Crowned Ridge Sharp-Tailed Grouse Research Study Annual Report

Crowned Ridge I and II Wind Energy Projects
Grant, Codington, and Deuel Counties, South Dakota

Prepared for:

Crowned Ridge Wind I and Crowned Ridge Wind II, LLC

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WEST

EXECUTIVE SUMMARY

Crowned Ridge Wind I, an indirect, wholly owned subsidiary of NextEra Energy Resources, LLC (NEER), constructed the Crowned Ridge I Wind Energy Facility (CRI) in Grant and Codington counties, South Dakota and began commercial operations in December 2019. Crowned Ridge Wind II, LLC, a wholly owned, indirect subsidiary of NEER, began constructing Crowned Ridge II Wind Energy Facility (CRII) immediately to the south of the CRI Project boundary in May 2020 and began commercial operations in December 2020. Shortly after CRII began commercial operation, ownership of CRII was transferred from NEER to Northern States Power Company (NSP). CRI worked collaboratively with South Dakota Game, Fish and Parks (SDGFP) to develop a prairie grouse research study to better understand the effects of wind energy on prairie grouse populations.

While some information exists on the potential impacts of wind energy development on prairie grouse populations, no studies have directly measured potential impacts to plains sharp-tailed grouse (STGR) population parameters from wind energy infrastructure. The presence of known STGR within CRI and CRII provides a valuable opportunity to evaluate the potential effects of the CRI and CRII turbines on STGR. In accordance with Permit Condition Number 45 of the South Dakota Public Utility Commission order, CRI will undertake two years of independently conducted post-construction prairie grouse lek monitoring to evaluate the Project’s effects on the local prairie grouse populations. In addition, CRI worked collaboratively with SDGFP to develop a Grouse in Lieu Mitigation Plan that incorporates an approved lek monitoring study plan and a robust telemetry study. The overall goal of this study is to quantify the effects of wind energy development on prairie grouse seasonal habitat selection and demography. During the 2020 and 2021 field seasons, lek counts and surveys were conducted within and around CRI and CRII to understand the extent of the local breeding STGR population. In addition, STGR were marked with Global Positioning System (GPS) transmitters to collect information about habitat selection and demography in relation to wind energy infrastructure.

In 2021 STGR lek surveys were conducted where landowner permission was obtained. Surveys were conducted at 20 of 30 known leks in 2021. Breeding activity was documented at 16 of the 20 accessible leks. Nest and brood survival of GPS marked females during the 2021 breeding season was 51.7% and 46.2%, respectively. Female survival during the breeding season was 26.5% and overall survival of male and female STGR from April 01 to November 15, 2021 was 26.3%. Reported demographic rates were generally comparable to other studies evaluating STGR demography. However, all demographic rates were lower than those estimated in 2020. Differences may largely be explained by climatic variability between years. To date, 629,126 locations have been obtained from radio-marked STGR in this study. An additional year of data collection (2022) will allow us to develop a cumulative report on all three years (2020–2022) of data collection following the 2022 field season.

REPORT REFERENCE

Smith, K., C. Stumpner, C. LeBeau, and T. Runia. 2021. Sharp-Tailed Grouse Lek Survey and Capture Annual Report for the Crowned Ridge I and II Wind Energy Projects, Grant, Codington, Deuel Counties, South Dakota. Prepared by Western EcoSystems Technology, Inc. (WEST), Laramie, Wyoming. January 18, 2022.

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INTRODUCTION

Crowned Ridge Wind I, LLC (CRI) an indirect, wholly owned subsidiary of NextEra Energy Resources, LLC (NEER), constructed the Crowned Ridge I Wind Energy Facility in Grant and Codington counties, South Dakota. Construction began on 200 megawatts (MW) of the permitted 300 MW in August 2019 and began commercial operations in December 2019. Crowned Ridge Wind II, LLC (CRII), a wholly owned, indirect subsidiary of NEER, began constructing Crowned Ridge II Wind Energy Facility immediately to the south of the CRI Project boundary in May 2020 and began commercial operations in December 2020. Shortly after CRII began commercial operation, ownership of CRII was transferred from NEER to Northern States Power Company (NSP). CRI worked collaboratively with South Dakota Game, Fish and Parks (SDGFP) to develop a Grouse In Lieu Mitigation Plan (Mitigation Plan; Crowned Ridge Wind LLC 2019a, b) that incorporated an approved lek monitoring study plan and a robust telemetry study to better understand the effects of wind energy on prairie grouse populations, with the overall goal of informing future siting and permitting decisions.

