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Note

Assessing Spring Direct Mortality to Avifauna From Wind Energy Facilities in the Dakotas

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ABSTRACT The Northern Great Plains (NGP) contains much of the remaining temperate grasslands, an ecosystem that is one of the most converted and least protected in the world. Within the NGP, the Prairie Pothole Region (PPR) provides important habitat for >50% of North America's breeding waterfowl and many species of shorebirds, waterbirds, and grassland songbirds. This region also has high wind energy potential, but the effects of wind energy developments on migratory and resident bird and bat populations in the NGP remains understudied. This is troubling considering >2,200 wind turbines are actively generating power in the region and numerous wind energy projects have been proposed for development in the future. Our objectives were to estimate avian and bat fatality rates for wind turbines situated in cropland- and grassland-dominated landscapes, document species at high risk to direct mortality, and assess the influence of habitat variables on waterfowl mortality at 2 wind farms in the NGP. From 10 March to 7 June 2013–2014, we completed 2,398 searches around turbines for carcasses at the Tatanka Wind Farm (TAWF) and the Edgeley-Kulm Wind Farm (EKWF) in South Dakota and North Dakota. During spring, we found 92 turbine-related mortalities comprising 33 species and documented a greater diversity of species ($n = 30$) killed at TAWF (predominately grassland) than at EKWF ($n = 9$; predominately agricultural fields). After accounting for detection rates, we estimated spring mortality of 1.86 (SE = 0.22) deaths/megawatt (MW) at TAWF and 2.55 (SE = 0.51) deaths/MW at EKWF. Waterfowl spring (Mar–Jun) fatality rates were 0.79 (SE = 0.11) and 0.91 (SE = 0.10) deaths/MW at TAWF and EKWF, respectively. Our results suggest that future wind facility siting decisions consider avoiding grassland habitats and locate turbines in pre-existing fragmented and converted habitat outside of high densities of breeding waterfowl and major migration corridors. © 2016 The Wildlife Society.

KEY WORDS bat, bird, carcass, collision, fatality, mortality, turbine, wildlife, wind energy.

As demands for energy increase around the world, so does the need to generate electricity without emitting harmful pollutants or greenhouse gases (National Wind Coordination Collaborative [NWCC] 2010, Korner-Nievergelt et al. 2011, Vladislavleva et al. 2013). Wind energy offers one renewable energy solution and the United States Department of Energy (DOE) has targeted that 20% of electricity be generated from wind by 2030 (DOE 2008, Fargione et al. 2012, Rollins et al. 2012). Currently, wind energy is the fastest growing energy source in the world (Warudkar and Ahmed 2013).

The Northern Great Plains (NGP) has strong and consistent winds, ideal conditions for wind energy development (Fargione et al. 2012, Gue et al. 2013, Niemuth et al. 2013). South Dakota and North Dakota rank fifth and sixth, respectively, in wind energy resource potential in the United States, and each state is capable of producing over 200 times its current energy usage (American Wind Energy Association 2014). However, this area also has much of North America's remaining temperate grasslands, an ecological system that is the most converted and least protected in the world (Hoekstra et al. 2005, Fargione et al. 2012). Within the NGP, the Prairie Pothole Region (PPR) contains millions of glacial wetlands, many of which are interspersed among remaining grassland and cropland. The PPR is the main breeding area for many of the upland nesting duck species in North America (Batt et al. 1989, Sorenson et al. 1998, Loesch et al. 2013) and it annually supports over half of the North American breeding waterfowl population (Bellrose 1980, Loesch et al. 2013). The PPR also provides important breeding habitat for shorebirds, waterbirds, and grassland songbirds (Knopf 1996; Dinsmore et al. 1999; Rich et al. 2004; Niemuth et al. 2005, 2013), including almost 40% of the species on the Partners in Flight Continental Watch List (Rich et al. 2004). Thus, in an area important to

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energy development and breeding birds, siting decisions that incorporate collision risk to birds are crucial to minimizing potential mortality risk associated with wind turbines.

The ecological footprint of wind energy developed in the PPR is likely to affect many species of wildlife (Fargione et al. 2012). Habitat loss, fragmentation, and direct mortality are some of the concerns associated with wind energy (NWCC 2010, Fargione et al. 2012). Although indirect effects of wind energy are important, most research examining wildlife interactions with turbines has concentrated on direct mortality (Barclay et al. 2007, Kuvlesky et al. 2007, Arnett et al. 2008, Fargione et al. 2012, Beston et al. 2015). Up to 75% of bird mortalities at wind farms in the United States were songbirds (Erickson et al. 2002, Johnson et al. 2002, Kuvlesky et al. 2007, NWCC 2010), which are the most numerous of North America's migratory species (NWCC 2010). Although current fatality rates for most species are unlikely to significantly affect songbird population trends (National Academy of Sciences 2007, Manville 2009, NWCC 2010), even small changes in populations have biological consequences (Longcore et al. 2013). This is especially true for rarer species of conservation concern (e.g., Sprague's pipit [*Anthus spragueii*]; Drewitt and Langston 2006, Fargione et al. 2012, Beston et al. 2015).

Evidence of bat mortality (~450,000 bats/year; Cryan 2011) associated with wind turbines has generated increased interest in bat migration patterns (Baerwald and Barclay 2011) because most fatalities in North America are migratory tree-roosting bats, including the hoary (*Lasiurus cinereus*), eastern red (*L. borealis*), and silver-haired (*Lasionycteris noctivagans*) bat (Arnett et al. 2008, Baerwald and Barclay 2011, Jameson and Willis 2012). Some studies of wind energy facilities have documented high fatality rates in certain species of bats, which may have long-term population effects (Kunz et al. 2007, Cryan and Barclay 2009). As wind energy facilities increase in number and size, bird and bat mortalities also are expected to increase (Erickson et al. 2001, Johnson et al. 2002). More importantly, the interaction of direct and indirect impacts from wind energy for birds and bats may cause increased mortality and risk of predation, alter the availability of food and breeding resources, and potentially affect demographics and population viability (Kunz et al. 2007, National Research Council 2007).

Loss et al. (2013) reported that per turbine mortality of all avian species was lowest in the Great Plains but that an estimated 23% of total wind energy mortality in the United States occurred in this area. Studies used for the analysis were from 5 states (South Dakota, Minnesota, Iowa, Oklahoma, and Texas), making it difficult to predict future impacts across the NGP. Previous research by Kiesecker et al. (2011) noted that wind energy potential in the Great Plains could be sufficient to meet the output capacity goal of 20% mandated by the DOE, even if turbines were restricted to siting only on previously disturbed lands (e.g., cultivated cropland). However, future construction would include areas where limited wind energy-related mortality data exists. Additionally, few studies have compared fatality rates in disturbed versus undisturbed lands. Our objectives were to document species colliding with turbines in the PPR, calculate fatality rates for species of concern at the state and federal level, and assess differences in fatality rates for a wind farm that is primarily encompassed by agricultural fields versus a wind farm that is mostly pasture or grasslands.

