 1950s and 1960s, a decline in breeding success due to the widespread use of organochlorine-based pesticides. Some protection was afforded bald eagles with passage of the Bald Eagle Protection Act in 1940,[7] but bald eagle numbers began to increase substantially only after DDT was banned in the U.S. in 1972. Since that time the number of breeding pairs has increased rapidly and substantially to the point that recovery targets (e.g., 1,200 breeding pairs in the northern U.S.; USFWS 1983) were significantly exceeded in the late 1990s. The species was proposed for delisting in 1999, and, with the exception of the Sonoran Desert sub-population, the bald eagle was removed from the endangered species list in June 2007. The Sonoran Desert sub-population was delisted in September 2011. The bald eagle currently is considered a species of "Least Concern" by the

[7] Amended to include Golden Eagle in 1962, aka 'BGEPA'

**Figure 1. 2006 bald eagle breeding pairs in the contiguous United States**

Based on annual state surveys, which largely ceased after 2000.
From http://www.fws.gov/midwest/Eagle/population/chtofprs.html




International Union for Conservation of Nature (BirdLife International 2009).

Buehler (2000) provided an estimate of 100,000 individual bald eagles as of 1999 with the largest numbers in Alaska and British Columbia, and numbers may be substantially higher (USFWS 2009a). The last reliable estimate of the number of breeding pairs – more than 9,000 in the contiguous U.S. – comes from the national survey of 2006 (Figure 1). A national monitoring protocol for assessing future trends in bald eagles was developed as part of the delisting plan (USFWS 2009b) and was intended to work with state-based nest surveys.

Annual surveys of bald eagles remain a fixture in many states as the rapid increase in bald eagles from the lows of the 1950s and 1960s continues to be a newsworthy item – especially in states where the species had been extirpated.[8] Paradoxically, expanding and thriving bald eagle populations as well as tight budgets are causing many states to stop survey efforts, which will complicate the ability to monitor future status and trends in this species.

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[8] e.g., Ohio (http://newsdemocrat.com/main.asp?SectionID=2&SubSectionID=2&ArticleID=119620), Virginia (http://www.vagazette.com/articles/2011/09/09/news/doc4e68ac589a3a8109626317.txt), New Jersey (http://www.njherald.com/story/16351531/recovery-of-bald-eagle-in-nj-a-success-story), and Michigan (http://www.mlive.com/news/muskegon/index.ssf/2011/07/bald_eagle_population_continue.html), Arizona (http://www.azcentral.com/arizonarepublic/news/articles/2010/09/28/20100928arizona-bald-eagle-population-gain.html)

## B. Golden Eagle

Several long-term studies of golden eagles in different regions of the U.S. have raised concerns that this species is declining (Kochert and Steenhof 2002) – a tentative conclusion reached by the Service in its 2009 Final Environmental Assessment (USFWS 2009a) and shared by others (e.g., Katzner et al. 2012). Habitat changes that negatively affect the eagle prey base have been suggested as explanations for these declines. Eagle abundance may track fluctuations in preferred prey species, e.g., black-tailed jackrabbit, making it a challenge to separate cyclical declines from declines resulting from long-term habitat shifts or human disturbance (Kochert and Steenhof 2002; USFWS 2009a).

Stable or increasing trends of migrating golden eagles were reported in counts from the early 1970s to 2004 in eastern Canada and the eastern U.S. following a decline recorded between the 1930s and early 1970s (Kochert and Steenhof 2002; Farmer et al. 2008). In western North America, both longer-term (since the 1980s) and recent declines were indicated at most sites analyzed through 2005 (Smith et al. 2008). In the Great Basin, increases in adult detection rates but decreases in migratory immature golden eagles may indicate reduced reproduction (Hoffman and Smith 2003; Smith et al. 2008). In a recent review of current research and monitoring at the 2010 North American Golden Eagle Science Meeting (GOEA Science Meeting 2010), nine of the 28 regional reports estimated population status, and of these, six estimated declines in numbers based on territory occupancy or migration counts.

In 2003, the Service contracted with WEST, Inc. to design and conduct aerial surveys to provide statistically rigorous estimates of golden eagle abundance in four Bird Conservation Regions (BCRs) comprising an estimated 80% of the golden eagle population in the contiguous U.S. Good et al. (2007) described the methods and results for the initial pilot survey conducted in 2003. Surveys were not conducted in 2004 and 2005. Surveys were resumed in 2006 with a somewhat modified protocol and have been repeated annually from 2006 through 2011 using this same protocol and survey transects (Nielson et al. 2012). The estimated average number of golden eagles in the regions surveyed from 2006-2010 was approximately 23,000 (Table 1) with no statistically significant change in numbers detected over that period. Because the Great Plains BCR was not surveyed in 2011, no total was provided for that year (see Nielson et al. 2012 for further discussion). The total number of golden eagles classified as juveniles has declined significantly in two of the four BCRs. No significant trends in the numbers of golden eagles classified as juveniles have been observed in the Great Basin or Northern Rockies, or when analyzed across the entire study area during the same period (Nielson et al. 2012).

The surveys were designed to detect an average 3% change in eagle numbers per year over a 20-year period with a statistical power of 80% (alpha = 0.1) assuming surveys would be conducted annually. An inability to detect small changes is to be expected at this stage of the project, but larger changes could be detected. Kochert and Steenhof (2002) recommended that any survey of golden eagle populations should continue for a minimum of ten years because of possible fluctuations in numbers of eagles in response to prey cycles referenced earlier in this section.

The USGS, the Service, and WEST have developed a log-linear hierarchical model that integrates the WEST survey data and Breeding Bird Survey (BBS) data, and enables scaling of the BBS data to population density estimates. BBS data have been assumed to be of limited value for estimating golden eagle population levels (e.g., Kochert et al. 2002), but tests of the model indicate that BBS and WEST survey data provide consistent estimates of

## Table 1. Estimated population totals (all ages) of golden eagles in each Bird Conservation Region (BCR)

Excludes military lands, elevations > 10,000 ft, large water bodies, and large urban areas. Data from 2003 and 2006–2010 as estimated from WEST, Inc. aerial surveys (Nielson et al. 2012). Estimates for 2006-2010 were obtained by pooling observations across years to improve estimates of detection probabilities. Thus, estimates for 2006-2009 have been updated and are slightly different than those presented in previous reports. BCR 17 was not surveyed in 2011 and the total was not calculated. Ninety-percent confidence intervals are in parentheses.