Energy development represents a potential threat to prairie grouse populations directly through habitat loss and indirectly by avoidance of otherwise suitable habitats (Hovick et al. 2014). While the potential impacts of renewable energy development are less well known, there is an increasing body of literature evaluating the response of prairie grouse to wind energy infrastructure (LeBeau et al. 2020). In Wyoming, LeBeau et al. (2014) reported lower greater sage-grouse (*Centrocercus urophasianus*) nest and brood survival in habitats closer to wind turbines two years following development. However, over a 6-year period after development, LeBeau et al. (2017b) failed to detect negative effects on greater sage-grouse nest, brood, or summer female survival, suggesting variability in survival was better explained by temporal variability than wind energy infrastructure. In Idaho, Columbian sharp-tailed grouse (*Tympanuchus phasianellus columbianus*) nest survival was not influenced by proximity to turbines (Proett et al. 2019). Greater prairie chicken (*T. cupido*) nest and female survival was also reportedly not influenced by proximity to wind turbines in Nebraska or Kansas (Winder et al. 2014, Harrison et al. 2017, Smith et al. 2017). Nonetheless, it is well documented that anthropogenic features can increase levels of habitat fragmentation and result in adverse population level effects for prairie grouse (Hovick et al. 2014).

Avoidance behaviors associated with wind energy infrastructure could possibly mask the ability to detect any potential survival consequences. LeBeau et al. (2017b) did find greater sage-grouse selection for brood-rearing and summer habitats was negatively correlated with surface disturbance associated with wind energy infrastructure. Similar displacement behaviors have also been documented for greater prairie chickens, with avoidance of wind turbines in Kansas (Winder et al. 2014). These results suggest that there is some level of indirect loss of potentially suitable habitat as a result of wind energy infrastructure. However, our current understanding does not indicate that avoidance behaviors translate to population level effects (LeBeau et al. 2017a). LeBeau et al. (2020) reviewed studies and conducted a meta-analysis that evaluated the effect of wind energy development on prairie grouse, with the main objective to determine the magnitude of effects of distance to wind turbines on habitat selection, lek attendance, and survival. The body of evidence suggested that impacts to prairie grouse did not extend beyond 1.4 mile (mi, 2.3 kilometer [km]) from wind turbines (Winder et al. 2014), and all 10 studies evaluated investigated the effects of wind turbines along a gradient where the impact was expected to be greatest in close proximity to wind turbines, but dissipated as distance from wind turbines increased.

While some information exists on the potential impacts of wind energy development, no studies have directly measured potential impacts to plains sharp-tailed grouse (STGR; *T.p. jamesi*) from wind energy infrastructure. The presence of known STGR within CRI and CRII (hereafter Projects) and the high probability of lek occurrence surrounding the Projects (Runia et al. 2021), provides a valuable opportunity to evaluate the potential effects of wind energy development on STGR. Understanding how STGR respond to wind energy projects could lead to the development of focused avoidance, minimization, and mitigation measures that benefit all stakeholders and the conservation of these prairie grouse.

Objectives

The overall goal of this study was to quantify the effects of wind energy development on STGR seasonal habitat selection and demography over a three-year period. Specifically, the study analyzed spatial and demographic data collected from lek trends and marked individuals. The study was designed to collect pre- and post- construction data along a gradient from wind turbines and over a period that included construction and operations for multiple STGR breeding cycles. Specifically, the objectives include:

1) Predict the relative probability of habitat selection to estimate potential displacement effects and impacts to habitat connectivity associated with the Projects using prairie grouse use locations and habitat data.
2) Predict nest, brood, and annual adult survival relative to the Project infrastructure.
3) Investigate the possibility of estimating population growth rates relative to the Project infrastructure by incorporating the results from the displacement, survival, and lek trend analyses to provide an overall understanding of the effects on population viability.