STUDY AREA

During 2013 and 2014, we surveyed 2 wind facilities in North Dakota (ND) and South Dakota (SD) during spring (Mar–Jun). Mean (30-year) spring temperature ranged from −1.2°C to 18.9°C with mean annual (30-year) precipitation of 49.6 cm (North Dakota Agricultural Weather Network Center 2014, South Dakota Office of Climatology 2014). The study area was located within the Missouri Coteau of the Prairie Pothole Region (Bluemle 1979) in the Dakotas. The PPR consists of rolling hills interspersed with many temporary, seasonal, and semi-permanent wetlands (Stewart and Kantrud 1971, Bluemle 1979). Prior to European settlement, the predominant vegetation of the Missouri Coteau was native mixed-grass prairie (Kuchler 1964). Although over half of the grassland has been converted to agriculture, the area contains a large portion of the intact grassland remaining east of the Missouri River (Stephens et al. 2008). Land use in the study area consisted of cultivated land (62%), grassland (17%), development (14%), wetlands (3%), and forested cover (4%; U.S. Department of Agriculture 2014). Native vegetation was predominantly western wheatgrass (*Pascopyrum smithii*), needle-and-thread (*Stipa comata*), green needlegrass (*Nassella viridula*), prairie Junegrass (*Koeleria cristata*), and blue grama (*Bouteloua gracilis*; Blank and Fosberg 1989). Cultivated crops in the study area included corn, soybeans, alfalfa, wheat, and sunflower.

The Tatanka Wind Farm (TAWF; Acciona Wind Company, Chicago, IL), located 36 km south of Kulm, ND, was commissioned in 2008 and at approximately 5,700 ha, is the largest wind farm in the Dakotas. The wind farm was oriented from southwest to northeast; 59 turbines were located in McPherson County, SD, and 61 turbines were located in Dickey County, ND (Fig. 1). Each of the 1.5-megawatt (MW) operational turbines (Acciona; model AW–77/1500) had an 80-m tower with 3, 37-m blades. The wind farm was capable of operating between wind speeds of 3.5 and 25 m/second (Acciona Wind Company, unpublished data). Over 90% of the turbines were located in grassland or pasture, although some conversion to row-crop agriculture occurred at specific turbines during the study period.

The Edgeley-Kulm Wind Farm (EKWF; Nextera Energy Resources, Juno Beach, Florida) was commissioned in 2003 and was located 3.2 km east of Kulm, ND in LaMoure County. The wind facility was oriented north to south and each of the 41 operational 1.5-MW turbines (General Electric, Fairfield, CT, model CWE IEC IIa) had a 64.5-m tower with 3 blades between 35 and 41 m in length. The wind facility was capable of operating between wind speeds of 3.6 and 25 m/second (Nextera Energy Resources, unpublished data). All but 1 turbine in LaMoure County was located in row-crop (i.e., corn, soybean) agricultural fields.

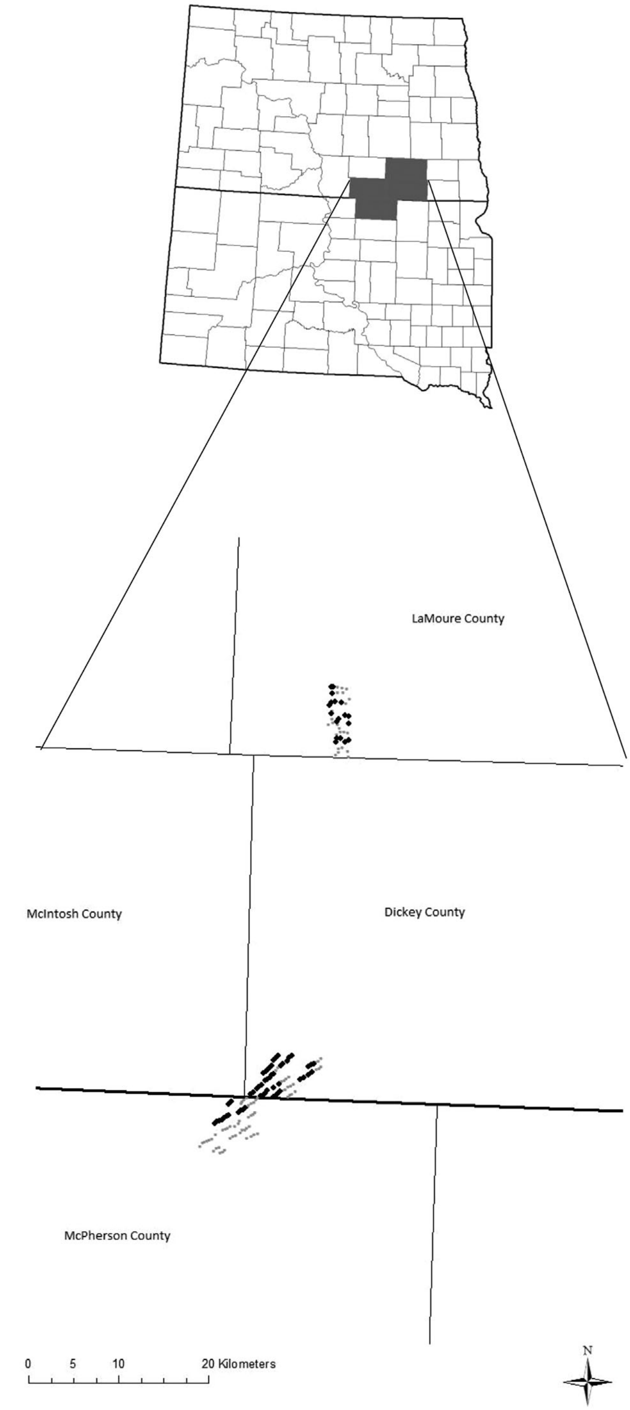

Figure 1. Study area including the Tatanka Wind Farm within Dickey and McIntosh counties, North Dakota and McPherson County, South Dakota, and the Edgeley-Kulm Wind Farm within LaMoure County, North Dakota. Black circles denote wind turbines searched for bird and bat carcasses in 2013 and 2014 and gray circles turbines not searched in 2013 and 2014.

METHODS

We obtained landowner access and searched for bird and bat carcasses at 52 turbines at TAWF and 17 turbines at EKWF from 11 March to 7 June 2013 and from 10 March to 6 June 2014. We randomly selected turbines for searching from those we had private landowner permission to access. We selected the sampling period to coincide with spring migration and the initial nesting period for most grassland nesting birds (e.g., waterfowl, shorebirds, upland game, raptors, and passerines). We did not conduct searches after the first week of June because vegetation height in grasslands and in croplands limited searcher efficiency.

The United States Fish and Wildlife Service (USFWS) recommends search plots have widths equal to twice the turbine height (USFWS 2012). Therefore, we centered a 1.5-ha circular plot (radius of approx. 70 m from turbine base) around each turbine to ensure we searched all areas within 50 m of the turbine (Anderson et al. 1999, Johnson et al. 2002), including distances out to twice the turbine height (USFWS 2012). A 2-person crew surveyed each 1.5-ha plot using parallel transects, maintaining 4–6 m between transects (Smallwood and Thelander 2008), depending on snow cover, grass height, and topography.

We searched a sub-sample of turbines daily because many migratory species are small and there is a potential for bias associated with high numbers of periodic mortalities (USFWS 2012); we randomly selected these turbines from the overall sample of accessible turbines. We searched 20 turbines/day based on the time needed for a 2-person team to complete a search. We established a 3-day search rotation where we searched a subset of 10 turbines (all were at TAWF) daily and then rotated the searching of 10 other turbines among those for which we had access, with 10 turbines at EKWF searched every third day.