| Year | Great Basin (BCR 9) | Northern Rockies (BCR10) | Southern Rockies/ Colorado Plateau (BCR16) | Badlands and Prairies (BCR17) | Total |
|---|---|---|---|---|---|
| 2003 | 10,939<br>(7,522; 15,754) | 4,831<br>(2,262; 8,580) | 4,998<br>(3,199; 7,275) | 6,624<br>(4,611; 9,207) | 27,392<br>(21,556; 35,369) |
| 2006 | 4,301<br>(2,687; 6,093) | 6,074<br>(3,594; 9,116) | 4,196<br>(2,728; 5,889) | 9,358<br>(6,448; 12,544) | 23,930<br>(19,545; 28,957) |
| 2007 | 6,043<br>(4,238; 7,955) | 7,150<br>(4,102; 11,209) | 2,714<br>(1,568; 4,022) | 9,025<br>(6,350; 11,995) | 24,933<br>(20,296; 30,664) |
| 2008 | 4,217<br>(2,830; 5,771) | 7,433<br>(5,039; 10,387) | 1,526<br>(804; 2,359) | 6,109<br>(4,076; 8,305) | 19,286<br>(15,802; 23,349) |
| 2009 | 4,812<br>(3,389; 6,397) | 7,185<br>(4,455; 10,873) | 2,588<br>(1,229; 4,153) | 6,011<br>(3,572; 8,777) | 20,597<br>(16,314; 25,666) |
| 2010 | 5,680<br>(3,542; 8,117) | 7,554<br>(4,831; 10,961) | 2,503<br>(1,361; 3,830) | 8,095<br>(5,158; 11,736) | 23,833<br>(18,948; 29,541) |
| 2011 | 6,199<br>(4,732; 8,555) | 6,862<br>(4,853; 9,994) | 2,917<br>(2,053; 4,228) | – | – |

population trends within the overlapping BCRs. Extension of this modeling approach to all BCRs encompassing golden eagle range and to the expanded time period provided by BBS surveys (1968-2010) could provide a more robust analysis of golden eagle population trends. Preliminary results based on this extension suggest that golden eagle populations appear to be stable over the time period and BCRs analyzed (Brian Millsap, U.S. Fish and Wildlife Service, personal communication). A paper is in preparation and will be submitted for peer-review and publication. Until the results are published, the approach and results should be considered preliminary.

# III. Anthropogenic Sources of Eagle Take

Accurate estimation of the causes and magnitude of anthropogenic sources of mortality (take) for bald and golden eagles – including wind energy development – is important for several reasons. First, modeling that sets current take thresholds incorporates assumptions of age-specific survival.

Second, reduction in mortality attributable to wind energy development requires a better understanding of the magnitude and risk factors associated with that mortality and development of practices that avoid and minimize fatalities. Third, if mitigation offsetting unavoidable take is required, mitigation opportunities and evaluation will be enhanced by an understanding of the importance of adult survival and productivity, defined as fledgling production/nesting, in affecting trends in eagle populations.

## A. Wind Energy – Vulnerability of Eagles

Eagles may collide with wind turbines, and an important part of the take permit application process is an accurate estimation of whether and how many collision strikes will occur at individual projects. Impact estimates are based on models that utilize a variety of assumed risk factors, such as activity levels in the project area and estimated relationships between exposure, avoidance, and collision risk (USFWS 2011). Estimates of eagle avoidance come from analysis of eagle activity and eagle fatalities at existing projects (e.g., Whitfield 2009, but see Ferrer et al. 2012). Fatality estimates come from comprehensive and systematic searches for all bird and bat carcasses, usually at a subset of turbines at a project. Fatality reports also come from "incidental finds," defined as carcasses not found as part of the standardize search process, but during maintenance or other visits to individual turbines at the project site. Fatalities are adjusted for various detection biases, which have been discussed thoroughly elsewhere (e.g., Huso 2011; Strickland et al. 2011). Any error in the estimation or application of these adjustment terms could lead to over- or under-estimated eagle fatality rates and, therefore, compromised risk predictions.

How many golden eagles are killed at wind facilities? The longest and most detailed record comes from the Altamont Pass Wind Resource Area (Altamont) in California, a 37,000-acre area containing approximately 4,500 mostly old-generation turbines in dense aggregations or turbine strings.[9] Large numbers of golden eagle fatalities (and raptor fatalities, in general) have been reported from Altamont (Table 2), but developing a consistent methodology for estimating golden eagle fatality rates at Altamont and comparing those estimates with other projects has been a challenge for a variety of reasons, including lack of consistent sampling of all turbine strings (due to access constraints); lack of site-specific scavenger adjustment factors; long search intervals and varying search protocols; and varying operation of turbine strings, in part related to attempts to mitigate avian fatalities. As a result, estimates of average annual Altamont-wide adjusted fatality rates vary considerably from 30 to 70 golden eagles per year (e.g., see Smallwood and Thelander 2008, Smallwood and Karas 2009, and ICF 2011 for details), and recent estimates of annual eagle fatalities between 1998 and 2008 have ranged from 15 to 50 golden eagles (ICF 2011).

Detailed studies of golden eagle behavior at Altamont suggest that most of the eagle fatalities have been sub-adults and non-breeding adults (floaters) because current home ranges of breeding eagles have kept them out of the project area (Hunt 2002). Population-level consequences of the high fatality rate are not certain. For example, all territories in the vicinity of the Altamont remained occupied after multiple years of tracking (Hunt and Hunt 2006), and there was no evidence for a lack of

[9] Construction of wind turbines at Altamont began in the 1960s and continued into the 1980s. Capacity of turbines installed during this period ranged from 40 to 400 kW; most turbines were 100 kW and 150 kW. Repowering at Altamont began in 2005, and large numbers of shorter, lower-capacity wind turbines are being replaced by fewer taller, higher-rated wind turbines.

## Table 2. Golden eagle fatalities compiled from publicly available reports and from the Altamont Pass Wind Resource Area (Altamont)

Eagle carcasses were located systematically ("carcass search") or incidentally, and these are reported separately for each project with the exception of Altamont where sources are combined. Fatality reports are not adjusted for searcher efficiency or scavenger removal. Time period corresponds to the the period of data collection. MW Capacity is total project capacity calculated as the nameplate capacity of individual turbines multiplied by the number of turbines installed. For Altamont, MW capacity and the number of turbines has declined since 1998, so a range or an approximation are presented. Full citations for reports are provided in the Literature Cited section.

| Project Name | State | Time Period | MW Capacity | # Turbines | # Fatalities | Method | Reference |
|---|---|---|---|---|---|---|---|
| Buena Vista | CA | 2008 | 38.00 | 38 | 1 | incidental | Insignia (2009) |
| Buena Vista | CA | 2008 | 38.00 | 38 | 2 | carcass search | Insignia (2009) |
| Diablo | CA | 2005-2007 | 20.46 | 31 | 1 | incidental | WEST (2006); WEST (2008) |
| Diablo | CA | 2005-2007 | 20.46 | 31 | 1 | carcass search | WEST (2006); WEST (2008) |
| Elkhorn | OR | 2010 | 101.00 | 61 | 1 | carcass search | Enk et al. (2011) |
| Elkhorn | OR | 2010 | 101.00 | 61 | 3 | incidental | Enk et al. (2011) |
| Foote Creek Rim (Phase I) | WY | 2001-2002 | 41.40 | 69 | 1 | incidental | Young et al. (2003d) |
| Goodnoe | WA | 2009 | 94.0 | 47 | 1 | carcass search | URS (2010) |
| High Winds | CA | 2005 | 162.00 | 90 | 1 | incidental | Kerlinger et al. (2006) |
| High Winds | CA | 2005 | 162.00 | 90 | 1 | carcass search | Kerlinger et al. (2006) |
| Pine Tree | CA | 2009-2010 | 135.00 | 90 | 1 | unknown; not in the report | BioResource Consultants (2010) |
| Shiloh 1 | CA | 2009 | 150.00 | 100 | 1 | carcass search | Kerlinger et al. (2010) |
| **Altamont-wide** | **CA** | **1998-2007** | **480-556** | **~5,000** | **495** | **carcass search and incidental** | **Smallwood and Karas (2009)** |

available non-breeding adults to replace annual losses among breeders. Nest productivity in the Altamont vicinity, however, is not sufficient to replace estimated collision fatalities (Hunt and Hunt 2006). Altamont eagle studies were begun after installation and operation of wind turbines. Suitable nesting sites can be found in the Altamont. It is possible that eagles nested in the area prior to development of the wind energy facilities, although no golden eagles currently nest within the Altamont boundaries (Grainger Hunt, Peregrine Fund, personal communication).

