BEFORE THE PUBLIC UTILITIES COMMISSION

OF THE STATE OF SOUTH DAKOTA

IN THE MATTER OF THE APPLICATION BY NORTH BEND WIND PROJECT, LLC FOR A PERMIT TO CONSTRUCT AND OPERATE THE NORTH BEND WIND PROJECT IN HYDE COUNTY AND HUGHES COUNTY, SOUTH DAKOTA

SD PUC DOCKET EL21-018

PRE-FILED TESTIMONY OF MICHAEL BOLLWEG, INDIVIDUALLY AND ON BEHALF OF JUDI BOLLWEG, TUMBLEWEED LODGE, LLC, AND BOLLWEG FAMILY, LLLP

Q. State your name.

A. Michael Bollweg.

Q. State your occupation.

A. I am a farmer. I also manage a hunting lodge.

Q. What is your educational background.

A. I graduated from South Dakota State University in 1996 with a Bachelor of Science degree in agriculture. My resume/background is attached hereto as Exhibit A.

Q. Who are you providing testimony on behalf of today?

A. I am testifying on behalf of myself, Judi Bollweg, Bollweg Family, LLLP, and Tumbleweed Lodge. Judi Bollweg has provided me with a special power of attorney allowing me to speak on her behalf. (See Exhibit B.)

Q. Where do you live?

A. I live in Hughes County, South Dakota, at 20152 321st Avenue, Harrold, South Dakota 57563.

Q. How long have you been farming?

A. I have worked for our farming operation for 34 years. I have worked in all aspects of the farming operation on my own behalf, on behalf of Bollweg Farms, and on behalf of my mother, Judi Bollweg.

Q. How much land do you farm?

A. Approximately 3,910 acres.

Q. Where is the land you farm located?

A. The land we farm is generally located as follows:

- SE¼ of Section 2, Township 112, Range 74 – 160 acres

- N½ of the NW¼ of Section 14, Township 112, Range 74 – 70 acres
- S½ of Section 23, Township 112, Range 74 – 320 acres
- SE¼ of Section 24, Township 112, Range 74 – 160 acres
- NE¼ of Section 21, Township 111, Range 74 – 160 acres
- S½ of the SE¼ of Section 16, Township 111, Range 74 – 80 acres
- SW¼ of Section 11, Township 111, Range 74 – 160 acres

Q. What crops do you grow?

A. Wheat, sunflowers, soy beans, corn, grain sorghum, and cover crops.

Q. What is the name of the hunting lodge you manage?

A. Tumbleweed Lodge.

Q. Where is Tumbleweed Lodge?

A. It is located in Hughes County, South Dakota.

Q. What is the lodge's main purpose?

A. The lodge provides hunting opportunities for clients from all over the country.

Q. When did Tumbleweed Lodge open?

A. Tumbleweed Lodge has been hosting hunting guests since the early 1980s. The preserves began in 1988.

Q. Tell us more about Tumbleweed Lodge.

A. It is a family business. It has 40 employees (all but one who are from South Dakota). The business has consistently paid South Dakota sales and tourism tax, and has generated license sales and fees for South Dakota Game, Fish, and Parks. Financial details can be found in Exhibit C, which is **confidential**. It promotes South Dakota's proud heritage of hunting. In 2011 it was recognized as one of the top 10 hunting lodges in the World. It is one of the

the oldest, most established upland hunting preserves in the state. We hosted the annual Governor's Hunt for 15 years. In 2014 Governor Daugaard presented us with the Brent Wilbur Habitat Award; "to a landowner who has reached the highest standards of conservation stewardship in managing their lands for the benefit of South Dakota's diverse wildlife resources." We were recognized as one of the Top 20 Wing Shooting Destinations in the world (in A Wingshooter's World). Our business model will continue for generations. Our employees are the backbone of our operation and they rely on our family as a significant source of their income. Our economic impact spans across the entire state of South Dakota. Irresponsible turbine locations will have a crippling effect on our operation as guests have clearly stated they will not return. We average nearly 400 guests each season and most would tell you they come here to avoid the blinking lights, concrete jungles, and incessant noise. We are firmly tied to the area, land, and State of South Dakota. We are not a developer building the system and then selling the business.

Q. How much hunting land does Tumbleweed Lodge have?

A. There are multiple hunting areas. Of the 3,910 acres, 2,800 acres are in preserve:

- Tumbleweed North is a preserve that consists of 2,400 acres located as follows:
  - S½ of Section 33, Township 112, Range 74 – 320 acres
  - S½ of Section 34, Township 112, Range 74 – 320 acres
  - Section 3, Township 111, Range 74 – 640 acres
  - Section 4, Township 111, Range 74 – 640 acres
  - W½ of Section 9, Township 111, Range 74 – 320 acres
  - NE¼ of Section 10, Township 111, Range 74 – 160 acres
- Tumbleweed South is a preserve that consists of 400 acres located as follows:

* N½ of Section 27, Township 111, Range 74 – 320 acres
* N½ of SE¼ of Section 27, Township 111, Range 4 – 80 acres

- Gregg Outlot consists of 66 acres and is adjacent to West Bend. The legal description is NE¼ of Section 9, Township 108, Range 74. (Not near the proposed project.)
- Bollweg Outlot consists of 10 acres and is adjacent to West Bend. The legal description is NW¼SW¼ of Section 10, Township 108, Range 74. (Not near the proposed project.)

Q. What other family businesses have you been involved in?

A. In addition to farming and managing the hunting lodge, I spent a substantial part of my career working for Bollweg Spraying. Bollweg Spraying was owned and operated by my late father, Donald Bollweg. My father was an aerial applicator. He operated numerous spray planes. While working for Bollweg Spraying I provided ground support for the pilots. I also determined which crop protection to use for the various applications. While working for Bollweg Spraying I learned practical and safe spraying practices. For example, my father and I laid out farm fields to be two miles long to minimize the amount of turning the planes had to make to spray the fields. My family has always had the entrepreneur spirit and a steward of the land. I was heavily involved with the inception and growth of Harrold Grain Co. taking active rolls in grain grading, marketing, and loadout operations before we sold it. I was also involved in our construction business which involved digging/laying waterlines for area farm operations. It also included major land development in which we would clean up the rocks and blow dirt filled fences of overgrazed, eroded lands and develop productive crop land, riparian buffers along waterways and establish new tree belts.

Q. Do you use aerial spraying in your farming operation?

A. Yes. Use of agricultural chemicals is necessary for the profitable operation of our farm. These need to be used safely and efficiently. Because many of the chemical applications to our fields come late in the season it is necessary to use planes to spray mature crops that are too tall to spray with ground rigs.

Q. What do you spray for?

A. Currently it is necessary to spray our wheat and sunflowers. Those fields are currently subject to several threats. One example is the fungal pathogen fusarium graminearum. Fusarium graminearum causes head blight in wheat. Crop pests such as the red sunflower seed weevil and head moths are a threat to sunflowers. It should be noted that the current threats to our crops may change; pests and diseases evolve. The threats of tomorrow may not actually exist but as evolution occurs new threats appear that require new technology. During extreme wet conditions when ground application isn't an option, aerial application is your only option for all crops.

Q. What proposed turbines will cause problems for the pilots spraying your fields?

A. I am asking that the PUC deny the applications for turbines/towers #6, 8, 9, 14, 15, 20, 21, and 22. Tower #6 in particular will have an effect upon Tumbleweed Lodge.

Q. Why are these towers problematic?

A. These towers effectively box in our fields making it dangerous and/or impossible to spray them.

Q. Why would it be dangerous or impossible to spray them?

A. Because of the space needed for the planes to turn around. I belong to a trade organization (the SDAA) which has retained an expert who had determined what the normal turn around is for agricultural sprayers. These are the typical safe and normal turn around areas used by spray planes which typically spray our fields. The towers that are proposed are well within the safe ingress and egress areas of our fields. The height of the proposed towers is nearly 500 feet, and an aeronautical study done by the FAA to go up to 600 feet was requested. The study was conducted at the request of ENGIE-North Bend and it states the proposed heights up to 625 feet. FAA Aeronautical Study No. (ASN) 2021-WTE-1926-OE. Signature Control No: 482124683-492930030 (Exhibit D).

Q. If you are unable to spray your fields, what will the result be?

A. We will lose money. Based upon my training in agronomy and my practical work as a farmer for 34 years, there is a real financial cost to my loss of the ability to farm the lands. The current costs of losing the rights to protect our fields from pests and disease could run in the hundreds of dollars per/acre. The evolution of pests and diseases could increase the costs of the problems and increase the need to be able to spray our fields by aircraft.

Q. If only turbines 14 and 15 were removed, would that provide a safe east/west flight pattern on SW 1/4 Section 11-111-74 and a safe north/south flight pattern on NE 1/4 Section 10-111-74?

A. Please see Cody Christensen's expert report and supplements (Exhibits E, F and G) regarding concerns with regard to proposed towers 8, 9, 14, 15, 20-22. His report was provided after the initial assessment the PUC is referencing on page 8 of 84. There is still a threat with a north/south pattern. If north-south spraying patterns are blocked by neighboring turbines applicators will be forced to fly east-west. There are commercial bee keepers in the area who like to place their hives by sun flower fields. Applicators try to spray later in the day when the bees have returned to their hives so they are not killed. Flying east-west later in the day will cause the pilots to be looking into the sunset while flying. Crop dusting is done close to the ground and flying looking into the sunset increases the chance of having a plane crash. The same goes for morning spraying when the bees are less active; flying into the sunrise is a concern as well. Removing towers 14 and 15 would greatly reduce the dangers of an east/west flight pattern on the SW¼ section 11. Removing towers 14 and 15 will not eliminate the dangers to apply products in a north/south pattern on section 10. Tower 21 wouldn't affect an east/west application however it still poses a serious threat in a north/south application eliminating the ability to spray north/south. I anticipate Tower 20 would be a threat with regard to being in the way of the turning radius. These fields need to be sprayed in either direction or it poses a hardship. Terry Barber will testify that ag pilots still need to make a "clean up" pass on all edges of the field as previously mentioned. A letter from the NAAA (National Agricultural Aviation Association) is attached as Exhibit H and it discusses their conclusions for required distances for aircraft to safely turn. The safe distance form turbines to spray is 9,585 feet or 1.82 miles.

Q. What effect will proposed tower #6 have on Tumbleweed Lodge?

A. Our determination that tower #6 poses a threat to the operation is based on the following:

- I am not aware of any studies that exist concerning tolerable amounts of either shadow flicker or audible noise operation to wildlife. Studies might be successful concerning how humans are affected but would not be transferable to the effects upon wildlife; wildlife have senses and abilities well beyond what humans possess. My objections are based upon real life, in the testimony of Corbin Korzan and recommendations of various wildlife governmental organizations tasked with protecting our natural resources. Mr. Korzan's observations of the effect of the towers on his family's lodge operation are more fully discussed below.

- I have been involved in the hunting lodge business for decades. I try to pay attention to matters that might affect wild game. I looked at various studies, including recommendations of the federal government, showing concern for the effects of turbines on prairie chickens and sharp tail grouse.
- Wind Energy and Wildlife Resource Management in Iowa: Avoiding Potential Conflicts (attached as Exhibit I). Relevant excerpts from this study are as follows:
  - An emerging concern for birds is wind turbines placed within or very near large expanses of grassland. In some western states, ground-nesting lesser prairie-chickens have been found to abandon their nesting grounds when wind turbines were erected and operated nearby. It is quite likely that Iowa's greater prairie-chickens, a state endangered species requiring large expanses of unbroken habitat, would exhibit similar behavior. Many other ground-nesting grassland birds have yet to be studied, but some of these species already are in steep decline nationwide and cannot risk another factor that might potentially threaten their survival. Avoid placement of turbines in or near areas where highly "area-sensitive" wildlife species, such as prairie-chickens, are known. Area-sensitive species require expansive, unfragmented habitat. For prairie-chickens in particular, a separation distance of at least 5 miles from all known leks (breeding grounds) is strongly recommended.
- The Siting Guidelines for Wind Power Projects in South Dakota (attached as Exhibit J).

- The Prairie Grouse Management Plan for South Dakota 2017-2021 (attached as Exhibit K). Relevant excerpts from this study are as follows:
    - o Avoid activities near (~ 2 mi) lek sites that could interrupt lekking and nesting activity from March 1–July 30. If disruptive activities cannot be avoided, limit disruptive activities to three hours after sunrise to one hour before sunset. Disruptive activities could include but are not limited to well drilling and operation (water or energy development), burying pipeline or other utilities, building roads, vehicle traffic, direct disruption by human presence, wind tower construction and operation, or low flights by air craft or drones. (p. 17)
    - o Avoid development (e.g., roads, power lines, structures, energy development) in grasslands within occupied range, especially within 1 mi of lek sites. Where development occurs within occupied range, leks within 5 mi of development should be monitored indefinitely. (p. 17)
    - o The impacts of wind energy on greater prairie-chickens are generally equivocal and the impacts on sharp-tailed grouse have not been studied. Greater prairie-chicken lek persistence was ~0.5 for leks <0.62 mi from a turbine, ~0.9 for leks 1.86 mi from a turbine, and >0.95 for leks ≥3.73 mi from a turbine during the 3-year post-construction period for a study in Kansas (Winder et al. 2015a). The rate of lek abandonment was 3× higher for leks <4.97 mi from a

turbine compared to leks ≥4.97 mi from a turbine (22% vs 8%) supporting the USFWS's 4.97-mi buffer zone for wind energy development (Manville 2004). The increased rate of lek abandonment within 4.97 mi of wind turbines is concerning because female prairie-chicken activity centers are nearly always centered within 3.1 mi of active leks (Winder et al. 2015b).

  - There is also evidence that other forms of development within occupied habitat could have a negative impact on prairie grouse. Greater prairie-chickens were found to avoid power lines by 330 ft in Oklahoma (Pruett et al. 2009). A habitat-based greater prairie-chicken lek site model revealed a weak avoidance effect of roads at a 3.1-mi scale in Kansas (Gregory et al. 2011). A similar modeling effort in Minnesota suggests road density at a 2-mile scale was a negative predictor of lek presence (USFWS HAPET 2010). Significantly more roads occurred within 1,640 and 3,280 ft of inactive sharp-tailed grouse leks when compared to active leks in Minnesota (Hanowski et al. 2000). (p. 19)

- All three of the above describe displacement distances of nesting birds as well as recommendations.
- The testimony of Corbin Korzan of Kimball, South Dakota. His family experienced firsthand the negative impact on his property when wind turbines were placed close to their land. They were forced to sell when the pheasants/upland game disappeared.

- When Applicant's representatives were pressed at a Hughes County meeting what the purpose of the indemnity clause would be if no harm is claimed, Engie representatives Casey Willis and Brett Koeneke both conceded that noise and shadow flicker do indeed pose a negative harmful effect. This can be found in the enclosed transcript of the meeting held on June 7, 2021 (Exhibit L). After being pressed for the truth by Commissioner Brown, Brett Koenecke and Casey Willis ultimately conceded in the public meeting there are indeed negative effects.
- There are lek locations on and near our property. They are discussed in the North Bend Wind Project Field Studies Summary 2016 – 2020 at pages 18-21 (Exhibit M). Lek Location 21 is on Bollweg property. I believe it to be active. Lek Location 14 is only a ½ mile from our property that is in preserve. Towers 6, 8, and 10 appear to be within a ½ mile from it. Tower 9 is right on top of it, tower 15 a ¼ mile from it. Lek Location 15 is within a few hundred feet of our farm property located in Section 16/21. Tower 27 is located right on top of it.
- Manville, A. M., II. 2004. Prairie grouse leks and wind turbines: U.S. Fish and Wildlife Service justification for a 5-mi buffer from leks; additional grassland songbird recommendations. Division of Migratory Bird Management, USFWS, Arlington, VA, peer-reviewed briefing paper. This briefing paper is attached as Exhibit N. This briefing paper discusses notes the following:
    - Given continuing uncertainties about structural impacts on prairie grouse, especially the lack of data regarding impacts from wind facilities, and the clearly declining trends in prairie grouse

populations, we urge a precautionary approach by industry and recommend a 5-mile buffer where feasible.

- o While we acknowledge that much research continues on prairie grouse and the impacts of tall structures, including wind turbines – and thus much of the data have yet to be peer reviewed and published – several studies and their recommendations have been published and are used as the basis for our 5-mile recommendation. Most compelling was the recommendation by Connelly et al. (2000:978) calling for protection of breeding habitats within 11.2 mi (18 km) of the leks of migratory populations of Sage-grouse (see discussion beyond). See also Giesen and Connelly (1993) beyond for a discussion of management guidelines for Columbian Sharp-tailed grouse.
- o We believe it is important to clarify that avoidance of vertical structures by grassland and sage-steppe-obligate wildlife is not a new issue, and the Service's recommendations are not merely reactive to current recommendations promoting wind power development nationwide. Concerns were brought to the Division of Migratory Bird Management as early as 2000 regarding the possible impacts of wind turbines on prairie grouse, including noise, habitat disruption, disturbance, fragmentation, and increased predator access (R. Reynolds and N. Niemuth, FWS Habitat and Population Evaluation Team, Bismark, ND 2000 pers. comm.). Much research

has also been conducted on the impacts of high-tension power transmission and electric distribution lines on prairie grouse, providing a detailed body of literature on a related structural issue (e.g., Connelly et al. 2000, Braun et al. 2002, Hagen 2003, Wolfe et al. 2003a and 2003b, Pitman 2003, Hagen et al. 2004, Patten et al. 2004, and Connelly et al. 2004).

- Because range wide, the majority of remaining LPCH populations are fragmented and isolated into “islands” of unfragmented, open prairie, thus we assert that a 5-mile buffer from a lek is recommended to protect the wind power industry from later determinations that construction activities could significantly impact important LPCH populations and habitat corridors needed for future recovery.
- Hagen et al. (2004:79), in “guidelines for managing lesser prairie-chicken populations and their habitats,” recommended that wind turbines and other tall vertical structures be constructed >1.25 mi (2 km) from known or potentially occupied LPCH habitat, at a minimum. This recommended area represents a buffer beyond already existing LPCH home ranges (Figure 2). If wind facilities must be placed in known LPCH habitats, Hagen et al. (2004) suggested they be positioned along prairie edge or clustered in sites with other disturbances.

- Sage-Grouse. they recommended protecting sagebrush and herbaceous understory within 2 mi (3.2 km) of all occupied leks. For non-migratory populations, leks should be considered the center of year-round activity and treated as the focal points for management activities. For non-migratory populations where sagebrush is not uniformly distributed, suitable habitats should all be protected out to 3.1 mi (5 km) from all occupied leks.
- C. Braun (2004 pers. comm.) Wind generators, he indicated, were quite tall and could be seen and avoided by Sage-grouse for long distances. Noise (especially humming), motion, and height all may negatively affect Sage-grouse, although he indicated we still don't know the specific effects. Braun therefore felt that FWS could defend our 5-mile recommendation even though definitive data showing impacts are still being collected.
- Service's Recommendation for 5-Mile Buffer from Leks. The intent of the Service's recommendation for a 5-mile zone of protection is to buffer against increased mortality (both human-caused and natural), against habitat degradation and fragmentation, and against disturbance. In considering our recommendation, FWS recognizes major declines in populations and habitats of prairie grouse. All species of prairie grouse are in varying stages of decline – some populations declining precipitously -- requiring a major focus on direct human impacts, disturbance from structures, and

> fragmentation of habitats. While wind plants are new additions to prairie grouse habitats in the Midwest and West, cumulative impacts from human development and exploitation must be assessed with great care and considerable detail. To reverse these declines will take significant commitment from industry, the Service, and other stakeholders. We view the voluntary nature of our guidance and specifically our 5-mile recommendation as a reasonable effort needed to conserve these important resources.

- In addition, the PUC's own witness, Tom Kirschenmann, testified on May 10, 2019 (a copy of which is enclosed as Exhibit O) concerning the effect of the wind turbines upon grouse and prairie chicken. Mr. Kirschenmann is the Director for the state Wildlife Division in the South Dakota Game, Fisher, and Parks Department. His directive was to study, evaluate, and assist in the management of all wildlife and associated habitats. When he testified, he was the Deputy Director of Wildlife Division and Chief of the Terrestrial Resources Section.
- Mr. Kirschenmann provided testimony as to potential impact to wildlife as the result of the construction of a wind project. (pp.6-7). He testified that there was direct and indirect impact upon birds and bats. He referred to a study, Shaffer, J.A., and D.A. Buhl. 2016. Effects of wind-energy facilities on breeding grassland bird distributions. Conservation Biology 30:50-71 that showed that 7 of 9 species of grassland birds had reduced densities around wind turbines over time. This study is attached to his testimony.

- He noted that there was research into the effects of wind energy on habitat avoidance which has shown that some species will not use grassland or wetland habitat within a certain distance of a wind turbine (p. 8 citing 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. The Journal of Wildlife Management 77:587-598, and Shaffer and Buhl 2016). Both articles are attached to his testimony.
- Mr. Kirschenmann recommended that there was a need to monitor confirmed leks less than 1 mile from proposed turbines (p.20). This is certainly less restrictive than the 5 miles recommended by the A.M. Manville briefing paper discussed above, but regardless turbine 6 is within the 1 mile referenced by Mr. Kirschenmann.

Q. What other concerns do you have if the PUC allows the project to move forward as is?

A. Prairie chickens and sharp tail grouse populations will be affected. Both are indigenous to the region. Materials submitted to the PUC by ENGIE reference prairie chicken leks (breeding grounds). We have ground that has native sharp tail grouse habitat and prairie chicken habitat, and we promote our lodge as having an opportunity for our clients to hunt those birds. I have read many studies on the needs of sharp tail grouse and prairie chickens and have read the testimony of Tom Kirschenmann, a wildlife specialist for the South Dakota Department of Game, Fish and Parks (Exhibit O). The studies he references are the studies that I as a lodge owner, in developing hunting habitat, would use in attempting to develop our hunting lodge. The PUC used him as an expert witness (Exhibit O). He testified on May 10, 2019, concerning the effect of the wind turbines upon prairie chicken and sharp tail grouse. His directive was to study, evaluate, and assist in the management of all wildlife and associated habitats. When he testified he was the Deputy Director of Wildlife Division and Chief of the Terrestrial Resources Section. He provided testimony as to potential impact to wildlife as the result of the construction of a wind project (pp. 6-7). He testified there was a direct and indirect impact upon birds and bats. He referred to a study (Shaffer and Buhl, 2016; attached as Exhibit P) that showed that 7 of 9 species of grassland birds had reduced densities around wind turbines over time. He noted there was research into the effects of wind energy on habitat avoidance; some species will not use grassland or wetland habitat within a certain distance of a wind turbine (pp. 8) citing Loesch et al. 2013 (Exhibit Q), and Shaffer and Buhl, 2016 (Exhibit P). Mr. Kirschenmann recommended that three was a need to monitor confirmed leks less than 1 mile from a proposed turbine (pp. 20). This is certainly less restrictive than the 5 miles recommended by the federal study. Regardless, turbine 6 is within the 1-mile referenced by Mr. Kirschenmann. I believe that his testimony and research is consistent with my observations in developing habitat.

Q. If these birds are hunted, won't the populations shrink anyway?

A. The Prairie Grouse Management Plan for South Dakota 2017-2021 (Exhibit K) compiled by the South Dakota Department of Game, Fish, and Parks discusses hunting and its effect on birds. It reads as follows:

> <u>HUNTING SEASON STRUCTURE AND AUTHORITY</u>
>
> Hunting is currently authorized from the third Saturday of September through the first Sunday in January (Administrative Rule 41:06:09:01) with a combined daily bag of three prairie grouse (Administrative Rule 41:06:09:03). The season and bag limit is set by the SDGFP commission on a 3-year cycle with the next two cycles occurring in 2017 and 2020.

The current hunting season structure has very little impact on the long-term population. Hunting mortality is thought to be mostly compensatory because prairie grouse are short-lived, have high reproductive potential, and are subject to a relatively low harvest rate. Only 2 out of 195 marked female prairie grouse were harvested by hunters during a 3-year study in Hyde and Hand counties (unpublished data from Runia and Solem 2015). Only 17 out of 209 marked adult prairie grouse were harvested during a 3-year study on the FPNG (Kirschenmann 2008). Hunter harvest would have very little, if any, impact on the population at these observed harvest rates (Powell et al. 2011). Prairie grouse have a large distribution in SD and local populations likely respond to environmental and local habitat conditions.

Prairie grouse hunting is most popular during the first few weeks of the season based on license sales and field staff observation. During the first few weeks of the season, prairie grouse are loosely scattered across the landscape in small coveys and family groups which is favorable for hunting. As the season progresses, flock sizes increase and hunting success generally declines sharply. Prairie grouse hunting pressure declines after the first few weeks in response to lower success and as hunters shift effort to other upland game such as pheasants. Some broods may not be fully grown if the season started earlier in the season, and a later start date could sacrifice some of the most productive days of the season. An earlier start date could also make it more difficult to differentiate between prairie grouse and young pheasants. The current bag limit is thought to be socially and biologically acceptable. For these reasons, the SDGFP does not foresee any major recommended changes to the current hunting season structure. The SDGFP will continue to monitor the population, examine hunting statistics, and review public and SDGFP staff input when developing hunting season recommendations.

Q. What have other lodge owners observed after turbines have been constructed near their hunting grounds?

A. I was a board member of the South Dakota Game Bird Association which become inactive. However, last year it was resurrected of sorts as a new organization was established called the South Dakota Upland Outfitters Association in which I am a member. Corbin Korzan's father, Curt Korzan, was the president up to the time of his death. I work with many of the operators of other lodges and exchange information to make our operations better. In particular, I spoke with Corbin Korzan who told me of the detrimental effects of turbines to his family's hunting grounds. The turbines, in effect, drove the pheasants out of the grounds. It also drove out deer and other wildlife. His testimony is based upon his observations and experience, that the addition of turbines resulted in his family having to abandon prime hunting ground.

Q. Does your property contain whooping crane stopover sites?

A. Yes. I have enjoyed seeing them and watching their spring dancing displays. They have been officially recognized by the US Fish and Wildlife and SDGFP in the SW¼ of Section 9, Township 111, Range 74. Supporting documentation from the South Dakota Department of Game, Fish and Parks is attached as Exhibit Z.

Q. Will the proposed towers affect the whooping crane stopover sites?

A. Yes. I am attaching a map filed by ENGIE (Exhibit R) on the North Bend Wind Project regarding incidental whooping crane observations in Hyde and Hughes County, South Dakota. In the map, there are red dots representing where whooping cranes were observed.

Besides the location we've been aware of in Section 9, we also recognize ENGIE-North Bend has made a determination whooping crane activity has also been observed in Section 16, Township 111, Range 74. There is a red dot representing the observation of whooping crane activity located in the middle of Section 16, Township 111, Range 74. When you overlap the proposed wind turbine locations it is smack dab in between proposed towers 27 and 19 (see a second map dated 6/4/2021 as Exhibit S). Whooping cranes are an endangered species. I have reviewed several articles regarding whooping cranes. They are as follows:

- Whooping Cranes and Wind Development - An Issue Paper. By Regions 2 and 6, U.S. Fish and Wildlife Service. April 2009. (Exhibit T)
- Whooping Cranes Steer Clear of Wind Turbines When Selecting Stopover Sites. Ecological Society of America. March 11, 2021. (Exhibit U)
- Wind Turbines Deter Whooping Cranes from Stopover Sites, Study Confirms. Ecological Applications. March 2021. (Exhibit V)
- Heterogeneity in Migration Strategies of Whooping Cranes. Aaron T. Pearse, Kristine L. Metzger, David A. Brandt, Mark T. Bidwell, Mary J. Harner, David M. Baasch, and Wade Harrell. The Condor, Ornithological Applications. Volune 122, 2020, pp. 1-15. (Exhibit W)
- Derby, C. E., M. M. Welsch, and T. D. Thorn. 2018. Whooping crane and sandhill crane monitoring at five wind energy facilities. Proceedings of the North American Crane Workshop 14:26-34. (Exhibit X)

My family has worked to preserve a thriving population of grouse, prairie chickens, Hungarian partridge, bald eagles, whooping cranes, etc. Our operations have spanned over four decades and as stated above, Governor Daugaard presented us with the elite Brent

Wilbur Habitat Award.

Q. What else would you like to add?

A. I would like to add the following:

- I dispute ENGIE's claim that the lek on our property is inactive. The lek may have been inactive at the time of their study, however I farm near that location each spring and have seen first hand the drumming grounds more years than not in the springtime. So much so, we maintain an area of native grass/water/waterway near the location in the western part of our preserve. Despite being labeled as inactive, that doesn't mean there isn't a grouse population in that location. They've been spotted at the location, they just weren't actively strutting for a partner. We have hunters who harvest grouse on that ground.
- Our land and our guests benefit from the leks located on our land and adjacent to it. Similar to regional populations of deer (or other upland game) benefit from the protection of our hundreds of acres of trees planted or ponds developed on our properties.

Q. Have you been following what is occurring in other counties/hearings involving ENGIE and its representatives?

A. Yes. On August 10, 2021, there was a hearing of the Hyde County Commissioners involving ENGIE representative Casey Willis. At the concern of a landowner, Doug Knox, Casey Willis agreed to removed turbine #47 from consideration after hearing from the Knox family. Doug Knox pointed out his concerns in particular were the effects it would have on the wildlife supported by their farm and the livestock farm yard. I can only conclude Casey Willis recognizes these concerns to the point he approved the removal of #47 from consideration during that meeting. This continues to support my concerns that wind turbines erected close to wildlife populations, especially those of us that rely on a managed population as a source of income, will have a negative impact on said population. The transcript of this hearing is attached as Exhibit Y.

Dated this 31 of January, 2022.

Michael J. Bollweg
MICHAEL BOLLWEG

Michael J Bollweg 09/25/1973

United States Air Force Academy – Cadet: 1991-1992 Honorable Discharge
North Dakota State University – 1992-1994
South Dakota State University - Bachelor of Science in Agriculture
Graduated: December 1996
34 years farming experience
Former Grain grader-Grain quality manager – Harrold Grain Company
SD Dept of Agriculture Commercial Applicator License holder for 30 years: #AP1607
SD Dept of Agriculture Private Pesticide Applicator License: #9077349
SD Dept of Agriculture Pesticide Dealer License: #DL1801
Member: South Dakota Aviation Association SDAA
Member: South Dakota Upland Outfitters Association
Former Board Member: South Dakota Game Bird Association
Former Board Member: City of Harrold – approximately 6 years.
Former School Board Member: Highmore-Harrold School District – 11 years.
Community service: Volunteer JH and High School football coach, Youth Wrestling board member/volunteer coach

Vice President - Bollweg Spraying Service Inc. Ground Crew Manager – Sales Agronomist: Made recommendations for crop protection product application by ground and air. Lead applicator for ground applications. Trained new employees how to operate liquid application equipment. (Corporation is now dissolved) Mentored under my father, Don Bollweg who amassed more than 20,000 hours of time in aircraft prior to his retirement with an extensive background in land management and agronomy. Continue at this capacity present day (minus aerial application) with Bollweg Farms – sole proprietor.

I have more than 6000 hours in multiple ground row sprayer applicators; having applied crop protection products on 600,000-800,000 acres. Blumhardt, Loral, Wilmar, Apache, and Case IH Patriot.

Manager/Executive Director of Tumbleweed Lodge – overseeing all aspects from Marketing, employee management/hiring, marketing, habitat development. Incorporating value added agriculture utilizing crop and grass lands by harvesting commodities while maintaining essential habitat to operate a successful hunting lodge establishment.

Judi Bollweg – owner (sole proprietor) of Tumbleweed Lodge.

Tumbleweed Lodge has held a South Dakota Hunting Preserve permit since 1988. I began as a bird cleaner/guide/raised birds. 1996-present Developed overgrazed, eroded livestock pastures with old barb wire fencing buried in 3' of dirt into a rich habitat region for upland birds and game on the preserve lands we are currently operating. Supporting pheasants, Hungarian partridge, sharp-tail grouse, prairie chickens, waterfowl, deer and antelope. Planted and established nearly 140 acres of tree belts essential for wildlife habitat, erosion prevention on 2800 acres of land enrolled in preserve lands. (We own/operate a total of nearly 4000 acres and lease an additional 8400 acres for hunting.) In 2014 received the prestigious Brent Wilbur Habitat Award – "Presented by Governor Dennis Daugaard and the family of Brent Wilbur to a landowner who has reached the highest standards of conservation stewardship in managing their lands for the benefit of South Dakota's diverse wildlife resources." Was honored to be selected as one of the Host Operations for the South Dakota Governor's Hunt spanning from 2000-2014. In 2011 – Named one of the Top 10 Best Hunting Lodges in the World – Outdoor Channels "Outdoors 10 Best". Top 20 Greatest Wingshooting Destinations in the World – Steve Smith "A Wingshooters World"

The most unique niche with Tumbleweed Lodge is the variety of upland bird species we support which brings guests in from all over the country- throughout the world. You can hunt pheasants throughout most if not all of South Dakota, but only a few smaller regions of the state support the four species we target, pheasants, Hungarian partridge, sharp-tail grouse, prairie chickens as well as waterfowl.

In 2019 we purchased a 100kW Generac generator to support the lodge in the event of rolling brown outs, compromised electric grid system; as we noticed in February 2021.

PARTNERS, RETAIL

Hunters make big impression for S.D. retailers

Submitted

Oct. 25, 2019

This paid piece is sponsored by the South Dakota Retailers Association.

Retail businesses across South Dakota are welcoming hunters from near and far in celebration of the pheasant hunting season.

“Communities around the state are welcoming hunters, with many shops and stores working together to create special events,” said Nathan Sanderson, executive director of the South Dakota Retailers Association. “Hunting season is a great opportunity to showcase our world-renowned hospitality and beautiful landscapes while supporting rural communities and local businesses.”

Many South Dakota businesses actively serve the hunting and shooting community. Pheasant lodges, hunting outfitters and hundreds of stores that sell guns, ammunition, licenses, hunting gear and food look forward to our state’s fall hunting tradition. Businesses promoted our unofficial state holiday with displays and banners declaring “Rooster Rush” is here in South Dakota.

“We love meeting and talking with the new people that come in, whether it is their first time in the state or just their first time in the store,” said Mike Fairchild, general manager of Trav’s Outfitter in Watertown. “Of course, we love seeing returning folks when they walk through the door – this year, next year and the one after that – we know they’ll keep coming back to hunt.”

Local mom-and-pop businesses understand the significant economic impact resident and non-resident hunters have in South Dakota. Hunting alone contributes $700 million each year to the state's economy, supporting 18,000 jobs – many of them in retail and hospitality businesses.

Michael Bollweg of Tumbleweed Lodge in Harrold diversified the farm by adding a hunting resort and guiding business. He hosts repeat guests who describe driving up the mile-long, cottonwood-framed driveway to his family's lodge as a "coming home" experience.

From tumbleweedlodge.com

"While an upland bird hunting adventure initially draws them here, sunrises and sunsets of purple and red hues igniting the sky coupled with star-filled nights keep them coming back," Bollweg said. "Our guests continually remind us just how special of a place we live in to be able to raise our families while managing our abundant natural resources."

Retailers and citizens across South Dakota recognize the value private landowners, particularly our farmers and ranchers, provide in support of wildlife populations and habitat in a state where more than 80 percent of the land is owned by private citizens.

"Operations within the hunter service industry are much more than the brick and mortar of the lodge," Bollweg said. "We must remember the generational value of the ring-necked pheasant and the splendor of our uninterrupted landscape make South Dakota one of the last wild destinations."

Pheasant season in South Dakota runs Oct. 19 through Jan. 5. As you travel around South Dakota this fall, thank the men and women in blaze orange who make a significant contribution to small communities and local businesses around the state.

TAGS: hunting | South Dakota Retailers Association | Trav's Outfitter | Tumbleweed Lodge

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FarmProgress


Lon Tonneson

Top South Dakota game lodge shares pheasant farming tips

Slideshow: Intense crop management has helped Michael Bollweg successfully raise both grain and game birds.

Lon Tonneson | Jul 14, 2020

It would be a stretch to say Michael Bollweg of Harrold, S.D., has a livestock operation. Pheasants, Hungarian partridges, sharp-tailed grouse and prairie chickens aren’t the usual suite of animals on South Dakota farms, and Bollweg doesn’t exactly raise them.

But it’s absolutely true that Bollweg, 46, who graduated from South Dakota State University with degrees in agronomy and ag business, manages his farm with those upland game birds in mind. All four species can be found on land Bollweg owns south of Harrold and some additional acres that he leases for grouse and prairie chickens.

Additionally, Bollweg releases some pheasants and Hungarian partridges early in the year to supplement the wild populations on two hunting preserves he’s licensed to operate through the state.

Bollweg operates Bollweg Farms and also Tumbleweed Lodge . It has been named one of the 10 greatest hunting lodges in the world by The Outdoor Channel, and as one of the top 20 wing shooting destinations in the world by outdoor author Steve Smith. The lodge, started by Michael’s parents, has been operating for more than 30 years.

The ag management that makes the lodge so successful is intense.

“We’re still learning,” Bollweg says. “I’ll be the first to admit we’re picking up new ideas all the time.”

Here’s a look at what works well for Bollweg Farms and the Tumbleweed Lodge:

No-till. Bollweg Farms has been using no-till farming practices for 30 years to conserve soil. It’s a natural fit for a hunting operation, too, since it leaves more cover on the ground compared to tillage practices.

Diverse rotations. Spring wheat, winter wheat, corn, soybeans and grain sorghum are the main crops in the farm’s rotations, often seeded in 90- and 180-foot-wide strips.

“We have found that winter wheat, in particular, is a better nesting cover than cold-season grasses that you tend to find in CRP,” Bollweg says. Bollweg Farms also plants canola, turnip, radish, vetch and forage peas as cover crops.

Predator control. The operation traps and disposes of egg robbers, such as skunks, raccoons, feral cats, coyotes, badgers and opossums. However, eagles and other protected birds of prey abound in the area, and the Tumbleweed Lodge accepts that the birds will dine on pheasant.

“That’s just nature,” Bollweg says. “We appreciate the beauty of America’s bird.”

Insects. Bollweg plans for them just as other producers do — but not always for the same reasons.

“We have a good mix of cold- and warm-season grasses, along with legumes like alfalfa and clover that attract insects. So those birds, in the spring and early summer as they’re getting of age, they’re eating bugs.”

Winter habitat. Shelterbelts are designed with a minimum of five rows of trees, primarily eastern red cedar, but also chokecherry, plum and apricot.

Water. There are natural ponds throughout the property, and the lodge also has a geothermal well. The heat is pulled off to help heat the lodge and dog kennel and the water then flows into two of the ponds.

Drones. The lodge not only uses them to film hunters on their hunts at Tumbleweed, but also to scout some of the hard-to-reach places on the farm for weeds or other issues.

Farm roads. Roads through the property are graveled, and that’s not solely for the ease of getting hunters around. Upland game birds need grit.

Bollweg emphasizes his operation is a working farm that, if anything, requires a little more intense management.

“It’s value-added agriculture. You’re developing your resources,” Bollweg says. “You’re developing a great bird population simply by being a good steward of the land.”

Nixon is a writer from Pierre, S.D.

1.

IN FLIGHT: An iron pheasant in flight welcome hunters to Tumbleweed Lodge at Bollweg Farms near Harrold, S.D.

2.

HUNTERS' LODGE: The Tumbleweed Lodge is where hunters stay.


Lon Tonneson

3.

BIRD'S VIEW: A pheasant's view of the grass cover and cedar trees at Bollweg Farms.


Courtesy of Bollweg Farms

4.

WATER SOURCE: Wetlands provide an important source of water for wildlife.

5.

CLEAR AREA: Mowed strips in food plots to give pheasants a way to move around.

6.

DENSE COVER: Pheasant cover fits in well with cropland.

Source URL: https://www.farmprogress.com/land-management/top-south-dakota-game-lodge-shares-pheasant-farming-tips

SPECIAL POWER OF ATTORNEY

I, Judi Bollweg, individually and on behalf of Tumbleweed Lodge and Bollweg Family, LLLP, give my son, Michael Bollweg, a special power of attorney to testify on my behalf relating to all matters concerning my request to intervene in Docket EL21-018 - In the Matter of the Application by North Bend Wind Project, LLC for a Permit to Construct and Operate the North Bend Wind Project in Hyde County and Hughes County, South Dakota. I also give Michael Bollweg the power to handle all aspects of my case, including submitting evidence, calling witnesses, and all related matters concerning my intervention.

In Witness Whereof, I have hereunto signed my name this 26th day of October, 2021.

Judi Bollweg
JUDI BOLLWEG, INDIVIDUALLY AND
ON BEHALF OF TUMBLEWEED LODGE
AND BOLLWEG FAMILY, LLP

ACKNOWLEDGMENT

STATE OF SOUTH DAKOTA)
) ss.
COUNTY OF Hughes)

On this 26th day of October, 2021, before me, a Notary Public, within and for said County, personally appeared Judi Bollweg, to me known to be the person described in and who executed the foregoing instrument and acknowledged that she executed the same as her free act and deed.

[signature]
Notary Public MY COMMISSION EXPIRES 10-11-2024

Specimen Signature of Attorney-In-Fact

Michael J. Bollweg
Michael Bollweg

Mail Processing Center
Federal Aviation Administration
Southwest Regional Office
Obstruction Evaluation Group
10101 Hillwood Parkway
Fort Worth, TX 76177

Aeronautical Study No.
2021-WTE-1926-OE

Issued Date: 11/29/2021

Lauren Kaapcke
North Bend Wind Project
3760 State Street, Suite 200
Suite 200
Santa Barbara, CA 93105

**** DETERMINATION OF NO HAZARD TO AIR NAVIGATION ****

The Federal Aviation Administration has conducted an aeronautical study under the provisions of 49 U.S.C., Section 44718 and if applicable Title 14 of the Code of Federal Regulations, part 77, concerning:

Structure:	Wind Turbine 30
Location:	Pierre, SD
Latitude:	44-23-03.63N NAD 83
Longitude:	99-39-22.82W
Heights:	1957 feet site elevation (SE)
	625 feet above ground level (AGL)
	2582 feet above mean sea level (AMSL)

This aeronautical study revealed that the structure would have no substantial adverse effect on the safe and efficient utilization of the navigable airspace by aircraft or on the operation of air navigation facilities. Therefore, pursuant to the authority delegated to me, it is hereby determined that the structure would not be a hazard to air navigation provided the following condition(s) is(are) met:

As a condition to this Determination, the structure is to be marked/lighted in accordance with FAA Advisory circular 70/7460-1 M, Obstruction Marking and Lighting, white paint/sychronized red lights-Chapters 4,13(Turbines),&15.

Any failure or malfunction that lasts more than thirty (30) minutes and affects a top light or flashing obstruction light, regardless of its position, should be reported immediately to (877) 487-6867 so a Notice to Airmen (NOTAM) can be issued. As soon as the normal operation is restored, notify the same number.

It is required that FAA Form 7460-2, Notice of Actual Construction or Alteration, be e-filed any time the project is abandoned or:

__X__ At least 10 days prior to start of construction (7460-2, Part 1)
__X__ Within 5 days after the construction reaches its greatest height (7460-2, Part 2)

See attachment for additional condition(s) or information.

This determination expires on 05/29/2023 unless:

(a) the construction is started (not necessarily completed) and FAA Form 7460-2, Notice of Actual Construction or Alteration, is received by this office.
(b) extended, revised, or terminated by the issuing office.

NOTE: REQUEST FOR EXTENSION OF THE EFFECTIVE PERIOD OF THIS DETERMINATION MUST BE E-FILED AT LEAST 15 DAYS PRIOR TO THE EXPIRATION DATE. AFTER RE-EVALUATION OF CURRENT OPERATIONS IN THE AREA OF THE STRUCTURE TO DETERMINE THAT NO SIGNIFICANT AERONAUTICAL CHANGES HAVE OCCURRED, YOUR DETERMINATION MAY BE ELIGIBLE FOR ONE EXTENSION OF THE EFFECTIVE PERIOD.

This determination is subject to review if an interested party files a petition that is received by the FAA on or before December 29, 2021. In the event a petition for review is filed, it must contain a full statement of the basis upon which it is made and be submitted to the Manager of the Rules and Regulations Group. Petitions can be submitted via mail to Federal Aviation Administration, 800 Independence Ave, SW, Washington, DC 20591, via email at OEPetitions@faa.gov, or via facsimile (202) 267-9328.

This determination becomes final on January 08, 2022 unless a petition is timely filed. In which case, this determination will not become final pending disposition of the petition. Interested parties will be notified of the grant of any review. For any questions regarding your petition, please contact Rules and Regulations Group via telephone – 202-267-8783.

This determination is based, in part, on the foregoing description which includes specific coordinates and heights. This determination is valid for coordinates within one (1) second latitude/longitude and up to the approved AMSL height listed above. If a certified 1A or 2C accuracy survey was required to mitigate an adverse effect, any change in coordinates or increase in height will require a new certified accuracy survey and may require a new aeronautical study.

If construction or alteration is dismantled or destroyed, you must submit notice to the FAA within 5 days after the construction or alteration is dismantled or destroyed.

Additional wind turbines or met towers proposed in the future may cause a cumulative effect on the national airspace system. All information from submission of Supplemental Notice (7460-2 Part 2) will be considered the final data (including heights) for this structure. Any future construction or alteration, including but not limited to changes in heights, requires separate notice to the FAA.

Obstruction marking and lighting recommendations for wind turbine farms are based on the scheme for the entire project. ANY change to the height, location or number of turbines within this project will require a reanalysis of the marking and lighting recommendation for the entire project. In particular, the removal of previously planned or built turbines/turbine locations from the project will often result in a change in the marking/lighting recommendation for other turbines within the project. It is the proponent's responsibility to contact the FAA to discuss the process for developing a revised obstruction marking and lighting plan should this occur.

In order to ensure proper conspicuity of turbines at night during construction, all turbines should be lit with temporary lighting once they reach a height of 200 feet or greater until such time the permanent lighting configuration is turned on. As the height of the structure continues to increase, the temporary lighting should be relocated to the uppermost part of the structure. The temporary lighting may be turned off for periods when they would interfere with construction personnel. If practical, permanent obstruction lights should be installed and operated at each level as construction progresses. An FAA Type L-810 steady red light fixture shall be used to light the structure during the construction phase. If power is not available, turbines shall be lit with self-contained, solar powered LED steady red light fixture that meets the photometric requirements of an FAA Type L-810 lighting system. The lights should be positioned to ensure that a pilot has an unobstructed view of at least one light at each level. The use of a NOTAM (D) to not light turbines within a project until the entire project has been completed is prohibited.

This determination does include temporary construction equipment such as cranes, derricks, etc., which may be used during actual construction of the structure. However, this equipment shall not exceed the overall heights as indicated above. Equipment which has a height greater than the studied structure requires separate notice to the FAA.

This determination concerns the effect of this structure on the safe and efficient use of navigable airspace by aircraft and does not relieve the sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body.

This aeronautical study considered and analyzed the impact on existing and proposed arrival, departure, and en route procedures for aircraft operating under both visual flight rules and instrument flight rules; the impact on all existing and planned public-use airports, military airports and aeronautical facilities; and the cumulative impact resulting from the studied structure when combined with the impact of other existing or proposed structures. The study disclosed that the described structure would have no substantial adverse effect on air navigation.

An account of the study findings, aeronautical objections received by the FAA during the study (if any), and the basis for the FAA's decision in this matter can be found on the following page(s).

This determination cancels and supersedes prior determinations issued for this structure.

If we can be of further assistance, please contact Lan Norris, at (404) 305-6645, or Lan.norris@faa.gov. On any future correspondence concerning this matter, please refer to Aeronautical Study Number 2021-WTE-1926-OE.

Signature Control No: 482124683-502793525 (DNH -WT)
Mike Helvey
Manager, Obstruction Evaluation Group

Attachment(s)
Additional Information
Case Description
Map(s)

Additional information for ASN 2021-WTE-1926-OE

All FAA determinations and circularized cases are public record and available at the FAA's public website; https://oeaaa.faa.gov. The distribution for proposals circularized for public comments includes all "known" aviation interested persons and those who do not have an aeronautical interest but may become involved with specific aeronautical studies. Notification includes both postcard mailers and email notifications to those with registered FAA accounts. The FAA does not have a database for all persons with an aeronautical and non-aeronautical interest. Therefore, the public is encouraged to re-distribute and forward notices of circularized cases to the maximum extent possible. Additionally, it is incumbent upon local state, county and city officials to share notice of circularized cases with their concerned citizens.

A list of commonly used acronyms and abbreviations is available at the end of this document. A full list is available at the FAA's public website at https://oeaaa.faa.gov/oeaaa/downloads/external/content/FAA_Acronyms.pdf .

1. PROPOSAL DESCRIPTION

Proposed are 78 wind turbines for a wind farm project previously studied and determined under Aeronautical Study Numbers (ASN) 2020-WTE-6722-OE through 2020-WTE-6778-OE. The proposed wind farm would be located approximately 9.72 NM to 17.18 NM southwest of the Airport Reference Point (ARP) for Highmore Municipal (9D0), Highmore, SD.

For the sake of efficiency, all of the wind turbines in this project that have similar impacts are included in this narrative.

The proposed wind turbines' described heights and locations are expressed in Above Ground Level (AGL) height, Above Mean Sea Level (AMSL) height and latitude (LAT)/longitude (LONG).

ASN	AGL	AMSL	LAT	LONG
2021-WTE-1897-OE	625	2531	44-24-14.09N	99-45-37.19W
2021-WTE-1898-OE	625	2537	44-24-29.75N	99-45-25.56W
2021-WTE-1899-OE	625	2549	44-24-47.14N	99-45-10.48W
2021-WTE-1900-OE	625	2555	44-24-58.11N	99-44-52.07W
2021-WTE-1901-OE	625	2576	44-24-56.24N	99-44-11.46W
2021-WTE-1902-OE	625	2574	44-25-09.31N	99-43-47.36W
2021-WTE-1903-OE	625	2576	44-25-22.58N	99-43-16.26W
2021-WTE-1904-OE	625	2595	44-25-22.22N	99-42-29.07W
2021-WTE-1905-OE	625	2609	44-25-48.13N	99-42-29.21W
2021-WTE-1906-OE	625	2615	44-26-04.17N	99-42-03.53W
2021-WTE-1907-OE	625	2601	44-26-14.09N	99-41-31.24W
2021-WTE-1908-OE	625	2590	44-26-45.55N	99-41-27.62W
2021-WTE-1909-OE	625	2597	44-26-12.67N	99-40-49.51W
2021-WTE-1910-OE	625	2601	44-26-36.34N	99-40-39.24W
2021-WTE-1911-OE	625	2623	44-26-59.00N	99-39-37.37W
2021-WTE-1912-OE	625	2652	44-27-22.62N	99-39-24.13W
2021-WTE-1913-OE	625	2641	44-27-34.24N	99-39-06.08W
2021-WTE-1914-OE	625	2641	44-27-02.27N	99-38-51.47W
2021-WTE-1915-OE	625	2635	44-27-05.00N	99-38-23.71W

2021-WTE-1916-OE	625	2613	44-26-13.94N	99-39-37.13W
2021-WTE-1917-OE	625	2602	44-26-14.67N	99-39-05.84W
2021-WTE-1918-OE	625	2614	44-26-11.16N	99-38-19.60W
2021-WTE-1919-OE	625	2593	44-25-47.95N	99-40-03.95W
2021-WTE-1920-OE	625	2607	44-25-39.69N	99-39-18.72W
2021-WTE-1921-OE	625	2610	44-25-45.84N	99-38-10.32W
2021-WTE-1922-OE	625	2586	44-24-59.88N	99-40-31.94W
2021-WTE-1923-OE	625	2606	44-25-09.31N	99-40-00.74W
2021-WTE-1924-OE	625	2603	44-24-47.29N	99-38-49.76W
2021-WTE-1925-OE	625	2584	44-24-05.15N	99-38-57.93W
2021-WTE-1926-OE	625	2582	44-23-03.63N	99-39-22.82W
2021-WTE-1927-OE	625	2591	44-22-46.04N	99-37-38.00W
2021-WTE-1928-OE	625	2601	44-23-03.23N	99-36-59.77W
2021-WTE-1929-OE	625	2559	44-21-43.65N	99-40-05.43W
2021-WTE-1930-OE	625	2583	44-21-52.04N	99-39-22.57W
2021-WTE-1931-OE	625	2585	44-22-11.49N	99-38-49.81W
2021-WTE-1932-OE	625	2603	44-22-21.17N	99-37-50.90W
2021-WTE-1933-OE	625	2603	44-21-39.61N	99-37-51.51W
2021-WTE-1934-OE	625	2618	44-22-10.77N	99-36-38.02W
2021-WTE-1935-OE	625	2638	44-22-11.27N	99-35-37.93W
2021-WTE-1936-OE	625	2646	44-22-14.52N	99-35-11.08W
2021-WTE-1937-OE	625	2655	44-22-19.08N	99-34-33.76W
2021-WTE-1938-OE	625	2660	44-22-20.39N	99-33-59.26W
2021-WTE-1939-OE	625	2701	44-21-43.59N	99-33-58.88W
2021-WTE-1940-OE	625	2584	44-20-25.80N	99-41-27.57W
2021-WTE-1941-OE	625	2634	44-19-39.92N	99-41-16.64W
2021-WTE-1942-OE	625	2635	44-19-39.65N	99-40-47.40W
2021-WTE-1943-OE	625	2635	44-19-48.56N	99-40-31.36W
2021-WTE-1944-OE	625	2633	44-19-48.09N	99-40-01.59W
2021-WTE-1945-OE	625	2654	44-20-03.83N	99-39-17.00W
2021-WTE-1946-OE	625	2644	44-20-25.97N	99-38-55.58W
2021-WTE-1947-OE	625	2643	44-20-26.32N	99-38-03.12W
2021-WTE-1948-OE	625	2630	44-21-01.05N	99-37-09.32W
2021-WTE-1949-OE	625	2624	44-21-23.72N	99-36-40.27W
2021-WTE-1950-OE	625	2704	44-19-36.66N	99-38-19.96W
2021-WTE-1951-OE	625	2701	44-19-49.25N	99-38-07.56W
2021-WTE-1952-OE	625	2712	44-19-35.42N	99-37-03.20W
2021-WTE-1953-OE	625	2716	44-19-33.27N	99-36-35.07W
2021-WTE-1954-OE	625	2695	44-19-51.49N	99-36-29.77W
2021-WTE-1955-OE	625	2677	44-20-09.09N	99-36-25.12W
2021-WTE-1956-OE	625	2666	44-20-26.56N	99-36-25.21W
2021-WTE-1957-OE	625	2665	44-20-37.87N	99-35-56.02W
2021-WTE-1958-OE	625	2681	44-20-50.81N	99-35-43.52W
2021-WTE-1959-OE	625	2668	44-21-01.78N	99-35-28.91W

2021-WTE-1960-OE	625	2680	44-18-54.66N	99-39-35.60W
2021-WTE-1961-OE	625	2680	44-18-54.41N	99-38-57.55W
2021-WTE-1962-OE	625	2714	44-19-07.18N	99-38-25.44W
2021-WTE-1963-OE	625	2704	44-18-41.87N	99-38-16.92W
2021-WTE-1964-OE	625	2728	44-19-00.91N	99-37-37.78W
2021-WTE-1965-OE	625	2675	44-18-22.87N	99-39-37.47W
2021-WTE-1966-OE	625	2665	44-18-17.21N	99-38-49.83W
2021-WTE-1967-OE	625	2656	44-17-48.93N	99-39-37.15W
2021-WTE-1968-OE	625	2578	44-25-22.14N	99-41-48.48W
2021-WTE-1969-OE	625	2602	44-25-54.22N	99-41-28.13W
2021-WTE-1970-OE	625	2605	44-25-19.63N	99-39-35.11W
2021-WTE-1971-OE	625	2563	44-22-38.45N	99-39-36.68W
2021-WTE-1972-OE	625	2596	44-20-35.11N	99-40-18.46W
2021-WTE-1973-OE	625	2585	44-20-57.86N	99-40-01.75W
2021-WTE-1974-OE	625	2659	44-21-00.55N	99-36-24.43W

2. TITLE 14 CFR PART 77 - OBSTRUCTION STANDARDS EXCEEDED

a. Section 77.17(a)(1); exceeds a height of 499 feet AGL at the site of the object. The proposals would all exceed this standard by 126 feet.

b. Section 77.17(a)(3); a height within a terminal obstacle clearance area, including an initial approach segment, a departure area, and a circling approach area, which would result in the vertical distance between any point on the object and an established minimum instrument flight altitude within that area or segment to be less than the required obstacle clearance.

The following proposed turbines would increase the Minimum Safe Altitude (MSA) for Highmore Municipal (9D0) Highmore, SD. The RNAV (GPS) RWY 13 and RNAV (GPS) RWY 31 would increase from 3600 feet AMSL to ______ feet AMSL.

3700 feet AMSL
2021-WTE-1897-OE
2021-WTE-1906-OE
2021-WTE-1907-OE
2021-WTE-1910-OE
2021-WTE-1911-OE
2021-WTE-1912-OE
2021-WTE-1913-OE
2021-WTE-1914-OE
2021-WTE-1915-OE
2021-WTE-1916-OE

2021-WTE-1917-OE
2021-WTE-1918-OE
2021-WTE-1920-OE
2021-WTE-1921-OE
2021-WTE-1923-OE
2021-WTE-1924-OE

2021-WTE-1928-OE
2021-WTE-1932-OE
2021-WTE-1933-OE
2021-WTE-1934-OE

2021-WTE-1935-OE
2021-WTE-1936-OE
2021-WTE-1937-OE
2021-WTE-1938-OE
2021-WTE-1941-OE
2021-WTE-1942-OE
2021-WTE-1943-OE
2021-WTE-1944-OE
2021-WTE-1945-OE
2021-WTE-1946-OE

2021-WTE-1947-OE
2021-WTE-1948-OE
2021-WTE-1949-OE
2021-WTE-1954-OE
2021-WTE-1955-OE
2021-WTE-1956-OE
2021-WTE-1957-OE
2021-WTE-1958-OE
2021-WTE-1959-OE
2021-WTE-1960-OE

2021-WTE-1961-OE
2021-WTE-1965-OE
2021-WTE-1966-OE
2021-WTE-1967-OE
2021-WTE-1969-OE
2021-WTE-1970-OE
2021-WTE-1974-OE

3800 feet AMSL
2021-WTE-1939-OE
2021-WTE-1950-OE
2021-WTE-1951-OE
2021-WTE-1952-OE
2021-WTE-1953-OE
2021-WTE-1962-OE
2021-WTE-1963-OE
2021-WTE-1964-OE

The following proposed turbines would increase the MSA for Miller Municipal (MKA) Miller, SD. The RNAV (GPS) RWY 15 and RNAV (GPS) RWY 33 would increase from 3600 feet AMSL to ________ feet AMSL.

3700 feet AMSL

2021-WTE-1935-OE
2021-WTE-1936-OE
2021-WTE-1937-OE
2021-WTE-1938-OE

3800 feet AMSL
2021-WTE-1939-OE

c. Section 77.17(a)(4); a height within an en route obstacle clearance area, including turn and termination areas, of a Federal Airway or approved off-airway route, that would increase the minimum obstacle clearance altitude.

The following proposed turbines would increase the Minimum Obstruction Clearance Altitude (MOCA) along Victor Airway 120 (V-120) from PIERRE (PIR) VORTAC, 100 radial to MITCHELL (MHE) VOR/DME from 3400 feet AMSL to ________ feet AMSL.

3700 feet AMSL
2021-WTE-1941-OE
2021-WTE-1942-OE
2021-WTE-1943-OE
2021-WTE-1960-OE
2021-WTE-1961-OE
2021-WTE-1965-OE
2021-WTE-1966-OE
2021-WTE-1967-OE

3800 feet AMSL
2021-WTE-1962-OE
2021-WTE-1963-OE
2021-WTE-1964-OE

3. TITLE 14 CFR PART 77 - EFFECT ON AERONAUTICAL OPERATIONS

a. Section 77.29(a)(1); impact on arrival, departure, and en route procedures for aircraft operating under visual flight rules. At a height greater than 499 feet AGL, the proposed wind farm would extend into airspace normally used for VFR en route flight and may be located within 2 statute miles (SM) of potential VFR Routes as defined by FAA Order 7400.2, Section 6-3-8. The turbines within 2 SM of a VFR Route would have an adverse effect upon VFR air navigation.

b. Section 77.29(a)(6); potential effect on ATC radar, direction finders, ATC tower line-of-sight visibility, and physical or electromagnetic effects on air navigation, communication facilities, and other surveillance systems. The turbines would be within the radar line of sight (RLOS) of the Gettysburg, SD (QJB) CARSR and may affect the quality and/or availability of the primary radar signals.

4. TITLE 14 CFR PART 77 - FURTHER STUDY AND PUBLIC COMMENTS

In order to facilitate the public comment process, all 78 studies were circularized under ASN 2021-WTE-1926-OE on 08/27/2021, to all known aviation interests and to non-aeronautical interests that may be affected by the proposal. There was one comment submitted by the South Dakota Aeronautics Commission as a result of the circularization concluding on 10/03/2021. The comment(s) is summarized as follows:

Comments: South Dakota (SD) has limited radar coverage in most areas. This proposed windfarm appears to be adjacent to another farm with shorter turbines, the obvious confusion could easily lead to another fatal accident similar to the April 27, 2014 crash where an aircraft collided with one of the turbines in this other field resulting in the death of the 4 people on the plane.

There are rules that apply to obstructions in controlled airspace. These rules were created long before 600+ foot wind turbines were proposed. Current SD rules allow obstructions to be erected without, aeronautics commission approval, if they do not exceed the maximum heights. With no over whelming justification requiring the turbines to be erected in this airspace, I will oppose any proposal that makes it tougher to fly in the airspace the commission has authority over.

FAA Response: In accordance with FAA Order 7400.2, Par. 6-1-1, an aeronautical study must be conducted for all complete notices received by the FAA. As required, an extensive aeronautical study was conducted on this wind farm proposal which included an evaluation of the impact to Radar coverage, navigational facilities, IFR procedures and VFR operations. The study considered available traffic data within the vicinity of the wind farm and determined that there was not a significant volume of traffic. Therefore, the wind turbines are not considered to have a substantial adverse effect on VFR or IFR traffic. Flight operations conducted below the minimum safe altitudes specified in 14 CFR Part 91, such as agricultural, land surveys, law enforcement, etc., are not considered in determining the extent of adverse effect. Additionally, the FAA does not have land-use authority for privately owned/leased property and does not issue building permits. A determination issued by the FAA does not relieve the project sponsor of compliance responsibilities relating to any law, ordinance, or regulation of any Federal, State, or local government body. Questions or comments regarding the justification for commercial land development projects, lease/purchase agreements, site selection, etc., should be directed to the private property owners, state, county and/or local city municipalities.

5. BASIS FOR DETERMINATION

a. IFR Effects - The aeronautical study identified an IFR effect(s) for 9D0, MKA airports and V-120. MSAs are the minimum obstacle clearance altitudes within a specified distance from the navigation facilities upon which procedures are predicated. MSA altitudes are designed for emergency use only and are not routinely used by pilots or by air traffic control. Consequently, MSAs are not circulated for public comment as they are not considered a factor in determining the extent of adverse effect. MOCAs assure obstacle clearance over the entire route segment to which they apply and assure navigational signal coverage within 22 NM of the associated VOR navigational facility. For that portion of the route segment beyond 22 NM from the VOR, where the MOCA is lower than the MEA and there are no plans to lower the MEA to the MOCA, a structure that affects only the MOCA would not be considered to have substantial adverse effect. Other situations require study as ATC may assign altitudes down to the MOCA under certain conditions. Further study revealed that only the MOCA along V-120 is effected and is not routinely assigned by ATC. The proposed structures would have no other effect on any other existing or proposed arrival, departure, or en route IFR operations or procedures.

b. VFR Effects - The aeronautical study identified no effect on any existing or proposed VFR arrival or departure operations. The proposals would be located beyond the traffic pattern airspace for any known public use or military airports. The aeronautical study identified no effect on any existing or proposed VFR arrival or departure operations. At 625 feet AGL, the structures would be located within the altitudes commonly used for en route VFR flight. In coordination with ATC, an analysis of potential VFR Routes and available traffic data indicated that an average of less than one VFR aircraft per day may be affected by the proposed wind farm. In accordance with FAA Order 7400.2, the proposed wind farm would not affect a significant volume of aircraft and therefore, it is determined they will not have a substantial adverse effect on en route VFR flight operations.

c. RADAR Effects - The aeronautical study identified the proposed turbines as being within the RLOS of the Gettysburg, SD (QJB) CARSR as described above. The proposed turbines may affect the quality and/or availability of the QJB primary radar signals. There would be no effect on the secondary (Beacon) radar system. Impacts to radar only require a review by the responsible ATC facility and military services. Further study determined the structures would have no substantial adverse effect on military or air traffic operations at this time.

d. Charting and Cumulative Effects - The proposed structures would be charted on VFR sectional aeronautical charts and appropriately obstruction marked/lighted to make them more conspicuous to airmen should circumnavigation be necessary.

The cumulative impact of the proposed structures, when combined with other proposed and existing structures, is not considered to be significant. Study did not disclose any substantial adverse effect on existing or proposed public-use or military airports or navigational facilities, nor would the proposals affect the capacity of any known existing or planned public-use or military airport.

6. Determination - It is determined that the proposed construction would not have a substantial adverse effect on the safe and efficient utilization of the navigable airspace by aircraft or on any air navigation facility and would not be a hazard to air navigation providing the conditions set forth in this determination are met.

****

ACRONYMS & ABBREVIATIONS

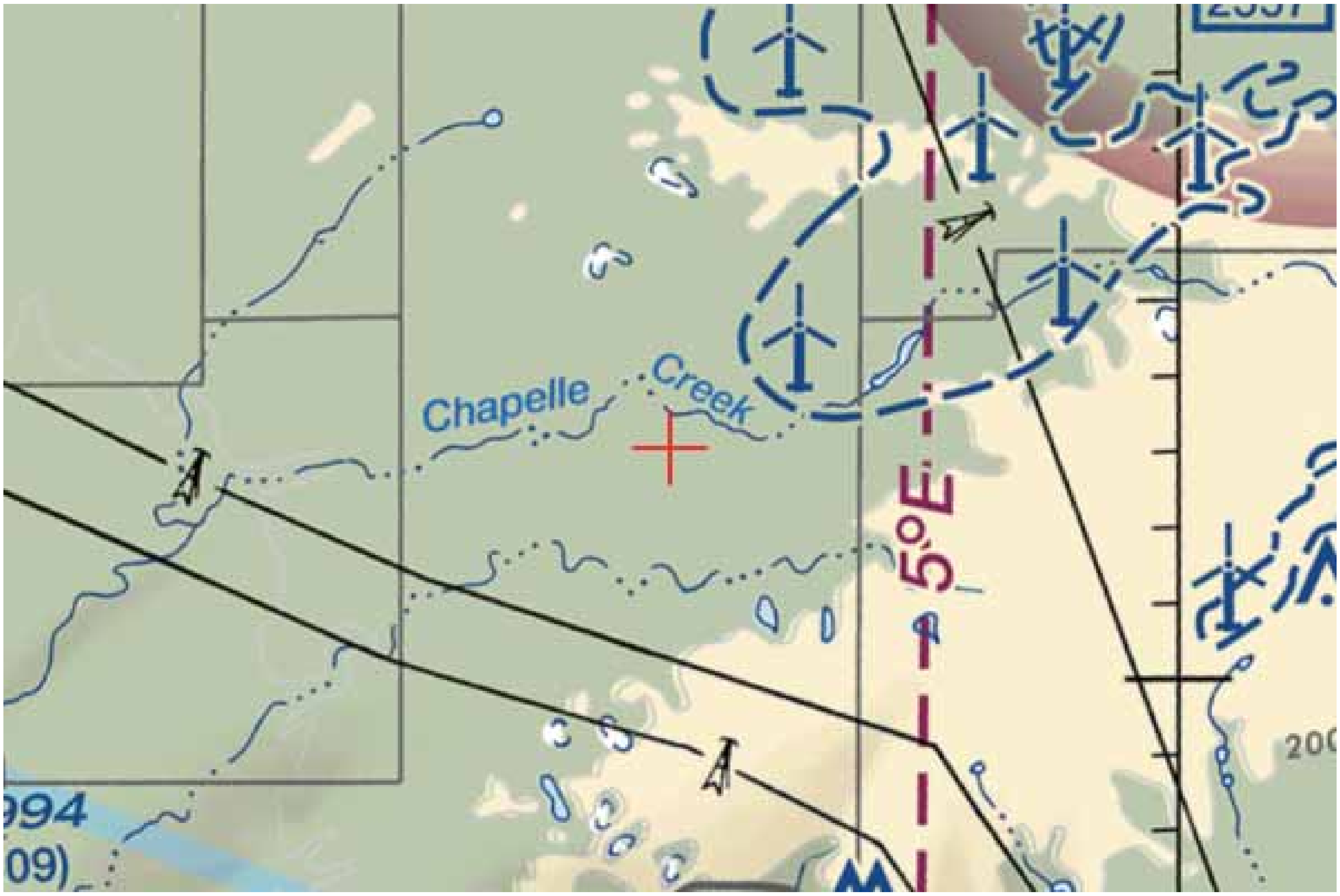
AGL, Above Ground Level
AMSL, Above Mean Sea Level
ARP, Airport Reference Point
ARSR, Air Route Surveillance Radar
ARTCC, Air Route Traffic Control Center
ASN, Aeronautical Study Number
ASR, Airport Surveillance Radar
ATC, Air Traffic Control
ATCT, Air Traffic Control Tower
CARSR, Common Air Route Surveillance Radar
CFR, Code of Federal Regulations
DME, Distance Measuring Equipment
FAA, Federal Aviation Administration
FUS, Fusion
GPS, Global Positioning System
IFR, Instrument Flight Rules
LAT, Latitude
LONG, Longitude

Min, Minimum
MSL, Mean Sea Level
MVA, Minimum Vectoring Altitude
NA, Not Authorized
NAS, National Airspace System
NEH, No Effect Height
NM, Nautical Mile
NOTAM, Notice to Airmen
NPF, Notice of Preliminary Findings
OE, Obstruction Evaluation
Part 77 - Title 14 Code of Federal Regulations (CFR) Part 77, Safe, Efficient Use and Preservation of the Navigable Airspace.
RLOS, Radar Line of Sight
SE, Site Elevation
SM, Statute Miles
TERPS, Terminal Instrument Procedures
TPA; Traffic Pattern Airspace
V, Victor Airway
VFR, Visual Flight Rules
WTW, Wind Turbine West

Case Description for ASN 2021-WTE-1926-OE

Wind Turbines as part of North Bend Wind Project

Sectional Map for ASN 2021-WTE-1926-OE



09/02/2021

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

My name is Dr. Cody Christensen, I serve in a professional capacity as the only tenured aviation faculty member in South Dakota wherein my role at South Dakota State University, I am tasked with teaching, service, and research related to aviation education. My primary role within the university is teaching new pilots, commercial pilots, and advanced systems in aviation operations. I have been a licensed pilot for over twenty years, a FAA Goal Seal flight instructor for 15 years, and hold certificates in both single and multiengine aircraft including an Air Transport Pilot (ATP) certificate. I am answering your questions as a former airline captain for a small regional airline operating into and out of the Midwest, including South Dakota and the area depicted in Hughes County.

This letter is in request to addressing agricultural flight operations around wind turbines, specifically around T112N, R074W section 10, and 11 in Hughes County, SD. Three main considerations must be factored when addressing the pilot perspective of operations around obstacles. Those three factors include margin of safety, operation of aircraft, and aircraft performance factors associated with the flight.

The first main consideration when evaluating an operating area, whether that be a field to spray or a ground-based maneuver designated by the Federal Aviation Administration (FAA) for training such as an Eight on Pylon, is the margin of safety. The margin of safety when obstacles are present in a field decreases options in the event of an emergency such as a powerplant failure or stall/spin situation. From personal experience I know that operating directly behind or in between wind turbines creates considerable turbulence that can lead to loss of control events- a leading cause of aircraft accidents in the United States. Additionally, flying with known obstacles increases workload because the pilot must evaluate the proper course of action with little to no room for error. The margin of safety decreases as the height and number of obstacles increases.

The second consideration when operating around obstacles that are unavoidable is that of operation of aircraft including pilot training and pilot response. Professional agricultural pilots knowingly take considerable, calculated risks related to obstacles other pilots do not take. They are responsible for flying between 3-12 feet above the ground, making multiple low passes, multiple takeoff and landings, and operating to the max capacity of the aircraft. Doing this operation on a zero wind, cool day, with no elevation or obstacles take precision and professional skills few possess. Adding additional obstacles that decrease the margin of safety and decrease the reaction time a pilot has to react to unforeseen situations such as mechanical issues, bird strikes, wire strikes, wind changes, and product issues decreases the safety of the operation.

The final major concern when operating around obstacles is the aircraft performance, including climb rate, turn radius, and environmental conditions. The climb rate of a standard Air Tractor 502, a common midlevel agricultural application aircraft, is 664 feet per minute and a typical working speed of 135mph. Every second the airplane is traveling approximately 198 feet per second while on target. At the end of a field the pilot would turn off the spray and begin a climb, followed shortly by a climbing turn usually away from the spray pass to complete a course reversal to realign for the next spray pass. In a normal situation with no obstacles, ending the spray and the initial climb out might all occur within five to eight seconds, resulting in a straight-line distance of almost ¼ mile. The turnaround for ag operators, generally considered a 45° downwind turn, followed by a 225-course reversal to come back on target requires a 30-45° turn to do a back-to-back turn. The time of the course reversal is approximately 25 seconds, resulting in close to one mile of total distance traveled per swath. Assuming a 30° bank, the calculated turn radius of an aircraft going 135mph is 2,119 feet and the diameter of the turn is 0.8 miles. It should be noted that for an Air Tractor 502, it is close to one mile to make a turn, but for an Air Tractor 802, currently the largest single engine commercially used ag application airplane, that distance increases to 1.82 miles to complete a turn.

As early discussed, an Air Tractor 502 climb rate is 664 feet per minute or approximately 11 feet per second (fps) climb rate. Considering at the end of the field, an applicator pulls up into a climb, it would take 18 seconds (200ft/ 11fps) to clear a 200 feet obstacle located at the end of a field. Using a working speed of 135MPH or 198fps the aircraft would travel forward 3,564ft (198fps*18 sec to climb) to clear a 200ft obstacle. If a 600-foot obstacle was considered, it would take 54 seconds to outclimb the obstacle and would travel forward over two miles (198fps *54sec= 10,800ft). Even assuming the pilot slowed to 111mph (best rate of climb at max weight) the distance covered is still 1.6 miles (162fps *54 sec). This assumes the pilot adds max power, performs a perfect climb, the airplane performs perfect, and the field conditions were conducive to a climb (sea level, standard atmosphere, low humidity, calm or head winds prevailing). Anything less than perfect conditions would decrease the climb rate and make the field in question non flyable.

The other option would be instead of pulling up to climb over an obstacle to fly around it, below it, or through the blade arc or guy-wire, all of which are not prudent options, especially considering any abnormal operations. Additionally, the turbulence created by the wind turbines would have a direct and immediate impact on the pilot operating downwind of the turbine.

In reviewing the plat map of 112N, R 074W, section 10 and 11 in Hughes County, SD I am most concerned about the placement of towers 8, 9, 14, &15 within the sections and any towers that are adjacent such as #20-22 as they are well within a normal margin of safety for a typical pilot to safety spray that area. Based on the map and field layout, an east/west swath pattern would prevail and the presence of wind turbines or any obstacle at the end of those fields, especially on two sides, would be detrimental to safety. In my opinion, I would advise against a pilot maneuvering in the field presented with obstacles in the placement suggested.

Respectfully,

Cody Christensen, Ed.D
Airline Transport Pilot
FAA Gold seal flight instructor

11/03/2021

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

In regards to the follow up question asked by the SD Public Utilities commission:

> *"In order to accommodate a safe turn radius at the end of a field for an agricultural application aircraft, what is Mr. Christensen recommending as an appropriate setback for a wind turbine from the property line to safely spray that field. Please explain and provide supporting calculations."*

I recommend a setback for a wind turbine no less than 0.8 miles from the end of field.

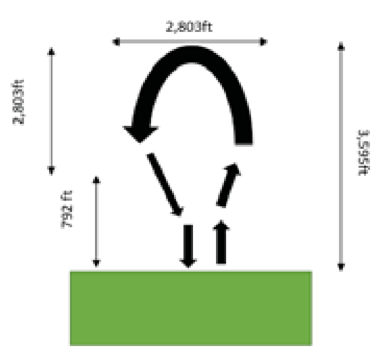
The calculations used to support the 0.8-mile setback include:

A straight out or teardrop/lightbulb pattern leaving the field including a climb, a 180° turn back on target = 3,595ft lateral distance from end of field.

Four seconds to climb and space for lateral distance = 792ft

Then 180° turn = 2,803ft radius

Lateral distance (792ft) +turn (2,803ft) = 3,595ft lateral distance from end of field = 0.68 miles *15% margin of error = 0.782 mile, rounded up to 0.8-mile minimum setback from obstacles, such as wind turbines.



Calculation:

-Assuming no obstacles, at the end of field, approximately four seconds to climb (135MPH= 198fps*4 sec) = 792ft

-A radius turn is equal to the velocity squared (V^2) divided by 11.26 times the tangent of the bank angle as described in the *Pilot Handbook of Aeronautical Knowledge* (2016):

$$R = \frac{V^2}{11.26 \times \text{tangent of bank angle}}$$

V= 135mph

Air Tractor 502 working speed *Air Tractor AT-502 FAA Approved Flight Manual*. (1987).

Tangent bank angle = 30°

$$\frac{18{,}225}{11.26 \times 0.57735} = 2{,}803\text{ft radius}$$

Based on the standard Air Tractor 502 (smaller size compared to Air Tractor 802), a setback of 0.8 miles is required with minimal margin of error. This would not take into consideration a faster working speed, non-standard atmospheric days, tailwinds, or pilot error outside of a marginal 15% addition to the calculation. Additionally, this calculation does not add any safety distance margin for the turbulence (which can be considerable) coming off the blades of the turbines.

Based on the provided calculation, I recommend a setback for a wind turbine no less than 0.8 miles from the end of field.

Respectfully,

Cody Christensen, Ed.D.
Airline Transport Pilot
FAA Gold seal flight instructor

Works Cited

Pilots Handbook of Aeronautical Knowledge. (2016). (FAA-H-8083-25B)
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/

Air Tractor AT-502 FAA Approved Flight Manual. (1987). Air Tractor, INC. Olney, Texas.

January 4, 2022

James Malters
727 Oxford St.
Worthington, MN 56187

Mr. Malters,

In regards to the STAFF'S FOURTH SET OF DATA REQUESTS TO MR. MICHAEL BOLLWEG EL21-018:

(a) Does Dr. Christenson maintain that a pilot cannot safely fly around a turbine that is shut down and not moving as ordered for the Crowned Ridge Wind II Project?

No.

If the wind towers were not in operation, it would substantial decrease the turbulence created by the wind turbines. As long as the distance from the field to the obstacle can be maintained, pilots could safety operate around a wind turbine.

(b) Please explain how flying around a wind turbine that is shut down is different than flying around other stationary obstacles, such as a power line, grain bin, house, trees, or cell tower.

As a professional pilot and flight instructor, I do not see a major difference between obstacles when height and circumference are adequately considered. I would not try to outmaneuver an obstacle without proper setback clearances for any stationary obstacles such as a wind turbine, powerline, grain bin, house, trees, or cell tower. The height and size of the obstacle must be taken into consideration when operating an aircraft in the vicinity of known obstacles.

I would recommend if a 100 ft grain bin was located within the area of operation, it would be considered much like a 100-foot shut down wind turbine would be except that a wind turbine can rotate so the orientation of the blades in relation to the aircraft turn would have to be taken into consideration. An operator could fly closer to a 100 ft grain bin because the climb required to clear a 100ft bin is less than a taller obstacle.

A 600-foot-tall grain bin with the same circumference as a 600-foot- tall wind turbine would be treated with equal caution. I have yet to encounter a 600-foot-tall grain bin so the best description would be trying to operate in downtown Manhattan with 60 story buildings on multiple sides. It would be possible to operate around them, but the distance between the building (wind turbine/grain bin/obstacle) would need to be sufficiently away to allow for a proper turn. The margin of error decreases and safety margins virtually disappear.

If the PUC request was to evaluate a new tower that was 600ft tall with known guy wires, I would treat it the same as a 600-foot wind turbine using the height and circumference of the obstacle. The tower along with the guywires constitute an obstacle that is not able to be flow through. Yes, it is possible to fly under, over, or through guy wires but the margin of safety decreases with each pass. Flying under or through stopped wind turbine blades is much like guy wires.

As a professional pilot I would not fly under shut down wind turbine blades, nor would I teach that maneuver to any student.

4-3) Refer to the response to staff data request 2-4. Mr. Christensen recommend a setback for a wind turbine no less than 0.8 miles from the end of the field. Is Mr. Christensen aware of any governmental entity that has ordered a similar setback for wind turbines from a property line to facilitate aerial spraying? If so, please provide supporting documentation.

I am not aware of any governmental entity that has ordered a similar setback for wind turbines from property line to facilitate aerial spraying. My job was to evaluate the threats to safety to agricultural spray aircraft posed by the turbines. That analysis had to do with the hard science of physics as it applied to aircraft and pilot performance. No political considerations were evaluated. Governmental agencies sometimes take other factors into consideration.

Respectfully,

Cody Christensen, Ed.D.
Airline Transport Pilot
FAA Gold seal flight instructor

NAAA
NATIONAL AGRICULTURAL AVIATION ASSOCIATION ®

July 30, 2020

South Dakota Public Utilities Commission
Capitol Building, 1st Floor
500 E. Capitol Ave
Pierre, SD 57501-5070
Phone (605) 773-3201

Dear Chairman Hanson, Vice Chairman Nelson, Commissioner Fiegen, and Utility Analyst Thurber:

The National Agricultural Aviation Association (NAAA) would like to bring to your attention our concern with towers erected without considering the safety of aerial applications made to South Dakota's cropland. These could be utility towers, wind-energy towers, or other, similar structures.

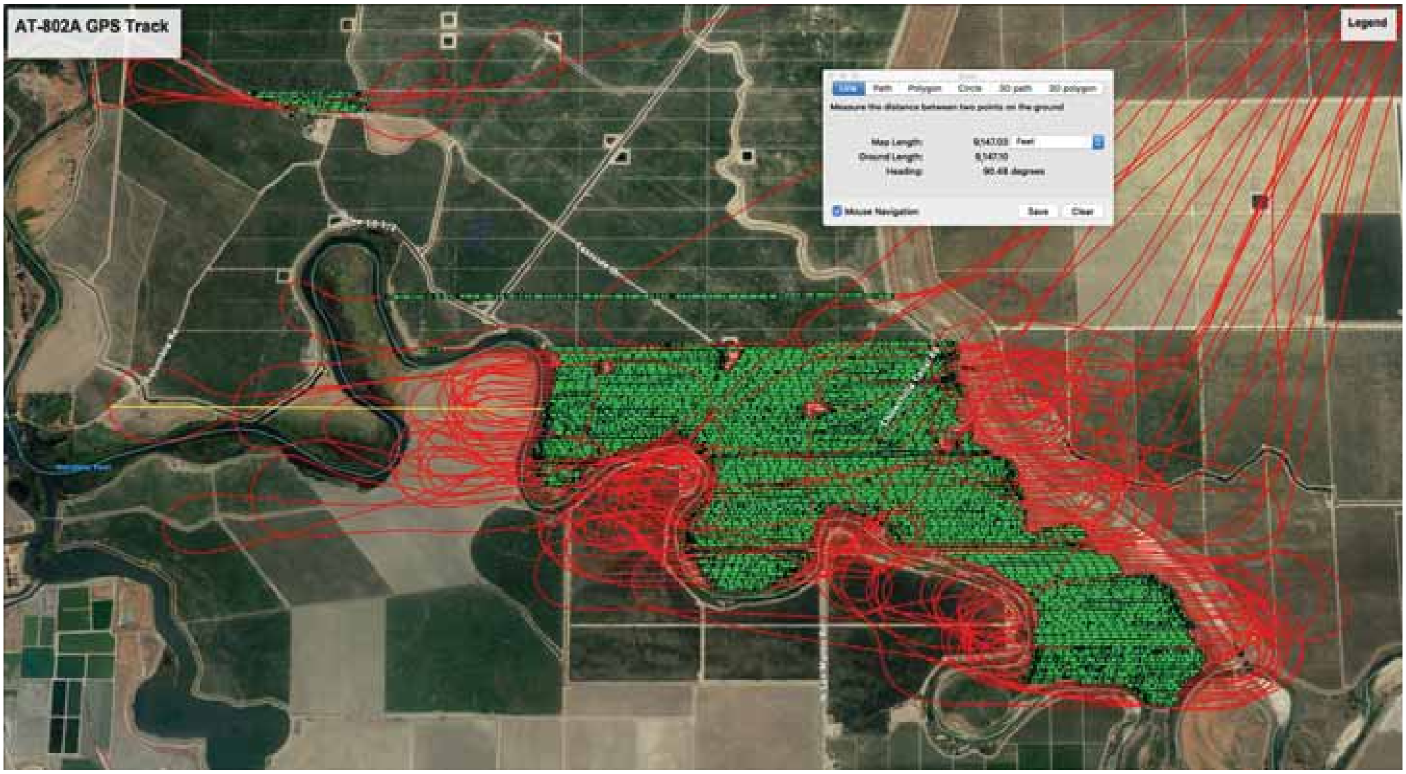
In terms of background about the aerial application industry, it is responsible for treating over 127 million acres of U.S. cropland either by seeding, fertilizing, or applying plant protecting pesticides. The NAAA represents over 1,600 members in in the field of aerial application, which consists mostly of small business owners and pilots licensed as commercial applicators that use aircraft to enhance the production of food, fiber and bio-fuel; protect forestry; protect waterways and ranchland from invasive species; and provide services to agencies and homeowner groups for the control of mosquitoes and other health-threatening pests. Within agriculture and other pest control situations, aerial application is a vitally important method for applying pesticides, for it permits large areas to be covered rapidly—by far the fastest application method of crop inputs—when it matters most. It takes advantage, more than any other form of application, of the often too-brief periods of acceptable weather for spraying and allows timely treatment of pests while they are in critical developmental stages, often over terrain that is too wet or otherwise inaccessible for ground applications. It also treats above the crop canopy, thereby not disrupting the crop and damaging it, nor compacting the soil.

Although the average aerial application company is comprised of but six employees and two aircraft, as an industry these businesses, as earlier stated, treat nearly 127 million acres of U.S. cropland each season, which is about 28% of all cropland used for crop production in the U.S.—this doesn't include the substantial amount of aerial applications that are made to pasture and rangeland. Aerial pest control for managers of forests, rangeland, waterways and public health also add to these many millions of acres treated annually. While there are alternatives to making aerial applications of pesticides, these options have several disadvantages compared to aerial application. In addition to the speed and timeliness advantage aerial application has over ground application, there is also a yield difference. Driving a ground sprayer through a standing crop results in a significant yield loss. Research from Purdue University found that yield loss from ground sprayer wheel tracks varied from 1.3% to 4.9% depending on boom width. While this study was conducted in soybeans, similar results could be expected in other crops as well. Research summarized by the University of Minnesota describes how soil compaction from ground rigs can negatively affect crop yields due to nitrogen loss, reduced potassium availability, inhibition of root respiration due to reduced soil aeration, decreased water infiltration and storage, and decreased root growth. Aerial application offers the only means of applying a crop protection product when the ground is wet and when time is crucial during a pest outbreak. A study on the application efficacy of fungicides on corn applied by ground, aerial, and chemigation applications (attached with these comments) further demonstrates that aerial application exceeds ground and chemigation application methods in terms of yield response. The success of aerial application using manned aircraft has resulted in an industry that will celebrate 100 years in 2021. Throughout its 100-year history, the industry has constantly improved itself through the use of research and technology. Aerial applicators constantly strive to incorporate the latest technology that can improve accuracy, including GPS guidance, flow control for variable and constant rate applications, and on-board weather monitoring equipment. Electronic valves that will allow flow to be controlled on individual nozzles is currently being evaluated for use on agricultural aircraft.

Regarding towers, they can be extremely difficult for aerial applicators to see, as their work is conducted while flying at over 100 mph just 10 feet off the ground. From 2008 – 2018, there were 22 agricultural aviation accidents from collisions with METs, communication towers, towers supporting powerlines and wind turbines resulting in nine fatalities. For all general aviation, there have been 40 tower related accidents and incidents resulting in 36 fatalities over the same 11-year period. As such, NAAA has developed the following information on safe distances towers should be located from cropland. It has come to NAAA's attention that a wind farm sponsor in South Dakota has proposed a setback of a mere 500 feet, which is far too short a distance for making safe aerial applications in a field adjacent to a wind turbine or tower location site with a fixed-wing aircraft.

NAAA has calculated a safe distance using aircraft speed and average turn time to estimate the total distance required to make a safe turn via a fixed-wing ag aircraft. An AT-802A with a working speed of 145 mph was used as the example aircraft. The working speed was taken from the midpoint between 130 and 160 mph as denoted on Air Tractor's specifications page for the AT-802A: https://airtractor.com/aircraft/at-802a/. An agricultural turn time of 45 seconds was used; this information was gleamed from operators' experience and used in comments made to EPA on several pesticide re-registrations. A speed of 145 mph is equal to 213 feet per second; 45 seconds to turn multiplied by 213 feet per second is equal to 9,585 feet or 1.82 miles needed to make the turn.

The second method NAAA used to provide evidence on the distance required to make a turn while conducting an aerial application was via GPS as-applied aerial application maps and Google Earth. Google Earth was used to measure the distance into the field that two turns required. The first was one of the shorter turns from the application from when the aircraft was lighter. This turn pushed 2,273 feet or 0.43 miles into the adjacent field. The second was from a longer turn made when the aircraft was fully loaded. This turn penetrated 9,147 feet or 1.73 miles into the adjacent field.

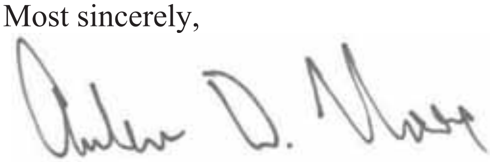


A Google Earth map showing an application made by an AT-802A. Green represents the flight path spray on, while red represent the flight path with spray off. The yellow line is the ruler tool used to measure the total length into the field a longer turn required: 9,147 feet (1.73 miles).

NAAA hopes that you the South Dakota Public Utilities Commissions finds the above information helpful and takes into account the dangers wind turbines and other obstacles represent to the safety of agricultural aviators in South Dakota where agriculture is such an integral part of the economy.

Thank you for the opportunity to share this information.