The data collected provides detailed information on STGR habitat selection, survival, and movements in and around the Projects and associated infrastructure that can be used to achieve the objectives stated above. The purpose of this report is to summarize information collected during the 2020 and 2021 field seasons. In addition to lek survey and capture efforts, we summarized demographic rates (nesting, brood rearing, and survival), and telemetry location data collected during the first two breeding seasons of the study at the Projects in accordance with reporting requirements of the Mitigation Plan, with emphasis on the 2021 field season.

METHODS

The objectives of the study necessitated capturing, marking, and monitoring approximately 60 STGR per year from leks observed in and around the Projects using Global Positioning System (GPS) technology. An important component of these objectives includes monitoring historic leks and surveying for previously unknown leks within six mi (10 km) of the Projects. Prior to any surveys, landowners were contacted to gain permission to access their lands and all surveys were coordinated with SDGFP and local authorities.

Lek Counts and Surveys

Pre-construction lek surveys along with previously known lek locations provided by the SDGFP identified eight leks within the Projects boundaries and 11 leks within six mi of the Project boundaries (19 total leks; Figure 1). In addition, biologists located 11 previously undocumented leks with ground-based and helicopter surveys during the 2020 field season. During each field season, biologists searched for previously undocumented leks and visited known leks to count the number of individual STGR attending each lek. Biologists conducted ground-based lek counts during three to four occasions at all known leks. Counts were spaced approximately seven days apart and occurred between 30 minutes before sunrise and 90 minutes after sunrise. Observers scanned each lek for a minimum of 10 minutes and counted the total number of individuals attending the lek. In the event a known lek was not located, observers searched within 1.2 mi (1.9 km; when landowner access was possible) to determine if the lek moved. The 1.2 mi search area was based on inter-annual movement of lek locations documented in prairie grouse populations (Hovick et al. 2015). Lek counts were only conducted when conditions included clear to partly cloudy skies, wind speeds less than 20 mi/hour (32 km/hour), and no moderate or heavy precipitation.

Sharp-tailed Grouse Capture

STGR were captured on and near leks using walk-in drift traps during the spring lekking period; March – late April (Haukos et al. 1990). All STGR were sexed, aged, and fitted with a GPS-Ultra High Frequency (UHF) solar-powered telemetry unit with a modified rump-mounting harness (Bedrosian and Craighead 2009). Our goal was to maintain a sample size of 60 individuals entering each field season. Female STGR were targeted for capture. Males were targeted after peak female lek attendance passed. We used Ecotone Harrier GPS-UHF units (Saker GPS-GSM model L) that were approximately 0.6 ounces (17.0 grams) in mass (less than 3% body weight). SDGFP reviewed and approved all capture and handling procedures and collection under a scientific collection permit (Permit No. 14).