We recorded date, start time, end time, observer(s), wind facility, turbine number, turbine status (i.e., operating, not operating, under maintenance) for each search as per the USFWS protocol (USFWS 2012). When we located a carcass, we flagged the remains and continued the search. After we searched the entire plot, we returned to each carcass and recorded date, species, sex and age (when possible), observer, turbine number, wind facility, distance from turbine (including global positioning system [GPS] coordinates), and condition of carcass (entire, partial, scavenged). We took digital photographs of each carcass and wore sterile vinyl gloves when handling all carcasses. In the event that we could not identify a carcass, we placed the carcass in a labeled plastic bag (USFWS 2012) for further examination in the laboratory (South Dakota State University). We handled all carcasses in accordance with research permits granted by the USFWS (Permit no. MB03605B-0), South Dakota Department of Game, Fish and Parks (Permit no. 33), North Dakota Game and Fish Department (Permit no. GNF03343177), and the Institutional Animal Care and Use Committee (Approval no. 12-064E) at South Dakota State University.

We assigned cause-specific mortality for all carcasses or body parts (e.g., primary, secondary, and tail feathers, head, wing, tarsi) found; we determined probable cause of death based on injuries and proximity to turbines (Smallwood and Thelander 2008). We used condition of carcasses to classify each as occurring during spring migration (i.e., during the Mar–Jun search season) or as having occurred during the remaining part of the year (i.e., non-spring migration).

Additionally, we classified all carcasses as either small-bodied or large-bodied (i.e., <38 cm body length or ≥38 cm body length, respectively) because size can influence detection probability of the carcass (Smallwood and Thelander 2008). Potential injuries associated with wind turbine collision included severed or twisted torso, decapitation, severed wing(s), tail, or leg(s), and other forms of blunt trauma (Smallwood and Thelander 2008). We attributed predation to carcasses with feathers plucked and scattered. We estimated number of days since death by assessing carcass decomposition and date of previous site visit (Smallwood and Thelander 2008).

We evaluated observer detection bias by placing carcasses of salvaged birds randomly in turbine search plots. We used 26 species of birds (both small- and large-bodied) for detection trials and used birds that were obtained via USFWS collection, individuals found and collected during a previous turbine search, trapped (i.e., European starling [*Sturnus vulgaris*]), or raised domestically (rock pigeon [*Columba livia*]). Each week, we placed 8–12 bird carcasses in plots scheduled to be searched within 7 days. We used a double-blind approach where the location and number of carcasses placed in each plot varied and was unknown to searchers (Higgins et al. 2007). We then calculated search detection rates for non-raptors classified as small-bodied or large-bodied (Smallwood 2007, Smallwood and Thelander 2008).

We estimated overall fatality rates and species-specific fatality rates yearly at each wind facility. We estimated adjusted mortality using the following equation: $M_a = M_u/D$, where M_u is unadjusted mortality expressed as the number of fatalities/wind turbine/period or number of fatalities/MW of rated wind power capacity per period, and D is the overall detection probability determined by searcher detection trials (K. Smallwood, Independent Environmental Services Professional, personal communication). We calculated the standard error, (SE[M_a]), using the delta method (Smallwood and Thelander 2008):

$$\mathrm{SE}[M_a] = \left[(1/D \times \mathrm{SE}[M_u])^2 + \left(M_u \times 1/D^2 \times \mathrm{SE}[D]\right)^2\right]^{1/2}$$

We made no adjustment for background mortality (caused by factors independent of wind turbines and associated infrastructure), which is typically small (Smallwood and Thelander 2008). Additionally, we did not adjust for crippling bias, search radius bias, or carcass removal by maintenance personnel. Consequently, our adjusted estimates of mortality are likely conservative (Smallwood and Thelander 2008).

We conducted scavenging trials by placing small- and large-bodied carcasses randomly at turbines. We obtained fresh (≤1 day old) carcasses from our turbine searches and from the USFWS. We monitored each carcass by placing a Moultrie M-880 low glow infrared motion-triggered game camera (Moultire, Birmingham, AL) placed on stakes 1.5–3.0 m from the carcass and monitored each carcass at least once/day for 21 days. We recorded date and time and condition of carcass. We used the novel scavenger removal method to estimate the cumulative proportion of carcasses remaining since the last fatality search (Smallwood et al. 2010).

RESULTS

We completed 2,398 turbine searches and found 141 bird and bat fatalities. We excluded 49 carcasses from mortality estimates because they were identified as non-turbine related ($n = 3$; i.e., predation of a hen on nest) or non-spring migration ($n = 46$; e.g., outside of Mar–Jun, often found as snow melted) mortalities (Table 1). We used 52 carcasses for the 2013 data analysis and 40 carcasses for the 2014 data analysis; mortalities remained relatively constant throughout the field season (Fig. 2). We found carcasses ranging from 4 m to 72 m ($\bar{x} = 35.12$, SE = 1.83) from turbines (Table 2). Carcasses included in analyses were comprised of 33 species and included 56 (61.0%) waterfowl, 20 (21.7%) passerines, 5 (5.4%) waterbirds, 5 (5.4%) upland game birds, 4 (4.3%) shorebirds, and 2 (2.2%) bats (Tables 3 and 4). Forty-eight (52%) carcasses were intact, 25 (27%) were considered scavenged, and 19 (21%) were dismembered. Land cover in the 1,600-m buffer was dominated by cropland at EKWF and grass/pasture at TAWF (Table 5). Between 2013 and 2014, land use changes were minimal around turbines; at TAWF, hay/alfalfa decreased 1% and cropland increased 1%. Remaining land cover percentages were unchanged between years at both farms.

Overall detection rates, including both years and both size classes, were 47% (SE = 0.05) at TAWF and 37% (SE = 0.07) at EFWF. Large bird detection rates for both wind facilities were 70% (SE = 0.10) and 65% (SE = 0.07) in 2013 and 2014, respectively. Small bird detection rates were 22% (SE = 0.10) in 2013 and 25% (SE = 0.06) in 2014. For both sites over both years, the average large bird (>38 cm) detection rate was 67% (SE = 0.06), whereas the average small bird (<38 cm) detection rate was 24% (SE = 0.05). We conducted 76 scavenging trials and mean number of days for first scavenging for small- and large-bodied carcasses differed ($t_{74} = 2.27$, $P = 0.03$) and was 9.4 (SE = 1.15, $n = 31$) and 13.1 (SE = 1.08, $n = 45$) days, respectively. Number of days for first scavenging ranged from 3 to 21 days and approximately 65% of scavengers were mammalian; the remaining 35% of documented scavengers were avian.

Unadjusted mortality extrapolated to unsearched turbines for 2013 and 2014 spring mortality at TAWF was 84 and 87 individuals, respectively, and 39 and 21 individuals, respectively, at EKWF. After adjusting for detection rates, we estimated spring mortality at TAWF at 303 (95% CI = 0–645) individuals in 2013 and 171 (95% CI = 73–269) individuals in 2014. Adjusted estimates for the EKWF were 62 (95% CI = 4–120) individuals in 2013 and 52 (95% CI = 0–110) individuals in 2014. We estimated fatality rates during our sampling period as 1.86 (SE = 0.22) deaths/MW at TAWF and 2.55 (SE = 0.51) deaths/MW at EKWF. Rates did not differ among turbines searched daily and those searched every other (or third) day; therefore, we did not adjust for scavenging because the lower range for scavenging was equal or greater than our search interval. Fatality rates

Table 1. All carcasses found during mortality searches at the Tatanka Wind Farm in McPherson County, South Dakota and Dickey County, North Dakota, and the Edgeley-Kulm Wind Farm in LaMoure County, North Dakota, USA, 2013–2014. Spring mortalities occurred March–June and non-spring mortalities occurred July–February.