For a variety of reasons Altamont fatality numbers may be an outlier with regard to golden eagle fatalities at wind energy facilities. In addition to the characteristics mentioned earlier (i.e., the dense configuration of older-generation turbines), high prey densities and lack of breeding eagles possibly attract sub-adults and floaters to the Altamont, contributing to the high activity and high fatality rates. In addition, the limited amount of repowering that has occurred at Altamont suggests that eagle (and raptor) fatality rates will decline as the older turbines are replaced by fewer, taller, and higher power-rated turbines. Initial results of the repowering suggest that golden eagle fatality rates could decline by more than 80% with complete turbine replacement and comparable power output (Insignia 2009; Smallwood and Karas 2009; ICF 2011).

A search of publicly available reports for 72 wind energy projects representing more than 7,000 MW of installed capacity also suggests that Altamont fatality rates are unusually high. A total of 15 golden eagle fatalities between 2001 and 2010 were recorded at eight of the 72 projects conducting systematic carcass searches satisfying specific selection criteria;[10] at the remaining 64 projects, of which all but one overlapped with some portion of golden eagle breeding and non-breeding range, there were no reports of eagle fatalities (Table 2).[11] The public reports noting eagle fatalities included a combination of systematic carcass surveys and incidental finds. Total project capacity and number of turbines are also provided for projects with eagle fatality reports to facilitate comparison amongst the projects and Altamont.

Additional data are available in a separate compilation of eagle fatalities covering a multiple year period, prepared by the Service. Service regional offices reported five bald eagle and 54 golden eagle fatalities at wind energy facilities other than Altamont, with most fatality reports originating between 2006 and 2011 (Table 3; Pagel et al. 2011; Brian Millsap, U.S. Fish and Wildlife Service, unpublished data).[12] Fatality reports are mostly incidental and not the result of systematic searches, and project location details are not available. The 29 golden eagle fatalities from Wyoming involved eight wind energy projects that occur within close geographic proximity (Brian Millsap, U.S. Fish and Wildlife Service, personal communication). The compilation also includes 14 golden eagle fatalities from California, but it is uncertain as of this writing whether that total includes the 2010 and 2011reports of golden eagle fatalities at the Pine Tree Wind Energy Facility near Tehachapi, CA.[13]

We are not able to determine the degree of overlap between these different summaries, although there likely is some overlap. The public reports cover a slightly longer period than that covered in the Service reports, and do not include “incidental” fatalities reported elsewhere (e.g., Anderson et al. 2004) that do not meet the criteria for inclusion in the summary of public reports described above. These different sets of data do suggest that the situation at Altamont is unusual, and that collision risk to eagles varies among wind energy projects. Preliminary analysis of data from 13 wind projects in the western U.S. sorted by “fatalities” or “no fatalities” showed a large separation in these two

[10] Included reports satisfied the following criteria: 1) bias trials were used to adjust fatality estimates; 2) surveys took place during all seasons of occupancy; and 3) used accepted protocols in search and data summaries.

[11] For references on additional sites consult Strickland et al. 2011.

[12] Data are currently under Service review and may change.

[13] http://articles.latimes.com/2011/aug/03/local/la-me-wind-eagles-20110803 and http://articles.latimes.com/2012/feb/16/local/la-me-eagles-20120216 for a recent report of two eagle fatalities

## Table 3. Eagle fatalities reported at wind energy facilities in the U.S.

Data in this report were compiled from reports provided by each of the U.S. Fish and Wildlife Service Regional Offices. The data reflect the results of systematic surveys as well as incidental observations provided to the Service by wind energy developers and their consultants. Data were reported by Service regional offices and compilation by state was done by AWWI staff. Data summary does not include summaries from Altamont Pass Wind Resource Area or reports from regional offices where no take reports were received. It was presumed that the absence of a report from a region indicated an absence of known fatalities (Brian Millsap, USFWS, personal communication).

| State/Province | Bald Eagle | | Golden Eagle | |
|---|---|---|---|---|
| | Date | # | Date | # |
| California | _ | _ | 2006-2011 | 14 |
| Iowa | 2011 | 1 | _ | _ |
| New Mexico | _ | _ | no date | 5 |
| Ontario | 2010-2011 | 2 | _ | _ |
| Oregon | _ | _ | 2009-2011 | 5 |
| Washington | _ | _ | 2009 | 1 |
| Wyoming | 2010-2011 | 2 | 2009-2011 | 29 |

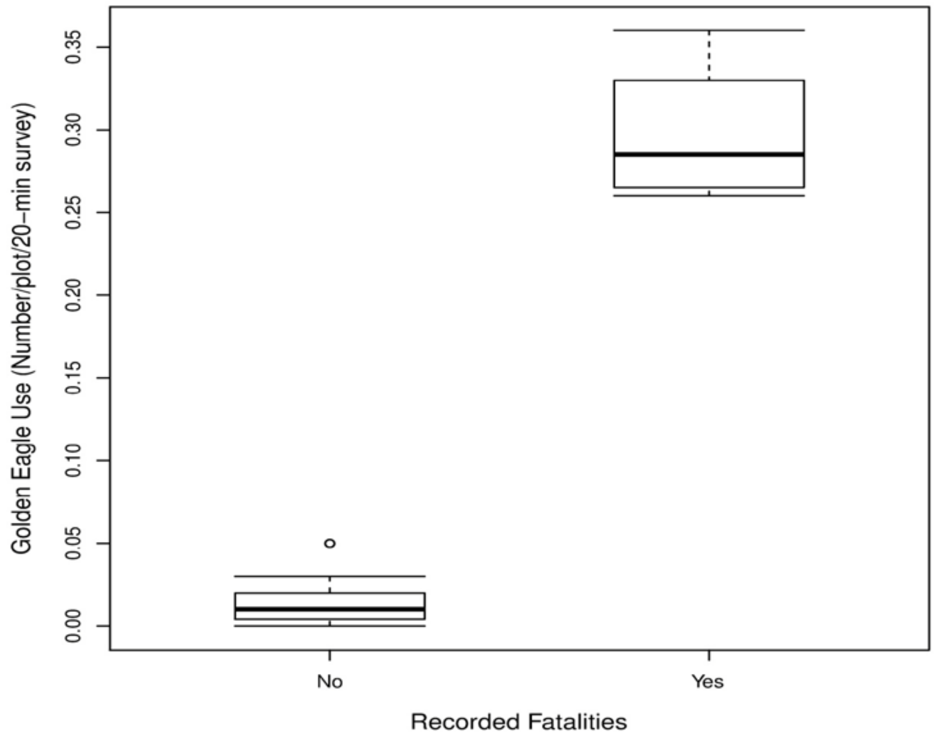
categories based on pre-construction estimates of activity (Figure 2). Specific behaviors may also increase golden eagle vulnerability to collision. Hunt (2002) suggested that prey availability and topographic conditions interact to create a high-risk area for golden eagles at Altamont. High abundance of ground squirrels is promoted by habitat management for the federally endangered San Joaquin kit fox, and the data suggest that eagles are most vulnerable to blade strikes while hunting (e. g., Hunt 2002).