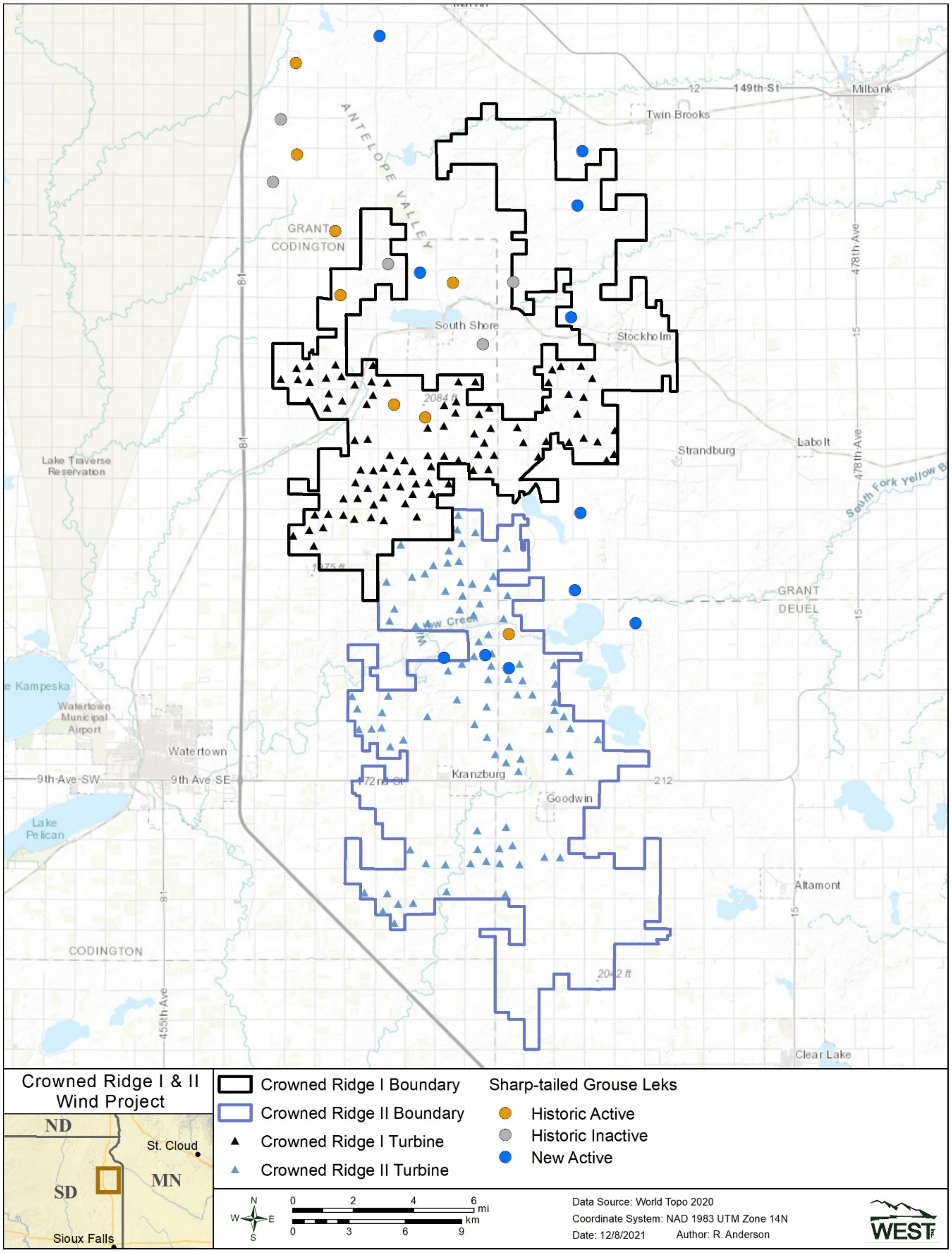

Figure 1. Known historic active, historic inactive, and new active (identified in 2020) sharp-tailed grouse leks within Crowned Ridge I and Crowned Ridge II Wind Energy Project boundaries surveyed during the 2021 breeding season.

Sharp-tailed Grouse Monitoring

The solar-powered GPS units fit to each individual, uploaded locations via cellular transmission to an FTP website. This enabled near real-time assessment of location data. GPS units were programmed to collect locations every 15 minutes. In addition, these units had Very High Frequency (VHF) capability so units could be retrieved in the event of mortality. Following capture, marked STGR were tracked using the uploaded GPS data. In the event locations were localized for more than a day indicating a mortality, a biologist visited the location to retrieve the GPS unit and determine cause of death, if possible.

Nests were located by visually inspecting location data that indicated homing by females to a single location (± GPS location error). STGR have an approximately 23-day incubation period (Johnsgard 1983). If a female left the nest location prior to the 23-day period, we considered the nest to have failed. However, biologists visited each nest to confirm nest fate using visual diagnostics. We defined nest success when at least one egg hatched (Rotella et al. 2004). Hatched eggs typically have a uniform break near the center with membranes that are detached from the egg shell. However, eggs may not always provide information about nest fate due to scavenging once the hen and chicks have left the nest bowl.

The biologist also manually tracked the bird with VHF telemetry to visually observe chicks or observe brooding behavior by the female (e.g., distraction displays or injury feigning) to confirm nest fate. When a female successfully hatched a nest, we determined brood fate during the initial telemetry visit by visually observing the female with at least one chick or the female exhibited brooding behavior. Brood status was confirmed with telemetry visits at approximately 35 days post-hatch, and we considered a female to have successfully reared a brood when at least one chick was present with the female during the 35-day visit. If brood status could not be determined during the 35-day visit, a second visit was conducted the following day.