Species	Scientific name	No. of spring turbine mortalities	No. non-spring turbine mortalities	Predation of female on nest	Total
Canada goose	*Branta canadensis*		9		9
Mallard	*Anas platyrhynchos*	39	9	1	49
Gadwall	*A. strepera*	2	2		4
Green-winged teal	*A. crecca*	1			1
Northern pintail	*A. acuta*	7	4		11
Northern shoveler	*A. clypeata*		1		1
Blue-winged teal	*A. discors*	2	3	2	7
Redhead	*Aythya americana*	5	2		7
Anatidae spp.			2		2
Ring-necked pheasant	*Phasianus colchicus*	3	1		4
Sharp-tailed grouse	*Tympanuchus phasianellus*	2	1		3
Eared grebe	*Podiceps nigricollis*	1			1
American white pelican	*Pelecanus erythrorhynchos*	1	3		4
Swainson's hawk	*Buteo swainsoni*		1		1
Red-tailed hawk	*B. jamaicensis*		1		1
Buteo spp.			1		1
Sora	*Porzana carolina*	1			1
Virginia rail	*Rallus limicola*	1			1
American coot	*Fulica americana*	1	1		2
Upland sandpiper	*Bartramia longicauda*	2			2
Wilson's snipe	*Gallinago delicata*	2	1		3
Eastern wood-pewee	*Contopus virens*	1			1
Red-eyed vireo	*Vireo gilvus*	1			1
Warbling vireo	*V. olivaceus*	1			1
Tree swallow	*Tachycineta bicolor*	1			1
Barn swallow	*Hirundo rustica*	2			2
Brown creeper	*Certhia americana*	1			1
Swainson's thrush	*Catharus ustulatus*	1			1
European starling	*Sturnus vulgaris*	2			2
Snow bunting	*Plectrophenax nivalis*	2			2
American tree sparrow	*Spizella arborea*	1	1		2
Savannah sparrow	*Passerculus sandwichensis*	1			1
Le Conte's sparrow	*Ammodramus leconteii*	1			1
Song sparrow	*Melospiza melodia*	1			1
Dark-eyed junco	*Junco hyemalis*	1			1
Western meadowlark	*Sternella neglecta*	1			1
Red-winged blackbird	*Agelaius phoeniceus*	1			1
Common grackle	*Quiscalus quicula*	1			1
Brown-headed cowbird	*Molothrus ater*		1		1
Unknown bird spp.			2		2
Silver-haired bat	*Lasionycteris noctivagans*	2			2

(deaths/MW) between the farms did not differ in either year (SEs overlapped), even though TAWF was predominantly grassland and EKWF was row-crop agriculture (Table 5). However, birds of 30 species were found at TAWF, whereas birds of 9 species were found at EKWF. Anseriformes and Passeriformes were the orders with the greatest mortalities (Tables 3 and 4). Mallard (*Anas platyrhynchos*), northern pintail (*A. acuta*), and redhead (*Aythya americana*) were the species most commonly found and approximately 60% of waterfowl mortality was male.

Because a majority (56 of 92 fatalities) of our carcasses were waterfowl (Family: Anatidae), we calculated unadjusted and adjusted mortality of waterfowl at each wind facility. After combining large-bird detection rates for both years at each wind facility, we estimated unadjusted spring waterfowl mortality at 0.55 (SE = 0.06) deaths/MW at TAWF and 0.51 (SE = 0.10) deaths/MW at EKWF. Adjusted spring waterfowl fatality rates were 0.79 (SE = 0.11) deaths/MW at TAWF and 0.91 (SE = 0.27) deaths/MW at EKWF.

DISCUSSION

Fargione et al. (2012) suggested that siting wind energy developments on disturbed lands, which are seemingly low in wildlife value, rather than in large, intact natural habitats, may reduce impacts to wildlife. Although our study documented no difference in fatality rates between a wind facility situated in intact grassland and one in agricultural lands, the diversity of species killed at the wind facility located in grasslands was >3 times higher than that located in agricultural fields. Most (67%) of the species found at EKWF were waterfowl, which are locally abundant in almost every habitat because of the density of wetlands that provide migration stopover points and breeding and brooding habitats (Loesch et al. 2013, USFWS 2014). Although many dabbling ducks (e.g., mallard, northern pintail,

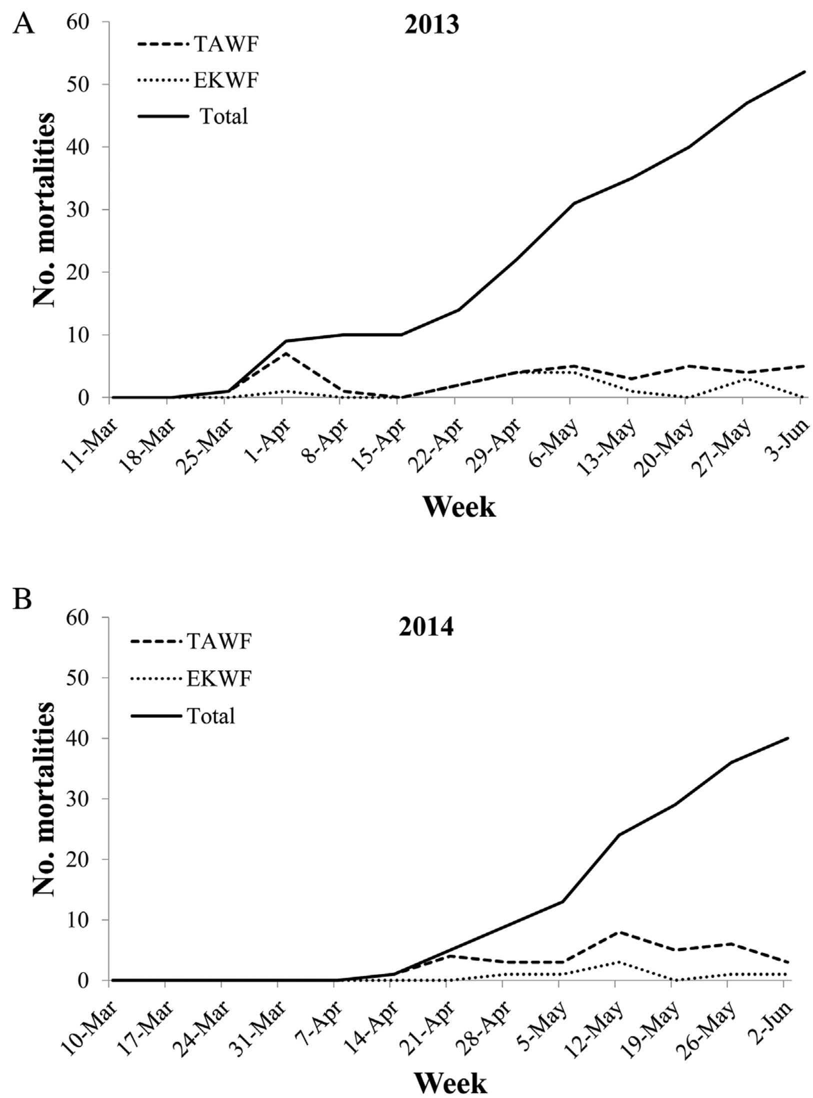

Figure 2. Weekly and cumulative wind energy related-mortalities in spring for birds and bats in 2013 (A) and 2014 (B) at the Tatanka Wind Farm (TAWF) in McPherson County, South Dakota and Dickey County, North Dakota, and the Edgeley-Kulm Wind Farm (EKWF) in LaMoure County, North Dakota, USA.