A more salient question is the proportion of the "true" number of eagle fatalities collectively or at individual projects. Accurately estimating this proportion will depend on accurate estimation of the different biases including: 1) searcher efficiency – if an eagle is present in a search plot what is the probability of it being found; 2) scavenging rate – what is the rate at which scavengers remove eagle carcasses from search areas; 3) areal bias – what proportion of the area where eagle carcasses occur is searched; and 4) background mortality – what proportion of eagle carcasses located were the result of collision strike versus other causes? The size of the adjustments for the first two factors is influenced by vegetation cover and topography. Searcher efficiency for large raptors has been variously estimated between 80 to 100% (e.g., Anderson, et al. 2004; Whitfield 2009; Strickland et al. 2011). Scavenging losses are estimated to be low, but there are challenges in using appropriate surrogate carcasses for estimating scavenging on eagles (e.g., Whitfield 2009). Background mortality, or mortality from other sources, is rarely estimated. Where it has been estimated for all bird species, background mortality has been substantial (Johnson et al. 2000; Olson 2001), but comparable data do not exist for eagles.

The Service data reported above (Pagel et al. 2011) are noteworthy in that they represent some of the first confirmed fatalities of bald eagles at wind energy projects. The lack of bald eagle fatality data

## Figure 2. Average pre-construction golden eagle use values for facilities with and without observed golden eagle fatalities

Erickson 2011; compiled by WEST, Inc.




**Data from the following sources:**

| Wind Energy Facility | Use Estimate | Fatality Estimate |
|---|---|---|
| Campbell Hill, WY | Taylor et al. 2008 | WEST 2012 *In preparation* |
| Combine Hills, WA | Young et al. 2003c | Young et al. 2006 |
| Diablo Winds, CA | WEST 2006 | WEST 2006, 2008 |
| Elkhorn, OR | WEST 2005 | Enk et al. 2011 |
| Foot Creek Rim, WY | Johnson et al. 2000 | Young et al. 2003b |
| Grand Ridge, IL | Derby et al. 2009 | Derby et al. 2010 |
| Hopkins Ridge, WA | Young et al. 2003a | Young et al. 2007 |
| Klondike, OR | Johnson et al. 2002 | Johnson et al. 2003 |
| Leaning Juniper, OR | Kronner et al. 2005 | Kronner et al. 2007; Gritski et al. 2008 |
| Nine Canyon, WA | Erickson et al. 2001 | Erickson et al. 2003 |
| Stateline, OR/WA | Erickson et al. 2002 | Erickson et al. 2004b |
| Vansycle, OR | Erickson et al. 2002 | Erickson et al. 2000 |
| Wild Horse, WA | Erickson et al. 2003b | Erickson et al. 2008 |

makes it impossible to evaluate relative vulnerability of bald eagles to collision fatality. A recent observational study conducted at a small wind energy facility on Pillar Mountain, Kodiak Island, AK in 2006-2007, 2010, and 2011, indicated that bald eagles actively avoided operating wind turbines at this facility (Sharp et al. 2011). No bald eagle fatalities have been recorded at the Pillar Mountain wind project, although no systematic surveys have been conducted (Lynn Sharp, Tetra Tech, personal communication). Substantial numbers of fatalities have been reported for white-tailed eagles, a congener of the bald eagle, in Smøla, Sweden where 41 fatalities have been reported at this coastal wind energy facility during the last five years (Nygård 2011).

Although assessment of the impact of wind energy development on eagles has focused on collision fatalities, the definition of take also includes reductions in productivity due to direct disturbance effects causing lower nest productivity, or indirect effects that include abandonment of nesting territories or foraging areas. The models the Service uses to estimate eagle take thresholds weigh the consequences of these types of take differently (USFWS 2009a). It is important therefore, to understand the relative importance of collision fatalities versus avoidance behavior leading to displacement and productivity declines to best inform risk assessment and mitigation practices (see USFWS 2009a). There are, however, too few studies examining the effects of wind energy development on nesting raptors, in general (e.g., Madders and Whitfield 2006), and golden eagles, in particular (e.g., Gregory 2010, Johnson et al. 2000; Young et al 2010), to estimate the scope and importance of such effects. (See more detailed discussion below.)

## B. Other Anthropogenic Contributors to Eagle Mortality and Threats to Eagles

Sources of anthropogenic eagle mortality include electrocution, shooting, collision, poisoning, and in the eastern U.S., incidental trapping (Katzner et al. 2012). Systematic, unbiased estimates of the relative frequency and magnitude of these sources of eagle take generally are not available. Under-reporting may be common and variation in detection is likely; carcasses from electrocution or collision are more likely to be found, while other sources of mortality that are latent in effect, such as poisoning, may go relatively undetected. Multiple compilations have been conducted based on searches of available sources, but lack of consistent and systematic reporting and detection bias limits our ability to extrapolate these compilations accurately to a population context.

Wood et al. (1990, cited in Buehler 2000) reported a summary of 1,428 individual bald eagles necropsied by the National Wildlife Health Center (NWHC) from 1963 to 1984. Of these individuals, 329 (23%) died from trauma, primarily impact with wires and vehicles; 309 (22%) died from gunshot; 158 (11%) died from poisoning; 130 (9%) died from electrocution; 68 (5%) died from trapping; 110 (8%) from emaciation; and 31 (2%) from disease; cause of death was undetermined in 293 (20%) of the cases.

Kochert et al. (2002) reported that humans caused over 70% of recorded golden eagle deaths, directly or indirectly. Accidental trauma (collisions with vehicles, power lines, or other structures) was noted as the leading cause of death (27%), followed by electrocution (25%), gunshot (15%), and poisoning (6%) (Franson et al. 1995, cited in Kochert et al. 2002). Ingesting poisoned carcasses intended for mammalian predator control and ingestion of lead shot (30-50% of eagles tested with elevated blood levels) was also an important source of mortality.

## Table 4. Anthropogenic sources of eagle mortality 2006-2011

Fatality numbers and percentages are derived from TetraTech (2011). The factors listed below do not include all factors potentially affecting eagle numbers such as loss and deterioration of foraging and nesting habitat, which are thought to be important but have yet to be systematically quantified.

| Mortality Source | Bald Eagle Fatalities | | Golden Eagle Fatalities | |
|---|---|---|---|---|
| | # | % | # | % |
| vehicle strike | 199 | 5.8% | 119 | 4.5% |
| aircraft strike | 85 | 2.5% | 36 | 1.4% |
| train strike | 28 | 0.8% | 1 | 0.0% |
| wire collision | 22 | 0.6% | 27 | 1.0% |
| collision/electrocution | 33 | 1.0% | 0 | 0.0% |
| electrocution | 357 | 10.4% | 1,316 | 50.0% |
| turbine blade collision (Altamont) | N/A | 0.0% | 565 | 21.5% |
| turbine blade collision (other) | 1 | 0.0% | 12 | 0.5% |
| unknown collision | 36 | 1.1% | 10 | 0.4% |
| gun shot | 737 | 21.5% | 138 | 5.2% |
| trap | 195 | 5.7% | 42 | 1.6% |
| poisoning | 1,257 | 36.8% | 349 | 13.3% |
| illegally taken | 18 | 0.5% | 4 | 0.2% |
| unknown trauma | 452 | 13.2% | 11 | 0.4% |
| **Total** | 3,420 | 100.0% | 2,630 | 100.0% |