Analysis

Nest, Brood, and Adult Survival

Survival estimates were calculated for each demographic rate (nest, brood, and adult survival) with the Kaplan-Meier product limit estimator (Kaplan and Meier 1958) modified for staggered entry (Pollock et al. 1989) to provide context with other observed sharp-tailed grouse survival rates. Survival analysis periods (t) for nests, brood, and females and males separately during the breeding season were t = 23 days, t = 35 days, and t = 136 (April 01 to August 15), respectively. For female survival during the breeding season, we assessed survival from April 01 to August 15 to be consistent with previous studies (e.g., Manzer and Hannon 2008, Milligan et al. 2020b). In addition, we assessed survival of all marked individuals during a 228-day study period (April 01 to November 15). We excluded individuals that died within two days of capture (n = 4) to remove potential bias in survival estimates because we could not rule out the possibility that these mortalities were associated with capture-related stress. Captures were conducted to minimize stress and individuals were released as soon as possible following capture. Survival analyses were performed with package ‘survival’ in Program R (Therneau 2020).

Habitat Use and Movement

We used 95% Kernel Utilization Distributions (KUD; default bivariate; Worton 1989) to estimate seasonal home ranges for individuals during the breeding season (May 01 to August 15) to understand the extent of habitats used during the breeding season. Locations were removed from each individual less than three days after capture, and we assumed that individuals acclimated to the GPS transmitters after this period. Seasonal range estimates were restricted to individuals that survived or were not censored due to transmitter failure before August 15 to ensure that seasonal ranges were calculated consistently, by number of locations and over the same time period, for each individual. Seasonal ranges were estimated with package ‘AdehabitatHR’ in Program R (Calenge 2006). The centroid of each seasonal range was used to calculate the distance to lek of capture for each individual in order to provide summary statistics.

RESULTS

Lek Counts and Surveys

We obtained landowner permission to survey 20 of the 30 historic leks and leks identified in 2020 (Table 1, Figure 1). Lek counts occurred between March 24 and April 23, 2021. Of the 20 leks where landowners granted access, 17 were active during at least one visit. The mean count of STGR at leks was eight individuals (Figure 2; range = 1–31). Leks 4 and 5, two historic leks within CRI (Figure 1) were active during the 2021 lekking period. On average, maximum lek counts were approximately 24% higher during 2021 than 2020 (Figure 3).

Table 1. Summary of sharp-tailed grouse (STGR) lek attendance near Crowned Ridge I and Crowned Ridge II Wind Energy Project boundaries surveyed during the 2020 and 2021 breeding seasons.

Lek number	Status	Max count 2020[a]	Max count 2021[a]
1	Historic	2 (0–2)	6 (0-6)
2	Historic	NA[c]	NA[c]
3	Historic	0	0
4	Historic	2 (0–2)	7 (0-7)
5	Historic	22 (18–22)	22 (14-22)
6	Historic	2 (0–2)	0
7	Historic	0	0
8	Historic	NA[c]	NA[c]
9	Historic	5 (1–5)	12 (7-12)
10	Historic	0	2 (0-2)
11	Historic	12 (0–12)	26 (19-26)
12	Historic	NA[c]	NA[c]
13	Historic	0	0
14	Historic	3 (0–3)	8 (0-8)
15	Historic	NA[c]	NA[c]
16	Historic	11 (8–11)	13 (12-13)
17	Historic	0	6 (0-6)
18	Historic	NA[c]	4 (2-4)
19	Historic	NA[c]	NA[c]
20	Located in 2020	7 (5–7)	1 (0-1)
21	Located in 2020	23 (18–23)	31 (24-31)
22	Located in 2020	5 (3–5)	NA[c]
23	Located in 2020	6 (1–6)	2 (0-3)
24	Located in 2020	5[b]	6 (0-6)
25	Located in 2020	9[b]	NA[c]
26	Located in 2020	5[b]	NA[c]
27	Located in 2020	4[b]	13 (0-13)
28	Located in 2020	9[b]	NA[c]
29	Located in 2020	5 (1–5)	NA[c]
30	Located in 2020	16 (12–16)	8 (5-8)

[a] Range of counts in parenthesis.