northern shoveler [*Anas clypeata*], blue-winged teal [*A. discors*], and gadwall [*A. strepera*]) use cropland for nesting cover, especially in areas with high wetland densities, both overall abundance and reproductive success is lower in cropland landscapes than in grasslands (Higgins 1977, Boyd 1985, Bethke and Nudds 1995, Greenwood et al. 1995, Drever et al. 2007). Thus, siting wind energy facilities outside grassland areas that are considered important for waterfowl breeding may reduce turbine-related waterfowl mortality. Coincidentally, avoiding areas with high waterfowl breeding densities, based on USFWS Habitat and Population Evaluation Team data, also may reduce overall mortality because these areas represent critical habitat for many other species of wetland-dependent birds (Reynolds et al. 2006, Niemuth et al. 2008, Fargione et al. 2012).

We estimated the fatality rates for all species found during searches, but many of those estimates are imprecise. The lower bound seasonal mortality estimate for most species was 0, typically because of low detection rates. Lack of precision is common among many wind energy mortality studies with searcher detection rates varying upwards from 0.11 (Smallwood 2013). Additionally, our search goal of 20 turbines daily with only a 2-person search team may have added to difficulties finding small-bodied birds.

We were unable to attribute detected avian mortality to resident or migrant populations and thus, could not establish an effect on local or regional populations for 2 reasons. First, our estimates excluded those individuals killed by vehicular-collision, power lines, barbed-wire fences, predation, or those killed outside of the spring migratory period; although we did record these carcasses separately. And second, many of the species recovered both migrate through and nest in the study area. Classifying these carcasses as either a migrant or a resident would have been speculation at best.

Our estimated fatality rates for most species were low; yet, many migratory bird populations are declining (North American Bird Conservation Initiative 2014), and additional sources of mortality, such as wind energy, may be of concern.

Table 2. Distances carcasses were found from turbines at the Tatanka Wind Farm in McPherson County, South Dakota and Dickey County, North Dakota, and the Edgeley-Kulm Wind Farm in LaMoure County, North Dakota, USA, 2013–2014.

Distance from turbine (m)	No. carcasses	% of carcasses
0–10	8	9
11–20	17	18
21–30	11	12
31–40	18	20
41–50	18	20
51–60	14	15
61–70	5	5
>70	1	1

Our fatality rate estimates for just our sampling period (a 13-week span) are similar to full-year estimates at other wind facilities in the United States (Johnson et al. 2002, Erickson et al. 2005, Smallwood and Thelander 2008). However, fatality rates at multiple phases of construction ranged from 2.86 deaths/MW/year to 5.93 deaths/MW/year at Buffalo Ridge, Minnesota (Johnson et al. 2002). Comparatively, estimates from the Altamont Pass Wind Resource Area for 3 sets of turbines were 2.28, 1.51, and 1.82 deaths/MW/year (Smallwood and Thelander 2008). We likely underestimated bat mortality at TAWF and EKWF (Bicknell and Gillam 2013) because 90% of bat fatalities occur between July and September (Erickson et al. 2002, Kuvlesky et al. 2007), a period outside the sampling frame for our study. Collision risk also can vary seasonally, thus influencing species-specific mortality estimates (Kuvlesky et al. 2007). We recognize our results do not reflect turbine-mortality for all species in our area throughout the year.

We did not find carcasses of any federally threatened or endangered species during our study; however, 5 listed or candidate migratory birds (whooping crane [*Grus americana*], least tern [*Sterna antillarum*], piping plover [*Charadrius melodus*], red knot [*Calidris canutus rufa*], and Sprague's pipit) and 1 threatened bat (northern long-eared bat [*Myotis septentrionalis*]) migrate through or breed within the Missouri Coteau (USFWS 2015). Other species are considered regional conservation priorities, particularly wetland and grassland species that are experiencing habitat loss and fragmentation due to grassland conversion for production agriculture (Wright and Wimberly 2013) and tile drainage (Stodola et al. 2014). We categorized species of concern for our region as those referenced in North Dakota's 100 Species of Conservation Priority (Hagen et al. 2005); South Dakota's Heritage Species, Priority Species listed in

Table 3. Spring (Mar–Jun) turbine-strike species found during mortality searches at the Tatanka Wind Farm in McPherson County, South Dakota and Dickey County, North Dakota, USA, 2013–2014, including number of carcasses found for each species, estimated mortalities based on searcher detection rates, and the 80% confidence interval for those estimates.

		Tatanka					
		2013			2014		
Species	Scientific name	Found	Estimated	80% CI	Found	Estimated	80% CI
Gadwall	*Anas strepera*	1	3	0–7[a]	1	4	0–9[a]
Mallard	*A. platyrhynchos*	12	40	24–56	15	55	38–72
Blue-winged teal	*A. discors*				2	7	0–14
Northern pintail	*A. acuta*	4	14	5–23	3	11	3–19
Green-winged teal	*A. crecca*				1	4	0–9[a]
Redhead	*Aythya americana*	2	7	1–13	2	7	0–14
Ring-necked pheasant	*Phasianus colchicus*	1	3	0–7[a]			
Sharp-tailed grouse	*Tympanuchus phasianellus*	2	7	1–13			
Eared grebe	*Podiceps nigricollis*				1	10	0–23[a]
American white pelican	*Pelecanus erythrorhynchos*	1	3	0–7[a]			
Virginia rail	*Rallus limicola*	1	16	0–41[a]			
Sora	*Porzana carolina*	1	16	0–41[a]			
American coot	*Fulica americana*				1	4	0–9[a]
Upland sandpiper	*Bartramia longicauda*				2	20	1–39
Eastern wood-pewee	*Contopus virens*				1	10	0–23[a]
Warbling vireo	*Vireo gilvus*				1	10	0–23[a]
Red-eyed vireo	*V. olivaceus*	1	16	0–41[a]			
Tree swallow	*Tachycineta bicolor*	1	16	0–41[a]			
Barn swallow	*Hirundo rustica*	2	32	3–61			
Brown creeper	*Certhia americana*	1	16	0–41[a]			
Swainson's thrush	*Catharus ustulatus*	1	16	0–41[a]			
European starling	*Sturnus vulgaris*	1	16	0–41[a]			
Snow bunting	*Plectrophenax nivalis*	1	16	0–41[a]			
American tree sparrow	*Spizella arborea*				1	10	0–23[a]
Savannah sparrow	*Passerculus sandwichensis*				1	10	0–23[a]
Song sparrow	*Melospiza melodia*	1	16	0–41[a]			
Dark-eyed junco	*Junco hyemalis*	1	16	0–41[a]			
Western meadowlark	*Sternella neglecta*				1	10	0–23[a]
Common grackle	*Quiscalus quicula*	1	16	0–41[a]			
Silver-haired bat	*Lasionycteris noctivagans*	1	16	0–41[a]			

[a] Indicates negative lower confidence interval value truncated to 0.