Most sincerely,



Andrew D. Moore
Chief Executive Officer

Wind Energy and Wildlife Resource Management in Iowa:
Avoiding Potential Conflicts

Introduction

Iowa is on its way to ranking among the world's leading producers of wind-generated electrical energy. In our efforts to become less dependent upon fossil fuels, nuclear power, hydropower and other sources with frequent environmental concerns, the possibility of this "green" energy has caused much excitement. Many Iowans eagerly await expansion of this low-cost (after initial infrastructure investments) source of electricity as one step towards energy independence.

The Governor, General Assembly, and Department of Natural Resources all consider wind energy development in Iowa a high priority. With much open farmland upon which wind generators might be placed, and in a region of nation realizing relatively high average wind velocities, Iowa seems destined to be a national focal point for wind energy development. Many state and national conservation organizations also support increasing wind energy production.

No energy source has yet been found to be without some degree of environmental costs, however, and wind energy is no exception. It has been demonstrated that if proper siting of wind turbines is not carefully planned, certain locations may result in collisions with, and death of, both wild birds and bats. In one or two noteworthy instances, excessive mortality of hawks, eagles and other birds of prey has resulted in major modifications to both design and placement of wind turbines, or even periodic shut-downs of large facilities. Additional costs involved with such measures can reduce cost-effectiveness of energy production.

Iowa currently exercises minimal regulation on locating wind farms. Nevertheless, some energy companies recognize the benefits of consulting with wildlife resource managers *before* final decisions are made on siting of new facilities. Such actions will result in greater trust and cooperation between energy producers and those charged with protecting our wildlife resources This can lead to an orderly and beneficial development of Iowa's wind energy.

An *ad hoc* Iowa wind energy and wildlife discussion group has met infrequently to review current developments regarding wind energy and wildlife interactions. The group consists of representatives from Iowa DNR's Wildlife Bureau and Energy Section, US Fish & Wildlife Service, several non-governmental conservation organizations, energy companies, the Iowa Renewable Energy Association and other interested parties. The group has no rule-making or regulatory authority; rather it simply works cooperatively to discuss mutual concerns and to learn of the latest developments.

Wildlife Concerns

Just what are the problems wind turbines might pose to our wildlife and other natural resources? The most obvious is direct collisions of birds and bats with rotating blades. Fortunately for birds, the annual mortality rate at most Midwestern wind farms appears to remain relatively low and probably insignificant. An exception occurs when turbines are placed in or very near major migration corridors and pathways, such as large river valleys and ridgetops or bluffs. Because birds tend to follow or congregate along these natural landscape features during their semi-annual migrations, wind turbines placed near these features have potential for causing significant bird kills in spring and fall. A few examples of such landscapes in Iowa include the Des Moines River, Little Sioux River, Wapsipinicon River, Loess Hills, and Mississippi River blufflands. Still, with Iowa's mostly open landscape, birds generally are widely dispersed throughout much of the year and chance of interaction with turbines is small.

Bats present an entirely different situation. For reasons still mostly unknown, bat collisions and mortality is much higher than for birds at many wind farms. Early efforts are underway to attempt a better understanding of the problem, but little is known at this time. However, bats usually are associated with trees or wooded areas and wetlands, where the insects on which they feed are abundant. Wind turbines placed near woodlands and wetlands thus might reasonably be expected to result in more bat deaths than turbines situated in open farmlands.

An emerging concern for birds is wind turbines placed within or very near large expanses of grassland. In some western states, ground-nesting lesser prairie-chickens have been found to abandon their nesting grounds when wind turbines were erected and operated nearby. It is quite likely that Iowa's greater prairie-chickens, a state endangered species requiring large expanses of unbroken habitat, would exhibit similar behavior. Many other ground-nesting grassland birds have yet to be studied, but some of these species already are in steep decline nationwide and cannot risk another factor that might potentially threaten their survival. A leading cause of much bird decline is related to fragmentation, or "parcelization", of their remaining habitat, breaking it into parcels too small to meet certain birds' survival or reproductive needs. It has been suggested that wind turbines placed in the middle of a large grassland may similarly fragment habitat and greatly reduce its value. This is a question in need of much additional research.

In summary, adverse effects of wind turbines on birds and bats have been documented in some locations, but much remains to be learned. A few energy companies or developers have collaborated with wildlife researchers to conduct some desperately needed studies. They are to be recognized for their commitment to better conservation of all our natural resources. Nevertheless, much more research is needed, especially in comparing "before and after" effects upon wildlife where wind farms are constructed. Information garnered would be invaluable in helping with future wind farm siting decisions.

Wind Turbine Siting Recommendations and Guidelines

Until we more fully understand how wildlife interacts with wind turbines, interim guidelines have been prepared to help wind energy developers and producers do a better job of designing and siting their wind farms. The list of recommendations below will serve as a starting point for things that *should* be considered when planning wind energy developments. These have been collected from a variety of sources, chief among them the US Fish & Wildlife Service Interim Guidelines for siting and construction of wind energy facilities, and recommendations from the

National Wind Coordinating Committee. Keep in mind that this list is a *work in progress*, subject to change as new information is gained.

Siting Recommendations:

- Avoid placing turbines at locations where any species of fish, wildlife or plants protected under the federal Endangered Species Act have been documented. Information may be obtained by contacting the Iowa Department of Natural Resources Endangered Species Coordinator or Wildlife Bureau staff. Any action resulting in losses to federally-listed species could result in substantial fines or other penalties.
- Avoid placing turbines in or near recognized bird concentration areas or migration pathways, including lakes, wetlands, forests, river valleys, ridge tops or bluff tops, large grasslands, known bird roosting areas, public wildlife areas, parks, and areas with frequent incidence of fog mist or low clouds. While there is no firm information on the amount of buffer zone needed between turbines and these habitats, a separation distance of at least one mile might be considered an absolute minimum (more for prairie-chickens—see below).
- Avoid placement of turbines in or near areas where highly "area-sensitive" wildlife species, such as prairie-chickens, are known. Area-sensitive species *require* expansive, unfragmented habitat. For prairie-chickens in particular, a separation distance of at least 5 miles from all known leks (breeding grounds) is *strongly* recommended.
- Avoid placing turbines near documented bat hibernation, breeding or nursery colonies and in migration corridors (see bird recommendation above) or between known colonies and feeding areas.
- Avoid placement of multiple turbines in close proximity to one another or perpendicular to known migration pathways (typically north-south). Widely spaced turbines, in arrays parallel to normal bird migration routes, can reduce collisions.
- Reduce or eliminate availability of carrion within wind farms, to reduce chances of attracting eagles, vultures and other raptors colliding with turbine blades. Neither dead livestock nor wildlife should be left within or near wind farm boundaries.
- Place wind turbines in areas already fully developed for agriculture, especially row-crop farming, where there is minimal extant wildlife habitat—Iowa is especially rich in such lands, and it has been estimated that as much as 80% of Iowa's landscape might be considered suitable for wind energy development with few adverse effects upon wildlife.
- If wildlife habitat losses or fragmentation must be mitigated, develop a plan to create or restore habitat *away* from the wind farm site. This will serve to attract birds, bats and other wildlife away from the development and reduce collisions. Wherever possible, coordinate habitat mitigation sites with other public or private wildlife lands, to connect, enlarge or enhance those areas.
- Certain landscapes, such as the Loess Hills in western Iowa and the "Iowa Great Lakes Region" in northwest Iowa, are known for their beauty, rarity *and* for extensive wildlife breeding and migrating activities. Such landscapes should be avoided entirely both for biological and aesthetic reasons.
- Consider possible *cumulative* regional effects of multiple wind energy projects. While one project alone may result in few concerns for wildlife, multiple projects across one landscape could significantly multiply adverse effects.

- A map of Iowa, denoting areas of particular concern for possible adverse effects by wind turbines upon wildlife and habitat, has been developed and is updated periodically. Construction within these areas may not necessarily result in wildlife conflicts, and consultation with DNR wildlife biologists can assist developers in finding suitable sites within these potentially sensitive landscapes, or in suggesting plan modifications to minimize adverse effects.

Turbine Design and Operation Recommendations:

- Tubular support towers with pointed tops, rather than lattice supports, greatly reduce opportunities for birds to perch or nest upon the structures. Avoiding placement of permanent external ladders or platforms on tubular towers also reduces nesting and perching.
- Avoid use of guy wires for turbine or meteorological tower supports. Any existing guy wires should be marked with recommended bird deterrent devices (Avian Power Line Interaction Committee 1994).
- Taller turbines, having a top-of-rotor sweep exceeding 199 ft., may require lights for aviation safety. The minimum amount of pilot warning and avoidance lighting necessary should be used, and unless otherwise required by the Federal Aviation Administration, only white strobe lights should be used at night. These should be minimized in number, intensity, and number of flashes per minute. Solid red or pulsating red lights should *not* be used, as they appear to attract more night-migrating birds than do white strobes.
- Electric power lines should be placed underground wherever possible, or should utilize insulated, shielded wire when placed above ground, in order to reduce bird perching and electrocution.
- Where the height of rotor-sweep area produces high wildlife collision risks, tower heights should be adjusted to lower risks.
- If wind turbine facilities absolutely must be located in areas known for high seasonal concentration of birds, it is essential that a bird monitoring program be established, with at least three years of data collected to determine peak use periods. Data may be collected by direct observation, radar, infrared or acoustic methods. When birds are highly concentrated in or near the site, turbines should be shut down until birds have dispersed.
- When older facilities must be upgraded or retrofitted, the guidelines above should be employed as closely as possible.

Ideally, a site study plan and description of turbine structural and lighting design should be submitted to Iowa DNR well in advance of final siting decisions, for review by staff wildlife experts and advisements on acceptability or suggestions for modifications and/or monitoring. Hiring a reputable environmental consultant with a strong background in bat and bird ecology is strongly recommended. A baseline inventory of wildlife and evaluation of habitat should be considered for every site under serious consideration for windfarm development. Use of National Wind Coordinating Committee study guidelines will allow for comparison with other studies. Special attention should be paid to Spring and Fall migration seasons, reviewing migrational use of the proposed site by raptors, waterfowl, shorebirds, gulls, songbirds and bats. Upon completion and startup of wind energy generation, monitoring wildlife populations and migrations should be conducted for at least 2-3 years.

Related Links

The following websites of other agencies and organizations may be useful in further understanding of potential wind energy and wildlife conflicts, and how to reduce or mitigate threats to wildlife:

http://www.fws.gov/habitatconservation/wind.pdf
http://www.nationalwind.org/publications/siting.htm
http://www.dnr.wi.gov/org/es//science/energy/wind/guidelines.pdf
http://www.aplic.org

For more information, contact Doug Harr, DNR Wildlife Diversity Coordinator, doug.harr@dnr.iowa.gov , or Lee Vannoy, DNR Energy Section, lee.vannoy@dnr.iowa.gov .

Siting Guidelines for Wind Power Projects in South Dakota

Introduction

The South Dakota Bat Working Group in cooperation with the Department of South Dakota Game, Fish and Parks compiled these siting guidelines for wind power developers and other stakeholders to utilize as they consider potential wind power sites in South Dakota. Wind power siting and permitting processes vary by county and/or city. The Public Utilities Commission has agreed to distribute siting guidelines to all stakeholders involved in the development of wind power in South Dakota, since at this time no state environmental regulations exist in association with siting of wind turbines.

Wind siting guidelines relevant to South Dakota were adapted from the National Wind Coordinating Committee's (NWCC) Permitting of Wind Energy Facilities: A Handbook and the Kansas Renewable Energy Working Group (KREWG) Environmental and Siting Committee's Siting Guidelines for Windpower Projects in Kansas. The National Wind Coordinating Committee's guidelines are available online at the following website address: http://www.nationalwind.org/publications/siting.htm and the Kansas Renewable Energy Working Group's guidelines are available online at the following address: http://www.kansasenergy.org/krewg/reports/KREWGSitingGuidelines.pdf.

South Dakota's guidelines address activities and concerns associated with siting and permitting wind turbines. Successfully siting a wind power project often relies on trade-offs between community acceptability and economic viability, which relates to adequate communication.

Although wind power is considered "green energy," many concerns have been expressed about the effects of their presence on plants and animals native to South Dakota. Specific areas of South Dakota have been identified as potential sites for wind energy development, and these sites are located in, but not limited to, the Coteau des Prairies in eastern South Dakota and the Missouri River in central South Dakota, which are unique/rare in South Dakota. Additional areas in other regions of the state may be identified/added by ongoing studies or further infrastructure development (e.g., transmission lines and substations).

Wind energy issues in South Dakota are similar to those in other states. Most residents of South Dakota respect their local resources, wildlife, and environment, and have concerns regarding the exploitation and/or degradation of those resources. Developers, recognizing the opportunity to establish renewable energy generation facilities, may not be aware of concerns expressed by agencies, groups, or individuals regarding wind farm impacts. Each project should be evaluated on a case by case basis. Cumulative impacts will undoubtedly accrue as development proceeds within regions (e.g., Missouri River, Coteau des Prairies, Prairie Pothole) and across the state. These cumulative effects may differ in type and significance from those experienced at individual project sites. In particular, the cumulative effects on natural and biological resources, such as habitat (e.g., native prairie) and wildlife (e.g., birds and bats), require consideration from all stakeholders; however, impacts on other resources are also important. For further development and sustainability of the wind energy industry, it is important by all stakeholders to evaluate the context of the collective merits of all projects.

Most guidelines within this document are issues and concerns identified by other parties, e.g., NWCC and KREWG, which are shared in South Dakota, but some guidelines are tailored to address the concerns and issues specifically to this state. These guidelines address issues/concerns associated with the pre-construction, construction or post-construction of wind turbines and have been divided into eleven general categories:

1) Land Use
2) Natural and Biological Resources
3) Noise
4) Visual Resources
5) Public Interaction
6) Soil Erosion and/or Water Quality
7) Health and Safety
8) Cultural, Archaeological, and Paleontological Resources
9) Socioeconomic, Public Service, and Infrastructure
10) Solid and Hazardous Wastes
11) Air Quality and Climate.

The guidelines outlined in this document are neither mandates nor regulations. They have been compiled/developed: 1) to encourage developers to select potential wind sites using a process that is acceptable to all stakeholders (e.g., state agencies/departments, federal agencies, sportsmen/women groups, local communities, developers, landowners, wildlife advocacy groups, and/or tribal agencies); 2) to protect South Dakota rare/unique areas (e.g., Coteau des Prairies, Missouri River, and Prairie Potholes) and thus the state's natural beauty; 3) to minimize deleterious effects to wildlife; 4) to help provide information to all involved/interested parties; and 5) to promote a responsible, guided, uniform approach to the siting of wind power projects in South Dakota.

1) Land Use - Wind development may be compatible with a variety of other land uses, including agriculture, grazing, open space, and habitat conservation, depending on the site, size, and design of the project. Other land uses, such as hunting/fishing, bird watching, and wildlife photography as well as resource values need to be considered when siting large wind projects in remote areas of South Dakota. Stakeholders need to understand all the land use issues associated with a site before finalizing development plans, permit conditions, or other requirements.

   a) Contact resource agencies (Table 1), property-owners and other stakeholders early to identify potentially sensitive land uses and issues. Ensure that all the stakeholders fully understand the entire project in order to address and resolve potential land use issues.

   b) Look at all the land use relationships and objectives for an entire wind resource area. Land use concerns are specific to different regions of South Dakota thus early scoping and planning is crucial to reducing potentially incompatible uses. Contact appropriate experts (Table 2) and resource agencies to research and evaluate the issues prior to selecting a specific site within the respective region.

   c) Careful consideration should be given to the impact of wind power projects in areas that are unique/rare in South Dakota, such as the Coteau des Prairies, Missouri River, and Prairie Pothole regions (Figure 1), particularly in areas that are relatively unfragmented. Special care should be given to avoid damage to unfragmented landscapes and high quality remnants in wetland and prairie ecosystems (e.g., tall grass, mixed grass, and short grass prairie). If possible, wind energy development should be located on already altered landscapes, such as cultivated or developed lands. An undeveloped buffer adjacent to intact prairies is also desirable.

   d) Consider the potential impacts of both wind and non-wind (e.g., roads, transmission lines, substations) project development in the wind resource area before development projects are proposed, and develop a plan for the area that avoids or minimizes land use conflicts. Design the project site layout to limit the use of the land, consolidate necessary infrastructure requirements wherever possible, and evaluate current transmission lines and market access.

   e) Learn the rules that govern where and how a wind project may be developed in the project area. Become aware of potential conflicts between lease provisions and permitting agency (e.g., The Public Utilities Commission and/or local governments) conditions for project development.

2) Natural and Biological Resources - Bird and bat collision mortality and behavioral avoidance associated with wind energy facilities have been a controversial siting consideration. Typically, bats have a higher incidence of mortalities at wind energy sites than birds, though this depends on the site. Biological resource surveys at each potential wind power site in the early stages of planning can help determine whether serious conflicts are likely to occur at a particular site, but cumulative effects with multiple sites in a particular region/area must also be acknowledged and/or investigated and minimized/avoided. In some instances, the impact wind turbines have on birds, bats, and other sensitive biological resources can be adequately mitigated. However, wind development may be inappropriate in certain areas in South Dakota.

   a) Consider the biological setting early in project evaluation and planning. Use biological and environmental experts to conduct a preliminary biological reconnaissance of the likely site area. Communicate with personnel from wildlife agencies (e.g., South Dakota Game, Fish and Parks (SDGFP), U. S. Fish and Wildlife Service, U. S. Geological Survey, and Natural Resources Conservation Service; Table 1) and universities (e.g., South Dakota State University, University of South Dakota, Dakota State University, Black Hills State University, and Northern State University; Table 2). If a proposed turbine site has a large potential for biological conflicts and an alternate site is eventually deemed appropriate, the time and expense of detailed wind resource evaluation work may be lost.

   b) Contact the local resource management agency (e.g., local South Dakota Conservation District and SDGFP regional office, Appendix A) early in the planning process to determine if there are any resources of special concern in the area under consideration.

   c) Involve local environmental/natural resources groups (e.g., South Dakota Wildlife Federation, local chapters of Audubon Society, local chapters of The Wildlife Society, Izaak Walton League, The Nature Conservancy, South Dakota Bat Working Group, Ducks Unlimited, United Sportsmen for South Dakotans; Table 3) as soon as practicable. Early involvement of these organizations may provide additional resource information as well as minimize potential conflicts.

   d) Avoid unnecessary ecological impacts of wind power development through proper planning. Examine landscape levels of key wildlife habitats, migration corridors, staging/concentration area, and breeding/brood-rearing areas to help develop general siting strategies. Situate turbines so they do not interfere with important wildlife movement corridors and staging areas.

e) Avoid large, intact areas of native vegetation. Sites where native vegetation is scarce or absent will have substantially fewer biological resource concerns.

f) Careful review should be given to sites with legally protected wildlife (e.g., state or federal threatened or endangered species, migratory birds) present or potentially present. Recognize that other declining or vulnerable species (not legally protected) may also be present. Investigate wildlife issues associated with each potential wind energy site and determine the apparent impacts of each potential wind energy site on species of concern.

g) Avoid lattice-designed towers or other designs providing perches for avian predators. Avoid placing perches of any sort on the nacelles of turbines. Address potential adverse affects of turbine warning lights on migrating birds and bats. Minimize effects of meteorological towers when investigating wind energy potential by using tubular monopoles rather than lattice structures with guy wires and lighting systems, which could represent a hazard to birds.

h) Bury power lines and/or place turbines near existing transmission lines and substations, where possible. Infrastructure should be able to withstand periodic burning of vegetation, where prescribed burns are practiced. Minimize number of roads and fences.

i) Mitigate for habitat loss in areas where there is ecological damage in the siting of a wind power facility. Appropriate actions include but are not limited to ecological restoration, long-term management agreements, conservation easements, or fee title acquisitions to protect lands with similar or higher ecological quality as that of the wind power site.

j) Consider possible cumulative regional impacts from multiple wind energy projects when conducting environmental assessments and making mitigation decisions. Evaluation of these impacts could result in significant changes to project plans.

k) Consider turbine designs (e.g., wind turbines with tubular monopoles rather than lattice structures with guy wires) or deterrents, which minimize potential impacts on flying animals such as birds and bats.

l) Consider timing of construction and maintenance activities (including mowing) to minimize impacts on native flora (plants) and fauna (animals), including ground-nesting birds. Avoid construction and maintenance activities during breeding season (April to July) and, if possible, during migration (April – June and August – October).

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m) Develop a stringent plan for preventing the introduction or establishment of non-native/invasive flora (plants) in disturbed areas and establishing the financial means to do so the duration of the wind power project.

3) Noise - Noise emitted by wind turbines tends to be masked by the ambient (background) noise from the wind itself and tends to fall off sharply with increased distance, therefore noise-related concerns are likely to occur at residences closest to the site, particularly those sheltered from prevailing winds. Advanced turbine technology and preventive maintenance can help minimize noise during project operation.
   a) Design projects with adequate setbacks from dwelling units, especially where the dwelling unit is in a relatively less windy or quieter location than the turbine(s). Recognize that residents who object to noise created by wind energy may replace residents who support wind systems. Efforts should be made to place the turbines in disturbed areas (e.g., croplands) as stated above.

   b) Avoid locating marginally noisy turbines in projects with nearby residences. In areas potentially sensitive to acoustic levels, e.g., nearby residences or natural surroundings, consider taking efforts to prevent problems by upgrading turbines with sound reduction technology.

4) Visual Resources - There are ways to reduce the visual impact of wind projects, but there may be tradeoffs to consider. One of the best tools for assessing project impact is the use of visual simulations.
   a) Consider visual impact of wind power projects when siting turbines. Evaluate the impact of siting turbines on the quality of the surrounding landscape, especially in areas where aesthetic qualities and/or neighboring properties might be affected. Prepare and use visual simulations and/or viewshed analyses to provide information to landowners, the general public, and other key stakeholders to identify potential impacts to visual resources from wind power developments.

   b) Educate all stakeholders about what to expect from a wind project.

   c) Prepare to make impact tradeoffs and coordinate planning efforts in all jurisdictions and with all stakeholders.

   d) Listen to the communities and stakeholders in all project phases and be prepared to adapt design to minimize industrial characteristics and structures and minimize visual exposure from sensitive areas.

   e) Minimize the need for developed roads or cut and fill techniques. Consider possibilities and benefits of using roadless project designs or designs relying on current roads, especially in remote or sensitive visual areas.

f) Identify designated scenic byways and popular landscapes and avoid siting turbines in areas that are readily visible from those sites. Priority should be given to wind power projects in sites where the natural landscape has already experienced significant change from human-related causes.

5) Public Interaction - It is important to inform all stakeholders of the benefits and tradeoffs associated with each wind power project, therefore wind projects entail public involvement. This makes it easier for all stakeholders to communicate and cooperative with each other in order to make informed decisions in the best interest of all parties.
   a) Prepare and implement a public education program to discuss the benefits and tradeoffs involved in wind generation.

   b) Provide objective information or access to objective information that allows interested parties to make informed decisions. Decision making by all stakeholders is enhanced through accurate and comprehensive information sharing and opportunities for communication between stakeholders. Invite public input in regards to wind power projects through public meetings and public forums.

6) Soil Erosion and/or Water Quality - Temporary and permanent soil disturbance results from wind projects. Care must be taken to estimate and control both runoff and erosion from each wind power site, particularly in areas where access roads and facilities are located in steep terrain, especially near waterways (e.g., creeks and rivers) and wetlands.
   a) Minimize the footprint of the project and evaluate alternative turbine pad and access road siting and layouts. Minimize improved roads and construction staging areas and avoid sensitive habitats (e.g., native prairies and wetlands).

   b) Preferably conduct construction and maintenance of wind power sites when the ground is frozen or when soils are dry and the native vegetation is dormant. Conduct ongoing operation and maintenance activities, as practical, by using light conveyances in order to minimize habitat disturbance and the need for improved roads.

   c) Whenever possible, avoid road construction on steep slopes.

   d) When selecting the appropriate erosion control measures, be aware that although some measures may require greater initial expense, significant savings will occur over the life of the project in reduced maintenance and replacement costs. Furthermore, a well-developed erosion and sediment control plan may also reduce regulatory delays in approving and monitoring the project.

e) Use certified weed-free seed of local ecotypes of native vegetation when reseeding disturbed areas and consider revegetation re-growth and cover. Consider animal and plant compositions when determining the frequency and timing of mowing near turbines.

7) Health and Safety - Most of the safety issues associated with wind energy projects can be dealt with through adequate setbacks, security, safe work practices, and the implementation of a fire control plan.
   a) Consider safety setback distances from wind turbines and habitable dwellings, public highways, and property lines when evaluating specific parcels for development. Setbacks should provide adequate spacing from falling ice, blown turbine parts, and major structural failure, which can mitigate siting issues.

   b) Design facilities and turbine pads to prevent or avoid public and worker safety problems. Consider the benefits of underground wiring between turbines and project substation.

8) Cultural, Archaeological, and Paleontological Resources - During project design and site development, important cultural and fossil resource sites should be avoided and protected or else a mitigation plan should be developed. Special care should be taken to preserve the confidentiality as well as the integrity of certain sensitive resources or sites sacred to Native Americans.
   a) Identify and avoid potentially sensitive cultural, historical, or pre-historical resources and involve all stakeholders early on.

   b) Consult with the South Dakota State Historical Society (Table 1) and other qualified professional specialists familiar with cultural and fossil resources in the project development area.

   c) Some sensitive resources and sites may be confidential to Native Americans. Respect this confidentiality and work closely with tribal representatives to protect these resources by avoiding disruption to these sites.

   d) Design project site layout to avoid sensitive resources, if possible.

   e) Prepare a monitoring and mitigation plan for protection of sensitive resources during construction and operation of the project. Require appropriate mitigation of unavoidable impacts and monitor to ensure measures are implemented.

   f) Allow adequate time in the project schedule for data and specimen recovery, mapping, analysis, and reporting.

9) Socioeconomic, Public Services, and Infrastructure - Developers and other stakeholders should coordinate with local communities and/or agencies to determine how the project may affect the community's fire protection and transportation systems and nearby airports and communications systems. Communities should work with wind project developers to ensure that any financial burden placed on them will be compensated through appropriate/reasonable property tax or other revenues.

a) Identify any community services, costs, and infrastructure that may be affected by a project and work to involve all stakeholders in solving any conflicts and designing mitigation plans. Work with all the concerned stakeholders to develop appropriate mitigation for unavoidable impacts and monitor compliance to ensure the measures are implemented. Attempt to avoid or minimize potential impacts on community services, costs, and infrastructure.

b) House Bill 1235, passed during Legislative Session 2003, is an act to provide for the taxation of wind energy property in South Dakota, encouraging developers to build in South Dakota yet help local communities. As any changes to the property tax rate are considered, local taxing jurisdictions should seek to recover only those costs directly associated with services to the wind development to avoid discouraging new wind projects. Involve local communities in economic plan and work to be good neighbors.

c) Recognize that some districts, counties, and/or cities do not have an established zoning and/or permitting process applicable to wind power development. Do not exploit this fact rather work with appropriate local officials to establish reasonable parameters and make the process as clear to the public as possible.

d) Use local contractors and providers for supplies, services, and equipment, when possible, during the construction and operation phases of the project.

e) Acknowledge that there may not be specific needs by local communities for electricity generated by the proposed wind power project, therefore substantive public benefits should be provided beyond hosting the renewable energy facility.

f) Provide information to all stakeholders in regards to future project expansions to ensure all stakeholders have precise information. Recognize that developers may not be fully informed about future expansions and stakeholders may have issues and concerns that are dependent on the project scale.

g) Expanded projects may involve impacts not specifically addressed during the initial project. Anticipate and make provisions for future site decommissioning and restoration.

10) Solid and Hazardous Wastes - Solid wastes need to be collected from dispersed sites and properly disposed of in a manner consistent with other power plants or facilities. Non-hazardous fluids should be used where possible, and a Hazardous Materials Waste Plan should be developed if their use cannot be avoided. By performing major maintenance and repair work off-site, certain problems can be avoided.

a) Ensure that construction wastes are collected from all wind power sites and disposed of at a licensed facility. Waste disposal practices should not be different in wind power from those required at other power plants or repair facilities.

b) Anticipate fluid leaks and avoid hazardous leaks by using non-hazardous fluids. Design a Hazardous Materials Waste Plan to address avoidance, handling, disposal, and cleanup, when necessary.

c) Conduct turbine maintenance facilities and major turbine repairs off-site.

11) Air Quality and Climate - Wind projects produce energy without generating many of the pollutants associated with fuel combustion. Temporary, local emissions associated with project construction and maintenance can be minimized, and any micro-climatic impacts should be insignificant.

a) Address air quality issues potentially associated with construction and operation of the wind generation project. Mitigate any impacts during sensitive operations so the overall impact is relatively small and temporary.

Table 1. Contact Information for agencies in South Dakota.

Name	Specialty	Agency	Address	Telephone	Email
Silka Kempema	Birds and Bats	SDGFP	523 E Capitol Ave Pierre, SD 57501	605-773-2742	silka.kempema@state.sd.us
Natalie Gates	Federal Wildlife Regulations	USFWS	420 South Garfield Avenue, Suite 400 Pierre, SD 57501	605-224-8693	natalie_gates@fws.gov
Jill Shaffer	Bird Research	USGS/NPWRC	8711 37th St. SE Jamestown, ND 58401	701-253-5547	jshaffer@usgs.gov
Ken Higgins	Grassland Birds	USGS/SDSU	Dept of Wildlife & Fisheries Sciences Box 2140B, Brookings, SD 57007	605-688-6121	terry_symens@sdstate.edu
Kevin Luebke	Wildlife Conservation	NRCS	200 4th St SW Huron, SD 57350	605-352-1242	kevin.luebke@sd.usda.gov
Great Plains Office	Diane Mann-Klager	BIA	115 4th Ave SE Aberdeen, SD 57401	605-226-7343	Diane.Mann-Klager@bia.gov
Paige Hoskinson	Archeology	SHPO	900 Governors Drive Pierre, SD 57501	605-773-6004	paige.hoskinson@state.sd.us

Table 2. Contact information for experts and/or universities in South Dakota

Name	Specialty	Organization	Address	Telephone	Email
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Manager	USFWS Huron WMD	Rm 309 Federal Bldg 200 4th St SW Huron, SD 57350	605-352-5894	HuronWetlands@fws.gov

Appendix B. Acronyms used in tables and appendices.

Acronyms	**Description**
BHSU	Black Hills State University
BIA	Bureau of Indian Affairs
DSU	Dakota State University
NPWRC	Northern Prairie Wildlife Research Center
NRCS	Natural Resources Conservation Service
NSU	Northern State University
NWR	National Wildlife Refuge
SDGFP	South Dakota Game, Fish and Parks
SDACD	South Dakota Association of Conservation Districts
SDSU	South Dakota State University
SHPO	State Historic Preservation Office
USD	University of South Dakota
USFWS	U. S. Fish and Wildlife Service
USGS	U. S. Geological Survey
WMD	Wetlands Management District

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Name	Specialty	Agency	Address	Telephone	Email
Silka Kempema	Birds and Bats	SDGFP	523 E Capitol Ave Pierre, SD 57501	605-773-2742	silka.kempema@state.sd.us
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Jill Shaffer	Bird Research	USGS/NPWRC	8711 37th St. SE Jamestown, ND 58401	701-253-5547	jshaffer@usgs.gov
Ken Higgins	Grassland Birds	USGS/SDSU	Dept of Wildlife & Fisheries Sciences Box 2140B, Brookings, SD 57007	605-688-6121	terry_symens@sdstate.edu
Kevin Luebke	Wildlife Conservation	NRCS	200 4th St SW Huron, SD 57350	605-352-1242	kevin.luebke@sd.usda.gov
Great Plains Office	Diane Mann-Klager	BIA	115 4th Ave SE Aberdeen, SD 57401	605-226-7343	Diane.Mann-Klager@bia.gov
Paige Hoskinson	Archeology	SHPO	900 Governors Drive Pierre, SD 57501	605-773-6004	paige.hoskinson@state.sd.us

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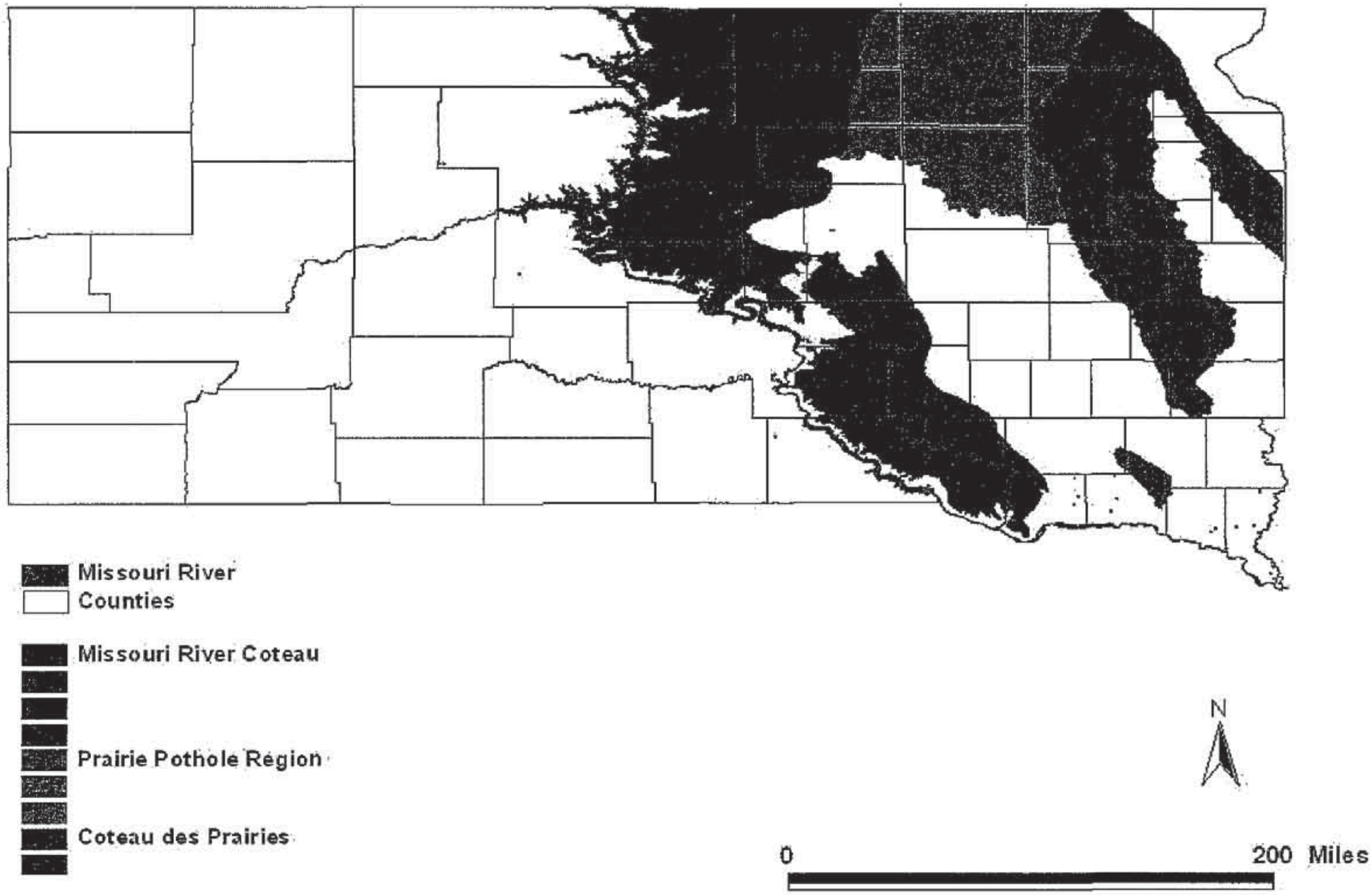
Figure 1. Regions in South Dakota: Wind Power Siting Guidelines



PRAIRIE GROUSE MANAGEMENT PLAN FOR SOUTH DAKOTA 2017−2021

Sharp-tailed Grouse

Greater Prairie-Chicken

SOUTH DAKOTA DEPARTMENT OF GAME, FISH AND PARKS

PIERRE, SOUTH DAKOTA

WILDLIFE DIVISION REPORT 2017−03

JULY 2017

ACKNOWLEDGMENTS

This plan is a product from hours of discussion, debate, effort and input of many wildlife professionals. In addition, those comments and suggestions received from private landowners, hunters, and those who recognize the value of prairie grouse and their associated habitats were also considered.

This document is for general, strategic guidance for the Division of Wildlife (DOW) and serves to identify the role that the DOW plays, how we function, and what we strive to accomplish related to prairie grouse management. By itself this document is of little value; the value is in its implementation. This process will emphasize working cooperatively with interested publics in both the planning process and the regular program activities related to prairie grouse management. This plan will be utilized by Department staff and Commission on a regular basis and will be formally evaluated at least every five years. Plan updates and changes, however, may occur more frequently as needed.

All text and data contained within this document are subject to revisions for corrections, updates, and data analyses.

Management Plan Coordinator—Travis Runia, South Dakota Department of Game, Fish and Parks (SDGFP).

SDGFP Management Plan Team— Nathan Baker, Paul Coughlin, Josh Delger, Jacquie Ermer, Casey Heimerl, John Kanta, David Mallett, Mark Norton, Tim Olson, Brian Pauly, Alex Solem, and Chad Switzer.

Recommended citation:

South Dakota Department of Game, Fish and Parks. 2017. Prairie Grouse Management Plan for South Dakota, 2017–2021. Completion Report 2017–03. South Dakota Department of Game, Fish and Parks, Pierre, South Dakota, USA.

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LIST OF ACRONYMS

CRP	Conservation Reserve Program
CREP	Conservation Reserve Enhancement Program
DOW	Division of Wildlife
FPNG	Fort Pierre National Grassland
NRCS	Natural Resources Conservation Service
SDGFP	South Dakota Department of Game, Fish and Parks
SDSU	South Dakota State University
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service

EXECUTIVE SUMMARY

Sharp-tailed grouse (*Tympanuchus phasianellus*) and greater prairie chickens (*T. cupido*), collectively hereafter referred to as prairie grouse, are the most abundant grouse species in South Dakota (SD). The vast expanses of open grassland found throughout much of SD provide ideal habitat for these two game birds. Although slight differences in micro and macro habitat requirements exist between these two species, management strategies are similar enough to warrant a single management plan for prairie grouse in SD.

As prairie obligates, prairie grouse are dependant upon grasslands for nearly all annual life cycle needs. Although weather can influence prairie grouse demographics from year to year, habitat quantity and quality have the primary influence over prairie grouse distribution and abundance. The "Prairie Grouse Management Plan for South Dakota 2017–2021" focuses on issues related to the abundance and quality of grassland habitat. This management plan also provides overview information including the history of prairie grouse in SD, general ecology, monitoring and current status, hunting season structure and authority, hunter and harvest trends, habitat trends, research and issues, and challenges and opportunities facing prairie grouse, private landowners, and wildlife managers.

The South Dakota Department of Game, Fish and Parks' (SDGFP) goal for prairie grouse management in SD is to maintain or expand sustainable prairie grouse populations by fostering partnerships, promoting grassland habitat stewardship, and applying biological and social sciences. Objectives and strategies have been developed to guide implementation of this plan.

INTRODUCTION

South Dakota is home to two species of true prairie grouse, the sharp-tailed grouse and greater prairie-chicken, hereafter prairie-chicken. Prairie grouse are medium sized (16–18 inches long, 1.3–2.2 pounds) round-bodied and short-legged game birds native to grasslands, steppe, and mixed-shrub habitats of North America. Their cryptic coloration functions as camouflage and allows the birds to blend into the grassland habitat, reducing detection from predators. The unique feathering of the legs and nostrils make them especially adapted to cold and snowy climates found in SD. The feathering of the legs and feet is more pronounced in sharp-tailed grouse, whereas the feet of prairie-chickens appear nearly featherless. Although most prominent in sharp-tailed grouse, an additional adaptation to winter weather in both species is the lateral pectinate scales on their feet which perform like snowshoes.

The primary differentiating feature between the two species of prairie grouse is the shape of the tail. Sharp-tailed grouse, like the name suggests, have tail feathers which come to a sharp point while tail feathers of prairie-chickens are gently rounded. The distinct dark barring over much of the body of a prairie-chicken also differs from the generally non-barred dark colored dorsal and light colored ventral coloration of sharp-tailed grouse. The long pinnae, or ear feathers which are erected during male courtship displays, are absent on sharp-tailed grouse. Both species of male prairie grouse have colored external air sacs located on each side of the neck which are inflated during courtship. These air sacs are purple for sharp-tailed grouse and orange for prairie-chickens.

As their name suggests, prairie grouse are found primarily within landscapes dominated by grassland habitat. The unique behavior and habitat use of prairie grouse make them an exciting game bird and valued watchable wildlife species. Most hunting occurs on open grasslands with the aid of dogs, often pointing breeds. The explosive flush of prairie grouse attracts thousands of hunters to SD each year. In 2015, nearly 13,000 hunters harvested about 50,000 prairie grouse. South Dakota is one of the few states where both species of prairie grouse can be harvested under liberal hunting regulations. Hunting is authorized from the third Saturday of September through the first Sunday in January with a combined daily bag limit of three prairie grouse.

The unique lekking behavior of prairie grouse (described below) attracts numerous wildlife viewers each year. Several viewing blinds are annually available for public use on the Fort Pierre and Buffalo Gap National Grasslands as well as Custer State Park. The amazing sight and sound of the prairie grouse courtship display is an annual sign that spring is soon to arrive on the prairies. Prairie grouse are an indicator of a functioning prairie ecosystem which suggests landscape-level habitat exists for other prairie obligate species. Prairie grouse are considered "flagship" species for conservation of prairie habitat throughout their range and in SD.

This management plan identifies and provides detailed objectives and strategies which will be used to meet the goal for prairie grouse management in SD. The future of prairie grouse in SD is primarily dependent upon prairie habitat, thus the bulk of this plan focuses on prairie habitat management. Because important prairie grouse habitat intersects many ownership boundaries, this plan addresses issues related to both public and private land. Without a doubt, many prairie-dependent species, both game and nongame, will benefit from the implementation of this plan.

HISTORICAL INFORMATION AND CURRENT DISTRIBUTION

Prior to European settlement, SD's landscape was a rolling sea of mixed and tallgrass prairie which likely supported sharp-tailed grouse nearly statewide. Sharp-tailed grouse are considered a landscape species which requires substantial grassland habitat at a landscape level to persist (Hanowski 2000). Mass conversion of grassland to cropland has reduced the distribution of sharp-tailed grouse particularly in southeastern SD. The current distribution of sharp-tailed grouse includes nearly all of western SD and about half of the eastern portion of the state (Figure 1). Although sharp-tailed grouse still occur in every county west of the Missouri River, conversion of prairie to cropland has undoubtedly reduced their abundance west river and statewide.

Prairie-chickens may have been native to portions of eastern and central SD in limited numbers prior to European settlement (summarized in Flake et al. 2010). While conversion of prairie to cropland strictly reduced the distribution and abundance of sharp-tailed grouse, prairie-chickens actually expanded in distribution and increased in abundance when portions of the landscape were converted to cropland. Prairie-chickens benefit greatly when waste grain from agricultural fields is available in northern states such as SD. As European settlement and associated agriculture marched north and west across the prairies, prairie-chicken populations exploded and "followed the plow" all the way to prairie Canada (Johnsgard and Wood 1968, Houston 2002). During the early 1900s prairie-chickens could be found nearly statewide in SD. It is likely that they benefited from the extirpation of bison which resulted in the associated temporary increase in vegetation height across the state. The distribution and abundance of prairie-chickens probably peaked at the turn of the 20th century (Johnsgard and Wood 1968). It became quite apparent that a landscape dominated by grasslands with interspersed cropland provided ideal habitat for prairie-chickens.

The range of prairie-chickens quickly declined as agriculture became too intense and cattle grazing reduced grass height over much of their newly acquired range. As prairie-chickens are also landscape species, their current distribution occurs where large tracts of native prairie remain, mostly in central SD (Figure 2). Prairie-chickens are thought to be limited within SD by lack of grassland habitat in the east and grass height in the west.

Although prairie grouse are primarily birds of the open prairies in SD, one exception is the Black Hills National Forest. Sharp-tailed grouse do occur in the Black Hills, primarily within herbaceous openings such as those created by wildfires or timber harvest. The Black Hills were historically less wooded and probably had greater amount of suitable habitat for sharp-tailed grouse.

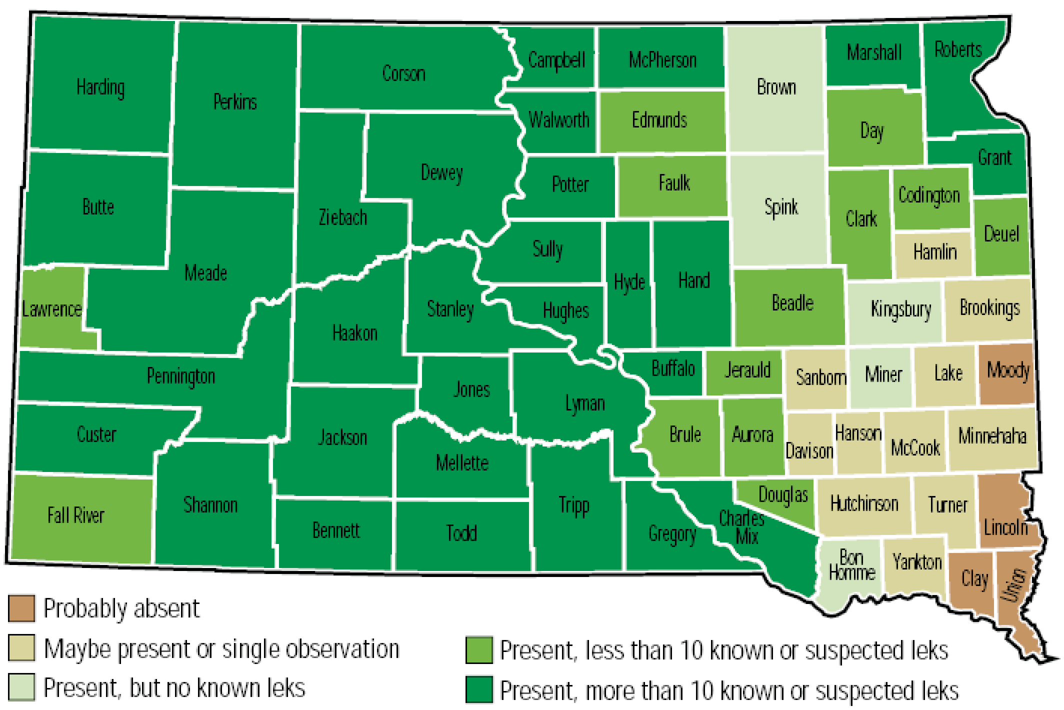

Figure 1. Distribution and general abundance of sharp-tailed grouse in South Dakota (Flake et al. 2010).

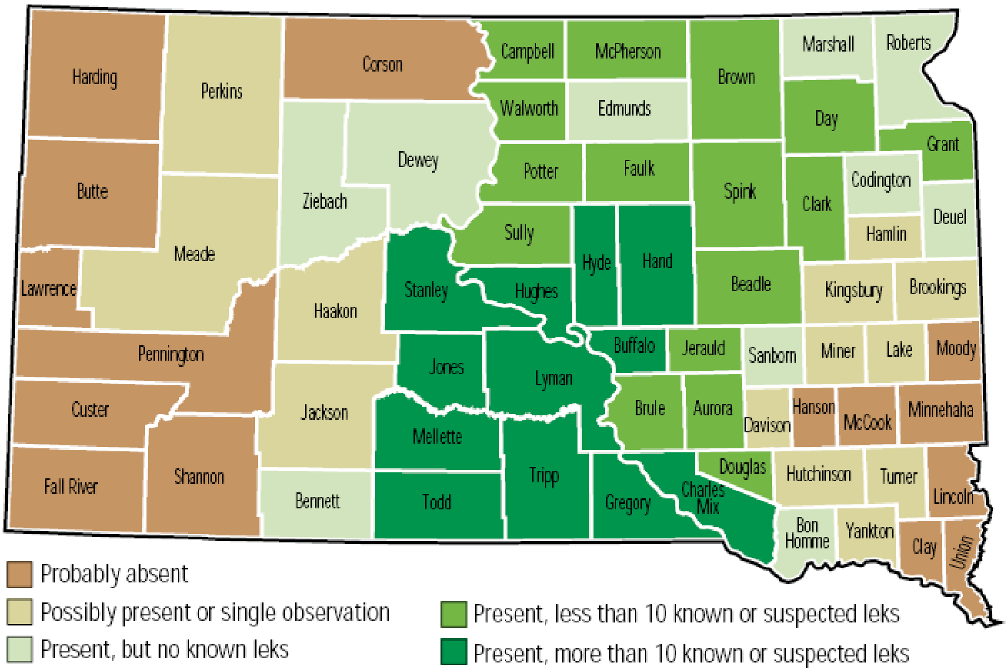

Figure 2. Distribution and general abundance of greater prairie-chickens in South Dakota (Flake et al. 2010).

PRAIRIE GROUSE ECOLOGY

Leks, also known as "dancing grounds" for sharp-tailed grouse and "booming grounds" for prairie-chickens, are located in areas of high breeding potential and typically exist within centers of large tracts of suitable prairie habitat (Merrill et al. 1999, Niemuth 2000, Hanowski et al. 2000). Leks are the focal point for reproductive ecology and behavior in prairie grouse. Prairie grouse leks are typically located on knolls or on a gentle rise, although prairie-chicken leks are sometimes located on flat bottomlands such as a dry wetland. Males gather on leks primarily during spring to defend territories and attract females during the breeding season. While it is not unusual for hens to visit several leks during a single season, males typically attend one lek each year and likely return to the same lek year after year.

In SD, male prairie grouse begin defending territories on leks as early as late February with peak activity coinciding with peak hen attendance in early April. Sharp-tailed grouse display behavior involves rapid foot stomping, rapid tail vibrations (tail rattling), inflation of purple air sacs, and aggressive face-off behavior with other males. Prairie-chickens raise their pinnae and tail feathers while producing loud booming noises by inflating their orange external air sacs. Aggressive behavior between males is common, with some males even leaping several feet in the air during face-offs. The booming noise made by male prairie-chickens can be heard from several miles away during calm conditions.

Lekking activity can start well before daylight and last for several hours. Leks are attended during evening, although duration and display behavior is usually less intense. Male sharp-tailed grouse may also defend territories on leks during fall, although duration and intensity of display behavior is minimal. Lek attendance during fall is thought to be important in recruiting young males that did not establish a territory during the previous spring.

Hen prairie grouse may attend several leks before selecting a male for copulation. After breeding, hen prairie grouse will not visit a lek again unless her nest is destroyed. Most hen prairie grouse will initiate a nest within a few miles of the lek they visited for breeding, although some may nest 10 mi away or farther. Nest initiation typically occurs within several days to a week after copulation.

Mean nest initiation date was April 22 during a 3-year study on the Fort Pierre National Grassland (FPNG) (Norton 2005). First nests of the year are usually located in residual grass or herbaceous vegetation, and sometimes under a small shrub such as western snowberry (*Symphoricarpos occidentalis*), as green up has yet to occur (Eng et al. 1988). First nest clutches typically contain 14 dull brown eggs (Norton 2005). Incubation begins before the last 1–2 eggs are laid and continues for 23 days. Nest success has been found to be higher when residual cover conceals the nest and the landscape consists of primarily intact grasslands (Frederickson 1995, McCarthy et al. 1998, Ryan et al. 1998,). Mammalian predators are the primary cause of nest loss, although nest success of 80% has been documented on the ideal and intact habitat of the FPNG (Norton 2005). Hens may re-nest up to three times if previous nests are destroyed, but clutch size and egg size decreases with subsequent nesting attempts.

Although incubation begins before the last egg is laid, all eggs hatch concurrently after 23 days of incubation. Newly hatched chicks will remain in the nest bowl for about a day before the hen leads the brood to habitats containing plentiful insects, primarily areas with abundant forbs such as non-native sweet clover (*Melilotus spp.)* and other native wildflowers. By 10 days of age, young grouse are capable of short flights and by 8–10 weeks they resemble adults in size. Chick survival was found to be about 36% during a 3-year study on the FPNG (Norton 2005). Young-of-the-year grouse will remain in loose family groups well into the fall. Only female prairie grouse provide parental care for nests and young.

During spring and summer, adult prairie grouse spend a majority of their time in grasslands including grass and alfalfa hay fields. Their diet consists of plant material such as seeds, berries, and buds but can also include insects. During fall, prairie grouse form flocks which may contain both species and remain together through winter. Prairie grouse also utilize waste grain from agricultural fields, mostly during fall and winter. Waste grains from agricultural crops are used by sharp-tailed grouse, but are not necessary for winter survival; however, waste grains likely contribute to prairie-chicken survival and persistence in some landscapes. In SD, prairie-chickens likely rely on waste grains during winter and remain within 1–2 mi of this food source during the entire winter. The interaction between agriculture and prairie-chicken distribution and abundance is described in detail in the historical information section.

Prairie grouse are well-adapted to survive severe winter weather in open grassland habitat. During winter, prairie grouse use woody cover for shelter or simply roost in the snow. This unique behavior of snow roosting protects prairie grouse from harsh winds and blowing snow in open habitats. Sharp-tailed grouse will occasionally roost in trees during winter. As winter transitions to spring, large flocks of prairie grouse disperse across the landscape in preparation for the breeding season.

SURVEYS AND MONITORING

Traditional Lek Surveys

The most widely used method to survey prairie grouse throughout their range is the spring lek survey. Male attendance on leks is relatively stable throughout the breeding season while female attendance is highly variable and exhibits distinct peaks. In SD, observers search established survey areas which are approximately 40 mi^2 for prairie grouse leks and count all males attending each lek. The number of males/mi^2 is tracked from year to year and is considered an index to the spring population. Currently, 10 traditional surveys (Figure 3) are conducted annually throughout the state. These surveys have been conducted since the 1940s, although consistent protocol and routes were not established until the early 1950s. From that time forward, direct comparisons can be made (Figure 4).

Occupancy Modeling

Data collection began in 2014 to develop a spatially explicit habitat-based occupancy model. Results of the model will be used to develop an expected distribution map for prairie grouse which could be used to focus conservation efforts and prioritize certain geographic areas. The model will be developed by determining presence or absence of prairie grouse leks on 1 mi^2 sample units across the state. Samples were spatially balanced across the state and occurred along a gradient of landscape-level grassland availability. Each 1 mi^2 area is searched 2–3 times per year and the final presence/absence data set will be used in conjunction with landscape level covariates to develop an occupancy model. A total of 423 sections were searched from 2014–2016 field seasons. Results from this modeling effort could also be used to develop an improved monitoring framework. A final report for data collected from 2014–2016 is expected in 2018.

Age Ratio Surveys

Wings from hunter harvested prairie grouse are also collected during the first two weeks of the season at wing collection boxes located west of the Missouri River. (http://www.gfp.sd.gov/hunting/small-game/prairie-grouse-wing-boxes.aspx). Hunters are encouraged to place one wing from each harvested grouse in 1 of 18 collection boxes. Each wing is identified to species (sharp-tailed grouse or greater prairie-chicken) and aged (adult or hatch year) to determine species harvest distribution and age ratios. The ratio of hatch year to adult grouse can be used to gauge production during that specific year (Figure 5). Biologists use these data to relate grouse production to weather variables to predict grouse production in future years.

Figure 3. Prairie grouse traditional lek survey areas.

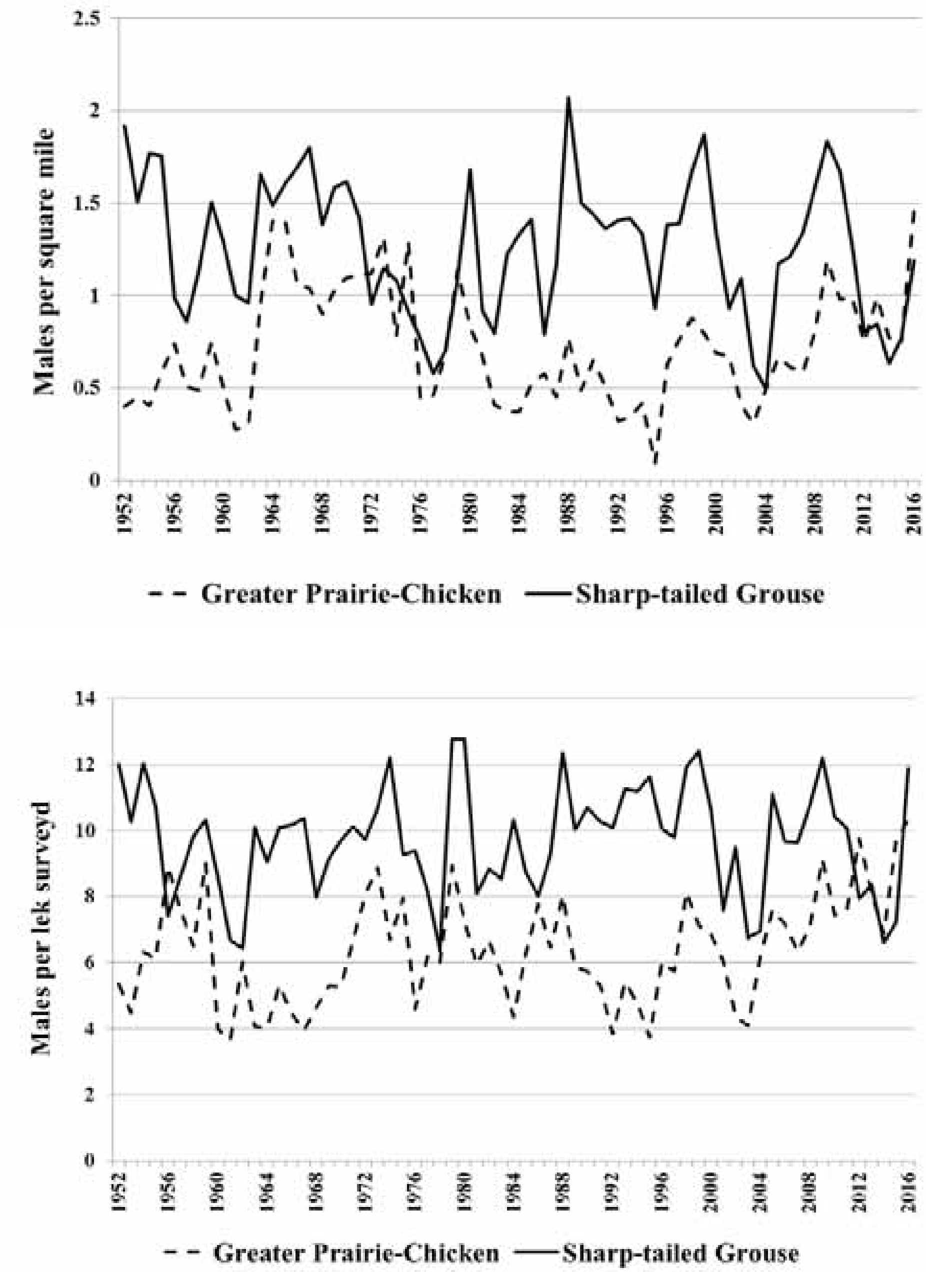

Figure 4. Results of prairie grouse traditional lek surveys 1952–2016.

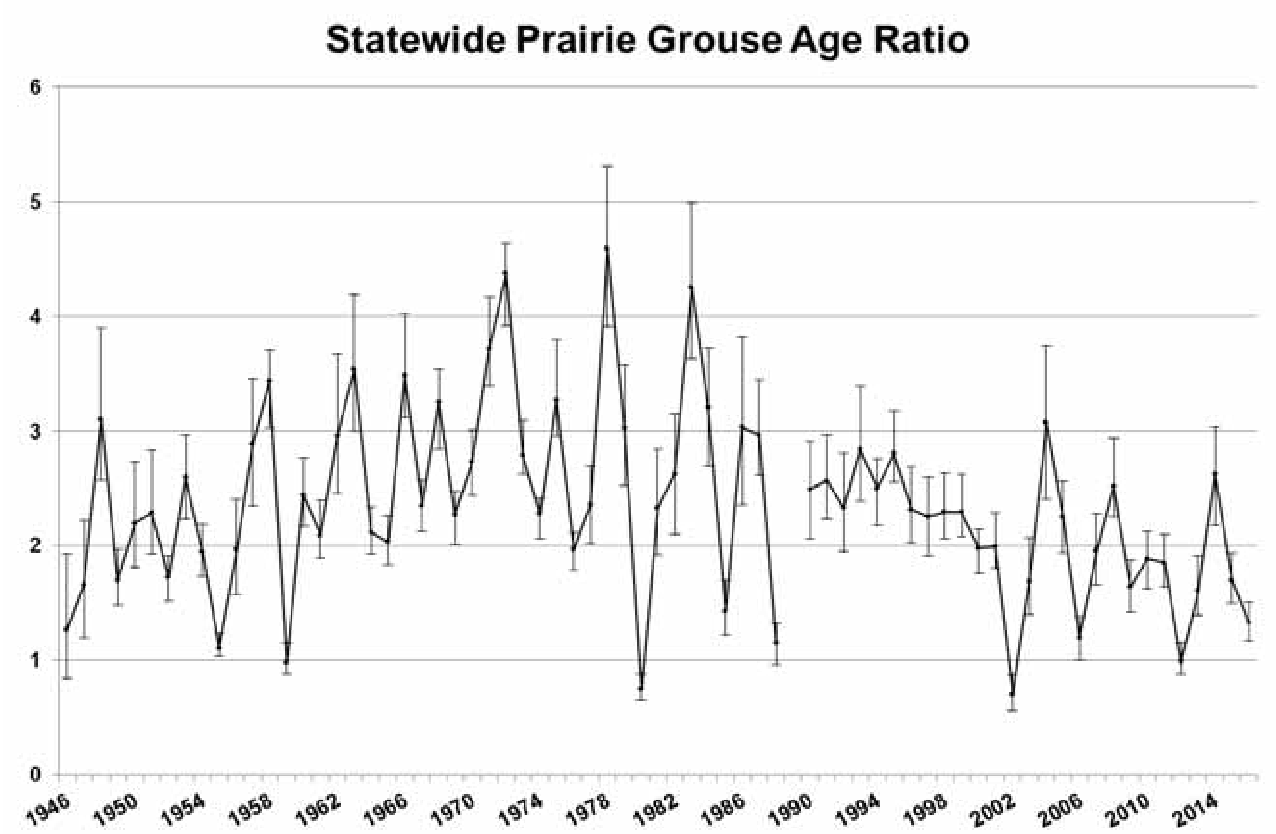

Figure 5. Statewide prairie grouse age ratio (± 95% confidence interval) from fall hunter-harvested sharp-tailed grouse and greater prairie-chickens 1946–2016.

PRAIRIE GROUSE RESEARCH

Rice and Carter (1982) investigated the relationship between grassland management practices and their subsequent influence on prairie grouse populations on the FPNG from 1974–1978. Specifically, they evaluated grazing regimes and resulting residual grass available to nesting grouse. Comparisons were made among rest-rotation, deferred-rotation, winter pasture, bull pasture, and wildlife areas. Prairie grouse production was compared among systems and related to available grass cover. Rest-rotation systems included a series of pastures in which one pasture was rested for an entire year. The pasture grazed last was the rested the following year. The deferred-rotation systems consisted of a series of pastures, which were all rotationally grazed once during the growing season. The wildlife area was not grazed during the study. Bull pastures were stocked at very low density. The winter pasture was not grazed during the growing season.

The rest-rotation ungrazed pastures, winter pastures, and bull pastures yielded the most nests-broods/acre and also possessed the highest amount of residual cover for nesting. Even when grazed rest-rotation pastures were included in analyses, rest-rotation pastures had more nest-broods/acre than deferred rotation pastures. The wildlife area study plots had among the highest amounts of residual grass, but much of the grass was produced on lowland sites which prairie grouse avoided for nesting.

The key finding of this study was that grazing systems which produced at least 900 lbs/acre of forage provided adequate residual cover for prairie grouse nesting and brood rearing. The authors recommended rest-rotation and winter grazing systems be used on the FPNG as a way to boost local prairie grouse populations.

Fredrickson (1995) evaluated the success of a prairie-chicken reintroduction effort during 1985–1989. Prairie-chickens were captured on the FPNG and Lower Brule Indian Reservation and released in south-central McPherson County during 1986–1988. Birds were fitted with radio collars and tracked to determine survival, home range, and habitat use. The reintroduction effort was deemed unsuccessful as no prairie-chickens were observed in the release area for 5 years (1989–1993) following the last year of releases. Cause for the lack of success in the release area was attributed to habitat deficiencies, particularly during winter. Most of the released prairie-chickens traveled up to 20 mi during winter to find adequate croplands for winter food that were adjacent to high quality grassland for roosting. Within the release area, adequate grass cover was lacking near available crop fields. Most of the migrating prairie-chickens were killed by predators before they could return to the release area after each winter.

Norton (2005) estimated prairie-chicken and sharp-tailed grouse brood habitat use, nest success, and hen and brood survival on the FPNG during 2003–2005. Overall combined nest success was approximately 75%, which is one of the highest estimates ever recorded. Breeding season hen survival was approximately 82% during the three-year study. Brood survival was also an astonishing 85% and chick survival was estimated at 36%. Prairie grouse broods avoided the use of smooth brome and selected for forb cover such as sweet clover. This study demonstrated how prairie grouse can exhibit very high reproductive potential in landscapes dominated by well managed grasslands.

Kirschenmann (2008) studied the spatial ecology and harvest of prairie grouse on the FPNG during 2003–2005. Mean home range size for hens with broods was 184 ha for sharp-tailed grouse and 174 ha for prairie-chickens. Mean distance from lek of capture to nest sites was 1.98 km for prairie-chickens and 2.03 km for sharp-tailed grouse. Hens of both species selected pastures that were not grazed the previous year. Only 17 of 209 (8.1%) marked adult prairie grouse were reported as harvested by hunters during the 3-year study. Dog training had minimal impacts on prairie grouse behavior. Flushing distance was similar between areas open and closed to dog training. Results of this study indicate repeated flushes from dog training did not cause prairie grouse to exhibit more "wild" behavior during the hunting season.

Runia (2009) investigated how large-scale land use affects the distribution and abundance of prairie grouse in northeastern SD with an emphasis on the influence of CRP. Land use surrounding prairie grouse leks was compared to land use surrounding non-lek locations at several spatial scales. Landscapes surrounding prairie grouse leks contained higher proportions of pasture and CRP at several spatial scales. Spatially explicit habitat suitability models also were developed in a geographic information system to predict which landscapes are most likely to support prairie grouse leks. Strongest models occurred at the 1 mile scale which is similar to other similar studies (Merrill et al. 1999, Niemuth 2000). A similar study documented landscape level habitat characteristics associated with prairie-chicken leks on the extreme eastern fringe of their range (Orth 2012). Orth (2012) documented the need for a higher proportion of grassland on the landscape needed for lek locations, as well as, the avoidance of trees and wetlands within ½ mile of the lek location.

A recently completed research project collected base line data on a pre-construction wind energy site in central SD (Runia and Solem 2015). A control site (wind energy development not anticipated) with similar landscape characteristics was used as a comparison. Annual survival was 44% and nest success was 31%. Survival and nest success were similar between sharp-tailed grouse and prairie-chickens. Prairie grouse hens selected for nest sites within grassland dominated landscapes and avoided trees when considering only macro-scale habitat variables. This study demonstrated that prairie-chickens and sharp-tailed grouse select for and are most successful in tracts of unfragmented grasslands for reproduction. The study will be repeated if wind energy development occurs.

From 2009–2015, Geaumont and Graham (2015) studied the relationship between grassland habitat attributes and sharp-tailed grouse reproductive success on the Grand River National Grassland. Similar to past studies, they found sharp-tailed grouse selected for and were more successful using areas with taller grass for nesting and brood-rearing. Estimated overall nesting success with average habitat covariate values was 52%. Brood survival to 60 days was 55% based on average habitat covariate values. Maximum grass height was 8.2 inches for nest sites and 7.3 inches at random locations. For broods less than 14 days old, maximum grass height was 8.6 inches and 8.2 inches at random locations. For broods older than 14 days old, maximum grass height was 10.0 inches and 8.9 inches at random locations.

HUNTING SEASON STRUCTURE AND AUTHORITY

Hunting is currently authorized from the third Saturday of September through the first Sunday in January (Administrative Rule 41:06:09:01) with a combined daily bag of three prairie grouse (Administrative Rule 41:06:09:03). The season and bag limit is set by the SDGFP commission on a 3-year cycle with the next two cycles occurring in 2017 and 2020.

The current hunting season structure has very little impact on the long-term population. Hunting mortality is thought to be mostly compensatory because prairie grouse are short-lived, have high reproductive potential, and are subject to a relatively low harvest rate. Only 2 out of 195 marked female prairie grouse were harvested by hunters during a 3-year study in Hyde and Hand counties (unpublished data from Runia and Solem 2015). Only 17 out of 209 marked adult prairie grouse were harvested during a 3-year study on the FPNG (Kirschenmann 2008). Hunter harvest would have very little, if any, impact on the population at these observed harvest rates (Powell et al. 2011). Prairie grouse have a large distribution in SD and local populations likely respond to environmental and local habitat conditions.

Prairie grouse hunting is most popular during the first few weeks of the season based on license sales and field staff observation. During the first few weeks of the season, prairie grouse are loosely scattered across the landscape in small coveys and family groups which is favorable for hunting. As the season progresses, flock sizes increase and hunting success generally declines sharply. Prairie grouse hunting pressure declines after the first few weeks in response to lower success and as hunters shift effort to other upland game such as pheasants. Some broods may not be fully grown if the season started earlier in the season, and a later start date could sacrifice some of the most productive days of the season. An earlier start date could also make it more difficult to differentiate between prairie grouse and young pheasants. The current bag limit is thought to be socially and biologically acceptable. For these reasons, the SDGFP does not foresee any major recommended changes to the current hunting season structure. The SDGFP will continue to monitor the population, examine hunting statistics, and review public and SDGFP staff input when developing hunting season recommendations.

HUNTER & HARVEST TRENDS

Prairie grouse hunters and harvest have been estimated annually by analyzing response from hunter survey cards since 1945. Hunter and harvest numbers have been steadily declining since 1975 (Figure 6). In 2016, an estimated 7,879 resident and 5,386 non-resident prairie grouse hunters harvested approximately 56,888 prairie grouse. Although harvest is a summation of both species of prairie grouse, prior to 2006, 60% of the bag was thought to be sharp-tailed grouse. Much of the prairie grouse harvest occurs in the central and western portion of the state (Figure 7). In 2006, hunters were asked specifically how many of each species of prairie grouse they harvested. Results from this survey revealed the 2006 harvest was approximately 76% sharp-tailed grouse, 20% prairie-chickens, and 4% unknown.

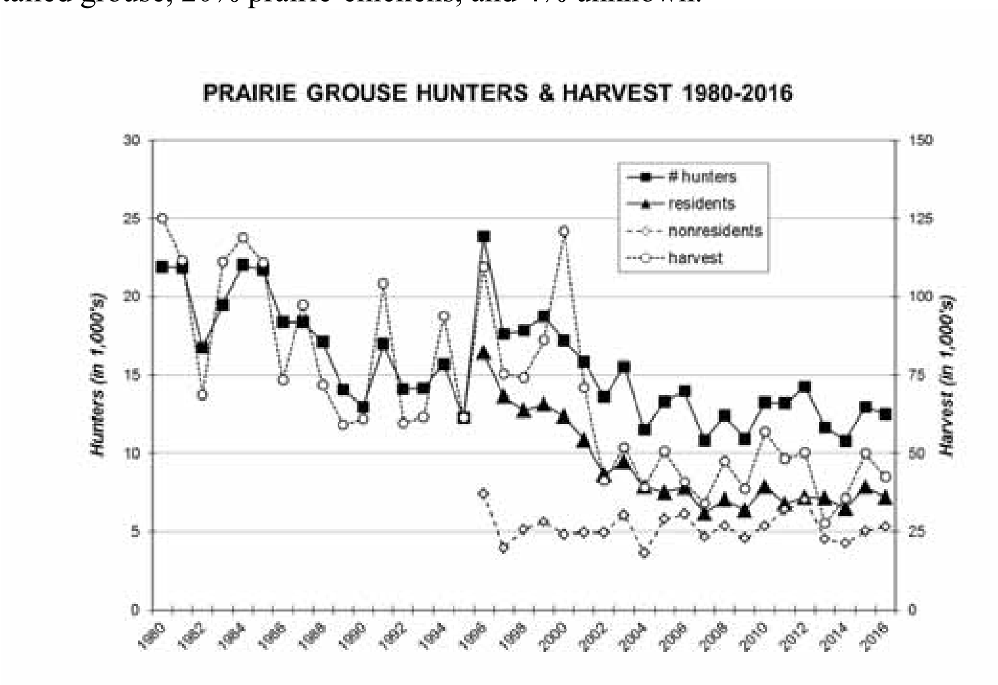

Figure 6. Prairie grouse hunters and harvest, 1980–2016.

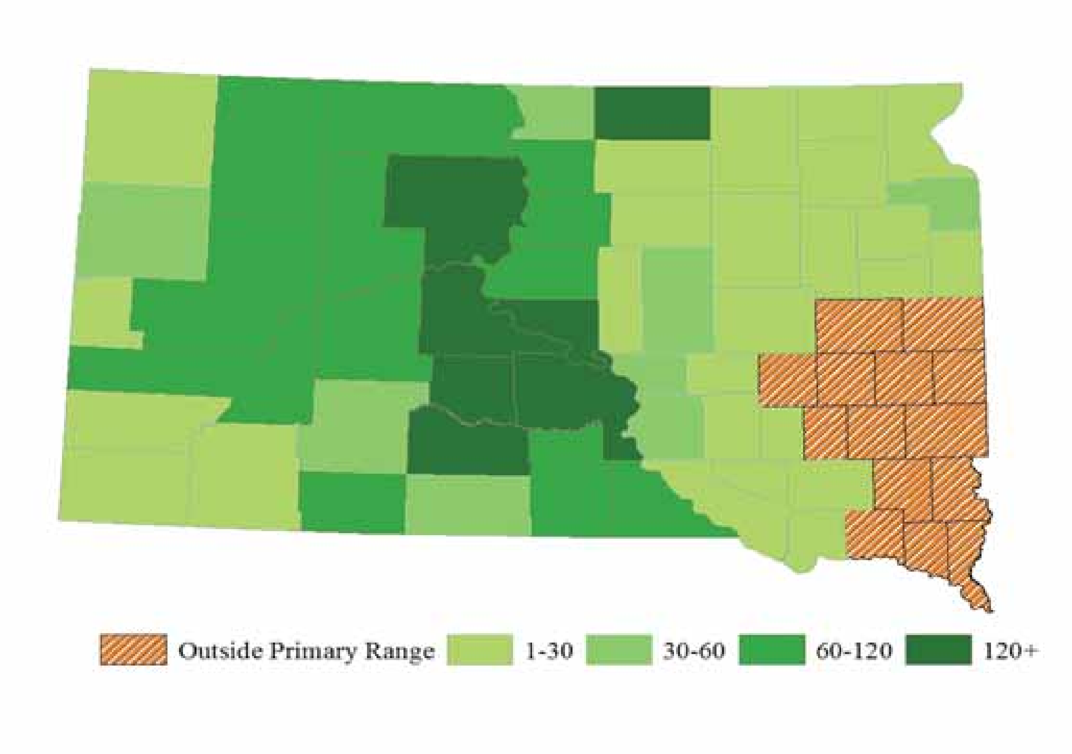

Figure 7. Average prairie grouse harvest/100 mi^2, 2006–2015.

HABITAT TRENDS

Prairie grouse require landscapes that contain a high percentage of grassland to persist (Merrill et al. 1999, Hanowski et al. 2000, Niemuth 2000). Since European settlement, grasslands have become one of the most imperiled ecosystems in the Great Plains primarily due to conversion to cropland (summarized in Samson et al. 2004). Range wide, severe loss of native grasslands has resulted in a decrease in abundance and distribution of prairie grouse (Johnsgard and Wood 1968) and these declines continue (Silvy and Hagen 2004). Sharp-tailed grouse were once found in 21 states, but habitat loss has reduced their range to portions of 11 states. Prairie grouse are prime examples of how large-scale land use changes can influence the distribution and abundance of landscape prairie obligates. Further conversion of grassland to cropland has been identified as a primary threat to prairie grouse throughout the northern Great Plains (Vodehnal and Haufler 2008).

South Dakota's landscape has changed substantially since European settlement in the late 1800s. Early settlers found the rich soils of eastern SD to be very productive for agricultural crops and quickly converted much of the grassland landscape to cropland. Conversion of grassland to cropland was more intense in the far eastern portion of the state because of higher annual precipitation. More recently, high commodity prices fueled by the ethanol industry and improvements in agricultural technology (e.g. improved crop genetics) have resulted in mass conversion of grassland to cropland in SD (U.S. GAO 2007). Total cropland in SD increased by nearly 2.8 million acres in the last 40 years (USDA NASS 2017, Figure 8) as more land, primarily grasslands, have been converted to cropland.

During the 15-year period of 1982–1997, 1.82 million acres of grassland were converted to cropland (U.S. GAO 2007). A more recent study found 1.84 million acres of grassland were lost, primarily to conversion to cropland, from 2006–2012 (Reitsma et al 2014). Wright and Wimberly (2013) estimated 450,000 acres of grassland were converted to corn or soybeans between 2006 and 2011. Grassland to cropland conversion continues at a rate of approximately 50,000 acres per year (Stubbs 2007) and the rate of conversion appears to be accelerating (Rashford et al. 2011). Using these statistics, it is reasonable to say that SD has lost an estimated 4.5 million acres of grassland to cropland conversion since the early 1980s. Much of the recent conversions are occurring within the Missouri Coteau (Stubbs 2007, Stephens et al. 2008) which also represents the eastern fringe of the prairie grouse range in SD. This region contains vast grasslands that are vulnerable to future conversion (Stephens et al. 2008, Rashford et al. 2011).

Bauman et al. (2016) recently completed a fine-scale inventory of all undisturbed grasslands in eastern South Dakota delineating remaining tracts of native sod grasslands, which are potentially important prairie grouse habitat on the fringe of their range. Overall, 5,488,025 acres (24.2%) of the approximately 22.6 million acres in eastern SD were designated as potentially undisturbed. Nearly 1 million acres of the approximately 5.5 million acres of undisturbed land (17.5%) had some level of permanent conservation protection status. In total, they identified 962,734 acres of undisturbed habitat that is protected from future conversion, representing only 4.3% of eastern SD's total land base. While all grassland represent prairie grouse habitat, undisturbed grasslands are particularly important, especially when the diverse native plant community still persists.

While grasslands are being converted to cropland at alarming rates, there is interest by landowners to keep land in grassland in perpetuity. In fact, as of October 2015, 650 landowners representing 203,000 acres were on the waiting list to enroll their land in a perpetual grassland easement through the U.S. Fish and Wildlife Service (USFWS; Bill Mulvaney, personal communication). Recent funding allows for approximately 21,813 acres of enrollment annually and 903,589 acres are currently protected by grassland easements in SD.

Conversion of grassland to cropland has been substantial, but the Conservation Reserve Program (CRP) authorized under the 1985 Farm Bill has returned some cropland to grassland (Figure 9). Through this program, landowners receive an annual rental payment to convert eligible cropland to perennial cover (mostly grass) for 10–15 year contracts. As of October 1, 2016, SD had 972,000 acres of CRP. As much as 1.77 million acres of CRP has been enrolled at one time in SD which occurred in 1995. Although CRP can benefit prairie grouse (Rodgers and Hoffman 2005, Nielson et al. 2006, Runia 2009), it represents a short-term solution to a long term habitat loss problem.

In addition to declines in grassland habitat quantity, invasive plant species have also reduced grassland habitat quality across SD. Non-native grasses such smooth brome (*Bromus inermis*), Kentucky bluegrass (*Poa pratensis*), and crested wheatgrass (*Agropyron cristatum)* compete with native grasses and provide lower quality habitat than native plant communities. Moreover, invasive weeds such as Canada thistle (*Cirsium arvense*) and leafy spurge (*Euphorbia esula*) are difficult to control and can become dominant if not managed. Fire suppression also has allowed encroachment of woody species such as eastern red cedar (*Juniperus virginiana*) into otherwise open grasslands, thereby reducing or even eliminating prairie grouse habitat. Loss of grasslands to invasive eastern red cedar along the Missouri River breaks and in similar landscapes along its larger western tributary rivers (e.g. White River and Cheyenne River) has gotten the attention of both the ranching community and wildlife managers.

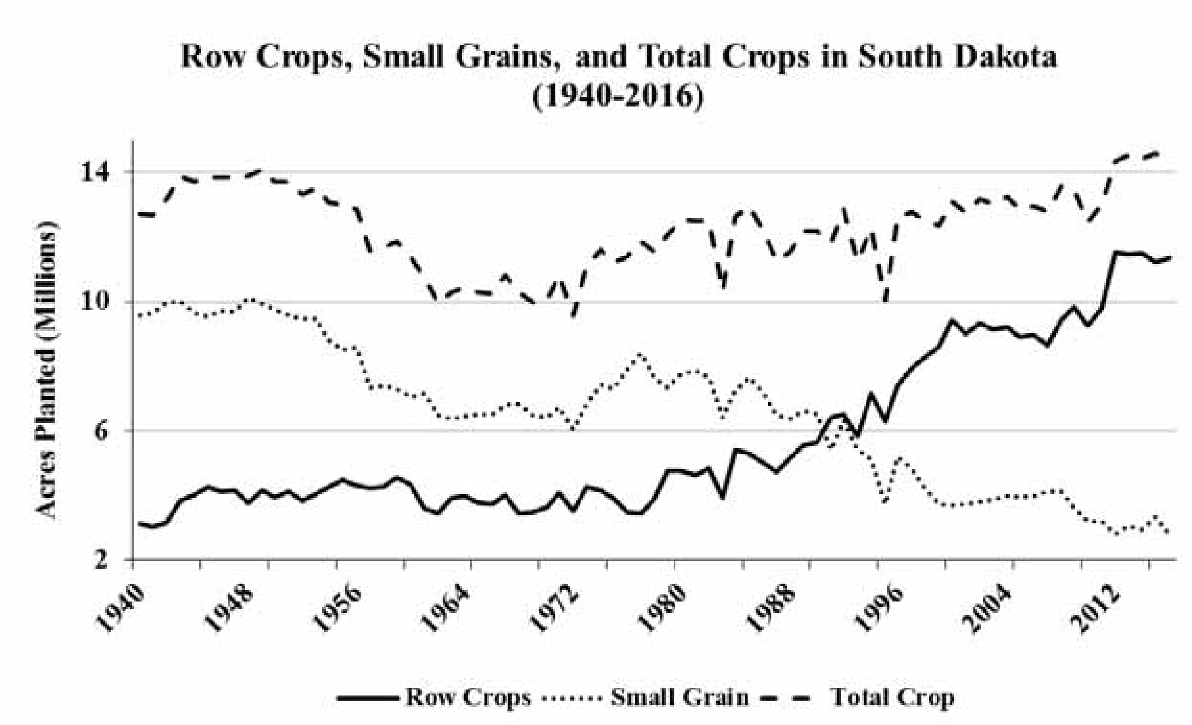

Figure 8. Total cropland in South Dakota 1940–2016 (USDA NASS 2017).

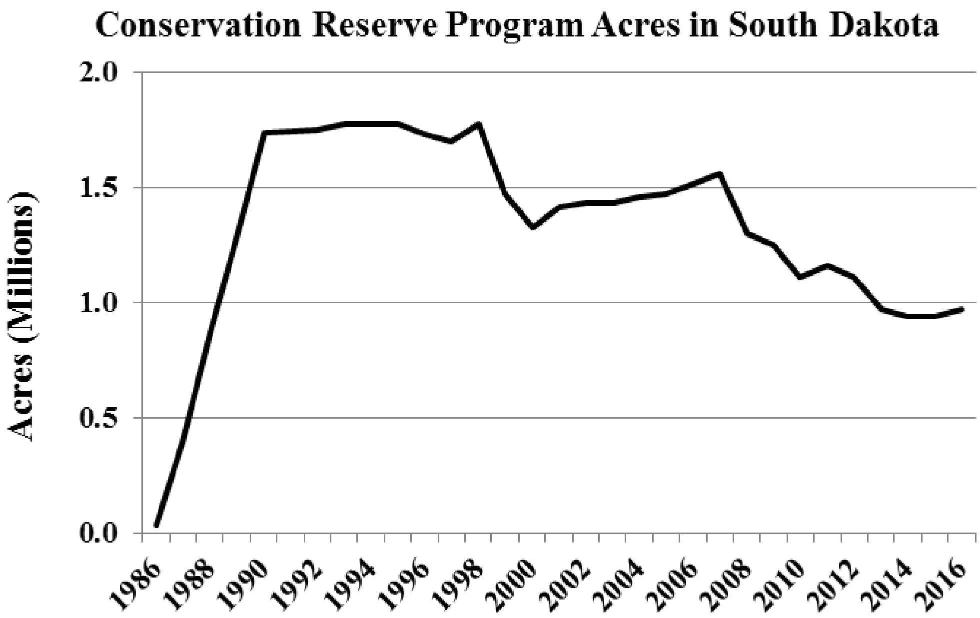

Figure 9. Total Conservation Reserve Program acres in South Dakota 1985–2016.

HABITAT BEST MANAGEMENT PRACTICES

Prairie grouse require large blocks of unfragmented grassland to persist. Prairie grouse use grasslands during all seasons, but they are particularly critical during the breeding, nesting, and brood-rearing season. The following Best Management Practices apply primarily to occupied prairie grouse habitat, but some could also be applied to areas where there is a desire to restore suitable habitat in currently unoccupied areas. Occupied habitat can be difficult to define, but areas within 5 mi of active leks, especially grasslands, could generally be expected to be occupied by prairie grouse. Best Management Practices for prairie grouse habitat may not be Best Management Practices for all wildlife species. The following list was developed using best available science and expert opinion.

- Maintain existing grasslands as grasslands (e.g., do not convert to cropland), especially unfragmented tracts within occupied prairie grouse range.

- Restore grasslands within occupied range and in areas where current grassland availability does not support prairie grouse.

- Use high diversity mixes of native grasses, forbs and shrubs for restorations and establishments. Some introduced forbs may be appropriate for some ecological sites but should be selected judiciously.

- Manage existing grasslands with disturbance regimes (grazing, fire) that encourage growth of diverse communities of native grasses, forbs and shrubs. Livestock grazing, particularly when part of a well-designed rotation or system that results in multiple levels of vegetation height and structure, is compatible with prairie grouse habitat needs. Management regimes that result in 8–12 inches of maximum residual grass height during normal conditions are adequate for providing concealment for nesting and slightly taller growing vegetation for brood rearing. Rotational grazing could be designed to provide adequate residual cover on at least some pastures or paddocks within a larger operation. Local climate, weather, and ecological conditions may limit site-specific forage production, which could make residual cover goals less practical or even unattainable during some years or in some locations.

- Use spot spraying herbicide application in lieu of field-level herbicide applications to control noxious weeds.

- Delay grassland haying until after the primary nesting season (after July 30). Haying is generally less effective at maintaining plant diversity and desirable nesting and brood rearing habitat structure than managed grazing or prescribed fire.

- Cropland retirement programs such as CRP are beneficial to prairie grouse. Short-term cropland retirement programs such as CRP should be prioritized to the current breeding range, or areas where the addition of grassland is expected to expand the range. Periodic management such as prescribed fire once every 3 years and/or grazing once every other year should occur to maintain plant diversity and desirable nesting and brood rearing habitat structure.

- Avoid establishing trees within large blocks of existing grasslands, especially native prairie within the occupied range. Remove encroaching trees from grasslands, especially ecological sites within native prairie where trees did not historically occur.

- Remove abandoned buildings which could harbor mammalian nest predators.

- Avoid activities near (~ 2 mi) lek sites that could interrupt lekking and nesting activity from March 1–July 30. If disruptive activities cannot be avoided, limit disruptive activities to three hours after sunrise to one hour before sunset. Disruptive activities could include but are not limited to well drilling and operation (water or energy development), burying pipeline or other utilities, building roads, vehicle traffic, direct disruption by human presence, wind tower construction and operation, or low flights by air craft or drones.

- Avoid development (e.g., roads, power lines, structures, energy development) in grasslands within occupied range, especially within 1 mi of lek sites. Where development occurs within occupied range, leks within 5 mi of development should be monitored indefinitely.

ISSUES, CHALLENGES, AND OPPORTUNITIES

Loss of grassland habitat, primarily through conversion to cropland, is currently and will be the primary threat to prairie grouse in SD. History has demonstrated how prairie grouse population declines are linked to landscape level land use changes. Because SD's landscape changes are driven by many factors, it will be challenging to slow these habitat trends. With challenges also come opportunities, and many opportunities do exist to maintain, manage, and restore prairie grouse habitat on private and public land in SD.

Partnership-based programs and initiatives which promote sound stewardship of grasslands on private lands are essential to management of prairie grouse habitat. The partnerships among SDGFP, USFWS, Ducks Unlimited, Pheasants Forever, Bird Conservatory of the Rockies, and the Natural Resources Conservation Service (NRCS) to station biologists in NRCS and USFWS service centers has been a successful way to expedite delivery of grassland conservation programs. It will be imperative to continue to support the efforts of the SD Grassland Coalition in their mission to improve stewardship of grasslands through sustainable and profitable management. It is important for the SDGFP to continue to promote grazing stewardship practices through cost-share for department programs. For further information about SDGFP programs and other habitat resources, visit the Habitat Pays web site (http://habitat.sd.gov/).

There are opportunities to promote and advocate for local, state, and national policies which would be favorable to prairie grouse habitat. Federal policies, particularly Farm Bill provisions, can have huge influences on landuse decisions. Participation in a variety of technical committees, working groups, joint ventures, advisory boards, and associations will assure prairie grouse habitat needs are included in decision making processes. It is critical to sustain working relationships with other public land management agencies, such as U.S. Department of Agriculture Forest Service, US Bureau of Land Management and SD School and Public Lands, to foster similar land use goals which benefit prairie grouse and other prairie obligate species.

South Dakota has been identified as one of the top geographic locations for wind energy development within the United States. According to the U.S. Department of Energy, SD's resource potential for wind energy includes vast areas with wind power classifications of good to superb (Figure 10). As of February 21, 2017, SD had 13 operational wind energy projects capable of generating 884 MW of power (SD PUC 2017). Many of SD's large intact grasslands occur in areas of high wind potential such as the Missouri Coteau and vast areas of western SD. Wind energy development has occurred in occupied prairie grouse habitat and future development is likely. It will be imperative to work with wind energy developers to minimize potential impacts on prairie grouse habitat from wind energy development.