[b] Located via helicopter survey and were unable to obtain landowner permission for subsequent visits

[c] No landowner permission

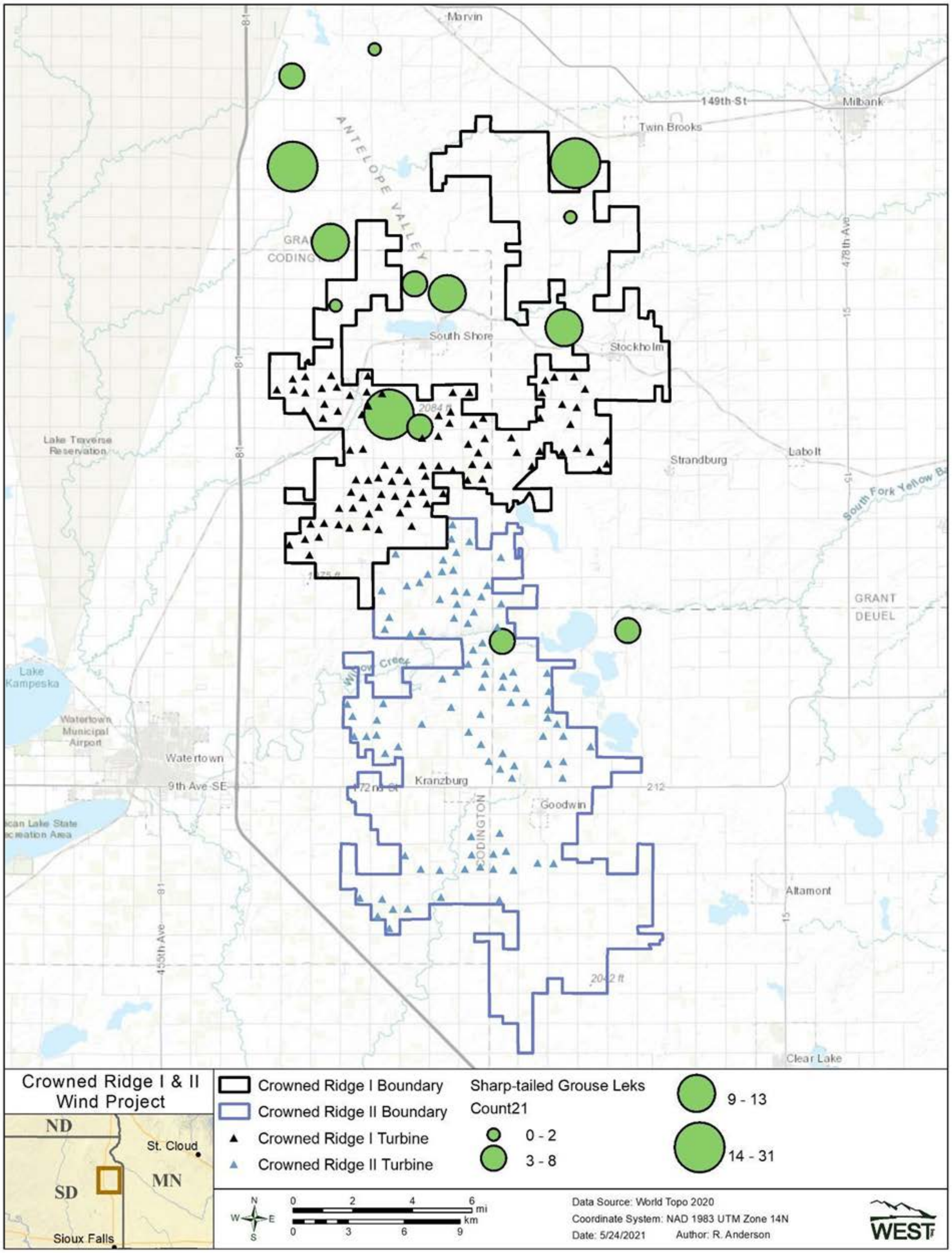

Figure 2. Maximum lek counts at sharp-tailed grouse leks within Crowned Ridge I and Crowned Ridge II Wind Energy Project boundaries surveyed during the 2021 breeding season.

