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Author(s): Joel E. Pagel Kevin J. Kritz Brian A. Millsap and Robert K. Murphy Eric L. Kershner and Scott Covington

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BALD EAGLE AND GOLDEN EAGLE MORTALITIES AT WIND ENERGY FACILITIES IN THE CONTIGUOUS UNITED STATES

Joel E. Pagel[1]
U.S. Fish and Wildlife Service, 6010 Hidden Valley Road, Carlsbad, CA 92011 U.S.A.

Kevin J. Kritz
U.S. Fish and Wildlife Service, P.O. Box 25486, Denver, CO 80225 U.S.A.

Brian A. Millsap and Robert K. Murphy
U.S. Fish and Wildlife Service, Albuquerque, NM 87103 U.S.A.

Eric L. Kershner and Scott Covington
U.S. Fish and Wildlife Service, 4401 North Fairfax Drive, Arlington, VA 22203 U.S.A.

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Eagles are among the bird species that can be injured or killed by collision at wind energy facilities when the birds are flying at the same height above ground as the blades of horizontal-axis wind turbines (Drewitt and Langston 2006). Regions of the United States with wind resources adequate for wind energy development (National Renewable Energy Laboratory 2009) often overlap habitats important to Bald Eagles (*Haliaeetus leucocephalus;* Buehler 2000) and Golden Eagles (*Aquila chrysaetos*; Kochert et al. 2002). Golden Eagles, in particular, use open spaces and wind resources similar to those valuable for wind energy facilities. High levels of collision mortality are well documented for Golden Eagles at the Altamont Pass Wind Resource Area (APWRA) in California (Smallwood and Thelander 2008, Smallwood and Karas 2009), where published estimates of annual mortality ranged as high as 66.7 to 75.0 Golden Eagles per year in 2005–2007 (Smallwood and Thelander 2008; Drewitt and Langston 2006). Elsewhere, assessments of eagle mortality at commercial-scale and/or private wind energy facilities are either seldom conducted or in some cases not made available for public review. Meanwhile, terrestrial-based commercial wind energy (facilities where electrical power is produced for sale to the local or national power grid) installed in the contiguous United States reached an estimated 51 630 megawatts by September 2012, and likely will increase substantially by 2015 (U.S. Department of Energy 2011a, 2011b), suggesting potential for increased interaction between eagles and wind energy facilities.

Concerns over the effects of this trend on North America's Bald Eagles and Golden Eagles exist, but are weakly substantiated due to a lack of published documentation of mortalities. Our objective was to summarize documented cases of eagle mortality at wind energy facilities in the contiguous United States, excluding APWRA, during the last 15 years, as a starting point for future assessments.

Methods

We retrieved information on eagle mortalities and injuries that occurred from 1997 to 30 June 2012 at wind energy facilities, by using public-domain sources, including documents from wind energy companies released to the U.S. Fish and Wildlife Service. We omitted anecdotal or unsubstantiated accounts and considered only cases with unambiguous physical evidence of mortality or injury. We did not include eagle mortalities from APWRA because of the availability of information reported from that location that has been published elsewhere. Although not all reports of mortality we reviewed included carcass necropsies, we considered collision as the likely cause of mortality for eagles discovered beneath operating wind turbines and/or which exhibited dismemberment or other gross external evidence of blunt force trauma. However, losses of eagles at wind energy facilities reported here included one eagle mortality attributed to electrocution on a power line. Last, we encountered six records of eagles injured by blunt force trauma at wind facilities and, due to the severity of their injuries, three were subsequently euthanized or deemed non-releasable. Of the remaining three, one injured eagle was released after extensive rehabilitation, and we are unaware of the final disposition of the remaining two. We included these as mortalities because the individuals were likely removed from the population. We only reported fatalities with strong and compelling information; we did not include 17 records where eagle mortality was not fully substantiated; i.e., the report lacked physical evidence or a reliable first-person source.