Eighty to 100 golden eagles were reported killed on highways near Rock Springs, WY, in winter 1984–1985 (Phillips 1986). More than 200 golden eagles were electrocuted in Wyoming during an 18-month period between 2007 and 2009.[14]

A more recent review of the literature and databases concerning eagle fatalities found documentation of 6,956 bald eagle and 3,715 golden eagle fatalities recorded in the contiguous United States since 1960 (Tetra Tech 2011), of which 3,420 bald eagle and 2,630 golden eagle fatalities recorded since 2006 (Table 4). Fifty percent of all (natural and human-caused) bald eagle fatalities and 35% of golden eagle fatalities were from undetermined causes (Tetra Tech 2011). Of the known human causes of fatality, poisoning (37%), shooting (22%), electrocution (10%), and accidental trauma (as defined above, 11%) were the most commonly reported fatality sources for bald eagles; the remaining 20% included illegal take, trapping, and unknown trauma (Tetra Tech 2011). Golden eagle fatalities with known causes were dominated by electrocution (50%), collisions with wind turbines at Altamont (21%), and poisonings (13%); the remaining 16% included several sources such as accidental trauma, trapping, and shooting. This study reported only 12 eagle fatalities at wind energy facilities other than Altamont (Tetra Tech 2011) – fewer than the

[14] e.g., www.ens-newswire.com/ens/jul2009/2009-07-14-092.html

numbers reported in the survey of 72 publicly available reports described earlier, but that study contained a few additional reports that did not meet the criteria of the previously described survey.

Hunt (2002) recorded the deaths of 100 radio-tagged eagles during his seven-year study. Wind turbine blades killed at least 42 eagles, although he concluded that the actual number may have been higher because the blades occasionally destroyed the transmitter. Twelve eagles were electrocuted, all outside Altamont. Altogether, human-related fatalities, including wire strikes, vehicle strikes, and poisoning, accounted for at least 68% of the total (Hunt 2002); the remaining 32% died either through natural or otherwise unknown causes. Use of transmitters that provide the ability to locate carcasses is a promising technique for systematically obtaining eagle mortality data, although potential biases remain if significant numbers of instrumented eagles are not recovered (Hunt 2002).

Elevated blood lead levels are prevalent and quantifiable in both eagle species, and may have significant impacts on eagle populations. For example, elevated lead levels may contribute indirectly to eagle mortality by weakening eagles and reducing their ability to hunt or by making them more susceptible to the sources of mortality mentioned above, e.g., collision and electrocution (Redig 1979). Lead poisoning was reported in 338 bald and golden eagles turned in from 34 states to the NWHC from 1963 to the early 1990s (Franson et al. 1995 cited in Buehler 2000). Kramer and Redig (1997) noted a high incidence of lead poisoning: 138 out of 634 bald eagles admitted to the Raptor Center at the University of Minnesota (Raptor Center) from 1980 to 1995 had elevated blood lead levels.

The primary source of lead was thought to be lead shot used in waterfowl hunting. In 1991, lead shot was banned from hunting in federal areas, and this ban was implemented statewide in Minnesota and Wisconsin. Lead shot was banned from the range of the California condor in California in 2008. Both situations showed that decline in blood lead levels can be rapid following a ban. Between 1991 and 1995, although there was no significant change in the incidence of lead poisoning in eagles admitted to the Raptor Center, there were declines in the percentage of eagles with blood levels considered either fatal or clinical – from 50% pre-ban (N = 72) to 36% post-ban (N = 66) (Kramer and Redig 1997). Eagles admitted to the Raptor Center for miscellaneous trauma had sub-clinical blood lead levels consistent with the view that chronic lead exposure decreases an eagle’s ability to hunt or increases risk of injury (Redig 1979). In California, Kelly et al. (2011) reported declines of golden eagles with elevated blood lead levels (> 10 µg/dL) from 77% of those sampled (N = 17) to 32% (N = 38) one year after the 2008 ban. The persistence of a substantial incidence of lead poisoning in eagles suggests ingestion of lead from other sources, such as disintegrated bullets in ungulate carcasses (e.g., Hunt et al. 2006).

Other contaminants and toxins also kill eagles or result in reduced productivity and recruitment and the extensive source list includes carbofuran, DDT and dieldrin, famphur, heptachlor, mercury (bald eagles), pentobarbitol, phorate, secondary anti-coagulant, strychnine, and thallium to cite several [see Buehler et al. (2000) and Kochert et al. (2002) for more detail].

Most discussions of threats to eagle species focus on mortality, but indirect factors, such as loss of foraging and nesting habitat resulting in reduced productivity, also are assumed to be important threats (e.g., Buehler 2000 and references cited therein). As part of the bald eagle recovery efforts, for example, buffer zones around nests have been implemented routinely to protect nesting eagles from disturbance and habitat alterations (e.g., Mathisen et al. 1977). More recently, oil and gas development has been associated with reduced nesting of raptors, including golden eagles in Wyoming and Utah (Smith et al. 2010).

The predicted effects of climate change are thought to be the greatest threat to all wildlife,[15] but the ecological implications of a warming climate on eagles are just beginning to be addressed. Both eagle species range across multiple climate regions and have broad prey bases. Bald eagles in Michigan nest nearly a month earlier at present than in the 1960s when monitoring began; the mean egg-laying date is 12.4 days earlier in 2006 versus 1988. In Arizona, wintering bald eagles are concentrating approximately 30 miles farther north and 2,000 feet higher in elevation since the 1970s (Terry Grubb, U.S. Forest Service, personal communication). Effects of climate change may include changes in distribution and abundance of prey animals due to vegetation changes in response to warming or changes in environmental conditions at the onset of nesting. In the Great Basin, climate change is predicted to exacerbate the negative impacts of altered fire regimes and invasive annual grasses on the quality of golden eagle habitat (Wagner 1998). Given the presumed importance of prey availability as a factor limiting golden eagle productivity, modeling the effects of climate projections on eagles should be a high priority.

# IV. Mitigating Eagle Take

Under the current draft Eagle Guidance, procedures (aka "Advanced Conservation Practices") are described for avoiding and minimizing take of eagles in the development of wind energy facilities. After such procedures are followed and there remains unavoidable take, wind energy developers are asked to obtain programmatic take permits to legally enable incidental take of eagles. For bald eagles, at present, these permits can be issued assuming that the take threshold for a management unit is not exceeded (USFWS 2009a). For golden eagles, modeling has predicted that additional mortality would lead to population declines. Therefore, to receive a programmatic take permit, the developer would be required to implement compensatory mitigation that numerically offsets predicted fatalities to result in a net take of zero (aka "no net loss"). This offset could be accomplished by reducing take from another source (reducing mortality) or, in theory, by increasing eagle carrying capacity either through increases in productivity (number of fledged young) or post-fledging survival.

The challenge is developing a menu of scientifically justifiable options for numerically offsetting take at wind energy facilities. For example, electrocution at power poles is assumed to be a significant source of eagle mortality, and there are models that can predict the number of eagle fatalities avoided with retrofitting of problem poles. The Service has proposed power-pole retrofitting as one mechanism for offsetting eagle take, but additional options are needed.