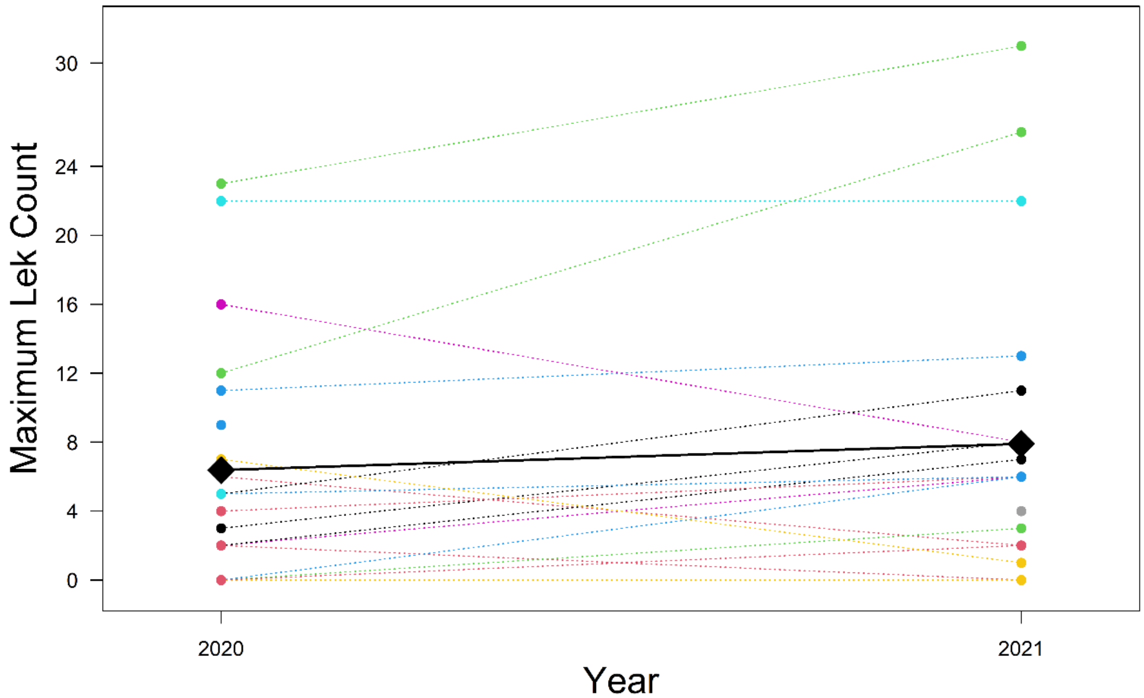

Figure 3. Trends in sharp-tailed grouse (STGR) leks monitored during 2020 and 2021 spring breeding seasons near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects. Pointes connected by dashed lines represent individual leks and the solid black line connects the mean maximum lek count for each year.

Sharp-tailed Grouse Captures

We targeted five leks for capture between April 3 and April 19, 2021 (Table 2). We captured the majority of STGR at Lek 5 and Lek 21 located in the south central portion of CRI and northeast of CRI, respectively. We trapped Lek 9 in 2021, however we did not capture any STGR there. We did not trap Lek 20 in 2021 as we observed minimal lekking activity during surveys. Similarly, we did not target Lek 30 for capture due to fewer individuals observed in 2021 compared to 2020. Overall, we placed 53 telemetry units on 49 females and four males during 2021 (Table 2).

Table 2. Summary of sharp-tailed grouse (STGR) captures at the Crowned Ridge I and Crowned Ridge II Wind Energy Projects during the 2020 and 2021 breeding seasons.