Table 4. Spring (Mar–Jun) turbine-strike species found during mortality searches at the Edgeley-Kulm Wind Farm in LaMoure County, North Dakota, USA, 2013–2014, including number of carcasses found for each species, estimated mortalities based on searcher detection rates, and the 80% confidence interval for those estimates.

		Edgeley-Kulm					
		2013			2014		
Species	Scientific name	Found	Estimated	80% CI	Found	Estimated	80% CI
Mallard	*Anas platyrhynchos*	6	21	10–32	6	38	18–58
Redhead	*Aythya americana*	1	3	0–7[a]			
Ring-necked pheasant	*Phasianus colchicus*	2	7	1–13			
Wilson's snipe	*Gallinago delicata*	2	10	0–21[a]			
European starling	*Sturnus vulgaris*	1	5	0–12[a]			
Snow bunting	*Plectrophenax nivalis*	1	5	0–12[a]			
Le Conte's sparrow	*Ammodramus leconteii*	1	5	0–12[a]			
Red-winged blackbird	*Agelaius phoeniceus*				1	14	0–32[a]
Silver-haired bat	*Lasionycteris noctivagans*	1	5	0–12[a]			

[a] Indicates negative lower confidence interval value truncated to 0.

the All Bird Conservation Plan, and Species of Greatest Conservation Need listed in the South Dakota Wildlife Action Plan (South Dakota Game, Fish and Parks 2014); and the USFWS Birds of Conservation Concern (USFWS 2008*a*) and Birds of Management Concern (USFWS 2011). Overall, we found 14 species of conservation priority as mortalities at wind turbines during our spring study, including the American white pelican (*Pelecanus erythrorhynchos*), upland sandpiper (*Bartramia longicauda*), northern pintail, redhead, sharp-tailed grouse (*Tympanuchus phasianellus*), Le Conte's sparrow (*Ammodramus leconteii*), brown creeper (*Certhia americana*), silver-haired bat (*Lasionycteris noctivagans*), eared grebe (*Podiceps nigricollis*), eastern wood-pewee (*Contopus virens*), American tree sparrow (*Spizella arborea*), savannah sparrow (*Passerculus sandwichensi*), dark-eyed junco (*Junco hyemalis*), and western meadowlark (*Sternella neglecta*). Of these, 3 species were found at EKWF and 13 were found at TAWF, consistent with the idea that many bird species of conservation concern are less abundant and may experience less turbine mortality at sites where turbines are placed within pre-existing land disturbance (e.g., agricultural fields; Fletcher et al. 2011, Fargione et al. 2012).

Many of the species we reported as turbine-mortalities, such as the mallard and barn swallow (*Hirundo rustica*), were not included in the above state and federal lists but remain protected under the Migratory Bird Treaty Act (USFWS 2013). Most of the species we reported were found as turbine mortalities at other facilities nationwide (Johnson et al. 2002, Smallwood and Thelander 2008). Additional wind facilities constructed in the NGP, PPR, and elsewhere may have an increased effect on these populations. In 2014, 822 new turbines were proposed for construction in the 4-county area surrounding our study sites (USFWS, unpublished data). Assuming fatality rates comparable to our results, we estimate that an additional 2,290 deaths would occur in the 4-county area during the spring migration period (Mar–Jun). These additional turbines have the potential to affect species we documented as susceptible to turbine-strikes and enhance the risk of mortality to threatened and endangered species in the region. Any wind turbines sited in bird migration corridors and the fatalities associated with them remain a justifiable concern (Erickson et al. 2005, Kuvlesky et al. 2007).

Table 5. Land-cover percentages at the Tatanka Wind Farm (TAWF) in McPherson County, South Dakota and Dickey and McIntosh counties, North Dakota, and the Edgeley-Kulm Wind Farm (EKWF) in LaMoure County, North Dakota, 2013–2014.

Land-cover Class	TAWF (%)	EKWF (%)
Grass/Pasture	70	6
Crops	6	69
Wetlands	13	16
Hay/Alfalfa	8	6
Trees	2	1
Development	1	2

MANAGEMENT IMPLICATIONS

Despite low precision in mortality estimates, our fatality counts and associated mortality estimates indicate that wind energy operations on the NGP and in the PPR have the potential to negatively affect many avian species. Although fatality rates for a cropland-dominated and a grassland-dominated wind facility were similar, more species of concern were found at the fatality with the majority of turbines located in grassland habitats. Future siting of wind facilities focused on pre-existing disturbed land, such as cropland, at the turbine-site scale may help to reduce avian mortality. Our results suggest involved parties consider siting future wind energy facilities in cropland landscapes with wind-energy resources ($\geq$6.5 m/s average annual wind speed at an 80-m height; DOE 2015) in areas with low densities of nesting ducks (<25 breeding pairs per square mile; USFWS 2008*b*). Because important upland duck nesting habitats often coincide with critical habitats for other grassland-dependent species, the use of these areas also may reduce overall mortality.

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LITERATURE CITED

American Wind Energy Association. 2014. U.S. wind energy: state maps and rankings. http://www.awea.org/resources/statefactsheets.aspx/. Accessed 29 Sep 2014.

Anderson, R., M. Morrison, K. Sinclair, and D. Strickland. 1999. Studying wind energy-bird interactions: a guidance document. National Wind Coordinating Committee, Washington, D.C., USA.

Arnett, E. B., W. K. Brown, W. P. Erickson, J. K. Fiedler, B. L. Hamilton, T. H. Henry, A. Jain, G. D. Johnson, J. Kerns, R. R. Kolford, C. P. Nicholson, T. O'Connel, M. Piorkowski, and J. R. Tankersly. 2008. Patterns of bat fatalities at wind energy facilities in North America. Journal of Wildlife Management 72:61–78.

Baerwald, E. F., and R. M. R. Barclay. 2011. Patterns of activity and fatality of migratory bats at a wind energy facility in Alberta, Canada. Journal of Wildlife Management 75:1103–1114.

Barclay, R. M. R., E. F. Baerwald, and J. C. Gruver. 2007. Variation in bat and bird fatalities at wind energy facilities: assessing the effects of rotor size and tower height. Canadian Journal of Zoology 85:381–387.

Batt, B. D. J., M. G. Anderson, C. D. Anderson, and F. D. Caswell. 1989. The use of prairie potholes by North American ducks. Pages 204–227 *in* A. van der Valk, editor. Northern prairie wetlands. Iowa State University Press, Ames, USA.

Bellrose, F. C. 1980. Ducks, geese, and swans of North America. Second edition. Stackpole, Harrisburg, Pennsylvania, USA.

Beston, J. A., J. E. Diffendorfer, and S. Loss. 2015. Insufficient sampling to identify species affected by turbine collisions. Journal of Wildlife Management 79:513–517.

Bethke, R. W., and T. D. Nudds. 1995. Effects of climate change and land use on duck abundance in Canadian prairie-parklands. Ecological Applications 5:588–600.

Bicknell, L. J., and R. H. Gillam. 2013. Survey of bat mortalities at a wind-energy facilities in North Dakota. Journal of Fish and Wildlife Management 4:139–143.

Blank, R. R., and M. A. Fosberg. 1989. Cultivated and adjacent virgin soils in northcentral South Dakota: I. chemical and physical comparisons. Soil Science Society of America Journal 53:1484–1490.

Bluemle, J. P. 1979. Geology of Dickey and LaMoure counties. North Dakota Geological Survey Bulletin 70, Grand Forks, USA.