The impacts of wind energy on greater prairie-chickens are generally equivocal and the impacts on sharp-tailed grouse have not been studied. Greater prairie-chicken lek persistence was ~0.5 for leks <0.62 mi from a turbine, ~0.9 for leks 1.86 mi from a turbine, and >0.95 for leks ≥3.73 mi from a turbine during the 3-year post-construction period for a study in Kansas (Winder et al. 2015a). The rate of lek abandonment was 3× higher for leks <4.97 mi from a turbine compared to leks ≥4.97 mi from a turbine (22% vs 8%) supporting the USFWS's 4.97-mi buffer zone for wind energy development (Manville 2004). The increased rate of lek abandonment within 4.97

mi of wind turbines is concerning because female prairie-chicken activity centers are nearly always centered within 3.1 mi of active leks (Winder et al. 2015b). Although previous research found female greater prairie-chickens avoid turbines in their space use and movements, turbines did not negatively affect nest-site selection, nest survival, or adult survival (McNew et al. 2014, Winder et al. 2014a, Winder et al. 2014b). An unpublished study from a 36 turbine wind farm in an unfragmented Nebraska landscape found no influence of wind energy development on nesting, brood-rearing, or special ecology of greater prairie-chickens (Harrison 2015).

There is also evidence that other forms of development within occupied habitat could have a negative impact on prairie grouse. Greater prairie-chickens were found to avoid power lines by 330 ft in Oklahoma (Pruett et al. 2009). A habitat-based greater prairie-chicken lek site model revealed a weak avoidance effect of roads at a 3.1-mi scale in Kansas (Gregory et al. 2011). A similar modeling effort in Minnesota suggests road density at a 2-mile scale was a negative predictor of lek presence (USFWS HAPET 2010). Significantly more roads occurred within 1,640 and 3,280 ft of inactive sharp-tailed grouse leks when compared to active leks in Minnesota (Hanowski et al. 2000).

The SDGFP occasionally receives comments of concern about the effect of dog training on prairie grouse hunting opportunity. Dog training on wild game birds is allowed from August 1 through the Friday preceding the third Saturday in September. See the SDGFP Hunting Handbook for all restrictions. Research has shown dog training has very little influence on prairie grouse behavior and is not expected to detrimentally impact hunting opportunity. The SDGFP will continue to consider public comments, staff input and emerging research when considering changes to dog training rules.

There are also opportunities to further inform the public about prairie grouse behavior, habitat needs and trends, and hunting/viewing opportunities. The SDGFP has many media available to further inform the public about prairie grouse and encourage them to participate in hunting or viewing opportunities. The SDGFP's recently published "Grouse of Plains and Mountains" book is an excellent resource for information related to all grouse species in SD and is available at https://gfp.sd.gov/shopping/Catalog.aspx?cat=6 . With increased public awareness of the challenges facing prairie grouse, more interest in the preservation of these great birds and their habitats may occur.

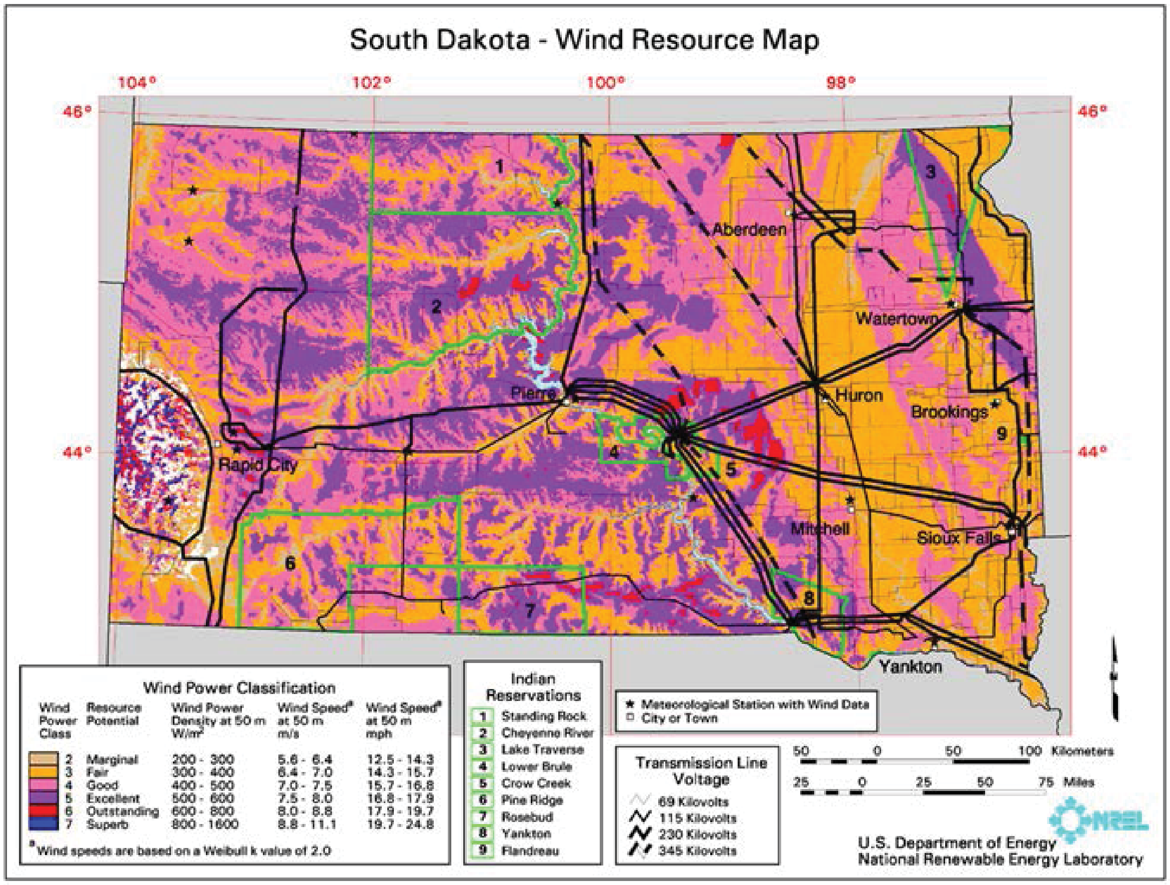

Figure 10. Wind energy classification classes for South Dakota (U.S. Department of Energy 2010).

GUIDING PHILOSOPHY

Vision – Who Do We Strive To Be?

The South Dakota Game, Fish and Parks will conserve our state's outdoor heritage to enhance the quality of life for current and future generations.

Mission – What Do We Do?

The South Dakota Game, Fish and Parks provides sustainable outdoor recreational opportunities through responsible management of our state's parks, fisheries and wildlife by fostering partnerships, cultivating stewardship and safely connecting people with the outdoors.

GOALS

Provide outdoor recreational opportunities – Optimize the quantity and quality of sustainable hunting, fishing, camping, trapping and other outdoor recreational opportunities.

Serve as stewards of our state's outdoor resources – Maintain and improve our outdoor resources to ensure sustainability.

Inspire confidence – Instill trust from the people we serve through transparency and accountability.

Foster professional excellence – Develop and empower highly engaged and well-trained staff.

VALUES

Excellence – We believe in a culture of professionalism and accountability to meet the expectations of our customers and empower staff to succeed.

Stewardship – We believe in applying biological and social sciences to conserve and respectfully manage our state's outdoor resources for current and future generations.

Integrity – We believe in being transparent and honest by promoting high ethical standards.

Compassion – We believe in the dignity of each person and genuinely care for the people we serve.

PRAIRIE GROUSE MANAGEMENT GOAL

Maintain or expand sustainable prairie grouse populations by fostering partnerships, promoting grassland habitat stewardship, and applying biological and social sciences.

OBJECTIVE 1: Promote and implement responsible stewardship of prairie grouse habitat on public and private lands.

STRATEGIES

1.1 Advocate for current and future United States Department of Agriculture (USDA) Farm Bill programs and policies in the Commodities, Conservation, Energy, and Crop Insurance titles that incentivize native grassland preservation, protection, and enhancement.

1.2 Maintain support for Conservation Reserve Program (CRP) in federal farm legislation through continued cooperation with the Governor's Office, USDA, other state and federal agencies, non-governmental conservation organizations, coalition groups (e.g. Northern Great Plains Working Group, Association of Fish & Wildlife Agencies), landowners and agricultural groups.

1.3 Advocate for land use policies and procedures, including local zoning and property tax assessment which preserve and protect native grassland functions and values in a fair and equitable manner. Note: the South Dakota legislature created the Agricultural Land Assessment Implementation and Oversight Advisory Task Force to provide guidance to the Department of Revenue on the implementation of the productivity system of assessing agricultural land. The Task Force holds meetings during the legislature's interim calendar to review assessment information and make recommendations to the legislature for potential revisions to the productivity system.

1.4 Continue to advocate for strategic use of existing and new continuous CRP practices that provide quality prairie grouse habitat (West River SAFE, Grasslands CRP). Use designated prairie grouse priority areas (Vodehnal and Haufler 2008) and results of the occupancy modeling project to guide specific CRP advocacy.

1.5 Annually seek and provide assistance to landowners with expiring CRP contracts, by providing re-enrollment options into general and continuous CRP, or other programs that are available for maintaining all or a portion of this grassland habitat. At the appropriate times, use direct mailings to producers with expiring CRP contracts.

1.6 Maintain existing partnerships with Pheasants Forever, Natural Resources Conservation Service, Bird Conservatory of the Rockies, and Ducks Unlimited to fund partnership biologists to assist private landowners with technical assistance and the promotion of grassland-related conservation programs. Continually assess the need for technical services provided by partnership biologists and staff the appropriate positions as budgets allow.

1.7 Continue to provide financial commitment to the 81,000 acres enrolled in the Conservation Reserve Enhancement Program (CREP) and utilize funding sources as they become available to enroll the project goal of 100,000 acres in the CREP.

1.8 Continue to support perpetual conservation easements and fee title acquisitions of grassland habitat by other public and private entities.

1.9 Remain engaged with the Governor's Habitat Conservation Initiative and the Habitat Conservation Board.

1.10 Continue to promote grassland habitat stewardship and sustainability through the Habitat Pays initiative, and through support of landowner-based conservation stewardship interests such as the South Dakota Grassland Coalition and South Dakota Soil Health Coalition. (http://habitat.sd.gov/workshops/default.aspx).

1.11 Continue to be involved in providing technical assistance for and participation in state-level policy making processes related to Farm Bill delivery through the State Technical Committee, Sub-Committees, and Working Groups.

1.12 Maintain support for the vision and mission of the Prairie Pothole Joint Venture and Northern Great Plains Joint Venture to implement grassland stewardship by serving on appropriate management boards and technical committees.

1.13 Continue to promote grazing stewardship practices through department private lands cost-share programs, partner programs, and other initiatives when and where appropriate.

1.14 Continue to financially support and advocate for completion of South Dakota State University (SDSU) Extension's inventory of undisturbed (native) lands in western South Dakota.

1.15 Utilize SDSU Extension's inventory of undisturbed (native) lands across the state to better target SDGFP's private lands technical and financial assistance programs on native sod areas in high priority landscapes.

1.16 Continue to participate in public scoping opportunities with federal agencies that manage native grasslands and convey recommendations which support public land uses that best maintain or enhance prairie grouse habitats.

1.17 Where prairie grouse are the primary habitat management species, best management practices for prairie grouse habitat management (page 16 of this plan) will be used with discretion to guide development and updates of Game Production Area management plans within fiscal, biological, and land use constraints.

1.18 Continue to use all available prairie grouse research findings to guide the environmental review process of proposed development projects (e.g. communication towers, wind energy, oil and gas, livestock grazing and allotment revisions, livestock infrastructure, recreational sites, trails, roads, prescribed fire, post-fire land management, etc.) where the

SDGFP has the opportunity to provide environmental review. Use Habitat Best Management Practices to guide environmental review process.

1.19 Participate in the greater prairie-chicken and sharp-tailed grouse interstate working group and assist in the development of a national prairie grouse conservation plan.

1.20 Explore the feasibility of using grass banking as a way to cooperatively and concurrently manage grassland habitat on Game Production Areas and nearby private lands.

OBJECTIVE 2: Monitor prairie grouse abundance, harvest, hunter numbers and hunter satisfaction.

STRATEGIES

2.1 Annually conduct traditional lek surveys and summarize data to determine changes in population status.

2.2 Periodically review prairie grouse lek survey protocol and discuss changes that could improve data collection efficiency and accuracy.

2.3 Annually conduct and summarize results of hunter harvest surveys to project prairie grouse harvest, number of prairie grouse hunters, and hunter satisfaction.

2.4 Continue to collect wings from hunter harvested prairie grouse in western South Dakota to evaluate age ratio and species composition of harvested grouse. Continue to collaborate with Forest Service biologists to relate weather variables to prairie grouse production on federal lands and other areas using wing data. Ensure that information gathered is shared among SDGFP and other participating agencies.

2.5 Continue to annually coordinate with federal land management agencies to collect prairie grouse habitat information, population/trend data and hunter-harvest statistics. Ensure that information gathered is shared among SDGFP and other participating agencies.

OBJECTIVE 3: Evaluate research needs and prioritize on an annual basis.

STRATEGIES

3.1 Annually collaborate with stakeholders and summarize research needs and ideas.

3.2 By December 2018, prepare completion report for prairie grouse occupancy modeling project.

3.3 At least one staff member will attend the semi-annual meeting of the Prairie Grouse Technical Committee meeting. This meeting facilitates the exchange of information between states on survey techniques, harvest regulations, research and habitat management.

3.4 Continue to attend scientific meetings that will exchange information related to prairie grouse management.

OBJECTIVE 4. Provide prairie grouse hunting opportunities on private and public land

STRATEGIES

4.1 Use all available biological and social data to develop 3-year hunting season recommendations for SDGFP Commission consideration.

4.2 Continue to enroll large blocks of well managed grasslands into the walk-in area program, especially in central and western South Dakota where high density prairie grouse populations exist.

4.3 Collaborate with SD School and Public Lands and the Bureau of Land Management to provide public access to land-locked public lands through access agreements and easements.

4.4 Continue to provide the South Dakota Hunting Atlas in print, as a pdf document, interactive map within the department's website, as a smartphone application, and as a map file for certain GPS units.

4.5 Annually prepare a prairie grouse hunting forecast based on spring lek counts and the production model based on weather variables.

OBJECTIVE 5. Promote public, landowner, agency and industry awareness of prairie grouse and habitat management issues of highest conservation concern.

STRATEGIES

5.1 Provide an electronic copy of "Prairie Grouse Management Plan for South Dakota 2017-2021" on the SDGFP web site. Printed copies will be available upon request.

5.2 Periodically include articles about prairie grouse and prairie grouse habitat in the SD Conservation Digest and Landowners Matter Newsletter.

5.3 Develop a prairie grouse habitat best management practices fact sheet for SD landowners.

5.4 By 2019, add a web page about prairie grouse under the outdoor learning section of the department website which includes descriptions, videos and pictures of prairie grouse display behavior.

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(The following is an excerpt from the June 7th, 2021, Commissioner Proceedings, Hughes County, South Dakota)

COMMISSIONER: Okay. Wind project update. Thanks, Ben.

COMMISSIONER: Thank you.

COMMISSIONER: Come on in.

MR. WILLIS: Good afternoon. My name is Casey Willis. I'm with ENGIE North America, so I'm the project developer for a project that we have partially in Hughes County, partially in Hyde County called the North Bend Wind Project. So, first off, I apologize for not being here before. Obviously, there's been some limitations for a lot of folks in the past 16 months or so. This is actually my first authorized travel out here, so thank you for allowing me to come in front of you.

Just to give you kind of an overview. We have been working out here with the landowners since about 2015 signing easements. It's usually the start of how a wind project begins and develops is we partner with some of the landowners to determine if there's interest.

The project itself is located on about 40,000 acres of easements that have been signed over time. This represents about 75 landowner groups. In that period of time, once we have a significant period of easements signed, we've been doing what I'd call baseline biological and environmental studies over the past couple of years. It was partially in conjunction with the adjacent Triple H wind project, which is now operating, and in addition to that, finalizing interconnect studies.

The interconnect studies are kind of the significant milestone for any wind project. Here in this area, it's the Southwest Power Pool where you enter into the interconnection queue and they evaluate the capacity on the system and what happens when you inject wind power at a particular location, what upgrades are needed, how does that factor in with existing resources' demand, other energies that have queue positions, so that process is fairly technical and it goes through several iterations and takes years to complete.

So we're now at a point where we know that basically the queue position that we have, that it's viable. In some instances, you can have a queue position where you think it will work great, and, unfortunately, it triggers eighty, a hundred million dollars of upgrades that can't be absorbed by a project. Project doesn't work in that location.

In this instance, we think it does. Our queue position is on a WAPA line. It's kind of on the southeast side of the project that exists right there. It's the Fort Thompson to Oahe 230-kilovolt line.

As of the moment right now, we have not formally signed a turbine supply agreement. Part of the reason for that is we also have not signed a power purchase agreement to sell power from the project, nor have signed the balance of plan, which is who the -- the construction contractor. Those are what I would deem as, like, the key major contracts. Generally, you try to sign them all at the same time.

We're fairly confident this project will be very competitive, similar to how Triple H was. And we've been very competitive in submitting bids into various proposals to sell power to different entities, and we think we'll be successful at some point in the not too distant future.

Right now, if everything aligns perfectly, we would look to start construction in 2022. This would obviously -- we obviously would need permits in hand before, in order to do that.

So if everything worked out perfectly, we'd look at starting construction in early 2022 and attempt to complete construction and have it be operating by the end of 2022. That may not happen. It could slip slightly, just depending on how things progress out in terms of negotiations and selling power.

So the second -- the map in here just shows the general project boundary of how it sits across the Hughes and Hyde County line. Right at the moment, we kind of envision it split 50/50 between turbine locations, and it shows the location that we're interconnecting into.

In terms of the project size, what we're targeting is a 200-megawatt project. This would be considered kind of a moderate-sized project. In comparison, the Triple H project is slightly bigger at 250-megawatts.

The turbine model that we believe is the most competitive here is the GE model. It's just slightly different than the one that was used at Triple H. It's just it happens that the turbine manufacturers continually innovate the models they offer and so this is basically like a slight upgrade. It's the new model for the next -- you know, the next year that they would deliver part -- or turbines for it.

So what we're looking at using is a G -- it's a General Electric 2.82 127 machine. What that means is that each turbine can generate up to 2.82 megawatts each, and the rotor on the turbine is 127 meters.

So based on that, what we're going to look to do is prepare permit applications that would request a total of 78 locations of which we would only build 71. That difference represents alternatives that are within there. It gives us a little bit of flexibility in the event that, as we do geotech studies, that there's something from a soils standpoint that would not work with one location, we can supplement it out for another, but no more than 71 would be built.

So I mentioned that the size of the rotor is 127 meters. What that means is that at the 12 o'clock position, the turbine would be just under 500 feet.

So for reference, the Triple H turbines out there are 486 feet at tip height, so it's slightly taller. From a broad perspective, these are actually on the smaller size for wind turbines these days. What we're finding is that the nameplate capacity of the turbine has been increasing and the size of the turbines have been larger with time.

The reason -- the reason we're able to use a smaller turbine here is the higher consistent wind speeds in that area that we found.

I'd mention again, the point of interconnect is on the Fort Thompson to Oahe. We're currently working with state lands on a location that WAPA would own and build a switch arc right at that location.

This project would not have an overhead transmission line. What happens is that we'll build this project's substation immediately adjacent to it. All of the -- all of the turbines have been collected at a 34.5 kilovolt level. What that means is they're basically -- it's a lower voltage after it's stepped up in the turbine. They're strung together. And all of those lines are trenched and in the ground so that they're not overhead.

And then this last video that I include in here is -- it shows the usable turbine area. And the reason I include this is that at the start of when I started speaking, I mentioned 40,000 acres under an easement. Oftentimes, there's an assumption that we can place turbines anywhere, and that doesn't -- that's not the case, really.

It's -- once you factor in those setbacks that we would use as a company, or in this case, county setbacks that have been adopted, it significantly reduces the area where you can consider placing a turbine.

So in this figure, it reduces it down by over -- almost 80 percent. 21 percent of the leased area we can actually use and consider. After that, there's even spacing aspects. We can't put turbines too close to each other, perpendicular to the wind or parallel to the wind, otherwise they wag each other in terms of the performance, so there's a fairly limited area where you can place the turbines.

So overall, this project would represent a capital investment of about 250 to $270 million. The project is likely to create about six to eight new full-time positions during operation.

This is lightly lower than a stand-alone project and it's because the Triple H project employs -- I don't know the exact figure. We'll call it 15 to 18 because it's the same turbine model. Because they're in close proximity, we anticipate that there would be some efficiencies there where we'd hire anywhere from six to eight, but that's just kind of -- that's a best guess at this point.

During construction, we typically see about up to 400 people on-site at any one time -- excuse me. Up to 400 people that are employed, 130 on-site at any one time.

The property taxes in South Dakota are dictated by state statute. It's based on the production from the site itself. And also the nameplate capacity of the project as a whole. And the reason -- I would guess the reason for that is in certain years there's a higher production and lower production, so by including a calculation based on the size of the project, it balances that out.

Our estimate, based on the annual production over the life of the project, is that it will produce just under a million dollars a year or about 29 million in taxes over the life of the project. That's split out between the state, the counties, and the school districts -- the school district calculation.

The state would receive about 300,000 or 8.8 over the 30-year life. The counties, roughly 337,000 annually, or about 10.1 million, and the school district calculation tracks alongside of that.

What we find -- and obviously this is going to generate, you know, income for the local -- for the residents that are participating. And we find that there's a fair amount of indirect benefit that comes with other local services that are used in conjunction with the project operation as well as in -- during construction itself.

So that's kind of a high-level overview of what we're contemplating. And I am here for any questions that you may have.

COMMISSIONER: Casey, I have a quick question for you.

MR. WILLIS: Sure.

COMMISSIONER: I mean, we're hearing all the positives and the dollars and everything. There was a lot of questions back when we were setting the setbacks about health and effects on wildlife. Have you guys done any updated studies? I am assuming that concerns you guys. Have you done any updated studies on anything?

MR. WILLIS: So I'll touch on the health one. That doesn't. The reason I say that is there's fairly significant studies that I can provide you that have documented that there is not health effects caused by wind turbines. These are done and replicated in different countries, different county agencies, different states. I can provide you a list of those studies, but that's fairly conclusive.

From the biological aspect, I mentioned that we've done three years of studies. In large part -- you know, this particular area I don't find is particularly sensitive, and a large part is because there's a lot of tilled areas used in agricultural production.

We don't find this from our studies in our baseline work. And even what we found at Triple H, which has a very similar kind of habitat dynamic, that the impacts are fairly minimal.

COMMISSIONER: Okay. Do you have any other questions?

COMMISSIONER: ENGIE, is it a U.S. company or is it a foreign company?

MR. WILLIS: It's a French company.

COMMISSIONER: It's a French company.

MR. WILLIS: So it's a -- I should go beyond that. It's a conglomerate that is Belgium and French, and it has ties to building the Suez Canal, but yet -- so my aspect, I work for ENGIE North America and our headquarters are based in Houston.

COMMISSIONER: Is there any U.S. companies that puts up wind turbines?

MR. WILLIS: I'm sure the answer is yes, but you get various players in the market. So I -- this project itself -- this project itself, I worked for the prior company called Infinity Renewables. We were entirely a U.S.-based company. The difference is is that our role at that time was develop and de-risk a project, because the capital costs associated with building it were -- far exceeded what a small company can do.

There are a lot of companies that operate like that. And then they partner with a larger partner with a balance sheet they can build on and operate it.

What ENGIE did is they bought out Infinity. I came on as an employee along with 20 or 30 other folks, so they're an owner-operator long-term and always have been, but they brought in a group that can develop as well. So that's a long way of me saying, in some instances there are, like NextEra is a Florida-based company that builds projects. They have a project in Hyde County. There are probably other ones, but there definitely are a lot of European-owned utilities that have groups in the

U.S. that owner-operate projects.

COMMISSIONER: I just know from past, you know, experience, when you're dealing with an overseas company, when it comes to money or problems, you're toast. If you have to go to court on something, they're gone.

I used to ship grain to China. I got paid before it got to Seattle, you know, stuff like that. So if there was ever an issue, you know, there was already prior inspection. But, you know, I've seen foreign companies come in, do projects. When it doesn't work out, they either try to flip them or they dissolve and you're left with damage. How can we be sure that ENGIE won't be one of them?

MR. WILLIS: Right. So grain, you can pick up and move, right? I can't pick up and move a project once this is done. I'll give you the example of the Triple H project, that is a $300 million project that is in the ground.

Let's assume ENGIE went bankrupt. There's power purchase agreements with Wal-Mart and Boston University that have significant value. They would take -- someone would buy that project out of bankruptcy -- Brett could probably speak to this a bit better than I can -- it would own and operate the project because there's still significant value. In terms of protecting the community, there's a decommissioning bond and plan associated with that project that is required by the Public Utilities Commission to ensure that the infrastructure would be removed in the event that an entity was not there.

I don't see that as an issue. That really hasn't occurred. There's value in these projects. You can't move them.

COMMISSIONER: So -- if it's okay, Chairman. With that being said, you can't move them and the life is 30 years, then what? Because what happens that we're seeing right now, and it's been reported, especially down south, is when these things have been basically decommissioned, some of them are being cut up and put in landfills where they take them. A lot of them aren't being taken because the landfills won't take them anymore because they don't -- they'll never go away, what they're built from.

Number two is that when they sit there long enough and it's time to get rid of them, the company that originally started it is long gone and sold again and sold to the third company that took the last bit of money. Even though they had a bond during the revenue days, the bond is now gone and they've bankrupted. And now there is nobody to take it down, and the farmers or the landowners or the counties or the state, which is what they're fighting over right now, on how to handle this.

So, I mean, it's new territory for a lot of us, and some of them are still being rebuilt and going. But our concern is for the guy that says, Okay, now what happens with ENGIE, because ENGIE does not keep them, I'm understanding. They sell them as well.

MR. WILLIS: No.

COMMISSIONER: They've kept all their windmills they've built? Every one so far?

MR. WILLIS: Correct. We're operators.

COMMISSIONER: When you say "operators" --

MR. WILLIS: We own and operate the projects. We don't -- we don't --

COMMISSIONER: For how long?

MR. WILLIS: 30 -- the life of the project. I mean, there could be circumstances where, as a company farther down the line, that you're right, it could be sold to a different entity.

COMMISSIONER: Are any of these entities owned by a U.S. company?

MR. WILLIS: From my company -- from --

COMMISSIONER: Any of these windmill companies that you know out here right now.

MR. WILLIS: NextEra is a significant player in the U.S. market. What are the projects in the south that you're referencing?

COMMISSIONER: In Oklahoma right now.

MR. WILLIS: What's that?

COMMISSIONER: In Oklahoma. I can't give you a name --

MR. WILLIS: Okay.

COMMISSIONER: -- right off the top of my head.

MR. WILLIS: The recycling aspect, no, that's a significant issue that the industry is aware of. It's something that we'd like to resolve, but, yeah, there are some issues. It's not every part can be recycled. That is absolutely the case. The blades, in particular, are composite.

COMMISSIONER: Right. And they're dealing with that in Sioux Falls right now. They're hauling them as long as they're taking them, but even that, we're told, is going to come to an end. So then what happens to them?

MR. WILLIS: The aspect that I mentioned, again, is --

COMMISSIONER: Because they'll never go away. I mean, these things, what we're told, the carbon fibers will never disintegrate, ever.

MR. WILLIS: Right. The actual removal is covered in the decommissioning plan as required by the PUC during the life of the project. We're required to fund it, so that ensures the removal of it.

COMMISSIONER: As long as you still have financial --

MR. WILLIS: Or anybody that owns it has to -- is required to take on that commitment.

COMMISSIONER: As long as they have the financial wherewithal to do it; correct?

MR. WILLIS: No. I mean, you want to explain the bond better than I can?

MR. KOENECKE: Sure. The -- all the wind farms that have been built since -- well, this current bulge, since 2017 have been required to escrow funds through a South Dakota bank to pay for the decommissioning, so that builds up a cash balance over time --

COMMISSIONER: So that will never go away?

MR. KOENECKE: -- so that goes along with the project and can't be spent without authority of the Public Utilities Commission.

COMMISSIONER: Why was there some states or even in different counties, why are they putting moratoriums on building wind turbines here in the last six months to a year? What's going on in them areas?

MR. WILLIS: I don't know.

MR. KOENECKE: I'm not familiar with --

MR. WILLIS: Perception sometimes.

MR. KOENECKE: I would say one thing I know is that there are some counties that haven't done the hard work of putting their zoning and construction ordinances in place. That -- I'm familiar with that, I guess. But as far as other reasons, I couldn't speak to what those are.

If a county hasn't prepared and hasn't done the work and are not ready for it, and then they feel, Oh, my gosh, there's an announcement, we've got to react to that. I guess, I've seen that. But, otherwise, I don't know about a moratorium that's just been put in place. I couldn't speak to that.

COMMISSIONER: Do you have another one?

COMMISSIONER: Yes. On the WAPA line you said you're going to be using, so am I understanding correctly that the power that is generated from these dams right now doesn't utilize the line fully today, so there's room on that line for more power?

MR. WILLIS: It depends on how the power flows from that area. That's taken into account because the power generated from dams, gas-fired power plants, coal-powered --

COMMISSIONER: Let's just talk about WAPA here with our dams.

MR. WILLIS: Right.

COMMISSIONER: Is this line empty then? It's not used?

MR. WILLIS: It's not that it's empty. It's -- there's capacity to allow just additional generation, so those dams would have been factored into the analysis as the baseline.

COMMISSIONER: So when you say there's capacity available, that's assuming that the dams are not running or if they're running at full?

MR. WILLIS: I would imagine it's the latter.

COMMISSIONER: So if they're all running at full capacity --

MR. WILLIS: Yes.

COMMISSIONER: -- there's still capacity on that line for these?

MR. WILLIS: It doesn't necessarily mean it all goes through that line. It can go to a variety of locations. It depends on where the substations are.

So the one that it interconnects to is the fairly large one north of Fort Thompson.

COMMISSIONER: So let me ask you this, then: By the wind turbines that are operating, if they're operating, because they go on and off based upon the wind.

MR. WILLIS: Right.

COMMISSIONER: Will they interfere with this dam, mainly Oahe or Fort Thompson, would their power source having to shut or go, they'll -- it never effects when there are things awry, then?

MR. WILLIS: To my knowledge, no.

COMMISSIONER: Will all the power be dumped right on just that WAPA line or it's going to go into other lines as well.

MR. WILLIS: It kind of flows -- you don't direct electrons. They go from a high to a low source, right?

COMMISSIONER: Okay.

MR. WILLIS: They go to the load center. So they would generally stay locally.

That said, there are -- you know, I mentioned -- I keep mentioning Triple H because it's an obvious example. We had a power purchase contract with Wal-Mart. We're not delivering electrons directly

to Wal-Mart stores. It's -- you know, it's a paper transaction --
COMMISSIONER: Right.
MR. WILLIS: -- that's tied to their corporate incentives.
COMMISSIONER: Right.
MR. WILLIS: They fund, invest in renewables. That's kind of how it works.
COMMISSIONER: Because who kind of controls most of -- where do we buy our power from now? Who is that big company?
COMMISSIONER: East River?
COMMISSIONER: No. Where do they get it from?
COMMISSIONER: Basin Electric.
COMMISSIONER: Basin Electric.
COMMISSIONER: Yep.
COMMISSIONER: So you'll be dumping a lot of this into Basin Electric; right?
MR. WILLIS: No, it's the WAPA system. Triple H is in the Basin system.
COMMISSIONER: Okay.
MR. WILLIS: It's all part of the Southwest Power Pool as a whole, which is the regional transmission authority that they all operate within.
COMMISSIONER: I mean, I've got to be honest with

you, after watching Texas this year, it's kind of a head-scratcher. You know, I don't know if we all have enough pickups to power our houses if we get pretty dependent on renewable energy.

MR. WILLIS: Yeah. So we recommend that -- that was not caused -- what occurred in Texas, in terms of the winter, was not completely caused by renewables. And that's been --

COMMISSIONER: I agree.

MR. WILLIS: Right?

COMMISSIONER: They just got a little too dependent and --

MR. WILLIS: No. Actually, it has to do with winterization of energy resources as a whole. So this was something that was flagged ten to fifteen years ago in a prior freeze as a problem, and that was what happened, to a lot of oil and gas facilities as well. Certainly renewables went down.

We had projects in Texas as well. What happens is that -- you know, in South Dakota we use winter packages in the turbines because it's consistently cold.

In Texas we don't typically do that. It's kind of like taking a parka to Miami in the summer. You're probably not going to need it.

The same goes with a lot of the energy productions facilities in Texas. There's other aspects, too, ERCOT is really unique. It's an isolated island. Texas is independent and always has been. They can't pull any power from additional areas to offset when generation goes down. That's another component that was problematic as well.

COMMISSIONER: Thank you. Connie?

COMMISSIONER: Thank you, Mr. Chairman. I have just a couple of questions, Casey. When we were talking about our setbacks, were you the one that was on the phone that time with us?

MR. WILLIS: I was, yes.

COMMISSIONER: Okay. Well, thank you for being here. It's nice to put a face with a name.

MR. WILLIS: Yes.

COMMISSIONER: And I -- at that time I had a question and asked about the residents, so I'd like to kind of look at that map.

MR. WILLIS: Sure.

COMMISSIONER: Where we have all of these little dots and -- so these are the -- these are people where they're actually living on these little dots. Is that --

MR. WILLIS: Yes.

COMMISSIONER: -- what I'm seeing?

MR. WILLIS: They're occupied residents per the county's description, yes.

COMMISSIONER: So when we were talking about that, about -- my question back then was: How many people are within this project area? And you didn't have that answer.

MR. WILLIS: I still don't know that I have that necessarily.

COMMISSIONER: Okay.

MR. WILLIS: I don't know the exact number. I am going to guess, and I am only going to guess this because I've seen our noise analysis --

COMMISSIONER: Okay.

MR. WILLIS: -- that will be coming with an application. It's probably 50 homes, give or take. If in 40 acres plus a half-mile boundary around that 40 -- excuse me 40,000 acres, so it's a fairly large area. I want to say 50 to 60 homes.

COMMISSIONER: So what does it mean by -- so I'm just looking at the map. Just, please, bear with me. So what -- what does it mean by the proposed net locations? What's those triangles?

MR. WILLIS: Those are -- so what we use are net towers, which are essentially -- and this is what we've used to test the wind speeds at various levels. It helps us to assess whether something is viable or not. I've had projects that we put them up and wind speed is not what we thought. Those are temporary.

COMMISSIONER: Okay.

MR. WILLIS: So they're placed out there. There's probably five or six of them over significant periods of time that are up right now. And that's what we use to assess the wind speeds.

COMMISSIONER: Okay. So I just have a couple of requests, if that's --

COMMISSIONER: Go ahead.

COMMISSIONER: Okay. So my questions are -- or my request to you would be -- I'm a numbers person, so my question would be: I'd like to know, could I get a copy of your calculations of how you generated 971,000 a year for taxes?

MR. WILLIS: Yes.

COMMISSIONER: And how that was broke down amongst the state, counties, and school districts?

MR. WILLIS: Yeah. I can do that to a certain degree. What it does depend on is the net capacity factor.

COMMISSIONER: Sure.

MR. WILLIS: That's a proprietary thing.

COMMISSIONER: Okay.

MR. WILLIS: It's not something -- we use the accurate one, but it's kind of -- it's not something that's shared publicly, but that's what we base the tax calculations on.

COMMISSIONER: I guess I don't understand.

MR. WILLIS: So it's -- it's kind of like asking someone: How much is in your bank account? That's the rough equivalent, so it's proprietary. It's what we collect. It's based on the --

COMMISSIONER: You might be looking for more capacity factor.

MR. WILLIS: Capacity factor is -- the net capacity factor is the average wind production once you factor in electrical losses.

COMMISSIONER: Yeah.

MR. WILLIS: So it's the 50 percent value. The median, I should say. So in certain areas you hear net capacity factor at 40 percent. So 40 percent of the time it's produced -- it produces 40 percent of the power over 365 days a year.

COMMISSIONER: Sure. Okay. So can you tell me -- let's say it's 40 percent, whatever that number is.

MR. WILLIS: Yeah.

COMMISSIONER: Whatever that is, can you tell me what the ones that are currently right there, like they're right in here already; right? Are you estimating those same numbers? You guys have -- you own something real close to this; right?

MR. WILLIS: Right.

COMMISSIONER: Can you tell me what those actual numbers are? And where I am trying to go with this is: Are those numbers close to what this is -- what those estimates are?

MR. WILLIS: But remember, they're variable. So -- right? You're going to have some instances where wind production is lower than expected.

COMMISSIONER: Yep.

MR. WILLIS: Net capacity is the 50 percent of the median and sometimes it's higher, so it depends on what the wind production was for a particular year.

In terms of Triple H, we just started operating within the first six months so we haven't paid the taxes at least for the first year yet. I can tell you what the estimates were. It's the same idea. It's based on the net capacity factor, but it's no different than, you know, the calculation -- I can provide the calculations. It will have the average

estimate, but it won't include the capacity factor.
    COMMISSIONER: Okay. Great. Thanks. I'm trying to debate whether to ask this next question.
    COMMISSIONER: Go ahead.
    COMMISSIONER: I guess I will. So here is my last question: Is there federal funding tied to this? How does that work? I'm just curious because I'm a number person, so --
    MR. WILLIS: No, that's fine.
    COMMISSIONER: -- is it so much per tower? How does that work?
    MR. WILLIS: So it's called a production tax credit. There's a tax credit.
    COMMISSIONER: Okay.
    MR. WILLIS: I think it's 2.1 -- I don't even remember off the top of my head, but either -- it's 2.1 -- let me get back to you on the exact number --
    COMMISSIONER: Okay.
    MR. WILLIS: -- because it's variable. There's an -- so essentially what happens is we have a tax equity partner that will come in. Usually it's a bank that has a tax liability. That's how it's monetized essentially, the federal tax credit.
    COMMISSIONER: Right. Okay. So dumb it down for me.

COMMISSIONER: We do that with housing all the time. If you're going to build with housing authority, whatever, you get a tax credit back when you buy it, the banks do. So how I -- I think what your question is is how do you do that with this? How is that calculated out? I can get you to the penny on -- South Dakota Housing is doing a tax credit for a senior housing center. So I would imagine the tax credit is handled the same way for this; correct?

COMMISSIONER: It figures into the financing is, I think -- my limited understanding of it is when these guys put the project out for financing and go through that process, that gets figured in at that point is how I understand it.

MR. WILLIS: That is correct.

COMMISSIONER: I haven't done that kind of work on that side of a transaction, but the financing is where they take that out and turn that into -- it's essentially financial reward or whatever you want to say to the wind farm company. It figures into their costs of doing business and their costs of production, and all of those things, but that's where it comes in at is in the financing part with the bonds that are sold or however they choose to do it.

COMMISSIONER: Does that make sense?

COMMISSIONER: Kind of. So -- okay. So you go to a bank or you bond it. The turbine, the project itself gets -- you borrow the money to borrow this 250 to 270 million to build the towers?

MR. WILLIS: It's not bonded, necessarily. This gets a little outside of my background, so I apologize for that. I'll try to give you a better explanation when I come in.

COMMISSIONER: Okay.

MR. WILLIS: Essentially you have an entity. It's not bonded, but you have an entity that has a tax liability that wants to look to offset that, so they're putting up -- they're contributing a portion into the project, it's kind of a silent partner, to utilize that tax credit for themselves.

COMMISSIONER: Okay.

COMMISSIONER: So instead of really going out and borrowing funds at 7 percent, it may be down to 1.5, and that bank basically eats the rest for the credit for that, and they get a credit or tax deal for it. I can show you on a --

COMMISSIONER: Yeah, I -- okay.

COMMISSIONER: And I think that can all --

COMMISSIONER: And we can take this offside.

I'm just curious how it works.

MR. WILLIS: I can get you a better explanation from our finance folks better than I can explain it.

COMMISSIONER: Great. Thank you.

COMMISSIONER: Any more questions for Casey? Tom? Melanie? Any more questions?

COMMISSIONER: One more thing. The health deal, there's no health issues to any of the public here. But do you have your people that sign up for it, do they have to sign any paperwork saying that you're held harmless of any health issues?

MR. WILLIS: I mean, I think there's hold harmless language in most development easements that I'm aware of. Yeah, we have those, for sure.

COMMISSIONER: So if there's no health issue, there shouldn't really need to be a health --

MR. WILLIS: It's a common --

COMMISSIONER: -- held harmless.

MR. WILLIS: You're the lawyer here.

MR. KOENECKE: They're complex agreements and they cover a number of things. And there's certainly nothing in there that would hold us harmless from negligence or criminal standpoint, but there are things in there as far as you do agree to live with some of the known effects as well and so --

COMMISSIONER: What are they?
MR. WILLIS: Generally, noise.
MR. KOENECKE: Generally.
MR. WILLIS: And flicker.
MR. KOENECKE: Shadow flicker would be the two that I can think of. If you're going to take the money from hosting a turbine and be a part of the project, you don't get to then be an opponent of the project.
COMMISSIONER: You can't sue yourself basically.
MR. KOENECKE: That's kind of the general line of thinking there, but certainly there's no exemption from negligence or criminal matters or anything like that.
COMMISSIONER: Any more questions? Okay. Thanks, gentlemen, for your time.
MR. WILLIS: Thank you.
COMMISSIONER: Nice meeting you, too, by the way.
MR. WILLIS: Yeah.
COMMISSIONER: Appreciate you coming in.
MR. WILLIS: Yes. It's much nicer in person than over the phone. Thank you.
(End of transcription)

STATE OF SOUTH DAKOTA)
:SS
COUNTY OF LINCOLN)

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To all of which I have affixed my signature this 12th day of September, 2021.

/s/ Paige K. Frantzen
Paige K. Frantzen, Notary Public
Expiration Date: December 22, 2023

Briefing Paper

Prairie Grouse Leks and Wind Turbines: U.S. Fish and Wildlife Service Justification for a 5-Mile Buffer from Leks; Additional Grassland Songbird Recommendations

Date: July 30, 2004 [Prairie Grouse Lek 5 Mile Public.doc]

Issue: The U.S. Fish and Wildlife Service (FWS, Service, or we) recommended "... avoiding placing wind turbines within 5 miles [8 km] of known leks (communal pair formation grounds[a]) in known prairie grouse habitat" (see p. 4, item 7, Site Development Recommendations) in our *Interim Guidelines to Avoid and Minimize Wildlife Impacts from Wind Turbines*, a notice of its availability published July 10, 2003 in the *Federal Register*. Some have questioned the validity of this recommendation, specifically the distance metric. While many grouse biologists consider 3 distinct groups of grouse in North America, including forest grouse (*e.g.*, Ruffed, Blue, and Spruce), prairie grouse (*e.g.*, Greater and Lesser Prairie-chickens and Sharp-tailed Grouse), and Sage-grouse (F. Hall 2004 personal communication [hereafter pers. comm.]), the Service's guidance included prairie and sage grouse within the same general "prairie grouse" category. This briefing paper provides justification for the Service's recommendation for a 5-mile buffer from occupied prairie grouse leks.

The Service reiterates that our wind siting guidelines are voluntary; we are not restricting installation of wind turbines or wind facilities within a 5-mile radius of active leks. Prior to any site selection, we recommend that the wind consultant/company/contractor assess the complete habitat requirements and habitat use and needs of whatever species of prairie and sage grouse is involved (*e.g.,* Greater and Lesser Prairie-chickens, and Gunnison and Greater Sage-grouse, and Columbia Sharp-tailed Grouse) at the site. All habitat requirements of prairie grouse should be considered, *i.e.*, habitats for courting and breeding (leks), nesting, brooding, resting, feeding, migrating, and wintering. Given continuing uncertainties about structural impacts on prairie grouse, especially the lack of data regarding impacts from wind facilities, and the clearly declining trends in prairie grouse populations (see below), we urge a precautionary approach by industry and recommend a 5-mile buffer where feasible. The public comment period on our voluntary guidance will continue to be open through July 10, 2005. We strongly encourage all interested parties to provide suggestions and recommendations on our voluntary guidance that will help improve its reliability and update its usability. Comments on the distance metric, especially those derived from ongoing scientific studies, will be important.

It also was recommended that we include a brief discussion on the declining populations of grassland and sage-steppe obligate songbirds and the need to protect their habitats. This briefing statement will review their habitat needs and will briefly discuss disturbance and habitat fragmentation.

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[a] Leks are technically not "communal pair formation grounds." Sage-grouse, for example, are not "pair forming" on leks and only a few males complete most of the breeding (F. Hall 2004 pers. comm.). Leks may best be described as traditional display areas normally located on very open sites in or immediately adjacent to breeding (nesting and early brood-rearing) habitats (J. Connelly 2004 pers. comm.).

Prairie Grouse Status:

All species of prairie grouse are declining, some severely. The range and population of the Lesser Prairie-chicken (LPCH) have declined > 90% since European settlement of the great plains 100 years ago (Giesen 1998). The Attwater's Greater Prairie-chicken has been Federally listed as endangered in its entire range -- now Texas -- since 1967. The LPCH is currently listed as a candidate species under ESA in CO, KS, NM, OK, and TX. A "candidate species" is a plant or animal for which FWS has sufficient information on their biological status and threats to propose listing under ESA, but for which development of a listing regulation is precluded by other higher priority listing activities. It is a formal ESA designation, although candidate species do not receive legal protections under the Act.

The Gunnison Sage-grouse, found in the Gunnison Basin (CO and UT) was candidate-designated under ESA in 2000. Their listing priority has recently been elevated. Populations of the Greater Sage-grouse have declined 66-92% during the past 30 years in western Canada where they are listed as endangered (Aldridge and Brigham 2002). Throughout North America, Sage-grouse distribution has been reduced by at least 50% since the early 1900s, with extirpation in 5 of 16 States and 1 of 3 Canadian Provinces. Breeding populations of Sage-grouse have declined 45-80% from numbers estimated in the 1950s (Connelly and Braun 1997, Braun 1998, Connelly *et al.* 2004). The Greater Sage-grouse in the Columbia Basin (WA and OR) was also designated as a candidate species. In April 2004, FWS published a 90-day finding in the *Federal Register* (69 FR 21484) with regard to range-wide listing petitions for the Greater Sage-grouse. The FWS found that the petitions and additional information available in our files present substantial information indicating that listing may be warranted. This positive 90-day finding triggered a FWS status review of the species which will result in a 12-month finding that is to be available in December 2004 (K. Kritz 2004 pers. comm.). In June 2004, the Western Association of Fish and Wildlife Agencies published a comprehensive, science-based assessment of the Greater Sage-grouse and its habitat, reviewing landscape information for the past 100 years, population data for the past 60 years, and the available literature (Connelly *et al.* 2004; see beyond).

While wind turbines and wind facilities are new additions to prairie grouse habitats in the Midwest and West, their impacts to grouse populations could add to the cumulative effects of human development and exploitation from other sources in grouse and songbird habitats. With these continuing uncertainties, we recommend that the industry take a cautious approach. Prairie grouse did not evolve with tall vertical structures present so the addition of wind turbines and their supporting infrastructure represents a significant change in the species' environment (J. Connelly 2004 pers. comm.). Given the declining or precarious status of grouse populations, the impacts of wind development on prairie grouse must be evaluated with great care and considerable detail. Prairie grouse are "indicator organisms," showing us the health of their environments, and sage grouse are "sensitive keystone species," representing critical components of their habitats (Lyon and

Anderson 2003, S. Harmon 2004 pers. comm.). Grassland and sage-steppe-obligate songbirds (*e.g.*, Sage Sparrow, Brewer's Sparrow, Sage Thrasher, and Black-chinned Sparrow) are also showing serious population declines. Grassland songbirds are the fastest declining suite of birds in North America (Johnson *et al.* 2004).

<u>Justification for Our Distance Recommendation</u>:

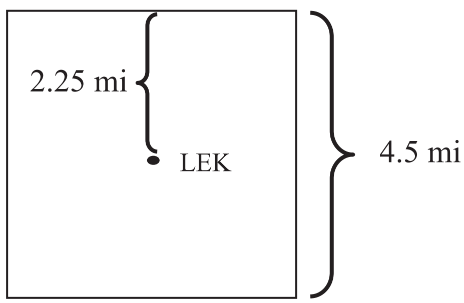
While we acknowledge that much research continues on prairie grouse and the impacts of tall structures, including wind turbines – and thus much of the data have yet to be peer reviewed and published – several studies and their recommendations have been published and are used as the basis for our 5-mile recommendation. Most compelling was the recommendation by Connelly *et al.* (2000:978) calling for protection of breeding habitats within 11.2 mi (18 km) of the leks of migratory populations of Sage-grouse (see discussion beyond). See also Giesen and Connelly (1993) beyond for a discussion of management guidelines for Columbian Sharp-tailed grouse.

Extensive personal communications with many grouse specialists were also important in helping us make our determination. The published reviews (some of which were in press at the time of our recommendation) are included below.

We believe it is important to clarify that avoidance of vertical structures by grassland and sage-steppe-obligate wildlife is not a new issue, and the Service's recommendations are not merely reactive to current recommendations promoting wind power development nationwide. Concerns were brought to the Division of Migratory Bird Management as early as 2000 regarding the possible impacts of wind turbines on prairie grouse, including noise, habitat disruption, disturbance, fragmentation, and increased predator access (R. Reynolds and N. Niemuth, FWS Habitat and Population Evaluation Team, Bismark, ND 2000 pers. comm.). Much research has also been conducted on the impacts of high tension power transmission and electric distribution lines on prairie grouse, providing a detailed body of literature on a related structural issue (*e.g.*, Connelly *et al.* 2000, Braun *et al.* 2002, Hagen 2003, Wolfe *et al.* 2003a and 2003b, Pitman 2003, Hagen *et al.* 2004, Patten *et al.* 2004, and Connelly *et al.* 2004).

***Lesser Prairie-chicken*s**

Mote *et al.* (1998:18) reported the findings of the Lesser Prairie-Chicken Interstate Working Group (represented by CO Division of Wildlife, KS Department of Wildlife and Parks, NM Department of Game & Fish, OK Department of Wildlife Conservation, and TX Department of Parks & Wildlife). This State-led team of species experts, with input and review by researchers and academics, identified the need for a contiguous block of 20 mi^2 (52 km^2) of high quality rangeland habitat to successfully maintain a local population of LPCH. If this area represented a hypothetical square home range (Figure 1), its boundaries would be approximately 4.5 x 4.5 mi (7.2 km) and a lek located in its center would be 2.25 mi (3.6 km) from the nearest side. If the hypothetical contiguous block were a circle (Figure 2), its radius would be 2.5 mi (4.1 km) in length from a lek located in its center. In Figure 2, we incorporated an additional 1.25-mi (2 km) minimum protection buffer zone beyond this hypothetical home range as recommended by Hagen *et al.* (2004:79), discussed below. Because range wide, the majority of remaining LPCH populations are fragmented and isolated into "islands" of unfragmented, open prairie, thus we assert that a 5-mile buffer from a lek is recommended to protect the wind power industry from later determinations that construction activities could significantly impact important LPCH populations and habitat corridors needed for future recovery.



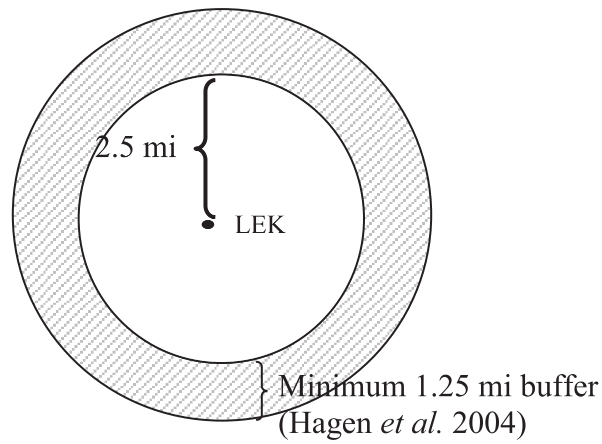


Fig 1. 20 mi^2 protected habitat.

Fig 2. 20 mi^2 protected habitat using 2.5 mi radius from lek; with additional buffer zone recommended by Hagen *et al.* (2004), protected area = 44.2 mi^2.

Figures 1 and 2 illustrate the minimum scale of unfragmented habitat necessary to maintain a LPCH local population (S. Harmon 2004 pers. comm., B. Obermeyer 2004 pers. comm., after Mote *et al.* 1998:18).

Other individual studies however, discussed in the next several paragraphs, have suggested recommendations for protected distances less than those presented by Mote *et al.* (1998). These variations may reflect differences between individual populations, the variability in the complexity of different habitats, habitat fragmentation and disturbance, and other unknowns. For example, Pitman (2003:45, 49) and J. Pitman (2004 pers. comm.) noted that > 80% of LPCH hens nested closer to a lek other than their lek of capture and they moved on average > 1.9 mi (3 km) from their capture location to initiate a nest. He indicated that the presence of buildings, improved roads, power lines, agricultural edge, and oil and gas wellheads all eliminated potential nesting habitat for a radius of up to 0.62 mi (1 km; p. 46). Roads, power lines and sometimes agricultural edge are all anthropogenic features associated with wind energy facilities. He suggested that in order to maintain movement between sub-populations of LPCH, habitat fragments should not be further than 6.2 mi (10 km; p. 142) apart. The recommendation was based on the dispersal distance of juvenile females although the sample size was very small.

As a further example, Hagen (2003:156, 177) and C. Hagen (2004 pers. comm.) studied LPCH in southwestern KS. He concluded that landscape features, the proportion of an area occupied by power lines, and the proximity of human structures clearly reduced otherwise suitable habitat. The mean distance chickens avoided structures was 0.9 mi (1.4 km; p. 162). However, Hagen (2004 pers. comm.) cautioned that data are presently lacking that indicate what happens to LPCH as habitat patches become smaller or as patch quality becomes less diverse and as anthropogenic features become more abundant. The distances in his study may reflect the "tolerance" level of LPCH to structures in fragments of < 12,350 ac (5,000 ha) in size of moderate quality. He recommended that as patch size becomes smaller and/or of lower quality, the LPCH will be less tolerant to disturbance and fragmentation. Until data can support an alternate hypothesis, Hagen (2003:159) and C. Hagen (2004 pers. comm.) suggested protecting as large a buffer around remaining habitat as possible.

Hagen *et al.* (2004:79), in "guidelines for managing lesser prairie-chicken populations and their habitats," recommended that wind turbines and other tall vertical structures be constructed >1.25 mi (2 km) from known or potentially occupied LPCH habitat, at a minimum. This recommended area represents a buffer beyond already existing LPCH home ranges (Figure 2). If wind facilities must be placed in known LPCH habitats, Hagen *et al.* (2004) suggested they be positioned along prairie edge or clustered in sites with other disturbances.

Wolfe *et al.* (2003a:18) assessed LPCH habitat use and avian impacts in OK and NM. They indicated that while a common suggestion is to manage for nesting habitat within 1 mile (1.6 km) of a gobbling ground (lek), much larger areas are more likely to sustain broods. On average, hens nested 2.3 miles (3.7 km) from the lek on which they were captured (the record distance was 13.7 mi [21.9 km], p. 9), while successful nests averaged 2.6 miles (4.2 km) from the lek upon which the hen was captured. Their research also suggested that fragmentation from roads, fences, and power lines are a greater mortality factor than what had previously been thought. Collisions with human-built structures may be additive to other mortality. Wolfe *et al.* (2003b) reported that fragmentation likely elevated LPCH mortality due to collisions with fences and power lines. Wolfe *et al.* (2003a:16 and 2003b) noted that scavenging, especially by mammals, can occur at > 50% of the carcasses within days, resulting in collision rates that are likely higher than they had reported. Wolfe *et al.* (2003b) and Patten *et al.* (2004a:1) reported that females in both NM and OK suffered greater mortality from collisions with human-built structures than did males. Females were reported less susceptible to predation in both NM and OK, but more susceptible to collisions with fences, power lines, and vehicles (Patten *et al.* 2004a:9; 0.29 for female mortality due to predation vs. 0.48 for female mortality due to collisions, N=79 females, based on the Kendall's τ correlation matrix).

Patten *et al*. (2004a:12-13) noted that female LPCHs tend to breed only during a single year in OK, making the OK population more susceptible to annual environmental stochasticity (randomness) and a higher probability of going extinct within the near future. In NM, breeding was more likely to also occur in the 2nd and 3rd years. Habitat fragmentation, based on evidence from their study, can markedly affect the likelihood of population persistence and survival (p. 14). Patten *et al*. (2004a:28) modeled the probability of extirpation of LPCH in OK over the next 30 years. A few "bad years," they concluded (*i.e.,* climatic changes resulting in unfavorable weather conditions, low food yields, and heavy predation) could put the species over the brink, giving conservation professionals little time to react. This "too little, too late" scenario occurred with the Attwater's Prairie-chicken, largely due to the unavailability of necessary habitat that prairie grouse require (S. Harmon 2004 pers. comm.).

For LPHCs, increased habitat fragmentation and isolation of existing populations are of major concern. The placement of wind plants in a critical corridor area between 2 or more populations might permanently prevent connectivity. Potential connectivity corridors, however, have not been fully identified (D. Wolfe 2004 pers. comm.).

Greater Prairie-chickens

Although many studies have identified prairie grouse avoidance of vertical structures, to date, the only documented case of interaction specifically between prairie grouse and a commercial wind facility comes from northwestern MN. This information, however, is anecdotal in nature, collected peripheral to other research. As a result, no peer review or statistical testing of the findings are possible at this time. Society and Toepfer (2003:47) reported in their study area, composed of a habitat patch approximately 3 x 4 mi (4.8 x 6.4 km), that some individual Greater Prairie-chickens (GPCH) appeared to tolerate to some degree a small complex of 3 wind turbines. Specifically, researchers documented 6 active leks within 2 mi (3.2 km) of the 3 wind turbines, 1 lek within 0.6 mi (1 km) of the nearest turbine, and 1 hen with a brood immediately adjacent to a turbine. However, Society and Toepfer (2003:47) cautioned that further development and expansion of wind power on this site could negatively impact the use of the grassland by Chickens.

When considering this case, the Service contacted the primary investigator and discussed the observations at length. For the following 3 reasons, we find that Society and Toepfer's (2003) observations may not necessarily be in conflict with other researchers' findings and our voluntary siting guidelines. First, it is important to emphasize that this study site is relatively small and isolated within a landscape of primarily cultivated fields. As a result, individual GPCHs in the local population have little alternative than to continue using the habitat, regardless of its level of fragmentation.

Second, the documentation of active leks within 5 miles of the turbines may reinforce what is widely known about the behavior and life history of male Prairie Grouse. Within these species, females are the primary dispersers, whereas males "imprint" on a particular lek and nearby leks, and remain in the vicinity until their death. For this reason, males are very unlikely to leave historic leks, regardless of habitat quality or disturbance. Unless a particular human activity results in direct adult mortality, local lek counts may not decline for many years following a particular fragmentation event. An often-cited example of this behavior involves Greater Sage-grouse cocks observed strutting on the busy airport runway in Jackson Hole, WY. The runway was constructed over an historic lek, yet cocks continued to display on the site for many years because there is little alternative habitat in the small, isolated valley (P. Deibert 2004, pers. comm.).

Third, the population of GPCHs inhabiting this particular study site is considered very robust compared to other studies of Prairie Grouse. Lek counts in the small study area are known to be as high as 40 birds/lek. Given the small habitat scale and high density of both leks and birds per unit area, it is clear that amount of habitat, and not necessarily survivability, is a primary limiting factor constraining this population. Consequently, birds within this population are likely to be observed in all portions of useable space, and anecdotal sitings near the wind turbines neither confirm nor deny prairie grouse tolerance of commercial wind facilities in more typical habitats. However, these sitings offer the possibility that prairie grouse may be more tolerant of wind turbines than current research data suggest (S. Harmon 2004 pers. comm., B. Obermeyer 2004 pers. comm.). The preliminary findings also imply that, if other factors are not limiting to GPCHs, turbines might not be avoided elsewhere. However, while birds may persist near turbines, survival of those individuals may be compromised, resulting in a population decline. Until more studies are conducted, we can only speculate about cause-and-effect and survivorship (B. Millsap 2004 pers. comm.).

Because Prairie Grouse are relatively long-lived birds (often 3-6 years), and because they exhibit high site fidelity and clumped distribution on the landscape, the Service cautions that anecdotal sitings of individuals near wind turbines are neither unexpected nor informative about the cumulative effects of structural avoidance and habitat fragmentation on populations as a whole. Comprehensive, long-term studies in unconstrained habitats are essential to determining what level of habitat avoidance can be expected in response to wind turbine construction in occupied Prairie Grouse range (S. Harmon 2004 pers. comm.).

Patten *et al.* (2004b:1-2, 32) examined habitat fragmentation and its impacts on GPCH. Because of virtually no habitat fragmentation and a high continuity of tallgrass prairie in their study area, their estimate of home range size was determined to be the smallest of any study for this species. The minimum habitat size needed to avoid impacts to GPCHs in their study area was estimated at about 38.5 mi^2 (99.7 km^2). If the hypothetical contiguous block were a circle (Figure 4), its radius would be 3.5 mi (5.6 km) in length from a lek located in its center. When we incorporated an additional minimum 1.25-mi (2 km) protection zone recommended by Hagen *et al* (2004:79), the area of the larger circular home range is 70.9 mi^2 (184.3 km^2). If this area represented a hypothetical square home range (Figure 3), its boundaries would be approximately 6.2 x 6.2 mi (10 km) and a lek located in its center would be 3.1 mi (5 km) from the nearest side.

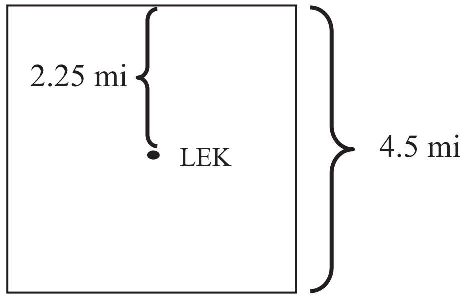


Fig 3. 20 mi^2 home range.

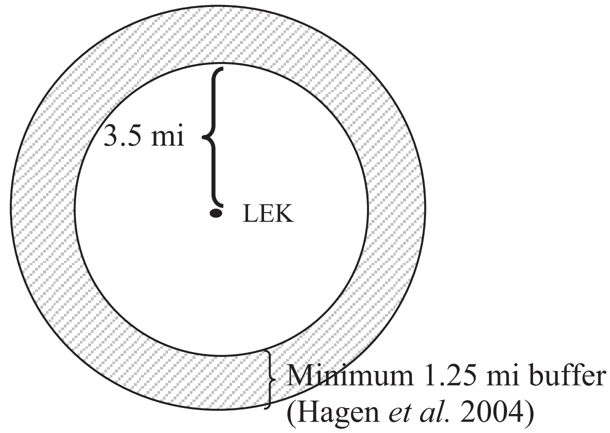


Fig 4. 38.5 mi^2 protected habitat using 3.5 mi radius from lek; with additional buffer zone recommended by Hagen *et al.* (2004), protected area = 70.9 mi^2.

Figures 3 and 4 show the minimum area of un-fragmented habitat necessary to maintain a local population of GPCH (S. Harmon 2004 pers. comm., B. Obermeyer 2004 pers. comm., after Patten *et al.* 2004b:1-2,32).

Results of the Patten *et al.* (2004b:2, 32) study predict that increased habitat fragmentation will force individual GPCHs to expand their home range, resulting in a decrease in survivorship from more predation, collisions, and energy expenditures.

Sage-grouse

Connelly *et al.* (2000) recently revised and expanded the guidelines for the management of Sage-grouse, originally published by Braun *et al.* (1977). Based on seasonal movements among populations, Connelly *et al.* (2000:969) summarized the 3 types of Sage-grouse populations: 1) those which are non-migratory and do not make long-distance movements (*i.e.* > 6 mi [10 km] one-way), 2) those which exhibit one-stage migration between 2 distinct seasonal ranges, and 3) those which exhibit 2-stage migration among 3 distinct seasonal ranges. Connelly *et al.* (2000:969) further reported that migratory Sage-grouse can occupy areas in excess of 1,042 mi^2 (2,700 km^2). Connelly *et al.* (2000:977-978) developed recommendations for habitat protection upon which, in part, the Service's guidance is based. Specifically, for non-migratory populations occupying habitats that are uniformly distributed, they recommended protecting sagebrush and herbaceous understory within 2 mi (3.2 km) of all occupied leks. For non-migratory populations, leks should be considered the center of year-round activity and treated as the focal points for management activities. For non-migratory populations where sagebrush is not uniformly distributed, suitable habitats should all be protected out to 3.1 mi (5 km) from all occupied leks. For migratory populations of Sage Grouse, breeding habitats within 11.2 mi (18 km) of active leks should be protected, recognizing that nesting birds may move > 11.2 mi (18 km) from leks to nest sites. This recommendation (Figures 5 and 6) obviously represents a protected area much larger than the 5-mile suggestion by the Service. While Connelly *et al.* (2000) made a distinction between resident and migratory (2 types) populations, in radio telemetry research conducted by Hall in Lassen County, CA, from 1998-2001 (F. Hall 2004 pers. comm.), his team discovered that some Sage-grouse populations include both resident and migratory birds down to the individual lek level. Specifically, they found resident, 1-stage and 2-stage females present on each of 9 leks (unpublished data). Populations are not always either resident or migratory.

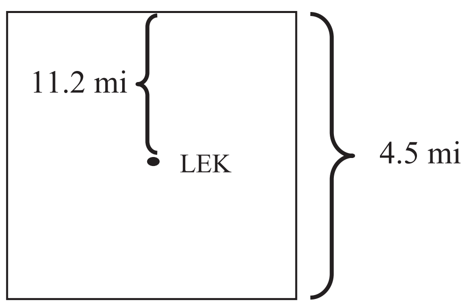


Fig 5. 502 mi^2 home range.

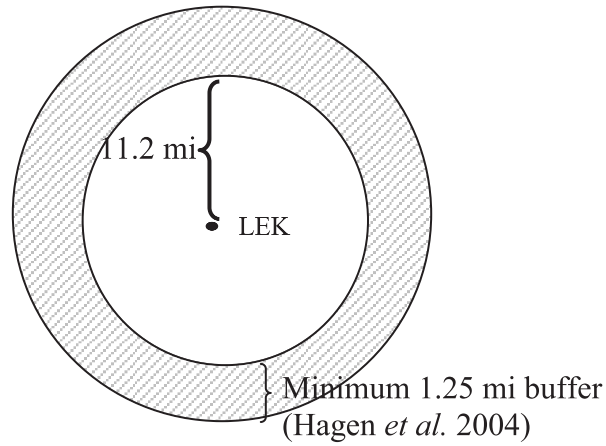


Fig 6. 394 mi^2 protected habitat using 11.2 mi radius from lek; with additional buffer zone recommended by Hagen *et al.* (2004), protected area = 486.95 mi^2.

Figures 5 and 6 illustrate the recommended protected breeding habitat for migratory populations of Sage-grouse based on a hypothetical square and circular home range, after Connelly *et al.* (2000:978) with buffer suggested by Hagen *et al.* (2004:79).

C. Braun (2004 pers. comm.) provided further comment on the recommendations discussed by Connelly *et al.* (2000:978) above (he was a coauthor of this article). For non-migratory populations of Sage-grouse, he felt a distance of 2 mi (3.2 km) was sufficient to protect breeding habitat from leks where no habitat disturbance was present. Where habitat disturbances were noted, he recommended a 3-mile (5 km) no-disturbance zone. For migratory populations, he reiterated Connelly *et al*'s 11-mile (18 km) no-disturbance zone from active leks. These recommendations he felt were based on "best professional judgment" and should change only when "no impacts could be demonstrated" by industry for zones of disturbance of lesser distance from leks. Wind generators, he indicated, were quite tall and could be seen and avoided by Sage-grouse for long distances. Noise (especially humming), motion, and height all may negatively affect Sage-grouse, although he indicated we still don't know the specific effects. Braun therefore felt that FWS could defend our 5-mile recommendation even though definitive data showing impacts are still being collected. C. Aldridge (2004 pers. comm.) also felt the Service's 5-mile distance recommendation "was reasonable" and represented an adaptive management approach by the FWS. He indicated that it was in "everybody's best interest to err on the safe side" especially due to issues regarding avoidance (including known and unknown impacts), landscape effects of wind and other structures, and the simple occurrence of birds versus their overall survival.

For the biologists who have worked on Sage-grouse for some time, it was noted that birds seem to be especially susceptible to disturbance and will often abandon nests even in later stages of incubation. Certainly wind turbine construction and maintenance activities fall under the category of "disturbance" (J. Connelly 2004 pers. comm.).

Connelly *et al.* (2004) published the most comprehensive, science-based synthesis of the Greater Sage-grouse and its habitat needs yet conducted. While the Conservation Assessment did not provide minimum distance recommendations from wind turbines, it did discuss wind energy development as one of several factors that could impact sagebrush ecosystems and thereby Sage-grouse. Noise from wind turbine rotor blades and bird mortality were cited as issues of concern regarding wind energy (Chap. 7:42-43). Connelly *et al.* (2004) were not optimistic about the future of Sage-grouse because of long-term population declines coupled with loss and degradation of habitat and other factors such as disease (ES:5). They also raised concerns about the distribution, configuration, and characteristics of Grouse migration corridors which unfortunately are largely unknown in most portions of the Sage-grouse range (Chap. 4:19). Disturbance issues were also discussed regarding lek distribution and highways (Chap. 13:12-13. Lyon and Anderson (2003) further documented effects of disturbance on breeding Sage-grouse.

Braun *et al.* (2002:345, 346) reported that the sagebrush-obligate species, Gunnison and Greater Sage-grouse, were particularly susceptible to noise near leks and to the placement of overhead power lines at least 0.5 mi (0.8 km) from any Greater Sage-grouse breeding and nesting grounds. Development was viewed as a negative impact in this study, characterized by a loss of habitat and disturbances associated with structures, roads, and noise – especially during the breeding season.

F. Hall (2004 pers. comm.) in a Lassen County, CA study on Greater Sage-grouse has recently documented significant impacts from overhead power transmission and communication distribution lines to this species out to 3.7 mi (6 km). When these lines are placed near turbines, they could provide perches for Golden Eagles and nest sites for Common Ravens. This concern coincides with the Service's recommendation (see Turbine Design and Operation, no. 4, p. 4) to place electric power lines underground or on the surface as insulated, shielded wire to minimize strike and electrocution problems.

In a related study, Popham and Gutierrez (2003:331, 332) radio-tagged 65 female Greater Sage-grouse in northern CA of which 45 radio-tagged hens were tracked to their nests. Successful grouse nests were located farther from the nearest lek (2.2 mi [3.6 km], SE= 811 m) than were nests that were unsuccessful (1.2 mi [1.96 km], SE=384 m; p. 331). Others, however, have not noticed this difference (J. Connelly 2004 pers. comm.). Popham and Gutierrez noted that native shrub-steppe habitat had been degraded due to excessive grazing, juniper encroachment, agriculture, and anthropogenic development.

Results from the Popham and Gutierrez study represent a portion of the entire ongoing project being conducted by Hall and his team in Lassen County, CA (F. Hall 2004 pers. comm.).

Johnsgard (2002:116) indicated that there was no obvious relationship between lek location and nest site. In 5 different studies involving more than 300 nests the average distance between lek and Sage-grouse nest where the females was first seen or captured was 3.5 mi (5.6 km). This distance is greater than the mean interlek distance from several studies, which ranged from 0.8- 3 mi (1.3- 4.8 km; Wakkinen *et al.* 1992, Johnsgard 2002:116, J. Connelly 2004 pers. comm., R. Hazlewood 2004 pers. comm.).

Columbia Sharp-tailed Grouse

Disturbance to Sharp-tailed Grouse was reported by Baydack and Hein (1987:538) in southwestern Manitoba. While males were reported present during disturbances (*e.g.*, parked vehicles, propane exploders, scarecrows, taped voices, radio sounds, and a leashed dog), female Sharptails were not observed on leks during test disturbances. Disturbance appeared to limit reproductive opportunities for both sexes. They concluded that continued disturbance over several seasons could bring about population declines.

Giesen and Connelly (1993) reported on movements and management needs of Columbia Sharp-tailed Grouse in the West. While wind turbines were unavailable to assess during this time frame, reported Grouse movements between breeding areas and winter range – varying from 1.6 mi (2.6 km) to 12.4 mi (20 km) depending on study and location (p. 327) – could be impacted by current and proposed wind development. They specifically indicated the lack of experimental data on the effects of habitat alterations on this species. Among their recommendations, Giesen and Connelly (1993:331) suggested avoiding vegetation manipulation within a 1.25-mi (2 km) radius of the active lek in order to protect the nesting and brood-rearing habitats of this Sharp-tailed Grouse.

Suitable But Abandoned Habitat

During periods of population decline, prairie grouse may abandon lekking sites in smaller, fragmented habitats and congregate into larger, more intact areas (core habitat). Given that many grouse species are currently at population lows, human development of suitable but abandoned prairie grouse habitat could severely impede efforts to restore their numbers. In other words, protection of core prairie grouse habitat through the use of the Service's 5-mile buffer is a conservative approach (B. Obermeyer 2004 pers. comm.).

Obermeyer and Applegate (unpublished data) located 31 active GPCH leks in a 181-mi^2 area (465 km^2, 115,000 acres) of native rangeland in eastern Greenwood County, KS, during spring of 1997. Lek influence within the study area, as defined by a 1.9-mi (3-km) radius, was 152.6 mi^2 (391.4 km^2; Figure 7). Generally, the stronger leks were located in the more unfragmented areas of native rangeland. A much larger zone of lek influence at this study area was noted just a few years previous. Lek distribution along the western boundary shrank by approximately 6 miles between 1987 and 1997 (B. Obermeyer 2004 pers. comm.). Development of suitable but abandoned prairie grouse habitat (*e.g.*, unoccupied, historical leks) could seriously impede prairie grouse restoration efforts.

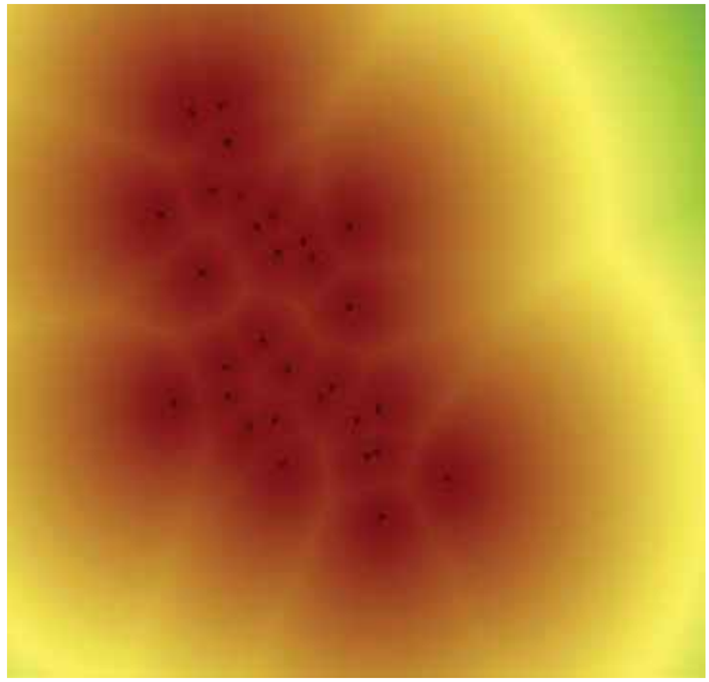


Figure 7. Dots represent 1997 locations of GPCH leks within a 115,000-acre block of tallgrass prairie in KS. Yellow area = ~237 mi^2 (608 km^2; unpubl. data).

Concerns for Other Grassland and Shrub-Steppe Avifauna in Relation to Wind Energy Development

Manes *et al.* (2004 manuscript in preparation, R. Manes, S. Harmon, B. Obermeyer, and R. Applegate 2004 pers. comm.) summarized the documented effects of wind facilities on birds, indicating that Golden Plovers and Lapwings had been displaced by as much as 0.5 mi (0.8 km) from wind facilities in Denmark (citing Pederson and Poulsen 1991) while in Netherlands, Lapwings and Curlews avoided areas within 0.15-0.3 mi (0.25 – 0.5 km) of wind turbines (citing Winkelman 1990).

Although focused on grassland passerines rather than prairie grouse, Leddy *et al.* (1999:101) recommended placing wind plants within cropland habitats in MN rather than in native grasslands. Research at the Buffalo Ridge Project in southwestern MN revealed that the Bobolink, Red-winged Blackbird, Savanna Sparrow, and Sedge Wren nested in densities 4 times higher in grasslands that were ~ 600 ft. (180 m) from wind turbines than those within ~ 260 ft (80 m) of turbines. Densities beyond 600 ft. were not evaluated (Leddy *et al.* 1999). Because of the trend for larger turbines, avoidance zones adjacent to the new generation turbines may differ from those of previous studies (R. Manes, S. Harmon, B. Obermeyer, and R. Applegate 2004 pers. comm.). Sage-steppe-obligate songbirds (*e.g.*, Sage Sparrow, Brewer's Sparrow, Sage Thrasher, and Black-chinned

Sparrow) are also showing population declines and management concerns should also focus on these species.

The Service asserts that by avoiding or minimizing construction of wind facilities in native prairie grasslands and native sage-steppe habitats, grassland- and sage-dependent native songbird species would be protected and habitat fragmentation would be avoided.

Service's Recommendation for 5-Mile Buffer from Leks

The intent of the Service's recommendation for a 5-mile zone of protection is to buffer against increased mortality (both human-caused and natural), against habitat degradation and fragmentation, and against disturbance. In considering our recommendation, FWS recognizes major declines in populations and habitats of prairie grouse. All species of prairie grouse are in varying stages of decline – some populations declining precipitously -- requiring a major focus on direct human impacts, disturbance from structures, and fragmentation of habitats. While wind plants are new additions to prairie grouse habitats in the Midwest and West, cumulative impacts from human development and exploitation must be assessed with great care and considerable detail. To reverse these declines will take significant commitment from industry, the Service, and other stakeholders. We view the voluntary nature of our guidance and specifically our 5-mile recommendation as a reasonable effort needed to conserve these important resources.

While migratory populations of Sage-grouse may require in excess of 11 miles in radius of protected habitat from active leks (Connelly *et al.* 2000:978), it can be argued that LPCH may require protection less than being suggested by FWS (Mote *et al.* 1998:18; 2.5 mi [4.1 km] distance from a lek located in the center of a circular home range). However, rangewide the majority of remaining LPCH populations are fragmented and isolated into "islands" of open prairie. Our 5-mile setback is intended to protect both Prairie Chickens and the wind industry. Later wind turbine construction, for example, could if in close proximity to leks significantly impact Prairie Chicken populations. Habitat corridors between leks and population centers could also be impacted by close development, likely impacting future recovery. Our distance recommendation will also help address decreasing habitat patch sizes and diminishing habitat complexity that will be affected as structures become more abundant and roads, power lines, vehicles, and human disturbance further fragment and impact habitats. Current distance recommendations for LPCHs may simply reflect the "tolerance" level of LPCHs to "structures" in fragments of < 12,350 ac (5,000 ha) in size of moderate complexity (C. Hagen 2004 pers. comm.). As patch size becomes smaller and less complex, the LPCH may likely be less tolerant of disturbance. Until data can support an alternate hypothesis, Hagen (2003:159) and C. Hagen (2004 pers. comm.) suggested protecting as large a buffer as possible for LPCH. Again, the Service's 5-mile recommendation seems reasonable (Figures 7 and 8) and applicable to all species of prairie grouse. As the necessary research is conducted to more clearly define the effects on grassland and sage-steppe species and as new data become publicly available, we will use it to refine our recommendation.

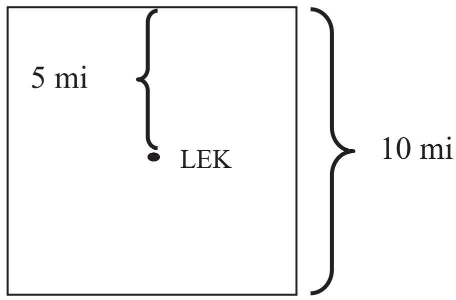


Fig 7. 100 mi^2

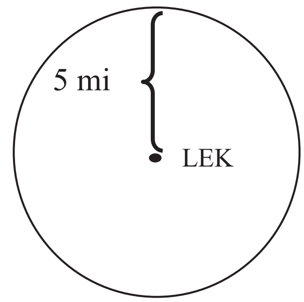


Fig 8. 78.5 mi^2

Figures 7 and 8. FWS summary of recommended 5-mile protection zone from active leks for populations of prairie grouse based on hypothetical square and circular home ranges with centrally-located leks, after S. Harmon (2004 pers. comm.), Connelly *et al.* (2000:978), Pitman (2003), Hagen (2003), C. Hagen (2004 pers. comm.), Wolfe *et al.* (2003a and 2003b), Patten *et al.* (2004a and 2004b), C. Braun (2004 pers. comm.), C. Aldridge (2004 pers. comm.), F. Hall (2004 pers. comm.), and B. Obermeyer (2004 pers. comm.).

The results from and concerns raised by a March 2003 Kansas City, MO, workshop on "Great Plains Wind Power and Wildlife" were used as further evidence by the Service to take a precautionary approach in recommending our 5-mile distance (R. Manes 2003 pers. comm.).

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Suggested citation:

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BEFORE THE SOUTH DAKOTA PUBLIC UTILITIES COMMISSION

DOCKET NO. EL19-003

IN THE MATTER OF THE APPLICATION BY CROWNED RIDGE WIND, LLC FOR A PERMIT OF A WIND ENERGY FACILITY IN GRANT AND CODINGTON COUNTIES, SOUTH DAKOTA, FOR CROWNED RIDGE WIND FARM

Direct Testimony of Tom Kirschenmann
On Behalf of the Staff of the South Dakota Public Utilities Commission
May 10, 2019

EXHIBIT
Staff
S3

Q: State your name.
A: Tom Kirschenmann

Q: State your employer.
A: State of South Dakota, Department of Game, Fish, and Parks

Q: State the program for which you work.
A: Division of Wildlife, Terrestrial Resource Section

Q: State the program roles and your specific job with the department.
A: The role of the Terrestrial Resources section is to study, evaluate, and assist in the management of all wildlife and associated habitats. Management includes game and non-game wildlife populations, habitat management on public lands and technical assistance and habitat development on private lands, population and habitat inventory, and environmental review of local and landscape projects. As the Deputy Director of the Wildlife Division and Chief of the Terrestrial Resources Section, I oversee and am involved with wildlife management and research, as well as habitat management consisting of the department's public lands and private lands programs.

Q: Explain the range of duties you perform.

A: Duties include leading the Terrestrial Resources section that includes three program administrators (Wildlife, Habitat, Wildlife Damage) and 23 wildlife biologists; coordinate and assist with the Division of Wildlife's Operations at four administrative regions; oversee wildlife research, management, and the establishment of hunting seasons for game species; oversee private lands and public lands habitat programs; coordinate environmental review evaluations and responses related to terrestrial issues with department staff; serve as the Department's liaison for several state and federal agencies; and represent the Department on state and national committees.

Q: On whose behalf was this testimony prepared?

A: This testimony was prepared on behalf of the Staff of the South Dakota Public Utilities Commission.

Q: What role does the Department of Game, Fish and Parks have in the permitting process of a wind energy development project?

A: Game, Fish and Parks has no regulatory authority when it comes to permitting wind energy development projects. The agencies role is to consult with developers and provide recommendations and suggestions on how to minimize or remove potential impacts to wildlife and associated habitats or provide available information to make informed decisions as related to natural resources.

Q: Have you reviewed the Application and attachments? How else did you learn details around the proposed project?

A: Yes, relevant sections of the application and attachments and also discussed project details with GFP biologists who had more direct communications with the developer.

Q: Did the GF&P provide comments and recommendations to Crowned about the project area? Please identify who provided those comments and provide a brief summary of them.

A: Game, Fish and Parks was initially contacted in October 2007 by TetraTech to request a search of GFP listed threatened or endangered species, and any additional environmental concerns for the project area. A response was sent in December of 2007 by Silka Kempema, wildlife biologist. During this initial contact, information about species of concern and important or sensitive wildlife habitats in the project area were shared with the applicant. Additionally, in November 2007, Doug Backland, wildlife biologist provided a shapefile of threatened, rare, or endangered species present within the project area (natural heritage database review). In December 2009, TetraTech contacted GFP to request an additional natural heritage database review. Game, Fish and Parks provided a list of species occurrences for the project area. In November of 2010, Western Area Power Administration (WAPA) contacted GFP with a scoping notice for the Crowned Ridge Wind Energy Center in Codington County, South

Dakota. GFP replied to the WAPA scoping notice in January 2011 with a letter describing important wildlife habitats (grasslands, wetlands, etc.), information about rare, endangered or threatened species that could occur in the project area as well as general wildlife survey guidelines. In March 2014, GFP provided historic grouse lek locations in and around the project boundary. Game, Fish and Parks was contacted by TetraTech in February 2015 requesting information regarding ecologically significant areas and listed endangered, threatened or special concern species at a potential wind energy development site in Codington and Grant Counties, South Dakota. Game, Fish and Parks staff replied to their request in March 2015 with a letter describing ecologically sensitive areas in the project area and advising an up-to-date Natural Heritage database request, based on the amount of time that passed since the previous request. Information was also included about important wildlife habitats, avoidance of turbine placement in and around public lands, recommendations on transmission line construction and general wildlife survey guidelines for pre and post construction surveys. In March 2017, GFP was first contacted by Nextera, and Ms. Kempema recommended an in-person meeting for the opportunity to review proposed turbine layout and wildlife surveys that had been conducted to-date. In April 2017, a conference call with GFP, USFWS and Nextera was conducted to share a project overview, as well as results from wildlife surveys. During this conference call, Ms. Kempema recommended Nextera avoid placing turbines in untilled grasslands and wetlands, and recommended a 1 mile no-construction buffer around grouse leks. Ms. Kempema also requested a copy of any wildlife survey reports, and recommended a site-visit with GFP and USFWS. In July 2017, GFP received a request from SWCA Environmental Consultants to request information regarding ecologically sensitive areas and federally and state listed endangered, threatened or special concern species in the Crowned Ridge project area. Results from a natural heritage database search was provided to SWCA in August 2017. On April 3rd, 2019, SWCA Environmental Consultants requested information regarding ecologically sensitive areas and federally and state listed endangered, threatened or special concern species in the Crowned Ridge project area. Results from a natural heritage database search were provided to SWCA on April 26th 2019.

Q: Do you agree with the comments and recommendations provided to Crowned Ridge by Ms. Kempema? If not, please explain.

A: Yes. These are typical discussion topics and recommendations our Department would share with wind power companies to identify, minimize, or reduce impacts to wildlife and wildlife habitats, especially those projects that are proposed in grassland and wetland habitats.

Q: Based on the information provided in the Application, in your opinion did Crowned Ridge utilize the proper studies and wildlife surveys

necessary to identify potential impacts to the terrestrial environment?

A: Pre-construction wildlife survey data usually incorporates a small snap-shot in time (ex. monthly large bird counts) but is used to assess risks for the life of a project (~30 years) therefore, it is important to perform surveys with a high degree of scientific rigor. The US Fish and Wildlife Service (USFWS) Land-Based Wind Energy Guidelines (hereafter referred to as USFWS guidelines) are intended to encourage scientifically rigorous survey, monitoring, assessment and research designs, produce potentially comparable data across the nation, and improve the ability to predict and resolve effects of wind energy development locally, regionally and nationally. These guidelines, along with GF&P siting guidelines (https://gfp.sd.gov/userdocs/docs/SDSitingGuides_2018-10-17.pdf) are voluntary suggestions (USFWS 2012).

Survey methods used by Crowned Ridge followed the USFWS guidelines, and were reasonable and appropriate. Crowned Ridge conducted aerial raptor nest surveys, avian use surveys, large bird use surveys, grouse lek surveys, bat acoustic surveys, bat habitat assessments and an endangered butterfly habitat assessment.

Q: **What are the potential impacts to wildlife as a result of the construction of a wind project?**

A: Direct; birds and bats can be killed by turbines due to direct strikes. Indirect; some species may be displaced from otherwise suitable habitat around turbines and roads. A research project on the effects of wind energy on breeding grassland bird densities in North and South Dakota showed seven of nine species of grassland birds had reduced densities around wind turbines over time (Shaffer and Buhl 2016).

Q: What potential impacts to wildlife habitat can result from a wind project?

A: Permanent loss; habitat is permanently converted to turbine pads, roads or buildings. This is often a small percent of the total project acreage (area define by wind easements or otherwise defined project boundary). Temporary loss; habitat is disturbed for a time during construction (e.g. widened roads, crane paths) but is restored. Fragmentation; habitat fragmentation is the division of a block of habitat into smaller, and at times into isolated patches. Habitat fragmentation can decrease the overall value of the remaining habitat.

Q: Can you suggest methods to address temporary and permanent changes to habitat?

A: Temporary impacts to habitat resulting from construction activities likely can be reclaimed by restoring impacted areas by grading and reseeding. Disturbed areas should be restored using native seed sources to reduce the introduction of new or discourage encroachment of already present exotic and/or invasive species.

For those areas that are permanently changed, lost grassland or wetland acres could be addressed through consideration of mitigation options. Disturbed areas again should be restored using native seed sources to reduce the introduction of new or discourage encroachment of already present exotic and/or invasive species. It would also be recommended that if lost acres are replaced to carry out these replacement activities in the closest possible proximity of the project.

Q: Are there any other impacts besides temporary and permanent habitat impacts that are likely to occur as a result of the project?

A: Indirect habitat impacts are also a consideration. Potential indirect impacts created by wind turbines and associated infrastructure raise concerns with habitat fragmentation and potential displacement, especially with regards to breeding grassland and wetland species. Research into the effects of wind energy on habitat avoidance has shown that some species will not use grassland or wetland habitat within a certain distance of a wind turbine (Loesch et al. 2013, Shaffer and Buhl 2016).

Q: Did GFP have any wildlife or habitat concerns regarding the proposed Crowned Ridge project? If yes, what are they?

A: Yes. The area of primary interest is the potential impacts to the various grassland habitats and associated wildlife.

Q: **Did GFP provide any recommendations to avoid wildlife and habitat impacts from Crowned Ridge? If yes, what were they?**

A: Yes. The primary recommendations were to site turbines and associated infrastructure in cropland, minimize fragmentation, utilize existing infrastructure and avoid siting turbines in grasslands, and completion of post-construction surveys for bat and bird mortality which could be used in assisting with operational adjustments in the future.

Q: Are there different types of grasslands?

A: Yes.

Q: Please describe the following: native prairie, hayland, pasture, CRP, and cropland.