The AWWI Eagle Workshop developed a list of potential mitigation options (Appendix A) that included reductions in eagle mortality from natural and anthropogenic sources and improving eagle productivity. Options included mitigating vehicle and train collisions, poisoning, shooting, and incidental trapping; reducing human activity that disturbs eagles causing reductions in nest occupancy or nestling survival; and management that enhances eagle carrying capacity by improving habitat in the breeding or wintering range.

As described previously, lead contamination from ingesting lead shot or bullet fragments in scavenged carcasses is widespread in eagles and a significant conservation concern (Kramer and Redig 1997; Hunt

[15] e.g., www.fws.gov/home/climatechange/impacts.html

et al. 2006). Implementing mechanisms to reduce eagle blood lead levels may present insurmountable challenges to wind energy developers and operators who might propose that as mitigation. We are also not aware of models that link elevated blood lead levels to eagle mortality or productivity. Despite these challenges, reducing lead contamination of eagles should be a major conservation priority even if this effort may not be useable for mitigating impacts on eagles at the project level.

Eagles are sometimes struck by vehicles or trains while feeding on carcasses of other wildlife on highways or train tracks. In some areas such collisions occur each year, and in substantial numbers (e.g., Phillips 1986). Where scientifically credible estimates of vehicle fatalities are available, a possible compensatory mitigation strategy would be to relocate carcasses away from roadways or tracks frequently enough to eliminate this cause of eagle mortality. Estimates of mortality from collisions from prior years could serve as a measure of the effectiveness of the mitigation action. Again, translating number of carcasses removed to a reduction in eagle fatalities needs to be modeled.

Reducing eagle take at existing wind energy facilities also has been suggested as mitigation for take at future projects. As described earlier the number of golden eagle fatalities at Altamont is large in comparison to all other projects. Repowering and other activities have been proposed at Altamont to achieve a 50% reduction in avian fatalities, and results to date suggest that repowering could accomplish even higher reductions.

Protecting golden eagle nest sites from sources of anthropogenic disturbance, such as recreational camping, climbing, off-highway vehicles (OHVs), and persecution from sheepherders, is another potentially effective mitigation alternative. Another approach to mitigation would involve habitat management that enhances eagle productivity and/or adult survival. Managing prey habitat in parts of the range where productivity is thought to lag could, in theory, effectively offset increased mortality by improving eagle productivity. Such increases would need to reflect a sustained increase in carrying capacity.

The menu of potential mitigation options is large, but we lack credible models estimating the impacts of these various mitigation options in offsetting eagle take. Developing these models is a major research priority discussed more fully below.

# V. Research and Conservation Priorities

Research on bald and golden eagles has taken on a renewed sense of urgency with the publication of the 2009 Eagle Rule, which identifies concerns about possibly declining golden eagle populations and risks to eagles of expanding wind energy development. In addition to the recent AWWI Eagle Workshop there have been numerous initiatives to define research priorities, particularly for golden eagles. The results of these efforts and resulting research initiatives were integrated into an evaluation of research priorities for the AWWI Research Program; these priority setting exercises are summarized in Appendix B.

Participants at the Workshop helped identify the following wind energy-eagle research areas (not listed in order of priority):

- Identifying and addressing information gaps on demography and status, particularly for golden eagles, relevant to calculating take thresholds.
- Developing unbiased estimates of eagle mortality.
- Creating models for avoidance and minimization siting and operational

strategies that reduce eagle fatalities at wind energy facilities.

- Expanding options for compensatory mitigation that offsets take at wind energy facilities.
- Coordinating and enhancing existing collaborative eagle research.

As part of the evaluation of AWWI's role and contribution to the above research priorities, we used the following criteria modified from the Research Plan that was approved by the AWWI Board on July 21, 2011:

- Supports or complements but does not duplicate, existing activities, e.g., Service-USGS Integrative Research when scientifically appropriate.
- Emphasizes near-term results to inform decision-making and regulation.
- Applies across a broad geographic range OR addresses a critical issue.
- Takes advantage of the AWWI Research Information System.
- Lays the groundwork to address long-term research questions.
- Is conducted with the highest standards and scientific rigor, and is subject to independent peer review.
- Offers a distinctive AWWI role.
- Attracts funding from public and private sectors.

Workshop participants also agreed that for the near term, AWWI should emphasize research on golden eagles that is directly relevant to wind energy development. Bald eagle populations appear to be thriving, although continued monitoring will be necessary to determine whether this trend continues. Expanding (and expanded) bald eagle populations will be confronted with increasing human development, and the sensitivity of bald eagles to this development is not completely understood (see Millsap et al. 2004). Wind energy development in coastal areas and near shore also is anticipated to increase, and the experience of white-tailed eagles in Sweden with wind energy development raises concerns that wind energy development could pose a greater risk to bald eagles in the future. Thus, it is important to understand bald eagle behavior as it relates to collision risk, and to determine the sensitivity of bald eagle nesting success to the proximity of operating wind energy facilities. Projects currently proposed in areas important for bald eagle nesting and foraging offer opportunities to study bald eagle interactions with wind facilities.

After thorough consideration of the research topics listed above, AWWI has chosen to focus over the next 12 months on expanding options for compensatory mitigation while continuing to identify, support, and collaborate with other research initiatives, as appropriate. A more detailed discussion of the research priorities, and AWWI's possible role and participation follows.

### *Expanding options for compensatory mitigation that offsets golden eagle take at wind energy facilities*

In the next 12 months, AWWI's top priority for addressing the challenge of wind energy development and eagle conservation will be to expand options for compensatory mitigation. AWWI in collaboration with technical experts and government agency staff will lead an expert elicitation process (e.g., Kuhnert et al. 2010) to develop alternative management scenarios that will increase either golden eagle productivity or adult survival and thereby offset golden eagle take at wind energy facilities.

Utilization of mitigation options would not be limited solely to wind energy facilities, but would have broad applications for offsetting eagle take from other anthropogenic sources as well as enhancing general golden eagle management. Mitigation options would focus on management that would increase eagle carrying capacity through habitat management, thus increasing productivity and adult survival, or by reducing anthropogenic sources of eagle mortality.

A possible extension of this project would entail working with wind energy companies to evaluate models developed through expert elicitation at proposed or existing wind energy facilities where a programmatic take permit is desired. Results of this evaluation would be used to adjust the models with subsequent application at new or other existing projects.

This project will expand and improve mitigation strategies for eagles, as discussed at the AWWI Eagle workshop. Expert elicitation is recognized and accepted as a valid scientific technique, and one that is appropriate when insufficient data are available, but there is a pressing need to make management decisions. AWWI has begun a scoping process for the project with the goal of providing new mitigation options by the end of the 2012 calendar year.

### *Identifying and addressing information gaps on demography and status, particularly for golden eagles relevant to calculating take thresholds*

Workshop participants emphasized the importance of this topic. Specific recommendations included linking population size, productivity, and age and sex ratios to effects on demographic rates. The possible impact of fluctuations in the prey base (e.g., jackrabbits, prairie dogs) or other covariates on eagle demography and adult survival is well recognized, but needs much greater research emphasis. The Service and USGS Integrative Research Collaboration (see Appendix B) along with other research efforts (e.g., BLM California desert, Todd Katzner, West Virginia University, personal communication) are addressing these questions, but more work is needed. AWWI will support these activities as appropriate.