[1] Email address: laurajosens@yahoo.com

Table 1. Mortalities of Bald Eagles and Golden Eagles associated with wind energy facilities in the contiguous United States during 1997 through June 2012, excluding Altamont Pass Wind Resource Area in California. These data underrepresent the total number of mortalities of eagles at wind energy facilities in the United States during this period; e.g., most were discovered incidentally during routine activities at facilities.

SPECIES	STATE	NUMBER OF FACILITIES WHERE MORTALITIES WERE REPORTED	NUMBER OF FATALITIES
Bald Eagle	Iowa	3	3
Bald Eagle	Maryland	1	1
Bald Eagle	Wyoming	2	2
Golden Eagle	California	13	27
Golden Eagle	Colorado	1	5
Golden Eagle	New Mexico	1	5
Golden Eagle	Oregon	2	6
Golden Eagle	Texas	1	1
Golden Eagle	Utah	1	1
Golden Eagle	Washington	2	5
Golden Eagle	Wyoming	7	29
Total		32[1]	85

[1] Both species were killed at two Wyoming facilities, yet each of the facilities is represented only once in the column total.

RESULTS AND DISCUSSION

We found a minimum of 85 eagle mortalities at 32 wind energy facilities in 10 states during 1997 through 30 June 2012 (Table 1, Appendix). Sixty-seven (78.8%) of these mortalities occurred during 2008–2012. Six (7.1%) mortalities were of Bald Eagles and 79 (92.9%) were of Golden Eagles. All but one mortality occurred at commercial-scale wind facilities; one dead adult Bald Eagle was discovered under a smaller-scale wind turbine with a blade radius of only 3.5 m. One Wyoming facility accounted for 12 Golden Eagle mortalities, the most for any single facility. Mortality of both species was recorded at two separate facilities in Wyoming. Adults made up 55.5% (20 birds) of the 36 Golden Eagle mortalities for which age class was reported. At APWRA, subadults composed 63.3% of 42 blade-strike mortalities of Golden Eagles (Hunt 2002); however, age class was unknown for more than half (54.4%) of the Golden Eagle mortalities (Appendix), so we could not make a clear comparison.

One possible explanation for limited records of Bald Eagle mortality is that this species may be less vulnerable than Golden Eagles to collisions at wind energy facilities. However, the White-tailed Eagle (*Haliaeetus albicilla*), a congener ecologically similar to the Bald Eagle, incurs substantial collision mortality at wind facilities in coastal Norway (Nygård et al. 2010). There may also be less overlap between the areas most important to Bald Eagles and current wind energy facilities in the contiguous United States than is the case for Golden Eagles. Another explanation is that discovery of carcasses of Bald Eagles, either incidentally or during surveys, at wind energy facilities east of the 100th meridian may be less likely because landscapes there are more heavily vegetated (row crops and forests) and thus carcasses are more likely to be concealed, particularly during spring and summer.

More than one-half (54.1%) of the eagle mortalities at wind energy facilities we report were discovered by a property owner or by facility employees during routine site operations. In contrast, less than one-fourth (18.8%) were found during surveys designed to document avian mortality (Appendix). One mortality (1.2%) was discovered via radiotelemetry, and one (1.2%) blade strike of an eagle from a territory near a turbine field was observed. Means of discovery of other mortalities (24.7%) were not evident from records we reviewed. Other than a sample of known-age individuals, records generally were too incomplete for us to assess biological or ecological factors associated with eagle mortality at wind energy facilities.

Designs of carcass surveys at wind energy facilities were either unknown to us or were such that inferences to total mortality could not be made. This, combined with the facts that most carcasses were discovered incidentally, and that reporting of mortalities was primarily voluntary with little or no effort directed toward finding the total number of eagles killed at a facility, suggest that the mortalities reported here underrepresent the actual number of eagle fatalities that have occurred at non-APWRA wind facilities in recent years.