A: Grasslands are areas that contain plants species such as graminoids and commonly used for grazing or set aside for conservation purposes. They can also be areas which are planted to a mixture of grasses and legumes for livestock grazing or feed. Native prairie is grassland upon which the soil has not undergone a mechanical disturbance associated with agriculture or any other type of development. Hayland is grassland that is managed by frequent mowing and often contains non-native plant species either intentionally or by encroachment. Pasture is grassland that may contain non-native plant species either intentionally or by encroachment and is managed by through grazing. In some instances hayland and pasture could be native prairie; in other situations hayland and pasture in particular could be land once cultivated and restored to grassland habitat. Conservation Reserve Program acres (CRP) is grassland that occurs on land that was once tilled and used for crop production and has now been seeded to herbaceous cover to address soil loss, water quality, and provide wildlife habitat. Cropland could be described as agricultural lands cultivated and used to grow crops such as corn, soybeans, small grains, and others.

Q: **Are there any areas of native prairie in the proposed project?**

A: Yes. Spatial analysis conducted by Bauman et al. (2016) has identified potentially undisturbed lands within the proposed project boundary. This is one of the best available spatial data sets representing the location of untilled native grasslands. The applicant also identified within the application an estimated 17,889 acres of untilled grassland within the project area (pg. 49).

Q: Do grasslands other than native prairie have conservation value?

A: Yes. Given the loss of native prairie, working grasslands like pasture, hayland, and conservation grassland plantings serve as surrogates for native grasslands.

Q: To your knowledge, are there grazed grasslands in the project area?

A: Yes.

Q: Do grazed grasslands have any conservation value and what is the impact to grassland wildlife?

A: All grasslands have a conservation value, including those managed through grazing. Grassland birds require a diversity of grassland types and structure to complete life-cycle requirements. Studies have shown that grassland birds respond primarily not to variation in plant species composition but to the structure that these plants provide. Grassland birds have evolved with a gradation of grazing intensities. Grassland wildlife diversity can be maximized by creating a heterogeneous landscape comprised of short, medium and tall vegetation structures. Grazing (haying and burning) management can provide this variation in vegetative structure. Changes in land management and annual precipitation levels can alter plant species composition and vegetation structure of grassland within a short timeframe.

Q: One of the GF&P's recommendations was that efforts should be made to avoid placement of turbines and new roads in grasslands, especially untilled native prairie. Based on the information in the Application and the proposed turbine layout, did Crowned Ridge demonstrate efforts to address this recommendation? Please explain.

A: Data from the application indicates that 17,889 acres of the 53,186 acre project area is native prairie habitat. From reviewing the available maps, resources, and other information available there were efforts to avoid placement of turbines on untilled native prairie as approximately 19 of the planned 130 turbines appear to be positioned in native prairie. A continued recommendation for wind development is to avoid untilled native prairie habitat to the greatest extent possible. It appears that multiple turbines are being planned in cultivated land (disturbed) which from a wildlife perspective is a positive siting approach. Some turbines will likely be placed on other types of grassland habitats (hay and pasture) within the project area. Avoidance of all grassland habitat will be challenging in this part of the state and in the project area as a high proportion of the total area is some type of grassland/herbaceous habitat as demonstrated by the application indicating that project construction easement is 26% grass/pasture (page 47).

Q: One of GF&P's concerns around wind farm development is the fragmentation of contiguous blocks of grasslands. Why is fragmentation a concern?

A: Fragmentation results in the direct loss of habitat and diminishes the value of remaining habitat. Habitat fragmentation is the division of large contiguous blocks of habitat into smaller, and in some instances isolated patches. Identification of contiguous blocks of habitat, especially in predominantly non-habitat landscapes is an important component of grassland and wetland bird conservation.

Q: Are there any areas of contiguous grassland habitat in the proposed project?

A: Yes. The northeastern portion, central portion and northwestern portion of the proposed project area have the highest level of contiguous blocks of grassland habitat.

Q: Based on the information available does the GF&P have concerns over the placement of turbines and roads in contiguous blocks of grassland?

A: Based on reviewing available information, fragmentation of grassland habitats were avoided/minimized in some of the project area through the proposed layout of the infrastructure of the wind farm. This is a result of primarily utilizing tilled agricultural fields for turbine locations. There are other locations of the project area which the placement of turbines will likely create some level of fragmentation of smaller grassland blocks (comprised of different grassland cover types: hay, pasture, etc.). Based on the location of the project area and the existing land-use, it will be challenging not to create some additional fragmentation of grassland habitat, and in some situations larger contiguous blocks comprised of different grassland cover types.

Q. Does the state or GF&P have specific mitigation recommendations that will minimize or compensate potential impacts from wind energy development if they cannot be avoided?

A. At the current time South Dakota does not have a state mitigation policy that can be provided to wind energy developers. However, there are resources available which can provide guidance and suggestions that can be considered as well as self-imposed actions or activities that can minimize natural resource impacts.

Q: What are potential mitigation considerations?

A: Mitigation can take multiple forms and accomplished in a multitude of ways. It could be an approach which implements an applied management activity/strategy on impacted lands which elevates these lands to a more productive state or higher ecological state (example – grazing management) to an approach which is more sophisticated and detailed using tools developed to calculate acres of habitat to be restored or created based on impacted acres and other relevant research data (example – decision support tool). Two examples that are available specifically for wind energy projects is a decision support tool based off the research conducted by Loesch et al. (2013) that considers breeding waterfowl and another which focuses on breeding grassland songbirds resulting from research findings of Shaffer and Buhl (2016). As stated earlier South Dakota does not have a state mitigation policy nor does the state endorse either study and resulting products, however it is worthy of mentioning these tools demonstrating resources available to developers and managers.

Q: The GF&P recommended that turbines should not be placed in or near wetland basins and special care should be made to avoid areas with high concentrations of wetlands. Do you believe that Crowned Ridge's proposed turbine layout incorporates this recommendation?

A: The application mentions under mitigation measures for wildlife that wetlands will be avoided or minimize disturbance of individual wetlands during project construction. These are appropriate measures. No turbines are planned in wetland basins. Reviewing the turbine layout and using NWI wetland information for the project area, some turbines appear to be placed in areas of higher concentrations of wetland basins (specifically in the central and eastern portions of the project). It will be challenging to avoid areas of wetland concentrations because of the number of wetland acres and basins found in this part of the state and project area. Recommendations to avoid areas of higher concentrations of wetlands is supported by findings from Loesch et al. (2013).

Q: Are you aware of any other wind farms near this proposed project?

A: Yes. I am aware of projects in the area by reviewing the map of wind projects found on the PUC website indicating projects either in the status of existence, proposed, pending, or under construction.

Q: Does the GF&P have any thoughts regarding the potential for cumulative impacts the Project may have?

A: As projects are completed and based on location and proximity to other projects, the question of cumulative impacts will become more apparent. Knowing the importance of native prairie tracts and other forms of grassland habitat to several grassland dependent species, continued development on these types of lands could result in reduced or limited habitat value. Placement of turbines in lands currently under cultivation and avoiding where possible the different varieties of grassland and wetland habitats will help minimize potential cumulative impacts.

Our agency will continue to work with wind developers and provide recommendations that we believe will help minimize cumulative impacts.

No different than offered to this project, the focus could include, but not limited to, recommendations on avoiding grassland habitats, in particular native prairie remnants, avoidance of high wetland complex areas, maximize the use of existing corridors for infrastructure, and pre and post construction surveys to assess the proposed project area that may assist in operational decisions.

Q: Do any State threatened or endangered species have the potential to be impacted by the wind farm?

A: There are two records of the state threatened Northern River Otter adjacent to the project boundary. Filing a storm water pollution prevention plan and putting in place practices to reduce or eliminate sedimentation will help negate potential negative impacts to Northern River Otters that may be in or near the project area.

Q: Are there any GF&P lands or other public lands that may be impacted by the wind farm?

A: It does not appear any Game Production Areas within the project area will be impacted by the project. There are six walk-in-area parcels within the project area; three turbines are planned on these properties. These properties are privately owned and an agreement with GFP opens them to free public access for hunting. Should a Walk-In Area be temporarily disrupted for construction, GFP would ask we are involved with those discussions to determine whether any action required from our agency to notify the public.

For clarification, Game Production Areas and Waterfowl Production Areas are not private land leased by GFP. Game Production Areas are owned by the State of South Dakota and managed by GFP. Waterfowl Production Areas are publicly owned and managed by the US Fish and Wildlife Service.

Q: Does the GF&P have any recommendations to protect those GF&P lands or other public lands?

A: The state does not have an established set-back policy or recommendation for wind turbine placement in proximity to state properties such as Game Production Areas. Set-back policies have been established at local levels by local government entities and in some instances have been suggested as the potential set-back distance from state properties. At this time it is the state's belief that these types of policies be established at the local level and at the discretion of the PUC Commission to impose such set-backs when considering wind energy permits.

Q: If the final turbine locations changed from those provided in the proposed turbine layout, could the potential terrestrial environment impacts change?

A: Yes.

Q: You mentioned the applicant requesting data from the Natural Heritage Database. What is the South Dakota Natural Heritage database? What type of information does it contain?

A: The South Dakota Natural Heritage database tracks species at risk. Species at risk are those that are listed as threatened or endangered at the state or federal level or those that are rare. Rare species are those found at the periphery of their range, those that have isolated populations or those for which we simply do not have extensive information on.

This database houses and maintains data from a variety of sources including site-specific surveys, research projects and incidental reports of species that cover a time period from 1979 to the present. It is important to note that the absence of data from this database does not preclude a species presence in the proposed project area.

Q: In summary, does GF&P offer any specific permit recommendations should the permit be granted?

A: Game, Fish & Parks would suggest performing post-construction avian and bat mortality monitoring for at least two years; one year of post-construction surveys is currently proposed by the developer in the PUC application to confirm operational trends are consistent with previously observed trends for other projects in the region. That consistency would have more assurance with two years of data.

Additionally, GFP recommends post-construction grouse lek monitoring of confirmed leks less than 1 mile from proposed turbines. This data could be useful information for future discussions around cumulative effects of wind energy development on prairie grouse. We also recommend consultation between the developers, GFP and the US Fish and Wildlife Service on proposed survey methodology for post-construction lek monitoring. GFP would request a copy of any future report to be shared with the US Fish and Wildlife Service and GFP.

Q: Does this conclude your testimony?

A: Yes.

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Education:

Eureka High School, Eureka, SD, 1989
BS: Wildlife and Fisheries Sciences, South Dakota State University, May 1993
MS: Wildlife Management, South Dakota State University, May 1996

Certifications:
Certified Wildlife Biologist, The Wildlife Society, July 2000
Level III Career Development Training, SD GF&P, 2007

Experience:

SOUTH DAKOTA GAME, FISH, AND PARKS, Pierre, SD
Wildlife Division Deputy Director (2016 - present) & Chief of Terrestrial Resources (11/08 - present)
Supervisor: Tony Leif, Director, Division of Wildlife, 605-773-4518

- Serve as the Wildlife Division's Deputy Director to assist with the overall management of the Division.
- Coordinate the management and research of game and non-game species statewide.
- Coordinate the management of the Departments habitat programs, including the private lands programs, public lands management, access programs, terrestrial environmental assessments, and programs related to the federal Farm Bill.
- Oversee a staff that includes a Program Administrator for Wildlife, Habitat and Wildlife Damage programs and 23 biologists.
- Serve as the Department's liaison or representative for several state and federal agencies and associated committees.
- Coordinate with non-government organizations, constituency groups, and agricultural groups on resource management programs, projects, and issues.
- Manage an annual budget of approximately $16M which includes research, direct payments to landowners for habitat, hunting access, and wildlife damage, and contracts to complete surveys, programs, and projects.
- Lead rules promulgation process for respective duties by presenting to the GFP Commission and assisting in writing administrative rules.

SOUTH DAKOTA GAME, FISH, AND PARKS, Pierre, SD
Wildlife Program Administrator, Game Management (12/07 – 11/08)
Supervisor: George Vandel, Assistant Director, Division of Wildlife, retired

- Coordinated the management and research of all game species statewide.
- Coordinated the accumulation and organization of data and regional suggestions in the development of hunting season recommendations.
- Drafted action sheets and present season recommendations to GF&P Commission.
- Assisted with the development and a team member that reviews hunting season applications and the Hunting Handbook.
- Supervised 9 biologists and 1 secretary stationed in five locations across the state.

- Served as department representative on committees (wildlife disease boards and poultry advisory board) and liaison to the SDSU Diagnostic Lab and APHIS Wildlife Services for Avian Influenza monitoring.
- "Press Release" review team member.
- Oversaw the Game Budget, including the contractual research projects with SDSU Wildlife and Fisheries Department and other academic institutions.
- Worked with the media addressing game and related issues, including live interviews, newspaper articles, and the writing of short articles.
- Team member in the development and implementation of the Mentored Hunting Program.
- Presented research and management information at regional meetings, Commission meetings, and to conservation organizations.

SOUTH DAKOTA GAME, FISH, AND PARKS, Huron, SD
<u>Sr. Wildlife Biologist</u> (1/05 – 12/07)
Supervisor: Tony Leif, Director, Division of Wildlife, 605-773-4518

- Oversaw management and research of upland game species statewide.
- Directed internal upland game research, analyses, and reports.
- Part of game staff committee that provided recommendations on all game seasons and license allocations.
- Served as Office Manager at the Huron GF&P District Office: directing day to day activities of Resource Biologist and Secretary within the Upland Game Section.
- Served as field co-leader with waterfowl biologist in the coordination of statewide Avian Influenza (AI) sampling.
- Worked with regional game staff on management, survey, research, and mortality projects.
- Administered the departments Wildlife Partnership Program for two years and provided guidance and direction upon request.
- Assisted with the coordination of meetings and trainings, including serving as chair person of the Prairie Grouse Technical Council (PGTC) meeting in October 2007.
- Served as department representative on several committees such as Midwest Pheasant Study Group, PGTC, Sage Grouse Council, Poultry Advisory Board (AI matters), and the National Wild Turkey Federation Technical Representative.
- Wrote management and scientific reports, as well as magazine and newspaper articles.
- Conducted presentations internally, as well as landowner and sportsmen club meetings.

PHEASANTS FOREVER, INC., St. Paul, MN
<u>Regional Wildlife Biologist</u>
South Dakota & Wyoming (4/00 – 1/05)
Illinois & Indiana (7/95 – 4/00)
Supervisor: Richard Young, VP Field Operations, 877-773-2070

- Established and maintained chapters comprised of grassroots volunteers and guided them in the development of habitat programs, fundraising efforts, and youth programs.
- Worked with chapters to develop wildlife habitat programs designed to fit the needs for both local and regional areas.
- Directed and assisted chapters with annual fund-raising events. Wrote grants to support local and state habitat efforts.
- Built partnerships between Pheasants Forever (both chapters and national) with local, state, and federal conservation agencies. Primary PF representative in developing SD Wildlife Habitat Extension Biologist (WHEB) program with SD GF&P and SD NRCS.
- Developed reporting system, submitted reports to GF&P, NRCS, and PF national, wrote grants, and some supervisory duties related to the WHEB program.
- Served on several state and federal habitat committees (State Technical Committee for both SD and WY, SD CRP sub-committee, WHIP sub-committee for SD and WY, SD School and

Public Lands, Northern Great Plains Joint Venture, Great Lakes and Upper Mississippi Joint Venture, IL Pheasant Fund Committee, IN DNR Gamebird Partnership Committee, IL DNR Conservation Congress).

- Organized and conducted wildlife habitat workshops for chapters, landowners, and other agency personnel.
- Established agenda, budget, and organized annual meeting for subgroup of co-Regional Wildlife Biologists, while serving as Mentor Group Leader.
- Wrote newspaper articles, interviewed for radio and TV shows, conducted presentations, and distributed newsletters.
- Educated volunteers about wildlife biology, habitat, wildlife interactions, and counsel on current, upcoming, and changes to state and federal conservation programs.

SOUTH DAKOTA STATE UNIVERSITY; Brookings, SD
Graduate Research Assistant (4/93 - 7/95; graduated 1996)
Supervisor: Dr. Daniel Hubbard, Professor, retired
Graduate Research Project.

- Research involved the comparison of avian and aquatic invertebrate abundances on conventional, organic, and no-till farming systems.
- Efforts included breeding waterfowl pair counts, waterfowl brood counts, wetland bird surveys, upland bird surveys, and aquatic invertebrate sampling.
- Other duties included surveying aquatic plants and collecting soil seed bank samples.
- Prepared bi-annual reports for USDA and EPA.

SOUTH DAKOTA STATE UNIVERSITY; Brookings, SD
Research Technician (3/92 - 8/92)
Supervisor: Diane Granfors, Graduate Research Assistant
Seasonal position.

- Assisted with wood duck study determining brood habitat and survival.
- Built, repaired, and placed wood duck nesting structures.
- Candled eggs, web tagged ducklings, banded hens, placed radio telemetry collars and acquired locations.

SOUTH DAKOTA STATE UNIVERSITY; Brookings, SD
Research Technician (10/90 - 3/91; 10/91 - 3/92)
Supervisor: Todd Bogenschutz, Graduate Research Assistant
Seasonal position.

- Aided on the research study that evaluated corn and sorghum as a winter food source for the ring-neck pheasant.
- Shared duties to feed pen birds on restricted diets.
- Sampled winter food plots.
- Assisted in extracting intestinal organs and taking anatomical measurements and weights.

SOUTH DAKOTA STATE UNIVERSITY; Brookings, SD
Research Technician (5/91 - 8/91)
Supervisor: John Lott, Graduate Research Assistant
Seasonal position.

- Worked on yellow perch food habit study.

- Used various equipment to sample fish and zooplankton. Aged fish and processed stomach contents. Sorted and tabulated zooplankton samples.

THE NATURE CONSERVANCY, Ordway Prairie, Leola, SD
<u>Intern/Preserve Worker</u> (5/90 - 8/90)
Supervisor: Andy Schollett, Preserve Manager
Seasonal position.

- Monitored grazing leases and rotations, conducted brome and prairie plant surveys, spraying of noxious weeds, fencing and general maintenance.

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Management and Conservation

Effect of Wind Energy Development on Breeding Duck Densities in the Prairie Pothole Region

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ABSTRACT Industrial wind energy production is a relatively new phenomenon in the Prairie Pothole Region and given the predicted future development, it has the potential to affect large land areas. The effects of wind energy development on breeding duck pair use of wetlands in proximity to wind turbines were unknown. During springs 2008–2010, we conducted surveys of breeding duck pairs for 5 species of dabbling ducks in 2 wind energy production sites (wind) and 2 paired reference sites (reference) without wind energy development located in the Missouri Coteau of North Dakota and South Dakota, USA. We conducted 10,338 wetland visits and observed 15,760 breeding duck pairs. Estimated densities of duck pairs on wetlands in wind sites were lower for 26 of 30 site, species, and year combinations and of these 16 had 95% credible intervals that did not overlap zero and resulted in a 4–56% reduction in breeding pairs. The negative median displacement observed in this study (21%) may influence the prioritization of grassland and wetland resources for conservation when existing decision support tools based on breeding-pair density are used. However, for the 2 wind study sites, priority was not reduced. We were unable to directly assess the potential for cumulative impacts and recommend long-term, large-scale waterfowl studies to reduce the uncertainty related to effects of broad-scale wind energy development on both abundance and demographic rates of breeding duck populations. In addition, continued dialogue between waterfowl conservation groups and wind energy developers is necessary to develop conservation strategies to mitigate potential negative effects of wind energy development on duck populations. © Published 2012. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS *Anas discors*, *A. platyrhynchos*, blue-winged teal, breeding population, mallard, Prairie Pothole Region, wind energy development, wind turbines.

Millions of glaciated wetlands and expansive grasslands make the Prairie Pothole Region (PPR) the primary breeding area for North America's upland nesting ducks (Batt et al. 1989). Wetland and grassland loss in the PPR due to settlement and agriculture has been extensive (Dahl 1990, Mac et al. 1998), and conversion to agriculture continues to reduce available habitat for breeding waterfowl and other wetland- and grassland-dependent birds (Oslund et al. 2010, Claassen et al. 2011). During recent years, anthropogenic impacts in the PPR have expanded to include energy development (e.g., wind, oil, natural gas; see Copeland et al. 2011: table 2.1). From 2002 to 2011, industrial wind energy production has increased 1,158% (i.e., 769–9,670 MW), 205% during the past 5 years (United States Department of Energy [USDOE] 2011). Impacts from wind energy development including direct mortality from strikes and avoidance of wind towers and associated infrastructure have been widely documented for many avian species, including raptors, passerines, upland gamebirds, shorebirds, and waterfowl, as well as bats (Drewitt and Langston 2006; Arnett et al. 2007, 2008; Kuvlesky et al. 2007).

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Wetland habitats in the PPR annually attract and support >50% of the breeding waterfowl population in North America (Bellrose 1980). The productivity and subsequent use of prairie wetlands by breeding ducks in the PPR are critical for the maintenance of continental duck populations (Batt et al. 1989, van der Valk 1989). Because of the potential for extensive wind energy development (USDOE 2008, 2011, Kiesecker et al. 2011), understanding the potential effect of wind power development on the use of wetland habitat by breeding duck pairs in the region is critical.

The potential impacts of wind energy development on breeding ducks are similar to other wildlife reviewed in Kuvlesky et al. (2007). Breeding pairs may abandon otherwise suitable wetland habitat, display behavioral avoidance thereby reducing densities of pairs using wetlands near wind turbines, and experience mortality from collision with turbines and associated infrastructure. Additionally, indirect effects on breeding ducks potentially include avoidance of associated grassland by nesting females, increased predation, or reduced reproduction. Wind towers and supporting infrastructure generally do not directly affect the wetlands that provide habitat for breeding ducks. However, ducks are sensitive to many forms of disturbance (Dahlgren and Korschgen 1992, Madsen 1995, Larsen and Madsen 2000). Avoidance related to the presence of towers, movement of blades (e.g., shadow flicker), blade noise (Habib et al. 2007), infrastructure development including roads and transmission lines (Forman and Alexander 1998, Ingelfinger and Anderson 2004, Reijnen and Foppen 2006), and maintenance activities have been documented for other avian species and may similarly affect breeding pairs and reduce the use of wetlands within and adjacent to wind farms.

The presence of wind energy development in high density wetland and breeding pair habitat in the PPR is relatively recent, and previous studies of the effects of land-based wind development on waterfowl (*Anatidae*) have focused primarily on collision mortality (Winkelman 1990, Johnson et al. 2000, Gue 2012) and the effect of wind farms on foraging behavior of wintering and migrating waterfowl (Winkelman 1990, Larsen and Madsen 2000, Drewitt and Langston 2006, Kuvlesky et al. 2007, Stewart et al. 2007). Wind development appears to cause displacement of wintering or migrating Anseriformes, and bird abundance may decrease over time (Stewart et al. 2007). However, habituation has been reported for foraging pink-footed geese (*Anser brachyrhynchos*) during winter (Madsen and Boertmann 2008). Displacement of duck pairs due to wind development could affect population dynamics similar to habitat loss (Drewitt and Langston 2006, Kuvlesky et al. 2007). However, little information exists on how land-based wind development affects the settling patterns, distribution, and density of duck pairs during the breeding season.

The number and distribution of breeding duck pairs in the PPR is related to annual wetland and upland conditions (Johnson et al. 1992; Austin 2002; Reynolds et al. 2006, 2007; U.S. Fish and Wildlife Service [USFWS] 2012). Wetland conditions in the PPR vary both spatially and temporally (Niemuth et al. 2010) and during dry years in the PPR, waterfowl are displaced to lesser quality habitats farther north (USFWS 2012) where productivity is generally reduced (Bellrose 1980). The long-term sustainability of breeding duck populations is dependent on availability and use of productive wetlands in the PPR that provide local breeding pair habitat when they are wet (Johnson and Grier 1988). Avoidance of wetlands near wind energy development by breeding ducks on otherwise suitable wetland habitat may result in displacement to lesser quality habitats similar to the effect of displacement during dry years. Given the relatively large development footprint (i.e., unit area/GW) for energy produced from wind relative to other energy sources such as coal (e.g., 7.4 times; wind = 72.1 km^2/TW-hr/yr, coal = 9.7 km^2/TW-hr/yr; McDonald et al. 2009) and the projected growth of the industry (USDOE 2008), a relatively large land area and subsequently a large number of wetlands and associated duck pairs in the PPR can potentially be affected.

We assessed the potential effects of wind energy development and operation on the density of 5 common species of breeding ducks in the PPR of North Dakota and South Dakota: blue-winged teal (*Anas discors*), gadwall (*A. strepera*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*), and northern shoveler (*A. clypeata*). Our objective was to determine whether the expected density of breeding duck pairs differed between wetlands located within land-based wind energy production sites (hereafter wind sites) and wetlands located within paired sites of similar wetland and upland composition without wind development (hereafter reference sites). We predicted that if disturbance due to wind energy development caused avoidance of wetlands by breeding duck pairs, then expected density of breeding pairs would be lower on wind energy development sites. We interpreted differences in estimated breeding pair densities between paired wind energy development sites and reference sites in the context of the current Prairie Pothole Joint Venture (PPJV) waterfowl conservation strategy for the United States PPR (Ringelman 2005).

STUDY AREA

We selected operational wind energy and paired reference sites as a function of the geographic location, the local wetland community and its potential to attract breeding pairs (i.e., $\geq$40 pairs/km^2; Reynolds et al. 2006), and wetland conditions. In 2008, 11 wind farms were operational in the PPR of North and South Dakota, USA. Of those, only 3 were located in areas with the potential to attract relatively large numbers of breeding duck pairs for the 5 species in this study (Loesch et al. 2012, OpenEnergyInfo 2012). We identified 2 existing wind energy production sites in the Missouri Coteau physiographic region (Bluemle 1991) of south-central North Dakota, USA, and north-central South Dakota, USA (Fig. 1). Both wind sites contained wetland communities with the potential to attract an estimated 46 breeding duck pairs/km^2 (mean density = 8.5 pairs/km^2 for the PPR; Reynolds et al. 2006, Loesch et al. 2012). The Kulm-Edgeley (KE) wind energy development consisted of 41 towers in a cropland-dominated landscape (e.g., 83% of

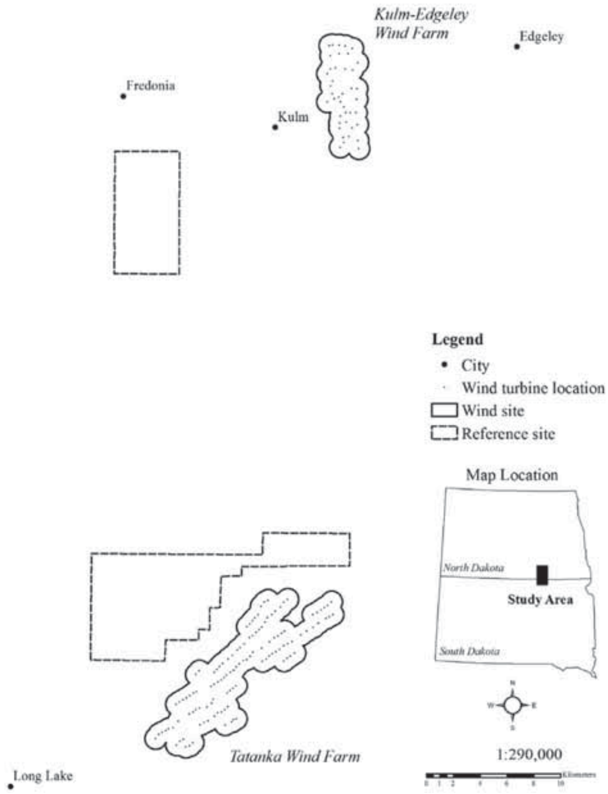

Figure 1. Paired study sites with and without wind energy development surveyed for breeding waterfowl pairs in North Dakota and South Dakota, USA, 2008–2010.

uplands were cropland; Table 1) and was located 3.2 km east of Kulm, North Dakota, USA. The Tatanka (TAT) wind energy development, consisted of 120 towers in a perennial cover-dominated landscape (e.g., 92% of uplands were perennial cover; native grassland, idle planted tame grass, alfalfa hay; Table 1) and was located 9.7 km northeast of Long Lake, South Dakota, USA. The KE site began operation in 2003; approximately 50% of the TAT towers were operational by 28 April 2008 and all were operational by 21 May 2008. Turbine locations were on-screen digitized using ESRI ArcGIS 9.2 software (ArcGIS Version 9.2, Environmental Systems Research Institute, Redlands, CA) and United States Department of Agriculture National Aerial Imagery Program (NAIP) imagery (ca. 2007).

The potential zone of influence for breeding waterfowl from a wind turbine to a wetland during the breeding season is unknown. The limited research that has been conducted to measure displacement of birds in grassland landscapes has primarily targeted migratory grassland passerines, and has identified relatively short (e.g., 80–400 m) distances (Leddy et al. 1999, Johnson et al. 2000, Shaffer and Johnson 2008, Pearce-Higgins et al. 2009). Compared to grassland passerines, waterfowl have relatively large breeding territories and mallards use multiple wetlands within their home range (e.g., 10.36 km^2 generalized to a circle based on a 1,608 m radius; Cowardin et al. 1988). Because the objective of this study was to test the potential effects of wind energy development on breeding duck pair density and not to identify a potential zone of influence, we chose a buffer size with the objective to spatially position sample wetlands in proximity to 1 or many turbines where a potential effect of wind energy development would likely be measurable. Consequently, we used the generalized home range of a mallard hen and buffered each wind turbine by 804 m (i.e., half the radius of a circular mallard home range; Cowardin et al. 1988), to ensure overlap of breeding territories with nearby wind turbines. The wind sites contained different numbers of turbines and as a result the sites were not equally sized (KE wind site = 2,893 ha; TAT wind site = 6,875 ha; Fig. 1).

We derived wetland boundaries from digital USFWS National Wetlands Inventory (NWI) data. We post-processed NWI wetlands to a basin classification (Cowardin et al. 1995, Johnson and Higgins 1997) where we combined complex wetlands (i.e., multiple polygons describing a basin) into a single basin and then classified them to the most permanent water regime (Cowardin et al. 1979). Wetlands partially or completely within the buffer areas were considered treatment wetlands.

For each of the 2 wind sites, we employed a rule-based process to select paired sites to control for differences in wetland and landscape characteristics among sites. We first

Table 1. Characteristics of wetland (i.e., number, area [ha], % of total wetland area) and upland (i.e., area [ha], % of total upland area) areas in development (wind) and paired reference sites in North Dakota and South Dakota, USA, where we surveyed wetlands for breeding duck pairs during spring 2008, 2009, and 2010. Sites included Kulm-Edgely (KE) and Tatanka (TAT) Wind Farms.

	KE wind			KE reference			TAT wind			TAT reference		
Class	Number	Area	%	Number	Area	%	Number	Area	%	Number	Area	%
Wetland												
Temporary	272	41.4	9	283	41.7	7	362	29.9	3	462	97.3	8
Seasonal	372	167.2	37	240	347.3	55	917	253.5	29	815	419.9	36
Semi-permanent	37	239.5	53	37	242.9	38	322	581.7	67	231	636.5	55
Total	681	448.1		560	631.9		1,601	865.0		1,508	1,153.7	
Upland												
Perennial cover[a]		416.3	16		1,324.4	37		5,428.4	92		6,039.7	85
Cropland		2,120.5	83		2,232.8	63		455.3	8		1,064.1	15
Other		6.6	<1		13.4	<1		18.3	<1		11.4	<1
Total		2,543			3,570.6			5,902.1			7,115.2	

[a] Includes native grassland, undisturbed grassland, and alfalfa hay landcover classes.

considered physiographic region and proximity to wind sites when identifying potential reference sites. To reduce the potential for environmental variation, especially wetness (Niemuth et al. 2010), between wind and reference sites, we only considered sites <25 km from the nearest turbine and within the Missouri Coteau physiographic region. Additionally, we assumed that wetlands >2.5 km from the nearest turbine were beyond a potential zone of influence. Using the distance and physiographic region criteria, we identified 3 potential reference sites of similar size for each wind site based on upland land use (i.e., proportion of cropland and perennial cover) and wetland density. For the 6 potential sites, we compared the wetland number and area (ha) for each class (i.e., temporary, seasonal, semi-permanent) between each potential reference site and the respective wind site to select the most similar reference site (Table 1). The KE reference site was located 11.3 km west of the KE wind site and the TAT reference site was located 3.2 km northwest of the TAT wind site (Fig. 1).

We identified 5,146 wetland basins encompassing 3,410 ha from NWI data within the wind and reference sites and considered each wetland a potential sample basin. Only temporary, seasonal, and semi-permanent basins were present at the wind sites so we did not survey lake wetlands at reference sites. We did not survey basins that extended >402 m from the boundary of a site to eliminate linear wetlands that potentially extended long distances from the wind and reference sites.

METHODS

Surveys

We surveyed sample wetlands during spring 2008, 2009, and 2010 to count local breeding duck pairs. We used 2 survey periods (i.e., 28 April–18 May, early; and 21 May–7 June, late) to account for differences in settling patterns for the 5 species (Stewart and Kantrud 1973, Cowardin et al. 1995) and to reduce potential bias associated with differences in breeding chronology among species (Dzubin 1969, Higgins et al. 1992, Naugle et al. 2000). We divided the wind and reference sites into 3 crew areas to spatially distribute survey effort across the sites, and crews of 2 observers conducted surveys on each of the 3 crew areas daily. The detection probability of duck pairs was likely not equal among observers (Pagano and Arnold 2009) and we minimized potential confounding of detection, observer, and survey area by rotating observers among crew areas and partners daily. Additionally, our analytical approach was not to compare population estimates for wind and reference sites, which may require development of correction factors (Brasher et al. 2002, Pagano and Arnold 2009), but rather to compare expected rates of pair abundance. Consequently, we assumed non-detection of ducks to be equal among all sites.

We surveyed wetlands within each crew area in a 2.59-km grid pattern based on public land survey sections (PLSS). We used maps with NAIP imagery and wetland basin perimeters from NWI to assist orientation and navigation to survey wetlands. Permission, accessibility, wetness, numbers of wetlands, size of wetlands, and numbers of birds affected the rate at which we surveyed PLSS. Surveys began at 0800 hours and continued until 1700 hours and were discontinued during steady rainfall or winds exceeding 48 km/hr. We surveyed most wetlands twice each year, once during each survey period. We visited all sample wetlands during the early survey period. We did not revisit wetlands that were dry during the early survey. Annual changes in access permission and wetland conditions due to precipitation resulted in some basins being surveyed during only 1 of the survey periods.

During the breeding season, waterfowl assemble into various social groupings that are influenced by sex ratios, breeding phenology, and daily activities (Dzubin 1969). We counted social groups of the 5 target species using established survey protocols (Hammond 1969, Higgins et al. 1992, Cowardin et al. 1995, Reynolds et al. 2006) and recorded observations for all sample wetlands that contained surface water regardless of whether birds were present or absent. We summarized field observations into 7 social groupings that we subsequently interpreted to determine the number of indicated breeding pairs for each species, basin, and survey period (Dzubin 1969, Cowardin et al. 1995). On average, the first count period (late April–early May) is regarded as an acceptable approximation of the breeding population for mallard and northern pintail (Cowardin et al. 1995, Reynolds et al. 2006). Consequently, we used observations during the early survey period to determine the number of indicated breeding pairs for mallard and northern pintail. Similarly, the second count period (late May–early June) is generally used to approximate the breeding population of blue-winged teal, gadwall, and northern shoveler (Cowardin et al. 1995, Reynolds et al. 2006) and we used observations during the late survey period to determine the number of indicated breeding pairs for these 3 species. We used indicated breeding pairs as the response variable in our models of estimated duck pairs.

We reduced disturbance during surveys by observing wetlands from 1 or more distant, strategic positions. We approached and surveyed portions of basins that were obscured by terrain or vegetation on foot. We noted birds leaving the wetland because of observer disturbance to minimize recounting on wetlands that we had not yet surveyed. We estimated the proportion of the wetland that was wet by visually comparing the surface water present in the basin relative to the wetland extent displayed on the field map. We recorded basins with no surface water as dry and not surveyed.

We used NAIP (ca. 2009) and on-screen photo-interpretation to develop a categorical variable describing the landcover of uplands (i.e., cropland, native grassland, idle planted tame grass, alfalfa hayland) adjacent to or surrounding all wetlands on the wind and reference sites. For wetlands touching multiple upland landcover classes, we assigned the class based on the largest wetland perimeter length. The exception was for idle planted tame grass, where we assigned the class if it touched any length of a wetland perimeter because of the limited presence of this class in the landscape and its positive influence on pair settling densities (Reynolds et al. 2007).

Data Analysis

The objective of our analysis was to compare estimates of expected wetland-level abundance of breeding pairs on the wind and reference sites among years. We used past analyses of breeding duck pairs in the United States PPR and their relationship to wetland and upland parameters to inform the selection of candidate covariates (Cowardin et al. 1988, 1995; Reynolds et al. 1996). Wetland-level covariates included wetland class (i.e., seasonal, semi-permanent, or temporary; Johnson and Higgins 1997), surface area of water in NWI basin (wet area), and square root (sqrt) of wet area to reflect the non-linear response to wetland area demonstrated by breeding ducks in the PPR (Cowardin et al. 1988, 1995; Reynolds et al. 2006). We used a categorical variable for upland landcover (i.e., perennial cover, cropland) adjacent to the wetland for the only upland covariate (Reynolds et al. 2007).

Generalized linear models with Poisson errors provided an appropriate statistical framework for the analysis (McCullagh and Nelder 1989, McDonald et al. 2000). Preliminary summaries of the breeding pair data showed, however, that all 5 species displayed indications of over-dispersion relative to standard Poisson assumptions (i.e., both excess zeros and infrequent large counts; Appendix A, available online at www.onlinelibrary.wiley.com; Zuur et al. 2007). We addressed these challenges, while maintain an approach consistent with past studies by conducting a 2-stage analysis. We began by selecting appropriate models and subsets of the covariates using a likelihood-based approach. Then we used a simulation-based Bayesian approach to estimate parameters of species-specific statistical models, site- and year-level contrasts between wind and reference sites, and lack-of-fit statistics. Our combined approach allowed us to take advantage of the strengths of both approaches (Royle and Dorazio 2008:74–75) to provide a thorough analysis of the data.

We analyzed indicated breeding pairs from counts for each of the 5 study species using separate models. Full Poisson regression models described expected breeding pairs as a log-linear function of site, year, wetland class, landcover, wet area, and sqrt (wet area). We used Akaike's Information Criterion (AIC) differences (Burnham and Anderson 2002) to compare full Poisson models with Zero-Inflated Poisson (ZIP) models. The ZIP models partially accounted for potential excess zeros due to 2 sources: 1) non-detections and 2) unoccupied, but suitable, wetlands. The ZIP models described the data as a mixture of the counts described by the log-linear model and a mass of excess zeros described by a logit-linear model (Zuur et al. 2007). We conducted a comparison of Poisson and ZIP models between the full Poisson model and ZIP model that included a single additional parameter describing the expected probability of a false zero. When AIC differences indicated the ZIP model was more appropriate (i.e., $AIC_{Poisson} - AIC_{ZIP} \geq 4$), we used ZIP models for all subsequent analysis. When ZIP models were selected, the full logit-linear model for excess zeros included covariates describing the upland vegetation cover class associated with each wetland (cover class; Stewart and Kantrud 1973), the area of the NWI basin covered by water (wet area), and the square root of wet area.

We expected that the full models would likely be most appropriate for the study species, as they were parameterized with covariates that have been identified as useful predictors of pair abundance in the Four-Square-Mile Breeding Waterfowl Survey (FSMS) dataset, which has been collected by the USFWS National Wildlife Refuge System since 1987 (Cowardin et al. 1995; Reynolds et al. 2006, 2007). Nonetheless, we sought to efficiently use the information in our less-extensive dataset by ensuring that we had selected a parsimonious subset of the covariates for each species-specific model. We removed a single covariate, or group of covariates in the case of factor variables, from the full model, ran the resulting reduced model, and recorded its AIC value (Chambers 1992, Crawley 2007:327–329). We repeated this procedure for every covariate. This resulted in a vector of AIC values that described, for each covariate, or covariate group, the effect of its removal on the AIC value of the full model. Reduced models for each species contained the set of covariates in the full model or the subset of covariates that resulted in increases in AIC values greater than 2 units per estimated parameter when they were removed from the full model (Arnold 2010).

After selecting a model structure for each species, we estimated the posterior distributions of model parameters with Markov Chain Monte Carlo (MCMC) simulation (Link and Barker 2009) in the Bayesian analysis software WinBUGS 1.4.1 (Spiegelhalter et al., 2003). The structure of the Bayesian ZIP models differed from the maximum likelihood models in 2 ways. The 12 site and year combinations were hierarchically centered and parameterized as normally distributed displacements from a common intercept (Gelman et al. 2004, Congdon 2005), and extra-Poisson variation due to large wetland-level counts was accommodated by a normally distributed error term (Appendix B, available online at www.onlinelibrary.wiley.com).

We conducted all statistical analyses in the R environment (R Development Core Team 2011). We used the generalized linear models capability of base R and the contributed package pscl (Jackman 2008) to estimate likelihoods and AIC values for Poisson and ZIP models. When selecting models and subsets of the covariates, we considered AIC differences greater than 4 to provide good evidence in favor of the model with the smaller value (Burnham and Anderson 2002). To generate Bayesian estimates of model parameters, we used the contributed R2WinBugs (Sturtz et al. 2005) package to run MCMC simulations in WinBUGS via R. For each model, we ran 2 Markov chains for 500,000 iterations and discarded the first 100,000 iterations from each chain to minimize the influence of starting values and prior distributions. We used minimally informative prior distributions and random starting values for model parameters and random effects. We evaluated convergence to the posterior distribution by examining plots of sequential draws for each parameter and also by the Gelman–Rubin statistic (Gelman et al. 2004). We estimated the number of uncorrelated samples generated by each Markov Chain by the Effective Sample Size (ESS; Kass et al. 1998, Streftaris and Worton 2008). We required at least 200 uncorrelated samples per chain for inference. We considered a model to have converged when its Gelman–Rubin statistic was <1.1 and the plots of sequential draws indicated that the chains had stabilized and were sampling from a similar space (Gelman et al. 2004). We tested for lack-of-fit of the model using a posterior predictive test (Gelman et al. 2004). Specifically, we compared the variance-mean ratio for the observed data to the variance-mean ratio of simulated data generated from the posterior draws of model parameters. We concluded that the model fit the data if the posterior proportion of simulated variance-mean ratios that exceeded the observed variance-mean ratio was greater than 0.01 and less than 0.99 (Congdon 2005). We then used the CODA (Plummer et al. 2009) package to summarize the posterior distributions of model parameters, convergence diagnostics, and derived quantities like lack-of-fit statistics and back-transformed estimates of abundance. Using the 800,000 posterior simulations from each model, modal values of categorical covariates, and median values of continuous covariates, we calculated species-, site-, and year-specific medians and 95% credible intervals of 1) the estimated posterior distribution of the log-scale model parameters, 2) the estimated posterior distribution of expected pair abundance on wetlands of median area, and 3) the estimated posterior distribution of the back-transformed contrast in expected pair abundance between wind and reference sites in each year. These quantities provided the basis for comparison of pair abundance between wind and reference sites.

We used point estimates of pair density for the median seasonal wetlands size (i.e., 0.2 ha) in grassland to assess the potential effect of wind energy development on breeding duck pair densities. We selected seasonal wetlands because they were the most numerous wetlands in our sample (58%) and because breeding duck pairs use seasonal wetlands at greater rates than other wetland classes (see Reynolds et al. 2006, 2007; Loesch et al. 2012); most pairs (54%) were observed on seasonal wetlands.

We evaluated the potential impact of wind energy development from both a statistical and biological perspective. We compared point estimates of density among sites and within years to either support or reject an effect. We assessed the potential biological impact of breeding pair avoidance of wind sites by calculating the proportional change in the estimated density of pairs between wetlands in wind and reference sites for each species and year. The percent change reflects the potential impact to breeding duck populations in the presence of wind energy development.

RESULTS

As a result of variable wetland conditions both within and among years, and annual changes in access to private land, we surveyed different numbers and area of wetland basins each year. Water levels in wetlands were low during 2008 and 35% of wetland basins visited during the early count contained water and generally were only partially full (e.g., seasonal regime, mean = 54% full, n = 684). Water levels increased in 2009 and 2010 and only 15% of 2,464 and 12% of 3,309 wetland basins, respectively, were dry during the early count. Basins containing water were also more full during 2009 (e.g., seasonal basin mean = 103% full, n = 1,089) and 2010 (e.g., seasonal basin mean = 93% full, n = 1,407). We conducted 5,339 wetland visits during the early count and 4,999 wetland visits during the late count. During the early count, we observed 5,287 indicated breeding pairs of mallard (3,456 [range = 146–552]) and northern pintail (1,831 [range = 51–310]), and 10,473 indicated breeding pairs of blue-winged teal (5,886 [range = 180–984]), gadwall (2,839 [range = 75–506]), and northern shoveler (1,748 [range = 55–318]) during the late count.

Model Selection and Estimation

Our ZIP models provided a substantially better fit than Poisson models for every species. Differences in AIC ($AIC_{poisson} - AIC_{zip}$) were 426 for blue-winged teal, 137 for gadwall, 218 for mallard, 384 for northern pintail, and 78 for northern shoveler. All of the covariates in the full model were retained for mallard, northern pintail, blue-winged teal, and northern shoveler. Wetland class was dropped for gadwall. Differences in AIC between the full model and the nearest reduced model were 11 for blue-winged teal, 3 for gadwall, 26 for mallard, 6 for northern pintail, and 29 for northern shoveler. The MCMC simulations converged for every species-specific model, indicating that the parameter estimates and credible intervals from these models provided a sound basis for inference. The maximum upper 95% credible interval of all R-hat values for any structural parameter was 1.01 for blue-winged teal, 1.01 for gadwall, 1.01 for mallard, 1.02 for northern pintail, and 1.04 for northern shoveler. The posterior predictive test indicated that the models fit the data for every species. The proportion of simulated variance-mean ratios that exceeded the observed variance-mean ratio was 0.52 for blue-winged teal, 0.75 for gadwall, 0.61 for mallard, 0.59 for northern pintail, and 0.72 for northern shoveler. Minimum effective sample sizes were 709 for blue-winged teal, 553 for gadwall, 307 for mallard, 346 for northern pintail, and 612 for northern shoveler.

Estimates

Differences in estimated breeding duck pair densities in a wind site and a reference site varied among site pairs (2), years (3), and species (5), and posterior median values of these 30 contrasts ranged from −0.281 to 0.130 (Table 2). Estimated patterns of contrasts for expected breeding duck pair density between wind and reference sites were similar for all species. Given median wet area and the mode of the categorical covariates, expected, basin-level densities of duck pairs for the 5 species was either statistically indistinguishable (14 of 30) between wind and reference sites or was lower (16 of 30) on wind sites than reference sites depending on site, year, and species (Fig. 2). Regardless of whether 95% credible intervals overlapped zero, density estimates were

Table 2. Log-scale estimated posterior medians and 95% of the estimated posterior distribution from the count portion of a zero-inflated, overdispersed Poisson model of indicated blue-winged teal (*Anas discors* [BWTE]), gadwall (*A. strepera* [GADW]), mallard (*A. platyrhynchos* [MALL]), northern pintail (*A. acuta* [NOPI]), and northern shoveler (*A. clypeata* [NSHO]) pairs on seasonal wetland basins for development (wind) and paired reference sites in North Dakota and South Dakota, USA. Sites are Kulm-Edgely (KE) and Tatanka (TAT) for years 2008 (08), 2009 (09), and 2010 (10).

			Reference			Wind		
Species	Site	Year	Median	2.5%	97.5%	Median	2.5%	97.5%
MALL	KE	08	0.47	0.21	0.73	0.15	−0.13	0.43
	KE	09	−0.49	−0.78	−0.22	−0.90	−1.17	−0.64
	KE	10	−0.42	−0.66	−0.20	−0.77	−1.04	−0.51
	TAT	08	0.29	0.02	0.56	0.41	0.17	0.65
	TAT	09	−0.38	−0.61	−0.14	−0.63	−0.89	−0.38
	TAT	10	−0.33	−0.55	−0.10	−0.47	−0.71	−0.22
BWTE	KE	08	−0.13	−0.25	−0.00	0.22	0.01	0.45
	KE	09	−0.46	−0.66	−0.27	−0.52	−0.74	−0.32
	KE	10	−0.13	−0.30	0.04	−0.58	−0.78	−0.39
	TAT	08	0.25	0.06	0.45	0.18	0.01	0.36
	TAT	09	−0.15	−0.32	0.02	−0.39	−0.58	−0.21
	TAT	10	0.03	−0.12	0.19	−0.19	−0.36	−0.02
NOPI	KE	08	−0.25	−0.61	0.12	−0.80	−1.24	−0.39
	KE	09	−0.80	−1.16	−0.45	−1.54	−1.93	−1.17
	KE	10	−0.72	−1.01	−0.42	−1.20	−1.56	−0.87
	TAT	08	−0.10	−0.46	0.27	0.16	−0.15	0.48
	TAT	09	−0.35	−0.63	−0.06	−0.76	−1.07	−0.44
	TAT	10	−0.15	−0.41	0.13	−0.38	−0.67	−0.07
GADW	KE	08	0.09	−0.17	0.37	−0.13	−0.43	0.18
	KE	09	−0.52	−0.77	−0.28	−0.91	−1.19	−0.64
	KE	10	−0.61	−0.83	−0.38	−1.42	−1.72	−1.14
	TAT	08	0.07	−0.18	0.34	0.17	−0.05	0.41
	TAT	09	−0.46	−0.69	−0.22	−0.55	−0.81	−0.29
	TAT	10	−0.69	−0.92	−0.46	−0.62	−0.86	−0.38
NSHO	KE	08	−0.35	−0.61	−0.08	−0.49	−0.79	−0.18
	KE	09	−0.91	−1.17	−0.67	−1.00	−1.29	−0.73
	KE	10	−0.78	−1.00	−0.57	−1.11	−1.39	−0.85
	TAT	08	−0.23	−0.49	0.00	−0.30	−0.52	−0.08
	TAT	09	−0.59	−0.80	−0.37	−0.99	−1.25	−0.74
	TAT	10	−0.36	−0.55	−0.16	−0.69	−0.90	−0.47

lower on sites with wind development for 26 of the 30 combinations (i.e., mallard and blue-winged teal: 12 combinations, 11 negative [range −6% to −36%]), 7 did not overlap zero; gadwall, northern pintail, northern shoveler: 18 combinations, 15 negative [range −5% to −56%], 9 did not overlap zero). The general pattern of results were similar for all species, consequently, we chose a representative early and late arriving species with the largest number of indicated breeding pairs, mallard and blue-winged teal, respectively, for detailed presentation of results.

Mallard and Blue-Winged Teal

Mallard and blue-winged teal comprised 59% of the indicated breeding pair observations (i.e., 3,473 mallard; 5,928 blue-winged teal). Full models were retained for both mallard and blue-winged teal, and the point estimate of density was greatest in 2008 for both KE and TAT sites, but varied among years and sites (mallard: wind median = 0.42 [range = 0.30–1.03], reference median = 0.41 [range = 0.21–0.97]; blue-winged teal: wind median = 0.51 [range = 0.42–0.94], reference median = 0.66 [range = 0.47–0.96]). For mallard, estimated breeding pair densities on seasonal wetlands at wind sites were lower for 5 of the 6 site-year combinations (median = 0.11, range = −0.28 to 0.11) and error bars representing 95% of the posterior distribution of the estimate did not overlap zero for 4 of the 6 site-year comparisons (Fig. 2A). Similarly, for blue-winged teal in 5 of the 6 site-year combinations, estimated pair densities were lower for seasonal wetlands on wind sites (median = −0.14, range = −0.24 to <0.01) and error bars representing 95% of the posterior distribution of the estimate did not overlap zero for 3 of the 6 site-year comparisons (Fig. 2B). Only 1 site-year combination for each of mallard and blue-winged teal suggested greater pair densities on wind sites, but in both cases 95% confidence intervals overlapped zero.

The estimated proportional change of mallard pair densities for wetlands in wind sites was negative in 5 of 6 site-year combinations (median = −10%, range = 13% [TAT 2008] to −34% [KE 2009]; Fig. 3A). The proportional change for blue-winged teal was also negative in 5 of 6 site-year combinations (Fig. 3B). The median estimate of proportional change for blue-winged teal densities between wind and reference sites was −18% (range 0% [KE 2009] to −36% [KE 2010]).

DISCUSSION

All 5 of our dabbling duck study species demonstrated a negative response to wind energy development and the reduced abundance we observed was consistent with behavioral avoidance. Avoidance of land-based wind energy development has been observed for numerous avian species during

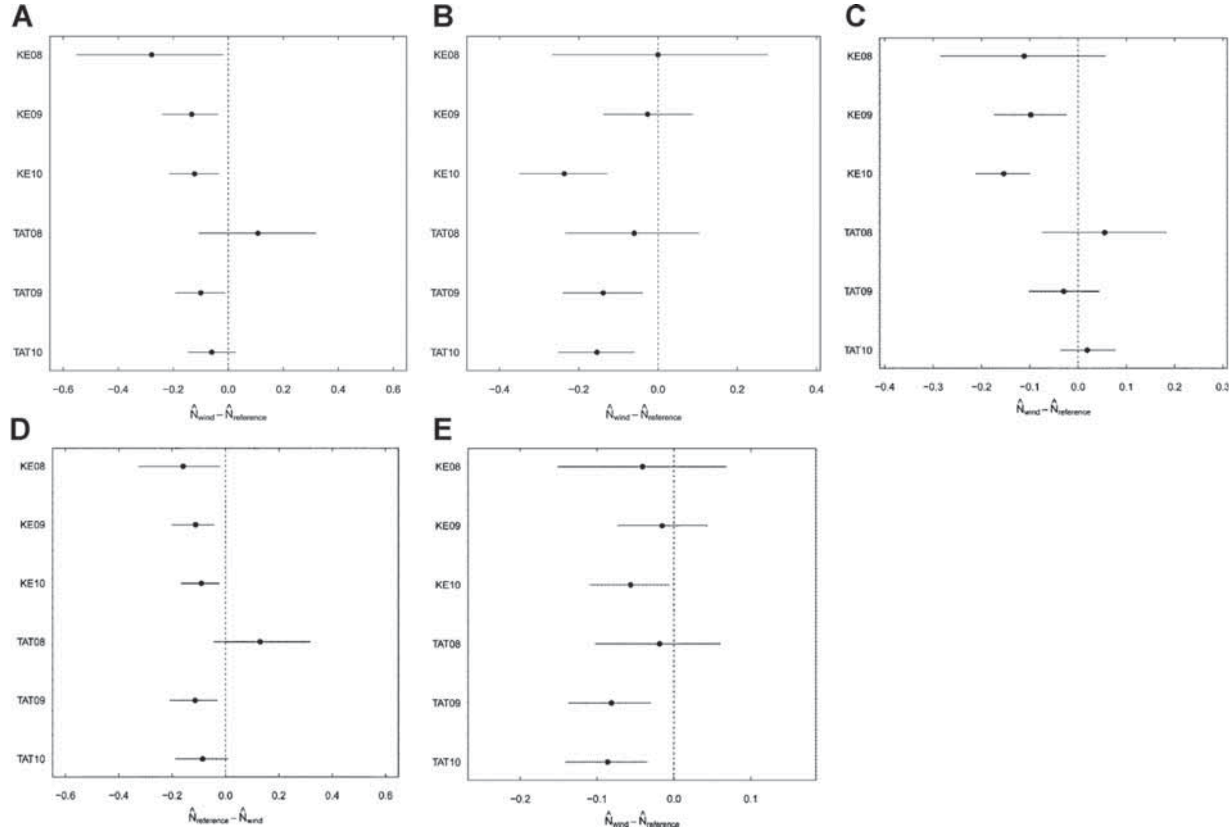

Figure 2. Year-specific estimated differences between estimated posterior median abundance of mallard (*Anas platyrhynchos*; A), blue-winged teal (*A. discors*; B), gadwall (*A. strepera*; C), northern pintail (*A. acuta*; D), and northern shoveler (*A. clypeata*; E) on a seasonal wetland of median area (0.2 ha) embedded in perennial cover on a wind site and its corresponding reference site in North Dakota and South Dakota. Error bars represent 95% of the posterior distribution of the estimate. Site-year combinations are Kulm-Edgely (KE) and Tatanka (TAT) for 2008 (08), 2009 (09), and 2010 (10).

breeding (Leddy et al. 1999, Johnson et al. 2000, Walker et al. 2005, Shaffer and Johnson 2008, see Madders and Whitfield 2006), and does not imply complete abandonment of an area but rather the reduced use of a site (Schneider et al. 2003). This is consistent with our results, where breeding pairs continued to use wetland habitat at the wind sites but at reduced densities.

Our selection of paired wind and reference sites and analytical approach were designed to control for differences in site characteristics and annual variation in habitat conditions, and to use well-understood relationships between breeding duck pairs and wetlands (Cowardin et al. 1995; Reynolds et al. 2006, 2007). Despite the large amount of breeding pair data we collected, discerning if the presence of wind energy development was the ultimate cause of the lower estimated pair abundance on the wind versus reference sites is difficult. However, we did detect a directional effect of wind energy development sites over a 3-year period at the 2 sites that are representative of areas with greater estimated duck densities, and adds to the body of evidence suggesting a negative effect of wind energy development. Reduced wetland use in high density wetland areas with the potential to attract and support relatively greater densities of breeding duck pairs is of concern to waterfowl biologists and managers because when wet, these areas are vital to the sustainability of North American duck populations. The somewhat limited temporal and geographic scope of our study and confounding between land use and duration of development prevents us from drawing strong conclusions about cumulative effects of wind energy development on breeding ducks (see Krausman 2011). Nonetheless, a 10–18% reduction in addition to other stressors is potentially substantial.

We observed larger negative displacement for most species and years in the KE wind site when compared to the TAT wind site. We found 2 notable differences in the wind sites that may have contributed to these results, the land use and age of development. The KE site was predominantly cropland and older than the grassland-dominated TAT site. The combination of multiple stressors, in this case agriculture and wind energy development, may have resulted in a greater impact to breeding ducks using wetlands in agricultural settings. Differences in estimated pair abundance between the cropland and grassland site suggest that greater habitat quality measured by the percent of grassland area and lack of cropping history in associated wetlands within a site may reduce avoidance of wind development when compared to agricultural landscapes. Breeding waterfowl may occupy wetlands at greater rates in grassland than cropland (Reynolds et al. 2007), nest success is generally greater in grasslands (Greenwood et al. 1995, Reynolds et al. 2001, Stephens et al.

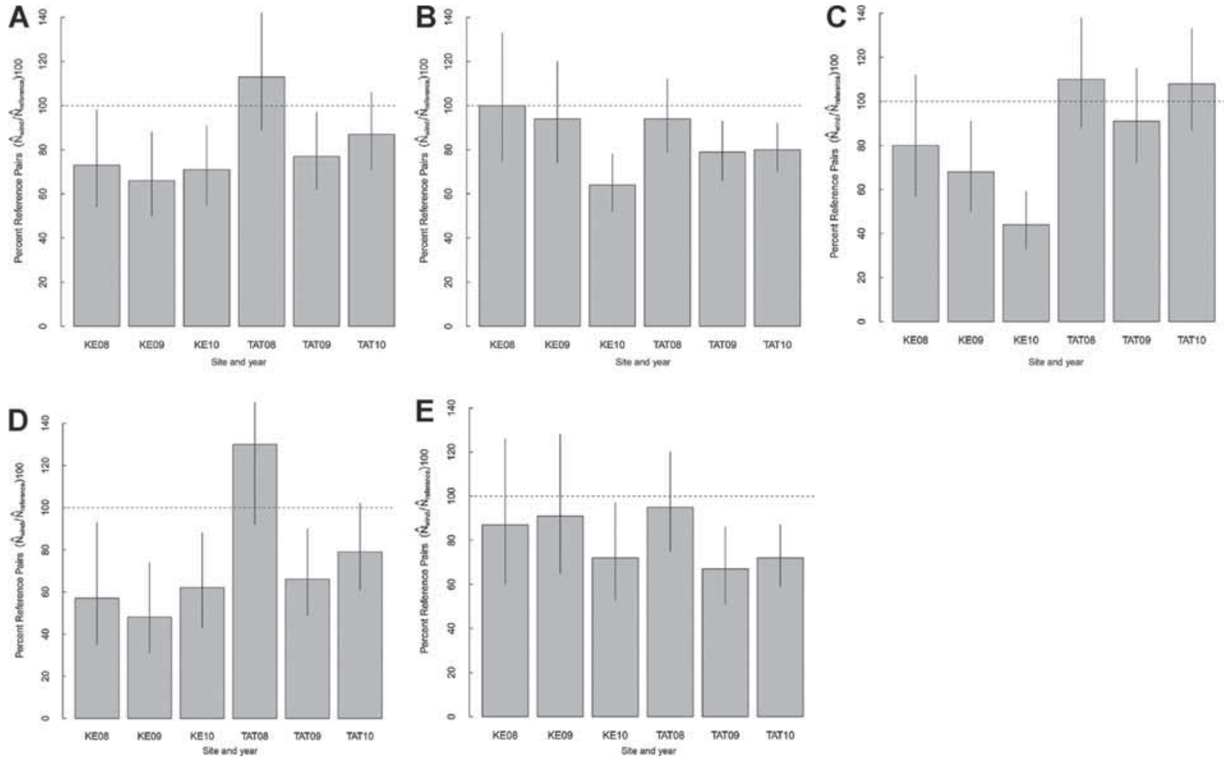

Figure 3. Year-specific estimated number of mallard (*Anas platyrhynchos*; A), blue-winged teal (*A. discors*; B), gadwall (*A. strepera*; C), northern pintail (*A. acuta*; D), and northern shoveler (*A. clypeata*; E) on a seasonal wetland of median area (0.2 ha) embedded in perennial cover on a wind site expressed as a percentage of pairs expected on the same wetland in the corresponding reference site in North Dakota and South Dakota. Error bars represent 95% of the posterior distribution of the estimate. Site-year combinations are Kulm-Edgely (KE) and Tatanka (TAT) for 2008 (08), 2009 (09), and 2010 (10).

2005), and wetlands in grass landscapes have greater occupancy rates by duck broods (Walker 2011), suggesting an overall greater productivity potential for breeding ducks in grassland versus cropland landscapes. The ability of intact habitat to reduce impacts of energy development is supported in current literature. In Wyoming, sage-grouse (*Centrocercus urophasianus*) residing in a fragmented landscape showed a 3 times greater decline in active leks at conventional coal bed methane well densities (1 well per 32 ha) than those in the most contiguous expanses of Wyoming big sagebrush (*Artemisia tridentata*) in North America (Doherty et al. 2010). A similar relationship has been document for large mammals. In the Boreal forest, woodland caribou (*Rangifer tarandus caribou*) populations could sustain greater levels of industrial development and maintain an increasing population when they resided in large forest tracts that were not fragmented by wildfires (Sorensen et al. 2008).

Our ability to support the hypothesis that habitat quality mitigates impacts could be confounded by time-lags in detecting impacts, as well as the potential for ducks to habituate to wind energy development over time but at a cost to individual fitness (Bejder et al. 2009). The KE wind site was cropland-dominated and began operation in 2003, whereas the TAT wind site was grassland-dominated and began operation in 2008, and was 3 years old during the final field season. Many recent studies for a variety of species and ecosystems have shown time lags between dates of first construction and full biological impacts. In Wyoming impacts to sage-grouse in some instances doubled 4 years post-development versus the initial year of development (Doherty et al. 2010) and lags varied from 2 to 10 years (Harju et al. 2010). In some instances, full biological impacts may not be apparent for decades. For example, 2 decades passed before impacts of forest logging resulted in woodland caribou population extirpation within 13 km of logging (Vors et al. 2007). In a review paper on the effects of wind farms to birds on 19 globally distributed wind farms using meta-analyses, time lags were important in detecting impacts for their meta-analyses with longer operating times of wind farms resulting in greater declines in abundance of Anseriformes (Stewart et al. 2007). Pink-footed geese foraging during spring appear to have habituated to the presence of wind turbines in Europe (Madsen and Boertmann 2008). We therefore cannot distinguish between these 2 competing hypotheses without additional study.

Wind resources are both abundant and wide-spread in the PPR in the United States (Heimiller and Haymes 2001, Kiesecker et al. 2011), and the development of an additional 37 GW of wind energy capacity in the PPR states is necessary to meet 20% of domestic energy needs by 2030 (USDOE 2008). The projected wind farm footprint in PPR states to support this target is approximately 39,601 km^2. Even if recommendations for siting energy development outside of intact landscapes suggested by

Kiesecker et al. (2011) are implemented by the wind industry, millions of wetlands occur in agricultural landscapes and our results indicate that wind energy development will likely reduce their use by breeding duck pairs.

Waterfowl conservation partners in the PPR use strategic habitat conservation (Reynolds et al. 1996, 2006; Ringelman 2005; USFWS 2006; Loesch et al. 2012) in an adaptive management framework to target protection, management, and restoration based on biological and landscape information, primarily in response to habitat loss from agricultural activities. From a habitat quality and conservation perspective, wind energy development should be considered as another stressor relative to the cumulative effects of anthropogenic impacts on limiting factors to breeding waterfowl populations.

The protection of remaining, high priority grassland and wetland resources in the United States PPR is the primary focus of waterfowl habitat conservation (Ringelman 2005, Niemuth et al. 2008, Loesch et al. 2012). Population goals and habitat objectives were established to maintain habitat for breeding pairs and the current productivity of the landscape (Ringelman 2005, Government Accounting Office 2007). Spatially explicit decision support tools (Reynolds et al. 1996, Niemuth et al. 2005, Stephens et al. 2008, Loesch et al. 2012) have been used effectively to target and prioritize resources for protection. New stressors such as energy development in the PPR that negatively affect the use of wetland resources have ramifications to breeding waterfowl populations (i.e., potential displacement to lower quality wetland habitat) and their conservation and management. Thus, population and habitat goals, and targeting criteria may need to be revisited if large-scale wind development occurs within continentally important waterfowl conservation areas like the PPR.

MANAGEMENT IMPLICATIONS

Balancing the development of wind energy and current conservation efforts to protect habitat for migratory birds is complex because most conservation and wind energy development in the region occur on private land (USFWS 2011). Given that breeding duck pairs do not completely avoid wetlands in and adjacent to wind energy developments and resource benefits remain, albeit at reduced levels, the grassland and wetland protection prioritization criteria used by conservation partners in the PPR (Ringelman 2005) could be adjusted to account for avoidance using various scenarios of acceptable impact. For example, the wind sites used in our study are in high priority conservation locations (Ringelman 2005, Loesch et al. 2012). After accounting for effects of duck displacement by wind development, their priority was not reduced for either site. Consequently, wind-development does not necessarily preclude these sites from consideration for protection. Additionally, using the measured negative impact of wind energy development and production on breeding duck pairs, opportunities to work with wind energy industry to mitigate the reduced value of wetlands in proximity to wind towers should be investigated. Continued partnership by the wind energy industry and wildlife conservation groups will be critical for continued research. Further, we suggest expanding our research both spatially and temporally to better address cumulative impacts, zone of influence, impacts on vital rates, potential habituation or tolerance, and/or lag effects of long-term exposure to wind energy development.

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Contributed Paper

Effects of wind-energy facilities on breeding grassland bird distributions

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Abstract: *The contribution of renewable energy to meet worldwide demand continues to grow. Wind energy is one of the fastest growing renewable sectors, but new wind facilities are often placed in prime wildlife habitat. Long-term studies that incorporate a rigorous statistical design to evaluate the effects of wind facilities on wildlife are rare. We conducted a before-after-control-impact (BACI) assessment to determine if wind facilities placed in native mixed-grass prairies displaced breeding grassland birds. During 2003–2012, we monitored changes in bird density in 3 study areas in North Dakota and South Dakota (U.S.A.). We examined whether displacement or attraction occurred 1 year after construction (immediate effect) and the average displacement or attraction 2–5 years after construction (delayed effect). We tested for these effects overall and within distance bands of 100, 200, 300, and >300 m from turbines. We observed displacement for 7 of 9 species. One species was unaffected by wind facilities and one species exhibited attraction. Displacement and attraction generally occurred within 100 m and often extended up to 300 m. In a few instances, displacement extended beyond 300 m. Displacement and attraction occurred 1 year after construction and persisted at least 5 years. Our research provides a framework for applying a BACI design to displacement studies and highlights the erroneous conclusions that can be made without the benefit of adopting such a design. More broadly, species-specific behaviors can be used to inform management decisions about turbine placement and the potential impact to individual species. Additionally, the avoidance distance metrics we estimated can facilitate future development of models evaluating impacts of wind facilities under differing land-use scenarios.*

Keywords: avoidance, before-after-control-impact design, climate change, displacement, renewable energy, upland birds, wind turbine

Efectos de las Instalaciones de Energía Eólica sobre la Distribución de las Aves de Pastizales en Época Reproductiva

Resumen: *La contribución de la energía renovable para cumplir con las demandas mundiales sigue creciendo. La energía eólica es uno de los sectores renovables con mayor crecimiento, pero continuamente se colocan nuevas instalaciones eólicas en los principales hábitats de fauna silvestre. Los estudios a largo plazo que incorporan un diseño estadístico riguroso para evaluar los efectos de estas instalaciones sobre la fauna son escasos. Realizamos una evaluación de control de impacto de antes y después (CIAD) para determinar si las instalaciones eólicas colocadas en praderas de pastos mixtos nativos desplazaron a las aves de pastizales en época reproductiva. Durante el periodo 2003-2012, monitoreamos los cambios en la densidad de aves en tres áreas de estudio en Dakota del Norte y del Sur (E.U.A). Examinamos si había ocurrido desplazamiento o atracción un año después de la construcción (efecto inmediato) y también el promedio de desplazamiento o atracción 2-5 años después de la construcción (efecto retardado). Analizamos estos efectos en general y dentro de franjas de distancia de 100, 200, 300 y >300 m de las turbinas. Observamos desplazamiento en siete de las nueve especies. Una especie no fue afectada por las instalaciones eólicas y una especie mostró atracción. El desplazamiento y la atracción ocurrieron generalmente dentro de los 100 m y frecuentemente se extendieron hasta los 300 m. En algunos casos, el desplazamiento se extendió más allá de los 300 m. El desplazamiento y la atracción ocurrieron un año después de la construcción y continuaron durante por lo*

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menos cinco años. Nuestra investigación proporciona un marco de trabajo para aplicar el diseño CIAD a los estudios de desplazamiento y resalta las conclusiones erróneas que pueden hacerse sin el beneficio de adoptar dicho diseño. En términos más generales, los comportamientos específicos de especie pueden usarse para informar a las decisiones de manejo sobre la colocación de turbinas y el impacto potencial para las especies individuales. Además, las medidas de distancia de evitación que estimamos pueden facilitar el desarrollo futuro de los modelos de evaluación de impacto de las instalaciones eólicas bajo escenarios diferentes de uso de suelo.

Palabras Clave: aves de tierras altas, cambio climático, desplazamiento, diseño de control de impacto de antes y después, energía renovable, evitación, turbina de viento

Introduction

Renewable energies will help meet energy demands while reducing carbon emissions and providing energy security (IPCC 2012). Globally, the contribution of wind power to energy demand is anticipated to be 20% by 2050 (IPCC 2011). The United States became the global leader in new wind capacity in 2012, representing 29% of global installed capacity due to sustained growth throughout the interior of the country (i.e., within the Great Plains) (USDOE 2013).

The Great Plains also supports the last remaining expanses of native temperate grasslands in North America (Stephens et al. 2008; Rashford et al. 2011; Doherty et al. 2013); thus, the increase in habitat loss and fragmentation associated with wind development has adverse impacts on wildlife (McDonald et al. 2009; Kiesecker et al. 2011). Wildlife are directly affected by wind facilities via collision mortality (Johnston et al. 2013; Péron et al. 2013) and indirectly affected through avoidance of turbines and related infrastructure (i.e., displacement [Drewitt & Langston 2006]). Per unit energy, wind energy has a larger terrestrial footprint than other forms of energy production (Kiesecker et al. 2011). Although the ground disturbance per turbine is relatively small (about 1.2 ha), other disturbances such as construction and operation of the facility, vehicular traffic, maintenance visits, turbine noise and movement, and changes to predator activity contribute to the impact of wind facilities (Arnett et al. 2007; Helldin et al. 2012; Gue et al. 2013).

Although displacement research on an international level has been ongoing for about 2 decades, Drewitt and Langston (2006) note that few displacement studies are conclusive, often because of the minimal magnitude of the effect, poor precision of estimates, and lack of study design allowing for strong inference assessments. For observational studies, the before-after-control (reference)-impact (BACI) design is considered the "optimal impact study design" (Green 1979) as exemplified by Irons et al. (2000) and Smucker et al. (2005) and is the preferred method to determine displacement of wildlife from wind facilities (Strickland et al. 2011). However, of the numerous displacement studies, most are short-term, are not BACI designs, and occur on only one wind facility (Supporting Information). Effective conservation strategies that reduce negative effects of wind facilities to sensitive wildlife require information from well-designed studies (Strickland et al. 2011). Preferred characteristics include a multi-species approach to understand prevalence of displacement behavior, a long-term perspective, and a design that allows for strong inference (e.g., BACI) (Stewart et al. 2007; Strickland et al. 2011). Pearce-Higgins et al. (2012) provide an example of a well-implemented wind-specific BACI design.

Our overall goal was to determine if wind facilities influenced distribution of sensitive and declining grassland-nesting birds (Supporting Information). Specifically, our objectives were to assess immediate and delayed effects of the placement of wind facilities. We assessed potential changes in bird distribution overall and at varying distances from wind turbines. We implemented a BACI design that incorporated multiple years, replicated impact and reference sites within 3 facilities, and 9 species, making our study one of a few that used a rigorous optimal impact assessment design (Supporting Information). Thus, our research provides a strong foundation for building a more refined understanding of how wind facilities influence grassland bird distribution temporally and spatially.

Methods

Collaboration with wind companies provided locations of impending construction within North Dakota and South Dakota (U.S.A.). We selected wind facilities situated within expanses of native grassland and in landscapes characterized by morainic rolling plains interspersed with wetlands, mixed-grass prairie pastures, and few planted grasslands, hayfields, or cropland (Bluemle 1991). Three wind facilities (hereafter, study areas) met our criteria: NextEra Energy's (NEE) South Dakota Wind Energy Center (SD), Highmore, South Dakota; Acciona's Tatanka Wind Farm (TAT), Forbes, North Dakota; and NEE's Oliver Wind Energy Center (OL), Oliver County, North Dakota (Table 1, Fig. 1). The study areas differed in several anthropogenic features (Table 1). The SD site was within the most heterogeneous landscape and had

Table 1. Summary characteristics of 3 wind facilities in North Dakota and South Dakota (U.S.A.) for which field survey data were collected for the study on effects of wind facilities on grassland birds.

Facility	*Pre-treatment year*	*Post-treatment years*	*No. treatment plots (size range, ha)*	*No. reference plots (size range, ha)*	*Row crop area (%)*	*Total area (km^2)*	*Roads* (km/km^2)*	*No. of turbines/km^2*
NextEra Energy SD Wind Energy Center	2003	2004-6, 8, 10, 12	5 (55-158)	3 (34-46)	20	34.5	0.6	0.8
Acciona Tatanka Wind Farm	2007	2009-10, 12	2 (43-441)	4 (11-109)	0	31.6	0.4	0.6
NextEra Energy Oliver Wind Energy Center	2006	2007, 9, 11	2 (122-260)	2 (37-274)	13	24.3	0.7	0.7

**Includes paved, gravel, and turbine roads.*

the highest percentage of lands under row-crop cultivation and the second most kilometers of roads, whereas TAT was within the least heterogeneous landscape of primarily grasslands. During the years we were on each study area (Table 1), TAT and OL had above-average precipitation and SD received below-average precipitation (NOAA 2015).

Because of the short time frame between facility site selection and construction, we conducted only 1 year of pre-treatment surveys. Within a study area, we selected turbine strings (i.e., turbines connected by a road) that would be placed in grazed mixed-grass prairie. We defined a turbine site as the area encompassing the turbines and extending 0.8 km on all sides of the turbine string, as long as the land and land cover remained grazed mixed-grass prairie. Reference sites were selected based on proximity to paired wind facilities (within 3.2 km) and similarity of land use and cover, topography, and elevation to turbine sites. Measures of vegetation structure were similar between turbine and reference sites and therefore were excluded as a possible confounding effect (Supporting Information).

We conducted total-area avian surveys (Stewart & Kantrud 1972) within a grid system (Shaffer & Thiele 2013) 2 times annually from late May to early July, from 0.5 hours after sunrise to 1100, on days of good visibility and good aural detectability (i.e., days with little or no precipitation and low to moderate winds [<40 km/hour]). We established avian survey plots with grids of fiberglass posts arranged in parallel lines spaced 200 m apart. Transect lines were established 100 m apart perpendicular to the grid lines. Observers recorded all birds seen and heard within 50 m of transects established within the grids. Genders of non-dimorphic species were determined by the presence or absence of song. For 9 grassland bird species (Table 2; Supporting Information), we computed the number of breeding pairs for each site (turbine and reference), survey, and year combination. A male and female observed together was considered a breeding pair; a male or female observed alone was also considered a breeding pair. The number of pairs was divided by the suitable breeding area in each turbine and reference site, as determined by breeding habitat for each species (Supporting Information), and multiplied by 100 to determine density per 100 ha (Supporting Information). We used the maximum of the biannual survey densities for each species-site-year combination to reflect peak breeding density.

We employed a BACI design (McDonald et al. 2000) to examine turbine effects on bird density. We used data from surveys conducted prior to and after turbine construction at turbine and reference sites. Using 2 different treatment specifications, we conducted analyses separately for each species and study area. The first analysis consisted of 2 treatment levels, turbine sites and reference sites, to assess overall effects of turbines on

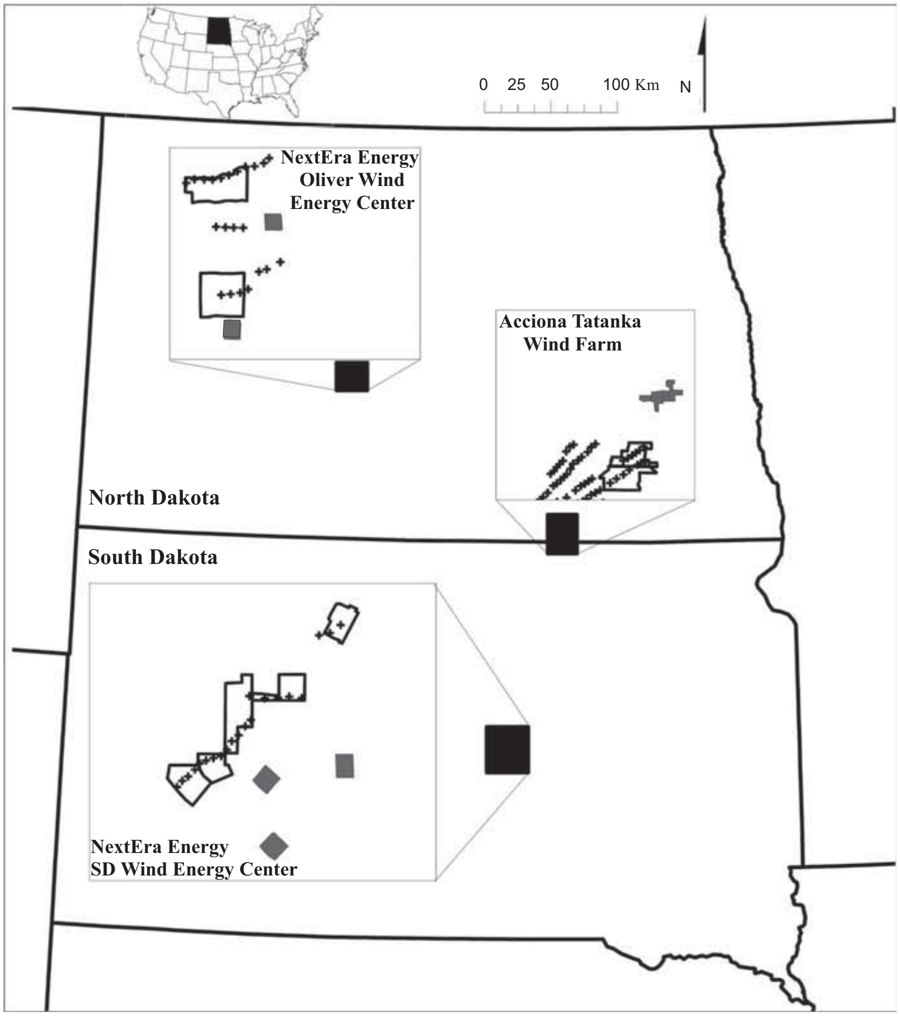

Figure 1. Map of studied wind-energy facilities in North Dakota and South Dakota (U.S.A.) (white polygons, turbine treatment sites; gray polygons, reference sites; plus symbol, turbine locations).

densities of breeding birds. For the second analysis, we divided turbine sites into 4 100-m distance bands from turbines (0-100 m, 100–200 m, 200–300 m, and >300 m), for a total of 5 treatment levels including the reference sites. We used repeated measures analysis of variance (RMANOVA) in SAS PROC MIXED (SAS Institute 2012) to assess effects of treatment and year on bird density (Verbeke & Molenberghs 2000). In the first treatment specification, year was the repeated measure and site within treatment was the experimental unit sampled each year. For the second treatment specification, site was included as a random block, year was the repeated measure, and site-by-treatment combinations were the experimental units sampled yearly. We accounted for autocorrelation among years by running a correlated error model (auto-regressive) (Littell et al. 2006).

Using the BACI design, we conducted planned contrasts among treatment means (Milliken & Johnson 2009) to estimate turbine effects. The contrasts tested whether average density for first post-treatment year minus average density for pre-treatment year was equal between turbine and reference treatments (H_0: $[\text{density}_{\text{turbine,1yr-post}} - \text{density}_{\text{turbine,pre}}] - [\text{density}_{\text{reference,1yr-post}} - \text{density}_{\text{reference,pre}}] = 0$) and if average 2- to 5-year post-treatment mean density (i.e., mean density for the 2 to 5 calendar years following turbine construction) minus average density for pre-treatment year was equal between turbine and reference treatments (H_0: $[\text{density}_{\text{turbine,2-5yr-post}} - \text{density}_{\text{turbine,pre}}] - [\text{density}_{\text{reference,2-5yr-post}} - \text{density}_{\text{reference,pre}}] = 0$). The former contrast tested for an immediate turbine effect, whereas the latter contrast tested for a delayed effect. Immediate effects were not testable at TAT because 1-year post-treatment data were not collected. For the delayed effects, the span of years in which surveys were conducted varied among study areas, and surveys were not done every year within that time span. To achieve a consistent time frame that could be assessed at all 3 study areas, we used the average of 2–5 years post-treatment to assess the delayed effect, rather than assessing effects for each post-treatment year separately.

Table 2. Test statistics from the contrasts comparing changes in bird density per 100 ha between reference and turbine sites from pre-treatment year to 1 year post-treatment in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (NEE Oliver Wind Energy Center [OL]), (U.S.A.) 2003–2012.*

Location and distance from turbines (m)	*Grasshopper Sparrow*	*Western Meadowlark*	*Bobolink*	*Upland Sandpiper*	*Killdeer*	*Savannah Sparrow*	*Clay-colored Sparrow*	*Chestnut-collared Longspur*	*Vesper Sparrow*
SD									
0-100	$t_{76} = -1.84$, $p = 0.07$	$t_{77} = -3.90$, $p<0.01$	$t_{57} = -1.25$, $p = 0.22$	$t_{83} = -1.33$, $p = 0.19$	$t_{92} = 3.21$, $p<0.01$			$t_{69} = 0.62$, $p = 0.54$	
100–200	$t_{76} = -0.31$, $p = 0.76$	$t_{77} = -0.73$, $p = 0.47$	$t_{57} = -0.26$, $p = 0.80$	$t_{83} = 0.38$, $p = 0.70$	$t_{92} = 0.70$, $p = 0.49$			$t_{69} = -1.09$, $p = 0.28$	
200–300	$t_{76} = -0.25$, $p = 0.81$	$t_{77} = -0.67$, $p = 0.50$	$t_{57} = -1.28$, $p = 0.20$	$t_{83} = -1.63$, $p = 0.11$	$t_{92} = 1.60$, $p = 0.11$			$t_{69} = -0.81$, $p = 0.42$	
>300	$t_{76} = 0.21$, $p = 0.83$	$t_{77} = -1.23$, $p = 0.22$	$t_{57} = -1.65$, $p = 0.10$	$t_{83} = -1.07$, $p = 0.29$	$t_{92} = 0.88$, $p = 0.38$			$t_{69} = 1.10$, $p = 0.27$	
Overall	$t_{29} = -0.11$, $p = 0.91$	$t_{20} = -2.27$, $p = 0.03$	$t_{36} = -1.71$, $p = 0.10$	$t_{32} = -1.23$, $p = 0.23$	$t_{25} = 2.01$, $p = 0.06$			$t_{39} = 0.50$, $p = 0.62$	
OL									
0–100	$t_{20} = -1.80$, $p = 0.09$	$t_{14} = 0.46$, $p = 0.65$	$t_{18} = -1.21$, $p = 0.24$	$t_{18} = -2.39$, $p = 0.03$	$t_{27} = 2.85$, $p = 0.01$	$t_{21} = -1.43$, $p = 0.17$	$t_{22} = -1.79$, $p = 0.09$		$t_{20} = 0.58$, $p = 0.57$
100–200	$t_{20} = -0.71$, $p = 0.49$	$t_{14} = 1.14$, $p = 0.27$	$t_{18} = -0.47$, $p = 0.64$	$t_{18} = 1.00$, $p = 0.33$	$t_{27} = 0.71$, $p = 0.48$	$t_{21} = -2.45$, $p = 0.02$	$t_{22} = -1.77$, $p = 0.09$		$t_{20} = 0.21$, $p = 0.83$
200–300	$t_{20} = 0.09$, $p = 0.93$	$t_{14} = 1.94$, $p = 0.07$	$t_{18} = 2.14$, $p = 0.05$	$t_{18} = -0.23$, $p = 0.82$	$t_{27} = -0.33$, $p = 0.74$	$t_{21} = -3.41$, $p<0.01$	$t_{22} = -0.76$, $p = 0.46$		$t_{20} = -1.64$, $p = 0.12$
>300	$t_{20} = 1.14$, $p = 0.27$	$t_{14} = 1.45$, $p = 0.17$	$t_{18} = 1.93$, $p = 0.07$	$t_{18} = -0.17$, $p = 0.87$	$t_{27} = -0.15$, $p = 0.88$	$t_{21} = -0.50$, $p = 0.62$	$t_{22} = -1.62$, $p = 0.12$		$t_{20} = 0.29$, $p = 0.77$
Overall	$t_{9} = 0.78$, $p = 0.46$	$t_{8} = 1.17$, $p = 0.28$	$t_{9} = 1.40$, $p = 0.20$	$t_{9} = -0.02$, $p = 0.99$	$t_{8} = -0.03$, $p = 0.98$	$t_{12} = -1.03$, $p = 0.32$	$t_{10} = -2.07$, $p = 0.06$		$t_{12} = 0.22$, $p = 0.83$

Cells with no values indicate an analysis for that species was not conducted because of low number of observations.

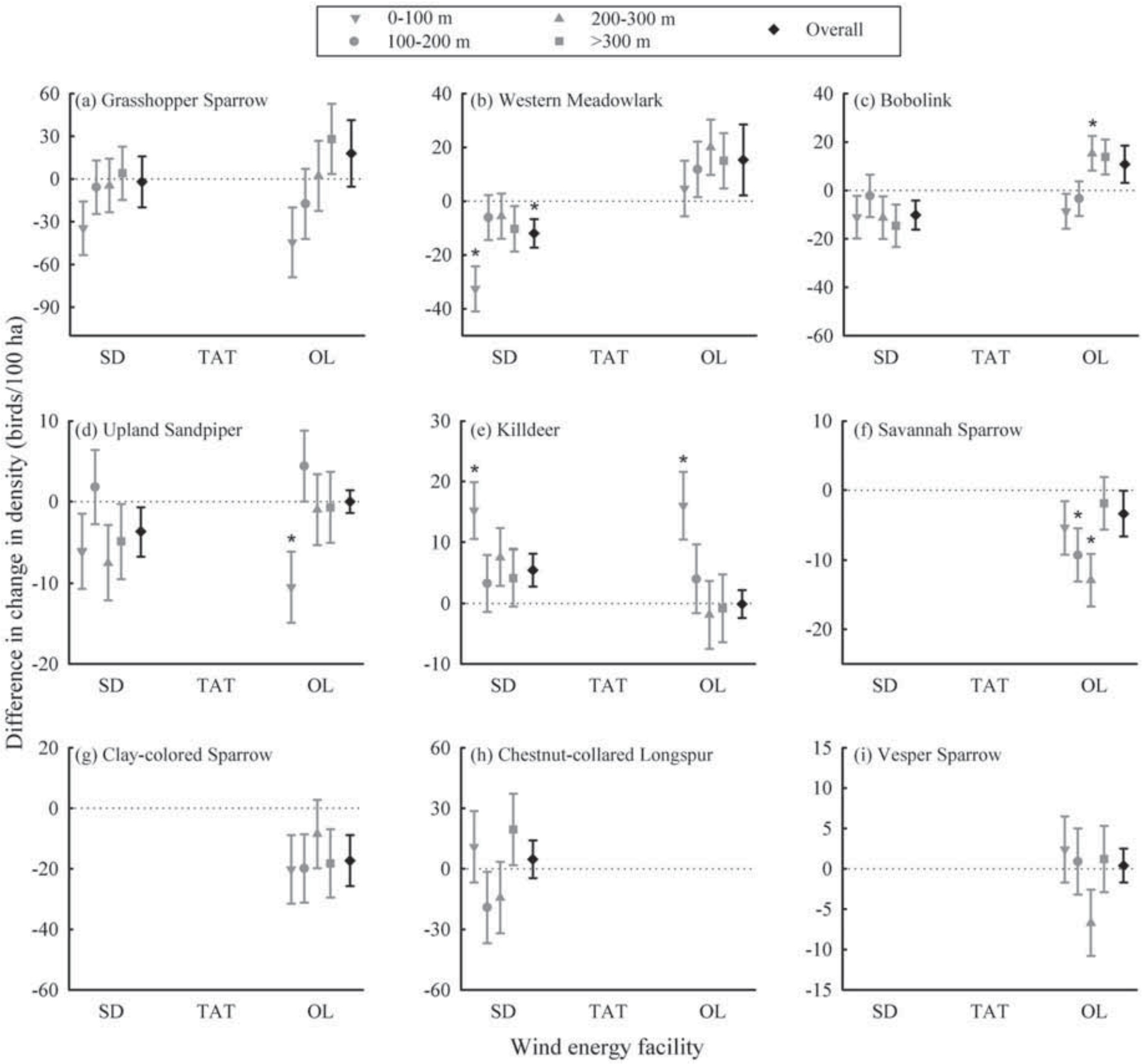

Figure 2. Difference in change in bird density/100 ha between reference and wind turbine sites from pre-treatment year to 1 year post-treatment (immediate effect) in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), 2003–2012 for (a) Grasshopper Sparrow, (b) Western Meadowlark, (c) Bobolink, (d) Upland Sandpiper, (e) Killdeer, (f) Savannah Sparrow, (g) Clay-colored Sparrow, (h) Chestnut-collared Longspur, and (i) Vesper Sparrow (difference = [$density_{turbine,1yr\text{-}post}$ – $density_{turbine,pre}$] – [$density_{reference,1yr\text{-}post}$ – $density_{reference,pre}$]; error bars, SE; value >0, positive effect; value <0, negative effect; asterisk, significant [α = 0.05] difference).