### *Developing unbiased estimates of eagle mortality*

Estimates of eagle mortality from different sources are an important component of take threshold models. To more systematically develop these estimates, the Service and USGS have plans to attach satellite transmitters to more than 100 golden eagles across multiple eagle management units. Transmitters will enable Service staff to locate dead eagles and perform a detailed necropsy to determine the cause of death (McIntyre et al. 2006). Application of this technology may ultimately provide our best and most unbiased estimate of the various anthropogenic and natural sources of eagle mortality, although sample sizes will be limited by cost. More systematic mortality data will also support the evaluation and modification of the prior models described earlier. To reduce bias, eagles selected for instrumentation should come from a broad geographic area independent of any particular source of eagle fatalities. AWWI will coordinate with the Service to develop accurate estimates of eagle fatalities at wind energy facilities and help publicize and distribute the results of the telemetry project.

### *Creating models for avoidance and minimization siting and operational strategies that reduce eagle fatalities at wind energy facilities*

In order to receive a programmatic take permit, the applicant must demonstrate that all applicable and scientifically supportable measures have been taken to avoid take through relevant siting and management practices. Workshop participants suggested that AWWI: 1) review existing data to develop models on the types of factors that have influenced take of golden eagles; 2) review the

Service's risk model by applying data and assessing the models' strengths and weaknesses, comparing and contrasting with other models that are available; and 3) further develop or revise the Service's explicit model for predicting mortality risk. These activities would help determine what questions currently are unanswerable and what new data or changes to existing data collection are needed. Workshop participants suggested an initial focus on steps 1) and 2). Step 3) would be a longer-term initiative to be accomplished through a collaborative RFP-driven process that would ask investigators to propose additional research topics. AWWI will support the Service-USGS efforts in this area.

### *Coordinating and enhancing existing collaborative eagle research*

Although this priority is last on the list, it is an area where AWWI is well-positioned to contribute. AWWI is developing a wind-wildlife research database (Research Information System – RIS) to enable rigorous analysis of wind-wildlife data in a secure environment. The database also will provide a web-based platform for searching publicly available reports and current research activities including research and reports on golden eagles relevant to the goal of reducing the impacts of wind energy development on this species. Several research activities are underway including the Service-USGS Integrative Research Project (see Appendix B), activities lead by the Service's Region 8, and numerous ongoing projects, which include telemetry and contaminants analysis (described in GOEA Science Meeting 2010). Leveraging existing data and coordinating research efforts are important, especially in a time of declining public and private budgets devoted to wildlife research.

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# Appendix A: Potential Sources of Compensatory Mitigation for Offsetting Take of Golden Eagles at Wind Energy Facilities

As discussed by participants at the AWWI Eagle Workshop
Denver, CO, November 15-17, 2011

**A. Habitat management: How can we enhance productivity and survival?**

1. Define terms clearly:
    a. Productivity is measured as the number of fledged young per nest.
    b. Survival is defined from post-fledging.
2. Identify the limiting factors for golden eagle productivity and survival.
    a. Research results might help us predict strategies for avoiding impacts.
3. Focus on research needed to define habitat management or restoration that will achieve no net loss.
    a. A literature review would be useful.
    b. Management needs to result in increased eagle carrying capacity.
    c. Study areas where eagles are thriving to identify the key components of high-quality habitat.
        i. Short-term research – how best to increase or selectively reduce abundance of eagle prey (e.g., prairie dogs)
        ii. Identification of prey species, prey ecology, and survival
        iii. Understanding of factors that help augment abundance of ground squirrels, jack rabbits and other key prey species
        iv. Role of non-native invasive species, such as cheat grass and investigate mechanisms for restoring native vegetation
4. Look at supplemental feeding in the winter to increase of survival of sub-adults and adults.

**B. Land protection: How best protect the quantity and quality of habitat?**

1. Define how many acres of habitat protection are necessary to offset predicted take.
2. Address decline of quantity and quality of habitats.
    a. Potentially focus on intermediate-quality areas.
3. Preserve existing high-quality habitat.
    a. Purchase conservation easements.

**C. Artificial nesting structures: What is the feasibility of encouraging or discouraging nesting in a territory?**

1. Evaluate proximity to (or recommended distance from) development.
2. Locate artificial nests closer to better prey concentrations.
3. Measure net benefit to species.

**D. Direct mortality offsets: Which are the most important options to investigate in the short term?**

1. Identify the metrics to evaluate effectiveness, including cost.
2. Develop options at a geographic scale appropriate for the eagle management unit, e.g., by BCR or some other relevant management scale.
3. Evaluate feasibility of reducing eagle fatalities from other sources.
   a. Reduce mortality from vehicle collisions by removing road kill carcasses from roads. (Can we identify the roads where there are kills?)
   b. Shift to non-toxic ammunition (hunter education/voluntary lead abatement).
   c. Reduce stock tank drowning.
   d. Reduce unintentional poisoning.
   e. Implement reward system to reduce poaching.
   f. Mark fences to reduce collisions.
   g. Reduce impacts of secondary trapping (e.g., by covering bait).
4. Evaluate cost-effectiveness of funding programs.
   a. Fund eagle rehabilitation centers.
   b. Fund livestock depredation compensation programs and compensate landowners that protect eagles.
   c. Decommission or repower old wind projects.
5. Improve management of public recreational activities (e.g., off-road vehicle management, climbing) that reduce eagle productivity.

# Appendix B: Compendium of Priority Golden Eagle Research Topics

Several recent initiatives and publications have defined research priorities for golden eagles and these helped frame the discussion at the AWWI Eagle Workshop on November 15-17, 2011 in Denver, CO. These priorities are summarized below.

**A. Kochert, M. N., K. Steenhof, C. L. Mcintyre, and E. H. Craig. 2002. Golden Eagle (*Aquila chrysaetos*), The Birds of North America Online (A. Poole, Ed.). Ithaca: Cornell Lab of Ornithology**

1. Develop population monitoring strategy for the western United States, where population declines are suspected.
2. Improve understanding of factors that influence population trends.
3. Determine effects of environmental contaminants (for example, heavy metals) and habitat alteration for both breeding and wintering grounds.
4. Assess whether survival rates vary across geographic areas and whether human-caused mortality is additive or compensatory.
5. Estimate the size of the floating segment of populations and determine how floaters interact with territorial breeders.
6. Establish whether the rate of interchange among golden eagle sub-populations creates genetically sub-structured populations.

**B. North American Golden Eagle Science Meeting, Minutes and Notes, September 21, 2010, Ft. Collins, CO**

In addition to the specific questions listed below, meeting participants recommended that research should be region-specific with a consistent approach and methodology across the species' range, and with meta-analysis of existing data as a top priority. These questions provided a jumping-off point for the USGS-USFWS Integrated Science Partnership research priorities described below.

1. What geographic areas and habitat attributes are most critical to the golden eagle and its chief prey resources across breeding and non-breeding seasons?
2. What are minimally biased, age-specific survival rates (especially for adults) and causes of mortality?
3. What are population sizes and trends on regional to continental scales?
4. What are basic attributes of reproductive success and population demography, including age structure, natality, and mortality, on regional to continental scales?
5. What are spatial use patterns of golden eagles, including seasonal home range configurations and connectivity among populations within and among regions?