Boyd, H. 1985. The large-scale impact of agriculture on ducks in the Prairie Provinces, 1950–1981. Canadian Wildlife Services Progress Notes 149. Canadian Wildlife Service, Environment Canada, Edmonton, Alberta.

Cryan, P. M. 2011. Wind turbines as landscape impediments to the migratory connectivity of bats. Environmental Law 41:355–370.

Cryan, P. M., and R. M. R. Barclay. 2009. Causes of bat fatalities at wind turbines: hypotheses and predictions. Journal of Mammalogy 90:1330–1340.

Dinsmore, S. J., S. K. Skagen, and D. H. Helmers. 1999. Shorebirds: an overview for the Prairie Pothole Joint Venture. Prairie Pothole Joint Venture, U.S. Fish and Wildlife Service, Denver, Colorado, USA.

Drever, M. C., T. D. Nudds, and R. G. Clark. 2007. Agricultural policy and nest success of prairie ducks in Canada and the United States. Avian Conservation and Ecology 2:5.

Drewitt, A. L., and R. H. W. Langston. 2006. Assessing the impacts of wind farms on birds. Ibis 148:29–42.

Erickson, W. P., G. D. Johnson, M. D. Strickland, D. P. Young Jr., K. Sernka, and R. Good. 2001. Avian collisions with wind turbines: a summary of existing studies and comparisons to other sources of avian collision mortality in the United States. National Wind Coordinating Committee, Washington, D.C., USA.

Erickson, W. P., G. D. Johnson, and D. P. Young. 2005. A summary and comparison of bird mortality from anthropogenic causes with an emphasis on collisions. U.S. Department of Agriculture Forest Service General Technical Report PSW-GTR-191, Albany, California, USA.

Erickson, W. P., G. D. Johnson, D. Young, M. D. Strickland, R. Good, M. Bourassa, K. Bay, and K. Sernka. 2002. Synthesis and comparison of baseline avian and bat use, raptor nesting and mortality information from proposed and existing wind developments. Report prepared for Bonneville Power Administration, Portland, Oregon, USA.

Fargione, J., J. Kiesecker, M. J. Slaats, and S. Olimb. 2012. Wind and wildlife in the northern Great Plains: identifying low-impact areas for wind development. PLoS ONE 7:e41468.

Fletcher, R. J., B. A. Robertson, J. Evans, P. J. Doran, J. R. R. Alavalapati, and D. W. Schemske. 2011. Biodiversity conservation in the era of biofuels: risks and opportunities. Frontiers in Ecology and the Environment 9:161–168.

Greenwood, R. J., A. B. Sargeant, D. H. Johnson, L. M. Cowardin, and T. L. Schaffer. 1995. Factors associated with duck nest success in the Prairie Pothole Region of Canada. Wildlife Monographs 128:1–57.

Gue, C. T., J. A. Walker, K. R. Mehl, J. S. Gleason, S. E. Stephens, C. R. Loesch, R. E. Reynolds, and B. J. Goodwin. 2013. The effects of a large-scale wind farm on breeding season survival of female mallards and blue-winged teal in the Prairie Pothole Region. Journal of Wildlife Management 77:1360–1371.

Hagen, S. K., P. T. Isakson, and S. R. Dyke. 2005. North Dakota comprehensive wildlife conservation strategy. North Dakota Game and Fish Department, Bismarck, USA.

Higgins, K. F. 1977. Duck nesting in intensively farmed areas of North Dakota. Journal of Wildlife Management 41:232–242.

Higgins, K. F., R. G. Osborn, and D. E. Naugle. 2007. Effects of wind turbines on birds and bats in southwestern Minnesota. Pages 153–176 *in* M. de Lucas, G. E. Janss, and M. Ferrer, editors. Birds and wind farms: risk assessment and mitigation. Servicios Informativos Ambientales/Quercus, Madrid, Spain.

Hoekstra, J. M., T. M. Boucher, T. H. Ricketts, and C. Roberts. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. Ecology Letters 8:23–29.

Jameson, J. W., and C. K. R. Willis. 2012. Bat mortality at a wind power facility in central Canada. Northwestern Naturalist 93:194–202.

Johnson, G. D., W. P. Erickson, M. D. Strickland, M. F. Shepherd, D. A. Shepherd, and S. A. Sarappo. 2002. Collision mortality of local and migrant birds at a large-scale wind-power development on Buffalo Ridge, Minnesota. Wildlife Society Bulletin 30:879–887.

Kiesecker, J. M., J. S. Evans, J. Fargione, K. Doherty, K. R. Foresman, T. H. Kunz, D. Naugle, N. P. Nibbelink, and N. D. Nieumuth. 2011. Win-win for wind and wildlife: a vision to facilitate sustainable development. PloS ONE 6:e17566.

Knopf, F. L. 1996. Prairie legacies: birds. Pages 135–148 *in* F. B. Samson and F. L. Knopf, editors. Prairie conservation: preserving North America's most endangered ecosystem. Island Press, Washington, D.C., USA.

Korner-Nievergelt, F., P. Korner-Nievergelt, O. Behr, I. Niermann, R. Brinkmann, and B. Hellriegel. 2011. A new method to determine bird and bat fatality at wind energy turbines from carcass searches. Wildlife Biology 17:350–363.

Kuchler, A. W. 1964. Potential natural vegetation of the conterminous United States. Special Publication 36. American Geographical Society, New York, USA.

Kunz, T. H., E. B. Arnett, W. P. Erickson, A. R. Hoar, G. D. Johnson, R. P. Larkin, M. D. Strickland, R. W. Thresher, and M. D. Tuttle. 2007. Ecological impacts of wind energy development on bats: questions, research needs, and hypotheses. Frontiers in Ecology and the Environment 5:315–324.

Kuvlesky, Jr. W. P., L. A. Brennan, M. L. Morrison, K. K. Boydstron, B. M. Ballard, and F. C. Bryant. 2007. Wind energy development and wildlife