One strength of a BACI design is that it allows researchers to assume that any naturally occurring changes occur at both the impact and control sites; thus, any changes observed at the impact sites can be attributed to the impact (Manly 2001). Therefore, we assumed annual variation in bird populations and weather effects were the same for turbine and reference sites within a study area. Vegetation structure also was similar between sites (Supporting Information). In addition, turbine and reference sites were spatially replicated within wind facilities; this allowed us to account for variability among sites and to test if, on average, changes in density differed between turbine and reference sites. Therefore, any immediate or delayed effects were due to the construction of the wind facility.

Results

Immediate Effects

We detected statistically significant immediate (1-year) displacement behavior for 3 of 9 species (Western

Table 3. Test statistics from the contrasts comparing changes in bird density/100 ha between reference and turbine sites from pre-treatment year to 2-5-years post-treatment in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), (U.S.A.), 2003–2012.*

Location and distance from turbines (m)	*Grasshopper Sparrow*	*Western Meadowlark*	*Bobolink*	*Upland Sandpiper*	*Killdeer*	*Savannah Sparrow*	*Clay-colored Sparrow*	*Chestnut-collared Longspur*	*Vesper Sparrow*
SD									
0-100	$t_{142} = -3.94$, $p<0.01$	$t_{145} = -3.86$, $p<0.01$	$t_{110} = -1.10$, $p = 0.27$	$t_{145} = -1.31$, $p = 0.19$	$t_{149} = 0.97$, $p = 0.33$			$t_{140} = -2.27$, $p = 0.02$	
100–200	$t_{142} = -1.94$, $p = 0.05$	$t_{145} = -1.34$, $p = 0.18$	$t_{110} = 0.41$, $p = 0.69$	$t_{145} = -1.32$, $p = 0.19$	$t_{149} = -0.56$, $p = 0.58$			$t_{140} = -2.52$, $p = 0.01$	
200–300	$t_{142} = -1.54$, $p = 0.13$	$t_{145} = -1.97$, $p = 0.05$	$t_{110} = -0.96$, $p = 0.34$	$t_{145} = -1.92$, $p = 0.06$	$t_{149} = -0.76$, $p = 0.45$			$t_{140} = -2.54$, $p = 0.01$	
>300	$t_{142} = -1.66$, $p = 0.10$	$t_{145} = -2.32$, $p = 0.02$	$t_{110} = -0.91$, $p = 0.37$	$t_{145} = -2.82$, $p = 0.01$	$t_{149} = 0.28$, $p = 0.78$			$t_{140} = -1.10$, $p = 0.27$	
Overall	$t_{54} = -1.99$, $p = 0.05$	$t_{52} = -4.12$, $p<0.01$	$t_{54} = -0.36$, $p = 0.72$	$t_{54} = -2.79$, $p = 0.01$	$t_{54} = 0.07$, $p = 0.94$			$t_{55} = -2.19$, $p = 0.03$	
TAT									
0-100	$t_{38} = -3.49$, $p<0.01$	$t_{41} = 0.16$, $p = 0.87$	$t_{33} = -5.34$, $p<0.01$	$t_{39} = 0.11$, $p = 0.91$	$t_{43} = 1.74$, $p = 0.09$	$t_{31} = -0.94$, $p = 0.35$	$t_{39} = -3.57$, $p<0.01$		$t_{47} = 1.18$, $p = 0.24$
100–200	$t_{38} = -2.54$, $p = 0.02$	$t_{41} = -0.01$, $p = 0.99$	$t_{33} = -5.69$, $p<0.01$	$t_{39} = -0.28$, $p = 0.78$	$t_{43} = 0.80$, $p = 0.43$	$t_{31} = -2.78$, $p = 0.01$	$t_{39} = -3.52$, $p<0.01$		$t_{47} = -0.61$, $p = 0.54$
200–300	$t_{38} = -2.43$, $p = 0.02$	$t_{41} = -0.21$, $p = 0.84$	$t_{33} = -6.85$, $p<0.01$	$t_{39} = -0.48$, $p = 0.63$	$t_{43} = 1.73$, $p = 0.09$	$t_{31} = -2.53$, $p = 0.02$	$t_{39} = -1.83$, $p = 0.08$		$t_{47} = -0.15$, $p = 0.88$
>300	$t_{38} = -1.75$, $p = 0.09$	$t_{41} = 0.13$, $p = 0.90$	$t_{33} = -4.78$, $p<0.01$	$t_{39} = -0.32$, $p = 0.75$	$t_{43} = 0.52$, $p = 0.60$	$t_{31} = -0.52$, $p = 0.61$	$t_{39} = -1.55$, $p = 0.13$		$t_{47} = 0.84$, $p = 0.41$
Overall	$t_{23} = -1.67$, $p = 0.11$	$t_{23} = 0.19$, $p = 0.85$	$t_{23} = -4.55$, $p<0.01$	$t_{23} = -0.15$, $p = 0.88$	$t_{11} = 1.51$, $p = 0.16$	$t_{22} = -0.93$, $p = 0.36$	$t_{20} = -1.37$, $p = 0.18$		$t_{22} = 0.37$, $p = 0.71$
OL									
0-100	$t_{36} = -3.62$, $p<0.01$	$t_{33} = -0.79$, $p = 0.43$	$t_{39} = -2.75$, $p = 0.01$	$t_{35} = -2.90$, $p = 0.01$	$t_{37} = 0.70$, $p = 0.49$	$t_{34} = -0.41$, $p = 0.68$	$t_{36} = -1.62$, $p = 0.11$		$t_{33} = 1.97$, $p = 0.06$
100–200	$t_{36} = -3.41$, $p<0.01$	$t_{33} = -1.41$, $p = 0.17$	$t_{39} = -2.31$, $p = 0.03$	$t_{35} = 0.15$, $p = 0.88$	$t_{37} = 0.42$, $p = 0.68$	$t_{34} = -1.32$, $p = 0.20$	$t_{36} = -1.61$, $p = 0.12$		$t_{33} = -0.52$, $p = 0.61$
200–300	$t_{36} = -3.35$, $p<0.01$	$t_{33} = -0.05$, $p = 0.96$	$t_{39} = 0.33$, $p = 0.74$	$t_{35} = -0.99$, $p = 0.33$	$t_{37} = -0.14$, $p = 0.89$	$t_{34} = -2.88$, $p = 0.01$	$t_{36} = -1.68$, $p = 0.10$		$t_{33} = -1.40$, $p = 0.17$
>300	$t_{36} = -0.98$, $p = 0.33$	$t_{33} = -0.56$, $p = 0.58$	$t_{39} = 0.01$, $p = 0.99$	$t_{35} = -0.58$, $p = 0.57$	$t_{37} = -0.72$, $p = 0.47$	$t_{34} = -0.28$, $p = 0.78$	$t_{36} = -2.09$, $p = 0.04$		$t_{33} = 0.25$, $p = 0.80$
Overall	$t_{12} = -1.82$, $p = 0.09$	$t_{16} = -0.53$, $p = 0.60$	$t_{16} = -0.34$, $p = 0.74$	$t_{16} = -1.01$, $p = 0.33$	$t_{7} = -1.34$, $p = 0.22$	$t_{16} = -0.65$, $p = 0.53$	$t_{16} = -1.79$, $p = 0.09$		$t_{16} = -0.09$, $p = 0.93$

Cells with no values indicate an analysis for that species was not conducted because of low number of observations.

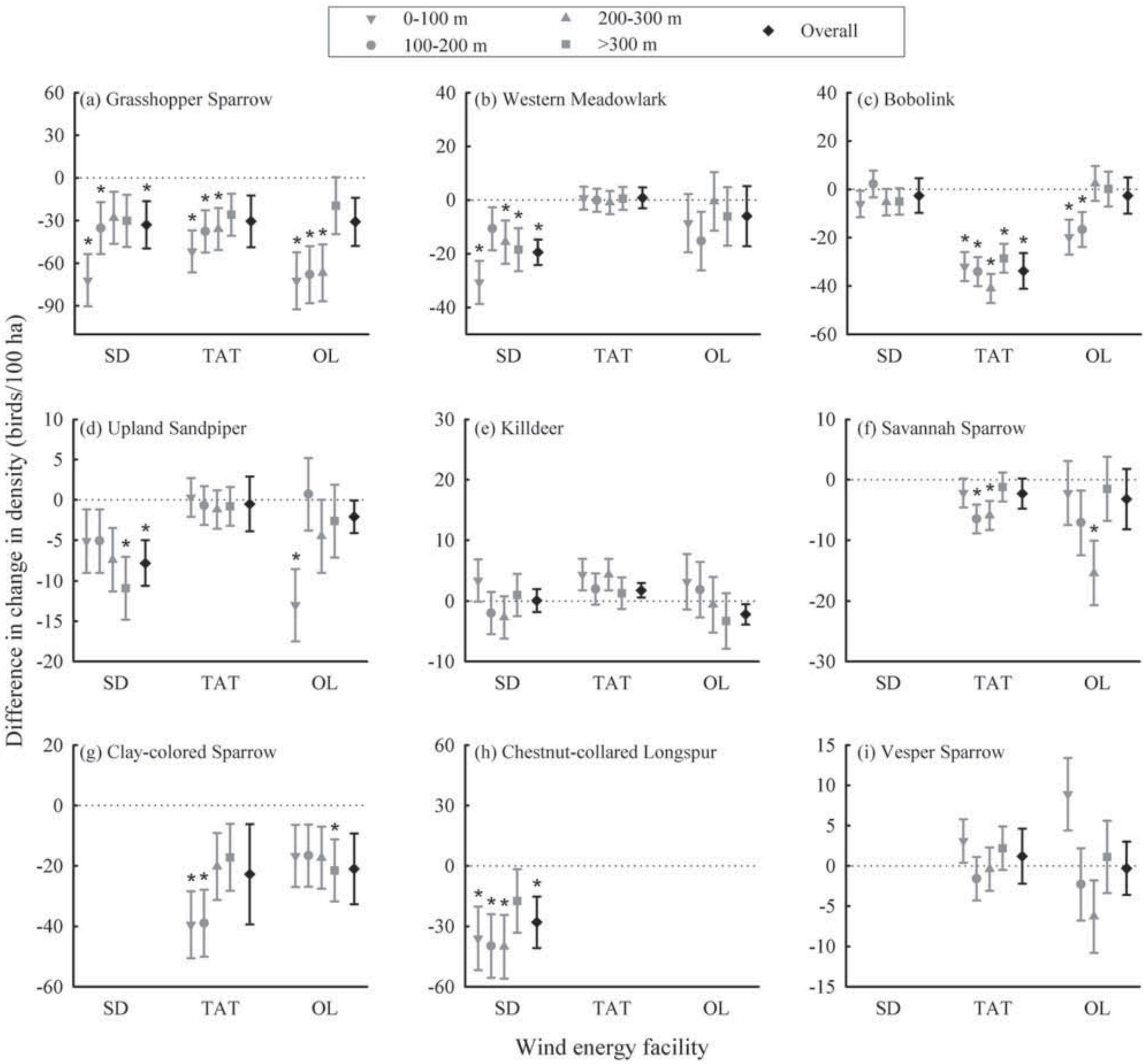

Figure 3. Difference in change in bird density/100 ha between reference and wind turbine site from pre-treatment year to 2–5 years post-treatment (delayed effect) in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), 2003–2012 for (a) Grasshopper Sparrow, (b) Western Meadowlark, (c) Bobolink, (d) Upland Sandpiper, (e) Killdeer, (f) Savannah Sparrow, (g) Clay-colored Sparrow, (h) Chestnut-collared Longspur, and (i) Vesper Sparrow (difference = [$density_{turbine,2\text{-}5yr\text{-}post}$ – $density_{turbine,pre}$] – [$density_{reference,2\text{-}5yr\text{-}post}$ – $density_{reference,pre}$]; error bars, SE; value >0, positive effect; value <0, negative effect; asterisk, significant [$\alpha = 0.05$] difference).

Meadowlark [*Sturnella neglecta*], Upland Sandpiper [*Bartramia longicauda*], and Savannah Sparrow [*Passerculus sandwichensis*]) and attraction for 2 species (Killdeer [*Charadrius vociferous*] and Bobolink [*Dolichonyx oryzivorus*]) (Table 2). For Western Meadowlark, displacement was detected at SD; effects were apparent overall and within 100 m (Fig. 2b). For Upland Sandpiper, displacement was detected at OL, but only within 100 m (Fig. 2d). Change in density of Savannah Sparrow was lower 100–300 m from turbines than at reference sites at OL, the one study area in which immediate effects could be determined for this species (Fig. 2f). Killdeer expressed attraction within 100 m of turbines at both study areas 1 year post-construction (Fig. 2e, Table 2). Bobolink exhibited a positive difference 200–300 m at OL (Fig. 2c, Table 2).

Wind facilities had no significant immediate effect on Grasshopper Sparrow (*Ammodramus savannarum*), Clay-colored Sparrow (*Spizella pallida*), or Chestnut-collared Longspur (*Calcarius ornatus*) (Table 2). However, the magnitude of differences (≥20 birds/100 ha) between turbine sites and reference sites suggested these species may have exhibited immediate displacement (Fig. 2a, 2g, 2h). Vesper Sparrow (*Pooecetes gramineus*) appeared unaffected by wind facilities (Fig. 2i).

Delayed Effects

We detected significant displacement behavior beyond 1 year for 7 species (Table 3). For Grasshopper Sparrow, we detected displacement overall at SD, within 200 m at all 3 study areas, and within 200–300 m at TAT and OL (Fig. 3a). Bobolink, Upland Sandpiper, Savannah Sparrow, and Clay-colored Sparrow exhibited displacement at 2 study areas each (Fig. 3c, 3d, 3f, 3g). Displacement occurred overall and at all distances for Bobolink at TAT, but only within 200 m at OL. Upland Sandpiper exhibited displacement overall and beyond 300 m at SD, but only within 100 m at OL. Displacement was observed within 200–300 m for Savannah Sparrow at both TAT and OL and within 100–200 m at TAT. For Clay-colored Sparrow, significant displacement occurred within 200 m at TAT and >300 m at OL. For Western Meadowlark and Chestnut-collared Longspur, displacement was detected at SD only. Effects were apparent overall, within 100 m, and beyond 200 m for Western Meadowlark (Fig. 3b) and overall and within 300 m for Chestnut-collared Longspur (Fig. 3h). Killdeer and Vesper Sparrow showed no delayed effects (Fig. 3e, 3i).

Discussion

The preferred design for testing impacts of energy infrastructure on wildlife is the BACI design (Evans 2008; Strickland et al. 2011), but examples are rare (Supporting Information). Our work provides a framework for applying a BACI design to behavioral studies and highlights the erroneous conclusions that can be made when the BACI approach is not used. If we had data from only impact sites (i.e., no reference sites) or had only post-treatment data (i.e., no pre-treatment monitoring) and thus not been able to use a BACI design, our conclusions would have been different. Obtaining data from impact and reference sites allowed us to discern changes in avian densities due to wind facilities as opposed to naturally occurring changes. For example, Grasshopper Sparrow at SD showed a large change in density on the turbine sites (i.e., a decrease of more than 60 birds/100 ha) from the pre-treatment year to the first year post-treatment (Supporting Information). Without reference sites, we may have interpreted this decrease in density to be due to turbine operation. However, we observed a similar change in density at reference sites, indicating the change on the turbine sites was probably due not to turbine operation but rather to normal annual variation in avian density. Pre-treatment data were used to account for differences among the turbine and reference sites prior to turbine construction, which allowed us to attribute post-treatment differences to turbine operation. For example, Grasshopper Sparrows at SD had higher average density for reference sites (60.1 birds/100 ha) than for turbine sites (38.3 birds/100 ha) in the first post-construction year (Supporting Information). Without pre-treatment data, this difference might have been interpreted as a turbine effect. However, pre-treatment data provided evidence of existing site differences of the same magnitude (Supporting Information) and therefore indicates there was no turbine effect.

By collecting data the year following construction and beyond 1 year post-construction, we were able to assess whether species exhibited immediate effects, delayed effects, or sustained effects. Because our turbine and reference sites were near one another and were similar with respect to landscape composition, vegetation, topography, and weather, the BACI design allowed us to assume that any naturally occurring changes happen at both the turbine and reference sites and therefore can be ruled out as alternative explanations. In addition, spatial replication of turbine and reference sites within study areas accounts for inherent variability among sites (Underwood 1992). Thus, any effects we observed were attributed to the operation of the wind facility.

Immediate effects were manifested by displacement or attraction the year following turbine construction. Birds returning in the spring following construction would encounter an altered landscape and would need to decide whether to settle near a wind facility or move elsewhere. In our study areas, Vesper Sparrows and Killdeer showed a high degree of tolerance to newly constructed wind facilities. Vesper Sparrows are often the first species to occupy disturbed areas (Jones & Cornely 2002); therefore, lack of displacement is not surprising given this life-history characteristic. Moreover, Johnson et al. (2000) reported attraction of Vesper Sparrows to turbines 1 year post-construction at grassland sites in Minnesota (U.S.A.). Killdeer prefer gravel substrates for nesting, and roadsides are preferred habitat (Jackson & Jackson 2000). Our finding that Killdeer density increased nearest to newly constructed turbines likely reflects similar habitat selection. Similarly, Johnson et al. (2000) reported higher than expected use of turbine plots in Minnesota by Horned Larks (*Eremophila alpestris*), another species that prefers disturbed areas. However, Erickson et al. (2004) found no evidence of attraction (or displacement) for this species in Oregon (U.S.A.).

Some species in our study areas did not exhibit immediate effects, yet we observed displacement in years beyond the first year post-construction (i.e., delayed effects). Species exhibiting breeding site fidelity might be more inclined to show delayed effects than immediate effects. Individuals will return to a turbine site 1 year post-construction due to site fidelity, but they may not return in subsequent years because of intolerance of the wind facility. In addition, new individuals may be unwilling to settle near turbines. We detected delayed displacement for Grasshopper Sparrow, Western Meadowlark, Bobolink, Upland Sandpiper, Clay-colored Sparrow, and Chestnut-collared Longspur, all of which exhibit breeding site fidelity (Hill & Gould 1997; Jones et al. 2007). Likewise, Johnson et al. (2000) reported delayed effects for Grasshopper Sparrow, Bobolink, and Savannah Sparrow, which also shows breeding site fidelity (Fajardo et al. 2009). On a Scottish wind facility 3 years post-construction, Douglas et al. (2011) detected delayed effects for 2 upland species, Red Grouse (*Lagopus lagopus scotica*) and European Golden Plover (*Pluvialis apricaria*); these 2 species are also site faithful (Jenkins et al. 1963; Parr 1980).

We considered a species to be exhibiting a sustained effect if displacement continued from 1 year post-construction into 2–5 years post-construction. In our study, sustained displacement usually occurred within 100 m (e.g., Western Meadowlark at SD and Upland Sandpiper at OL). Few other researchers have examined sustained effects. Pearce-Higgins et al. (2012) detected positive long-term effects in the United Kingdom for 2 upland species and negative effects for 2 waterbird species.

Consistency of behavioral responses to wind facilities varied across the 9 species of grassland nesting birds we monitored. Grasshopper Sparrows and Clay-colored Sparrows exhibited the most consistent results across study areas. The Grasshopper Sparrow is an area- and edge-sensitive species (Grant et al. 2004; Ribic et al. 2009) for which amount of grassland in the surrounding landscape is important (Berman 2007; Greer 2009). Wind facilities appear to be an additional landscape change not tolerated by Grasshopper Sparrows, and the construction of additional wind facilities throughout native grasslands could be detrimental to the species. Clay-colored Sparrows prefer grasslands intermixed with shrubs and woody edges (Grant & Knapton 2012). We speculate that removal of woody vegetation during construction of roads and turbines reduced breeding habitat for this species.

Bobolinks, Western Meadowlarks, Upland Sandpipers, and Savannah Sparrows exhibited inconsistent displacement behavior across study areas. Because we were not always present on study areas in the same years, we suspect inconsistencies resulted from habitat differences specific to study area that may have been influenced by variable precipitation patterns. The interaction of habitat conditions and species-specific life-history strategies may have influenced behavior. For example, Bobolinks exhibited strong displacement at TAT, which was the largest wind facility with the most intact grasslands and the highest precipitation. Densities of Bobolinks also were greatest at TAT (Supporting Information); hence, density dependent effects may arise at these higher densities and may result from habitat loss (both grassland and wetland) with construction of turbines. As a result of high precipitation, grasslands at this site were interspersed with many small wetlands containing nesting pairs of Red-winged Blackbirds (*Agelaius phoeniceus*). Red-winged Blackbirds and Bobolinks are antagonistic. Red-winged Blackbirds may displace Bobolinks from perches, and Bobolinks appear to avoid nesting near active blackbird nests (Martin & Gavin 1995). Thus, displacement of Bobolinks at TAT could have been more evident because of intra- or interspecific competition.

For other species, cumulative effects of wind facilities and other landscape changes might be the cause of inconsistent results. Western Meadowlarks are a gregarious species not reported to be sensitive to habitat area or habitat edges (Johnson & Igl 2001), and some degree of anthropogenic activity appears acceptable to them. However, we speculate that the degree of anthropogenic disturbance at SD surpassed the species' threshold of tolerance to human activity. The sustained displacement observed at SD could be the species' response to the additive stressors of wind-facility operation and recent land conversion from grassland to agricultural fields (Wright & Wimberly 2013). Increasing urbanization had a strong negative effect on the density of a congeneric species, Eastern Meadowlark (*Sturnella magna*), in grasslands (McLaughlin et al. 2014). Conversely, TAT, where no displacement effects were observed for Western Meadowlarks, has undergone little land conversion, was composed of 92% perennial grasslands (Loesch et al. 2013), and was located in a remote area rarely traversed by humans other than personnel associated with the wind facility. Upland Sandpiper displayed the most inconsistent results and a similar pattern as Western Meadowlark. The species is highly sensitive to habitat fragmentation (Ribic et al. 2009), and the strongest displacement effects occurred on the most fragmented study areas, SD and OL. No displacement was detected on the least fragmented study area. As with Western Meadowlarks, Upland Sandpipers may have reached a threshold beyond which additional landscape disturbance could not be tolerated and displacement behavior became apparent.

Our results for displacement distances for Grasshopper Sparrow (300 m), Bobolink (>300 m), Western Meadowlark (>300 m), Upland Sandpiper (100 m), Clay-colored Sparrow (200 m), Savannah Sparrow (300 m), and Chestnut-collared Longspur (300 m) were consistent with those reported by other researchers. In a literature review of North American grassland birds, Johnson and Stephens (2011) reported displacement extending 50–180 m from turbines. Stevens et al. (2013) found that mean plot occupancy for Le Conte's Sparrows

(*Ammodramus leconteii*) wintering in Texas was 4 times lower in plots <200 m from nearest wind turbine relative to >400 m from the nearest turbine. In the United Kingdom, 7 of 12 upland species exhibited displacement within 500 m (Pearce-Higgins et al. 2009). Winkelman (1992) found that shorebirds in a Netherlands wind facility occurred in significantly smaller numbers within 500 m from turbines. Thus, although displacement can occur as far as 500 m from turbines, most studies show displacement within 200 m.

Evaluating turbine effects overall and by distance from turbine allowed us to differentiate between localized displacement and site abandonment. For several species, immediate or delayed effects occurred by distance at a site, but there was no significant reduction in density at that site overall. This may have occurred because breeding pairs near turbines relocated short distances from turbines but not off the site completely. For example, Grasshopper Sparrow at OL showed an immediate reduction in density of birds near turbines and an increased density at distance categories >300 m and overall. Thus, Grasshopper Sparrows may not abandon sites completely; rather, they may relocate away from the turbines and establish territories farther from turbines. Without examining displacement by distance band, we would have missed this localized displacement and instead concluded there was no displacement. Niemuth et al. (2013) also found near-turbine displacement. They modeled mean occupancy for 4 waterbird species at 2 wind facilities in North Dakota, one of which was TAT, and found that species occurrences were not substantially reduced overall at either facility post-construction. However, occupancy was slightly and consistently lower for 3 of the 4 species at one wind facility. Thus, effects of wind facilities should be examined overall and by distance from turbines.

Our identification of species-specific behaviors to wind facilities can be used to inform management decisions about turbine placement in grasslands and the potential impact at an individual species level. Metrics of displacement distances can be used to parameterize models that quantify the potential loss of habitat under scenarios of differing land uses and corresponding avian community composition. Output from these models may help drive conservation planning, such as prioritizing landscapes of highest value for preservation or restoration.

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Supporting Information

A comparison of avian and mammal displacement studies in which impact assessment designs were used (Appendix S1), a description of avian habitat preferences and population status of focal species (Appendix S2), a description of vegetation surveys and a related table of least squares means for vegetation variables (Appendix S3), and 3 tables with least squares means for density of birds on reference and turbine sites (Appendix S4) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Supporting Information - Appendix S1.

Table S1.1. Studies of avian and mammal displacement from onshore wind facilities that used impact assessment designs of Before-After Control-Impact (BACI), Control-Impact (CI), Before-After (BA), and Impact-Gradient (IG) (Manly 2001).

Source	Country	Taxonomic group	Variable of interest	Season	No. wind Facilities	Impact assessment design	No. Yrs. Pre-Treatment	No. Yrs. Post-Treatment[a]
Winkelman 1992	Netherlands	multiple avian	abundance	year-round	1	IG, BACI	1-3	1
Osborn et al. 1998	USA	multiple avian	abundance flight height	breeding migration	1	CI	0	2
Leddy et al. 1999	USA	passerine	density	breeding	1	CI	0	1
Johnson et al. 2000a	USA	multiple avian	avian use	breeding migration	1	BACI	2	2
Johnson et al. 2000b	USA	multiple avian and mammal	abundance distribution use	year-round	1	BACI	2	1
Larsen and Madsen 2000	Denmark	waterbird	field utilization	winter	2	IG	0	1
Barrios and Rodriguez 2004	Spain	raptor	flight behavior	year-round	2	IG	0	1
de Lucas et al. 2004	Spain	passerine raptor	abundance productivity flight behavior	year-round	1	CI	0	2
Erickson et al. 2004	USA	passerine	avian use	breeding	1	BA, IG	1	1
de Lucas et al. 2005	Spain	multiple avian and mammal	abundance flight behavior	breeding	1	BACI, IG	1	1
Rabin et al. 2006	USA	ground squirrel	antipredator behavior	breeding	1	CI	0	1

Walter et al. 2006	USA	elk	distance home range	year-round	1	BA	1	2
Devereaux et al. 2008	UK	multiple avian	occurrence	winter	2	IG	0	1
Madsen and Boertmann 2008	Denmark	waterbird	field utilization	migration	3	IG	0	2
Pearce-Higgins et al. 2009	UK	multiple avian	occurrence flight height	breeding	12	CI	0	1
Douglas et al. 2011	UK	game bird waterbird	abundance occurrence	breeding	1	CI	0	2
Garvin et al. 2011	USA	raptor	abundance flight height	breeding	1	BA, CI	1	2
Jain et al. 2011	USA	bats	activity	migration breeding	1	CI	0	2
Pearce-Higgins et al. 2012	UK	game bird passerine waterbird	density	breeding	18	BACI	1	1-5
Rubenstahl et al. 2012	USA	passerine	productivity	breeding	1	IG	0	1
Hatchett et al. 2013	USA	passerine	productivity	breeding	1	IG	0	2
Loesch et al. 2013	USA	waterbird	density	breeding	2	CI	0	3
Niemuth et al. 2013	USA	waterbird	occurrence	breeding	2	CI	0	3
Stevens et al. 2013	USA	passerine	occupancy	winter	1	IG	0	2
Bennett et al. 2014	USA	passerine	productivity	breeding	1	IG	0	1
LeBeau et al. 2014	USA	game bird	fitness productivity	breeding	1	IG	0	2
McNew et al. 2014	USA	game bird	site selection productivity	breeding	1	BA, IG	2	3
Winder et al. 2014a	USA	game bird	fitness	year-round	1	BA, IG	2	3

Winder et al. 2014b	USA	game bird	home range distribution	year-round	1	BA, IG	2	3
Shaffer and Buhl, this paper	USA	passerine waterbird	density	breeding	3	BACI	1	3-4[b]

[a]Construction years were not included.
[b]We had 3-4 post-treatment years of data over the 5-year post-treatment time frame (i.e., 5 calendar years) used for analyses.

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Supporting Information - Appendix S2.

Table S2.1. Habitat classification, population trend, and conservation status of avian species that were sufficiently abundant to include in analyses examining the effects of wind energy development on avian density in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD], U.S.A.) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL], U.S.A.), 2003-2012.

Species	Habitat classification[a]	Population trend (%)[b]	Species of concern[b]
Grasshopper sparrow *Ammodramus savannarum*	grassland obligate	-2.5	no
Bobolink *Dolichonyx oryzivorus*	grassland obligate	-2.1	yes
Western meadowlark *Sturnella neglecta*	grassland obligate	-1.3	no
Killdeer *Charadrius vociferous*	generalist	-1.2	no
Upland sandpiper *Bartramia longicauda*	grassland obligate	0.5	yes
Clay-colored sparrow *Spizella pallida*	grassland/shrubland	-1.4	no
Vesper sparrow *Pooecetes gramineus*	grassland obligate	-0.9	no
Savannah sparrow *Passerculus sandwichensis*	grassland obligate	-1.2	no
Chestnut-collared longspur *Calcarius ornatus*	grassland obligate	-4.3	yes

[a]Habitat classification and concern rankings from NABCI (2014).

[b]Breeding Bird Survey population trends from Sauer et al. (2013).

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Supporting Information

Appendix S3. Description of vegetation surveys and analysis for the study on effects of wind energy facilities on grassland birds in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD], U.S.A.) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center (OL), U.S.A.), 2003-2012.

The mixed-grass prairie biome in North Dakota and South Dakota (U.S.A.) is a heterogeneous landscape of wetland complexes embedded within grasslands of highly scattered patches of low-growing trees and shrubs, such as S*ymphoricarpos occidentalis* (Hook) and *Prunus virginiana* (L.). Non-grassland habitats within sites were mapped using GPS units and digital photography because our focal species did not breed within all available habitat types within any particular site. For example, grasshopper sparrows were never detected within wetlands or colonies of black-tailed prairie dogs *Cynomys ludovicianus* (Ord). We accounted for the fact that some of our focal species have particular breeding habitat preferences by mapping area of wetlands (open water), woodlands, colonies of black-tailed prairie dogs, and exceptionally lush grass and deleting these areas from total area of each site, as applicable, so as to calculate suitable breeding area at a species level. Wetland area was removed for all nine of our focal species, woodland area was removed for all species except clay-colored sparrow, area of prairie-dog colony was removed for grasshopper sparrow (JAS, personal observation), and area of lush grass was removed for chestnut-collared longspur (Hill & Gould 1997).

Vegetation measurements were taken within the 50 m by 200 m cells formed by the avian survey grids. Cells were systematically chosen and sampling was conducted along 1-2 sampling lines. Percent composition of six basic life forms, bare ground (e.g., bare ground, cow pie, rock), grass, forb, shrub, standing residual, and lying litter, was estimated using a step-point sampler (Owensby 1973). Height-density (i.e., visual obstruction) was measured with a Robel pole (Robel et al. 1970). Vegetation height and litter depth were measured with a meter stick. Measurements were averaged to characterize each site.

To examine the similarity in vegetation metrics (e.g., vegetation height, proportion bare ground) between turbine and reference sites, a repeated measures analysis of variance was conducted to estimate and compare mean habitat features between turbine and reference sites and among years.

Vegetation characteristics did not significantly vary between reference and turbine sites except for VOR at TAT, where the difference was still quite small (see Appendix Table S2.1). As expected, yearly differences did occur for most vegetation characteristics. Therefore, the habitat was similar between reference and turbine sites and can be excluded as a possible confounding factor.

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Table S3.1. Least squares means of each vegetation variable for reference and turbine sites, at SD Wind Energy Center (SD) in Highmore, South Dakota (2003-2012); Acciona's Tatanka Wind Farm (TAT) in Forbes, North Dakota (2007-2012); and Oliver Wind Energy Center (OL) in Oliver Co., North Dakota (2006-2011), U.S.A. Sig. column indicates significance at a significance level of 0.05, t indicates significant difference between reference and turbine sites, y indicates significant difference among years, and t*y indicates a significant turbine*year interaction.

	SD			TAT			OL		
	Reference	Turbine	Sig. [a]	Reference	Turbine	Sig.	Reference	Turbine	Sig. [a]
VOR	0.97 (0.16)	0.74 (0.12)	y	0.93 (0.05)	1.33 (0.07)	t	1.09 (0.07)	0.77 (0.07)	t*y
Litter Depth	2.58 (0.41)	2.11 (0.32)	t*y	3.05 (0.28)	3.71 (0.38)	y	2.92 (0.34)	2.48 (0.34)	y
Veg Height	26.47 (2.32)	23.48 (1.81)	y	29.30 (1.90)	33.67 (2.65)	y	29.76 (2.05)	23.41 (2.05)	t*y
Bare Ground	0.03 (0.01)	0.03 (0.01)	y	0.02 (0.00)	0.01 (0.01)		0.01 (0.01)	0.04 (0.01)	
Forbs	0.11 (0.02)	0.10 (0.02)	t*y	0.17 (0.01)	0.21 (0.02)	y	0.12 (0.02)	0.15 (0.02)	y
Grass	0.64 (0.02)	0.65 (0.01)	y	0.62 (0.03)	0.58 (0.04)	y	0.68 (0.03)	0.59 (0.03)	
Lying Litter	0.16 (0.02)	0.17 (0.02)	t*y	0.08 (0.01)	0.05 (0.01)	y	0.09 (0.02)	0.09 (0.02)	
Res. Litter	0.05 (0.01)	0.05 (0.01)	y	0.04 (0.01)	0.05 (0.01)	y	0.08 (0.01)	0.07 (0.01)	y
Shrubs	---	---		0.07 (0.02)	0.09 (0.03)		0.02 (0.02)	0.05 (0.02)	y

[a]Most interaction effects were significant due to year differences rather than to differences between reference and turbine sites.

Supporting Information

Appendix S4. Least squares means (SE) of density / 100 ha for reference and turbine sites for 3 study sites in North Dakota and South Dakota (U.S.A.), 2003-2012.

Table S4.1. Least squares means (SE) of density/100 ha for reference and turbine sites each year at SD Wind Energy Center (SD) in Highmore, South Dakota.

	Year	Grasshopper Sparrow	Chestnut-collared Longspur	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer
Reference Sites	2003	124.3 (11.2)	56.7 (10.4)	22.0 (3.2)	8.5 (5.2)	2.3 (1.9)	3.2 (1.3)
	2004	60.1 (11.2)	42.3 (10.4)	22.0 (3.2)	12.9 (5.2)	1.5 (1.9)	0.0 (1.3)
	2005	62.1 (11.2)	36.2 (10.4)	15.5 (3.2)	6.6 (5.2)	2.9 (1.9)	0.7 (1.3)
	2006	100.6 (11.2)	65.8 (10.4)	30.3 (3.2)	5.2 (5.2)	3.7 (1.9)	2.2 (1.3)
	2008	130.7 (11.2)	120.6 (10.4)	37.6 (3.2)	14.8 (5.2)	1.8 (1.9)	0.8 (1.3)
	2010	87.4 (11.2)	39.8 (10.4)	23.2 (3.2)	18.2 (5.2)	5.1 (1.9)	0.0 (1.3)
	2012	79.4 (11.2)	60.3 (10.4)	15.5 (3.2)	42.4 (5.2)	2.6 (1.9)	1.7 (1.3)
Turbine Sites	2003	104.6 (8.6)	47.3 (8.1)	36.6 (2.5)	7.2 (4.0)	9.8 (1.5)	4.7 (1.0)
	2004	38.3 (8.6)	37.5 (8.1)	24.6 (2.5)	1.3 (4.0)	5.3 (1.5)	7.1 (1.0)
	2005	31.6 (8.6)	23.7 (8.1)	16.5 (2.5)	3.1 (4.0)	2.2 (1.5)	1.8 (1.0)
	2006	52.0 (8.6)	38.4 (8.1)	28.3 (2.5)	5.6 (4.0)	3.2 (1.5)	4.2 (1.0)
	2008	51.4 (8.6)	48.2 (8.1)	23.9 (2.5)	6.1 (4.0)	2.1 (1.5)	2.8 (1.0)
	2010	34.5 (8.6)	35.3 (8.1)	20.3 (2.5)	2.3 (4.0)	3.7 (1.5)	4.3 (1.0)
	2012	53.9 (9.7)	43.7 (8.8)	27.7 (2.8)	9.7 (4.5)	5.3 (1.6)	4.3 (1.2)
Reference Average		92.1 (4.6)	60.2 (7.1)	23.7 (1.2)	15.5 (2.9)	2.9 (0.8)	1.2 (0.5)
Turbine Average		52.3 (3.6)	39.1 (5.5)	25.4 (1.0)	5.0 (2.3)	4.5 (0.6)	4.2 (0.4)
Overall Average		72.2 (2.9)	49.7 (4.5)	24.6 (0.8)	10.3 (1.8)	3.7 (0.5)	2.7 (0.3)

Table S4.2. Least squares means (SE) of density/100 ha for reference and turbine sites each year at Acciona's Tatanka Wind Farm (TAT) in Forbes, North Dakota.

	Year	Grasshopper Sparrow	Clay-colored Sparrow	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer	Savannah Sparrow	Vesper Sparrow
Reference Sites	2007	67.6 (8.8)	27.1 (11.6)	13.8 (2.0)	39.0 (3.6)	8.8 (1.9)	0.2 (0.6)	5.2 (1.4)	6.4 (1.7)
	2009	55.1 (8.8)	31.9 (11.6)	13.1 (2.0)	22.1 (3.6)	10.3 (1.9)	1.4 (0.6)	3.0 (1.4)	4.6 (1.7)
	2010	84.4 (8.8)	30.6 (11.6)	17.2 (2.0)	31.0 (3.6)	11.5 (1.9)	1.2 (0.6)	4.3 (1.4)	1.9 (1.7)
	2012	93.7 (10.2)	92.4 (12.6)	10.8 (2.3)	31.4 (4.2)	4.1 (2.1)	2.9 (0.7)	10.5 (1.5)	5.7 (1.9)
Turbine Sites	2007	87.8 (12.5)	47.1 (16.4)	10.6 (2.9)	70.9 (5.1)	3.9 (2.7)	1.2 (0.9)	6.6 (1.9)	2.7 (2.4)
	2009	47.3 (12.5)	35.3 (16.4)	12.1 (2.9)	24.8 (5.1)	3.2 (2.7)	3.1 (0.9)	4.8 (1.9)	2.4 (2.4)
	2010	89.6 (12.5)	30.3 (16.4)	9.8 (2.9)	25.0 (5.1)	4.3 (2.7)	5.3 (0.9)	3.7 (1.9)	1.2 (2.4)
	2012	65.6 (12.5)	80.8 (16.4)	11.8 (2.9)	28.9 (5.1)	2.0 (2.7)	5.6 (0.9)	6.7 (1.9)	1.5 (2.4)
Reference Average		75.2 (4.6)	45.5 (10.0)	13.7 (1.0)	30.9 (2.0)	8.7 (1.4)	1.4 (0.3)	5.8 (1.0)	4.7 (0.8)
Turbine Average		72.6 (6.3)	48.4 (14.1)	11.1 (1.4)	37.4 (2.7)	3.3 (1.9)	3.8 (0.4)	5.4 (1.4)	2.0 (1.1)
Overall Average		73.9 (3.9)	46.9 (8.6)	12.4 (0.8)	34.1 (1.7)	6.0 (1.2)	2.6 (0.3)	5.6 (0.9)	3.3 (0.7)

Table S4.3. Least squares means (SE) of density/100 ha for reference and turbine sites each year at Oliver Wind Energy Center (OL) in Oliver County, North Dakota.

	Year	Grasshopper Sparrow	Clay-colored Sparrow	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer	Savannah Sparrow	Vesper Sparrow
Reference Sites	2006	105.2 (10.2)	25.6 (6.8)	28.0 (6.6)	42.0 (4.3)	7.7 (1.2)	1.3 (1.0)	2.5 (3.1)	1.3 (2.2)
	2007	65.6 (10.2)	21.2 (6.8)	10.0 (6.6)	19.0 (4.3)	4.9 (1.2)	1.3 (1.0)	7.9 (3.1)	2.4 (2.2)
	2009	133.6 (10.2)	33.4 (6.8)	49.3 (6.6)	16.1 (4.3)	8.0 (1.2)	2.7 (1.0)	8.0 (3.1)	0.0 (2.2)
	2011	56.3 (10.2)	13.7 (6.8)	31.5 (6.6)	49.5 (4.3)	6.9 (1.2)	1.4 (1.0)	1.4 (3.1)	0.0 (2.2)
Turbine Sites	2006	84.4 (10.2)	55.3 (6.8)	17.3 (6.6)	21.2 (4.3)	6.5 (1.2)	4.0 (1.0)	3.5 (3.1)	6.3 (2.2)
	2007	62.9 (10.2)	33.5 (6.8)	14.7 (6.6)	9.0 (4.3)	3.6 (1.2)	4.0 (1.0)	5.5 (3.1)	7.8 (2.2)
	2009	47.1 (10.2)	44.1 (6.8)	25.1 (6.6)	5.2 (4.3)	4.8 (1.2)	2.4 (1.0)	3.4 (3.1)	5.3 (2.2)
	2011	39.5 (10.2)	20.4 (6.8)	22.4 (6.6)	13.7 (4.3)	3.6 (1.2)	2.7 (1.0)	1.5 (3.1)	3.9 (2.2)
Reference Average		90.2 (4.7)	23.5 (4.6)	29.7 (3.1)	31.6 (2.2)	6.9 (0.8)	1.7 (0.5)	4.9 (2.3)	0.9 (1.8)
Turbine Average		58.5 (4.7)	38.3 (4.6)	19.9 (3.1)	12.3 (2.2)	4.6 (0.8)	3.3 (0.5)	3.5 (2.3)	5.8 (1.8)
Overall Average		74.3 (3.4)	30.9 (3.3)	24.8 (2.2)	22.0 (1.5)	5.7 (0.5)	2.5 (0.3)	4.2 (1.6)	3.4 (1.2)

Conservation Biology

Contributed Paper

Effects of wind-energy facilities on breeding grassland bird distributions

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Abstract: *The contribution of renewable energy to meet worldwide demand continues to grow. Wind energy is one of the fastest growing renewable sectors, but new wind facilities are often placed in prime wildlife habitat. Long-term studies that incorporate a rigorous statistical design to evaluate the effects of wind facilities on wildlife are rare. We conducted a before-after-control-impact (BACI) assessment to determine if wind facilities placed in native mixed-grass prairies displaced breeding grassland birds. During 2003–2012, we monitored changes in bird density in 3 study areas in North Dakota and South Dakota (U.S.A.). We examined whether displacement or attraction occurred 1 year after construction (immediate effect) and the average displacement or attraction 2–5 years after construction (delayed effect). We tested for these effects overall and within distance bands of 100, 200, 300, and >300 m from turbines. We observed displacement for 7 of 9 species. One species was unaffected by wind facilities and one species exhibited attraction. Displacement and attraction generally occurred within 100 m and often extended up to 300 m. In a few instances, displacement extended beyond 300 m. Displacement and attraction occurred 1 year after construction and persisted at least 5 years. Our research provides a framework for applying a BACI design to displacement studies and highlights the erroneous conclusions that can be made without the benefit of adopting such a design. More broadly, species-specific behaviors can be used to inform management decisions about turbine placement and the potential impact to individual species. Additionally, the avoidance distance metrics we estimated can facilitate future development of models evaluating impacts of wind facilities under differing land-use scenarios.*

Keywords: avoidance, before-after-control-impact design, climate change, displacement, renewable energy, upland birds, wind turbine

Efectos de las Instalaciones de Energía Eólica sobre la Distribución de las Aves de Pastizales en Época Reproductiva

Resumen: *La contribución de la energía renovable para cumplir con las demandas mundiales sigue creciendo. La energía eólica es uno de los sectores renovables con mayor crecimiento, pero continuamente se colocan nuevas instalaciones eólicas en los principales hábitats de fauna silvestre. Los estudios a largo plazo que incorporan un diseño estadístico riguroso para evaluar los efectos de estas instalaciones sobre la fauna son escasos. Realizamos una evaluación de control de impacto de antes y después (CIAD) para determinar si las instalaciones eólicas colocadas en praderas de pastos mixtos nativos desplazaron a las aves de pastizales en época reproductiva. Durante el periodo 2003-2012, monitoreamos los cambios en la densidad de aves en tres áreas de estudio en Dakota del Norte y del Sur (E.U.A). Examinamos si había ocurrido desplazamiento o atracción un año después de la construcción (efecto inmediato) y también el promedio de desplazamiento o atracción 2-5 años después de la construcción (efecto retardado). Analizamos estos efectos en general y dentro de franjas de distancia de 100, 200, 300 y >300 m de las turbinas. Observamos desplazamiento en siete de las nueve especies. Una especie no fue afectada por las instalaciones eólicas y una especie mostró atracción. El desplazamiento y la atracción ocurrieron generalmente dentro de los 100 m y frecuentemente se extendieron hasta los 300 m. En algunos casos, el desplazamiento se extendió más allá de los 300 m. El desplazamiento y la atracción ocurrieron un año después de la construcción y continuaron durante por lo*

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menos cinco años. Nuestra investigación proporciona un marco de trabajo para aplicar el diseño CIAD a los estudios de desplazamiento y resalta las conclusiones erróneas que pueden hacerse sin el beneficio de adoptar dicho diseño. En términos más generales, los comportamientos específicos de especie pueden usarse para informar a las decisiones de manejo sobre la colocación de turbinas y el impacto potencial para las especies individuales. Además, las medidas de distancia de evitación que estimamos pueden facilitar el desarrollo futuro de los modelos de evaluación de impacto de las instalaciones eólicas bajo escenarios diferentes de uso de suelo.

Palabras Clave: aves de tierras altas, cambio climático, desplazamiento, diseño de control de impacto de antes y después, energía renovable, evitación, turbina de viento

Introduction

Renewable energies will help meet energy demands while reducing carbon emissions and providing energy security (IPCC 2012). Globally, the contribution of wind power to energy demand is anticipated to be 20% by 2050 (IPCC 2011). The United States became the global leader in new wind capacity in 2012, representing 29% of global installed capacity due to sustained growth throughout the interior of the country (i.e., within the Great Plains) (USDOE 2013).

The Great Plains also supports the last remaining expanses of native temperate grasslands in North America (Stephens et al. 2008; Rashford et al. 2011; Doherty et al. 2013); thus, the increase in habitat loss and fragmentation associated with wind development has adverse impacts on wildlife (McDonald et al. 2009; Kiesecker et al. 2011). Wildlife are directly affected by wind facilities via collision mortality (Johnston et al. 2013; Péron et al. 2013) and indirectly affected through avoidance of turbines and related infrastructure (i.e., displacement [Drewitt & Langston 2006]). Per unit energy, wind energy has a larger terrestrial footprint than other forms of energy production (Kiesecker et al. 2011). Although the ground disturbance per turbine is relatively small (about 1.2 ha), other disturbances such as construction and operation of the facility, vehicular traffic, maintenance visits, turbine noise and movement, and changes to predator activity contribute to the impact of wind facilities (Arnett et al. 2007; Helldin et al. 2012; Gue et al. 2013).

Although displacement research on an international level has been ongoing for about 2 decades, Drewitt and Langston (2006) note that few displacement studies are conclusive, often because of the minimal magnitude of the effect, poor precision of estimates, and lack of study design allowing for strong inference assessments. For observational studies, the before-after-control (reference)-impact (BACI) design is considered the "optimal impact study design" (Green 1979) as exemplified by Irons et al. (2000) and Smucker et al. (2005) and is the preferred method to determine displacement of wildlife from wind facilities (Strickland et al. 2011). However, of the numerous displacement studies, most are short-term, are not BACI designs, and occur on only one wind facility (Supporting Information). Effective conservation strategies that reduce negative effects of wind facilities to sensitive wildlife require information from well-designed studies (Strickland et al. 2011). Preferred characteristics include a multi-species approach to understand prevalence of displacement behavior, a long-term perspective, and a design that allows for strong inference (e.g., BACI) (Stewart et al. 2007; Strickland et al. 2011). Pearce-Higgins et al. (2012) provide an example of a well-implemented wind-specific BACI design.

Our overall goal was to determine if wind facilities influenced distribution of sensitive and declining grassland-nesting birds (Supporting Information). Specifically, our objectives were to assess immediate and delayed effects of the placement of wind facilities. We assessed potential changes in bird distribution overall and at varying distances from wind turbines. We implemented a BACI design that incorporated multiple years, replicated impact and reference sites within 3 facilities, and 9 species, making our study one of a few that used a rigorous optimal impact assessment design (Supporting Information). Thus, our research provides a strong foundation for building a more refined understanding of how wind facilities influence grassland bird distribution temporally and spatially.

Methods

Collaboration with wind companies provided locations of impending construction within North Dakota and South Dakota (U.S.A.). We selected wind facilities situated within expanses of native grassland and in landscapes characterized by morainic rolling plains interspersed with wetlands, mixed-grass prairie pastures, and few planted grasslands, hayfields, or cropland (Bluemle 1991). Three wind facilities (hereafter, study areas) met our criteria: NextEra Energy's (NEE) South Dakota Wind Energy Center (SD), Highmore, South Dakota; Acciona's Tatanka Wind Farm (TAT), Forbes, North Dakota; and NEE's Oliver Wind Energy Center (OL), Oliver County, North Dakota (Table 1, Fig. 1). The study areas differed in several anthropogenic features (Table 1). The SD site was within the most heterogeneous landscape and had

Table 1. **Summary characteristics of 3 wind facilities in North Dakota and South Dakota (U.S.A.) for which field survey data were collected for the study on effects of wind facilities on grassland birds.**

Facility	*Pre-treatment year*	*Post-treatment years*	*No. treatment plots (size range, ha)*	*No. reference plots (size range, ha)*	*Row crop area (%)*	*Total area (km^2)*	*Roads* (km/km^2)*	*No. of turbines/km^2*
NextEra Energy SD Wind Energy Center	2003	2004-6, 8, 10, 12	5 (55-158)	3 (34-46)	20	34.5	0.6	0.8
Acciona Tatanka Wind Farm	2007	2009-10, 12	2 (43-441)	4 (11-109)	0	31.6	0.4	0.6
NextEra Energy Oliver Wind Energy Center	2006	2007, 9, 11	2 (122-260)	2 (37-274)	13	24.3	0.7	0.7

**Includes paved, gravel, and turbine roads.*

the highest percentage of lands under row-crop cultivation and the second most kilometers of roads, whereas TAT was within the least heterogeneous landscape of primarily grasslands. During the years we were on each study area (Table 1), TAT and OL had above-average precipitation and SD received below-average precipitation (NOAA 2015).

Because of the short time frame between facility site selection and construction, we conducted only 1 year of pre-treatment surveys. Within a study area, we selected turbine strings (i.e., turbines connected by a road) that would be placed in grazed mixed-grass prairie. We defined a turbine site as the area encompassing the turbines and extending 0.8 km on all sides of the turbine string, as long as the land and land cover remained grazed mixed-grass prairie. Reference sites were selected based on proximity to paired wind facilities (within 3.2 km) and similarity of land use and cover, topography, and elevation to turbine sites. Measures of vegetation structure were similar between turbine and reference sites and therefore were excluded as a possible confounding effect (Supporting Information).

We conducted total-area avian surveys (Stewart & Kantrud 1972) within a grid system (Shaffer & Thiele 2013) 2 times annually from late May to early July, from 0.5 hours after sunrise to 1100, on days of good visibility and good aural detectability (i.e., days with little or no precipitation and low to moderate winds [$<$40 km/hour]). We established avian survey plots with grids of fiberglass posts arranged in parallel lines spaced 200 m apart. Transect lines were established 100 m apart perpendicular to the grid lines. Observers recorded all birds seen and heard within 50 m of transects established within the grids. Genders of non-dimorphic species were determined by the presence or absence of song. For 9 grassland bird species (Table 2; Supporting Information), we computed the number of breeding pairs for each site (turbine and reference), survey, and year combination. A male and female observed together was considered a breeding pair; a male or female observed alone was also considered a breeding pair. The number of pairs was divided by the suitable breeding area in each turbine and reference site, as determined by breeding habitat for each species (Supporting Information), and multiplied by 100 to determine density per 100 ha (Supporting Information). We used the maximum of the biannual survey densities for each species-site-year combination to reflect peak breeding density.

We employed a BACI design (McDonald et al. 2000) to examine turbine effects on bird density. We used data from surveys conducted prior to and after turbine construction at turbine and reference sites. Using 2 different treatment specifications, we conducted analyses separately for each species and study area. The first analysis consisted of 2 treatment levels, turbine sites and reference sites, to assess overall effects of turbines on

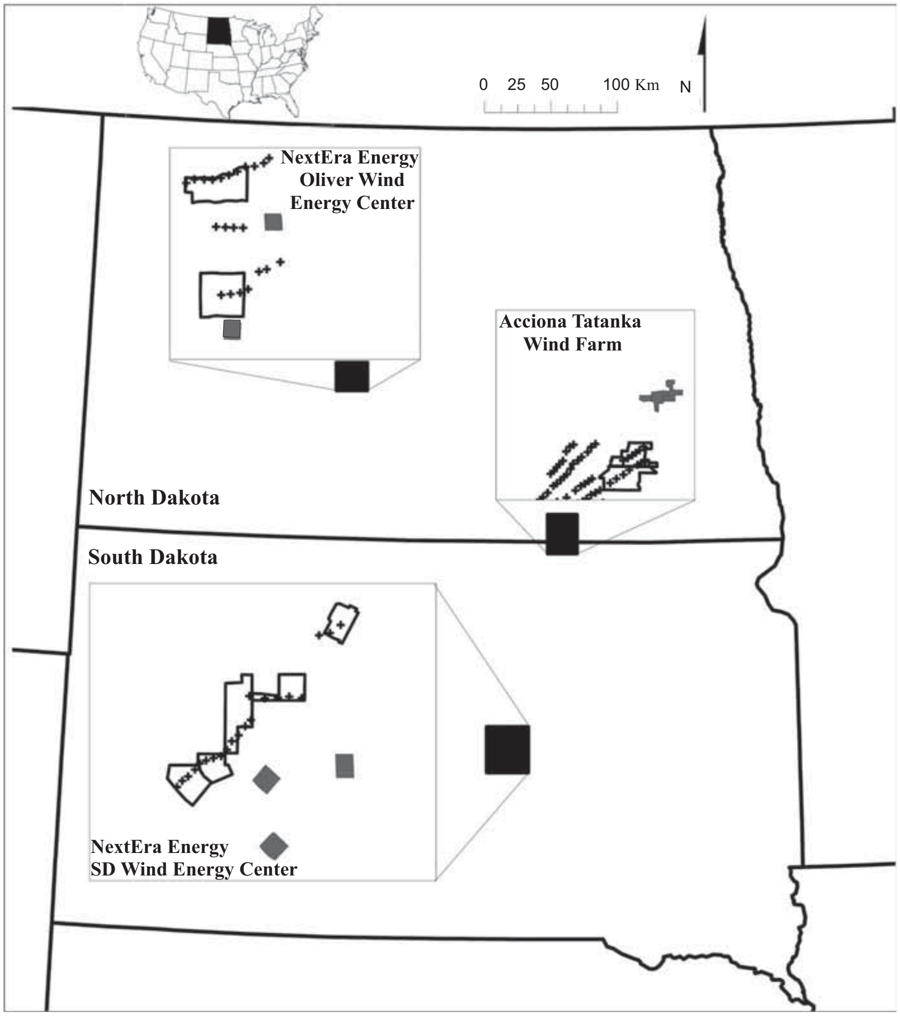

Figure 1. Map of studied wind-energy facilities in North Dakota and South Dakota (U.S.A.) (white polygons, turbine treatment sites; gray polygons, reference sites; plus symbol, turbine locations).

densities of breeding birds. For the second analysis, we divided turbine sites into 4 100-m distance bands from turbines (0-100 m, 100–200 m, 200–300 m, and >300 m), for a total of 5 treatment levels including the reference sites. We used repeated measures analysis of variance (RMANOVA) in SAS PROC MIXED (SAS Institute 2012) to assess effects of treatment and year on bird density (Verbeke & Molenberghs 2000). In the first treatment specification, year was the repeated measure and site within treatment was the experimental unit sampled each year. For the second treatment specification, site was included as a random block, year was the repeated measure, and site-by-treatment combinations were the experimental units sampled yearly. We accounted for autocorrelation among years by running a correlated error model (auto-regressive) (Littell et al. 2006).

Using the BACI design, we conducted planned contrasts among treatment means (Milliken & Johnson 2009) to estimate turbine effects. The contrasts tested whether average density for first post-treatment year minus average density for pre-treatment year was equal between turbine and reference treatments (H_0: $[\text{density}_{\text{turbine,1yr-post}} - \text{density}_{\text{turbine,pre}}] - [\text{density}_{\text{reference,1yr-post}} - \text{density}_{\text{reference,pre}}] = 0$) and if average 2- to 5-year post-treatment mean density (i.e., mean density for the 2 to 5 calendar years following turbine construction) minus average density for pre-treatment year was equal between turbine and reference treatments (H_0: $[\text{density}_{\text{turbine,2-5yr-post}} - \text{density}_{\text{turbine,pre}}] - [\text{density}_{\text{reference,2-5yr-post}} - \text{density}_{\text{reference,pre}}] = 0$). The former contrast tested for an immediate turbine effect, whereas the latter contrast tested for a delayed effect. Immediate effects were not testable at TAT because 1-year post-treatment data were not collected. For the delayed effects, the span of years in which surveys were conducted varied among study areas, and surveys were not done every year within that time span. To achieve a consistent time frame that could be assessed at all 3 study areas, we used the average of 2–5 years post-treatment to assess the delayed effect, rather than assessing effects for each post-treatment year separately.

Table 2. **Test statistics from the contrasts comparing changes in bird density per 100 ha between reference and turbine sites from pre-treatment year to 1 year post-treatment in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (NEE Oliver Wind Energy Center [OL]), (U.S.A.) 2003–2012.***

Location and distance from turbines (m)	*Grasshopper Sparrow*	*Western Meadowlark*	*Bobolink*	*Upland Sandpiper*	*Killdeer*	*Savannah Sparrow*	*Clay-colored Sparrow*	*Chestnut-collared Longspur*	*Vesper Sparrow*
SD									
0-100	$t_{76} = -1.84$, $p = 0.07$	$t_{77} = -3.90$, $p<0.01$	$t_{57} = -1.25$, $p = 0.22$	$t_{83} = -1.33$, $p = 0.19$	$t_{92} = 3.21$, $p<0.01$			$t_{69} = 0.62$, $p = 0.54$	
100–200	$t_{76} = -0.31$, $p = 0.76$	$t_{77} = -0.73$, $p = 0.47$	$t_{57} = -0.26$, $p = 0.80$	$t_{83} = 0.38$, $p = 0.70$	$t_{92} = 0.70$, $p = 0.49$			$t_{69} = -1.09$, $p = 0.28$	
200–300	$t_{76} = -0.25$, $p = 0.81$	$t_{77} = -0.67$, $p = 0.50$	$t_{57} = -1.28$, $p = 0.20$	$t_{83} = -1.63$, $p = 0.11$	$t_{92} = 1.60$, $p = 0.11$			$t_{69} = -0.81$, $p = 0.42$	
>300	$t_{76} = 0.21$, $p = 0.83$	$t_{77} = -1.23$, $p = 0.22$	$t_{57} = -1.65$, $p = 0.10$	$t_{83} = -1.07$, $p = 0.29$	$t_{92} = 0.88$, $p = 0.38$			$t_{69} = 1.10$, $p = 0.27$	
Overall	$t_{29} = -0.11$, $p = 0.91$	$t_{20} = -2.27$, $p = 0.03$	$t_{36} = -1.71$, $p = 0.10$	$t_{32} = -1.23$, $p = 0.23$	$t_{25} = 2.01$, $p = 0.06$			$t_{39} = 0.50$, $p = 0.62$	
OL									
0–100	$t_{20} = -1.80$, $p = 0.09$	$t_{14} = 0.46$, $p = 0.65$	$t_{18} = -1.21$, $p = 0.24$	$t_{18} = -2.39$, $p = 0.03$	$t_{27} = 2.85$, $p = 0.01$	$t_{21} = -1.43$, $p = 0.17$	$t_{22} = -1.79$, $p = 0.09$		$t_{20} = 0.58$, $p = 0.57$
100–200	$t_{20} = -0.71$, $p = 0.49$	$t_{14} = 1.14$, $p = 0.27$	$t_{18} = -0.47$, $p = 0.64$	$t_{18} = 1.00$, $p = 0.33$	$t_{27} = 0.71$, $p = 0.48$	$t_{21} = -2.45$, $p = 0.02$	$t_{22} = -1.77$, $p = 0.09$		$t_{20} = 0.21$, $p = 0.83$
200–300	$t_{20} = 0.09$, $p = 0.93$	$t_{14} = 1.94$, $p = 0.07$	$t_{18} = 2.14$, $p = 0.05$	$t_{18} = -0.23$, $p = 0.82$	$t_{27} = -0.33$, $p = 0.74$	$t_{21} = -3.41$, $p<0.01$	$t_{22} = -0.76$, $p = 0.46$		$t_{20} = -1.64$, $p = 0.12$
>300	$t_{20} = 1.14$, $p = 0.27$	$t_{14} = 1.45$, $p = 0.17$	$t_{18} = 1.93$, $p = 0.07$	$t_{18} = -0.17$, $p = 0.87$	$t_{27} = -0.15$, $p = 0.88$	$t_{21} = -0.50$, $p = 0.62$	$t_{22} = -1.62$, $p = 0.12$		$t_{20} = 0.29$, $p = 0.77$
Overall	$t_{9} = 0.78$, $p = 0.46$	$t_{8} = 1.17$, $p = 0.28$	$t_{9} = 1.40$, $p = 0.20$	$t_{9} = -0.02$, $p = 0.99$	$t_{8} = -0.03$, $p = 0.98$	$t_{12} = -1.03$, $p = 0.32$	$t_{10} = -2.07$, $p = 0.06$		$t_{12} = 0.22$, $p = 0.83$

**Cells with no values indicate an analysis for that species was not conducted because of low number of observations.*

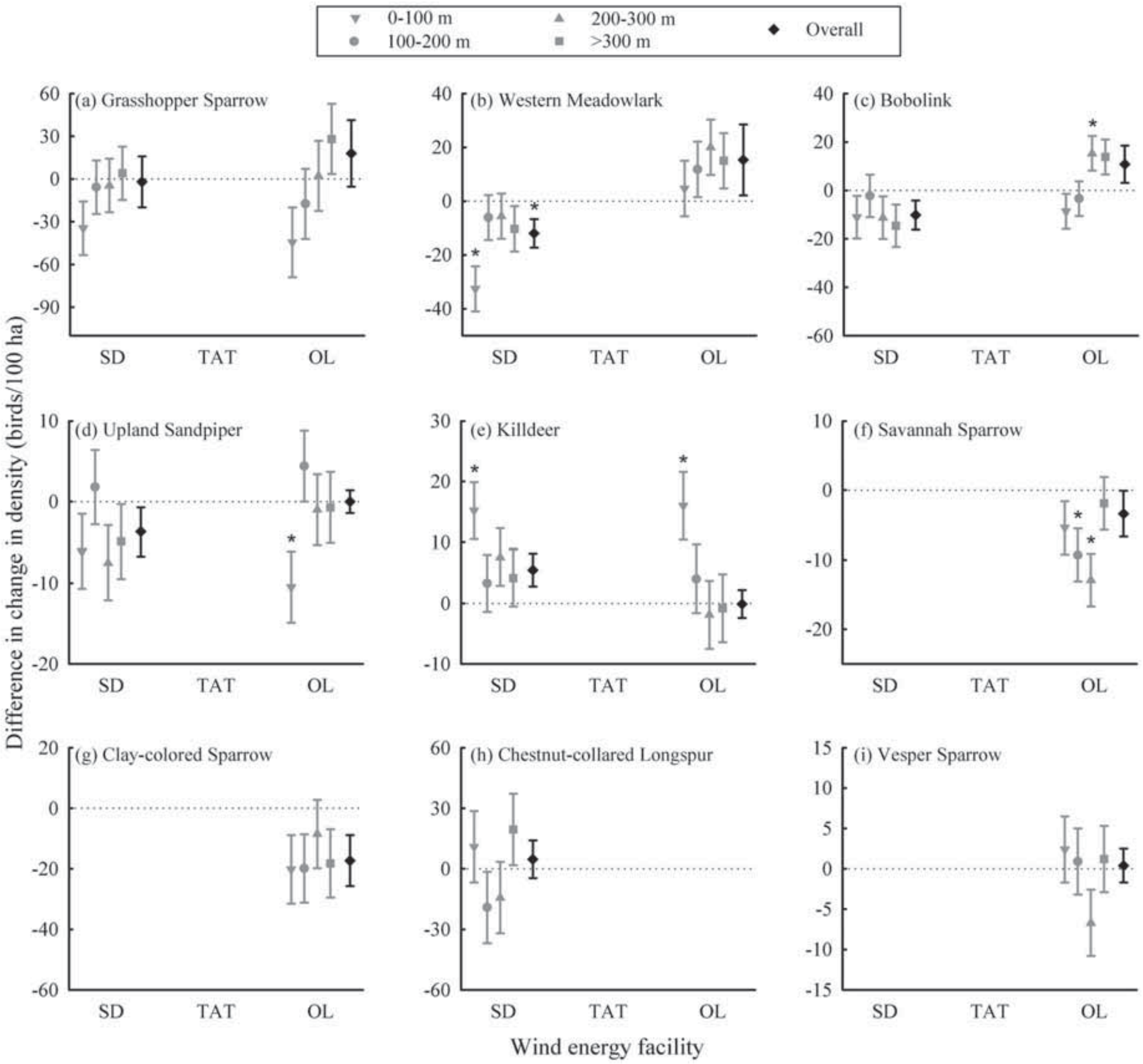

Figure 2. Difference in change in bird density/100 ha between reference and wind turbine sites from pre-treatment year to 1 year post-treatment (immediate effect) in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), 2003–2012 for (a) Grasshopper Sparrow, (b) Western Meadowlark, (c) Bobolink, (d) Upland Sandpiper, (e) Killdeer, (f) Savannah Sparrow, (g) Clay-colored Sparrow, (h) Chestnut-collared Longspur, and (i) Vesper Sparrow (difference = [$density_{turbine,1yr\text{-}post}$ − $density_{turbine,pre}$] − [$density_{reference,1yr\text{-}post}$ − $density_{reference,pre}$]; error bars, SE; value >0, positive effect; value <0, negative effect; asterisk, significant [α = 0.05] difference).

One strength of a BACI design is that it allows researchers to assume that any naturally occurring changes occur at both the impact and control sites; thus, any changes observed at the impact sites can be attributed to the impact (Manly 2001). Therefore, we assumed annual variation in bird populations and weather effects were the same for turbine and reference sites within a study area. Vegetation structure also was similar between sites (Supporting Information). In addition, turbine and reference sites were spatially replicated within wind facilities; this allowed us to account for variability among sites and to test if, on average, changes in density differed between turbine and reference sites. Therefore, any immediate or delayed effects were due to the construction of the wind facility.

Results

Immediate Effects

We detected statistically significant immediate (1-year) displacement behavior for 3 of 9 species (Western

Table 3. Test statistics from the contrasts comparing changes in bird density/100 ha between reference and turbine sites from pre-treatment year to 2-5-years post-treatment in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), (U.S.A.), 2003–2012.*

Location and distance from turbines (m)	*Grasshopper Sparrow*	*Western Meadowlark*	*Bobolink*	*Upland Sandpiper*	*Killdeer*	*Savannah Sparrow*	*Clay-colored Sparrow*	*Chestnut-collared Longspur*	*Vesper Sparrow*
SD									
0-100	$t_{142} = -3.94$, $p<0.01$	$t_{145} = -3.86$, $p<0.01$	$t_{110} = -1.10$, $p = 0.27$	$t_{145} = -1.31$, $p = 0.19$	$t_{149} = 0.97$, $p = 0.33$			$t_{140} = -2.27$, $p = 0.02$	
100–200	$t_{142} = -1.94$, $p = 0.05$	$t_{145} = -1.34$, $p = 0.18$	$t_{110} = 0.41$, $p = 0.69$	$t_{145} = -1.32$, $p = 0.19$	$t_{149} = -0.56$, $p = 0.58$			$t_{140} = -2.52$, $p = 0.01$	
200–300	$t_{142} = -1.54$, $p = 0.13$	$t_{145} = -1.97$, $p = 0.05$	$t_{110} = -0.96$, $p = 0.34$	$t_{145} = -1.92$, $p = 0.06$	$t_{149} = -0.76$, $p = 0.45$			$t_{140} = -2.54$, $p = 0.01$	
>300	$t_{142} = -1.66$, $p = 0.10$	$t_{145} = -2.32$, $p = 0.02$	$t_{110} = -0.91$, $p = 0.37$	$t_{145} = -2.82$, $p = 0.01$	$t_{149} = 0.28$, $p = 0.78$			$t_{140} = -1.10$, $p = 0.27$	
Overall	$t_{54} = -1.99$, $p = 0.05$	$t_{52} = -4.12$, $p<0.01$	$t_{54} = -0.36$, $p = 0.72$	$t_{54} = -2.79$, $p = 0.01$	$t_{54} = 0.07$, $p = 0.94$			$t_{55} = -2.19$, $p = 0.03$	
TAT									
0-100	$t_{38} = -3.49$, $p<0.01$	$t_{41} = 0.16$, $p = 0.87$	$t_{33} = -5.34$, $p<0.01$	$t_{39} = 0.11$, $p = 0.91$	$t_{43} = 1.74$, $p = 0.09$	$t_{31} = -0.94$, $p = 0.35$	$t_{39} = -3.57$, $p<0.01$		$t_{47} = 1.18$, $p = 0.24$
100–200	$t_{38} = -2.54$, $p = 0.02$	$t_{41} = -0.01$, $p = 0.99$	$t_{33} = -5.69$, $p<0.01$	$t_{39} = -0.28$, $p = 0.78$	$t_{43} = 0.80$, $p = 0.43$	$t_{31} = -2.78$, $p = 0.01$	$t_{39} = -3.52$, $p<0.01$		$t_{47} = -0.61$, $p = 0.54$
200–300	$t_{38} = -2.43$, $p = 0.02$	$t_{41} = -0.21$, $p = 0.84$	$t_{33} = -6.85$, $p<0.01$	$t_{39} = -0.48$, $p = 0.63$	$t_{43} = 1.73$, $p = 0.09$	$t_{31} = -2.53$, $p = 0.02$	$t_{39} = -1.83$, $p = 0.08$		$t_{47} = -0.15$, $p = 0.88$
>300	$t_{38} = -1.75$, $p = 0.09$	$t_{41} = 0.13$, $p = 0.90$	$t_{33} = -4.78$, $p<0.01$	$t_{39} = -0.32$, $p = 0.75$	$t_{43} = 0.52$, $p = 0.60$	$t_{31} = -0.52$, $p = 0.61$	$t_{39} = -1.55$, $p = 0.13$		$t_{47} = 0.84$, $p = 0.41$
Overall	$t_{23} = -1.67$, $p = 0.11$	$t_{23} = 0.19$, $p = 0.85$	$t_{23} = -4.55$, $p<0.01$	$t_{23} = -0.15$, $p = 0.88$	$t_{11} = 1.51$, $p = 0.16$	$t_{22} = -0.93$, $p = 0.36$	$t_{20} = -1.37$, $p = 0.18$		$t_{22} = 0.37$, $p = 0.71$
OL									
0-100	$t_{36} = -3.62$, $p<0.01$	$t_{33} = -0.79$, $p = 0.43$	$t_{39} = -2.75$, $p = 0.01$	$t_{35} = -2.90$, $p = 0.01$	$t_{37} = 0.70$, $p = 0.49$	$t_{34} = -0.41$, $p = 0.68$	$t_{36} = -1.62$, $p = 0.11$		$t_{33} = 1.97$, $p = 0.06$
100–200	$t_{36} = -3.41$, $p<0.01$	$t_{33} = -1.41$, $p = 0.17$	$t_{39} = -2.31$, $p = 0.03$	$t_{35} = 0.15$, $p = 0.88$	$t_{37} = 0.42$, $p = 0.68$	$t_{34} = -1.32$, $p = 0.20$	$t_{36} = -1.61$, $p = 0.12$		$t_{33} = -0.52$, $p = 0.61$
200–300	$t_{36} = -3.35$, $p<0.01$	$t_{33} = -0.05$, $p = 0.96$	$t_{39} = 0.33$, $p = 0.74$	$t_{35} = -0.99$, $p = 0.33$	$t_{37} = -0.14$, $p = 0.89$	$t_{34} = -2.88$, $p = 0.01$	$t_{36} = -1.68$, $p = 0.10$		$t_{33} = -1.40$, $p = 0.17$
>300	$t_{36} = -0.98$, $p = 0.33$	$t_{33} = -0.56$, $p = 0.58$	$t_{39} = 0.01$, $p = 0.99$	$t_{35} = -0.58$, $p = 0.57$	$t_{37} = -0.72$, $p = 0.47$	$t_{34} = -0.28$, $p = 0.78$	$t_{36} = -2.09$, $p = 0.04$		$t_{33} = 0.25$, $p = 0.80$
Overall	$t_{12} = -1.82$, $p = 0.09$	$t_{16} = -0.53$, $p = 0.60$	$t_{16} = -0.34$, $p = 0.74$	$t_{16} = -1.01$, $p = 0.33$	$t_{7} = -1.34$, $p = 0.22$	$t_{16} = -0.65$, $p = 0.53$	$t_{16} = -1.79$, $p = 0.09$		$t_{16} = -0.09$, $p = 0.93$

Cells with no values indicate an analysis for that species was not conducted because of low number of observations.

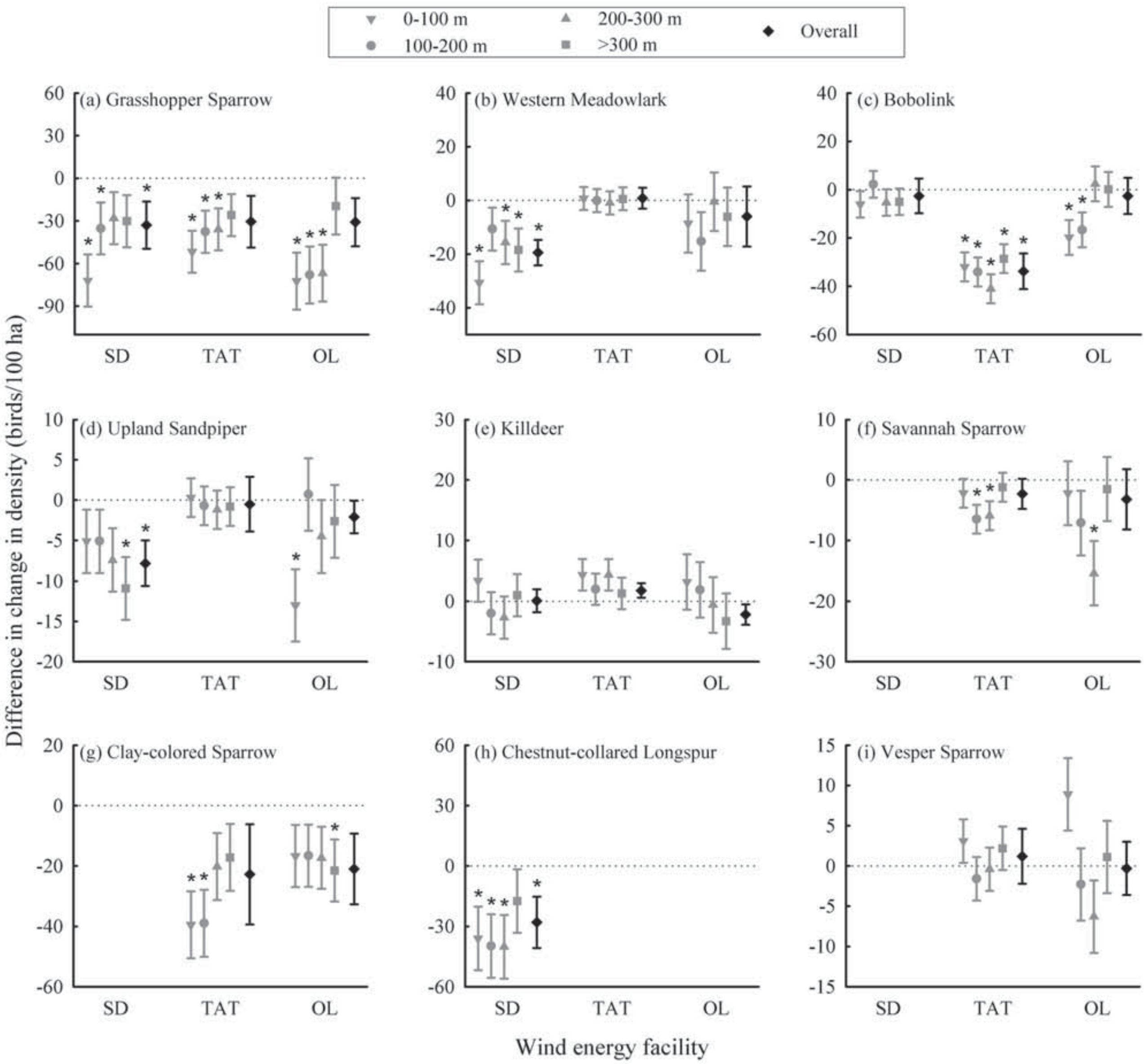

Figure 3. Difference in change in bird density/100 ha between reference and wind turbine site from pre-treatment year to 2–5 years post-treatment (delayed effect) in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD]) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL]), 2003–2012 for (a) Grasshopper Sparrow, (b) Western Meadowlark, (c) Bobolink, (d) Upland Sandpiper, (e) Killdeer, (f) Savannah Sparrow, (g) Clay-colored Sparrow, (h) Chestnut-collared Longspur, and (i) Vesper Sparrow (difference = [$density_{turbine,2\text{-}5yr\text{-}post}$ – $density_{turbine,pre}$] – [$density_{reference,2\text{-}5yr\text{-}post}$ – $density_{reference,pre}$]; error bars, SE; value >0, positive effect; value <0, negative effect; asterisk, significant [$\alpha = 0.05$] difference).

Meadowlark [*Sturnella neglecta*], Upland Sandpiper [*Bartramia longicauda*], and Savannah Sparrow [*Passerculus sandwichensis*]) and attraction for 2 species (Killdeer [*Charadrius vociferous*] and Bobolink [*Dolichonyx oryzivorus*]) (Table 2). For Western Meadowlark, displacement was detected at SD; effects were apparent overall and within 100 m (Fig. 2b). For Upland Sandpiper, displacement was detected at OL, but only within 100 m (Fig. 2d). Change in density of Savannah Sparrow was lower 100–300 m from turbines than at reference sites at OL, the one study area in which immediate effects could be determined for this species (Fig. 2f). Killdeer expressed attraction within 100 m of turbines at both study areas 1 year post-construction (Fig. 2e, Table 2). Bobolink exhibited a positive difference 200–300 m at OL (Fig. 2c, Table 2).

Wind facilities had no significant immediate effect on Grasshopper Sparrow (*Ammodramus savannarum*), Clay-colored Sparrow (*Spizella pallida*), or Chestnut-collared Longspur (*Calcarius ornatus*) (Table 2). However, the magnitude of differences (≥20 birds/100 ha) between turbine sites and reference sites suggested these species may have exhibited immediate displacement (Fig. 2a, 2g, 2h). Vesper Sparrow (*Pooecetes gramineus*) appeared unaffected by wind facilities (Fig. 2i).

Delayed Effects

We detected significant displacement behavior beyond 1 year for 7 species (Table 3). For Grasshopper Sparrow, we detected displacement overall at SD, within 200 m at all 3 study areas, and within 200–300 m at TAT and OL (Fig. 3a). Bobolink, Upland Sandpiper, Savannah Sparrow, and Clay-colored Sparrow exhibited displacement at 2 study areas each (Fig. 3c, 3d, 3f, 3g). Displacement occurred overall and at all distances for Bobolink at TAT, but only within 200 m at OL. Upland Sandpiper exhibited displacement overall and beyond 300 m at SD, but only within 100 m at OL. Displacement was observed within 200–300 m for Savannah Sparrow at both TAT and OL and within 100–200 m at TAT. For Clay-colored Sparrow, significant displacement occurred within 200 m at TAT and >300 m at OL. For Western Meadowlark and Chestnut-collared Longspur, displacement was detected at SD only. Effects were apparent overall, within 100 m, and beyond 200 m for Western Meadowlark (Fig. 3b) and overall and within 300 m for Chestnut-collared Longspur (Fig. 3h). Killdeer and Vesper Sparrow showed no delayed effects (Fig. 3e, 3i).

Discussion

The preferred design for testing impacts of energy infrastructure on wildlife is the BACI design (Evans 2008; Strickland et al. 2011), but examples are rare (Supporting Information). Our work provides a framework for applying a BACI design to behavioral studies and highlights the erroneous conclusions that can be made when the BACI approach is not used. If we had data from only impact sites (i.e., no reference sites) or had only post-treatment data (i.e., no pre-treatment monitoring) and thus not been able to use a BACI design, our conclusions would have been different. Obtaining data from impact and reference sites allowed us to discern changes in avian densities due to wind facilities as opposed to naturally occurring changes. For example, Grasshopper Sparrow at SD showed a large change in density on the turbine sites (i.e., a decrease of more than 60 birds/100 ha) from the pre-treatment year to the first year post-treatment (Supporting Information). Without reference sites, we may have interpreted this decrease in density to be due to turbine operation. However, we observed a similar change in density at reference sites, indicating the change on the turbine sites was probably due not to turbine operation but rather to normal annual variation in avian density. Pre-treatment data were used to account for differences among the turbine and reference sites prior to turbine construction, which allowed us to attribute post-treatment differences to turbine operation. For example, Grasshopper Sparrows at SD had higher average density for reference sites (60.1 birds/100 ha) than for turbine sites (38.3 birds/100 ha) in the first post-construction year (Supporting Information). Without pre-treatment data, this difference might have been interpreted as a turbine effect. However, pre-treatment data provided evidence of existing site differences of the same magnitude (Supporting Information) and therefore indicates there was no turbine effect.

By collecting data the year following construction and beyond 1 year post-construction, we were able to assess whether species exhibited immediate effects, delayed effects, or sustained effects. Because our turbine and reference sites were near one another and were similar with respect to landscape composition, vegetation, topography, and weather, the BACI design allowed us to assume that any naturally occurring changes happen at both the turbine and reference sites and therefore can be ruled out as alternative explanations. In addition, spatial replication of turbine and reference sites within study areas accounts for inherent variability among sites (Underwood 1992). Thus, any effects we observed were attributed to the operation of the wind facility.

Immediate effects were manifested by displacement or attraction the year following turbine construction. Birds returning in the spring following construction would encounter an altered landscape and would need to decide whether to settle near a wind facility or move elsewhere. In our study areas, Vesper Sparrows and Killdeer showed a high degree of tolerance to newly constructed wind facilities. Vesper Sparrows are often the first species to occupy disturbed areas (Jones & Cornely 2002); therefore, lack of displacement is not surprising given this life-history characteristic. Moreover, Johnson et al. (2000) reported attraction of Vesper Sparrows to turbines 1 year post-construction at grassland sites in Minnesota (U.S.A.). Killdeer prefer gravel substrates for nesting, and roadsides are preferred habitat (Jackson & Jackson 2000). Our finding that Killdeer density increased nearest to newly constructed turbines likely reflects similar habitat selection. Similarly, Johnson et al. (2000) reported higher than expected use of turbine plots in Minnesota by Horned Larks (*Eremophila alpestris*), another species that prefers disturbed areas. However, Erickson et al. (2004) found no evidence of attraction (or displacement) for this species in Oregon (U.S.A.).

Some species in our study areas did not exhibit immediate effects, yet we observed displacement in years beyond the first year post-construction (i.e., delayed effects). Species exhibiting breeding site fidelity might be more inclined to show delayed effects than immediate effects. Individuals will return to a turbine site 1 year post-construction due to site fidelity, but they may not return in subsequent years because of intolerance of the wind facility. In addition, new individuals may be unwilling to settle near turbines. We detected delayed displacement for Grasshopper Sparrow, Western Meadowlark, Bobolink, Upland Sandpiper, Clay-colored Sparrow, and Chestnut-collared Longspur, all of which exhibit breeding site fidelity (Hill & Gould 1997; Jones et al. 2007). Likewise, Johnson et al. (2000) reported delayed effects for Grasshopper Sparrow, Bobolink, and Savannah Sparrow, which also shows breeding site fidelity (Fajardo et al. 2009). On a Scottish wind facility 3 years post-construction, Douglas et al. (2011) detected delayed effects for 2 upland species, Red Grouse (*Lagopus lagopus scotica*) and European Golden Plover (*Pluvialis apricaria*); these 2 species are also site faithful (Jenkins et al. 1963; Parr 1980).

We considered a species to be exhibiting a sustained effect if displacement continued from 1 year post-construction into 2–5 years post-construction. In our study, sustained displacement usually occurred within 100 m (e.g., Western Meadowlark at SD and Upland Sandpiper at OL). Few other researchers have examined sustained effects. Pearce-Higgins et al. (2012) detected positive long-term effects in the United Kingdom for 2 upland species and negative effects for 2 waterbird species.

Consistency of behavioral responses to wind facilities varied across the 9 species of grassland nesting birds we monitored. Grasshopper Sparrows and Clay-colored Sparrows exhibited the most consistent results across study areas. The Grasshopper Sparrow is an area- and edge-sensitive species (Grant et al. 2004; Ribic et al. 2009) for which amount of grassland in the surrounding landscape is important (Berman 2007; Greer 2009). Wind facilities appear to be an additional landscape change not tolerated by Grasshopper Sparrows, and the construction of additional wind facilities throughout native grasslands could be detrimental to the species. Clay-colored Sparrows prefer grasslands intermixed with shrubs and woody edges (Grant & Knapton 2012). We speculate that removal of woody vegetation during construction of roads and turbines reduced breeding habitat for this species.

Bobolinks, Western Meadowlarks, Upland Sandpipers, and Savannah Sparrows exhibited inconsistent displacement behavior across study areas. Because we were not always present on study areas in the same years, we suspect inconsistencies resulted from habitat differences specific to study area that may have been influenced by variable precipitation patterns. The interaction of habitat conditions and species-specific life-history strategies may have influenced behavior. For example, Bobolinks exhibited strong displacement at TAT, which was the largest wind facility with the most intact grasslands and the highest precipitation. Densities of Bobolinks also were greatest at TAT (Supporting Information); hence, density dependent effects may arise at these higher densities and may result from habitat loss (both grassland and wetland) with construction of turbines. As a result of high precipitation, grasslands at this site were interspersed with many small wetlands containing nesting pairs of Red-winged Blackbirds (*Agelaius phoeniceus*). Red-winged Blackbirds and Bobolinks are antagonistic. Red-winged Blackbirds may displace Bobolinks from perches, and Bobolinks appear to avoid nesting near active blackbird nests (Martin & Gavin 1995). Thus, displacement of Bobolinks at TAT could have been more evident because of intra- or interspecific competition.

For other species, cumulative effects of wind facilities and other landscape changes might be the cause of inconsistent results. Western Meadowlarks are a gregarious species not reported to be sensitive to habitat area or habitat edges (Johnson & Igl 2001), and some degree of anthropogenic activity appears acceptable to them. However, we speculate that the degree of anthropogenic disturbance at SD surpassed the species' threshold of tolerance to human activity. The sustained displacement observed at SD could be the species' response to the additive stressors of wind-facility operation and recent land conversion from grassland to agricultural fields (Wright & Wimberly 2013). Increasing urbanization had a strong negative effect on the density of a congeneric species, Eastern Meadowlark (*Sturnella magna*), in grasslands (McLaughlin et al. 2014). Conversely, TAT, where no displacement effects were observed for Western Meadowlarks, has undergone little land conversion, was composed of 92% perennial grasslands (Loesch et al. 2013), and was located in a remote area rarely traversed by humans other than personnel associated with the wind facility. Upland Sandpiper displayed the most inconsistent results and a similar pattern as Western Meadowlark. The species is highly sensitive to habitat fragmentation (Ribic et al. 2009), and the strongest displacement effects occurred on the most fragmented study areas, SD and OL. No displacement was detected on the least fragmented study area. As with Western Meadowlarks, Upland Sandpipers may have reached a threshold beyond which additional landscape disturbance could not be tolerated and displacement behavior became apparent.

Our results for displacement distances for Grasshopper Sparrow (300 m), Bobolink (>300 m), Western Meadowlark (>300 m), Upland Sandpiper (100 m), Clay-colored Sparrow (200 m), Savannah Sparrow (300 m), and Chestnut-collared Longspur (300 m) were consistent with those reported by other researchers. In a literature review of North American grassland birds, Johnson and Stephens (2011) reported displacement extending 50–180 m from turbines. Stevens et al. (2013) found that mean plot occupancy for Le Conte's Sparrows

(*Ammodramus leconteii*) wintering in Texas was 4 times lower in plots <200 m from nearest wind turbine relative to >400 m from the nearest turbine. In the United Kingdom, 7 of 12 upland species exhibited displacement within 500 m (Pearce-Higgins et al. 2009). Winkelman (1992) found that shorebirds in a Netherlands wind facility occurred in significantly smaller numbers within 500 m from turbines. Thus, although displacement can occur as far as 500 m from turbines, most studies show displacement within 200 m.