**C. USGS Research Roundtable, Portland, OR, June 2011**

A list of priorities was developed at the Roundtable with a follow-up online survey to determine rankings of suggested topics. Four subject areas relevant to wind energy development were defined and subdivided; the results are summarized below.

| Survey Results Overall Priorities | % High priority | % Medium priority |
|---|---|---|
| **A. Understanding Mortality (7 respondents)** | | |
| a. Effect of local scale environment | 57.1% | 42.9% |
| b. Effect of turbine height, size, and type | 57.1% | 28.6% |
| c. Prey density | 28.6% | 71.4% |
| d. Habituation | 0.0% | 57.1% |
| e. Habitat fragmentation | 0.0% | 28.6% |
| **B. Improved Risk Assessment (8 respondents)** | | |
| a. Age class habits | 33.0% | 50.0% |
| b. Landscape/human-footprint predictors of risk | 16.7% | 66.7% |
| c. Core areas identification | 0.0% | 83.3% |
| d. Prediction of microscale movements | 16.7% | 83.3% |
| **C. Mitigation Measures (7 respondents)** | | |
| a. Evaluation of compensatory mitigation | 28.6% | 28.6% |
| b. Prey removal/management | 28.6% | 57.1% |
| c. Deterrence | 42.9% | 42.9% |
| d. Quantifying mitigation credits | 42.9% | 42.9% |
| **D. Monitoring (6 respondents)** | | |
| a. Monitoring protocols for eagle occurrence | 40.0% | 40.0% |
| b. Criteria for pre-construction evaluation | 100% | |

## D. USGS-USFWS Integrated Science Partnership

The Service and the USGS have initiated multiple golden eagle studies based on Service research questions derived from the research priorities identified at the September 2010 North American Golden Science Meeting. The five components are described below.

1. Develop a comprehensive survey and monitoring plan to enable estimation of the status of golden eagles at different spatial scales (national, regional, and project-level).
2. Model predictions of the occurrence of golden eagles in the western U.S. to identify important geographic areas and habitats for golden eagles during the breeding and non-breeding seasons.
3. Estimate golden eagle mortality at wind energy projects utilizing a super-population approach to estimate cumulative mortality from carcass surveys, accounting for carcass removal and non-detection.
4. Develop golden eagle habitat occupancy models and maps necessary for the mitigation of energy development, assessment of habitat connectivity, and examination of future change scenarios.
5. Develop an adaptive management framework for wind energy permitting with regard to take of bald and golden eagles at the project-level and at the regional level.

# Appendix C: AWWI Eagle Workshop Participants

The AWWI Eagle Workshop was held November 15-17, 2011 in Denver, CO to describe the current state of knowledge of bald and golden eagles and to identify research that would improve implementation of and compliance with the Eagle Guidance for wind energy.

**Technical Experts**

| | | |
|---|---|---|
| Mike | Azeka | AES Wind Generation |
| Jon | Bart | U.S. Geological Survey |
| Clint | Boal | U.S. Geological Survey Texas Cooperative Research Unit |
| Erica | Craig* | Aquila Environmental |
| Michael | Collopy* | University of Nevada, Reno |
| Wally | Erickson | Western EcoSystems Technology, Inc. |
| Joe | Grennan | RES Americas |
| Terry | Grubb* | U.S. Forest Service, Rocky Mountain Research Station |
| Al | Harmata | Montana State University |
| Grainger | Hunt* | The Peregrine Fund |
| Doug | Johnson | U.S. Geological Survey, Northern Prairie Wildlife Research Center |
| Todd | Katzner | West Virginia University |
| Philip | Kline | U.S. Department of the Interior, Office of the Solicitor |
| Karl | Kosciuch | Tetra Tech |
| Kevin | Kritz | U.S. Fish and Wildlife Service, Migratory Bird Management Program |
| Dave | Mehlman | The Nature Conservancy |
| Brian | Millsap | U.S. Fish and Wildlife Service, Southwest Region |
| Robert | Murphy | U.S. Fish and Wildlife Service, Division of Migratory Birds |
| Laura | Nagy** | Tetra Tech |
| Bob | Oakleaf | Wyoming Game and Fish Department |
| Jeff | Smith | H.T. Harvey & Associates |
| Dale | Strickland | Western EcoSystems Technology, Inc. |
| Jim | Watson | Washington Department of Fish & Wildlife |

* Attended by webinar

**Invited but unable to attend

**Observers**

| | | |
|---|---|---|
| Greg | Aldrich | Duke Energy |
| Justin | Allegro | National Wildlife Federation |
| John | Anderson | American Wind Energy Association |
| Mike | Best* | Pacific Gas & Electric Company |
| Erica | Brand* | Pacific Gas & Electric Company |
| Rene | Braud | American Wind Wildlife Institute Board of Directors |

| | | |
|---|---|---|
| Tim | Breen | U.S. Fish and Wildlife Service |
| Amedee | Brickey | U.S. Fish and Wildlife Service, Pacific Southwest Region |
| Travis | Brown | PacifiCorp; Avian Power Line Interaction Committee |
| Christina | Calabrese | EDP Renewables |
| Lew | Carpenter | National Wildlife Federation |
| Eliza | Cava | Defenders of Wildlife |
| David | Cottingham | U.S. Fish and Wildlife Service |
| Mike | Daulton | Audubon |
| Corey | Duberstein* | Pacific Northwest National Laboratory |
| Brandy | Gibson | BP Wind Energy |
| Rick | Greiner | Pattern Energy |
| Blayne | Gunderman | BP Wind Energy |
| Kevin | Harper | Ridgeline Energy |
| Ryan | Henning | RES Americas |
| Matt | Hogan | U.S. Fish and Wildlife Service, Mountain Prairie Region |
| Michael | Horn | GE Energy |
| Peggy | Jelen | Avian Power Line Interaction Committee |
| Silka | Kempema | South Dakota Game, Fish and Parks |
| Ginny | Kreitler* | National Audubon |
| John | Kuba* | Clean Line Energy Partners |
| Diana | Leiker | Tri-State Generation & Transmission, Inc.; Avian Power Line Interaction Committee |
| Brent | Leonard | PacifiCorp |
| Sherry | Liguori | PacifiCorp; Avian Power Line Interaction Committee |
| Jim | Lindsay | NextEra Energy Resources |
| Mike | Lockhart | National Wildlife Federation |
| Rick | Loughery* | Edison Electric Institute; Avian Power Line Interaction Committee |
| Heather | MacLeod | Edison Mission Energy |
| Natalie | McCue | Pattern Energy Group |
| Tom | Owens | U.S. Geological Survey |
| Mike | Pappalardo | NextEra Energy Resources |
| Steve | Pelletier | Stantec |
| Jay | Pruett | The Nature Conservancy, Oklahoma Chapter |
| David | Reinke | Shell WindEnergy |
| Roby | Roberts | EDP Renewables |
| Diane | Ross-Leech | Pacific Gas & Electric Company |
| Bob | Roy | First Wind |
| David | Savage | Pioneer Green Energy |
| Adam | Shor* | Electric Power Research Institute |
| Karin | Sinclair | National Renewable Energy Laboratory |

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| Steve | Slater | HawkWatch International |
| Heidi | Souder | National Renewable Energy Laboratory |
| Trish | Sweanor | U.S. Fish and Wildlife Service |
| Jason | Thomas* | Clean Line Energy Partners |
| Genevieve | Thompson | Audubon |
| Robert | Thresher | National Renewable Energy Laboratory |
| Katie | Umekubo | Natural Resources Defense Council |
| John | VanDerZee | EDP Renewables |
| Allison | Vogt | Association of Fish & Wildlife Agencies |
| Sarah | Webster | Wind Capital Group |
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