More Golden Eagle strikes were reported in March–June than in any other months (Fig. 1), although sample sizes were too small for statistical analyses. Whether this reflected a seasonal shift in mortality or just a change in detection was unclear from the data available, but this should be investigated as part of future studies. Nygård et al. (2010) reported a surge in adult White-tailed Eagles killed at wind facilities in Norway during the spring season.

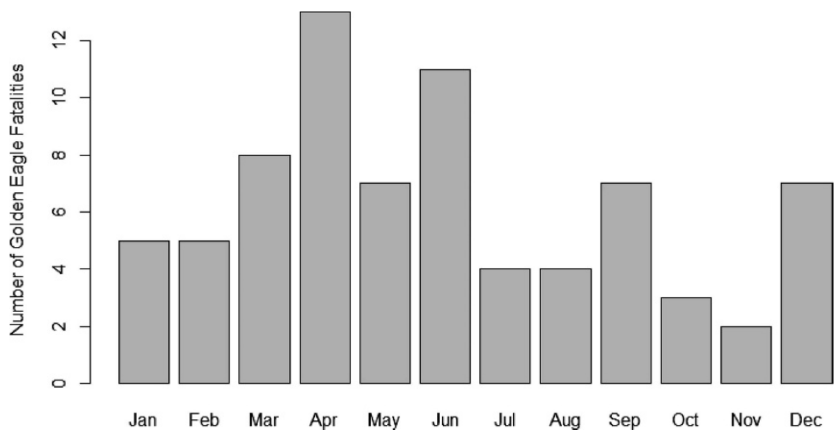

Figure 1. Seasonal distribution of Golden Eagle fatalities at wind facilities reported by month. Three of 79 Golden Eagle mortality records were not included due to lack of specificity of month of incident.

This summary likely conveys only a limited portion of eagles killed at non-APWRA wind energy facilities in the contiguous United States, considering the general lack of rigorous monitoring and reporting of eagle mortalities. Thus, our findings of the reported mortalities likely underestimate, perhaps substantially, the number of eagles killed at wind facilities in the United States. Even with this limitation, we report that blade-strike mortality of eagles is geographically widespread in the United States, and both Bald Eagles and Golden Eagles are killed. Given the projected growth in wind resource development in habitat frequented by Bald Eagles and Golden Eagles, estimation of total mortality and better understanding of factors associated with injury and death at wind facilities through robust and peer-reviewed research and monitoring should be a high priority.

MORTALIDAD DE *HALIAEETUS LEUCOCEPHALUS* Y *AQUILA CHRYSAETOS* EN INSTALACIONES DE ENERGÍA EÓLICA EN LA PARTE CONTINUA DE ESTADOS UNIDOS

RESUMEN.—Han muerto individuos tanto de *Haliaeetus leucocephalus* como de *Aquila chrysaetos* en instalaciones de energía eólica en Estados Unidos. Encontramos un mínimo de 85 águilas muertas, incluyendo 6 individuos de *H. leucocephalus* y 79 de *A. chrysaetos*, en 32 instalaciones de energía eólica en 10 estados desde 1997 hasta el 30 de junio de 2012. Probablemente nuestros resultados sub-representan, quizá substancialmente, los números de águilas muertas en Estados Unidos a causa de la producción de electricidad generada por el viento.

[Traducción del equipo editorial]

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Authors' Note: Between 30 June 2012 and the time of final acceptance of this manuscript, Bald and Golden eagles had been killed by wind-generated electricity production in three additional states: Idaho, Montana, and Nevada.

Appendix. Mortalities of Bald Eagles and Golden Eagles associated with wind energy facilities in the contiguous United States during 1997 through 30 June 2012, excluding Altamont Pass Wind Resource Area in California.