Evaluating turbine effects overall and by distance from turbine allowed us to differentiate between localized displacement and site abandonment. For several species, immediate or delayed effects occurred by distance at a site, but there was no significant reduction in density at that site overall. This may have occurred because breeding pairs near turbines relocated short distances from turbines but not off the site completely. For example, Grasshopper Sparrow at OL showed an immediate reduction in density of birds near turbines and an increased density at distance categories >300 m and overall. Thus, Grasshopper Sparrows may not abandon sites completely; rather, they may relocate away from the turbines and establish territories farther from turbines. Without examining displacement by distance band, we would have missed this localized displacement and instead concluded there was no displacement. Niemuth et al. (2013) also found near-turbine displacement. They modeled mean occupancy for 4 waterbird species at 2 wind facilities in North Dakota, one of which was TAT, and found that species occurrences were not substantially reduced overall at either facility post-construction. However, occupancy was slightly and consistently lower for 3 of the 4 species at one wind facility. Thus, effects of wind facilities should be examined overall and by distance from turbines.

Our identification of species-specific behaviors to wind facilities can be used to inform management decisions about turbine placement in grasslands and the potential impact at an individual species level. Metrics of displacement distances can be used to parameterize models that quantify the potential loss of habitat under scenarios of differing land uses and corresponding avian community composition. Output from these models may help drive conservation planning, such as prioritizing landscapes of highest value for preservation or restoration.

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Supporting Information

A comparison of avian and mammal displacement studies in which impact assessment designs were used (Appendix S1), a description of avian habitat preferences and population status of focal species (Appendix S2), a description of vegetation surveys and a related table of least squares means for vegetation variables (Appendix S3), and 3 tables with least squares means for density of birds on reference and turbine sites (Appendix S4) are available online. The authors are solely responsible for the content and functionality of these materials. Queries (other than absence of the material) should be directed to the corresponding author.

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Supporting Information - Appendix S1.

Table S1.1. Studies of avian and mammal displacement from onshore wind facilities that used impact assessment designs of Before-After Control-Impact (BACI), Control-Impact (CI), Before-After (BA), and Impact-Gradient (IG) (Manly 2001).

Source	Country	Taxonomic group	Variable of interest	Season	No. wind Facilities	Impact assessment design	No. Yrs. Pre-Treatment	No. Yrs. Post-Treatment[a]
Winkelman 1992	Netherlands	multiple avian	abundance	year-round	1	IG, BACI	1-3	1
Osborn et al. 1998	USA	multiple avian	abundance flight height	breeding migration	1	CI	0	2
Leddy et al. 1999	USA	passerine	density	breeding	1	CI	0	1
Johnson et al. 2000a	USA	multiple avian	avian use	breeding migration	1	BACI	2	2
Johnson et al. 2000b	USA	multiple avian and mammal	abundance distribution use	year-round	1	BACI	2	1
Larsen and Madsen 2000	Denmark	waterbird	field utilization	winter	2	IG	0	1
Barrios and Rodriguez 2004	Spain	raptor	flight behavior	year-round	2	IG	0	1
de Lucas et al. 2004	Spain	passerine raptor	abundance productivity flight behavior	year-round	1	CI	0	2
Erickson et al. 2004	USA	passerine	avian use	breeding	1	BA, IG	1	1
de Lucas et al. 2005	Spain	multiple avian and mammal	abundance flight behavior	breeding	1	BACI, IG	1	1
Rabin et al. 2006	USA	ground squirrel	antipredator behavior	breeding	1	CI	0	1

Walter et al. 2006	USA	elk	distance home range	year-round	1	BA	1	2
Devereaux et al. 2008	UK	multiple avian	occurrence	winter	2	IG	0	1
Madsen and Boertmann 2008	Denmark	waterbird	field utilization	migration	3	IG	0	2
Pearce-Higgins et al. 2009	UK	multiple avian	occurrence flight height	breeding	12	CI	0	1
Douglas et al. 2011	UK	game bird waterbird	abundance occurrence	breeding	1	CI	0	2
Garvin et al. 2011	USA	raptor	abundance flight height	breeding	1	BA, CI	1	2
Jain et al. 2011	USA	bats	activity	migration breeding	1	CI	0	2
Pearce-Higgins et al. 2012	UK	game bird passerine waterbird	density	breeding	18	BACI	1	1-5
Rubenstahl et al. 2012	USA	passerine	productivity	breeding	1	IG	0	1
Hatchett et al. 2013	USA	passerine	productivity	breeding	1	IG	0	2
Loesch et al. 2013	USA	waterbird	density	breeding	2	CI	0	3
Niemuth et al. 2013	USA	waterbird	occurrence	breeding	2	CI	0	3
Stevens et al. 2013	USA	passerine	occupancy	winter	1	IG	0	2
Bennett et al. 2014	USA	passerine	productivity	breeding	1	IG	0	1
LeBeau et al. 2014	USA	game bird	fitness productivity	breeding	1	IG	0	2
McNew et al. 2014	USA	game bird	site selection productivity	breeding	1	BA, IG	2	3
Winder et al. 2014a	USA	game bird	fitness	year-round	1	BA, IG	2	3

Winder et al. 2014b	USA	game bird	home range distribution	year-round	1	BA, IG	2	3
Shaffer and Buhl, this paper	USA	passerine waterbird	density	breeding	3	BACI	1	3-4[b]

[a]Construction years were not included.
[b]We had 3-4 post-treatment years of data over the 5-year post-treatment time frame (i.e., 5 calendar years) used for analyses.

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Supporting Information - Appendix S2.

Table S2.1. Habitat classification, population trend, and conservation status of avian species that were sufficiently abundant to include in analyses examining the effects of wind energy development on avian density in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD], U.S.A.) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center [OL], U.S.A.), 2003-2012.

Species	Habitat classification[a]	Population trend (%)[b]	Species of concern[b]
Grasshopper sparrow *Ammodramus savannarum*	grassland obligate	-2.5	no
Bobolink *Dolichonyx oryzivorus*	grassland obligate	-2.1	yes
Western meadowlark *Sturnella neglecta*	grassland obligate	-1.3	no
Killdeer *Charadrius vociferous*	generalist	-1.2	no
Upland sandpiper *Bartramia longicauda*	grassland obligate	0.5	yes
Clay-colored sparrow *Spizella pallida*	grassland/shrubland	-1.4	no
Vesper sparrow *Pooecetes gramineus*	grassland obligate	-0.9	no
Savannah sparrow *Passerculus sandwichensis*	grassland obligate	-1.2	no
Chestnut-collared longspur *Calcarius ornatus*	grassland obligate	-4.3	yes

[a]Habitat classification and concern rankings from NABCI (2014).

[b]Breeding Bird Survey population trends from Sauer et al. (2013).

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Supporting Information

Appendix S3. Description of vegetation surveys and analysis for the study on effects of wind energy facilities on grassland birds in South Dakota (NextEra Energy [NEE] SD Wind Energy Center [SD], U.S.A.) and North Dakota (Acciona Tatanka Wind Farm [TAT] and NEE Oliver Wind Energy Center (OL), U.S.A.), 2003-2012.

The mixed-grass prairie biome in North Dakota and South Dakota (U.S.A.) is a heterogeneous landscape of wetland complexes embedded within grasslands of highly scattered patches of low-growing trees and shrubs, such as S*ymphoricarpos occidentalis* (Hook) and *Prunus virginiana* (L.). Non-grassland habitats within sites were mapped using GPS units and digital photography because our focal species did not breed within all available habitat types within any particular site. For example, grasshopper sparrows were never detected within wetlands or colonies of black-tailed prairie dogs *Cynomys ludovicianus* (Ord). We accounted for the fact that some of our focal species have particular breeding habitat preferences by mapping area of wetlands (open water), woodlands, colonies of black-tailed prairie dogs, and exceptionally lush grass and deleting these areas from total area of each site, as applicable, so as to calculate suitable breeding area at a species level. Wetland area was removed for all nine of our focal species, woodland area was removed for all species except clay-colored sparrow, area of prairie-dog colony was removed for grasshopper sparrow (JAS, personal observation), and area of lush grass was removed for chestnut-collared longspur (Hill & Gould 1997).

Vegetation measurements were taken within the 50 m by 200 m cells formed by the avian survey grids. Cells were systematically chosen and sampling was conducted along 1-2 sampling lines. Percent composition of six basic life forms, bare ground (e.g., bare ground, cow pie, rock), grass, forb, shrub, standing residual, and lying litter, was estimated using a step-point sampler (Owensby 1973). Height-density (i.e., visual obstruction) was measured with a Robel pole (Robel et al. 1970). Vegetation height and litter depth were measured with a meter stick. Measurements were averaged to characterize each site.

To examine the similarity in vegetation metrics (e.g., vegetation height, proportion bare ground) between turbine and reference sites, a repeated measures analysis of variance was conducted to estimate and compare mean habitat features between turbine and reference sites and among years.

Vegetation characteristics did not significantly vary between reference and turbine sites except for VOR at TAT, where the difference was still quite small (see Appendix Table S2.1). As expected, yearly differences did occur for most vegetation characteristics. Therefore, the habitat was similar between reference and turbine sites and can be excluded as a possible confounding factor.

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Table S3.1. Least squares means of each vegetation variable for reference and turbine sites, at SD Wind Energy Center (SD) in Highmore, South Dakota (2003-2012); Acciona's Tatanka Wind Farm (TAT) in Forbes, North Dakota (2007-2012); and Oliver Wind Energy Center (OL) in Oliver Co., North Dakota (2006-2011), U.S.A. Sig. column indicates significance at a significance level of 0.05, t indicates significant difference between reference and turbine sites, y indicates significant difference among years, and t*y indicates a significant turbine*year interaction.

	SD			TAT			OL		
	Reference	Turbine	Sig. [a]	Reference	Turbine	Sig.	Reference	Turbine	Sig. [a]
VOR	0.97 (0.16)	0.74 (0.12)	y	0.93 (0.05)	1.33 (0.07)	t	1.09 (0.07)	0.77 (0.07)	t*y
Litter Depth	2.58 (0.41)	2.11 (0.32)	t*y	3.05 (0.28)	3.71 (0.38)	y	2.92 (0.34)	2.48 (0.34)	y
Veg Height	26.47 (2.32)	23.48 (1.81)	y	29.30 (1.90)	33.67 (2.65)	y	29.76 (2.05)	23.41 (2.05)	t*y
Bare Ground	0.03 (0.01)	0.03 (0.01)	y	0.02 (0.00)	0.01 (0.01)		0.01 (0.01)	0.04 (0.01)	
Forbs	0.11 (0.02)	0.10 (0.02)	t*y	0.17 (0.01)	0.21 (0.02)	y	0.12 (0.02)	0.15 (0.02)	y
Grass	0.64 (0.02)	0.65 (0.01)	y	0.62 (0.03)	0.58 (0.04)	y	0.68 (0.03)	0.59 (0.03)	
Lying Litter	0.16 (0.02)	0.17 (0.02)	t*y	0.08 (0.01)	0.05 (0.01)	y	0.09 (0.02)	0.09 (0.02)	
Res. Litter	0.05 (0.01)	0.05 (0.01)	y	0.04 (0.01)	0.05 (0.01)	y	0.08 (0.01)	0.07 (0.01)	y
Shrubs	---	---		0.07 (0.02)	0.09 (0.03)		0.02 (0.02)	0.05 (0.02)	y

[a]Most interaction effects were significant due to year differences rather than to differences between reference and turbine sites.

Supporting Information

Appendix S4. Least squares means (SE) of density / 100 ha for reference and turbine sites for 3 study sites in North Dakota and South Dakota (U.S.A.), 2003-2012.

Table S4.1. Least squares means (SE) of density/100 ha for reference and turbine sites each year at SD Wind Energy Center (SD) in Highmore, South Dakota.

	Year	Grasshopper Sparrow	Chestnut-collared Longspur	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer
Reference Sites	2003	124.3 (11.2)	56.7 (10.4)	22.0 (3.2)	8.5 (5.2)	2.3 (1.9)	3.2 (1.3)
	2004	60.1 (11.2)	42.3 (10.4)	22.0 (3.2)	12.9 (5.2)	1.5 (1.9)	0.0 (1.3)
	2005	62.1 (11.2)	36.2 (10.4)	15.5 (3.2)	6.6 (5.2)	2.9 (1.9)	0.7 (1.3)
	2006	100.6 (11.2)	65.8 (10.4)	30.3 (3.2)	5.2 (5.2)	3.7 (1.9)	2.2 (1.3)
	2008	130.7 (11.2)	120.6 (10.4)	37.6 (3.2)	14.8 (5.2)	1.8 (1.9)	0.8 (1.3)
	2010	87.4 (11.2)	39.8 (10.4)	23.2 (3.2)	18.2 (5.2)	5.1 (1.9)	0.0 (1.3)
	2012	79.4 (11.2)	60.3 (10.4)	15.5 (3.2)	42.4 (5.2)	2.6 (1.9)	1.7 (1.3)
Turbine Sites	2003	104.6 (8.6)	47.3 (8.1)	36.6 (2.5)	7.2 (4.0)	9.8 (1.5)	4.7 (1.0)
	2004	38.3 (8.6)	37.5 (8.1)	24.6 (2.5)	1.3 (4.0)	5.3 (1.5)	7.1 (1.0)
	2005	31.6 (8.6)	23.7 (8.1)	16.5 (2.5)	3.1 (4.0)	2.2 (1.5)	1.8 (1.0)
	2006	52.0 (8.6)	38.4 (8.1)	28.3 (2.5)	5.6 (4.0)	3.2 (1.5)	4.2 (1.0)
	2008	51.4 (8.6)	48.2 (8.1)	23.9 (2.5)	6.1 (4.0)	2.1 (1.5)	2.8 (1.0)
	2010	34.5 (8.6)	35.3 (8.1)	20.3 (2.5)	2.3 (4.0)	3.7 (1.5)	4.3 (1.0)
	2012	53.9 (9.7)	43.7 (8.8)	27.7 (2.8)	9.7 (4.5)	5.3 (1.6)	4.3 (1.2)
Reference Average		92.1 (4.6)	60.2 (7.1)	23.7 (1.2)	15.5 (2.9)	2.9 (0.8)	1.2 (0.5)
Turbine Average		52.3 (3.6)	39.1 (5.5)	25.4 (1.0)	5.0 (2.3)	4.5 (0.6)	4.2 (0.4)
Overall Average		72.2 (2.9)	49.7 (4.5)	24.6 (0.8)	10.3 (1.8)	3.7 (0.5)	2.7 (0.3)

Table S4.2. Least squares means (SE) of density/100 ha for reference and turbine sites each year at Acciona's Tatanka Wind Farm (TAT) in Forbes, North Dakota.

	Year	Grasshopper Sparrow	Clay-colored Sparrow	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer	Savannah Sparrow	Vesper Sparrow
Reference Sites	2007	67.6 (8.8)	27.1 (11.6)	13.8 (2.0)	39.0 (3.6)	8.8 (1.9)	0.2 (0.6)	5.2 (1.4)	6.4 (1.7)
	2009	55.1 (8.8)	31.9 (11.6)	13.1 (2.0)	22.1 (3.6)	10.3 (1.9)	1.4 (0.6)	3.0 (1.4)	4.6 (1.7)
	2010	84.4 (8.8)	30.6 (11.6)	17.2 (2.0)	31.0 (3.6)	11.5 (1.9)	1.2 (0.6)	4.3 (1.4)	1.9 (1.7)
	2012	93.7 (10.2)	92.4 (12.6)	10.8 (2.3)	31.4 (4.2)	4.1 (2.1)	2.9 (0.7)	10.5 (1.5)	5.7 (1.9)
Turbine Sites	2007	87.8 (12.5)	47.1 (16.4)	10.6 (2.9)	70.9 (5.1)	3.9 (2.7)	1.2 (0.9)	6.6 (1.9)	2.7 (2.4)
	2009	47.3 (12.5)	35.3 (16.4)	12.1 (2.9)	24.8 (5.1)	3.2 (2.7)	3.1 (0.9)	4.8 (1.9)	2.4 (2.4)
	2010	89.6 (12.5)	30.3 (16.4)	9.8 (2.9)	25.0 (5.1)	4.3 (2.7)	5.3 (0.9)	3.7 (1.9)	1.2 (2.4)
	2012	65.6 (12.5)	80.8 (16.4)	11.8 (2.9)	28.9 (5.1)	2.0 (2.7)	5.6 (0.9)	6.7 (1.9)	1.5 (2.4)
Reference Average		75.2 (4.6)	45.5 (10.0)	13.7 (1.0)	30.9 (2.0)	8.7 (1.4)	1.4 (0.3)	5.8 (1.0)	4.7 (0.8)
Turbine Average		72.6 (6.3)	48.4 (14.1)	11.1 (1.4)	37.4 (2.7)	3.3 (1.9)	3.8 (0.4)	5.4 (1.4)	2.0 (1.1)
Overall Average		73.9 (3.9)	46.9 (8.6)	12.4 (0.8)	34.1 (1.7)	6.0 (1.2)	2.6 (0.3)	5.6 (0.9)	3.3 (0.7)

Table S4.3. Least squares means (SE) of density/100 ha for reference and turbine sites each year at Oliver Wind Energy Center (OL) in Oliver County, North Dakota.

	Year	Grasshopper Sparrow	Clay-colored Sparrow	Western Meadowlark	Bobolink	Upland Sandpiper	Killdeer	Savannah Sparrow	Vesper Sparrow
Reference Sites	2006	105.2 (10.2)	25.6 (6.8)	28.0 (6.6)	42.0 (4.3)	7.7 (1.2)	1.3 (1.0)	2.5 (3.1)	1.3 (2.2)
	2007	65.6 (10.2)	21.2 (6.8)	10.0 (6.6)	19.0 (4.3)	4.9 (1.2)	1.3 (1.0)	7.9 (3.1)	2.4 (2.2)
	2009	133.6 (10.2)	33.4 (6.8)	49.3 (6.6)	16.1 (4.3)	8.0 (1.2)	2.7 (1.0)	8.0 (3.1)	0.0 (2.2)
	2011	56.3 (10.2)	13.7 (6.8)	31.5 (6.6)	49.5 (4.3)	6.9 (1.2)	1.4 (1.0)	1.4 (3.1)	0.0 (2.2)
Turbine Sites	2006	84.4 (10.2)	55.3 (6.8)	17.3 (6.6)	21.2 (4.3)	6.5 (1.2)	4.0 (1.0)	3.5 (3.1)	6.3 (2.2)
	2007	62.9 (10.2)	33.5 (6.8)	14.7 (6.6)	9.0 (4.3)	3.6 (1.2)	4.0 (1.0)	5.5 (3.1)	7.8 (2.2)
	2009	47.1 (10.2)	44.1 (6.8)	25.1 (6.6)	5.2 (4.3)	4.8 (1.2)	2.4 (1.0)	3.4 (3.1)	5.3 (2.2)
	2011	39.5 (10.2)	20.4 (6.8)	22.4 (6.6)	13.7 (4.3)	3.6 (1.2)	2.7 (1.0)	1.5 (3.1)	3.9 (2.2)
Reference Average		90.2 (4.7)	23.5 (4.6)	29.7 (3.1)	31.6 (2.2)	6.9 (0.8)	1.7 (0.5)	4.9 (2.3)	0.9 (1.8)
Turbine Average		58.5 (4.7)	38.3 (4.6)	19.9 (3.1)	12.3 (2.2)	4.6 (0.8)	3.3 (0.5)	3.5 (2.3)	5.8 (1.8)
Overall Average		74.3 (3.4)	30.9 (3.3)	24.8 (2.2)	22.0 (1.5)	5.7 (0.5)	2.5 (0.3)	4.2 (1.6)	3.4 (1.2)

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Research Article

Effect of Wind Energy Development on Breeding Duck Densities in the Prairie Pothole Region

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ABSTRACT Industrial wind energy production is a relatively new phenomenon in the Prairie Pothole Region and given the predicted future development, it has the potential to affect large land areas. The effects of wind energy development on breeding duck pair use of wetlands in proximity to wind turbines were unknown. During springs 2008–2010, we conducted surveys of breeding duck pairs for 5 species of dabbling ducks in 2 wind energy production sites (wind) and 2 paired reference sites (reference) without wind energy development located in the Missouri Coteau of North Dakota and South Dakota, USA. We conducted 10,338 wetland visits and observed 15,760 breeding duck pairs. Estimated densities of duck pairs on wetlands in wind sites were lower for 26 of 30 site, species, and year combinations and of these 16 had 95% credible intervals that did not overlap zero and resulted in a 4–56% reduction in breeding pairs. The negative median displacement observed in this study (21%) may influence the prioritization of grassland and wetland resources for conservation when existing decision support tools based on breeding-pair density are used. However, for the 2 wind study sites, priority was not reduced. We were unable to directly assess the potential for cumulative impacts and recommend long-term, large-scale waterfowl studies to reduce the uncertainty related to effects of broad-scale wind energy development on both abundance and demographic rates of breeding duck populations. In addition, continued dialogue between waterfowl conservation groups and wind energy developers is necessary to develop conservation strategies to mitigate potential negative effects of wind energy development on duck populations. © Published 2012. This article is a U.S. Government work and is in the public domain in the USA.

KEY WORDS *Anas discors*, *A. platyrhynchos*, blue-winged teal, breeding population, mallard, Prairie Pothole Region, wind energy development, wind turbines.

Millions of glaciated wetlands and expansive grasslands make the Prairie Pothole Region (PPR) the primary breeding area for North America's upland nesting ducks (Batt et al. 1989). Wetland and grassland loss in the PPR due to settlement and agriculture has been extensive (Dahl 1990, Mac et al. 1998), and conversion to agriculture continues to reduce available habitat for breeding waterfowl and other wetland- and grassland-dependent birds (Oslund et al. 2010, Claassen et al. 2011). During recent years, anthropogenic impacts in the PPR have expanded to include energy development (e.g., wind, oil, natural gas; see Copeland et al. 2011: table 2.1). From 2002 to 2011, industrial wind energy production has increased 1,158% (i.e., 769–9,670 MW), 205% during the past 5 years (United States Department of Energy [USDOE] 2011). Impacts from wind energy development including direct mortality from strikes and avoidance of wind towers and associated infrastructure have been widely documented for many avian species, including raptors, passerines, upland gamebirds, shorebirds, and waterfowl, as well as bats (Drewitt and Langston 2006; Arnett et al. 2007, 2008; Kuvlesky et al. 2007).

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Wetland habitats in the PPR annually attract and support >50% of the breeding waterfowl population in North America (Bellrose 1980). The productivity and subsequent use of prairie wetlands by breeding ducks in the PPR are critical for the maintenance of continental duck populations (Batt et al. 1989, van der Valk 1989). Because of the potential for extensive wind energy development (USDOE 2008, 2011, Kiesecker et al. 2011), understanding the potential effect of wind power development on the use of wetland habitat by breeding duck pairs in the region is critical.

The potential impacts of wind energy development on breeding ducks are similar to other wildlife reviewed in Kuvlesky et al. (2007). Breeding pairs may abandon otherwise suitable wetland habitat, display behavioral avoidance thereby reducing densities of pairs using wetlands near wind turbines, and experience mortality from collision with turbines and associated infrastructure. Additionally, indirect effects on breeding ducks potentially include avoidance of associated grassland by nesting females, increased predation, or reduced reproduction. Wind towers and supporting infrastructure generally do not directly affect the wetlands that provide habitat for breeding ducks. However, ducks are sensitive to many forms of disturbance (Dahlgren and Korschgen 1992, Madsen 1995, Larsen and Madsen 2000). Avoidance related to the presence of towers, movement of blades (e.g., shadow flicker), blade noise (Habib et al. 2007), infrastructure development including roads and transmission lines (Forman and Alexander 1998, Ingelfinger and Anderson 2004, Reijnen and Foppen 2006), and maintenance activities have been documented for other avian species and may similarly affect breeding pairs and reduce the use of wetlands within and adjacent to wind farms.

The presence of wind energy development in high density wetland and breeding pair habitat in the PPR is relatively recent, and previous studies of the effects of land-based wind development on waterfowl (*Anatidae*) have focused primarily on collision mortality (Winkelman 1990, Johnson et al. 2000, Gue 2012) and the effect of wind farms on foraging behavior of wintering and migrating waterfowl (Winkelman 1990, Larsen and Madsen 2000, Drewitt and Langston 2006, Kuvlesky et al. 2007, Stewart et al. 2007). Wind development appears to cause displacement of wintering or migrating Anseriformes, and bird abundance may decrease over time (Stewart et al. 2007). However, habituation has been reported for foraging pink-footed geese (*Anser brachyrhynchos*) during winter (Madsen and Boertmann 2008). Displacement of duck pairs due to wind development could affect population dynamics similar to habitat loss (Drewitt and Langston 2006, Kuvlesky et al. 2007). However, little information exists on how land-based wind development affects the settling patterns, distribution, and density of duck pairs during the breeding season.

The number and distribution of breeding duck pairs in the PPR is related to annual wetland and upland conditions (Johnson et al. 1992; Austin 2002; Reynolds et al. 2006, 2007; U.S. Fish and Wildlife Service [USFWS] 2012). Wetland conditions in the PPR vary both spatially and temporally (Niemuth et al. 2010) and during dry years in the PPR, waterfowl are displaced to lesser quality habitats farther north (USFWS 2012) where productivity is generally reduced (Bellrose 1980). The long-term sustainability of breeding duck populations is dependent on availability and use of productive wetlands in the PPR that provide local breeding pair habitat when they are wet (Johnson and Grier 1988). Avoidance of wetlands near wind energy development by breeding ducks on otherwise suitable wetland habitat may result in displacement to lesser quality habitats similar to the effect of displacement during dry years. Given the relatively large development footprint (i.e., unit area/GW) for energy produced from wind relative to other energy sources such as coal (e.g., 7.4 times; wind = 72.1 km^2/TW-hr/yr, coal = 9.7 km^2/TW-hr/yr; McDonald et al. 2009) and the projected growth of the industry (USDOE 2008), a relatively large land area and subsequently a large number of wetlands and associated duck pairs in the PPR can potentially be affected.

We assessed the potential effects of wind energy development and operation on the density of 5 common species of breeding ducks in the PPR of North Dakota and South Dakota: blue-winged teal (*Anas discors*), gadwall (*A. strepera*), mallard (*A. platyrhynchos*), northern pintail (*A. acuta*), and northern shoveler (*A. clypeata*). Our objective was to determine whether the expected density of breeding duck pairs differed between wetlands located within land-based wind energy production sites (hereafter wind sites) and wetlands located within paired sites of similar wetland and upland composition without wind development (hereafter reference sites). We predicted that if disturbance due to wind energy development caused avoidance of wetlands by breeding duck pairs, then expected density of breeding pairs would be lower on wind energy development sites. We interpreted differences in estimated breeding pair densities between paired wind energy development sites and reference sites in the context of the current Prairie Pothole Joint Venture (PPJV) waterfowl conservation strategy for the United States PPR (Ringelman 2005).

STUDY AREA

We selected operational wind energy and paired reference sites as a function of the geographic location, the local wetland community and its potential to attract breeding pairs (i.e., $\geq$40 pairs/km^2; Reynolds et al. 2006), and wetland conditions. In 2008, 11 wind farms were operational in the PPR of North and South Dakota, USA. Of those, only 3 were located in areas with the potential to attract relatively large numbers of breeding duck pairs for the 5 species in this study (Loesch et al. 2012, OpenEnergyInfo 2012). We identified 2 existing wind energy production sites in the Missouri Coteau physiographic region (Bluemle 1991) of south-central North Dakota, USA, and north-central South Dakota, USA (Fig. 1). Both wind sites contained wetland communities with the potential to attract an estimated 46 breeding duck pairs/km^2 (mean density = 8.5 pairs/km^2 for the PPR; Reynolds et al. 2006, Loesch et al. 2012). The Kulm-Edgeley (KE) wind energy development consisted of 41 towers in a cropland-dominated landscape (e.g., 83% of

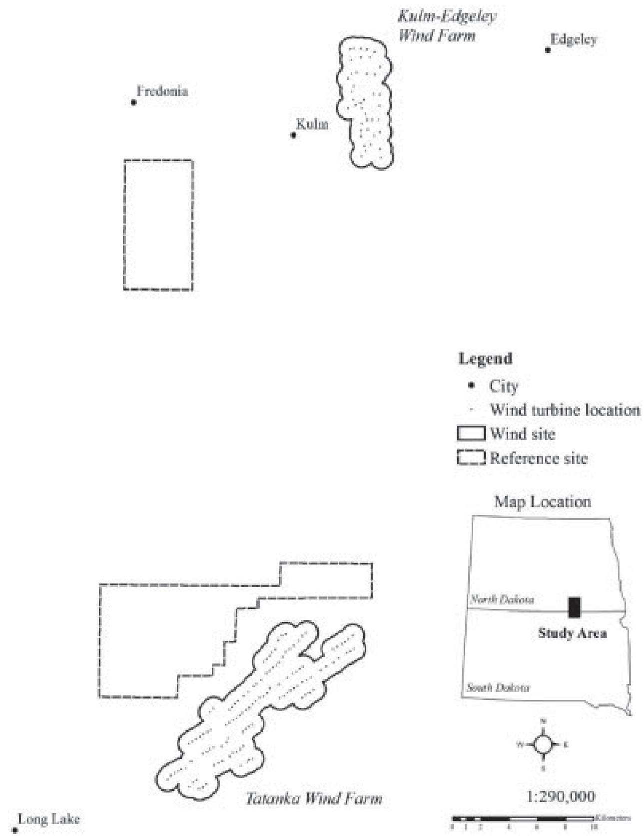

Figure 1. Paired study sites with and without wind energy development surveyed for breeding waterfowl pairs in North Dakota and South Dakota, USA, 2008–2010.

uplands were cropland; Table 1) and was located 3.2 km east of Kulm, North Dakota, USA. The Tatanka (TAT) wind energy development, consisted of 120 towers in a perennial cover-dominated landscape (e.g., 92% of uplands were perennial cover; native grassland, idle planted tame grass, alfalfa hay; Table 1) and was located 9.7 km northeast of Long Lake, South Dakota, USA. The KE site began operation in 2003; approximately 50% of the TAT towers were operational by 28 April 2008 and all were operational by 21 May 2008. Turbine locations were on-screen digitized using ESRI ArcGIS 9.2 software (ArcGIS Version 9.2, Environmental Systems Research Institute, Redlands, CA) and United States Department of Agriculture National Aerial Imagery Program (NAIP) imagery (ca. 2007).

The potential zone of influence for breeding waterfowl from a wind turbine to a wetland during the breeding season is unknown. The limited research that has been conducted to measure displacement of birds in grassland landscapes has primarily targeted migratory grassland passerines, and has identified relatively short (e.g., 80–400 m) distances (Leddy et al. 1999, Johnson et al. 2000, Shaffer and Johnson 2008, Pearce-Higgins et al. 2009). Compared to grassland passerines, waterfowl have relatively large breeding territories and mallards use multiple wetlands within their home range (e.g., 10.36 km^2 generalized to a circle based on a 1,608 m radius; Cowardin et al. 1988). Because the objective of this study was to test the potential effects of wind energy development on breeding duck pair density and not to identify a potential zone of influence, we chose a buffer size with the objective to spatially position sample wetlands in proximity to 1 or many turbines where a potential effect of wind energy development would likely be measurable. Consequently, we used the generalized home range of a mallard hen and buffered each wind turbine by 804 m (i.e., half the radius of a circular mallard home range; Cowardin et al. 1988), to ensure overlap of breeding territories with nearby wind turbines. The wind sites contained different numbers of turbines and as a result the sites were not equally sized (KE wind site = 2,893 ha; TAT wind site = 6,875 ha; Fig. 1).

We derived wetland boundaries from digital USFWS National Wetlands Inventory (NWI) data. We post-processed NWI wetlands to a basin classification (Cowardin et al. 1995, Johnson and Higgins 1997) where we combined complex wetlands (i.e., multiple polygons describing a basin) into a single basin and then classified them to the most permanent water regime (Cowardin et al. 1979). Wetlands partially or completely within the buffer areas were considered treatment wetlands.

For each of the 2 wind sites, we employed a rule-based process to select paired sites to control for differences in wetland and landscape characteristics among sites. We first

Table 1. Characteristics of wetland (i.e., number, area [ha], % of total wetland area) and upland (i.e., area [ha], % of total upland area) areas in development (wind) and paired reference sites in North Dakota and South Dakota, USA, where we surveyed wetlands for breeding duck pairs during spring 2008, 2009, and 2010. Sites included Kulm-Edgely (KE) and Tatanka (TAT) Wind Farms.

	KE wind			KE reference			TAT wind			TAT reference		
Class	Number	Area	%	Number	Area	%	Number	Area	%	Number	Area	%
Wetland												
Temporary	272	41.4	9	283	41.7	7	362	29.9	3	462	97.3	8
Seasonal	372	167.2	37	240	347.3	55	917	253.5	29	815	419.9	36
Semi-permanent	37	239.5	53	37	242.9	38	322	581.7	67	231	636.5	55
Total	681	448.1		560	631.9		1,601	865.0		1,508	1,153.7	
Upland												
Perennial cover[a]		416.3	16		1,324.4	37		5,428.4	92		6,039.7	85
Cropland		2,120.5	83		2,232.8	63		455.3	8		1,064.1	15
Other		6.6	<1		13.4	<1		18.3	<1		11.4	<1
Total		2,543			3,570.6			5,902.1			7,115.2	

[a] Includes native grassland, undisturbed grassland, and alfalfa hay landcover classes.

considered physiographic region and proximity to wind sites when identifying potential reference sites. To reduce the potential for environmental variation, especially wetness (Niemuth et al. 2010), between wind and reference sites, we only considered sites <25 km from the nearest turbine and within the Missouri Coteau physiographic region. Additionally, we assumed that wetlands >2.5 km from the nearest turbine were beyond a potential zone of influence. Using the distance and physiographic region criteria, we identified 3 potential reference sites of similar size for each wind site based on upland land use (i.e., proportion of cropland and perennial cover) and wetland density. For the 6 potential sites, we compared the wetland number and area (ha) for each class (i.e., temporary, seasonal, semi-permanent) between each potential reference site and the respective wind site to select the most similar reference site (Table 1). The KE reference site was located 11.3 km west of the KE wind site and the TAT reference site was located 3.2 km northwest of the TAT wind site (Fig. 1).

We identified 5,146 wetland basins encompassing 3,410 ha from NWI data within the wind and reference sites and considered each wetland a potential sample basin. Only temporary, seasonal, and semi-permanent basins were present at the wind sites so we did not survey lake wetlands at reference sites. We did not survey basins that extended >402 m from the boundary of a site to eliminate linear wetlands that potentially extended long distances from the wind and reference sites.

METHODS

Surveys

We surveyed sample wetlands during spring 2008, 2009, and 2010 to count local breeding duck pairs. We used 2 survey periods (i.e., 28 April–18 May, early; and 21 May–7 June, late) to account for differences in settling patterns for the 5 species (Stewart and Kantrud 1973, Cowardin et al. 1995) and to reduce potential bias associated with differences in breeding chronology among species (Dzubin 1969, Higgins et al. 1992, Naugle et al. 2000). We divided the wind and reference sites into 3 crew areas to spatially distribute survey effort across the sites, and crews of 2 observers conducted surveys on each of the 3 crew areas daily. The detection probability of duck pairs was likely not equal among observers (Pagano and Arnold 2009) and we minimized potential confounding of detection, observer, and survey area by rotating observers among crew areas and partners daily. Additionally, our analytical approach was not to compare population estimates for wind and reference sites, which may require development of correction factors (Brasher et al. 2002, Pagano and Arnold 2009), but rather to compare expected rates of pair abundance. Consequently, we assumed non-detection of ducks to be equal among all sites.

We surveyed wetlands within each crew area in a 2.59-km grid pattern based on public land survey sections (PLSS). We used maps with NAIP imagery and wetland basin perimeters from NWI to assist orientation and navigation to survey wetlands. Permission, accessibility, wetness, numbers of wetlands, size of wetlands, and numbers of birds affected the rate at which we surveyed PLSS. Surveys began at 0800 hours and continued until 1700 hours and were discontinued during steady rainfall or winds exceeding 48 km/hr. We surveyed most wetlands twice each year, once during each survey period. We visited all sample wetlands during the early survey period. We did not revisit wetlands that were dry during the early survey. Annual changes in access permission and wetland conditions due to precipitation resulted in some basins being surveyed during only 1 of the survey periods.

During the breeding season, waterfowl assemble into various social groupings that are influenced by sex ratios, breeding phenology, and daily activities (Dzubin 1969). We counted social groups of the 5 target species using established survey protocols (Hammond 1969, Higgins et al. 1992, Cowardin et al. 1995, Reynolds et al. 2006) and recorded observations for all sample wetlands that contained surface water regardless of whether birds were present or absent. We summarized field observations into 7 social groupings that we subsequently interpreted to determine the number of indicated breeding pairs for each species, basin, and survey period (Dzubin 1969, Cowardin et al. 1995). On average, the first count period (late April–early May) is regarded as an acceptable approximation of the breeding population for mallard and northern pintail (Cowardin et al. 1995, Reynolds et al. 2006). Consequently, we used observations during the early survey period to determine the number of indicated breeding pairs for mallard and northern pintail. Similarly, the second count period (late May–early June) is generally used to approximate the breeding population of blue-winged teal, gadwall, and northern shoveler (Cowardin et al. 1995, Reynolds et al. 2006) and we used observations during the late survey period to determine the number of indicated breeding pairs for these 3 species. We used indicated breeding pairs as the response variable in our models of estimated duck pairs.

We reduced disturbance during surveys by observing wetlands from 1 or more distant, strategic positions. We approached and surveyed portions of basins that were obscured by terrain or vegetation on foot. We noted birds leaving the wetland because of observer disturbance to minimize recounting on wetlands that we had not yet surveyed. We estimated the proportion of the wetland that was wet by visually comparing the surface water present in the basin relative to the wetland extent displayed on the field map. We recorded basins with no surface water as dry and not surveyed.

We used NAIP (ca. 2009) and on-screen photo-interpretation to develop a categorical variable describing the landcover of uplands (i.e., cropland, native grassland, idle planted tame grass, alfalfa hayland) adjacent to or surrounding all wetlands on the wind and reference sites. For wetlands touching multiple upland landcover classes, we assigned the class based on the largest wetland perimeter length. The exception was for idle planted tame grass, where we assigned the class if it touched any length of a wetland perimeter because of the limited presence of this class in the landscape and its positive influence on pair settling densities (Reynolds et al. 2007).

Data Analysis

The objective of our analysis was to compare estimates of expected wetland-level abundance of breeding pairs on the wind and reference sites among years. We used past analyses of breeding duck pairs in the United States PPR and their relationship to wetland and upland parameters to inform the selection of candidate covariates (Cowardin et al. 1988, 1995; Reynolds et al. 1996). Wetland-level covariates included wetland class (i.e., seasonal, semi-permanent, or temporary; Johnson and Higgins 1997), surface area of water in NWI basin (wet area), and square root (sqrt) of wet area to reflect the non-linear response to wetland area demonstrated by breeding ducks in the PPR (Cowardin et al. 1988, 1995; Reynolds et al. 2006). We used a categorical variable for upland landcover (i.e., perennial cover, cropland) adjacent to the wetland for the only upland covariate (Reynolds et al. 2007).

Generalized linear models with Poisson errors provided an appropriate statistical framework for the analysis (McCullagh and Nelder 1989, McDonald et al. 2000). Preliminary summaries of the breeding pair data showed, however, that all 5 species displayed indications of over-dispersion relative to standard Poisson assumptions (i.e., both excess zeros and infrequent large counts; Appendix A, available online at www.onlinelibrary.wiley.com; Zuur et al. 2007). We addressed these challenges, while maintain an approach consistent with past studies by conducting a 2-stage analysis. We began by selecting appropriate models and subsets of the covariates using a likelihood-based approach. Then we used a simulation-based Bayesian approach to estimate parameters of species-specific statistical models, site- and year-level contrasts between wind and reference sites, and lack-of-fit statistics. Our combined approach allowed us to take advantage of the strengths of both approaches (Royle and Dorazio 2008:74–75) to provide a thorough analysis of the data.

We analyzed indicated breeding pairs from counts for each of the 5 study species using separate models. Full Poisson regression models described expected breeding pairs as a log-linear function of site, year, wetland class, landcover, wet area, and sqrt (wet area). We used Akaike's Information Criterion (AIC) differences (Burnham and Anderson 2002) to compare full Poisson models with Zero-Inflated Poisson (ZIP) models. The ZIP models partially accounted for potential excess zeros due to 2 sources: 1) non-detections and 2) unoccupied, but suitable, wetlands. The ZIP models described the data as a mixture of the counts described by the log-linear model and a mass of excess zeros described by a logit-linear model (Zuur et al. 2007). We conducted a comparison of Poisson and ZIP models between the full Poisson model and ZIP model that included a single additional parameter describing the expected probability of a false zero. When AIC differences indicated the ZIP model was more appropriate (i.e., $AIC_{Poisson} - AIC_{ZIP} \geq 4$), we used ZIP models for all subsequent analysis. When ZIP models were selected, the full logit-linear model for excess zeros included covariates describing the upland vegetation cover class associated with each wetland (cover class; Stewart and Kantrud 1973), the area of the NWI basin covered by water (wet area), and the square root of wet area.

We expected that the full models would likely be most appropriate for the study species, as they were parameterized with covariates that have been identified as useful predictors of pair abundance in the Four-Square-Mile Breeding Waterfowl Survey (FSMS) dataset, which has been collected by the USFWS National Wildlife Refuge System since 1987 (Cowardin et al. 1995; Reynolds et al. 2006, 2007). Nonetheless, we sought to efficiently use the information in our less-extensive dataset by ensuring that we had selected a parsimonious subset of the covariates for each species-specific model. We removed a single covariate, or group of covariates in the case of factor variables, from the full model, ran the resulting reduced model, and recorded its AIC value (Chambers 1992, Crawley 2007:327–329). We repeated this procedure for every covariate. This resulted in a vector of AIC values that described, for each covariate, or covariate group, the effect of its removal on the AIC value of the full model. Reduced models for each species contained the set of covariates in the full model or the subset of covariates that resulted in increases in AIC values greater than 2 units per estimated parameter when they were removed from the full model (Arnold 2010).

After selecting a model structure for each species, we estimated the posterior distributions of model parameters with Markov Chain Monte Carlo (MCMC) simulation (Link and Barker 2009) in the Bayesian analysis software WinBUGS 1.4.1 (Spiegelhalter et al., 2003). The structure of the Bayesian ZIP models differed from the maximum likelihood models in 2 ways. The 12 site and year combinations were hierarchically centered and parameterized as normally distributed displacements from a common intercept (Gelman et al. 2004, Congdon 2005), and extra-Poisson variation due to large wetland-level counts was accommodated by a normally distributed error term (Appendix B, available online at www.onlinelibrary.wiley.com).

We conducted all statistical analyses in the R environment (R Development Core Team 2011). We used the generalized linear models capability of base R and the contributed package pscl (Jackman 2008) to estimate likelihoods and AIC values for Poisson and ZIP models. When selecting models and subsets of the covariates, we considered AIC differences greater than 4 to provide good evidence in favor of the model with the smaller value (Burnham and Anderson 2002). To generate Bayesian estimates of model parameters, we used the contributed R2WinBugs (Sturtz et al. 2005) package to run MCMC simulations in WinBUGS via R. For each model, we ran 2 Markov chains for 500,000 iterations and discarded the first 100,000 iterations from each chain to minimize the influence of starting values and prior distributions. We used minimally informative prior distributions and random starting values for model parameters and random effects. We evaluated convergence to the posterior distribution by examining plots of sequential draws for each parameter and also by the Gelman–Rubin statistic (Gelman et al. 2004). We estimated the number of uncorrelated samples generated by each Markov Chain by the Effective Sample Size (ESS; Kass et al. 1998, Streftaris and Worton 2008). We required at least 200 uncorrelated samples per chain for inference. We considered a model to have converged when its Gelman–Rubin statistic was <1.1 and the plots of sequential draws indicated that the chains had stabilized and were sampling from a similar space (Gelman et al. 2004). We tested for lack-of-fit of the model using a posterior predictive test (Gelman et al. 2004). Specifically, we compared the variance-mean ratio for the observed data to the variance-mean ratio of simulated data generated from the posterior draws of model parameters. We concluded that the model fit the data if the posterior proportion of simulated variance-mean ratios that exceeded the observed variance-mean ratio was greater than 0.01 and less than 0.99 (Congdon 2005). We then used the CODA (Plummer et al. 2009) package to summarize the posterior distributions of model parameters, convergence diagnostics, and derived quantities like lack-of-fit statistics and back-transformed estimates of abundance. Using the 800,000 posterior simulations from each model, modal values of categorical covariates, and median values of continuous covariates, we calculated species-, site-, and year-specific medians and 95% credible intervals of 1) the estimated posterior distribution of the log-scale model parameters, 2) the estimated posterior distribution of expected pair abundance on wetlands of median area, and 3) the estimated posterior distribution of the back-transformed contrast in expected pair abundance between wind and reference sites in each year. These quantities provided the basis for comparison of pair abundance between wind and reference sites.

We used point estimates of pair density for the median seasonal wetlands size (i.e., 0.2 ha) in grassland to assess the potential effect of wind energy development on breeding duck pair densities. We selected seasonal wetlands because they were the most numerous wetlands in our sample (58%) and because breeding duck pairs use seasonal wetlands at greater rates than other wetland classes (see Reynolds et al. 2006, 2007; Loesch et al. 2012); most pairs (54%) were observed on seasonal wetlands.

We evaluated the potential impact of wind energy development from both a statistical and biological perspective. We compared point estimates of density among sites and within years to either support or reject an effect. We assessed the potential biological impact of breeding pair avoidance of wind sites by calculating the proportional change in the estimated density of pairs between wetlands in wind and reference sites for each species and year. The percent change reflects the potential impact to breeding duck populations in the presence of wind energy development.

RESULTS

As a result of variable wetland conditions both within and among years, and annual changes in access to private land, we surveyed different numbers and area of wetland basins each year. Water levels in wetlands were low during 2008 and 35% of wetland basins visited during the early count contained water and generally were only partially full (e.g., seasonal regime, mean = 54% full, $n = 684$). Water levels increased in 2009 and 2010 and only 15% of 2,464 and 12% of 3,309 wetland basins, respectively, were dry during the early count. Basins containing water were also more full during 2009 (e.g., seasonal basin mean = 103% full, $n = 1{,}089$) and 2010 (e.g., seasonal basin mean = 93% full, $n = 1{,}407$). We conducted 5,339 wetland visits during the early count and 4,999 wetland visits during the late count. During the early count, we observed 5,287 indicated breeding pairs of mallard (3,456 [range = 146–552]) and northern pintail (1,831 [range = 51–310]), and 10,473 indicated breeding pairs of blue-winged teal (5,886 [range = 180–984]), gadwall (2,839 [range = 75–506]), and northern shoveler (1,748 [range = 55–318]) during the late count.

Model Selection and Estimation

Our ZIP models provided a substantially better fit than Poisson models for every species. Differences in AIC ($AIC_{poisson} - AIC_{zip}$) were 426 for blue-winged teal, 137 for gadwall, 218 for mallard, 384 for northern pintail, and 78 for northern shoveler. All of the covariates in the full model were retained for mallard, northern pintail, blue-winged teal, and northern shoveler. Wetland class was dropped for gadwall. Differences in AIC between the full model and the nearest reduced model were 11 for blue-winged teal, 3 for gadwall, 26 for mallard, 6 for northern pintail, and 29 for northern shoveler. The MCMC simulations converged for every species-specific model, indicating that the parameter estimates and credible intervals from these models provided a sound basis for inference. The maximum upper 95% credible interval of all R-hat values for any structural parameter was 1.01 for blue-winged teal, 1.01 for gadwall, 1.01 for mallard, 1.02 for northern pintail, and 1.04 for northern shoveler. The posterior predictive test indicated that the models fit the data for every species. The proportion of simulated variance-mean ratios that exceeded the observed variance-mean ratio was 0.52 for blue-winged teal, 0.75 for gadwall, 0.61 for mallard, 0.59 for northern pintail, and 0.72 for northern shoveler. Minimum effective sample sizes were 709 for blue-winged teal, 553 for gadwall, 307 for mallard, 346 for northern pintail, and 612 for northern shoveler.

Estimates

Differences in estimated breeding duck pair densities in a wind site and a reference site varied among site pairs (2), years (3), and species (5), and posterior median values of these 30 contrasts ranged from −0.281 to 0.130 (Table 2). Estimated patterns of contrasts for expected breeding duck pair density between wind and reference sites were similar for all species. Given median wet area and the mode of the categorical covariates, expected, basin-level densities of duck pairs for the 5 species was either statistically indistinguishable (14 of 30) between wind and reference sites or was lower (16 of 30) on wind sites than reference sites depending on site, year, and species (Fig. 2). Regardless of whether 95% credible intervals overlapped zero, density estimates were

Table 2. Log-scale estimated posterior medians and 95% of the estimated posterior distribution from the count portion of a zero-inflated, overdispersed Poisson model of indicated blue-winged teal (*Anas discors* [BWTE]), gadwall (*A. strepera* [GADW]), mallard (*A. platyrhynchos* [MALL]), northern pintail (*A. acuta* [NOPI]), and northern shoveler (*A. clypeata* [NSHO]) pairs on seasonal wetland basins for development (wind) and paired reference sites in North Dakota and South Dakota, USA. Sites are Kulm-Edgely (KE) and Tatanka (TAT) for years 2008 (08), 2009 (09), and 2010 (10).

			Reference			Wind		
Species	**Site**	**Year**	**Median**	**2.5%**	**97.5%**	**Median**	**2.5%**	**97.5%**
MALL	KE	08	0.47	0.21	0.73	0.15	−0.13	0.43
	KE	09	−0.49	−0.78	−0.22	−0.90	−1.17	−0.64
	KE	10	−0.42	−0.66	−0.20	−0.77	−1.04	−0.51
	TAT	08	0.29	0.02	0.56	0.41	0.17	0.65
	TAT	09	−0.38	−0.61	−0.14	−0.63	−0.89	−0.38
	TAT	10	−0.33	−0.55	−0.10	−0.47	−0.71	−0.22
BWTE	KE	08	−0.13	−0.25	−0.00	0.22	0.01	0.45
	KE	09	−0.46	−0.66	−0.27	−0.52	−0.74	−0.32
	KE	10	−0.13	−0.30	0.04	−0.58	−0.78	−0.39
	TAT	08	0.25	0.06	0.45	0.18	0.01	0.36
	TAT	09	−0.15	−0.32	0.02	−0.39	−0.58	−0.21
	TAT	10	0.03	−0.12	0.19	−0.19	−0.36	−0.02
NOPI	KE	08	−0.25	−0.61	0.12	−0.80	−1.24	−0.39
	KE	09	−0.80	−1.16	−0.45	−1.54	−1.93	−1.17
	KE	10	−0.72	−1.01	−0.42	−1.20	−1.56	−0.87
	TAT	08	−0.10	−0.46	0.27	0.16	−0.15	0.48
	TAT	09	−0.35	−0.63	−0.06	−0.76	−1.07	−0.44
	TAT	10	−0.15	−0.41	0.13	−0.38	−0.67	−0.07
GADW	KE	08	0.09	−0.17	0.37	−0.13	−0.43	0.18
	KE	09	−0.52	−0.77	−0.28	−0.91	−1.19	−0.64
	KE	10	−0.61	−0.83	−0.38	−1.42	−1.72	−1.14
	TAT	08	0.07	−0.18	0.34	0.17	−0.05	0.41
	TAT	09	−0.46	−0.69	−0.22	−0.55	−0.81	−0.29
	TAT	10	−0.69	−0.92	−0.46	−0.62	−0.86	−0.38
NSHO	KE	08	−0.35	−0.61	−0.08	−0.49	−0.79	−0.18
	KE	09	−0.91	−1.17	−0.67	−1.00	−1.29	−0.73
	KE	10	−0.78	−1.00	−0.57	−1.11	−1.39	−0.85
	TAT	08	−0.23	−0.49	0.00	−0.30	−0.52	−0.08
	TAT	09	−0.59	−0.80	−0.37	−0.99	−1.25	−0.74
	TAT	10	−0.36	−0.55	−0.16	−0.69	−0.90	−0.47

lower on sites with wind development for 26 of the 30 combinations (i.e., mallard and blue-winged teal: 12 combinations, 11 negative [range −6% to −36%]), 7 did not overlap zero; gadwall, northern pintail, northern shoveler: 18 combinations, 15 negative [range −5% to −56%], 9 did not overlap zero). The general pattern of results were similar for all species, consequently, we chose a representative early and late arriving species with the largest number of indicated breeding pairs, mallard and blue-winged teal, respectively, for detailed presentation of results.

Mallard and Blue-Winged Teal

Mallard and blue-winged teal comprised 59% of the indicated breeding pair observations (i.e., 3,473 mallard; 5,928 blue-winged teal). Full models were retained for both mallard and blue-winged teal, and the point estimate of density was greatest in 2008 for both KE and TAT sites, but varied among years and sites (mallard: wind median = 0.42 [range = 0.30–1.03], reference median = 0.41 [range = 0.21–0.97]; blue-winged teal: wind median = 0.51 [range = 0.42–0.94], reference median = 0.66 [range = 0.47–0.96]). For mallard, estimated breeding pair densities on seasonal wetlands at wind sites were lower for 5 of the 6 site-year combinations (median = 0.11, range = −0.28 to 0.11) and error bars representing 95% of the posterior distribution of the estimate did not overlap zero for 4 of the 6 site-year comparisons (Fig. 2A). Similarly, for blue-winged teal in 5 of the 6 site-year combinations, estimated pair densities were lower for seasonal wetlands on wind sites (median = −0.14, range = −0.24 to <0.01) and error bars representing 95% of the posterior distribution of the estimate did not overlap zero for 3 of the 6 site-year comparisons (Fig. 2B). Only 1 site-year combination for each of mallard and blue-winged teal suggested greater pair densities on wind sites, but in both cases 95% confidence intervals overlapped zero.

The estimated proportional change of mallard pair densities for wetlands in wind sites was negative in 5 of 6 site-year combinations (median = −10%, range = 13% [TAT 2008] to −34% [KE 2009]; Fig. 3A). The proportional change for blue-winged teal was also negative in 5 of 6 site-year combinations (Fig. 3B). The median estimate of proportional change for blue-winged teal densities between wind and reference sites was −18% (range 0% [KE 2009] to −36% [KE 2010]).

DISCUSSION

All 5 of our dabbling duck study species demonstrated a negative response to wind energy development and the reduced abundance we observed was consistent with behavioral avoidance. Avoidance of land-based wind energy development has been observed for numerous avian species during

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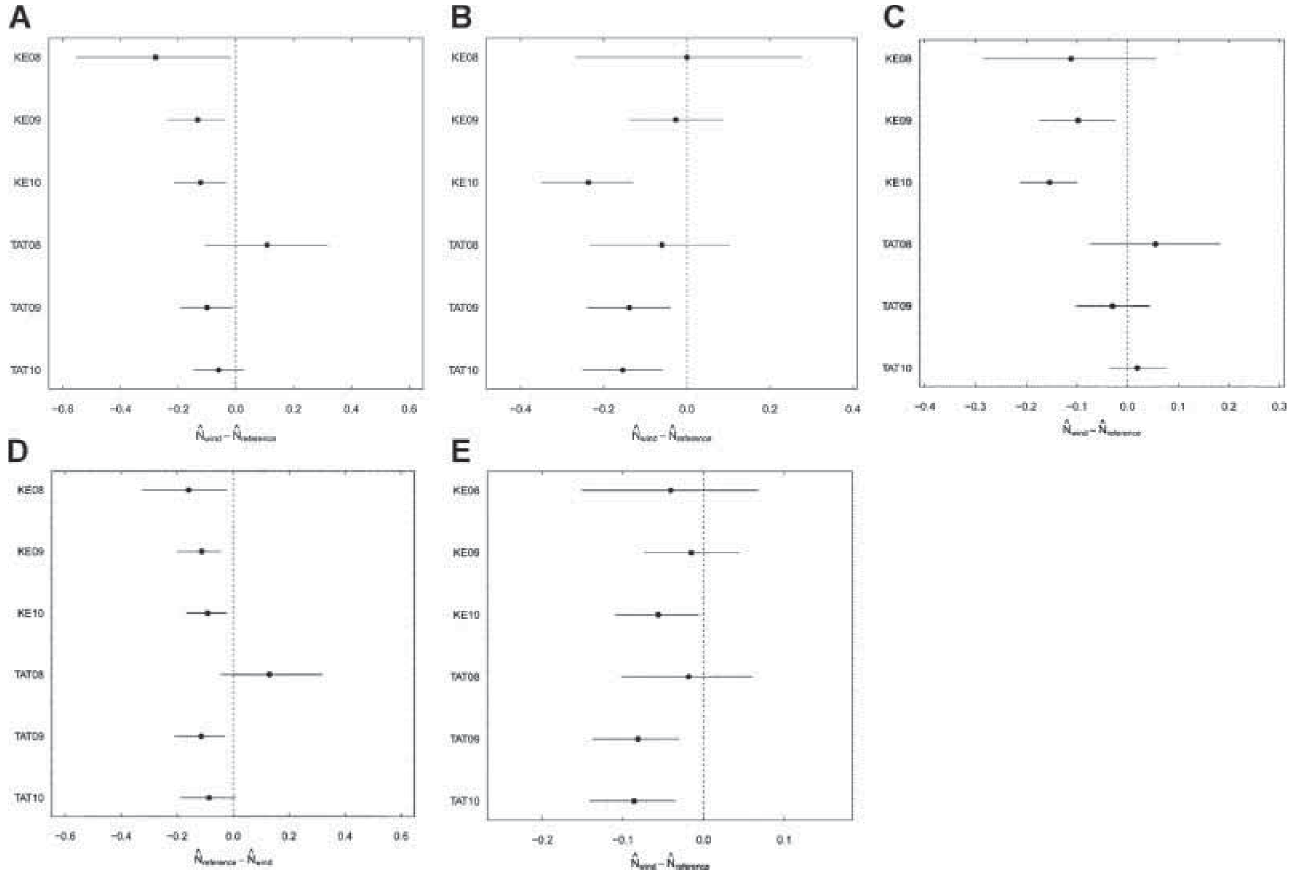

Figure 2. Year-specific estimated differences between estimated posterior median abundance of mallard (*Anas platyrhynchos*; A), blue-winged teal (*A. discors*; B), gadwall (*A. strepera*; C), northern pintail (*A. acuta*; D), and northern shoveler (*A. clypeata*; E) on a seasonal wetland of median area (0.2 ha) embedded in perennial cover on a wind site and its corresponding reference site in North Dakota and South Dakota. Error bars represent 95% of the posterior distribution of the estimate. Site-year combinations are Kulm-Edgely (KE) and Tatanka (TAT) for 2008 (08), 2009 (09), and 2010 (10).

breeding (Leddy et al. 1999, Johnson et al. 2000, Walker et al. 2005, Shaffer and Johnson 2008, see Madders and Whitfield 2006), and does not imply complete abandonment of an area but rather the reduced use of a site (Schneider et al. 2003). This is consistent with our results, where breeding pairs continued to use wetland habitat at the wind sites but at reduced densities.

Our selection of paired wind and reference sites and analytical approach were designed to control for differences in site characteristics and annual variation in habitat conditions, and to use well-understood relationships between breeding duck pairs and wetlands (Cowardin et al. 1995; Reynolds et al. 2006, 2007). Despite the large amount of breeding pair data we collected, discerning if the presence of wind energy development was the ultimate cause of the lower estimated pair abundance on the wind versus reference sites is difficult. However, we did detect a directional effect of wind energy development sites over a 3-year period at the 2 sites that are representative of areas with greater estimated duck densities, and adds to the body of evidence suggesting a negative effect of wind energy development. Reduced wetland use in high density wetland areas with the potential to attract and support relatively greater densities of breeding duck pairs is of concern to waterfowl biologists and managers because when wet, these areas are vital to the sustainability of North American duck populations. The somewhat limited temporal and geographic scope of our study and confounding between land use and duration of development prevents us from drawing strong conclusions about cumulative effects of wind energy development on breeding ducks (see Krausman 2011). Nonetheless, a 10–18% reduction in addition to other stressors is potentially substantial.

We observed larger negative displacement for most species and years in the KE wind site when compared to the TAT wind site. We found 2 notable differences in the wind sites that may have contributed to these results, the land use and age of development. The KE site was predominantly cropland and older than the grassland-dominated TAT site. The combination of multiple stressors, in this case agriculture and wind energy development, may have resulted in a greater impact to breeding ducks using wetlands in agricultural settings. Differences in estimated pair abundance between the cropland and grassland site suggest that greater habitat quality measured by the percent of grassland area and lack of cropping history in associated wetlands within a site may reduce avoidance of wind development when compared to agricultural landscapes. Breeding waterfowl may occupy wetlands at greater rates in grassland than cropland (Reynolds et al. 2007), nest success is generally greater in grasslands (Greenwood et al. 1995, Reynolds et al. 2001, Stephens et al.

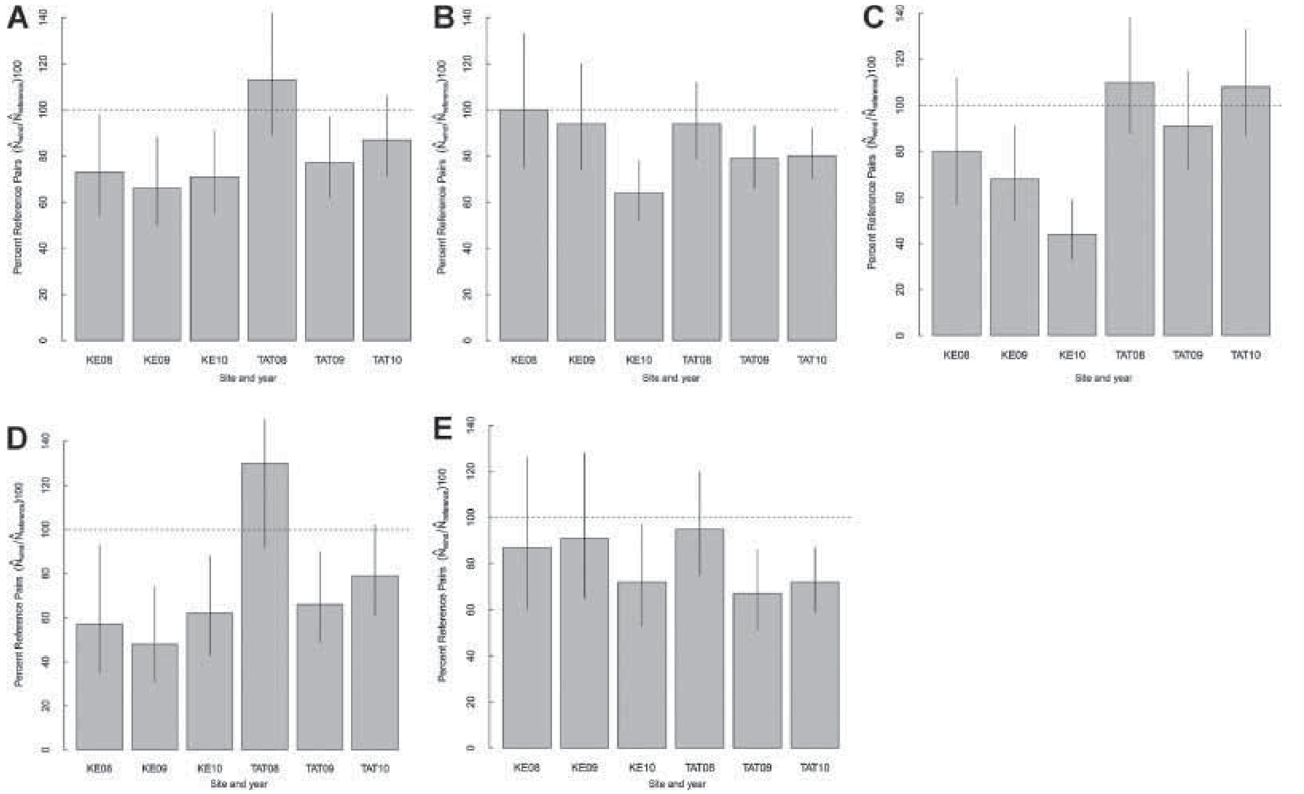

Figure 3. Year-specific estimated number of mallard (*Anas platyrhynchos*; A), blue-winged teal (*A. discors*; B), gadwall (*A. strepera*; C), northern pintail (*A. acuta*; D), and northern shoveler (*A. clypeata*; E) on a seasonal wetland of median area (0.2 ha) embedded in perennial cover on a wind site expressed as a percentage of pairs expected on the same wetland in the corresponding reference site in North Dakota and South Dakota. Error bars represent 95% of the posterior distribution of the estimate. Site-year combinations are Kulm-Edgely (KE) and Tatanka (TAT) for 2008 (08), 2009 (09), and 2010 (10).

2005), and wetlands in grass landscapes have greater occupancy rates by duck broods (Walker 2011), suggesting an overall greater productivity potential for breeding ducks in grassland versus cropland landscapes. The ability of intact habitat to reduce impacts of energy development is supported in current literature. In Wyoming, sage-grouse (*Centrocercus urophasianus*) residing in a fragmented landscape showed a 3 times greater decline in active leks at conventional coal bed methane well densities (1 well per 32 ha) than those in the most contiguous expanses of Wyoming big sagebrush (*Artemisia tridentata*) in North America (Doherty et al. 2010). A similar relationship has been document for large mammals. In the Boreal forest, woodland caribou (*Rangifer tarandus caribou*) populations could sustain greater levels of industrial development and maintain an increasing population when they resided in large forest tracts that were not fragmented by wildfires (Sorensen et al. 2008).

Our ability to support the hypothesis that habitat quality mitigates impacts could be confounded by time-lags in detecting impacts, as well as the potential for ducks to habituate to wind energy development over time but at a cost to individual fitness (Bejder et al. 2009). The KE wind site was cropland-dominated and began operation in 2003, whereas the TAT wind site was grassland-dominated and began operation in 2008, and was 3 years old during the final field season. Many recent studies for a variety of species and ecosystems have shown time lags between dates of first construction and full biological impacts. In Wyoming impacts to sage-grouse in some instances doubled 4 years post-development versus the initial year of development (Doherty et al. 2010) and lags varied from 2 to 10 years (Harju et al. 2010). In some instances, full biological impacts may not be apparent for decades. For example, 2 decades passed before impacts of forest logging resulted in woodland caribou population extirpation within 13 km of logging (Vors et al. 2007). In a review paper on the effects of wind farms to birds on 19 globally distributed wind farms using meta-analyses, time lags were important in detecting impacts for their meta-analyses with longer operating times of wind farms resulting in greater declines in abundance of Anseriformes (Stewart et al. 2007). Pink-footed geese foraging during spring appear to have habituated to the presence of wind turbines in Europe (Madsen and Boertmann 2008). We therefore cannot distinguish between these 2 competing hypotheses without additional study.

Wind resources are both abundant and wide-spread in the PPR in the United States (Heimiller and Haymes 2001, Kiesecker et al. 2011), and the development of an additional 37 GW of wind energy capacity in the PPR states is necessary to meet 20% of domestic energy needs by 2030 (USDOE 2008). The projected wind farm footprint in PPR states to support this target is approximately 39,601 km^2. Even if recommendations for siting energy development outside of intact landscapes suggested by

Kiesecker et al. (2011) are implemented by the wind industry, millions of wetlands occur in agricultural landscapes and our results indicate that wind energy development will likely reduce their use by breeding duck pairs.

Waterfowl conservation partners in the PPR use strategic habitat conservation (Reynolds et al. 1996, 2006; Ringelman 2005; USFWS 2006; Loesch et al. 2012) in an adaptive management framework to target protection, management, and restoration based on biological and landscape information, primarily in response to habitat loss from agricultural activities. From a habitat quality and conservation perspective, wind energy development should be considered as another stressor relative to the cumulative effects of anthropogenic impacts on limiting factors to breeding waterfowl populations.

The protection of remaining, high priority grassland and wetland resources in the United States PPR is the primary focus of waterfowl habitat conservation (Ringelman 2005, Niemuth et al. 2008, Loesch et al. 2012). Population goals and habitat objectives were established to maintain habitat for breeding pairs and the current productivity of the landscape (Ringelman 2005, Government Accounting Office 2007). Spatially explicit decision support tools (Reynolds et al. 1996, Niemuth et al. 2005, Stephens et al. 2008, Loesch et al. 2012) have been used effectively to target and prioritize resources for protection. New stressors such as energy development in the PPR that negatively affect the use of wetland resources have ramifications to breeding waterfowl populations (i.e., potential displacement to lower quality wetland habitat) and their conservation and management. Thus, population and habitat goals, and targeting criteria may need to be revisited if large-scale wind development occurs within continentally important waterfowl conservation areas like the PPR.

MANAGEMENT IMPLICATIONS

Balancing the development of wind energy and current conservation efforts to protect habitat for migratory birds is complex because most conservation and wind energy development in the region occur on private land (USFWS 2011). Given that breeding duck pairs do not completely avoid wetlands in and adjacent to wind energy developments and resource benefits remain, albeit at reduced levels, the grassland and wetland protection prioritization criteria used by conservation partners in the PPR (Ringelman 2005) could be adjusted to account for avoidance using various scenarios of acceptable impact. For example, the wind sites used in our study are in high priority conservation locations (Ringelman 2005, Loesch et al. 2012). After accounting for effects of duck displacement by wind development, their priority was not reduced for either site. Consequently, wind-development does not necessarily preclude these sites from consideration for protection. Additionally, using the measured negative impact of wind energy development and production on breeding duck pairs, opportunities to work with wind energy industry to mitigate the reduced value of wetlands in proximity to wind towers should be investigated. Continued partnership by the wind energy industry and wildlife conservation groups will be critical for continued research. Further, we suggest expanding our research both spatially and temporally to better address cumulative impacts, zone of influence, impacts on vital rates, potential habituation or tolerance, and/or lag effects of long-term exposure to wind energy development.

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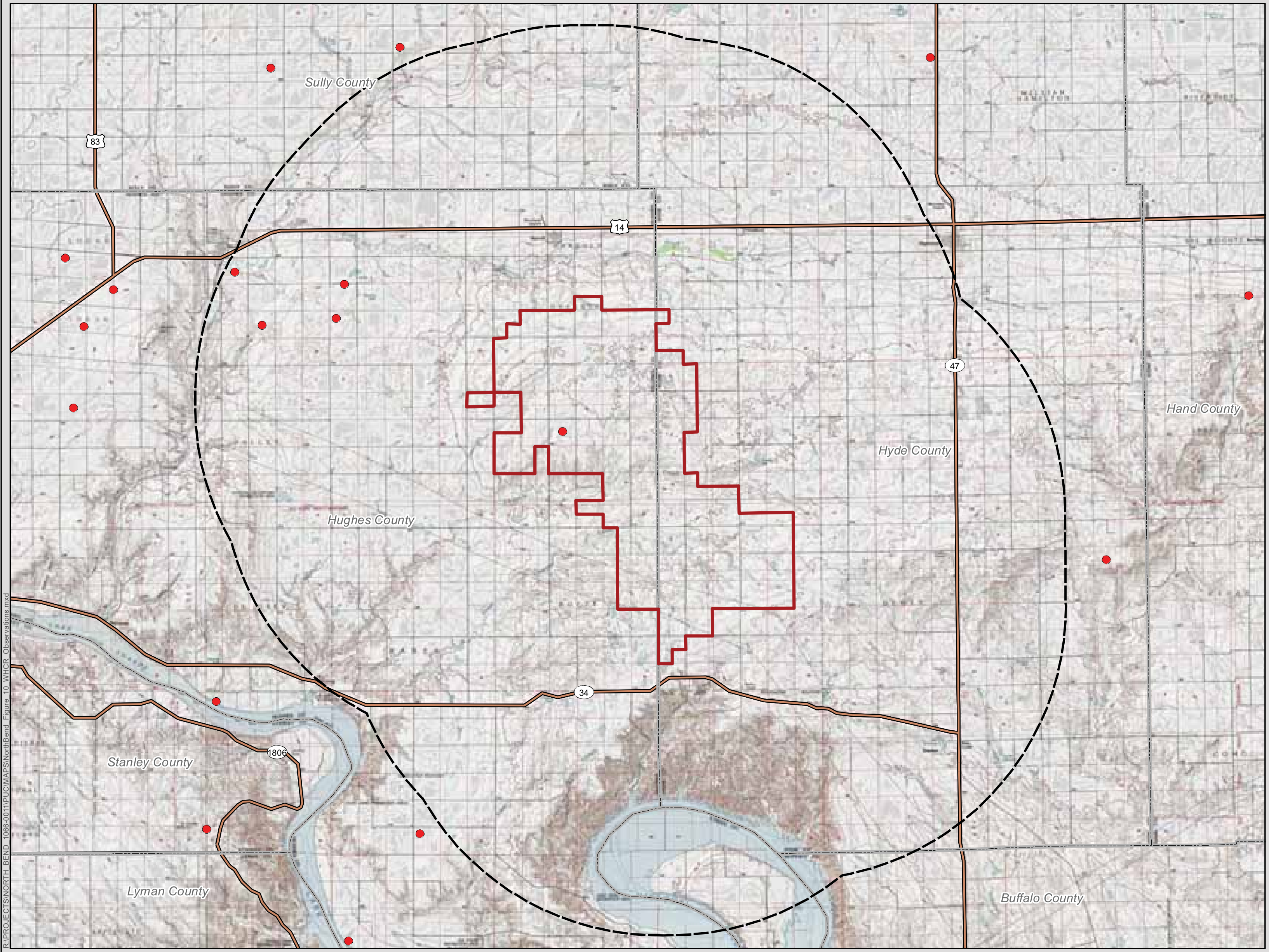

North Bend Wind Project

Figure 10
Incidental Whooping Crane Observations

Hughes and Hyde Counties, SD

- Project Area
- 10-mile Buffer
- Incidental Whooping Crane Observation
- Highway
- County Boundary

This document or presentation includes Whooping Crane migration use data from the Central Flyway stretching from Canada to Texas, collected, managed and owned by the U.S. Fish and Wildlife Service. Data were provided to Tetra Tech, Inc. as a courtesy for their use. The U.S. Fish and Wildlife Service has not directed, reviewed, or endorsed any aspect of the use of these data. Any and all data analyses, interpretations, and conclusions from these data are solely those of Tetra Tech, Inc.

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Michael Bollweg

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WHOOPING CRANES AND WIND DEVELOPMENT - AN ISSUE PAPER

By Regions 2 and 6, U. S. Fish and Wildlife Service

April 2009

Photo by Steve Sykes

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EXECUTIVE SUMMARY

Wind energy development is increasing in the United States. Much of the highest wind energy potential in the country occurs in the Great Plains region of the U.S. Fish and Wildlife Service's (USFWS, or Service) Regions 2 and 6, which include the U.S. portion of the endangered Aransas-Wood Buffalo Population (AWBP) whooping crane migration corridor in North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas. Ongoing and anticipated development of wind resources in the migration corridor of the AWBP is unprecedented and could place thousands more wind turbines, associated transmission lines, and other appurtenances in the Central Flyway path of the species in the coming decade.

The whooping crane is a species with a low reproductive rate and limited genetic material derived from the 15 whooping cranes that remained in the 1940s. Only 247 individuals occur in the current AWBP, the only wild self-sustaining population of the species. Although the species numbers are slowly increasing, they are far below the level required for recovery. A population viability analysis done in 2004 found that an additional 3% mortality, i.e., less than 8 individuals annually, would cause the species to undergo a decline, and preclude recovery.

Pursuant to Section 9 of the Endangered Species Act (ESA), it is unlawful for any person to take any federally-listed threatened or endangered fish or wildlife species, without special exemption. The ESA defines take as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct. Harm is further defined by USFWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). The risk of lethal take to whooping cranes from wind turbines is not known at this time, but it is acknowledged that the highest source of mortality to fledged cranes is from striking power lines. The best available information also indicates that whooping cranes may avoid stopover habitat that is developed with wind energy appurtenances, particularly turbines. This avoidance may deny them the use of important habitat, and thus may result in take in the form of harm by significant habitat modification.

As more wind energy facilities are built, including turbines, transmission lines, power stations, and roads, it is incumbent on the industry, Federal action agencies, and USFWS to provide the highest level of protection possible to whooping cranes, and to closely monitor the number of these birds killed and deterred from using preferred stopover locations. Wind energy companies with planned projects in the Great Plains should assess impacts, and if found likely to result in take of whooping cranes, projects without a Federal nexus should seek ESA compliance by applying for an incidental take permit through the section 10 permitting process. For projects with a Federal nexus, the Federal action agency would need to consult with the USFWS through the ESA Section 7 process for projects that may affect whooping cranes and must ensure that their activities will not jeopardize the continued existence of the species of adversely modify designated critical habitat.

Endangered Species Act compliance with USFWS on a project-by-project basis presents several problems: this approach does not provide for an efficient landscape-level analysis of impacts; it represents significant delays to the industry as projects are reviewed one-at-a-time by local Ecological Services field offices; it results in first-come first-served permitting without regard to a cohesive development strategy; and the cumulative amount of take anticipated would likely very quickly approach the maximum take that can be sustained by the population, leaving future projects with no prospects of receiving protection under Section 9 of the ESA. We believe that a more efficient approach, available through the habitat conservation planning process outlined in Section 10 of the ESA, is for the Service and industry to look collectively across the landscape at all existing, proposed, and reasonably foreseeable wind energy development, put in place adequate conservation measures, assess the cumulative impacts, and allocate take coverage that will not preclude recovery of the species. Section 10(a)(2)(A) of the ESA requires an applicant for an incidental take permit to submit a "conservation plan" that specifies, among other things, the impacts that are likely to result from the taking and the measures the permit applicant will undertake to minimize and mitigate such impacts. Conservation plans under the ESA have come to be known as "habitat conservation plans (HCP)." The HCP approach would help protect whooping cranes and would reduce the regulatory burden for both the wind industry and USFWS. This issue paper, prepared by USFWS Regions 2 and 6, provides a discussion of the status of the species, the threats posed by wind energy development, a description of options, and a recommendation to the industry to support the HCP approach.

INTRODUCTION

The USFWS supports the responsible development of renewable, sustainable energy sources, including wind energy. However, wind energy developments may present threats to wildlife and their habitats. Ongoing and anticipated development of wind resources in the migration corridor of the AWBP is unprecedented and could place thousands more wind turbines, associated transmission lines, and other appurtenances in the migratory path of the species in the coming decade. We recommend that potential impacts to whooping cranes be assessed and addressed cooperatively by the industry, the USFWS, and Federal action agencies.

Direct mortality of whooping cranes may occur as whooping cranes encounter turbines in bad weather or low light conditions at the beginning or end of migration flights, or when flying between roosts and foraging areas at stopover sites. However, this direct mortality due to collisions with turbines is expected to occur infrequently, because of low numbers of whooping cranes and their migration behavior. Currently, collisions with power lines are the greatest known source of mortality for fledged whooping cranes and have accounted for the death or serious injury of 46 whooping cranes since 1956 (Stehn and Wassenich 2008). In addition to direct impacts from power lines, the avoidance of stopover habitat by cranes, as well as the loss such habitat, due to the presence of turbines is a substantial indirect impact that is anticipated with the increase in wind energy development.

For wind energy development projects in the whooping crane migration corridor with a Federal nexus, the action agency will need to initiate section 7 consultation under the Endangered Species Act, as amended (ESA). A federal nexus is triggered when a federal ("action") agency provides funding, authorizes or carries out a program or project. Many wind energy projects do not have a Federal nexus; however; even in the absence of a Federal nexus, developers still need to avoid violating the take prohibitions contained in section 9 of the ESA, as well as the prohibitions in the Migratory Bird Treaty Act (MBTA) and Bald and Golden Eagle Protection Act (BGEPA). This issue paper is intended to:

1) Provide background information on whooping cranes, the threat posed by wind development in the whooping crane migration corridor, and opportunities to work with the wind industry.

2) Provide some options available to USFWS Regions 2 and 6, Federal action agencies, and the wind energy industry to avoid and minimize anticipated impacts of wind farm development and associated power line construction on whooping cranes.
3) Provide guidance to wind energy companies on compliance with the ESA.

STATUS OF WIND DEVELOPMENT IN THE WHOOPING CRANE MIGRATION CORRIDOR

Existing wind farms

The current level of existing wind energy development within the migration corridor of the AWBP is increasing. In Canada, the majority of wind farms being constructed in the prairie region appear to lie mostly outside of the migration corridor. The Service has not independently tabulated the number of wind farms operating, under construction, or proposed in the 7 states within the U.S. portion of the migration corridor (MT, ND, SD, NE, KS, OK, and TX). However, the Department of Energy, Western Area Power Administration figures indicate that approximately 2,433 known wind turbines have been constructed in the 1,400 mile whooping crane corridor in the United States (U.S.), with another 1,355 proposed for construction in the near to midterm future that will be connected to the federal power grid (Western Area Power Administration (WAPA), 2007). There are an additional substantial number of projects that would not be connected to the federal power grid and are not included in WAPA's database. The location of existing wind energy facilities is provided on a Department of Energy web page at http://www.eere.energy.gov/windandhydro/windpoweringamerica/wind_installed_capacity.asp.

Projected future wind energy development

Wind energy is the fastest growing form of energy development occurring in the United States today, and is an important component of a range of renewable energy resources, brought about by a new focus by the Federal and State governments on renewable energy and Federal government tax incentives through the provisions in the American Recovery and Reinvestment Act of 2009. Much of this development is currently occurring without Federal regulation as most projects to date are developed on private lands by private companies, without interconnections to federally owned transmission lines, Federal funding, or other Federal nexuses. Many states have developed, and, presumably more will develop, renewable energy portfolio standards requiring that certain proportions of energy generated or sold in their States be supplied by renewable forms of energy. Precise information on the number, size, and location of proposed wind farms and turbines is difficult to ascertain because wind energy companies are operating in a highly competitive market and avoid revealing their plans to competitors. Many wind energy developments implement a phased approach that is dependent on the performance of initial projects. The Service knows of several projects per state currently operating and multiple others under construction or in the planning stages. A large amount of project planning information is proprietary; however, the Service is aware of projects planned in the Central Flyway that consist of several thousand turbines. We cannot predict with accuracy how great an increase in wind turbine numbers to expect, but, depending on market forces, we anticipate several thousand new turbines and appurtenances in the whooping crane migration corridor in the next decade. Actual growth will become apparent as Federal action agencies and companies request review of their proposals under Federal wildlife protection laws.

The Great Plains states traversed by the whooping cranes during their fall and spring migrations are among the windiest states in the nation. The best places for wind energy development in these states overlap to a large extent the whooping crane migration corridor, and many of these areas provide attractive stopover sites. Thus, the potential for impacts to whooping cranes from future wind energy development is high. The Service, land owners, Federal regulatory and funding agencies, and the wind energy industry are responsible for ensuring that this new development occurs in a manner that is compatible with the recovery of the whooping crane.

STATUS OF THE WHOOPING CRANE POPULATION

The migratory AWBP is the only self-sustaining flock of whooping cranes remaining in the wild. These birds breed in the wetlands of Wood Buffalo National Park (WBNP) in Alberta and the Northwest Territories of northern Canada, and spend winters on the Texas coast at Aransas National Wildlife Refuge (Aransas NWR), Austwell, Texas, and surrounding areas.

Whooping cranes are currently listed as endangered except where two nonessential experimental populations exist in 18 eastern states adjoining or east of the Mississippi River, including the reintroduced population that migrates between Wisconsin and Florida (Figure 1) and a non-migrating population in Central Florida. In the United States, the whooping crane was listed as "threatened with extinction" in 1967 and as "endangered" in 1970. Both of these listings were grandfathered into ESA protection which established the U.S. Whooping Crane Recovery Team and facilitated further conservation actions on behalf of the species. In Canada, the whooping crane was designated as "endangered" in 1978 by the Committee on the Status of Endangered Wildlife in Canada and listed as endangered under the Canadian Species at Risk Act (SARA) in 2003 (Canadian Wildlife Service [CWS] and USFWS 2007). In the United States, critical habitat was designated in 1978 at five sites in four states that include portions of the Platte River in Nebraska; Cheyenne Bottoms State Waterfowl Management Area and Quivira National Wildlife Refuge, Kansas; Salt Plains National Wildlife Refuge, Oklahoma; and Aransas NWR and vicinity on the Texas coast. In Canada, critical habitat is pending. Proposed critical habitat areas in Canada consist of the nesting grounds in and adjacent to WBNP and migration staging and stopover areas in Saskatchewan (CWS and USFWS 2007).

Reasons for Listing and Current Threats

Growth of human populations in North America resulted in significant whooping crane habitat alteration and destruction. Historically, whooping cranes declined or disappeared as agriculture claimed the northern Great Plains of the United States and Canada (Allen 1952). Hundreds of whooping cranes were shot and, as the species became increasingly rare, eggs were collected and sold to collectors (Allen 1952). Declines also resulted from displacement by human activities and agricultural practices. The extensive drainage of wetlands in the prairie pothole region of Canada and the United States resulted in a tremendous loss of migration habitat available to whooping cranes (CWS and USFWS 2007). Original migration stopover habitat became unsuitable due to draining, fencing, sowing, and subsequent conversion of pothole and prairie wetlands to hay and grain production.

The International Whooping Crane Recovery Plan (CWS and USFWS 2007) lists the following as current threats and reasons for listing: human settlement/development, insufficient freshwater inflows, shooting, disturbance, disease, parasites, predation, food availability, sibling aggression, severe weather, loss of genetic diversity, climate change, red tide, chemical spills, collisions with power lines, fences, and other structures, collisions with aircraft and pesticides. Major current threats include limited genetics of the population with an estimated 66% of the genetic material lost during the decimation of the population, loss and degradation of migration stopover habitat, construction of additional power lines and communication towers, fences, degradation of coastal habitat, and threat of chemical spills in Texas. A spill from commercial vessels carrying dangerous, toxic chemicals that travel the Gulf Intracoastal Waterway daily through the heart of whooping crane winter habitat could contaminate or kill the cranes' food supply, or poison the cranes (Robertson et al. 1993). Another threat to the whooping crane is the decrease in the suitability of the species' winter habitat due to accelerating development within and adjacent to the designated critical habitat in Texas.

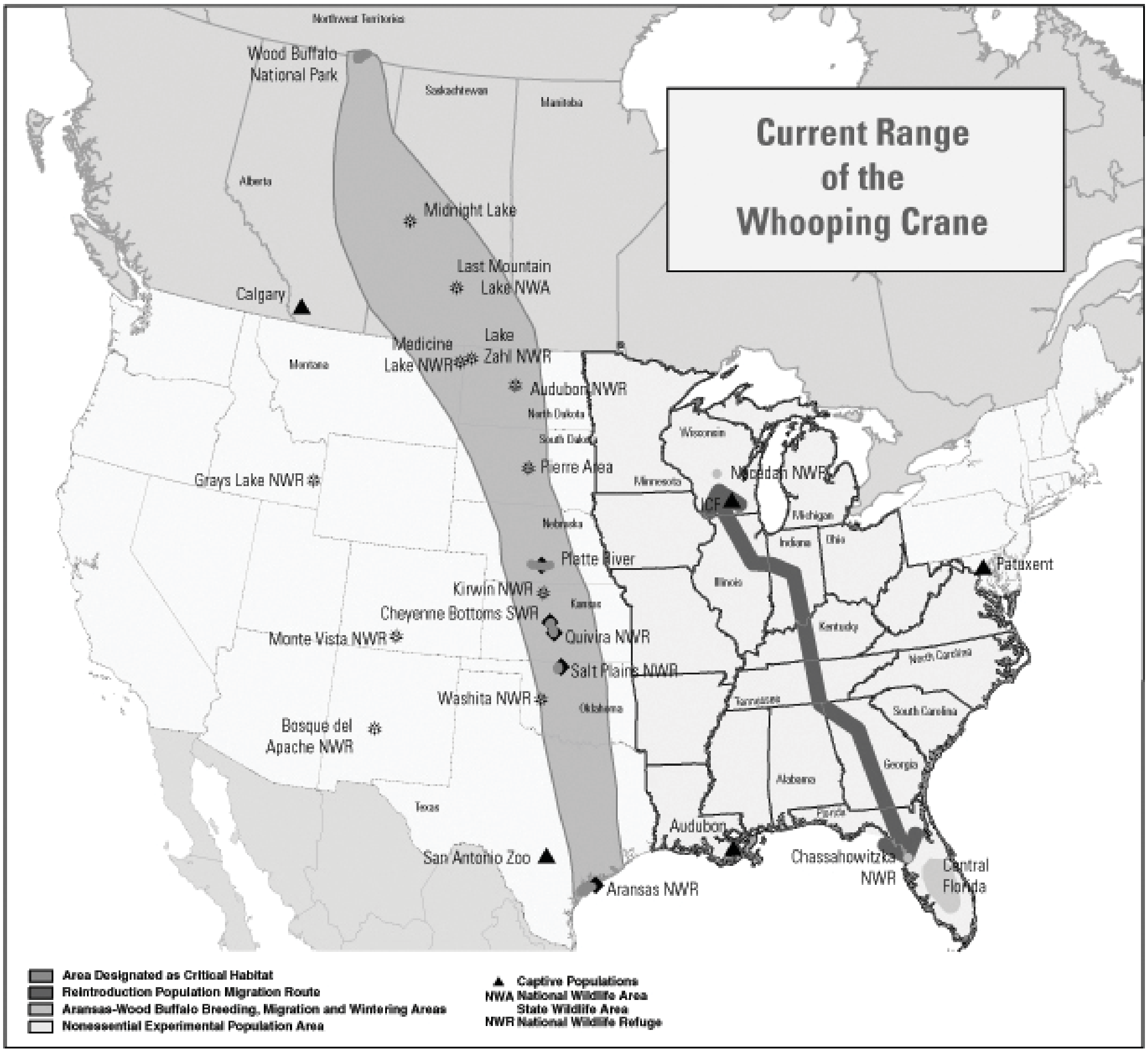

Figure 1 – Current Range of the Whooping Crane (Stehn and Wassenich 2008).

The threat of global climate change may adversely affect the water regime of WBNP, with potentially severe impacts on whooping crane reproduction (CWS and USFWS 2007). Permanently lowered water tables, for example, would shrink wetlands, reduce the availability of quality nesting sites, reduce invertebrate food availability, and allow predators to access nests and young. On the wintering area, a reduction in rainfall would reduce inflows and reduce the blue crab population that the cranes rely on for food. Sea level rise combined with land subsidence are projected to be about 17 inches on the Texas coast over the next 100 years (Twilley et al. 2001, as cited by CWS and USFWS 2007). This would reduce suitability of salt marsh and open water areas, making much of the present acreage too deep for use by whooping cranes (T. Stehn, USFWS, personal communication).