conservation: challenges and opportunities. Journal of Wildlife Management 71:2487–2498.
Loesch, C. R., J. A. Walker, R. E. Reynolds, J. S. Gleason, N. D. Niemuth, S. E. Stephens, and M. A. Erickson. 2013. Effect of wind energy development on breeding duck densities in the Prairie Pothole Region. Journal of Wildlife Management 77:587–598.
Longcore, T., C. Rich, P. Mineau, B. MacDonald, D. G. Bert, L. M. Sullivan, E. Mutrie, S. A. Gauthreaux, Jr. M. L. Avery, R. L. Crawford, A. M. Mannville, II., E. R. Travis, and D. Drake. 2013. Avian mortality at communication towers in the United States and Canada: which species, how many, and where? USDA National Wildlife Research Center, Fort Collins, Colorado, USA.
Loss, S. R., T. Will, and P. P. Marra. 2013. Estimates of bird collision mortality at wind facilities in the contiguous United States. Biological Conservation 168:201–209.
Manville, A. M., II. 2009. Towers, turbines, power lines, and buildings – steps being taken by the U.S. Fish and Wildlife Service to avoid or minimize take of migratory birds at these structures. Pages 262–272 *in* T. D. Rich, C. Arizmendi, D. Demarest, and C. Thompson, editors. Tundra to tropics: connecting habitats and people. Proceedings of the Fourth International Partners in Flight Conference, McAllen, Texas, USA.
National Academy of Sciences. 2007. Environmental impacts of wind-energy projects. The National Academies Press, Washington, D.C., USA.
National Research Council. 2007. Environmental impacts of wind energy projects. The National Academies Press, Washington, D.C., USA.
National Wind Coordination Collaborative [NWCC]. 2010. Wind turbine interactions with birds, bats, and their habitats: a summary of research results and priority questions. http://www.nationalwind.org/publications/bbfactsheet.aspx. Accessed 18 Jul 2013.
Niemuth, N. D., G. W. Beyersbergen, and M. R. Norton. 2005. Waterbird conservation planning in the Northern Prairie and Parkland Region: integration across borders and other bird conservation initiatives. U.S. Department of Agriculture Forest Service Technical Report, Pacific Southwest Research Station, Albany, California, USA.
Niemuth, N. D., R. E. Reynolds, D. A. Grandfors, R. R. Johnson, B. Wangler, and M. E. Estey, editors. 2008. Landscape-level planning for conservation of wetland birds in the US Prairie Pothole Region. Pages 533–560 *in* J. J. Millspaugh and F. R. Thompson, III, editors. Models for planning wildlife conservation in large landscapes. Elsevier Science, Burlington, Massachusetts, USA.
Niemuth, N. D., J. A. Walker, J. S. Gleason, C. R. Loesch, R. E. Reynolds, S. E. Stephens, and M. A. Erickson. 2013. Influence of wind turbines on presence of willet, marbled godwit, Wilson's phalarope and black tern on wetlands in the Prairie Pothole Region of North Dakota and South Dakota. Waterbirds 36:263–276.
North American Bird Conservation Initiative. 2014. The state of the birds report 2014. U.S. Department of the Interior, Washington, D.C., USA.
North Dakota Agricultural Weather Network Center. 2014. North Dakota Agricultural Weather Network Center. http://ndawn.ndsu.nodak.edu. Accessed 14 Aug 2014.
Reynolds, R. E., T. L. Shaffer, C. R. Loesch, and R. C. Cox Jr. 2006. The Farm Bill and duck production in the Prairie Pothole Region: increasing the benefits. Wildlife Society Bulletin 34:963–974.
Rich, T. D., C. J. Beardmore, H. Berlanga, P. J. Blancher, M. S. W. Bradstreet, G. S. Butcher, D. W. Demarest, E. H. Dunn, W. C. Hunter, E. E. Inigo-Elias, J. A. Kennedy, A. M. Martell, A. O. Panjabi, D. N. Pashley, K. V. Rosenberg, C. M. Rustay, J. S. Wendy, and T. C. Will. 2004. Partners in Flight North American Landbird Conservation Plan. Cornell Lab of Ornithology, Ithaca, New York, USA.
Rollins, K. E., D. K. Meyerholz, G. D. Johnson, A. P. Capparella, and S. S. Loew. 2012. A forensic investigation into the etiology of bat mortality at a wind farm: barotrauma or traumatic injury? Veterinary Pathology 49:362–371.
Smallwood, K. S. 2007. Estimating wind turbine-cause bird mortality. Journal of Wildlife Management 71:2781–2791.
Smallwood, K. S. 2013. Comparing bird and bat fatility-rate estimates among North American wind-energy projects. Wildlife Society Bulletin 37:19–33.
Smallwood, K. S., D. A. Bell, S. A. Snyder, and J. E. Didonato. 2010. Novel scavenger removal trials increase wind turbine-caused avian fatality estimates. Journal of Wildlife Management 74:1089–1097.
Smallwood, K. S., and C. Thelander. 2008. Bird mortality in the Altamont Pass wind resource area California. Journal of Wildlife Management 72:215–223.
Sorenson, L. G., R. Goldberg, T. L. Root, and M. G. Anderson. 1998. Potential effects of global warming on waterfowl populations breeding in the northern Great Plains. Climate Change 40:343–369.
South Dakota Game, Fish and Parks. 2014. Wildlife and habitat. http://gfp.sd.gov/wildlife. Accessed 29 Aug 2014.
South Dakota Office of Climatology. 2014. South Dakota Climate and Weather. http://climate.sdstate.edu/climate_site/climate.htm. Accessed 14 Aug 2014.
Stephens, S. E., J. A. Walker, D. R. Blunck, A. Jayaraman, D. E. Naugle, J. K. Ringelman, and A. J. Smith. 2008. Predicting risk of habitat conversion in native temperate grasslands. Conservation Biology 22:1320–1330.
Stewart, R. E., and H. A. Kantrud. 1971. Classification of natural ponds and lakes in the glaciated prairie region. Resource Publication 92: Bureau of Sports Fisheries and Wildlife, U. S. Fish and Wildlife Service, Washington, D. C., USA.
Stodola, K. W., B. J. O'Neal, M. G. Alessi, J. L. Deppe, T. R. Dallas, R. A. Beveroth, T. J. Benson, and M. P. Ward. 2014. Stopover ecology of American golden-plovers (*Pluvialis dominica*) in Midwestern agricultural fields. Condor 116:162–172.
U.S. Department of Agriculture. 2014. Cropland data layer. National Agricultural Statistics Service, USDA, Washington, D.C., USA. https://gdg.sc.egov.usda.gov. Accessed 16 Oct 2014.
U.S. Department of Energy [DOE]. 2008. 20% wind energy by 2030: increasing wind energy's contribution to US electricity supply. DOE, Washington, D.C., USA.
U.S. Department of Energy [DOE]. 2015. WINDExchange. http://apps2.eere.energy.gov/wind/windexchange/. Accessed 27 Apr 2015.
U.S. Fish and Wildlife Service [USFWS]. 2008*a*. Birds of conservation concern2008. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia, USA.
U.S. Fish and Wildlife Service [USFWS]. 2008*b*. Comprehensive management plan: North Dakota wetland management districts. United States Department of Interior, Fish and Wildlife Service, Lakewood, Colorado, USA.
U.S. Fish and Wildlife Service [USFWS]. 2011. Birds of management concern and focal species. United States Department of Interior, Fish and Wildlife Service, Division of Migratory Bird Management, Arlington, Virginia, USA.
U.S. Fish and Wildlife Service [USFWS]. 2012. U.S. Fish and Wildlife Service land-based wind energy guidelines. OMB Control No. 1018–0148. United States Department of Interior, Fish and Wildlife Service, Arlington, Virginia, USA.
U.S. Fish and Wildlife Service [USFWS]. 2013. Congressional and legislative affairs: digest of federal resource laws. http://www.fws.gov/laws/lawsdigest/resourcelaws.html. Accessed 30 Sep 2013.
U.S. Fish and Wildlife Service [USFWS]. 2014. Draft habitat management plan, Kulm Wetland Management District. U.S. Department of the Interior, Fish and Wildlife Service, Mountain-Prairie Region, Kulm, North Dakota, USA.
U.S. Fish and Wildlife Service [USFWS]. 2015. Endangered species. http://www.fws.gov/endangered. Accessed 26 Apr 2015.
Vladislavleva, E., T. Friedrich, F. Neumann, and M. Wagner. 2013. Predicting the energy output of wind farms based on weather data: important variables and their correlation. Renewable Energy 50:236–243.
Warudkar, V., and S. Ahmed. 2013. Wind resource assessment: a review. International Journal of Mining, Metallurgy, and Mechanical Engineering 3:204–207.
Wright, C. K., and M. C. Wimberly. 2013. Recent land use change in the western Corn Belt threatens grasslands and wetlands. Proceedings of the National Academy of Sciences of the United States of America 110:4134–4139.

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