SPECIES	YEAR	STATE/SITE	SEX	AGE	HOW RECOVERED
Golden Eagle	1997	CA - 1	female	subadult	incidental
	1999	CA - 2	unknown	unknown	unknown
		CA - 3	unknown	unknown	unknown
	2000	CA - 3	unknown	unknown	unknown
		CA - 4	unknown	unknown	unknown
	2001	CA - 3	unknown	unknown	unknown
	2002	CA - 3	unknown	unknown	unknown
		CA - 5	unknown	unknown	unknown
		CA - 5	unknown	unknown	unknown
	2004	CA - 6	unknown	unknown	survey
		NM - 1	unknown	unknown	unknown
		NM - 1	unknown	unknown	unknown
	2005	CA - 6	unknown	unknown	incidental
		CA - 7	unknown	unknown	incidental
		NM - 1	unknown	adult	unknown
		NM - 1	unknown	unknown	unknown
	2007	CA - 8	unknown	unknown	unknown
		CA - 9	unknown	unknown	unknown
	2008	NM - 1	unknown	unknown	incidental
	2009	CA - 10	unknown	unknown	incidental
		CO - 1	unknown	unknown	survey
		CO - 1	unknown	unknown	incidental
		OR - 2	unknown	adult	incidental
		WA - 1	unknown	adult	survey
		WY - 3	unknown	unknown	incidental
		WY - 3	unknown	adult	survey
		WY - 3	unknown	unknown	survey
	2010	CA - 10	unknown	unknown	incidental
		CA - 11	unknown	juvenile	telemetry
		CO - 1	unknown	adult	incidental
		OR - 2	unknown	unknown	survey
		OR - 2	unknown	subadult	incidental
		OR - 2	unknown	juvenile	incidental
		WY - 1	unknown	adult	incidental

Appendix. Continued.

Species	Year	State/Site	Sex	Age	How Recovered
		WY - 2	unknown	adult	incidental
		WY - 3	unknown	adult	incidental
		WY - 3	unknown	unknown	survey
		WY - 3	unknown	unknown	incidental
		WY - 3	unknown	subadult	survey
		WY - 3	unknown	unknown	incidental
		WY - 4	unknown	unknown	incidental
		WY - 5	unknown	unknown	survey
		WY - 5	unknown	unknown	survey
	2011	CA - 10	unknown	unknown	incidental
		CA - 10	unknown	unknown	incidental
		CA - 10	unknown	unknown	incidental
		CA - 10	unknown	adult	incidental
		CA - 12	male	juvenile	incidental
		CA - 12	unknown	adult	incidental
		CO - 1	male	adult	incidental
		CO - 1	unknown	unknown	incidental
		OR - 1	unknown	adult	incidental
		WA - 1	female	adult	incidental
		WA - 2	female	adult	incidental
		WA - 2	male	adult	observed
		WY - 1	unknown	unknown	incidental
		WY - 2	unknown	subadult	incidental
		WY - 3	unknown	subadult	incidental
		WY - 3	unknown	unknown	survey
		WY - 3	unknown	juvenile	survey
		WY - 4	unknown	unknown	incidental
		WY - 5	unknown	unknown	survey
		WY - 6	unknown	subadult	survey
		WY - 6	unknown	juvenile	incidental
		WY - 6	unknown	juvenile	incidental
		WY - 6	unknown	subadult	survey
		WY - 6	unknown	unknown	incidental
	2012	CA -10	unknown	adult	unknown
		CA - 10	unknown	adult	unknown
		CA - 10	unknown	subadult	unknown
		CA - 13	unknown	adult	unknown
		OR - 2	unknown	adult	incidental
		TX - 1	unknown	subadult	unknown
		UT - 1	unknown	adult	incidental
		WA - 2	unknown	unknown	unknown
		WY - 3	unknown	juvenile	incidental
		WY - 7	unknown	unknown	incidental
		WY - 7	unknown	unknown	incidental
		WY - 7	unknown	unknown	incidental
Bald Eagle	2010	WY - 4	unknown	adult	incidental
	2011	IA - 1	unknown	adult	incidental
		WY - 1	unknown	adult	survey
	2012	IA - 2	unknown	unknown	unknown
		IA - 3	male	adult	incidental
		MD - 1	male	adult	incidental