A catastrophic event could eliminate the wild, self-sustaining AWBP because this population has low numbers of individuals, slow reproductive potential, and limited genetic diversity. Therefore, the recovery strategy as stated in the International Recovery Plan includes protection and enhancement of the breeding, migration, and wintering habitat for the AWBP to allow the wild flock to grow and reach ecological and genetic stability. The numerical population (1,000 individuals) criterion for downlisting the species can only be achieved if threats to the species' existence are sufficiently reduced or removed (CWS and USFWS 2007).

Threats to whooping cranes have been alleviated to a degree sufficient to allow the AWBP to increase in size over a half century. Whooping cranes have responded positively to some conservation efforts. Marking of power lines to make them more visible, a technique shown to reduce sandhill crane collisions with power lines (Morkill 1990, Morkill and Anderson 1991, Brown and Drewien 1995), also helps reduce whooping crane mortality. Cooperative protection plans implemented by provincial, state, and Federal agencies are believed to have reduced losses due to shooting and disease (Lewis 1992). Forested riverine areas along the Platte River in Nebraska are being cleared to restore stopover habitat. Loss of critical winter habitat along the Gulf Intracoastal Water Way due to erosion has been reduced significantly through the use of concrete matting (Zang et al. 1993, Evans and Stehn 1997). Dredged material has been used to create winter habitat (Evans and Stehn 1997).

Current numbers

As of April 2009, the three populations of whooping cranes in the wild numbered 365 birds. Thirty whooping cranes form a non-migratory wild population in central Florida, and 88 whooping cranes form an eastern population that migrates between Wisconsin and Florida. The April, 2009 estimate for the size of the Aransas-Wood Buffalo flock is 247, down from 266 in November 2008 (T. Stehn, USFWS, personal communication). The AWBP is the only self-sustaining population of whooping cranes in the wild. Captive populations totaled 151 individuals at 11 facilities. Thus, as of April 2009, there were a total of 516 whooping cranes in North America.

Changes in population numbers

An estimated 10,000 whooping cranes were present in North America during pre-colonial times with the species ranging from the Canadian Arctic to Mexico and from the Rocky Mountains to the Atlantic Ocean (CWS and USFWS 2007). Numbers were reduced to less than 1,400 whooping cranes by the 1870s (Allen 1952). The species disappeared from the heart of its breeding range in the north-central United States by the 1890s. By the mid-1900s, only the small

AWBP population survived. Ironically, the steadfast use of a traditional summer area that appears to have saved the whooping crane as a small relict breeding population in WBNP prevents its voluntary return to what was once its principal nesting range in the prairies. Conversion of potholes and prairie to hay and grain production made much of the historic nesting habitat unsuitable for whooping cranes. The AWBP virtually reached the brink of extinction with just 15 birds left in the flock, including only 3 or 4 adult females, in 1941 (CWS and USFWS 2007). The continued existence of the species remained very much in doubt in the 1930s, 1940s and 1950s as the AWBP ranged between 15 and 33 individuals. With key conservation measures put in place, the population made a notable comeback after the 1950s. Key actions included the passage of the Migratory Bird Treaty Act in 1918 that gave the birds protection from shooting and egg collection, establishment of the Aransas National Wildlife Refuge in 1937 to conserve the wintering grounds, and discovery of the nesting area of AWBP in 1954 in the already existing Wood Buffalo National Park, Northwest Territories, Canada (CWS and USFWS 2007).

In the 1960s, numbers finally increased to a high for the decade of 56 in 1969. The flock first exceeded 100 individuals in 1986 and surpassed 200 individuals in 2004, a period of 18 years in which the population doubled (CWS and USFWS 2007).

The AWBP has a long-term recruitment rate of 13.9%, the highest of any North American crane population including sandhill cranes (Drewien et al. 1995). However, recruitment is lowered when the nesting grounds experience drought conditions. Annual mortality has averaged 9.4% in recent years (Reed 2004). Annual growth of the population during the past 65 years has averaged 4.5% per year. Population studies indicate there is a 10-year cycle in mortality/survival of unknown cause (Boyce and Miller 1985, Boyce 1987, Nedelman et al. 1987), though the crane cycle appears to correlate with population cycles of boreal forest predators (M. Boyce, U. of Calgary, personal communication). If new threats do not arise and habitat quality can be maintained, it is likely that the AWBP will continue to grow and maintain a low probability (<1.0%) of extinction over the next 100 years (Mirande et al. 1993, 1997).

Potential for population growth

The inherent capacity of whooping cranes to rebound demographically is low due to delayed sexual maturity (age 3-4 years) and a low reproductive rate (2 eggs in the annual nesting attempt with only 1 chick typically fledging). Furthermore, given the many threats to breeding, migration, and wintering habitat, it is unlikely the whooping crane will ever become abundant (CWS and USFWS 2007). Nevertheless, as nesting pairs gain experience they become more successful in rearing chicks, and since the species' is long-lived, if adult mortality is low and habitat conditions are favorable, continued population growth is likely (T. Stehn, USFWS, personal communication). Protection is needed for additional public and private land to accommodate an expanding crane population (CWS and USFWS 2007).

The sustained long-term growth of the whooping crane population, even at a relatively low level, has allowed the species to make a notable comeback. However, the current size of the AWBP at only 247 birds is still far from the targeted potential downlisting threshold of 1,000 individuals. Until this target is reached, the population will continue to lose genetic material with each generation, a critical factor for a species that already has lost two thirds of all genetic material during the 1941 population bottleneck. Substantial genetic variation is essential for population vitality and persistence. Thus, to increase chances for recovery, it is essential that the current rate of population growth be maintained.

Status of reintroduced populations

Recovery objectives call for the establishment of two additional self-sustaining populations of 100 individuals each in size within other parts of the historic range (CWS and USFWS 2007). Reintroductions began in 1975 and continue to the present. One of three reintroductions attempted, the Rocky Mountain population, has failed with all birds extirpated. The introduction of the non-migratory flock in Florida started in 1993 and the population is declining; mortality is too high and productivity too low for this population to have much of a chance of ever becoming self-sustaining (CWS and USFWS 2007). The eastern migratory population started in 2001 (which moves between Wisconsin and Florida) shows some promise, but early productivity has been disappointing and mortality is considerable (T. Stehn, USFWS, personal communication). Thus, it is imperative that all efforts continue to promote growth of the AWBP by reducing mortality, increasing productivity, and reducing threats to the population.

Effects of increased mortality on whooping crane recovery

According to the most recent population viability analysis done for the AWBP, the population would show a significant drop in probability of persistence (i.e. probability of species survival) if a 3% increase in absolute mortality were to occur (Reed 2004). At the current flock size of 247, 3% mortality equates to less than 8 birds annually. An annual loss of 8 birds added to the current mortality rate from existing sources would cause the AWBP to become a nonviable population with a probability of persistence (200 years into the future) predicted to be 86% (Reed 2004). A viable population is defined as having a ≥95% probability of persisting 200 years (Reed 2004). It should be noted that mortality of any birds in such a small population also represents a loss of genetic material and a setback for recovery efforts. For the species to survive, any increased mortality due to collisions with new obstructions in the migration corridor, including wind turbines, towers and new power lines, must be kept extremely low.

BIOLOGY OF WHOOPING CRANES IN MIGRATION

Location of the migration corridor

The AWBP whooping cranes migrate more than 2,400 miles twice annually between wintering and breeding grounds. Fall and spring migrations for the AWBP follow the same general path each year (Howe 1989, Kuyt 1992). The migration corridor basically follows a straight line, with the cranes traveling through Alberta, Saskatchewan, extreme eastern Montana, North Dakota, South Dakota, Nebraska, Kansas, Oklahoma and Texas (Figure 1). The primary migration corridor can be over 200 miles wide as cranes are pushed east or west by unfavorable winds, and occasionally cranes have been documented in Minnesota, Iowa, and Illinois.

Migratory behavior

As spring approaches, "dancing" behavior (running, leaping and bowing, unison calling, and flying) increases in frequency, and is indicative of pre-migratory restlessness (Allen 1952, Blankinship 1976, Stehn 1992a). Whooping cranes depart Aransas NWR generally between

March 25 and April 15, with the last birds usually leaving by May 1. Occasional stragglers may linger and not depart until mid-May. The spring migration is usually completed in 2-4 weeks, more rapidly than the reverse trip in the fall, as there is no known spring staging area.

Autumn migration normally begins in mid-September, with most birds arriving on the wintering grounds between late October and mid-November. Occasional stragglers may not arrive until late December. Whooping cranes are diurnal migrants and make regular stops to feed and rest. They generally migrate in groups of 1-5 birds (Johns 1992). Large groups of up to 30 sometimes use the same stopover location and may start a migration flight together. Figure 2 delineates the migration corridor as determined by confirmed sightings (Stephen 1979, Johnson and Temple 1980, Austin and Richert 2001, Tacha et al., USFWS, unpublished data) and radio-tracking whooping cranes during the period 1981-1984 (Kuyt 1992). The crane's first stop often occurs in northeast Alberta or northwest Saskatchewan, about 500 km southeast of their departure area in WBNP. Local weather conditions influence distance and direction of travel, but whooping cranes generally are capable of reaching the autumn staging grounds in the north-central portion of the Saskatchewan agricultural area on the second day of migration. Most of the cranes remain for 2 to 4 weeks in the large triangle between Regina, Swift Current, and Meadow Lake, where they feed on waste grain in barley and wheat stubble fields and roost in the many wetlands (Johns 1992). The remainder of the migration from Saskatchewan to the wintering grounds is usually rapid, probably weather-induced, and may be completed in as little as a week (Kuyt 1992).

Daily flights, timing, and distance covered

Whooping cranes spend approximately 3 months annually in migration. They can travel between 200-400 miles a day, attain an altitude of 6,200 feet, and can glide downward at up to 62 mph. Whooping cranes migrate primarily during daylight hours between about 0930 and 1700 hours, making soaring and gliding flights while taking advantage of favorable tailwinds and thermal currents to aid their flight. When conditions become unfavorable due to cessation of thermals late in the day or a wind shift, the cranes may start flap-flying for a short period, but soon tire and will look for suitable wetland habitat nearby. Although whooping cranes usually migrate during daylight hours, they will occasionally fly during periods of darkness. They stop nightly to roost in shallow wetlands and may fly out from wetlands during the day to feed in agricultural fields. If weather is unfavorable for migration, the cranes will stay in place for multiple days until conditions improve.

Whooping cranes in migration are most vulnerable to collisions with structures early in the morning or late in the day when light levels are diminished as they fly at low altitudes between roost and foraging sites. Although whooping crane migration flights are generally at altitudes of between 1,000 and 6,000 feet above the ground, whooping cranes fly at low altitudes when starting or ending a migration flight, especially when thermal currents are minimal or for brief periods during mid-day to drink and/or feed.

Habitats used in migration

Whooping cranes use a variety of habitats during migration (Howe 1987, 1989, Lingle 1987, Lingle et al. 1991, Johns et al. 1997), primarily croplands, and wetlands, including palustrine (marshy) wetlands. In the U. S., 75% of roost wetlands were less than 10 acres in size with 40% less than 1.24 acres. Roosting wetlands were generally located within 0.62 mile of feeding sites

(Howe 1987, 1989).

Clusters of migratory observations suggested that whooping cranes in Nebraska select roost habitat by recognizing local and larger-scale land cover composition (Richert et al. 1999, Richert and Church 2001). Habitat selection was influenced by social group, season, and landscape pattern (Richert 1999). Areas characterized by wetland mosaics appear to provide the most suitable stopover habitat (Johns et al. 1997, Richert et al. in press). In states and provinces, excluding Nebraska, whooping cranes primarily used shallow, seasonally and semi-permanently flooded palustrine wetlands for roosting, and various cropland and emergent wetlands for feeding (Johns et al. 1997, Austin and Richert 2001).

During migration, whooping cranes are often recorded in riverine habitats, especially in Nebraska. Cranes can roost on submerged sandbars in wide, unobstructed channels that are isolated from human disturbance (Armbruster 1990).

Migration Habitat Management and Research

Suitable stopover habitat is necessary for whooping cranes to complete their migration in good condition. There has been considerable alteration and destruction of natural wetlands, rivers, and streams, some of which served as potential roosting and feeding sites for migrating cranes. There may be additional areas along the migration route that need to be delineated and protected.

The availability of suitable migration stopover habitat within the AWBP migration pathway within the United States has been analyzed (Stahlecker 1988, 1992, 1997a, 1997b). National Wetland Inventory (NWI) maps, used in conjunction with aerial photo maps and suitability criteria (Armbruster 1990), are poor predictors (33% correct) of suitable roosts in Oklahoma, but good predictors (97% correct) of unsuitability (Stahlecker 1992). NWI map review in Nebraska is a good predictor of both suitability (63% correct) and unsuitability (73% correct). Wetlands suitable for overnight roost sites for migrating whooping cranes are available throughout the migration corridor in the Dakotas and Nebraska (Stahlecker 1997a, 1997b), but may be limited in Oklahoma (Stahlecker 1992). Suitable stopover habitat in the prairie pothole region of the Dakotas and eastern Montana does not appear to be limited at the present time, but as additional construction of wind power facilities, and other development activities occur in this area, this habitat, or the use of it, will be diminished. Similar sampling to evaluate roost availability in Kansas and Texas should be conducted.

Stopover Locations

Whooping cranes use migration stopover habitat opportunistically and may not use the same stopovers annually. Whooping cranes often stop wherever they happen to be late in the day when they find conditions no longer suitable for migration. This tendency can make for a very unpredictable pattern of stopover use, depending on daily weather conditions. It is not unusual to have a few cranes stopping at a small wetland or farm pond for a night at a location that they may never use again. Thus, a particular wetland pond might have whooping cranes using it just once a decade or even less. However, some areas are used by at least some whooping cranes on a regular basis, and would be considered traditional stopover sites. Some of these traditional stopover sites have been designated as critical habitat. These areas are located mostly where migration stopover habitat is in limited quantity and cranes make an effort to navigate directly to specific sites. Such areas include Salt Plains NWR in Oklahoma and Quivira NWR in Kansas.

However, in any given migration, whooping crane groups may be too far east or west of these "traditional" stopover sites, or may have favorable migration conditions when approaching such a site and not stop.

MIGRATION CORRIDOR DATABASE

Data collection - 1975 to the present

A Federal/State organized effort to report data on whooping cranes sighted in migration (Lewis 1992) was organized in 1975 and continues to the present time   Sightings are obtained opportunistically, often from public reports, with efforts made by biologists to confirm validity of all sightings. Sightings are placed into one of three categories (confirmed, probably, and not likely) based on program criteria. A confirmed sighting requires that an observation be made by a trained biologist or individual with similar bird identification skills. The data set includes 1,942 confirmed sightings made over 32+ years and incorporates data from 9 radio-telemetered whooping cranes followed in migration from 1981 to1985. These data were analyzed by Austin and Richert (2001) and then updated in 2007 and placed in GIS format (Tacha et al. USFWS, unpublished data).

Distribution of sightings in the migration corridor

The whooping crane migration corridor is essentially a straight line from west central Canada to Texas. However, the cranes are often blown east or west by strong winds that can carry them a considerable distance off the centerline of the migration corridor. This enlarges the corridor, expanding it to more than 200 miles in width. Excluding 36 outlying sightings, the percent of sightings through Spring 2007 occurring within the migration corridor are:

Location	% sightings	Comment
a) within 40 miles of centerline	75.1%	greatest chance of whooping crane stopovers
b) from 40-110 miles from centerline	19.7%	moderate chance of whooping crane stopovers
c) greater than 110 miles from center	5.2%	low chance of whooping crane stopovers
	100.0%	

Limitations and biases of the data set and what a single sighting point represents

Although the location of the migration corridor has been defined based on sighting data, it is very important to interpret this data set correctly. Movements of individuals are not completely known and are highly variable over both time and space. The migration corridor map is biased by heavy observation effort made at known migration stopovers. For example, the work of one volunteer at Salt Plains NWR accounts for 62% of all sightings reported from Oklahoma in the last 5 years. In contrast, whooping cranes stopping opportunistically in sparsely settled country may rarely be reported by a qualified individual.

Most whooping cranes complete their migration without being reported. Based on the 5 migrations between Spring, 2005 and Spring, 2007, reports were obtained for an estimated 4% of all stopovers (T. Stehn, USFWS, Austwell, TX, unpublished data). Every whooping crane makes approximately 7-9 stopovers in the U.S. during each migration (Kuyt 1992). Sometimes multiple roost sites are used at a given stopover. With current whooping crane numbers and an average group size of 3, an estimated 1,419 whooping crane group stopovers occur in the U.S. annually (T. Stehn, USFWS, unpublished data). Thus, the accumulated data set (n=1,942 through Fall 2007) represents only a small fraction of the actual stopovers and is thus vulnerable to the biases described above and to potential misinterpretation. Despite these limitations, the whooping crane migration database represents the best information currently available regarding whooping crane distribution during migration.

A low number or even lack of verified sightings at a particular location or county should not be construed as demonstration of a lack of use of that location by whooping cranes. Because so few migration stopovers are documented, one known whooping crane stopover in a county or at a particular location indicates the presence of suitable habitat, and may represent substantial use of the area by whooping cranes. It is important to understand that the lack of data from a particular location does not mean that whooping cranes do not ever stop there. It just means they have never been reported from that area by a qualified observer. Known stopovers in locations to the north and south of a given location also provide a strong indication that the site is within the whooping crane migration corridor, even if no sightings have been documented for that location. In addition, use of a location in the migration corridor by sandhill cranes can be a strong indicator of the presence of suitable habitat and potential use of the area by whooping cranes. Whooping cranes will often select a stopover site where sandhill cranes are already present.

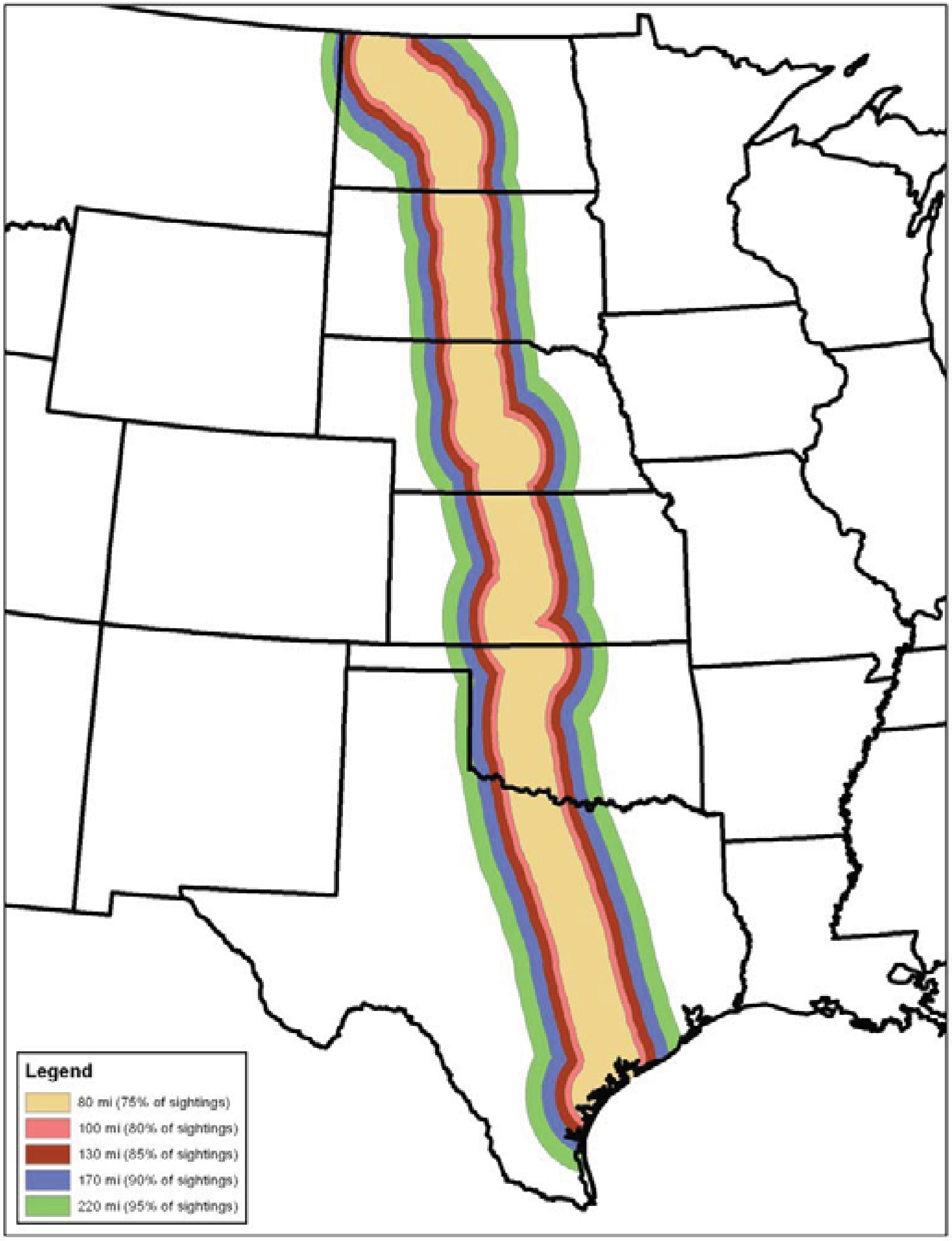

Figure 2. Ninety-five percent whooping crane migration corridor based on 1,858 confirmed sightings through Spring 2007 (Tacha et al., 2008. USFWS, unpublished data).

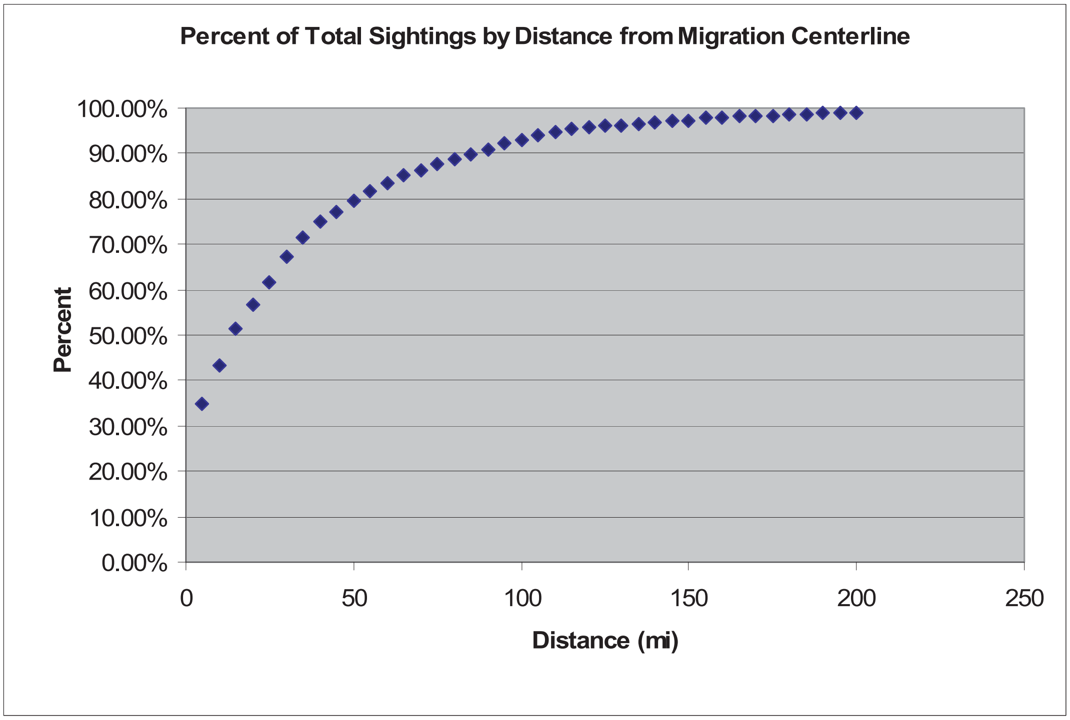

Figure 3. Distribution of points in the whooping crane migration corridor data base (Tacha et al., 2008. USFWS, unpublished data).

Whooping crane mortality in migration

Sixty to 80% of losses of fledged whooping cranes occur during migration (Lewis et al. 1992), a period comprising only about nine weeks (17%) of the bird's year, but losses are high because cranes are exposed to new hazards as they travel through unfamiliar environments (Lewis et al. 1992). Aerial surveys in WBNP indicate that summer losses are infrequent (B. Johns, CWS, personal communication). Only about 15% of the annual losses occur during the 5 to 6 months the cranes spent on the wintering grounds (Lewis et al. 1992). Mortality during April through November is five times greater than mortality during winter.

Few carcasses are ever found, thus information on causes of mortality is based on an extremely small sample size. The principal known cause of loss during migration is collision with utility lines (Lewis et al. 1992). Other known causes of mortality are shooting, other collisions or trauma, avian tuberculosis, and viral infections (Lewis et al. 1992).

Whooping crane collisions with power lines

Human settlement in the prairies brought rural electrification and the fencing of open lands. Currently, the number of power lines, communication towers, and wind turbines is increasing in the U.S. and may kill as many as 225 million birds annually (Manville 2005).

Collisions with power lines are a substantial cause of whooping crane mortality in migration (Brown et al. 1987, Lewis et al. 1992). Collisions with power lines have been responsible for the death or serious injury of at least 46 whooping cranes since 1956. In the 1980s, 2 of 9 radio-marked whooping cranes from AWBP died within the first 18 months of life as a result of power line collisions (Kuyt 1992). Of 27 documented mortalities in the Rocky Mountain experimental population, almost two thirds were due to collisions with power lines (40%) and wire fences (22%) (Brown et al. 1987). Twenty-one individuals within the Florida populations and three individuals in the migratory Wisconsin population have died from collisions with power lines (USFWS, unpublished data).

Currently, an estimated 804,500 km of bulk transmission lines and millions of km of distribution lines exist in the United States (Manville 2005). The number of miles of overhead lines in the central states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas as of 2007 is estimated at 77, 571 miles (Western Area Power Administration, 2007). With an increase in demand for additional transmission, many new power lines are being constructed or are proposed. Whooping cranes can collide with both types of lines (Stehn and Wassenich, 2008). Additional power line construction throughout the principal migration corridor will increase the potential for collision mortalities.

The Avian Power Line Interaction Committee (APLIC), composed of 9 investor-owned electric utilities and USFWS, was established in 1989 to address the issue of whooping crane collisions (Lewis 1997). In 1994, APLIC provided voluntary guidelines to the industry on avoiding power line strikes by migratory birds (APLIC 1994) with additional information on bird electrocutions (APLIC 2006). Tests of power line marking devices using sandhill cranes as surrogate research species have identified techniques effective in reducing collisions by up to 61% (Morkill 1990, Morkill and Anderson 1991, 1993, Brown and Drewien 1995). Techniques recommended include marking lines in areas frequently used by cranes and avoiding placement of new line corridors near wetlands or other crane use areas. Avian protection plan guidelines were put out jointly by the Edison Electric Institute's APLIC and USFWS (2005).

The American Recovery and Reinvestment Act (ARRA) of 2009 created significant provisions to benefit renewable energy. In addition to providing numerous incentives to wind energy developers and manufacturers such as tax credits, bonds, and loan programs, the ARRA also provided $11 billion for transmission activities and modernizing the electric grid. For example, the Western Area Power Administration (WAPA) was given spending authority for $3.25 billion of the ARRA funds. For the first time WAPA has the authority to construct transmission solely for the delivery of power generated from renewable energy. WAPA markets and delivers energy in a 15-state region including the upper Great Plains region which encompasses Montana, North Dakota, South Dakota, and Nebraska. The ARRA makes it highly possible that thousands to tens of thousands of new wind turbines and associated power lines and other appurtenances could be constructed in the whooping crane migration corridor in the coming years. This development and operation of facilities has the potential to cause significant additional mortality to whooping cranes. Cranes could be killed by wind turbines or power lines associated with wind farm development, and they could avoid using otherwise suitable habitat that is overlain with wind farms. Management and research are needed to reduce this new threat (CWS and USFWS 2007).

ANTICIPATED IMPACTS TO WHOOPING CRANES FROM TURBINES AND POWER LINES

Direct Impacts

Direct mortality of whooping cranes from wind energy development would reduce the size of the AWBP and could subsequently reduce the level of genetic variability within the flock. Removal of individuals from the flock would have a direct impact on the ability of the population to increase and reach downlisting targets. Whether the impact is at a level that precludes recovery depends on the number of individuals lost and the frequency at which they are lost. It should be noted, however, that mortality of any birds in such a small population as the AWBP of whooping cranes does represent a loss of genetic material and a setback for recovery efforts.

Wind farms, and the overhead transmission lines typically associated with them, represent increased structural hazards to this species. It is known that whooping crane collisions with power lines is a major threat to the species and that birds, including large birds, are killed by wind turbines. For any wind energy development project in the whooping crane migration corridor, an assessment needs to be made for potential whooping cranes use of the area to analyze risk.

Of direct concern is the potential for mortality via collision of whooping cranes with wind turbine blades. Because wind development is a fairly new, albeit rapidly increasing type of development in crane habitat, data on impacts of the wind industry to cranes has not been compiled or reported. Collision mortality with wind turbines has not been documented for whooping cranes or sandhill cranes. A research project involving observations of sandhill cranes in Wisconsin was initiated in spring 2009. Currently the study is funded for one year.The wind farms at the study site became operational in 2008. Information on sandhill cranes is relevant because they are considered a surrogate species for whooping crane behavior and habitat use in migration. This is important because with low whooping crane numbers limiting sample size, sandhill cranes can be used as an indicator of potential presence of whooping cranes.

Based on the known threat of wind turbines to other migratory birds, and to their large body size and low maneuverability, it is reasonable to expect that whooping cranes could be killed by turbine blades, given the number of existing and proposed wind turbines within the AWBP migration corridor. Whooping cranes may encounter turbines as they initiate or conclude a migration flight, a period when they sometimes fly for several miles at very low altitude due to a lack of thermal updrafts. Also, direct mortality might occur when whooping cranes occasionally fly at night or fly when visibility is limited by bad weather. Although whooping cranes generally migrate above the height of wind turbines, the cranes stop daily for food and for roosting at night. They will often make low flights of up to 2 miles from a roost site to forage late in the day or first thing in the morning. When the weather is unfavorable for migration, whooping cranes may remain at a stopover site for a few days to a few weeks. Their potential vulnerability to wind turbines is mostly associated with use at stopover locations. Crane biologists expect, except in these specific circumstances, that whooping cranes will see wind turbines and stay clear. However, cranes in close proximity to turbines may not be able to maneuver quickly enough to avoid turning blades. Thus, unless the whooping cranes recognize and steer clear of turbines, any crane use occurring within an estimated 2-5 miles of a wind turbine might result in mortality as they make local flights or start or end migration flights.

Direct mortality of whooping cranes by wind turbines is, at the present time, expected to be low, given the small number of whooping cranes in the AWBP flock migrating across the United States in spring and fall, and given that there are currently relatively few operational wind farms in the migration corridor. The Service is concerned that the risk of mortality will increase as more and more turbines are constructed.

The construction of power lines associated with wind farms is another concern for whooping crane survival during migration. As stated previously, power lines are the greatest known cause of mortality of fledged whooping cranes. Whooping cranes collide with power lines simply because they do not see them and/or can't maneuver quickly enough to avoid them. The small static wire that is usually situated above the other lines is especially hazardous to cranes, as well as other birds. The proximity of power lines to locations where birds are landing and taking off is critical (Lee 1978, Thompson 1978, Faanes 1987). No sandhill crane or waterfowl collisions were observed where distances from power lines to bird use areas exceeded 1 mile (Brown et al. 1984, 1987).

Wind farm impacts to whooping cranes should consider both the on-site power lines and any new transmission lines constructed to transport the produced electricity. USFWS recommends that all power lines on wind farms be placed underground. New transmission lines that cannot be buried and lie anywhere in the approximate 200-mile wide whooping crane migration corridor should be marked according to USFWS recommendations described in *APLIC 1994.* Although marking lines is expected to reduce collision mortality for cranes and other large birds between 53-89%, some whooping crane mortality is likely to occur on marked lines.

Indirect Impacts

Although most issues concerning wildlife and wind energy development initially focused on the direct effects of mortality from wildlife collisions with turbines and their associated infrastructure (power lines, guy wires, substation buildings, etc.), such collisions are no longer the sole focus of concern. The primary indirect effect of concern is complete avoidance by whooping cranes of stopover habitat. Also of concern are indirect effects caused by habitat fragmentation, loss of stopover habitat, and disruption of life cycles due to behavioral tendencies of many wildlife species to avoid vertical structures, including wind turbines.

Although the reaction of whooping cranes to wind turbines on the landscape is not fully known, the primary indirect effect of wind farm development may be that whooping cranes avoid wind turbines and do not use otherwise suitable stopover habitat located in wind farm areas. More research in this area is needed. A one-year funded study to be conducted in 2009-2010 at Horicon NWR in Wisconsin should provide additional information on how sandhill cranes react to turbines. Wind energy development could cause whooping cranes in the AWBP to avoid otherwise suitable habitat, forcing the birds to search for alternate stopover areas. However, any avoidance behavior is likely to be local and not alter the overall migration corridor of these birds. To measure the amount of habitat potentially removed from use by whooping cranes, it is recommended that wind energy developers calculate how many wetland acres are within the footprint of habitat overlain with turbines.

Removal of stopover habitat could result in increased mortality to the species if cranes are forced to use suboptimal habitat or fly farther to find stopover habitat away from a wind farm. This would lengthen the migration and take extra energy. Flying greater distances under low-light conditions could expose the cranes to additional dangers (hunting, power line collisions, etc.) as they search for stopover habitat. The cranes may be forced to use stopover habitat that is less suitable and thus be more subject to predation, disease, or human disturbance, all of which could increase mortality.

Loss of migration stopover habitat is a growing concern regarding the AWBP of whooping cranes (CWS and USFWS 2007). If significant loss in quality or quantity of stopover habitats were to occur, it would likely negatively affect the physical condition of migrating birds, which in turn would impact their likelihood of surviving migration, the reproductive rates on the breeding grounds, and overwinter survival. Any future population viability analyses for the whooping crane must address the importance of stopover habitat for this species (Reed 2004).

COMPLIANCE WITH THE ESA

Pursuant to section 9 of the ESA, it is unlawful for any person to take any federally-listed threatened or endangered fish or wildlife species, without special exemption. The ESA defines take as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or to attempt to engage in any such conduct. Harm is further defined by USFWS to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering (50 CFR 17.3). If whooping cranes avoid turbines, construction of wind farms could deny stopover habitat from the species, resulting in harm from habitat modification; such harm could result in take (defined in 50 CFR 17.3).

Take incidental to a lawful activity may be handled through formal consultation under section 7(a)(2), if a Federal agency action, funding, or permit is involved. Otherwise, an incidental take permit (ITP) pursuant to section 10(a)(1)(B) may be obtained upon completion of a satisfactory habitat conservation plan (HCP).

ESA compliance – activities with a Federal nexus

If a project has a Federal nexus (i.e. is carried out, funded, licensed or permitted by a Federal agency) and is in the whooping crane migration corridor with whooping crane stopover habitat located on or near the project, it will require consultation with the Service under section 7 of ESA. Wind energy projects on USFWS grassland or wetland easements, projects funded by the USDA, Rural Utilities Service, Department of Energy, or projects requiring Federal permits associated with construction of transmission lines and connection to the Federal power grid via interconnection agreements with the Department of Energy are examples of a Federal nexus.

ESA compliance – activities without a Federal nexus

If a project has no Federal nexus to trigger section 7 consultation under the ESA, but is in the whooping crane migration corridor and has the potential to either directly take whooping cranes or indirectly take stopover habitat, then the company still must ensure that its actions do not result in a violation of section 9 of the ESA. In the 1982 amendments to the ESA, Congress established a provision in Section 10 that allows for "incidental take" of endangered and threatened species of wildlife by non-federal entities. Incidental take is defined by the ESA as take that is "incidental to, and not the purpose of, the carrying out of otherwise lawful activity." The "incidental take permit" process was established under Section 10(a)(1)(B) of the ESA.

Section 10(a)(2)(A) of the ESA requires an applicant for an incidental take permit to submit a conservation plan that specifies, among other things, the impacts that are likely to result from the taking and the measures the permit applicant will undertake to minimize and mitigate such impacts. Conservation plans under ESA have come to be known as HCPs. As stated previously, with only 247 whooping cranes currently in the AWBP, the population cannot sustain much additional mortality from any source, including wind energy development. Therefore, for those activities that are likely to result in adverse impacts to the whooping crane, it would be necessary for project proponents to provide measures that will offset those impacts. The most effective way to deal with the provision of offsetting measures is on a programmatic basis, through programmatic HCP's where there is no federal nexus, and through programmatic NEPA and Section 7 consultations where a federal nexus exists.

RECOMMENDATIONS

Recommendations to minimize "take" of migratory birds

1. Implement USFWS's voluntary *Interim Guidance on Avoiding and Minimizing Impacts to Wildlife from Wind Turbines* available at <www.fws.gov/habitatconservation/wind.htm>, as they are intended to assist proposed wind energy projects in avoiding and minimizing impacts to wildlife and habitats. Additional information from USFWS efforts to address wind energy can be located at <http://www.fws.gov/ southwest/migratorybirds/windpower.html>.

2. If wind turbines are not already engineered to prevent perching by avian predators, anti-perching devices should be installed on each turbine. Tubular tower designs that eliminate perching sites on towers should be used. Do not use lattice towers as these attract birds to perch on the towers. Avoid use of guy wires to support towers, as birds are more likely to strike guy wires during migration. If guy wires must be used, ensure adequate high visibility marking to reduce the likelihood of collisions. Eliminate all structures on turbines and towers where birds may perch. Rounded and sloped surfaces that are too large in circumference for birds to grasp or too angled for birds to perch on are best.

3. Bury all electrical lines underground to the maximum extent possible, especially on the wind farm site. When it is not feasible to bury power lines, construct power lines in a manner consistent with guidance in the Avian Power Line Interaction Committee's (APLIC; <www.aplic.org>) *Suggested Practices for Avian Protection on Power Lines: The State of the Art in 2006*. This includes increasing the visibility of overhead transmission lines by using line marking devices, including aerial marker spheres, swinging plates, spiral vibration dampers, and bird flight diverters. For guidance on markers, see APLIC (1994). Additionally, The Edison Electric Institute's APLIC and USFWS's joint publication titled, *Avian Protection Plan Guidelines*, provides another toolbox for selecting and tailoring avoidance and minimization components applicable to specific projects. A copy of this document maybe obtained from the APLIC website at <http://www.aplic.org/>.

4. Use the minimum amount of pilot warning and obstruction avoidance lighting required by the Federal Aviation Administration (FAA). The FAA typically requires lights for aviation safety on all structures over 199 feet above ground level, which includes most modern wind turbines. Unless otherwise required by the FAA, only white (preferable) or red strobe lights should be used at night, and these should be the minimum number, minimum intensity, and minimum number of flashes per minute (longest duration between flashes) allowable by the FAA. The use of solid red or pulsating red warning lights at night should be avoided. Current research indicates that solid or pulsating (beacon) red lights attract nocturnally-migrating birds at much higher rates than white strobe lights. For most wind energy facilities, the close proximity and the great number of wind turbines at a facility precludes the need for all turbines to be lighted. The FAA has been willing in the past to negotiate with wind power developers to find a sensible

compromise on the percentage of turbines that require aviation safety lighting and on the color, intensity, and pulse rate of lights required.

Recommendations to avoid and minimize "take" of whooping cranes and mitigate unavoidable impacts

Location of wind farms

Wind farms should not be built near traditional whooping crane stopover locations, and should be placed as far away from the centerline of the whooping crane migration corridor as feasible. Wind farms should not be constructed in areas within a wetland mosaic suitable for whooping cranes to use. Individual turbines should be placed as far away from wetlands as possible.

USFWS encourages wind energy companies to use the National Wetland Inventory maps in conjunction with ground truthing to identify wetlands occurring within the proposed project area at 0.5-mile and 5-mile radii from the project site. Steps should be taken in determining the final location, extent, construction, and operation of project features to avoid any wetland impacts or loss, and mitigate any unavoidable wetland impacts. USFWS's NWI provides a Wetlands Digital Data and Mapping website, <http://wetlandsfws.er.usgs.gov/>, which contains all currently available electronic versions of the NWI maps. While coverage is not complete, it is being updated as progress is made on digitizing hard copy maps (K. Frazier, USFWS, Tulsa, Oklahoma, letter to HDR Engineering, November 17, 2007).

Construction and/or maintenance activities should be stopped if whooping cranes are observed on-site and birds should be left undisturbed until they leave the area as per the *Aransas-Wood Buffalo Population Whooping Crane Contingency Plan* (U.S. Fish and Wildlife Service 2006).

Turbine shutdown

If a whooping crane were to be killed by a wind turbine, USFWS could request that the wind farm cease operations during all or portions of the spring and fall whooping crane migration periods. These migration periods are prolonged, lasting 2 months in the fall and about 6 weeks in the spring. Companies should factor in the scenario of a possible required cessation of operations when selecting a wind farm site. As a general guideline, until more is learned about crane response to turbines, the USFWS recommends that operation of turbines be temporarily ceased immediately within 2 miles of the known presence of a whooping crane. Upon learning of the presence of a whooping crane, the sighting should be immediately reported to the nearest USFWS Ecological Services Field Office and the *Aransas-Wood Buffalo Population Whooping Crane Contingency Plan* (Contingency Plan) implemented. Wind farm employees are asked to work closely with the Ecological Services Field Office, as well as the USFWS whooping crane coordinator (Tom Stehn, (361) 286-3559, ext. 221, tom_stehn@fws.gov) and/or the USFWS lead for the Contingency Plan, Martha Tacha, (308) 382-6468, ext. 19, martha_tacha@fws.gov). As per Contingency Plan guidelines for a crane in a hazardous situation, the bird should be monitored during daylight hours by wind farm personnel. Once the daily movements of the whooping cranes are determined, it may be possible to re-start some nearby turbines, especially if the local movements of the cranes avoid the wind turbines and the weather is not expected to allow for resumption of a migration flight.

USFWS believes the measures listed below are necessary and appropriate to adequately mitigate impacts to the AWBP.

1. For every acre of habitat lost to the construction of wind turbines, (*i.e.*, the actual foot print of the wind farm), USFWS recommends that provisions be made for habitat mitigation following USFWS's *Mitigation Policy* (Federal Register V.46, No. 15, January 23, 1981).

2. In addition, our current best estimate is that whooping cranes will normally not use habitat within 0.5-miles of a wind turbine. Thus, mitigation is suggested for every wetland acre within 0.5-miles of a turbine that is suitable whooping crane habitat. To Suitable whooping crane habitat is defined as shallow wetlands in open, non-wooded areas free from human disturbance such as nearby roads or buildings with at least some water area less than 18 inches deep. This also includes marshes, small ponds, lake edges, or rivers.

3. USFWS encourages the wind energy industry to collaborate with USFWS to identify appropriate and suitable mitigation measures for development projects. In many cases, providing permanent protection for suitable whooping crane wetlands more than 5 miles from the project site is be the preferred action since whooping cranes may tend to avoid turbine arrays. Areas could be protected either by acquiring fee title lands or easement rights on lands that consist of suitable whooping crane stopover habitat. Protection in perpetuity of suitable stopover habitat in the corridor will help ensure alternate, relatively safe stopover areas are available for the cranes in the future. Development on these lands should be precluded. The acquisition of any property or easement should be coordinated with USFWS to ensure adequacy. However, even with additional protected areas, the overall impact of wind energy development is still anticipated to be a net loss of stopover habitat for the cranes since no new stopover wetlands are being created. Instead, wetlands would be protected from future loss.

   It is important to analyze the availability of stopover habitat for a given locale within the migration corridor. Analysis should include an assessment of the amount of suitable stopover habitat in the general area of the wind farm. If it turns out whooping cranes mostly avoid wind farms, will there be sufficient habitat remaining in the surrounding area for the whooping cranes to find stopover habitat or does the only stopover habitat occur on the wind farm?

4. Whooping crane survival and recovery depends on mortality, including that from collisions with power lines, to not increase. USFWS recommends that all power lines at wind farm sites be placed underground. If lines cannot be placed underground, then new transmission lines anywhere in the 200-mile wide whooping crane migration corridor should be marked according to the USFWS recommendations described in APLIC 1994. Although marking lines will reduce collision mortality for cranes and other large birds between 53-89%, some whooping crane mortality is likely to occur on marked lines.

5. The increased risk posed by new structures on the landscape associated with wind energy development can be mitigated by marking existing power lines in the migration corridor of the AWBP of whooping cranes. Whooping cranes saved by this marking technique on already existing structures can hopefully mitigate potential collision mortality on new structures including turbines and power lines associated with wind energy development. To mitigate for expected collisions, construction above ground of every mile of new marked line associated with wind energy development should be matched by marking and ensuring maintenance of markers on at least one mile of existing transmission and/or distribution lines in the whooping crane migration corridor line so that the net rate of collisions on all lines will actually decrease. This practice would insure that new line construction will not result in a net increase of whooping crane mortality and could be a mitigation strategy for an HCP for the wind energy industry for whooping crane issues. To determine the amount of line that should be marked, an analysis needs to be done as part of an HCP to calculate the current number of unmarked transmission lines in the whooping crane migration corridor and an estimate of annual mortality from those lines.

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Whooping cranes steer clear of wind turbines when selecting stopover sites

Date: March 11, 2021

Source: Ecological Society of America

Summary: An article reports that whooping cranes migrating through the U.S. Great Plains avoid 'rest stop' sites that are within 5 km of wind-energy infrastructure.

FULL STORY

As gatherings to observe whooping cranes join the ranks of online-only events this year, a new study offers insight into how the endangered bird is faring on a landscape increasingly dotted with wind turbines. The paper, published this week in *Ecological Applications*, reports that whooping cranes migrating through the U.S. Great Plains avoid "rest stop" sites that are within 5 km of wind-energy infrastructure.

Avoidance of wind turbines can decrease collision mortality for birds, but can also make it more difficult and time-consuming for migrating flocks to find safe and suitable rest and refueling locations. The study's insights into migratory behavior could improve future siting decisions as wind energy infrastructure continues to expand.

"In the past, federal agencies had thought of impacts related to wind energy primarily associated with collision risks," said Aaron Pearse, the paper's first author and a research wildlife biologist for the U.S. Geological Survey's Northern Prairie Wildlife Research Center in Jamestown, N.D. "I think this research changes that paradigm to a greater focus on potential impacts to important migration habitats."

The study tracked whooping cranes migrating across the Great Plains, a region that encompasses a mosaic of croplands, grasslands and wetlands. The region has seen a rapid proliferation of wind energy infrastructure in recent years: in 2010, there were 2,215 wind towers within the whooping crane migration corridor that the study focused on; by 2016, when the study ended, there were 7,622 wind towers within the same area.

Pearse and his colleagues found that whooping cranes migrating across the study area in 2010 and 2016 were 20 times more likely to select "rest stop" locations at least 5 km away from wind turbines than those closer to turbines.

The authors estimated that 5% of high-quality stopover habitat in the study area was affected by presence of wind towers. Siting wind infrastructure outside of whooping cranes' migration corridor would reduce the risk of further habitat loss not only for whooping cranes, but also for millions of other birds that use the same land for breeding, migration, and wintering habitat.

Story Source:

Materials provided by **Ecological Society of America**. *Note: Content may be edited for style and length.*

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1. Aaron T. Pearse, Kristine L. Metzger, David A. Brandt, Jill A. Shaffer, Mark T. Bidwell, Wade Harrell. **Migrating whooping cranes avoid wind-energy infrastructure when selecting stopover habitat**. *Ecological Applications*, 2021; DOI: 10.1002/eap.2324

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Wind Turbines Deter Whooping Cranes From Stopover Sites, Study Confirms

New research confirms that Whooping Cranes avoid wind turbines, causing loss of important stopover habitat for this species during migration. Photo by Laura Erickson

A new study published this month (March 2021) in the journal *Ecological Applications* reveals that migratory habitat for the Whooping Crane is being gradually reduced by wind energy development. Researchers found that this Endangered bird avoids turbines to a distance of 3.1 miles (5 kilometers), eliminating otherwise usable stopover sites if turbines are placed too close to them. Five percent of the best stopover habitat has already been functionally lost, the authors found. Many more wind facilities are being planned, indicating that unless steps are taken to distance turbines from stopover sites, this situation could grow even more dire.

“The results of this ground-breaking study are really eye-opening — the buildout of wind energy is already having a negative cumulative impact,” says Joel Merriman, Director of the Bird-Smart Wind Energy Campaign at American Bird Conservancy. “There are more than 10,000 wind turbines scattered throughout the Whooping Crane's migratory pathway. We now know that too many of these turbines are eliminating important migratory stopover habitat for this Endangered species.”

Each year, the last naturally occurring Whooping Crane population makes a 5,000-mile round trip, moving north in spring then south in fall along a narrow corridor between Canadian breeding grounds and wintering grounds in coastal Texas. Not marathon flyers, the birds must stop to rest and refuel several times along each seasonal journey.

There are a handful of well-recognized major stopover sites where migrating Whooping Cranes reliably concentrate that are designated Critical Habitat by the U.S. Fish and Wildlife Service. However, there are other stopover sites that these birds need as “stepping stones” to successfully complete their journey. Maintaining the availability and quality of these sites is a critical element of the continued conservation of this species. Many are on private lands, making protection more challenging. The study indicates that these smaller stopover sites are being functionally lost due to wind energy development.

And these impacts are growing. In the timespan of the study, from 2010 to 2016, the number of turbines quadrupled in the center of the migratory corridor. Overall, wind turbine placement was found to be essentially random in relation to Whooping Crane stopover habitat.

The study shows that Whooping Cranes avoided areas within 5 kilometers of wind turbines. Essentially, the presence of turbines rendered any habitat within that distance unusable.

This problem will only continue to grow unless turbine siting practices are improved. “There is good news here as well,” says Merriman. “The study also provides a clear blueprint for preventing additional migratory habitat loss from wind energy development: Avoid placing turbines in the species' migratory pathway and absolutely stop putting them within 5 kilometers of stopover sites.”

The Whooping Crane has been clawing its way from the brink of extinction for almost a century. One of the rarest and most threatened North American bird species, the crane's population had dropped to a low of fewer than 20 individuals in 1941. After many decades of collaborative conservation work by U.S. and Canadian partners, today the population stands at more than 800 individuals. About 500 of these constitute the only self-sustaining population, which nests in Canada's Wood Buffalo National Park and winters in and near the Aransas National Wildlife Refuge in Texas. There are two substantial reintroduced populations — a nonmigratory flock in Louisiana and a second migratory population in the eastern U.S. — plus about 150 birds in captivity.

Wind turbines are, unfortunately, just one part of the issue for Whooping Cranes. For some wind energy facilities, and particularly those in more rural locations, new powerlines must be constructed to connect the new facility to the energy grid. Powerlines are a primary source of mortality for Whooping Cranes due to collisions while in flight. This is one of the reasons a permit was canceled in June of this year for the “R-Project,” a proposed 200-mile transmission line that would have crossed an ecologically sensitive part of southeastern Nebraska.

“We need wind energy to combat climate change, but we have to be smart about facility development,” says Merriman. “This is particularly important for rare species like the Whooping Crane that have slow reproductive rates and thus less ability to recover from losses. These birds have enough challenges, including a small population, continued habitat loss, powerline collisions, illegal shooting … the list goes on. Now they're also having to dodge wind energy facilities. We can't afford to stand by while this species' remaining habitat is lost, especially when this loss is so clearly preventable."

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RESEARCH ARTICLE

Heterogeneity in migration strategies of Whooping Cranes

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ABSTRACT

Migratory birds use numerous strategies to successfully complete twice-annual movements between breeding and wintering sites. Context for conservation and management can be provided by characterizing these strategies. Variations in strategy among and within individuals support population persistence in response to changes in land use and climate. We used location data from 58 marked Whooping Cranes (*Grus americana*) from 2010 to 2016 to characterize migration strategies in the U.S. Great Plains and Canadian Prairies and southern boreal region, and to explore sources of heterogeneity in their migration strategy, including space use, timing, and performance. Whooping Cranes completed ~3,900-km migrations that averaged 29 days during spring and 45 days during autumn, while making 11–12 nighttime stops. At the scale of our analysis, individual Whooping Cranes showed little consistency in stopover sites used among migration seasons (i.e. low site fidelity). In contrast, individuals expressed a measure of consistency in timing, especially migration initiation dates. Whooping Cranes migrated at different times based on age and reproductive status, where adults with young initiated autumn migration after other birds, and adults with and without young initiated spring migration before subadult birds. Time spent at stopover sites was positively associated with migration bout length and negatively associated with time spent at previous stopover sites, indicating Whooping Cranes acquired energy resources at some stopover sites that they used to fuel migration. Whooping Cranes were faithful to a defined migration corridor but showed less fidelity in their selection of nighttime stopover sites; hence, spatial targeting of conservation actions may be better informed by associations with landscape and habitat features rather than documented past use at specific locations. The preservation of variation in migration strategies existing within this species that experienced a severe population bottleneck suggests that Whooping Cranes have maintained a capacity to adjust strategies when confronted with future changes in land use and climate.

Keywords: Grus americana, heterogeneity, migration strategy, Whooping Crane

Heterogeneidad en las estrategias migratorias de *Grus americana*

RESUMEN

Las aves migratorias usan numerosas estrategias para completar exitosamente los movimientos bianuales entre los sitios reproductivos y de invernada. La caracterización de estas estrategias permite entender el contexto para la conservación y el manejo de estas aves. Las variaciones en las estrategias entre y dentro de los individuos apoyan la supervivencia de la población como respuesta a los cambios en el uso del suelo y en el clima. Usamos datos de ubicación de 58 individuos marcados de *Grus americana* desde 2010 hasta 2016 para caracterizar las estrategias migratorias en las Grandes Llanuras de EEUU y las Praderas canadienses y la región boreal sur, y para explorar las fuentes de heterogeneidad en la estrategia migratoria, incluyendo uso del espacio, fechas y desempeño. *G. americana* completó migraciones de ~3,900 km que promediaron 29 días durante la primavera y 45 días durante el otoño, realizando 11–12 paradas nocturnas. A la escala de nuestro análisis, los individuos de *G. americana* mostraron poca consistencia en los sitios de parada usados entre las estaciones migratorias (i.e. baja fidelidad de sitio). En contraste, los individuos mostraron consistencia en las fechas, especialmente en las fechas de inicio de la migración. *G. americana* migró en diferentes momentos según la edad y el estatus reproductivo, donde los adultos con crías comenzaron la migración de otoño luego de otras aves, y los adultos con y sin crías comenzaron la migración de primavera antes que las aves sub-adultas. El tiempo transcurrido en los sitios de parada estuvo positivamente asociado con la longitud del tramo migratorio y negativamente asociado con el

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tiempo transcurrido en los sitios de parada previos, indicando que los individuos de *G. americana* adquirieron recursos energéticos en algunos sitios de parada que usaron para aprovisionar la migración. *G. americana* fue fiel a un corredor migratorio definido, pero mostró menos fidelidad en su selección de los sitios de parada nocturna; por lo tanto, el objetivo espacial de las acciones de conservación puede verse beneficiado al considerar las asociaciones con el paisaje y los rasgos del hábitat más que el uso pasado de los sitios específicos. La preservación de la variación en las estrategias migratorias existentes para esta especie que sufrió cuellos de botella poblacionales severos sugiere que *G. americana* ha mantenido su capacidad de ajustar las estrategias al ser confrontada con futuros cambios en el uso del suelo y el clima.

Palabras clave: estrategia migratoria, *Grus americana*, heterogeneidad

INTRODUCTION

The only self-sustaining and wild population of endangered Whooping Cranes (*Grus americana*), the Aransas–Wood Buffalo population, migrates nearly 4,000 km through central North America during spring and autumn (Kuyt 1992). Recovery efforts for this endangered species include providing protection and habitat during migration (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005). Whooping Cranes migrate across an extensive area that has been highly modified by urbanization and cultivation as well as hydrological alteration (Dahl 2011, Johnston 2013). Human population growth and continued agricultural and commercial development will lead to additional alteration to the corridor (Lark et al. 2015). Recovery actions include identifying areas to implement conservation actions and determining what kinds of conservation actions would be most effective (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2007). Conservation efforts can be targeted by characterizing migration strategies of Whooping Cranes.

Successfully completing migration is key to fitness of birds that move between seasonal environments as part of their life history strategy. Most individuals that migrate require more than a single flight; therefore, individuals need to stop during migration at sites where they can access resources such as safe roosting sites and high-quality food (Alerstam 2011, Stafford et al. 2014). Distance traveled during migration bouts and time at stopover sites vary greatly among migratory birds and are related to body size, type of flight, energetic and physiological constraints, characteristics of stopover sites (including resources present and disturbance), and distribution of quality stopover sites within the migration pathway (Piersma 1987, Warnock 2010). Constraints birds face during migration (e.g., timing, physiological), resource requirements (e.g., macronutrient), and conservation value and ecological functions of stopover sites visited (e.g., foraging; Mehlman et al. 2005) can be identified by comparing daily distances moved and time spent at stopover sites. Therefore, conservation and recovery actions can be guided by determining where, when, and how birds use migration corridors and stopover sites. Additionally, insight can be gained by identifying variability in migratory strategies employed, both within and among individuals, regarding flexibility that a population possesses that will be needed for adapting to a changing landscape (Chavez-Ramirez and Wehtje 2012, Gilroy et al. 2016).

We used location data to characterize migration strategies of Whooping Cranes and determined levels and sources of heterogeneity in aspects of migration strategy, including space use (use of geographic locations), timing (initiation and completion of migration), and performance (duration and rate of migration) metrics. This characterization included quantifying use of sites within the migration corridor to understand intensity of use by multiple birds, individual fidelity to stopover sites, and distances between sites. We also estimated migration chronology, length, and variability of these characteristics within and among individuals. Finally, we explored how Whooping Cranes allocated time and energy during migration by comparing distances moved daily and time spent at stopover sites. The answers to these questions will increase our understanding of Whooping Crane migration strategies and help stakeholders make more informed and targeted conservation decisions to support the recovery of this endangered species.

METHODS

Study Area

Whooping Cranes of the Aransas–Wood Buffalo population migrate through the Great Plains of the United States and Canadian Prairies and southern boreal region between wintering and breeding areas (Allen 1952). The central portion of the Whooping Crane migration corridor passes through Canadian provinces of Alberta and Saskatchewan and the states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas (Pearse et al. 2018). This region was historically dominated by a grassland biome and mixed-grass prairie. The majority of land is currently used for agricultural production, including annual crops grown for food, livestock feed, and biofuels, and pasture and haylands for ranching (Hartman et al. 2011). Gage et al. (2016) estimated that 82% of the Northern Great Plains has been converted to cropland. Wetlands, rivers, lakes, and reservoirs in the region support a diverse array of aquatic plant and animal communities and support millions of migratory waterfowl and waterbirds

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(Laubhan and Fredrickson 1997). Whooping Cranes use grasslands, croplands, wetlands, and rivers as roosting and foraging sites during migration (Pearse et al. 2017).

Field Methods and Data Acquisition

During 2009–2014, we captured 68 Whooping Cranes (~20% of the Aransas–Wood Buffalo population) and marked them with platform transmitting terminals with global position system (GPS) capabilities (North Star Science and Technology, Baltimore, Maryland, USA; Geotrak, Apex, North Carolina, USA), a device that uplinks GPS locations through a global satellite and data collection system (Service Argos 2008). Captures occurred at breeding areas within and near Wood Buffalo National Park and wintering sites along the Texas Gulf Coast. Capture teams consisted of individuals with experience handling endangered birds and a veterinarian. We caught pre-fledged juvenile cranes in the breeding areas by locating adults with young and using a helicopter to position personnel nearby for ground pursuit and hand capture (Kuyt 1979). In Texas, we captured cranes with leg snares that enclosed on their lower tarsus (Folk et al. 2005).

Transmitters logged 4–5 equally timed GPS locations daily, providing daytime and nighttime locations. We initially inspected GPS locations for errors by performing multiple assessments to determine plausibility of locations and omitted locations outside expected time sequences, with an implausible rate of displacement (>100 km h^{-1}), or forming an acute angle (<5°) at distances greater than 50 km (distance/angle; Douglas et al. 2012). We identified locations as collected during migration (spring and autumn) based on manual inspection of conspicuous movement patterns north during late winter to early summer (spring migration) or south during late summer to early winter (autumn migration). Fifty-eight of 68 marked cranes provided location data during migration. We classified locations as occurring in flight when instantaneous velocity was >2.6 m s^{-1}. Ground locations were categorized into individual stopover sites for each Whooping Crane by identifying clusters of locations based on distance, movement pattern, and manual inspection. In general, we delineated unique stopover sites if birds moved >10 km between ground locations and spent ≥1 night at the site. After identifying locations from each unique stopover site, we calculated stopover centroids by taking the mean of X and Y coordinates from each location identified within the stopover site.

We identified migration paths as complete and assumed all nighttime stopovers were accounted for when no 12-hr gaps in data existed. Migrations that began and ended at the traditional summering and wintering termini (i.e. in or near Wood Buffalo National Park, northern Canada; at or near Aransas National Wildlife Refuge, Texas Gulf Coast) were identified as full migrations. These migrations contrasted with truncated migrations that either did not start or end at these traditional sites. We organized marked birds into 5 age and social status categories. Individuals <1 yr of age were identified as juveniles with adults, because familial bonds persist beyond summer of hatching into autumn migration, winter, and subsequent spring migration (Urbanek and Lewis 2015). Individuals beginning their second summering period (first full summer >1 yr of age) were classified into a subadult age class for 1 yr. After this point, all birds were considered adults, which could be accompanied by young, without young, or in an unknown social status. We used status at capture, photographic evidence, and observations from project partners to determine social status of adults.

Data Analyses

Migration space use. We estimated a utilization distribution to characterize the spatial distribution of Whooping Cranes during migration and intensity of space use (Worton 1989). We divided the migration area of Whooping Cranes into hexagonal grid cells of 10-km radii (346 km^2) and determined number of stopovers within each cell. After ranking grid cells by stopover frequency, we calculated the cumulative proportion of stopovers found within each cell (i.e. cumulative proportion volume) and cumulative proportion of grid cells (i.e. cumulative distribution area). Volume metrics allowed us to identify and categorize intensity of stopover sites. We plotted utilization distribution area and volume (Powell 2000, Vander Wal and Rodgers 2012), fitted an exponential model to estimate this association, and determined where the slope of this relationship was 1.0. The volume at this inflection point represented a transition where, at cumulative volume values above, the proportion of occupied area increased at a greater rate than use. Thus, we identified grid cells above the critical value as being core migration areas and others as peripheral areas (Pearse et al. 2015).

Heterogeneity in migration timing, space use, and migration performance can be characterized by the degree of synchrony of behaviors that birds express within a population and degree of consistency within individual behaviors (Bauer et al. 2016). To quantify multiple use of sites by individuals by migration season and overall, we determined number of unique marked individuals occupying grid cells for each migration season. In nearly all instances, only one crane was marked within a parental group (i.e. mated pair and associated juvenile if present) or mated pair. If multiple individuals within one of these groups were marked, we removed data from one of the individuals. Therefore, we treated marked individuals as independent observations, which allowed for valid conclusions regarding synchrony in timing and space use during migration. The proportion of grid cells used by multiple marked individuals served as a measure of within-season overlap of space use, and we combined seasons by calculating a mean value. In addition,

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we calculated the average number of individuals that used each occupied grid cell. To quantify consistency of use by individuals, first we recorded number of migration seasons that individual marked cranes occurred within every grid cell. Then, for birds monitored for >1 season (n = 46), we estimated site fidelity by computing the proportion of all cells ever used by a particular bird that were used in more than one migration season. We also calculated the average number of times that an individual bird occupied a grid cell for all those used at least once.

Timing and migratory performance. We summarized calendar dates of migration initiation and completion for all migrations unless missing data precluded determination of an exact date. Migration time was the elapsed number of days cranes migrated each season. Number of locations cranes used as nighttime stopovers was reported for each migration season. Distance traveled during migration was determined by summing Euclidean distances between nightly stopover sites used by cranes, including beginning and ending locations. Finally, rate of migration was calculated by dividing distance traveled by time in migration (km day^{-1}).

We identified birds in 1 of 4 annual cycle categories: spring migration, summering, autumn migration, or wintering (Krapu et al. 2011, Pearse et al. 2015). We calculated the proportion of cranes in each of these categories by year. We then calculated an average and standard deviation for years 2011–2015, where >10 individuals provided data. We weighted each year equally and censored birds that were not detected during a particular day (i.e. no locations recorded). Averages and standard deviations were plotted by date.

To characterize migration timing in space, we split the migration pathway into 6 equal-sized areas encompassing all identified stopover sites. We categorized locations and stopover sites within each of these analysis zones so that we could determine timing and residency of migrating birds within each spatial zone by migration season (i.e. autumn and spring). We summarized spatially distinct timing with box plots, which included a median, 25th and 75th percentiles defining the box, 10th and 90th percentiles defining the whiskers, and 5th and 95th percentiles as outer points. Residency within spatial zones represented number of days birds were within each spatial zone, and we summarized residency with average days present and 95% confidence intervals. We also calculated site fidelity and spatial overlap metrics for each spatial zone to determine if these dynamics varied in space.

We modeled variation in 4 timing and performance metrics using mixed effects general linear models (*lme4* package, Program R; Bates et al. 2015, R Core Team 2017), including initiation and completion dates, migration time, and rate of migration. Analyses included only migrations in which social status of birds could be determined (i.e. removed unknown social designations, n = 78–105) and for migrations between traditional breeding and wintering grounds, because migrations originating or terminating from other locations were rare and generally had different timing and distances (Table 1). We were interested in timing and performance variation related to age and social status and included this variable as a fixed effect with 3 levels (family group, adult without young, or subadult). We included calendar year of migration event and individual bird as random effects, allowing estimation of variances associated with these effects. We calculated intraclass correlation coefficients (ICC) for individual birds and year to determine relative variation as measures of relative consistency of behaviors for individual birds and synchrony among birds within a particular migration event (*rptR* package; Stoffel et al. 2017). We included a bird's age and social status as fixed effects as described above, with ICC values to be calculated after controlling for variation due to this covariate. Standard errors for ICCs were calculated using 5,000 parametric bootstrap iterations. We used likelihood ratio tests for a fixed effect in linear models and to determine if ICCs were different from zero. We conducted all analyses by migration season (spring or autumn migration).

Migration bout distance and time at stopover sites. Distance between stops was the Euclidean distance between centroids of stopover sites. To explain variation in distance traveled between stopover sites (km), we performed generalized linear models (Proc MIXED, SAS 9.4; SAS Institute, Cary, North Carolina, USA) by season, where we used social status, natural log of days spent at originating stopover site, and total days in migration as independent variables. We used a log transformation of days because the independent variable was log transformed via Poisson regression, and we believed that extended stays would have diminishing effects. Stopover sites within an individual migration were identified as repeated measures.

We calculated time at individual stopover sites by adding up the number of nights that cranes spent at sites. We used general linear models (Proc GLIMMIX) for Poisson distributed data to explain variation in time at stopovers separately for each migration season. The response variable was days spent at a stopover site. Independent variables included social status, the natural log of days spent at a previous stopover site, and total days in migration. All stopovers within an individual migration were identified as repeated measures. Data used in analyses are available in the public domain from the U.S. Geological Survey ScienceBase data repository (Pearse et al. 2019).

RESULTS

We monitored migration of 58 individual Whooping Cranes for 1–11 migration seasons. Monitoring occurred

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TABLE 1. Migration phenology and performance summaries for Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016.

Variable	Spring						Autumn					
	n	Mean	Median	SD	5th percentile	95th percentile	*n*	Mean	Median	SD	5th percentile	95th percentile
Initiation date	122	Apr 6	Apr 6	14	Mar 19	Apr 30	102	Sep 27	Sep 23	18	Sep 2	Oct 25
Completion date	122	May 4	May 5	12	Apr 19	May 23	119	Nov 11	Nov 12	9	Oct 27	Nov 28
Migration time (days)	117	29	27	10	16	47	95	45	48	19	14	79
Migration rate (km day^{-1})	117	149	146	46	83	241	95	107	80	65	51	274
Nighttime stopovers	95	12	12	3	9	15	45	11	11	3	7	15
Multi-day stopovers	95	4	4	2	2	8	45	4	3	2	2	6
Migration distance (km)	109	3,920	3,882	137	3,797	4,172	111	3,881	3,845	114	3,780	4,116
Truncated migration distance (km)	13	3,379	3,244	542	2,758	4,858	11	2,878	2,771	469	2,470	4,181

between spring 2010 and autumn 2016. Each migration season, we monitored an average of 18.3 birds (minimum = 2; maximum = 33).

Migration Space Use

Grid cells contained 0–46 stopover locations, and 1,279 cells contained ≥1 stopover location. An exponential model describing the relationship between utilization area and volume provided an inflection point at 62% cumulative volume as a criterion to identify areas as core and peripheral in use intensity. The closest break point of stopover frequency to this criterion resulted in identifying core use areas as those with ≥3 identified stopover sites (i.e. locations used by a bird for ≥1 day). Core areas represented 25% (319) of grid cells with stopover sites and were generally spread throughout the migration area between summering and wintering areas (Figure 1).

Spatial overlap. Of 1,279 grid cells that had stopover site use, 45% were used by multiple birds across all migration seasons. Within season, proportion of cells occupied by more than one marked bird varied from 0.09 to 0.24 and averaged 0.15 (n = 13, SE = 0.01). Average number of birds using occupied grid cells per season was 1.22 (SE = 0.03). The greatest use by multiple birds occurred in analysis zone 2 (Figure 2), and other analysis zones had similar magnitude of use (Table 2).

Spatial consistency. For 46 birds monitored for multiple seasons (mean = 5.3 migrations), 0–0.19 proportion of grid cells were used during ≥2 migrations, and average site fidelity was 0.04 proportion of grid cells (SE = 0.01). Average number of times a bird occupied used grid cells was 1.04 (SE = 0.01). By spatial analysis zone (Figure 2), birds had the greatest fidelity in analysis zones 2 and 5 (Table 2). Zones 3 and 4 had similar fidelity and the lowest fidelity was found at zones 1 and 6.

Timing and Migration Performance

Migration timing. On average, ≥5% of marked birds migrated in spring for 60 days between March 21 and May 19 (Figure 3). Over 50% of cranes were in spring migration for 27 days between April 6 and May 2. Averaged across years, peak spring migration occurred on April 21, with an estimated 84% of cranes in migration status. Annual variation was greater at the second half of spring migration compared to the initial half. During autumn, ≥5% of birds migrated for 89 days between September 2 and November 29 (Figure 3). More than 50% of birds were in migration status for 44 days between September 28 and November 11. Across years, peak autumn migration occurred on October 27, with an estimated 91% of cranes in migration status. Annual variation in autumn migration status peaked at the end of the migration season in mid-November and generally was less than during spring migration.

Variation in timing during spring migration was consistent across zones, with inter-quartile ranges from 17 to

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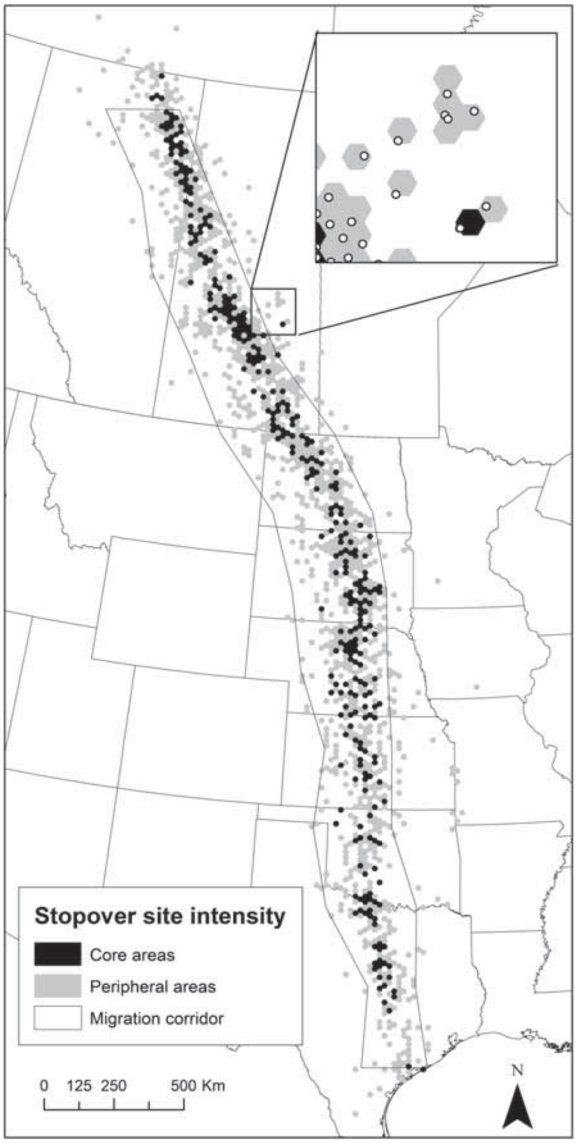

FIGURE 1. Stopover site intensity of areas used by migrating Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal regions, 2010–2016. Migration corridor from Pearse et al. (2018). Insert includes individual stopover locations (white points) overlaying identification of core and peripheral areas).

18 days. Residency within zones 3 and 4 averaged 8.7 days each and was greater than that of other zones, which had averaged residencies of 0.8–5.4 days. Timing among analysis zones in autumn migration revealed considerable overlap in timing of use within the northern 3 analysis zones and within the 3 southern zones (Figure 2). When in the northern zones (4–6), birds resided within respective areas with greater temporal variability than in the southern zones (1–3). Inter-quartile ranges (IQR) of the 3 northern zones were 24, 23, and 19 days, whereas the IQR of southern zones were 10, 11, and 13 days. Residency was brief for most zones during autumn (1.2–5.6 days on average) as compared to 25.8 days in zone 5.

Spring migration. Average initiation of spring migration occurred on April 6, with 90% of cranes initiating migration during a 42-day period between March 19 and April 30 (Table 1). Mean completion date of spring migration occurred on May 4. Cranes completed spring migrations in an average of 29 days, stopping at an average of 12 nighttime stopover sites. Rate of migration averaged 149 km day^{-1} for average trips of 3,920 km between traditional wintering and summering locations (Table 1).

Subadult Whooping Cranes initiated spring migration 10 days (SE = 2) later than birds in family groups and 8 days (SE = 3) later than adults without juveniles (Figure 4). Cranes showed consistency (ICC_{bird} = 0.41) in initiating spring migration and no synchrony (ICC_{year} = 0.00) during spring migration. Completion dates of spring migration also were later for subadult birds compared to cranes in other social groupings by 6–7 days (Figure 4). We found evidence of both consistency and synchrony in completion dates, with synchrony greater than consistency (Table 3). Time in migration and migration rate varied little due to social status during spring (Table 3). Migration time and rate both had modest and relatively equal levels of correlation within individuals and among birds.

Autumn migration. Autumn migration was initiated by 90% of Whooping Cranes over a 53-day period in September and October (Table 1), and average initiation date was September 27. Termination of autumn migration occurred over a shorter period of 32 days (90% of cranes), generally during November, with an average termination date of November 11. Cranes spent an average of 45 days in autumn migration and stopped at an average of 11 nighttime stopover sites. Rate of migration averaged 107 km day^{-1} (SE = 7), and cranes migrating between traditional summering and wintering locations traveled an average of 3,881 km.

Whooping Cranes migrating as part of a family group initiated autumn migration 9 days (SE = 5) later than adults migrating without young and 14 days (SE = 4) later than subadult birds (Figure 4, Table 3). Cranes showed more individual consistency compared with yearly synchrony in migration initiation date (ICC_{bird} = 0.48; ICC_{year} = 0.06). Cranes of different age and social status completed autumn migration at similar average dates (November 10–14; Figure 4). Correlations within individuals and among birds during the same years were similar and low, providing little evidence for consistency and synchrony. Compared with cranes as part of family groups, days in autumn migration was 9 days (SE = 5)

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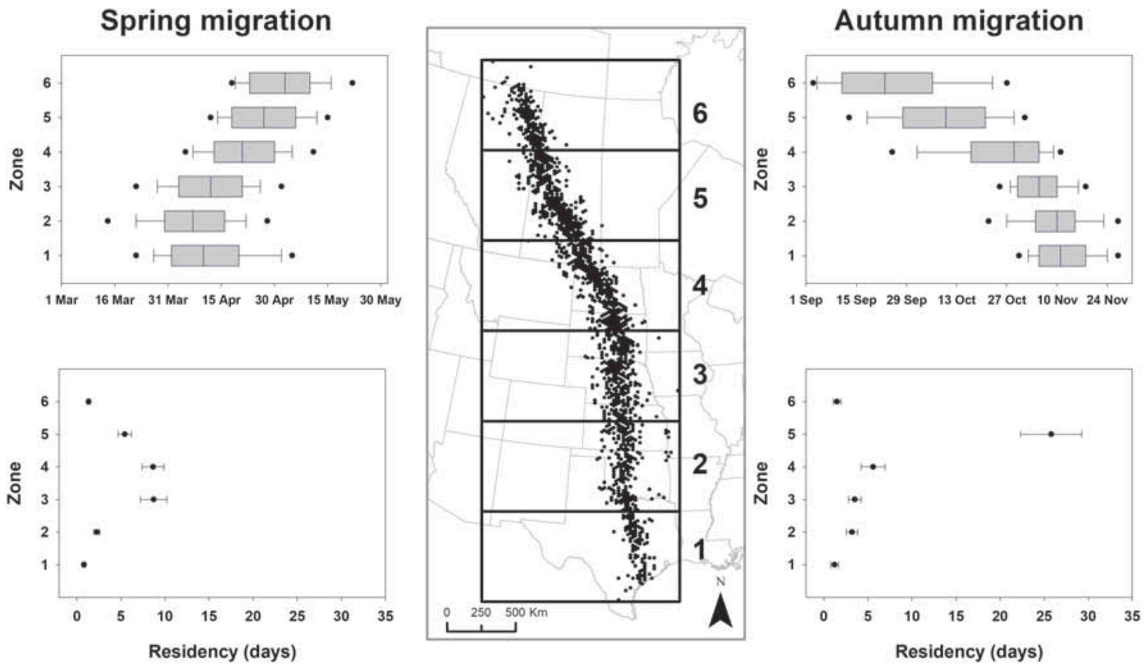

FIGURE 2. Spatial and temporal patterns of spring and autumn migrations of Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016. Box plots represent the distribution of dates when individuals occupied each spatial zone during migration. Boxplots were composed of the 25th, 50th, and 75th percentiles, the whiskers were the 10th and 90th percentiles, and outer points represented the 5th and 95th percentiles. Mean residence time (error bars represent 95% confidence limits) that Whooping Cranes spent in each spatial zone in spring and autumn migration.

TABLE 2. Spatial overlap and consistency metrics and 95% confidence limits by analysis zone of Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016. Overlap was indexed by the average proportion of grid cells wherein multiple marked birds resided and the average number of marked cranes using each grid cell each migration season. Consistency of use was indexed by the average proportion of grid cells wherein multiple individual birds resided and the average number of times an individual bird used a grid cell across migration seasons monitored.

	Overlap						Consistency					
Zone	Prop.[a]	LCL	UCL	Mean[b]	LCL[c]	UCL[d]	Prop.[e]	LCL	UCL	Mean[f]	LCL	UCL
1	0.16	0.11	0.21	1.23	1.15	1.31	0.02	0.00	0.03	1.02	1.00	1.05
2	0.21	0.16	0.26	1.41	1.28	1.53	0.07	0.04	0.09	1.09	1.05	1.12
3	0.14	0.08	0.20	1.17	1.10	1.25	0.03	0.01	0.05	1.04	1.02	1.06
4	0.16	0.11	0.21	1.19	1.13	1.25	0.03	0.01	0.04	1.03	1.01	1.05
5	0.17	0.12	0.21	1.27	1.16	1.38	0.06	0.03	0.08	1.07	1.04	1.10
6	0.08	0.03	0.13	1.09	1.04	1.14	0.01	0.00	0.02	1.01	1.00	1.02

[a] Mean proportion of grid cells wherein multiple marked birds resided each migration season.
[b] Mean number of marked cranes using each grid cell each migration season.
[c] Lower 95% confidence limit.
[d] Upper 95% confidence limit.
[e] Mean proportion of grid cells wherein individual birds resided across migration seasons.
[f] Mean number of times an individual bird used a grid cell across migration seasons monitored.

longer for adults without young and 11 days longer (SE = 4) for subadult birds (Figure 4, Table 3). Birds showed a similar and relatively low amount of correlation by individual or among birds within a year, suggesting little synchrony or consistency in migration length. Birds within family groups migrated at the greatest rate compared to birds of other social status (Figure 4, Table 3). Like date of initiation, we found evidence of individual

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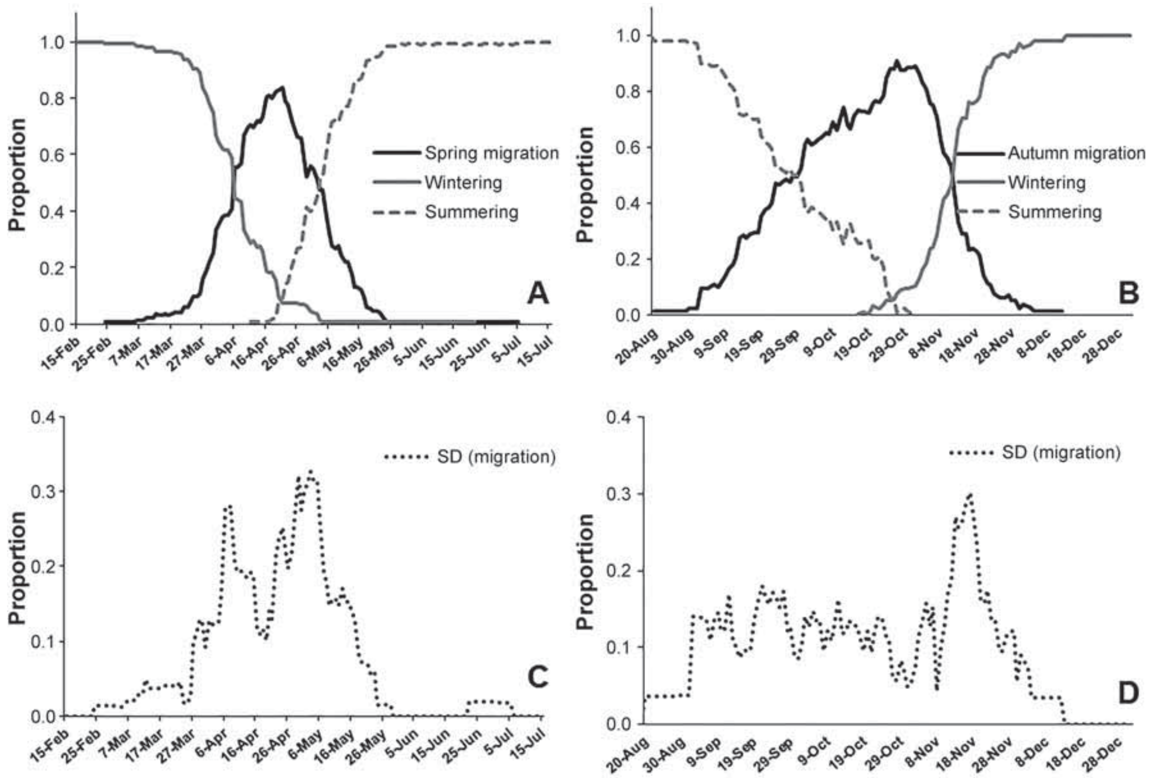

FIGURE 3. Average annual proportion of Whooping Cranes on wintering grounds, breeding grounds, and spring (**A**) and autumn (**B**) migration in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016. Annual variation (standard deviation) in proportion of Whooping Cranes in a spring (**C**) and autumn (**D**) migration status.

consistency in rate of migration (ICC_{bird} = 0.47) and less yearly synchrony (ICC_{year} = 0.04).

Migration Bout Distance and Time at Stopover Sites

Migration bout distance. Distance between stopover sites in spring averaged 307.7 km (*n* = 1,379, SD = 187.6, median = 308.0, 95th percentile = 632.7, maximum = 884.0). Whooping Cranes flew an average of 305.0 km between stopover sites during autumn migrations (*n* = 1,056, median = 256.4, SD = 222.5, 95th percentile = 730.3, maximum = 1,479.0).

During spring, migration flight distances between stopovers varied little by social status ($F_{2,109}$ = 1.0, P = 0.367; Figure 4). Cranes flew farther for each day they spent at the originating stopover site in the spring (ln[days]: β = 19.5, SE = 6.9, $F_{1,1056}$ = 8.0, P = 0.005; Figure 5B). They also flew 2.5 km less per migration flight bout during the spring for each additional day of their entire migration (β = −2.5, SE = 0.5, $F_{1,109}$ = 24.2, P < 0.001). Distances between stopover sites in autumn varied little among birds composed of family groups, adults without young, or subadults during autumn migration events ($F_{2,84}$ < 0.1, P = 0.975; Figure 4). Time spent at the originating stopover site was positively related to travel distance during autumn (ln[days], β = 40.4, SE = 7.7, $F_{1,661}$ = 27.4, P < 0.001; Figure 5A). On average, birds flew 1.2 km less per migration bout for each additional day cranes spent in their entire migration during autumn (β = −1.2, SE = 0.4, $F_{1,84}$ = 7.9, P = 0.006).

Time at stopover sites. During spring, stopover time averaged 2.5 days (*n* = 1,405, SD = 3.6, median = 1, 95th percentile = 8, maximum = 49). Whooping Cranes averaged 4.1 days at autumn migration stopovers (*n* = 1,179, SD = 8.7, median = 1, 95th percentile = 27, maximum = 62). Stopovers lasting a single night were most common overall (64% of stopovers), during spring migration (61%) and autumn migration (67%). For stopovers that were >1 night, average duration was 4.7 days in spring (*n* = 545, SD = 5.0, median = 3, 95th percentile = 15) and 10.2 days in autumn (*n* = 392, SD = 13.1, median = 3, 95th percentile = 40).

Time at spring stopover sites varied little by social status ($F_{2,109}$ = 0.6, P = 0.533; Figure 4). Natural log of time at previous stopover site also had little influence on time spent at the current stopover (β = −0.08, SE = 0.05,

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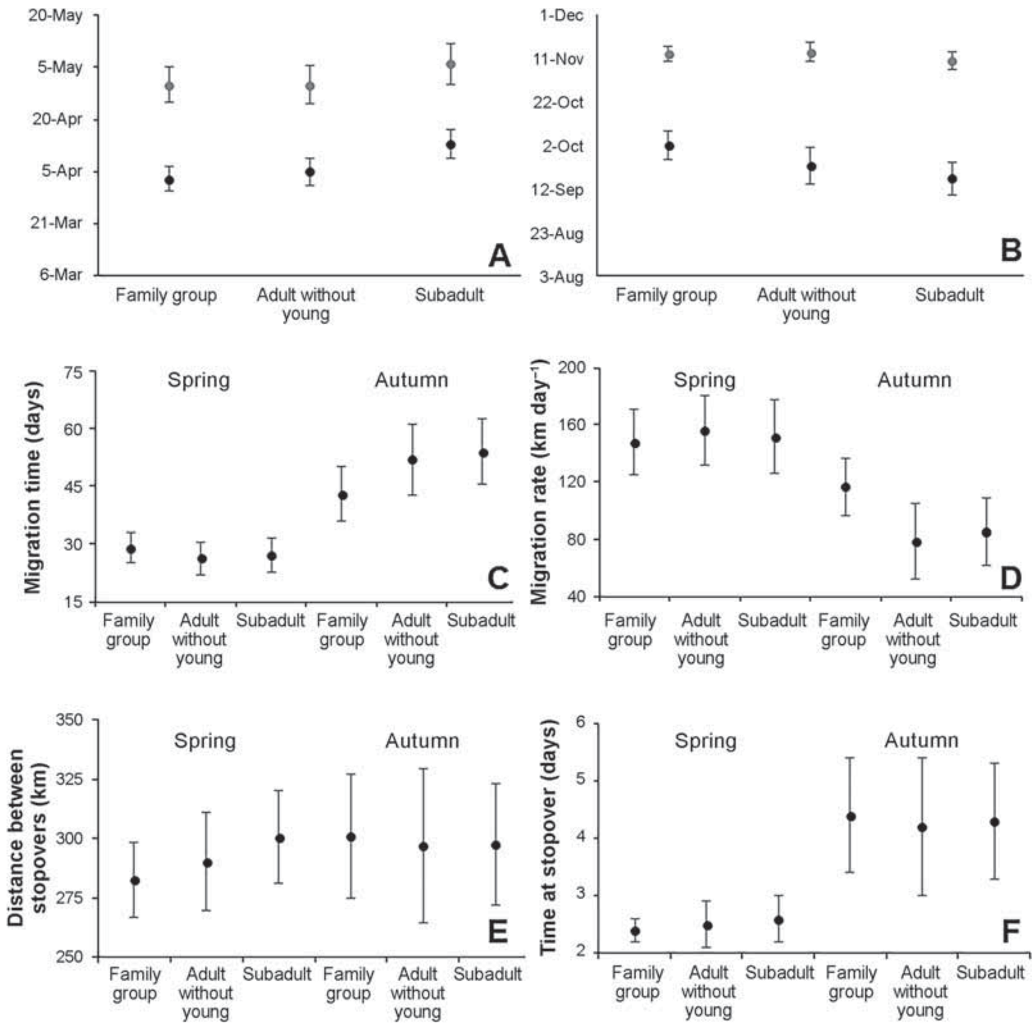

FIGURE 4. Model predicted means and standard errors of migration initiation (black) and completion dates (gray) in spring (**A**) and autumn (**B**) migrations, days in migration (**C**), migration rate (**D**), distance between stopovers (**E**), and time at stopover sites (**F**) by age and social status and migration season for Whooping Cranes migrating in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016.

$F_{1,1070}$ = 2.7, P = 0.102; Figure 5C). Total migration time was positively related to time spent at individual spring stopover sites (β = 0.024, SE = 0.003, $F_{1,109}$ = 60.1, P < 0.001). Time at autumn stopover sites varied little due to social or age status of birds ($F_{2,84}$ < 0.1, P = 0.975; Figure 4). Days spent (ln) at the immediate previous stopover site negatively influenced time at current stopover site (β = −0.23, SE = 0.08, $F_{1,714}$ = 9.0, P = 0.003; Figure 5D). Total migration time was positively related to time at autumn stopover sites (β = 0.019, SE = 0.004, $F_{1,84}$ = 24.3, P < 0.001).

DISCUSSION

Whooping Cranes migrated within a defined migration corridor but exhibited low levels of fidelity to specific stopover sites, suggesting they commonly select novel stopover locations each migration season. Fidelity to a general migration route but not to specific sites has been observed in another thermal soaring migrant, the Black Stork (*Ciconia nigra*), and this behavior was attributed to temporal variability in resource availability at stopover sites (Chevallier et al. 2011). Whooping Cranes primarily rely upon wetlands at stopover

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TABLE 3. Results of generalized linear models explaining variation in migration initiation date, completion date, migration time, and migration rate of Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016.

		Spring migration					Autumn migration				
Response variable	Effect	Estimate	SE	df	λ[a]	*P*	Estimate	SE	df	λ	*P*
Initiation date	Intercept	95.5	1.9				265.6	3.8			
	Status (FMG)[b]	−2.0	2.2	2	14.6	<0.001	9.1	4.1	2	15.5	<0.001
	Status (SBA)[c]	7.8	2.5				−5.2	4.4			
	ICC bird[d]	0.41	0.12	1	10.3	<0.001	0.48	0.13	1	5.3	0.011
	ICC year[e]	0.00	<0.1	1	0.0	1.0	0.06	0.06	1	0.8	0.190
Completion date	Intercept	119.7	2.6				317.7	2.0			
	Status (FMG)	0.6	1.6	2	16.3	<0.001	−0.8	2.2	2	2.7	0.253
	Status (SBA)	6.7	1.8				−3.9	2.5			
	ICC bird	0.25	0.11	1	6.4	0.006	0.17	0.12	1	2.3	0.066
	ICC year	0.43	0.16	1	41.2	<0.001	0.09	0.08	1	1.6	0.101
Migration time	Intercept	26.3	2.0				51.9	4.2			
	Status (FMG)	2.6	1.5	2	3.0	0.219	−9.1	4.6	2	8.4	0.015
	Status (SBA)	0.7	1.7				2.1	5.0			
	ICC bird	0.27	0.11	1	10.3	<0.001	0.19	0.14	1	1.0	0.160
	ICC year	0.29	0.14	1	25.5	<0.001	0.12	0.1	1	2.1	0.076
Migration rate	Intercept	156.2	11.4				78.4	12.2			
	Status (FMG)	−8.3	8.2	2	1.0	0.609	38.1	13.3	2	10.8	0.005
	Status (SBA)	−4.4	9.1				7.0	14.3			
	ICC bird	0.28	0.11	1	13.5	<0.001	0.47	0.13	1	3.5	0.032
	ICC year	0.34	0.15	1	31.0	<0.001	0.04	0.05	1	0.8	0.193

[a]Likelihood ratio test statistic.
[b]Birds within confirmed family groups (intercept represents adults without young).
[c]Subadult cranes.
[d]Intraclass correlation coefficient for consistency.
[e]Intraclass correlation coefficient for synchrony.

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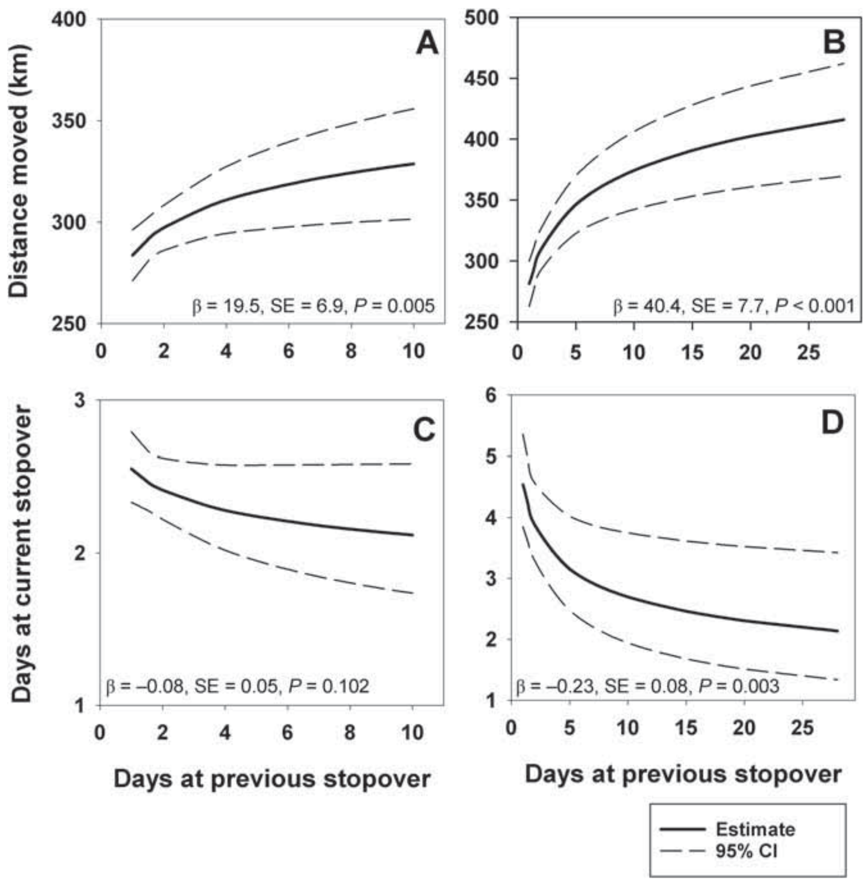

FIGURE 5. Estimates and 95% confidence limits describing migration strategies of Whooping Cranes in the Great Plains, Prairie Canada, and southern boreal region, 2010–2016. Predicted distances moved per migration bout increased with number of days at initial stopover during spring (**A**) and autumn (**B**) migrations. Number of days spent at current stopover sites in relation with days spent at previous stopover site during spring (**C**) and autumn migrations (**D**).

sites for foraging and nocturnal roosting (Austin and Richert 2005, Pearse et al. 2017). The ephemeral nature of surface water in wetlands may require cranes to be flexible in finding suitable stopover sites that are sufficient to meet their needs. Even at sites with more permanent and predictable surface water, foraging resources may vary among migrations, necessitating flexible site-selection behavior. Use of sites by multiple marked cranes not traveling together within the same year (i.e. spatial overlap) was more pronounced than site fidelity, averaging 16% of grid cells occupied by more than one marked bird and as great as 24% in a migration season. Birds not traveling together but using the same places in a migration season also supports the notion that birds responded to seasonal conditions or conspecific attraction in choosing stopover sites more so than relying on knowledge of sites used in previous years.

Because of the general nontraditional site selection across most of the migration corridor, conservation prioritization and targeting schemes may be more effective if they consider documented stopover site conditions (i.e. landscape and habitat features) rather than geographic locations used by Whooping Cranes in different parts of their migration corridor. For example, Whooping Crane sightings in the northern Great Plains were more likely at locations with greater wetland density, wetland types, and cropland area (Niemuth et al. 2018). Conservation strategies that rely entirely on prioritizing sites with a history of prior use may not be as effective across most of the migration corridor. However, site fidelity varied spatially and was more pronounced in some locations. For example, individuals expressed greater probability of reusing sites in Saskatchewan (zone 5; Table 2, Figure 2). Sites in this region were used by many of the marked birds for extended periods in autumn, which may allow for development of greater familiarity with high-quality sites within the region increasing the chance that they come back to these

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places in future migrations. Site fidelity also was more pronounced in a southern section of the migration corridor (zone 2), where core use sites were fewer (Figure 1), which may be an indication of more limited suitable site availability. Fewer choices coupled with the presence of large wildlife management areas of considerable past Whooping Crane use, including Salt Plains National Wildlife Refuge, Quivira National Wildlife Refuge, and Cheyenne Bottoms Wildlife Area, likely promoted higher fidelity to sites in this portion of the migration corridor.

Cranes showed consistency in migration initiation, but variation increased with completion of the migration. Migration strategies reflecting temporal, but not spatial, consistency have been observed in other species (Conklin et al. 2013, Thorup et al. 2013, López-López et al. 2014), but this pattern seems to be species-specific (Vardanis et al. 2016, Hasselquist et al. 2017). Consistency can suggest certain behaviors are controlled innately, which may reduce capacity for adaptation in the face of changing conditions. We found that initiation of migration during both seasons had more consistency, yet completion dates were less consistent, suggesting birds were able to modify consistent behaviors based on environmental cues. Therefore, variation in migratory strategy persists in this small population, indicating a capacity for adaptation. Long-term data suggests some directional changes in migration timing and route have occurred (Jorgensen and Brown 2017, Pearse et al. 2018), and reintroduced birds with genetic origins from the Aransas–Wood Buffalo Population have expressed a high capacity to modify migration and wintering behaviors in novel environments (Teitelbaum et al. 2016).

Timing and performance metrics reflected greater consistency than synchrony. Synchrony corresponds to how temporally distributed individuals were during migration. Autumn migration had little temporal synchrony and was more protracted than spring, where we observed synchrony in some metrics. Whooping Cranes regularly migrated at different times based on social status and age, and these temporal differences were the likely explanation for a lack of synchrony. Different temporal migration dynamics by age classes and protracted migrations resulted in individuals migrating for ~20% of the year (2.5 mo) whereas, from the perspective of the entire population, at least some birds were in migration status for ~40% of the year (5 mo). Although migrations may make up the shortest life stage each year for individual birds, conservation practices targeting migration can affect the population for nearly half the year.

Average migration flight bouts between stopover sites were similar seasonally and comparable to distances observed in other species with thermal soaring migration flight in White-naped Crane (*Grus vipio*), White Stork (*Ciconia ciconia*), and Osprey (*Pandion haliaetus*) (Ueta and Higuchi 2002, Alerstam et al. 2006, Rotics et al. 2016). Conservation planners can use these flight capabilities when determining spacing and distribution of stopover habitat necessary for completion of successful migration. The time Whooping Cranes spent at stopover sites was positively related with their subsequent flight distance. Lislevand et al. (2016) found a similar relationship in migration bout distances and time at stopover sites for Common Ringed Plovers (*Charadrius hiaticula*) during autumn migration. For Whooping Cranes this effect was greater in autumn than spring, which may be related to birds minimizing spring migration time, allowing arrival on the breeding grounds with enough time to complete breeding season events. We suspect cranes were able to build energy reserves during longer stays to fuel extended flights. The greater need for extended stays before longer migration flights in autumn also could be because the birds in autumn had just finished breeding and may be in poorer body condition when initiating migration as compared to birds initiating spring migration.

Time spent at stopover sites, not in flight, constitutes the majority of the time in the migratory period; therefore, to minimize total time in migration (Hedenström and Alerstam 1997), Whooping Cranes should limit length of migration stops, a behavior observed in other crane species (Kanai et al. 2002). During autumn migration, the correlation between length of stop and length of subsequent stops (e.g., shorter stops were followed by longer stops) indicated energy expenditure was an important consideration in autumn (Nilsson et al. 2013). The extended residency Whooping Cranes have during autumn in Saskatchewan, coupled with observations of diurnal habitat use and foraging behavior (Johns et al. 1997), provides evidence that Whooping Cranes acquire resources for migration at these sites. Continued conservation and management of wetlands and upland foraging resources in this region serve as a key recovery action to maintain important migration habitats (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2007). In spring, we speculate that migration was fueled from resources garnered during the end of the wintering period, as we documented few extended stays at stopover sites during spring where significant resources could be acquired. Whooping Cranes resided for the longest time during spring in mid-latitudes from northern Kansas to North Dakota, where they likely acquired food resources but to a lesser extent than autumn in Saskatchewan. Conservation actions in this mid-latitude area also would support continued recovery of Whooping Cranes but may be more difficult given the larger area in which cranes are dispersed.

We quantified migration timing and distances for birds that made migrations between traditional wintering areas along the Texas Gulf Coast and summering areas near Wood Buffalo National Park in Canada. Our exclusion of <10% of migrations that did not begin or end at these

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locations underestimated the variability in migration timing and performance metrics. These truncated migrations were most common for subadult birds that do not return to natal areas until their second or third summer to begin breeding. Therefore, our inferences pertain to the portion of the population that migrates between traditional wintering and summering locations, which constitutes most of the population of breeding individuals.

Conservation Implications

Conservation of habitats used by migratory birds throughout their annual cycle has been a common goal for landscape-scale conservation plans (e.g., U.S. Department of the Interior and Environment Canada 1986, Rosenberg et al. 2016), yet considerable efforts remain to meet these goals globally (Runge et al. 2015). A need exists to understand migration and migratory stopover sites to assist conservation and determine where and what types of habitats to conserve for birds in migration (Mehlman et al. 2005). These deficiencies partially arise because of difficulty in conducting research and conservation activities during times when individuals are migrating over large areas (Webster et al. 2002). For Aransas–Wood Buffalo Whooping Cranes, conservation actions directed at birds during migration will be inherently more challenging than actions at other times of the year. Whooping Cranes spread out over a much larger area in migration compared to their much more limited and predictable use of areas during breeding or wintering seasons (Allen 1952, Kuyt 1992). In addition, >50% of lands used by Whooping Cranes on summering and wintering grounds have some level of land protection (Canadian Wildlife Service and U.S. Fish and Wildlife Service 2005), as compared to 10% in migration (Pearse et al. 2015). Therefore, conservation protection in the migratory corridor remains a priority. Because most land in the Great Plains is in private ownership and most stopover sites occurred on these lands (Pearse et al. 2017), working with landowners will be required for success.

Even with these challenges, our work supports numerous opportunities to expand conservation for migrating Whooping Cranes and benefit other wetland-dependent species. Our findings indicate that Whooping Cranes have a relatively large migration distribution and revisit sites rarely. Therefore, cranes will have a continued need for a variety of well-distributed stopover habitats available along the migration corridor. To meet this need, land protection programs over extensive areas, such as through easement programs, may be more beneficial than intensive conservation actions at specific locations. Distances Whooping Cranes were able to migrate each day can provide partial insight as to the distribution of these habitats, although redundancy and diversity of wetlands may help mitigate pressures associated with seasonal and interannual dynamics, such as drought and fluctuating water levels. Prioritizing locations within the migration corridor could be directed by interpreting the amount of time cranes spent at various places within the migration corridor each season. Specifically, locations in mid-latitude locations from Kansas to North Dakota in spring and southern Saskatchewan in autumn were used for longer periods, providing support for their prioritization.

The ability for a species to adapt to change is partially dependent on variation in its behavior. We found that Whooping Cranes had flexible aspects to their migration strategy that will be necessary as the landscape continues to undergo conversion, such as from oil and gas extraction (Allred et al. 2015), wind energy development (Wiser and Bolinger 2017), and cropland expansion (Lark et al. 2015). Even with this flexibility, Whooping Cranes and other wetland obligate species likely have little ability to adapt to large-scale loss of wetlands and will continue to require an adequate network of wetlands to persist. Continued adaptation to climate change will remain necessary and, although Whooping Cranes have shown the ability to modify migration timing (Jorgensen and Brown 2017), their continued ability to adapt to intensified future climate change scenarios is unknown, as it is for numerous other species worldwide (Bellard et al. 2012).

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Ethics statement: Marking and capture were conducted under Federal Fish and Wildlife Permit TE048806, Texas research permit SPR-1112-1042, Aransas National Wildlife Refuge special use permit, Canadian Wildlife Service Scientific

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Permit NWT-SCI-10-04, Parks Canada Agency Research and Collection Permit WB-2010-4998, and Northwest Territories Wildlife Research Permits WL004807, WL004821, and WL500051. Procedures were approved by Animal Care and Use Committee at Northern Prairie Wildlife Research Center and Environment Canada's Animal Care Committees.

Author contributions: A.T.P., M.T.B., K.L.M., M.J.H., and D.M.B. formulated the questions; A.T.P. and D.A.B. analyzed data; all authors collected data and supervised data collection and wrote or provided review and revisions.

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PROCEEDINGS OF THE NORTH AMERICAN CRANE WORKSHOP

2018

WHOOPING CRANE AND SANDHILL CRANE MONITORING AT FIVE WIND ENERGY FACILITIES

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WHOOPING CRANE AND SANDHILL CRANE MONITORING AT FIVE WIND ENERGY FACILITIES

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Abstract: Biologists have expressed concern that individuals of the Aransas-Wood Buffalo Population of the federally-endangered whooping crane (*Grus americana*), numbering about 300, may be injured or killed by wind turbines during migration. To help address this concern and curtail (stop) turbine operations when whooping cranes approached turbines, we monitored the area around 5 wind energy facilities in North and South Dakota during spring and fall migration for whooping cranes and sandhill cranes (*G. canadensis*). Observers monitored cranes for 3 years at each facility from 2009 to 2013 (1,305 total days of monitoring), recording 14 unique observations for a total of 45 whooping cranes for which curtailment occurred during portions of 9 days. Observers also searched for dead cranes at the base of every turbine each day of monitoring. This resulted in approximately 92,022 cumulative individual inspections, during which no dead or injured cranes were detected. Based on our results and monitoring efforts at other wind energy facilities in the migration corridor, no whooping crane fatalities have been documented. Although migrating cranes use areas near turbines, they do not appear to be overly susceptible to collisions with wind turbines.

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Key words: avoidance, collision, *Grus americana*, *Grus canadensis*, North Dakota, sandhill crane, South Dakota, turbine, whooping crane, wind energy.

Concerns have been raised regarding the impact that wind energy development may have on whooping cranes (*Grus americana*). In particular, there is concern for the Aransas-Wood Buffalo Population (AWBP), which migrates along a corridor with extensive wind energy development in the Great Plains of the United States (USFWS 2009, Stehn 2011). The AWBP is very small, consisting of about 300 individuals (Butler and Harrell 2016) and, along with all whooping cranes, is protected under the Endangered Species Act (USDOI OS 1967). Wind energy development may have direct impacts (i.e., mortality) and/or indirect impacts (i.e., a decrease in suitability of migratory habitat and/or displacement) on whooping cranes. Mortality seems to be the greatest concern, as expressed in the International Recovery Plan for the Whooping Crane (CWS and USFWS 2005): "The development of wind farms in the whooping crane migration corridor has the potential to cause significant mortality. Cranes could be killed directly by wind turbines or from colliding with new power lines associated with wind farm development. Management and research are needed to reduce this new threat."

Whooping cranes (and the closely related sandhill cranes [*Grus canadensis*]) are known for their susceptibility to collisions with power lines (e.g., Faanes 1987, Stehn and Wassenich 2008, APLIC 2012). For example, of 50 carcasses of whooping cranes recovered from 1950 to 2010, 10 individuals died from collision with power lines (with cause of death unknown for an additional 12 whooping cranes; Stehn and Haralson-Strobel 2014). Standard management guidelines for power lines discourage their placement near areas of crane use (APLIC 2012). Whereas power lines have been a fixture of the Great Plains landscape for decades, modern, industrial-sized turbines are a new potential threat (USFWS 2009).

The migration corridor used by the AWBP extends from southern Texas to the Northwest Territories and Alberta in northern Canada, and includes the U.S. states of North Dakota, South Dakota, Nebraska, Kansas, Oklahoma, and Texas (Urbanek and Lewis 2015). In the middle of the corridor is a centerline representing the midpoint of the corridor (USFWS 2009). Whooping cranes use the migration corridor from roughly late March/early April to early May in spring and mid-September to mid-November in fall. The migration period is a vulnerable time because cranes may encounter storms in spring and fall; also recently fledged cranes will encounter hazards for the first time in new environments during the fall (Lewis et al. 1992,

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Stehn and Haralson-Strobel 2014).

Within the states crossed by the migration corridor, the number of wind turbines ranges from 583 turbines in South Dakota to 12,565 turbines in Texas (AWEA 2018); this includes areas outside of the corridor. Total area of these states ranges from 177,660 km^2 in Oklahoma to 676,587 km^2 in Texas (U.S. Census Bureau 2010). Development of wind turbines in all states along the migration corridor is ongoing (AWEA 2018).

Little is known for either species about whether use of an area is associated with increased risk of collision with turbines (USFWS 2009). No fatalities of whooping cranes have been attributed to collisions with wind turbines, but we know of 3 fatalities of sandhill cranes from collisions with wind turbines, all occurring outside of the migration period. One of these fatalities occurred between 2005 and 2007 at the Altamont Pass Wind Resource Area in California (Smallwood and Karas 2009) and 2 occurred on wintering grounds in Texas (Navarrete and Griffis-Kyle 2014). In a study of wintering sandhill cranes, Pearse et al. (2016) found only a slight overlap between the location of wind turbines in the Great Plains and winter habitat used by radio-tracked sandhill cranes before the towers came into existence. For other bird species, numerous factors have been studied regarding potential causes of collisions including characteristics of the birds, landscapes, and wind energy facilities, and correlations may be species and place dependent (e.g., Marques et al. 2014).

To address potential crane mortality, we developed and implemented standardized survey methods for monitoring use (defined as flying and/or standing) by whooping cranes and sandhill cranes at 5 wind energy facilities in North Dakota and South Dakota. Our objectives were to 1) identify whooping cranes using the area surrounding the facility during spring and fall migration periods, such that turbine operation could be curtailed (i.e., blades stopped) if whooping cranes were seen near the facilities; 2) document use (i.e., occurrence) of the facilities and surrounding areas by whooping cranes and sandhill cranes; and 3) document crane casualties. Although power lines are part of wind energy infrastructure, they were not evaluated in this study. Indirect effects were not specifically studied.

Because whooping cranes are rare, we also recorded observations of sandhill cranes in the Mid-Continent Population, which number in the hundreds of thousands with an overall stable population (Gerber et al. 2014). During each spring in 2009-2013, it is estimated that about 340,000 to 870,000 sandhill cranes passed through the Central Platte River Valley in Nebraska (Dubovsky 2016), which is located about 350 km south of the our southernmost study area. While similarly estimated numbers in North and South Dakota during migration are not known, in the Great Plains, sandhill cranes use a similar but broader migration path as whooping cranes and migrate during a similar timeframe—late February to late April in spring and mid-September to mid-December in fall (Gerber et al. 2014). Additionally, sandhill cranes use similar habitats during migration, are also susceptible to collisions with power lines (e.g., Murphy et al. 2009), and therefore may be at similar risks for collisions with turbines. They can be in the same locations as whooping cranes during migration and are protected under the Migratory Bird Treaty Act (USDOI 1918). Because of these similarities and relatively large population size, we consider the sandhill crane as a surrogate species for the whooping crane.

STUDY AREA

We monitored cranes at 5 wind energy facilities and associated buffer areas: PrairieWinds ND1, Baldwin, and Wilton Expansion facilities in North Dakota; and the Wessington Springs and PrairieWinds SD1 (also known as Crow Lake) facilities in South Dakota (Fig. 1). Although the Baldwin and Wilton Expansion facilities are adjacent, they were monitored in different years so are treated as separate facilities. A buffer area (i.e., land adjacent to but outside the facility) was delineated for each facility in order to focus efforts for curtailment, although this did not limit areas where observers could observe cranes. We used 1.6-km buffers to the outside of the turbines for the Prairie Winds ND1, Wessington Springs, Wilton Expansion, and combined Baldwin/Wilton Expansion studies, while 3.2-km buffers were used at Baldwin and PrairieWinds SD1. Buffer distances were determined based on direction from the U.S. Fish and Wildlife Service (USFWS) as well as permit conditions outlined in each project's Biological Assessment. Land covers were primarily grassland and cropfield, and the facilities ranged from 5 to 115 km from the centerline of the defined migration corridor of the AWBP of whooping cranes (Fig. 1, Table 1; USFWS 2009); the facilities are also in the broader migration

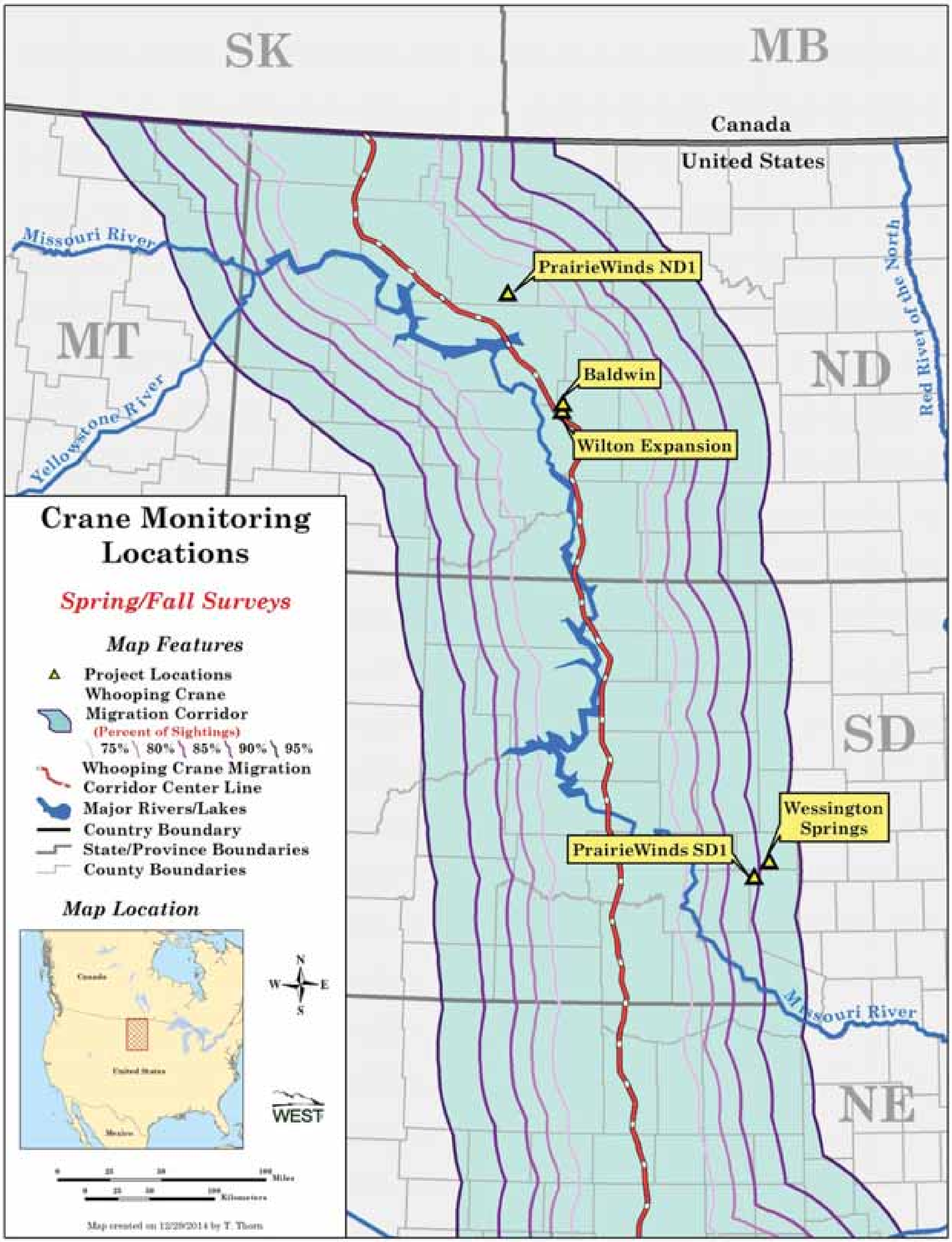

Figure 1. Wind energy facilities used as study areas in North Dakota and South Dakota for monitoring of use (flying and/or standing) by whooping cranes and sandhill cranes during spring and fall migration seasons from 2009 to 2013 (1 Apr-15 May and 10 Sep-31 Oct, respectively). The facilities are shown in relation to the migration corridor for the Aransas-Wood Buffalo Population of whooping cranes. U.S. migration corridor adapted from CWCTP (2009) after Austin and Richert (2001).

Table 1. The location, facility characteristics, and study years for wind energy facilities in North Dakota and South Dakota where monitoring of use (flying and/or standing) by whooping cranes and sandhill cranes was conducted for 3 years during spring and fall migration seasons from 2009 to 2013 (1 Apr-15 May and 10 Sep-31 Oct, respectively).

Wind energy facility	Location[a]	No. of turbines	Tower height (m)	Blade length (m)	Year online	Study years
PrairieWinds ND1	Max, Ward Co., N.D. (47.93700°N, 101.28288°W)	77	80	38	2009	2010-2012
Wilton Expansion[b]	Wilton, Burleigh Co., N.D. (47.12586°N, 100.69449°W)	33	80	38	2009	2010-2012
Baldwin[b]	Wilton, Burleigh Co., N.D. (47.17625°N, 100.68944°W)	64	80	40.3	2010	2011-2013
Wessington Springs	Wessington Springs, Jerauld Co., S.D. (44.00088°N, 98.60474°W)	34	80	38	2009	2009-2011
PrairieWinds SD1 (Crow Lake)	White Lake; Aurora, Brule, and Jerauld cos.; S.D. (43.89199°N, 98.74808°W)	108	80	38	2010-2011	2011-2013

[a] Nearest town followed by county, state, and coordinates.

[b] Due to close proximity, the Baldwin and Wilton Expansion wind energy facilities were monitored jointly in 2011 and 2012 and results were combined for those seasons.

path of sandhill cranes (Gerber et al. 2014). The number of turbines at each facility ranged from 33 to 108, and turbine towers were 80 m tall (Table 1).

METHODS

We monitored use at each of these facilities daily, weather permitting, from approximately 1 April through 15 May and 10 September through 31 October, which included the 5-95% occurrence date range in North Dakota and South Dakota for the AWBP during migration (Austin and Richert 2001, CWCTP 2009). Migration timing for sandhill cranes in the Dakotas is roughly similar where most birds migrate through during April and again in September through November (Gerber et al. 2014). We conducted crane surveys for 3 years (6 migration seasons) at each facility (Table 1). We monitored the Baldwin and Wilton Expansion facilities jointly for 2 years when monitoring seasons overlapped because the facilities are adjacent to each other, and results are combined for those 2 years.

Crane Use Surveys and Curtailment

We conducted driving surveys along public roads and other accessible roads (e.g., turbine access roads) within each wind facility and surrounding area to record location and number of cranes. During surveys each observer used a map showing the turbines, buffer area, and roads to assist in maximizing survey coverage. Observers monitored crane use daily from approximately sunrise to 1000 hours and from about 1600 hours to sunset.

Observers drove at speeds allowing them to drive safely and look for cranes, generally 32-56 km per hour, driving more slowly near areas cranes preferred such as cropfields and wetlands. Observers drove the same roads more than 1 time during a single morning or evening session. Observers stopped at vantage points to look and listen for cranes for roughly 3-10 minutes per stop (sometimes longer if cranes were detected). Vantage points were selected while on site by the observer as opposed to pre-selected vantage points in order to minimize the time observers spent looking at their map and allow the observer to determine in the field what constituted a vantage point. During these stops observers used binoculars and/or spotting scopes to scan the landscape for cranes whose relatively large bodies (at least 1 m in length) and loud flight calls aid in detectability. If a whooping crane was observed flying toward the turbines and flying at about the same height as the turbines, the observer called the operation manager at the facility, who then shut down operating wind turbines within a minimum of 3.2 km of the whooping crane location.

During migration, cranes use wetlands for roosting at night from which they fly to nearby crop fields and grasslands to feed during the day (Iverson et al. 1987, Anteau et al. 2011). Therefore, observers focused attention on areas of potential roosting habitat (e.g., shallow wetlands and ponds) during early morning and late evening. Later in the morning and earlier in the late afternoon, observers focused on potential foraging areas such as cropfields and hayfields. Observers also checked other potential roost habitat outside of the buffer area periodically to determine if cranes, especially whooping cranes, were near any of the study facilities. If whooping cranes were known to be in the area but outside the buffer zone (and not flying toward turbines), observers monitored their use during midday as well but we did not include these extra observation hours in our results. During inclement weather, observers also conducted monitoring during the middle of the day because cranes were more likely to remain on the ground in the absence of thermal updrafts for migration (Urbanek and Lewis 2015).

For each individual or group of whooping cranes or sandhill cranes seen or heard, observers recorded the approximate number of individuals, location (on a paper map), habitat type (for standing birds), and if any were flying. As part of coordinating our effort with the USFWS, we consulted with and informed them of any sighting of whooping cranes. For every observation of whooping cranes the observer(s) completed a Whooping Crane Report Field Sheet to document the sighting; each Field Sheet was submitted to the USFWS after the observation.

Casualty Searches

Although our primary purpose was to have observers on site to spot whooping cranes and curtail movement of turbine blades to prevent collisions, we did not have the manpower to simultaneously observe multiple locations along the perimeter of the facility, which can span several kilometers. For example, the footprint of turbines at PrairieWinds SD1 measured about 8 km by 20 km. There was a possibility that whooping cranes could have entered the air space of a facility without being detected. Therefore, observers also checked the ground below all the turbines at every facility daily for crane fatalities between the morning and evening monitoring periods (about 1000 to 1600 hr), or occasionally while conducting crane use surveys if convenient. Casualty searches included a visual scan of the area from a truck or by walking around the turbine. This method was chosen because cranes are relatively large-bodied birds deemed detectable from a distance, especially from a taller vehicle like a truck. Observers chose at their discretion a place with a good vantage point and with binoculars scanned the area underneath the turbine out to approximately 100-150 m away from the turbine for dead or injured cranes on the ground. If a portion of the search area was not visible from the truck, the observer left the vehicle and walked to that area. Search intensity and duration depended upon the terrain and vegetation around the turbine (e.g., grassland, cropfield) but was generally about 1-2 minutes. Typically the same observers were at a facility for the entire season and they became familiar with the terrain and search areas, enhancing their ability to notice if a crane body was suddenly present. This was not intended as a formal carcass search with bias correction efforts, such as is done for general bird fatality studies.

RESULTS

Crane Use Surveys

Whooping Cranes.—Observers detected whooping cranes at 4 facilities (none at PrairieWinds ND1). A total of 45 whooping cranes were recorded within or adjacent to our study areas. This number may represent multiple observations of the same individuals during multi-day observations at the PrairieWinds SD1 facility in spring 2013 (see below). Of 1,305 days of cumulative monitoring, curtailment of turbines occurred on portions of 9 days (0.7%) and only for short periods (<1 to 6 hr) on these 9 days.

Sandhill Cranes.—Observers monitored crane use for approximately 13,182 hours and recorded 486 observations of about 42,727 sandhill cranes at all facilities combined during this study. These sightings likely included multiple observations of the same individuals if they remained in the area for >1 day. Sandhill cranes were observed at all 5 facilities, but use varied greatly by year and facility, ranging from 0 to 9,662 cranes being observed per facility and per migration season and 519 to 10,171 cranes per facility annually (Fig. 2).

Curtailment

Below we summarize whooping crane sightings and curtailment actions for 4 facilities where whooping cranes were detected:

Baldwin/Wilton Expansion.—1) An observer watched 1 group of 3 whooping cranes for 2 days in

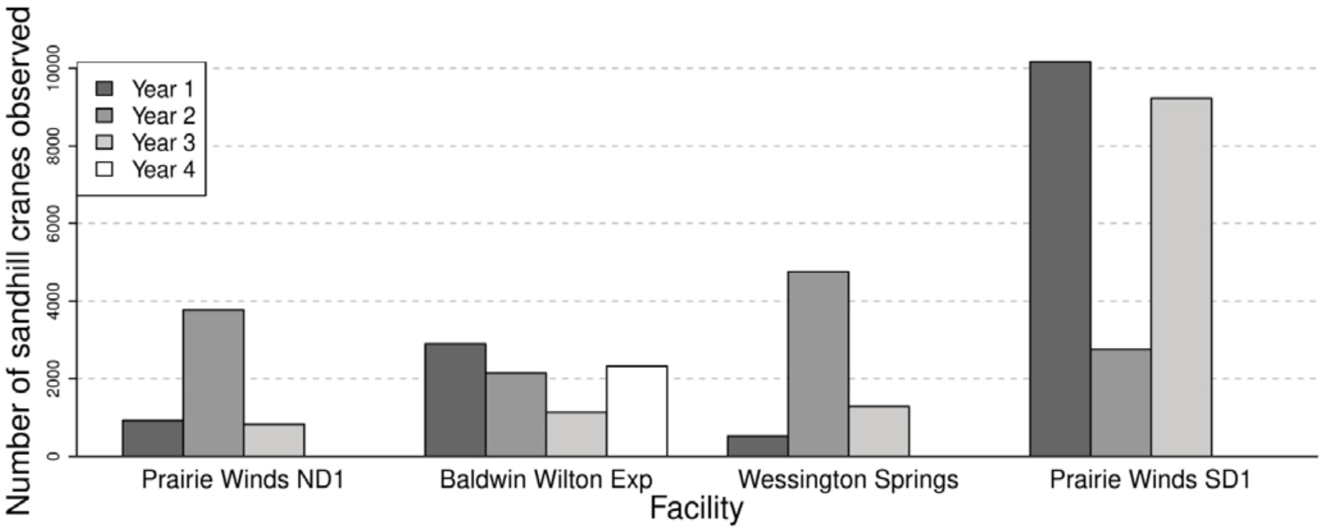

Figure 2. The annual total number of sandhill cranes observed during monitoring of use (flying and/or standing). The study occurred at 5 wind energy facilities in North Dakota and South Dakota from 2009 to 2013. Because the Baldwin and Wilton Expansion facilities were adjacent but had crane monitoring schedules that only partially overlapped, the Year 1 value for the Baldwin/Wilton Expansion is from monitoring at the Wilton Expansion facility only, and the Year 4 value is from the Baldwin facility only.

a flooded field of harvested corn 4.8 km east of the facilities in spring 2011, outside of the 1.6-km buffered study area. No turbines were curtailed. 2) In fall 2011 an observer detected 1 group of 2 whooping cranes flying approximately 200 m above the most southern group of turbines and traveling southeast away from the facilities. No turbines were curtailed because the cranes were migrating more than 100 m above the height of turbines and were already south of the wind facility and traveling south.

Wessington Springs.—An observer saw 1 group of 12 whooping cranes during the 2010 fall migration, initially about 1.6 km south of the southernmost turbines and flying south. The facility operator chose to curtail turbines for the remaining daylight hours while observers searched for additional whooping cranes; no more were observed.

PrairieWinds SD1.—1) An observer detected 1 whooping crane in spring 2011 along the southern edge of the buffer (i.e., about 3.2 km from the nearest turbine). The whooping crane was flying east-northeast with a group of 15 sandhill cranes. The observer followed the group for 6.4 km until it was past the facility along the southern edge of the buffer. No curtailment was implemented. 2) During the spring of 2013, whooping cranes were observed throughout the season as spring snow storms seemed to stall migration for several weeks. Observers recorded 26 whooping cranes over 9 days within the buffer area of the facility during surveys. Turbines were curtailed on portions of 8 days because cranes approached the facility. A minimum of 35 whooping cranes were also observed at White Lake, about 8.5 km south of the facility. These may have included some of the same individuals also recorded at the facility proper. 3) In fall 2013, an observer recorded 1 whooping crane flying with a group of sandhill cranes high over the facility outside of the survey period. No curtailment was implemented as they were flying above the height of turbines.

Casualty Searches

Observers found no injured or dead sandhill cranes or whooping cranes during daily scans at turbines during migration seasons. Observers found fatalities of other species incidentally, including bats, small birds, and raptors. For the 5 facilities combined, we conducted approximately 92,022 scans over the entire study period.

DISCUSSION

Whooping cranes and sandhill cranes were present near the 5 monitored wind facilities during migration. Their number and location varied greatly across seasons and years near these wind energy facilities.

Sometimes cranes stopped in the general area within a few kilometers of the turbines while at other times they flew high overhead, sometimes so high they were only heard. Of the 6 observations of whooping cranes described above, half were during the spring and half during the fall and they occurred during 3 different years. No crane casualties were recorded, and as a result of the relatively few sightings of whooping cranes over the 3-year study period per facility, minimal curtailment of turbines was required.

Our results could be a product of population size for the whooping cranes; the existence of so few whooping cranes makes the probability of 1 flying near a wind energy facility extremely small. However, during the same time period, 2009-2013, at least 40 whooping cranes in the AWBP died of causes other than turbine collisions, including 29 individuals from 2010 to 2011 alone (Stehn 2010, 2011; Harrell and Bidwell 2013; Harrell 2014). For sandhill cranes it is interesting that so many were observed during our study—over 42,000 cranes, yet we found no causalities under the wind turbines.

Across the migratory corridor of the AWBP, other researchers have also reported an absence of crane fatalities while monitoring at turbines. Within the region of this study, no crane fatalities were detected during crane use surveys at the Titan I wind energy facility in Hand County, South Dakota, in 2010, where both whooping cranes and sandhill cranes were observed (Nagy et al. 2012). Farther away, no crane fatalities were found during post-construction monitoring studies for fatalities of bats and birds at 4 other wind energy facilities within the migration corridor, including NPPD Ainsworth in Brown County, Nebraska; Barton Chapel in Jack County, Texas; and Buffalo Gap I and Buffalo Gap II in Nolan and Taylor Counties, Texas (see Appendix S1 of Erickson et al. 2014). Our study and these other studies suggest that whooping cranes and sandhill cranes do not necessarily avoid the general areas where turbines are located, yet collisions with turbines have so far not occurred.

Wind energy facility operators who choose to locate facilities in the migration corridor have to weigh the cost of curtailment efforts against the cost of doing nothing and potentially killing an endangered species, which would likely incur fines and negative publicity. As a preemptive strategy many wind energy developers place turbines away from wetlands used by cranes to the highest extent possible. This may be even more important for power lines associated with wind energy facilities since they are a known risk of crane mortality. Wind developers are able to obtain quality data on crane use to aid their decision making by working with USFWS personnel to obtain approximate locations of whooping crane sightings from the Whooping Crane Tracking Project Database (CWCTP 2016) and radio-tracked whooping cranes studied by Pearse et al. (2015). In fact, it is a common practice for wind developers with which we work to follow the USFWS's Wind Energy Guidelines (USFWS 2012), obtain information on crane use during the planning stage, and create a model of whooping crane use (TWI 2012) to assess the likelihood for whooping cranes to use a potential wind farm location.

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MEETING OF THE HYDE COUNTY COMMISSION

= =

Transcript of Proceedings
August 10, 2021
1:00 p.m.

= =

Hyde County Commission
Mel Buchheim, Acting Chairman
Ron Van Den Berg, Commissioner
Greg Swenson, Commissioner
Randy Olson, Commissioner
Randy Hague, Commissioner

Marilyn Ring, Auditor
Carrie Stephenson, Planning/Zoning Director

APPEARANCES

Emily Sovell,
Hyde County State's Attorney's Office.

Reported by Cheri McComsey Wittler, RPR, CRR
Precision Reporting, 213 South Main, Onida, South Dakota
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The following transcript of proceedings was taken at the Hyde County Auditorium in Highmore, South Dakota, on the 10th day of August, 2021, commencing at 1:00 p.m.; before Cheri McComsey Wittler, a Registered Professional Reporter, Certified Realtime Reporter, and Notary Public within and for the State of South Dakota.

MS. STEPHENSON: We do have Cheri Wittler here. She's a court reporter. So this will be all transcribed. So when you do speak, please speak clearly and loudly so she can hear you.

And if you are on the speaking list, as you come up I won't start your time yet but please say your name and she may need you to spell it for her as well so it can be part of the proper record. Once that gets done, we'll start your time so that won't be part of the three minutes as you're getting yourself on the record.

CHAIRMAN BUCHHEIM: Casey Willis, do you want to step forward, about your application for the conditional use permit, please.

MR. WILLIS: Sure.

My name is Casey Willis. I'm with Engie North America. I'm the developer on this project. This is the North Bend Wind Project we're proposing. It's in both Hughes and Hyde County this time, whereas Tripe H was exclusively in Hyde County.

We started this project about the same time as the Triple H Project, started approaching some of the landowners in 2015 or so assessing the wind regime. To date we have about 40,000 acres of land under easement with participating landowners, and that accounts for approximately 40 landowner groups in both Hughes and

Hyde County.

I mentioned we started this in 2015. We've done fairly extensive wind studies and biological assessments and other field studies as well as an interconnection evaluation. It does take quite a bit of time to get through. That was started in roughly 2017.

So in terms of major contracts for the project, we don't have power purchase agreements signed for the project just yet. We're actively submitting bids to various entities, and we're convinced that it's a fairly competitive project, as was Tripe H.

We've selected to use for this project a GE wind turbine. I'll go over some of the nuances, but it's essentially the same turbine that was installed in Tripe H. It's just a newer upgrade of it. They periodically do software upgrades and tweaks to their products that are kind of minor in nature to improve the performance, and that's essentially what the difference between the two is.

Same DOT contractor, Wanzek, would be utilized for the project, given their familiarity. And from the target standpoint, if everything aligns, we would like to start construction in early '22, which would put this project into commercial operation toward the end of the year in 2022.

So the overall generation capacity of this project is slightly smaller than Triple H. Triple H was 250 megawatts. This one is 200 megawatts. And that's determined by the interconnection capacity and size that's available along the line.

We're proposing -- in the CUP application we're proposing a request to build up to 51 locations in Hyde County. Concurrently, we're also proposing 27 locations in Hughes County. The point of interconnect is actually on an existing line that crosses through the area. It's a power line operated by Western Area Power Authority.

Some of you may have heard the scoping meeting that we had tied to their process back in January. What this would entail is WAPA would build a new switchyard, essentially, on that line, and we would build a substation immediately adjacent to it.

Both the switchyard that WAPA would construct and the project substation are actually located on leased land that's owned by the South Dakota State Lands. This is different than what we did with Triple H where we acquired small parcels. Slightly different there.

Similar to Triple H, there's no overhead transmission line because of the location of where we're proposing to build the substation. All of the turbines themselves will be connected underground by a 34 and a half kilovolt collection line. And at the project substation the voltage is then stepped up by transformer to 230 kV and injected onto the line.

In terms of operations and maintenance, I think you're all aware that we built an O&M facility on the 47 down here. Just given the fact that we're using essentially a very similar turbine and they're both from GE, our plan at this point is to utilize that facility to serve both projects.

We sized that area. It's probably sufficient to build another small building if we needed to on it. So rather than building a whole new operations and maintenance, that's the likely plan.

And the last item that is in this proposal is the request to build a permanent met tower. This helps us assess the performance in the wind regime. It's downwind from one of the -- a set of the turbines that are proposed. I'll go over that in a bit.

On to the schematic that shows the turbine itself, again, we're proposing to use a 2.82 megawatt 127 GE turbine. This is very similar to the Triple H one. It's about 10 feet taller so it comes in at just under 500 feet, which is actually on the smaller side of actually turbines that we're using these days. And it has more to do with the wind regime here being a lot stronger than other places so typically it results in a smaller turbine.

The next page it shows our usable turbine area. I mentioned at the beginning we had roughly 40,000 acres under easement. And that reflects basically the graphic on the left. Once you factor in all of the setbacks from the county ordinances, both Hughes and Hyde, they're actually very similar. And once you factor in other environmental constraints, microwave beam paths, houses, it significantly reduces the area where we can actually place turbines.

The map on the right shows what we're left with in terms of where we can place turbines. In addition to that -- it doesn't actually show the layout on this particular map. I'll show that on the next page. But that's what we start with when we try to figure out where to place turbines.

And then there's an element in spacing them appropriately. They can't be too close together. So it becomes a bit of a challenge to figure out where to place turbines.

The next map shows the proposed array in both Hughes and Hyde County. Again, 58 are proposed in Hyde. And it shows the three permanent met tower locations generally in the southeast.

The next map is the array, but it's just -- it's Hyde County alone. The first is both. The second is Hyde County alone. It shows the same thing.

And then I mentioned the State Lands parcel that we were proposing to build the substation on. It's generally in the southeast side of the area that we're looking at, on Holabird grade in Section 16. Again, the orange parcel shows our project substation, slightly smaller, and WAPA would propose a slightly larger one at 21 acres, I believe is what they're looking at.

The next two maps show the permanent met tower locations in just greater detail in terms of where they're at in the section. Again, we would only build one of those. We're looking at three. Over time we kind of rule out a couple of them. But, again, only one. It's an unguyed met tower 100 meters tall.

In terms of the benefits that this project would generate, the capital investment in both Hughes and Hyde County -- it's actually listed incorrectly as only Hyde County. It's both counties. It's 265 to 285 million.

I mentioned that there would be shared O&M activities. This would result in an additional 8 to 10 people being employed to support both projects at that existing facility. Similar to Triple H, there would be about up to 400 employed during construction with 130 on-site at any one point.

Over the life of the project it's expected to, on average, generate about $967,000 annually in production taxes based on the state statutes and how those are calculated for over 29 million over the life of the project.

Of that amount, roughly 293,000 goes to the state, and the counties would split, based on the percentage of the generation in each county, approximately 337,000, followed by the school districts with the exact same amount.

This project would also -- you know, similar to Triple H, it will create stable and long-term payments to the landowners that are participating and indirect benefits from the use of local services and sales tax generation.

The next slide shows the compliance with the Hyde County standards. We're in compliance with all of the established dwelling -- the array accounts for all of the setbacks from dwelling units, county roads, highways, noise, and shadow flicker.

In a couple of instances there are waivers that have been granted, just a couple of them, by the participating landowners, as allowed in the county's ordinance.

And then, finally, the last slide shows our preliminary schedule. So the main pacing item for us is actually the PUC facilities permit. It can take up to nine months, and the formal filing date was June 23. So the way this statute works is that the PUC has exactly nine months to render a decision on it. It can be done earlier, but the schedule essentially accounts for it taking the full time.

If that happens and it takes the full time, our plan would be to start construction in roughly April of 2022. Concurrently, we'd be starting final design and engineering on the project as we go into elements of like the delivery and the road use maintenance plan that would start later this fall and go up to the point of starting construction.

Civil work is started immediately and it would be done in the late spring to early summer and then shortly thereafter turbine deliveries would commence with the POI and substation being energized roughly October of 2022. And, finally, commercial operation date would be targeted around November.

Again, all of this is a little -- you know, for us to have this happen, all of our major contracts need to come together, permits need to be approved. In the event that, as an example, we are not able to sign a power purchase agreement in a timely fashion, it may push the schedule a little bit. But that is our target timeline.

So overall our request that's accounted for in the CUP is -- as I stated in the beginning, we're requesting the approval of up to 51 turbine locations, similar to what we requested with Triple H, the ability to move those around to microsite those turbines about 250 feet in the event that there's a need to, as long as it complies with all of the county standards.

The requested approval to build a project substation on the east half of Section 10, Township 110 North, Range 73 West, and that's the State Lands parcel I referenced, and that's along Holabird grade. And then finally the ability to build one of three proposed permanent met tower locations. And that would be an unguyed met tower up to 100 meters tall.

So that's what I have, if there's questions.

MS. STEPHENSON: Casey, I had one. I see that you had some that signed the waivers for the noise and the shadow flicker. I believe the only waiver that you provided was the one for the setback.

Do you have those other ones available?

MR. WILLIS: Yeah. It may actually be just in Hughes County. I'll double-check that.

MS. STEPHENSON: Okay. We just didn't have any in your application so we would need copies of those.

MS. SOVELL: And I think there was actually reference to six waivers on the setback.

MS. STEPHENSON: Yep. We fixed that.

CHAIRMAN BUCHHEIM: You said there's supposed to be 6 to 8 people employed in this deal.

MR. WILLIS: 8 to 10. That's on top --

CHAIRMAN BUCHHEIM: How many was supposed to be employed in the last one? You always said they would be living in Highmore and paying taxes and renting houses.

How many people will be working here on this project? I mean, to maintain them, keep them up.

MR. WILLIS: Right. So for Tripe H I believe it is about 15.

CHAIRMAN BUCHHEIM: Yep. I don't think we have any of them living here in Hyde County.

MR. WILLIS: I don't know. I don't know where they live. It's not something that --

CHAIRMAN BUCHHEIM: So it's something that instead of preaching that they're going to be living here and telling everybody that they're going to be living here and buying groceries, kids will be going to school here, well, that's not the case really. I just want to make sure that people know that.

MR. WILLIS: Yeah. I mean, it's not like we can dictate --

CHAIRMAN BUCHHEIM: I know. But when you preach they'll probably be living here --

MR. WILLIS: They have the opportunity.

CHAIRMAN BUCHHEIM: -- and attending school, that's really not -- that's kind of a false statement.

Another thing I had to say about your haul road agreement, where they're supposed to be traveling on them certain roads, well, there's a lot of times they weren't on the right roads.

MR. WILLIS: We tried to fix that where there were issues.

CHAIRMAN BUCHHEIM: Well, there were a lot of issues with it. I think that's got to be really strict. If that happens again, it's a sad situation.

MS. SOVELL: Casey, the haul road that's the working draft, is it the same in Hyde County -- despite the map differences, is it the same one they're using in Hughes, do you know?

MR. WILLIS: Yeah. Because Hughes has never dealt with a wind project so it seems like the logical thing to start with is what we did with Hyde. That's the template that we redlined and I sent to Mike and Carrie a couple of weeks, a month ago. That's exactly what they have as well.

COMMISSIONER HAGUE: Are you going to build it even if Hughes County doesn't go with it?

MR. WILLIS: It would be challenging, to be honest with you. We would have to reassess that. If you talk about reducing the project 30 -- by 35 percent, you're burdening the capital cost of the project, and it makes it costlier and less competitive. Ideally, no.

COMMISSIONER HAGUE: Okay.

COMMISSIONER OLSON: What is the per unit per person per year? What do they get?

MR. WILLIS: Per unit per person per year? Are you talking about the compensation to the landowners?

COMMISSIONER OLSON: Yes.

MR. WILLIS: That's proprietary. It's not something that we share. There's a confidentiality provisions in the easement.

COMMISSIONER OLSON: Okay.

CHAIRMAN BUCHHEIM: And how about your safety issues? I brought up the safety issues numerous times on that other project, but nobody ever did nothing about it.

MR. WILLIS: What safety issues? Can you clarify for me?

CHAIRMAN BUCHHEIM: Coming out of the gravel pit.

MR. WILLIS: We are not using that gravel pit again.

CHAIRMAN BUCHHEIM: I know it. And that's fine. But you never ever did straighten up that last problem I had with it.

MR. WILLIS: Right. No. I understand that there were issues that were raised.

CHAIRMAN BUCHHEIM: Yeah. And that little sign you put up down there, 10 miles an hour, that would never hold up in a court of law.

MR. WILLIS: I'm just telling you categorically we're not using that gravel pit because of the issues that occurred. We looked, at our own expense, at other options to supply gravel to alleviate that concern.

CHAIRMAN BUCHHEIM: Anybody else got any questions up here on the board?

MR. WILLIS: Can I step down?

CHAIRMAN BUCHHEIM: Yep.

MS. STEPHENSON: Do you guys have any other questions before we start the public portion?

All right. So we will start with the speakers. The first one on the list is Dick Knox. So, Dick, if you'll spell your name for our reporter here, and then we'll get your time started.

MR. DICK KNOX: Okay. I'm Dick Knox, spelled K-N-O-X. I've been a resident of Hyde County since 1958. My parents moved up here and bought the family farm/ranch that we are still ranching and farming on today.

I was the second generation to work that ranch. My sons, Doug and Dan, are the third generation. And I first come aware of this project because WAPA in Billings, Montana sent me this letter back in January. There's a place to put my name, address, telephone number, my concerns, and add more on the back if I needed to, which I did. I mailed it back to them in February. To this day I've never heard one single thing from them.

A month ago -- there was also a telephone number on here. A month ago I called them up. What did I get? An answering machine that said leave your name, address, telephone number, and we'll get back to you. So far nobody's got back to me.

I also found out that they had a cell phone number there so I called the cell phone number several days later. It just rang and rang and rang. Never even asked me for a message or nothing.

So then here I am today. I'm not -- I want to make this clear. Everything I'm talking about today will be in Pratt Township. That's where our farm is, our ranch is. That's where we operate out of, and that's what I'm talking about.

And I want to also make it clear that I'm not trying to trash this project. I'm going to talk about one thing that's greatly going to affect our operation in Pratt Township, and it's going to make it hard for anybody to live there and for that to be a headquarters of our operation.

So from there, there's 27 turbines projected to be put in Pratt Township, and there's one turbine out of the 27 is all I have a concern with and that's a turbine in Section 2/110/73. And it's Turbine No. 47. And that turbine is within your legal setback. I know that. So maybe I don't even have a legal right to be here. But as a landowner, and I still own land down there, I need to voice --

MS. STEPHENSON: 30 seconds.

MR. DICK KNOX: Okay. Well -- man, that went fast.

Anyway, this turbine is going to cause interference with our farm, and I'm here today to ask that that turbine be removed from Pratt Township. They can put it anywhere else they want to. Get it out of Pratt Township.

Man, I didn't think I could talk 30 seconds, let alone -- well, anyway, thank you for your time. I got to go then.

CHAIRMAN BUCHHEIM: Thank you.

MS. STEPHENSON: Okay. Our next speaker on the list is Paul Knox.

MR. PAUL KNOX: Paul Knox. I'm a lifelong resident, born and raised down there. My concerns, I have several. As being a school board member, the state has advised us through the business manager not to count any of this money that we're supposed to get off these projects until we actually get it. So what's that tell you? They going to go bankrupt in a couple of years and then just nothing here?

Our decommissioning bond is totally inadequate for what's going on down in Oklahoma and Kansas. Hundreds of towers sold to a shell company, and they're basically abandoned, filed bankruptcy, nobody there to clean it up.

Another concern of mine is the native prairie down there. 60 percent of that project's in native prairie, and that's a huge Native American village from Ree Heights to the river to Blunt. There are countless tepee rings down there. In fact, the other day I maybe discovered a turtle effigy on some family ground. Can we not try to protect that a little bit? There's not much native sod left.

And the setbacks. These towers keep getting bigger. Can we at least try to keep them a two-mile setback from a guy's building site?

That's all I have. Thank you.

MS. STEPHENSON: Our next speaker is Nick Nemec.

MR. NEMEC: I'm going to address the roads. Last year when they were doing construction it was probably toward the tail end of the two wettest years we've had in at least my lifetime. And the road -- the Holabird grade, which is the road I'm familiar with, did get pretty beat up.

But I have to give the company credit. They made a good-faith effort while they were in construction to maintain that road as best they could. There were road graders going up and down that road every day trying to smooth out ruts. They brought in more fill for bad spots. And now after they're done with construction --

And it wasn't just the Holabird grade where they were traveling was bad; the Holabird grade north of Holabird, which one of those construction vehicles never set foot on, was bad too. The roads were bad all over. And so it wasn't just construction that was causing bad roads. It was the weather that was causing the bad roads.

They did a good-faith effort of repairing them, I think. I'm on the Holabird grade just about every day. And, to my judgment, it's back to previous condition. In fact, on road approaches into fields they've actually improved them, and where township roads and county roads intersect, they've increased the radius so it's easier to get a semitruck around a lot of those corners. The approaches into fields, they've increased the radiuses there so it's easier to get a truck in and out of the field.

When they were hauling their extra dirt away, if you got ahold of them, they were more than willing to haul dirt to you to improve a field approach that wasn't one they were using. If you had a tower that bordered some of our land -- was on your land or -- they put these tower roads in to get to their towers.

Some of their tower roads are as good as a county road, and they don't mind if you use them to access your fields so that's a great improvement there. And so the road situation, I think, is way better than it was previously.

And then as far as setbacks, my daughter and son-in-law live --

MS. STEPHENSON: 30 seconds.

MR. NEMEC: My daughter and son-in-law live a mile and a half from wind turbines. And she says they don't even notice them. Now I realize they're further back than what the setback is, but they don't even hardly notice the turbine out there on the horizons.

MS. STEPHENSON: Our next one is Dan Knox.

(Mr. Knox distributes a document.)

MR. DAN KNOX: My name is Dan Knox, K-N-O-X. I want to thank you for the opportunity to speak to you on behalf of our farm and our family. I'd like to present a case for the removal of site 47 due to the proximity of our farm and, most importantly, my home.

Unless I am misunderstanding this, there's eight sites that have to be removed from this proposal, regardless. Hyde County themselves, with a similar board, eliminated two sites from the previous project. With the prevailing winds being from northwest to southeast, this proposed project will definitely carry sound onto our personal residence. We already experience sound from the previous project with a north wind on a calm day. It is the intensity of the added decibels that we are most concerned about.

I'd like to point out on those maps that I handed out that we own land on three sides of the quarter that site 47 sits on; therefore, this would truly put this tower in the middle of our farm.

I've stood up at previous meetings, always advocating for more legitimate setbacks to nonparticipating members. At the last meeting I went on record saying that I think it's only fair to respect the person who was there first. In this case, it's my family and I.

I also pointed out that Hyde County has ordinances to prevent participating members from pushing a feedlot or hog barn up against existing nonparticipating members' residences. The time I've spent around these turbines makes me firmly believe that with the prevailing winds at this site, even the approximate mile-ish setback is just not sufficient.

The landscape of our area has changed drastically due to these towers, and with the proposed project many of our acres will seem engulfed by this wind farm. And at the risk of sounding hypocritical, I would like everyone to know that I do have towers. My brother and I have many acres in the last project that we did not sign up. However, we purchased land that had towers constructed on it, as a result of an existing easement, that was not removable.

MS. STEPHENSON: 30 seconds.

MR. DAN KNOX: Once again, I'd like you to take into consideration that this tower I do believe with the northwest winds, especially with snowfall and as the tree leaves -- in the fall and winter, that sound will carry drastically more than even in the summer months. And I'd just like you to take that into consideration.

And I appreciate your time. Thank you.

MS. STEPHENSON: Our next speaker will be Doug Knox.

MR. DOUG KNOX: Doug K-N-O-X.

Doug Knox. I'm representing the Richard Knox Family Farm. We at the Richard Knox Family Farm feel we need to have our farm and farmyard safe and inviting in order to keep our family farm alive. Our farm has been in Hyde County since 1958, as my dad mentioned, with the next generation, my son Mason, also wanting to farm.

I feel the Richard Knox family has been an asset to Highmore and Hyde County. We have always supported Highmore and the county by buying local when available and always actively participated in community fundraisers benefiting local causes and people in need. Our farm has three owners, three to four full-time employees, and three to four part-time employees, all residents of Hyde County and/or Highmore.

As part owner of the Richard Knox Family Farm, I'm asking you the board to remove Turbine 47 to keep the turbine effects away from our farmyard. It is my understanding that many sites will have to be removed anyway. Removing this turbine will also allow substantial relief from the turbine effects on our headquarters and also benefit the large amounts of wildlife our farm shelters.

Our farm is not a 30-year project in Hyde County. It's a forever farm in Hyde County.

MS. STEPHENSON: Our next speaker will be Tonja Jessen.

MS. JESSEN: Tonja Jessen T-O-N-J-A J-E-S-S-E-N.

I'm going to kind of -- I guess just to summarize with Nick, I agree with everything he said with the roads. I drove a lot of roads last year, both Hyde, Hughes, Sully County, and it didn't matter where you were, it was just because of the wet. And I do agree that the company did an excellent job of putting those roads back to where they were.

As far as the speed and safety, I agree it can be an issue. However, as being a farm/ranch operation ourselves, we're driving big trucks up and down these roads too. And I've met a lot of grain trucks and gravel trucks over the years, and they don't slow up. They don't scoot over. You're riding your butt on the ridge -- on the lovely ridge that the county leaves on the edge, you're leveling it off. So the roads have always been an issue, but I do feel that the company did an excellent job of bringing them back, if not better than what they were.

As far as archaeological issues, I do know they have someone out there that's been checking, and this has been going on since the first project. They were doing the bird surveys, the archaeological. They're not taking any of it for granted.

They have a guy I don't know however long ago this first go-around went. And I did a lot of research and I talked to a gentleman that has all that research and he's done all the tepee ring sites and archaeological digs. Because they are a valuable part of our South Dakota history, and we don't want to disturb. And I feel like they're going an excellent job of making sure to keep that in mind when they're doing this project.

As far as the people living in Highmore or Hyde County, I do feel that there would be more people living here if we had housing. We are doing better. We have a housing committee that's working and trying to get homes into Highmore, but it's very hard to come into Highmore and live when you don't have housing available for someone to come in. And, unfortunately, Miller is not that far away. I do know some people are living over in Harrold. So, you know, you've got to get your housing where you can find it.

I have an old classmate that wants to move back to the area, and she cannot find land anywhere or a house to move back to. So it is hard to move back in. And, to be honest, how welcome do you suppose these new people are going to feel when they know this has been a fight from day one. They're probably not going to feel real welcomed into the community if they know the community's constantly been fighting it from day one. So that's something we need to work on.

MS. STEPHENSON: 30 seconds.

MS. JESSEN: But I do agree. I think we have a great opportunity to help build our community, our city, our county, and our school. To quote -- I think it's on the bottom of the school's website. We have the opportunity to build a better tomorrow today and I think this will be a great opportunity to expand and bring money and more people in.

MS. STEPHENSON: Mark Klebsch.

MR. KLEBSCH: K-L-E-B-S-C-H. I don't know. After that I got nothing.

I agree with everything she said about the roads. They're really way better than they are now than they used to be. You know, they were trouble during

construction, but they're really good now.
As far as -- I'm not going to argue about this and that and all that. But how it's been lately, I really do wish I had a dozen of them. Because one complaint, the cows never get under them. Jeez, the cows just love them. The shade would be great. But other than that, I agree with Nick and Tonja, all that stuff.
Thank you.
MS. STEPHENSON: That was the last person we had signed up. We will do one last call for anybody that wishes to speak.
Okay. Seeing none, we have no more speakers.
CHAIRMAN BUCHHEIM: Do you want to address anymore, Casey?
MR. WILLIS: Yeah. Just the one that comes to mind is the archaeological issues. I will just say that it's something we as a company and most wind companies actually take a complete 100 percent avoidance approach.
So basically we go out and survey the areas of disturbance prior to disturbance, identify eligible sites, flag them with construction fencing and avoid. We reroute things. That's not just this project, Triple H, that's every project.
Just generally speaking in an area where there is a lot of agricultural operations, there's not that

many sites typically. You would find more intact -- it's not to say there are not any. There certainly are. We're finding them out. And that's the whole point is we're flagging and avoiding them. That's what we do.

CHAIRMAN BUCHHEIM: Anybody have any questions here?

Make a motion to close the evidence.

COMMISSIONER SWENSON: I will.

COMMISSIONER HAGUE: Second.

CHAIRMAN BUCHHEIM: All in favor signify by saying aye.

(All indicate aye.)

CHAIRMAN BUCHHEIM: Any deliberation about this, or what do we want to do?

THE COURT REPORTER: Excuse me. Emily, do you want their discussion on the record?

MS. SOVELL: We have not in the past put the deliberations on the record. Do you want the deliberations on the record?

CHAIRMAN BUCHHEIM: No.

(The Commission deliberates off the record.)

COMMISSIONER VAN DEN BERG: I'll make a motion to approve the North Bend Wind Project with the contingency to eliminate Tower 47.

MS. SOVELL: Any contingencies regarding the haul road or anything else or just that contingency?

COMMISSIONER VAN DEN BERG: Just that contingency.

MS. SOVELL: Motion's on the table.

(Discussion off the record.)

COMMISSIONER HAGUE: I'll second it if we don't have any other major troubles.

CHAIRMAN BUCHHEIM: I got a lot of concerns about them staying on their own roads and everything they've been preaching to us. It never ever materialized before, what I thought.

(Discussion off the record.)

CHAIRMAN BUCHHEIM: All those in favor of this motion signify by saying aye.

(All but Chair Buchheim indicate aye.)

CHAIRMAN BUCHHEIM: Myself, nay.

MS. SOVELL: Okay. So then what we have done historically is with respect to the application, there is a signature for the original that will be take by the auditor for formal record.

I'll circulate that to Mel acting as Chair. You sign there.

In addition, historically we have adopted findings. I will go through what -- I have two different templates. I'll use something similar to in the past while he's signing off on that. You can tell me if you want other findings.

The hearing was held on August 10, 2021, before the Hyde County Board of Adjustment concerning Conditional Use Application No. CUP2021-001. The board, having heard evidence from Applicant North Bend Wind Project, LLC, hereby makes the following findings:

No. 1, Notice of the Hearing was published on July 29, 2021, and August 10, 2021. No. 2, proponents of the Conditional Use Permit stated in part economic development, increased tax base, compliance intent with local zoning ordinances, employment opportunities, and similar benefits.

Opponents of the CUP stated in part concerns regarding noise, impact upon established farmsteads, and impact upon archaeological sites.

Were there any other portions you want with respect to --

No. 4, the board further finds the Applicant's mode of conduct and location will not hinder the enjoyment and use of nearby properties and will not disrupt the appropriate use of land and resources of the county.

In closing, the board concludes the Conditional Use Permit is granted contingent upon removal of Tower

No. 47.

Does anyone want to motion to approve those findings with respect to CUP2021-001?

COMMISSIONER SWENSON: Yeah.

MS. SOVELL: Motion by Greg Swenson.

Second by --

COMMISSIONER VAN DEN BERG: I'll second.

MS. SOVELL: Okay. Call the vote.

CHAIRMAN BUCHHEIM: Rollcall or just --

MS. SOVELL: Let's do rollcall on this.

CHAIRMAN BUCHHEIM: Ronnie.

COMMISSIONER VAN DEN BERG: Yes.

CHAIRMAN BUCHHEIM: Greg.

COMMISSIONER SWENSON: Yes.

CHAIRMAN BUCHHEIM: Randy.

COMMISSIONER OLSON: Yes.

CHAIRMAN BUCHHEIM: Randy.

COMMISSIONER HAGUE: Yes.

CHAIRMAN BUCHHEIM: Myself, aye.

MS. SOVELL: So, with that, if you conclude the hearing or motion to conclude at this time, I will run down and put those in signature form, and we'll have them back up if you can wait for Carrie.

(Discussion off the record.)

COMMISSIONER VAN DEN BERG: I'll make a motion to adjourn.

CHAIRMAN BUCHHEIM: Anybody want to second that?

COMMISSIONER SWENSON: Yeah.

CHAIRMAN BUCHHEIM: All in favor signify by saying aye.

(All indicate aye.)

(The hearing is concluded at 1:55 p.m.)

STATE OF SOUTH DAKOTA)
:SS CERTIFICATE
COUNTY OF SULLY)

I, CHERI MCCOMSEY WITTLER, a Registered Professional Reporter, Certified Realtime Reporter and Notary Public in and for the State of South Dakota:

DO HEREBY CERTIFY that as the duly-appointed shorthand reporter, I took in shorthand the proceedings had in the above-entitled matter on the 10th day of August, 2021, and that the attached is a true and correct transcription of the proceedings so taken.

Dated at Onida, South Dakota this 10th day of September, 2021.

/s/ Cheri McComsey Wittler
Cheri McComsey Wittler,
Notary Public and
Registered Professional Reporter
Certified Realtime Reporter

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SOUTH DAKOTA DEPARTMENT OF
GAME, FISH AND PARKS
523 EAST CAPITOL AVENUE | PIERRE, SD 57501

Environmental Review Report

Project Information

Report Generation Date:	1/31/2022 11:30:30 AM
Project ID:	2022-01-31-274
Project Title:	Bollweg Trial 1
User Project Number(s):	
Project Type:	NRCS Projects/Practices
Project Activities:	None Selected
County(s):	Hughes
Township/Range/Section(s):	111N074W10; 111N074W11; 111N074W16; 111N074W2; 111N074W21; 111N074W3; 111N074W4; 111N074W9; 112N074W33
Watershed(s) HUC8:	None
Latitude/Longitude:	44.443553 / -99.734661

Contact Information

Organization:	NRCS -SD- Lyman Co
Contact Name:	Kyle Heimerl
Contact Phone:	605-869-2216
Contact Email:	richard.heimerl@usda.gov
Contact Address:	110 S Main Ave Kennebec SD 57544
Submitted On Behalf Of:	

Project Description

This is a test, no follow-up required

Introduction

The vision of South Dakota Department of Game, Fish and Parks (SDGFP) is to conserve our state's outdoor heritage to enhance the quality of life for current and future generations. SDGFP has a state-wide mission to manage wildlife and the habitats upon which they depend for their ecological values and enjoyment by the citizens of South Dakota and visiting publics. SDGFP strives to prevent or minimize unnecessary damage to species and their habitats by offering possible mitigation measures or alternative project actions.

Disclaimer

The information provided in this report can only be used as a site clearance letter if no conflicts with sensitive wildlife resources were detected. This information provides an indication of whether or not public or protected lands and sensitive resources are known or likely to be located near the proposed project's location. The information generated in this report does not replace Endangered Species Act consultation obligations with the U.S. Fish and Wildlife Service (USFWS) for federal listed species.

A majority of the sensitive species records in the report originate from the South Dakota Natural Heritage Database (SDNHD). The SDNHD tracks species at risk and certain unique habitats. These species may be monitored because they are rare, indicative of a vulnerable habitat type, or are are legally designated as state or federal threatened or endangered species. Rare species are those that are declining and restricted to limited habitat, peripheral to a jurisdiction, isolated or disjunct due to geographic or climatic factors or classified as such due to lack of survey data. A list of monitored species can be found at https://gfp.sd.gov/natural-heritage-program/. Many places in South Dakota have not been surveyed for rare or protected species and habitats and the absence of a species from a proposed project area does not preclude its presence. **Accuracy of species lists, report information and project recommendations should be verified after 90 days**.

This project was flagged for further review by South Dakota Game, Fish and Parks. This report is considered a draft for informational purposes only, and is not to be used for environmental clearances. Staff from South Dakota Game, Fish and Parks will contact you within 30 days to follow up.

Project Type Recommendations

No recommendations have been identified for this project type.

Project Location Recommendations
A federally endangered species was documented within or near the proposed project area.

A state endangered species was documented within or near the proposed project area.

Legal Obligations

South Dakota Endangered and Threatened Species Law

This state law (Chapter 34A-8) defines nongame, threatened and endangered species and wildlife and describes the relevant authorities of the Game, Fish and Parks Secretary and Commission. The SDGFP Commission may list, delist or change the status of state threatened or endangered species. The Secretary shall conduct investigations to address information needs on population, distribution, habitat needs, limiting factors and other data gaps to ensure these species are managed in perpetuity. Take of state threatened or endangered species is prohibited except for certain, authorized purposes or to protect life or property. This state law also prohibits the reintroduction of a species on the federal list of threatened or endangered species that is considered extirpated from the state, unless authorized by the South Dakota Legislature. More information about obtaining a state endangered take authorization is available here: https://gfp.sd.gov/forms/endangeredspecies/

Aquatic Invasive Species

South Dakota Administrative Rule 41:10:04:02 forbids the possession and transport of aquatic invasive species (AIS). Any construction vehicles, vessels, or equipment that will come into contact with surface waters in South Dakota that have previously been used outside of the state or in and AIS positive water within South Dakota must be thoroughly power washed with hot water (>140°F) and completely dried for a minimum of 7 days prior to use. All attached dirt, mud debris and vegetation must be removed and all compartments and tanks capable of holding standing water shall be drained and dry. This applies, but is not limited to, all equipment, pumps, lines, hoses and holding tanks. The list of AIS positive waters is available at http://sdleastwanted.com/maps/default.aspx or by calling 605-223-7706.

Federal Laws

The following federal laws contribute to the conservation and management of fish and wildlife resources in the United States: Endangered Species Act, Bald and Golden Eagle Protection Act, Migratory Bird Treaty Act, Clean Water Act, and the Fish and Wildlife Coordination Act. The National Environmental Policy Act (NEPA) requires compliance with these statutes and regulations.

Contact Information

U.S. Fish and Wildlife Service, Ecological Services Field Office *420 S. Garfield Ave, Suite 400 Pierre, South Dakota 57501 605-224-8693*

U.S. Army Corp of Engineers, South Dakota Regulatory Office *28563 Powerhouse Road Pierre, South Dakota 57501 605-224-8531*

Bald and Golden Eagle Protection Act

The Bald and Golden Eagle Protection Act (16 U.S.C. 668–668d) provides for the protection of the bald eagle (*Haliaeetus leucocephalus*) and golden eagle (*Aquila chrysaetos*). Under this federal act, “take of eagles, their parts, nests or eggs is prohibited unless a permit is issued for certain purposes and under certain circumstances as long as the authorized take is compatible with the preservation of eagles. Disturbance resulting in injury, decreased productivity, or nest abandonment by substantially interfering with normal breeding, feeding or sheltering behavior is also considered take. This report does not replace consultation with the USFWS regarding the protection of bald and golden eagles. Eagle nests are protected under this law, whether active or inactive.

Migratory Bird Treaty Act

The Migratory Bird Treaty Act (16 U.S. C. 703-712) provides international protection to migratory bird species included in treaties among the United States, Great Britain, Mexico and Japan. This federal act prohibits the taking, killing, possession and transportation (among other actions) of migratory birds, their eggs, parts, and nests, unless specifically permitted by regulations. This act has no provisions for allowing unauthorized take. Effective steps can be taken to avoid take of migratory birds. Work closely with the USFWS to identify protective measures to avoid migratory bird take. A list of migratory bird species protected under this act can be found at 50 CFR 10.13. Introduced bird species are not protected under this Act. This report does not replace consultation with the USFWS regarding the protection of migratory bird species.

Endangered Species Act

The Endangered Species Act (16 U.S.C. 1531–1544) provides protections for native plant and animal species that are in danger of becoming extinct. Under Section 9, it is unlawful for the “take” of a listed species. This is defined as “... to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect or attempt to engage in any such conduct”. However, a permit may be issued for take that is the result of an otherwise legal activity. Please contact the USFWS to determine if a permit is needed.

The USFWS is in charge of the protection of listed species and their critical habitat. Similarly, other federal agencies are also directed to conserve listed species and ensure their actions do not jeopardize a listed species existence or destroy or adversely modify critical habitat. As such, under Section 7, federal agencies should consult with the USFWS to ensure compliance with this Act.

This report does not replace consultation with the USFWS regarding listed species.

Clean Water Act

The intent of the Clean Water Act (33 U.S.C. 1251 et seq.) is “to restore and maintain the chemical, physical, and biological integrity of the Nation’s waters”. SDGFP has concerns for any impacts to wetlands, streams and riparian habitats from development. We recommend that proper planning take place to first and foremost avoid impacts to wetlands, streams, and associated riparian corridors. If dredge or fill materials will be placed into waterways or wetlands, the U.S. Army Corps of Engineers Regulatory Office should be contacted to determine if a 404 permit is needed.

Fish and Wildlife Coordination Act

The Fish and Wildlife Coordination Act (15 U.S.C. 661-667e) provides habitat protection by requiring a federal agency to consult with the USFWS and SDGFP (i.e. the state fish and wildlife agency) whenever an agency is proposing to control or modify a stream or other body of water. The intent of this consultation is to conserve wildlife resources by preventing habitat loss or damage. If control or modification of a water body is proposed, please begin consultation with the USFWS and SDGFP.

Table 1. Special Status Species Documented within 800 Meters of Project Vicinity

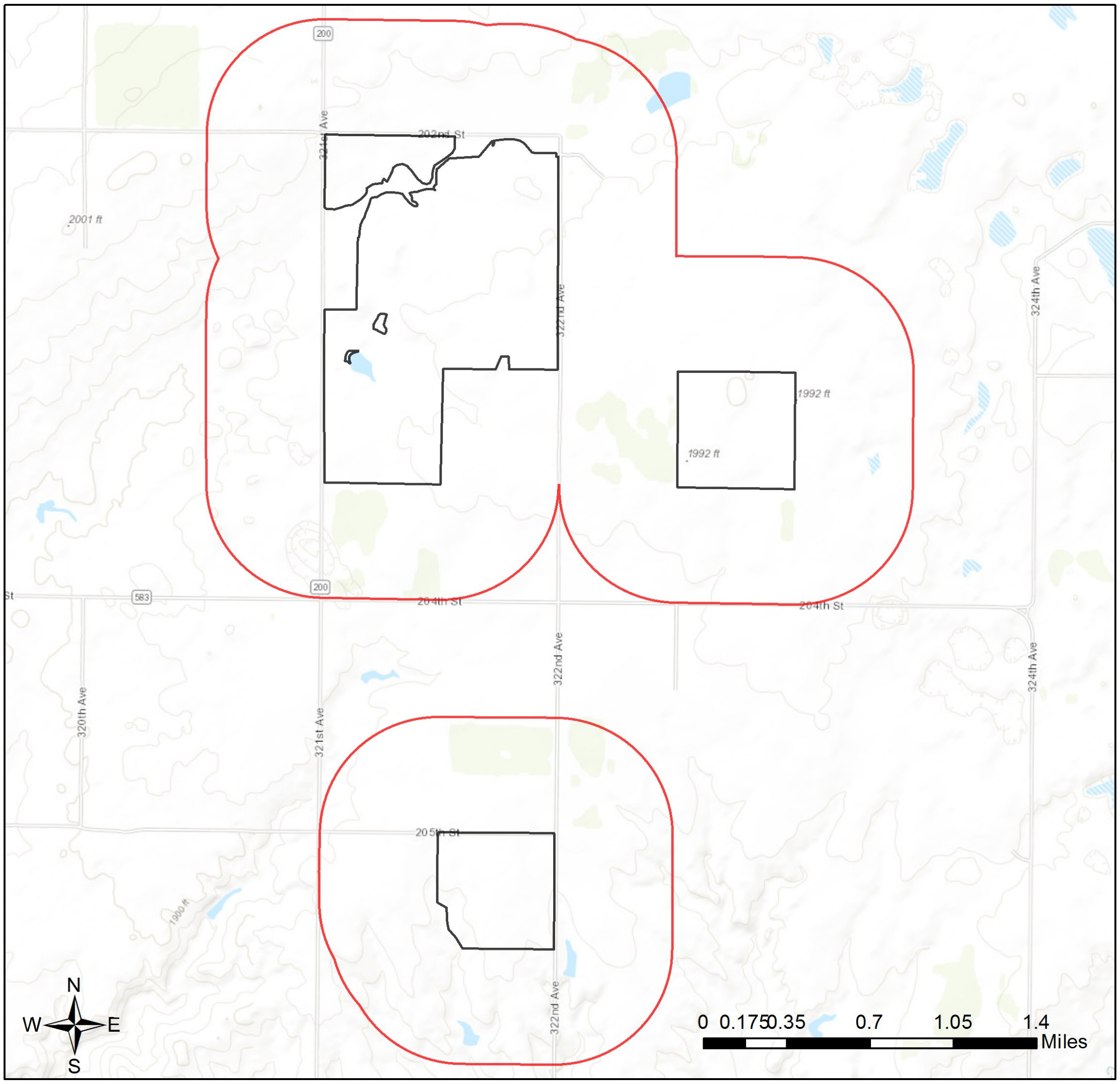
Scientific Name	Common Name	Taxonomic Group	Federal Status*	State Status*	Global Rank*	State Rank*	SGCN
Grus americana	Whooping Crane	Vertebrate Animal	FE	SE	G1	SNA	Yes

SGCN = Species of Greatest Conservation Need, FE = Federally Endangered, FT = Federally Threatened, SE = State Endangered, ST = State Threatened. For definitions of State and Global rank status, please see: https://gfp.sd.gov/rare-animals/ or https://gfp.sd.gov/rare-plants/.

No Protected Lands were detected within the project vicinity.

Bollweg Trial 1

Topo Basemap with Land Ownership, Tribal Lands, and Locator Map



- Project Boundary
- Buffered Project Boundary
- Game Production Areas
- SD Parks and Rec Areas
- School and Public Lands
- The Nature Conservancy Lands

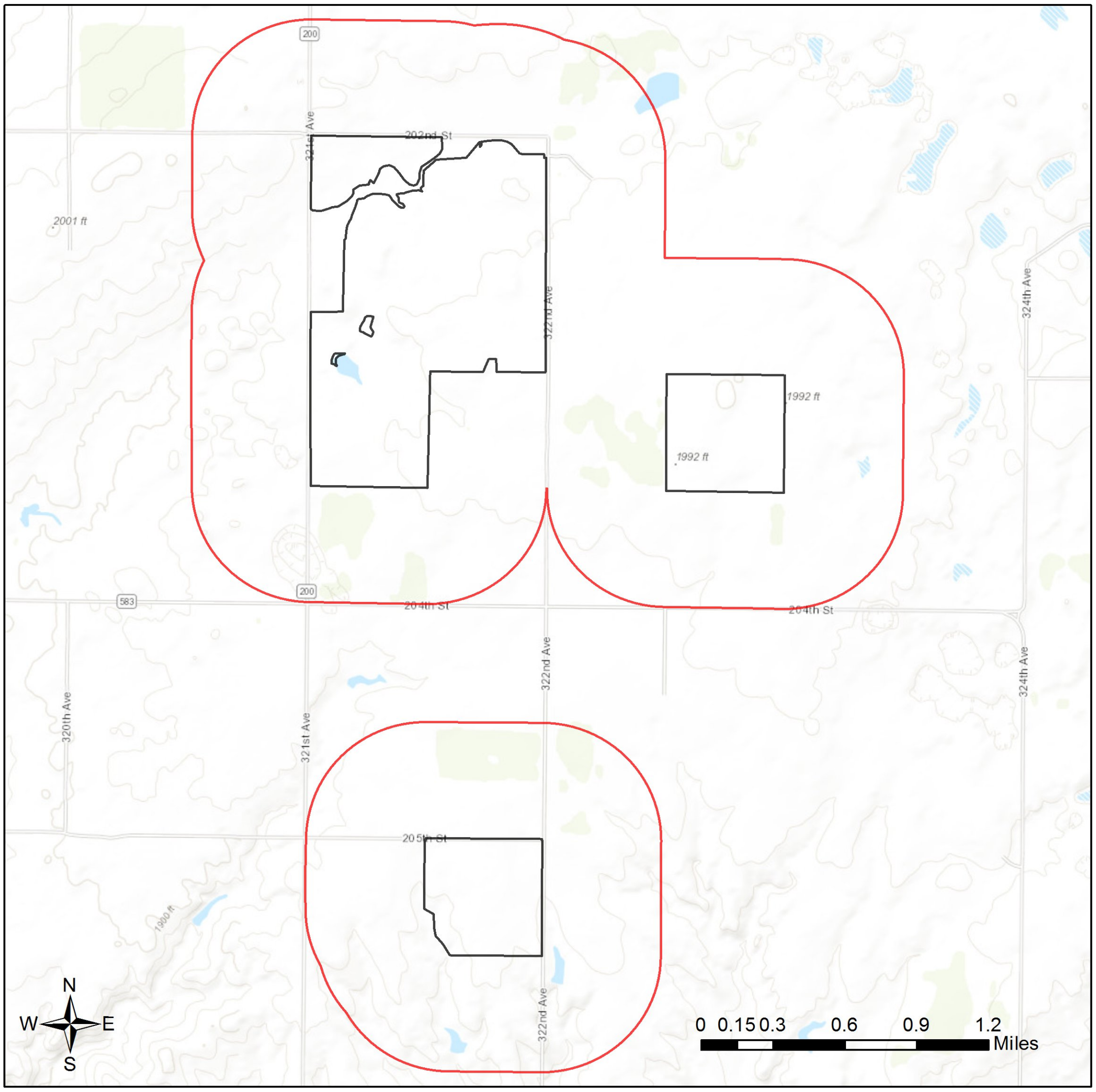
Federal Lands

- National Forest
- National Grassland
- Bureau of Land Management
- Bureau of Reclamation
- Corps of Engineers
- National Fish Hatchery
- National Park Service
- USFWS Wildlife Refuge
- Waterfowl Production Area

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community

Bollweg Trial 1

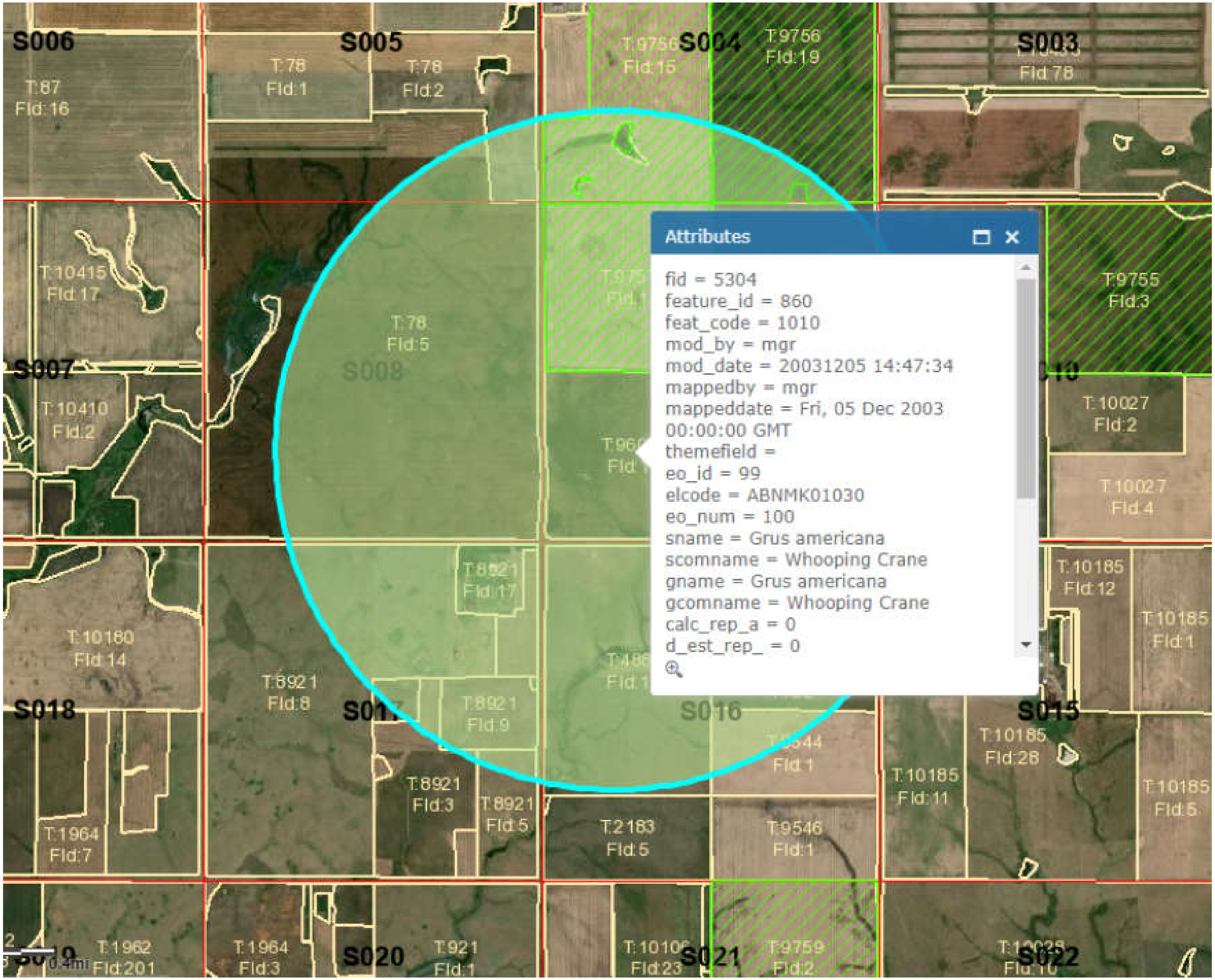
Web Map As Submitted By User



Project Boundary

Buffered Project Boundary

Service Layer Credits: Sources: Esri, HERE, Garmin, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), (c) OpenStreetMap contributors, and the GIS User Community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mappeddate = Fri, 05 Dec 2003
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eo_num = 100
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scomname = Whooping Crane
gname = Grus americana
gcomname = Whooping Crane
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d_est_rep_ = 0