Lek number	# Females	# Males	Capture Dates
		2020	
5	15	5	3/29/2020 − 4/22/2020
9	1	2	4/22/2020 − 4/24/2020
16	3	0	3/30/2020 − 4/21/2020
20	4	0	3/30/2020 − 4/4/2020
21	21	0	3/30/2020 − 4/17/2020
30	7	3	4/13/2020 – 4/24/2020
		2021	
5	15	1	4/3/2021 – 4/18/2021
11	9	2	4/3/2021 – 4/19/2021
16	10	1	4/4/2021 – 4/17/2021
21	15	0	4/3/2021 – 4/11/2021

Nest, Brood, and Seasonal Survival

We detected a nesting attempt from twenty-six of 30 (87%) females available to nest (i.e., those alive or with functioning transmitters after May 10, 2021; Table 3; Figure 4). We documented 26 first nests, and three re-nesting attempts. Kaplan-Meier nest survival estimate to 23 days for all nests was 51.7% (95% confidence intervals [CI] 36.4 to 73.5%; *n* = 15 successful nests). Estimates differed by nest attempt and were 46.2% (95% CI, 30.5 to 69.9 %; *n* = 12 successful first nests), and 100% (*n* =3 successful second nests) for first and second nest attempts, respectively.

Of the 15 successfully hatched nests, we determined brood success of 13 females (Figure 4). We were unable to determine the fate of two females with a hatched nest due to transmitter failure. Six of 13 females had at least one chick at 35 days post-hatch. Kaplan-Meier brood survival estimates from hatch to 35 days post-hatch was 46.2% (95% CI 25.7 to 83.0%).

We estimated survival of females during the breeding season (April 01 to August 15) from 52 individuals (four were excluded due to potential capture related mortality). Thirty-four females died during the breeding season and three were censored due to likely GPS transmitter failure. Kaplan-Meier female survival estimates during the breeding season was 26.6% (95% CI 16.7% to 42.5%). We estimated survival of males during the breeding season from five individuals. Three males died during the breeding season and one was censored due to likely GPS transmitter failure. Kaplan-Meier male survival estimates during the breeding season was 25.0% (95% CI 4.6 to 100%).

Overall, Kaplan-Meier survival estimates of all marked individuals during the 2021 study period (April 01 to November 15) was 26.3% (95% CI 16.8% to 41.4%; Figure 5). Survival estimates varied by month and were lowest in April (64.4%) and highest in September through November (100%; Table 4). Demographic estimates obtained from 2020 and 2021 field seasons are located in Tables 3 and 4, and Figure 5.

Table 3. Sharp-tailed grouse (STGR) demographic parameters assessed during the 2020 and 2021 field season near the Crowned Ridge 1 and Crowned Ridge II Wind Energy Projects.

Demographic Parameter	2020	2021
Nest initiation	91% (31 of 34)	87% (26 of 30)
Nest success	57.1% (42.9 - 76.1%)	51.7% (36.4 – 73.5%)
Brood success	57.9 % (39.5 - 85.0%)	46.2 (25.7 – 83.0%)
Female survival (April 01 to August 15)	43.3% (30.5 – 61.2%)	26.5% (16.7 – 42.5%)
Male survival (April 01 to August 15)	75.0% (50.3 – 100%)	25.0% (4.6 – 100%)
Overall survival (April 01 to November 15)	35.4% (24.2 – 51.6%)	26.3% (16.8 – 41.4%)

Table 4. Monthly Kaplan-Meier sharp-tailed grouse (STGR) survival estimates (95% confidence intervals in parenthesis) from radio-marked individuals near the Crowned Ridge 1 and Crowned Ridge II Wind Energy Projects, April through November, 2020 and 2021.

Month	2020 Survival Estimate (%)	2021 Survival Estimate (%)
April	90.4% (81.7 – 100%)	64.4% (49.8 – 83.3%)
May	73.1% (61.5 – 86.7 %)	68.3 (55.4 – 84.1%)
June	81.8% (69.7 – 96.1%)	70.5% (55.3 – 84.1%)
July	96.2% (89.0 – 100%)	89.5% (76.7 – 100%)
August	95.6% (88.2 – 100%)	93.8% (82.6 – 100%)
September	87.0% (74.2 – 100%)	100%
October	90.0% (77.8 – 100%)	100%
November	94.4% (84.4 – 100%)	100%

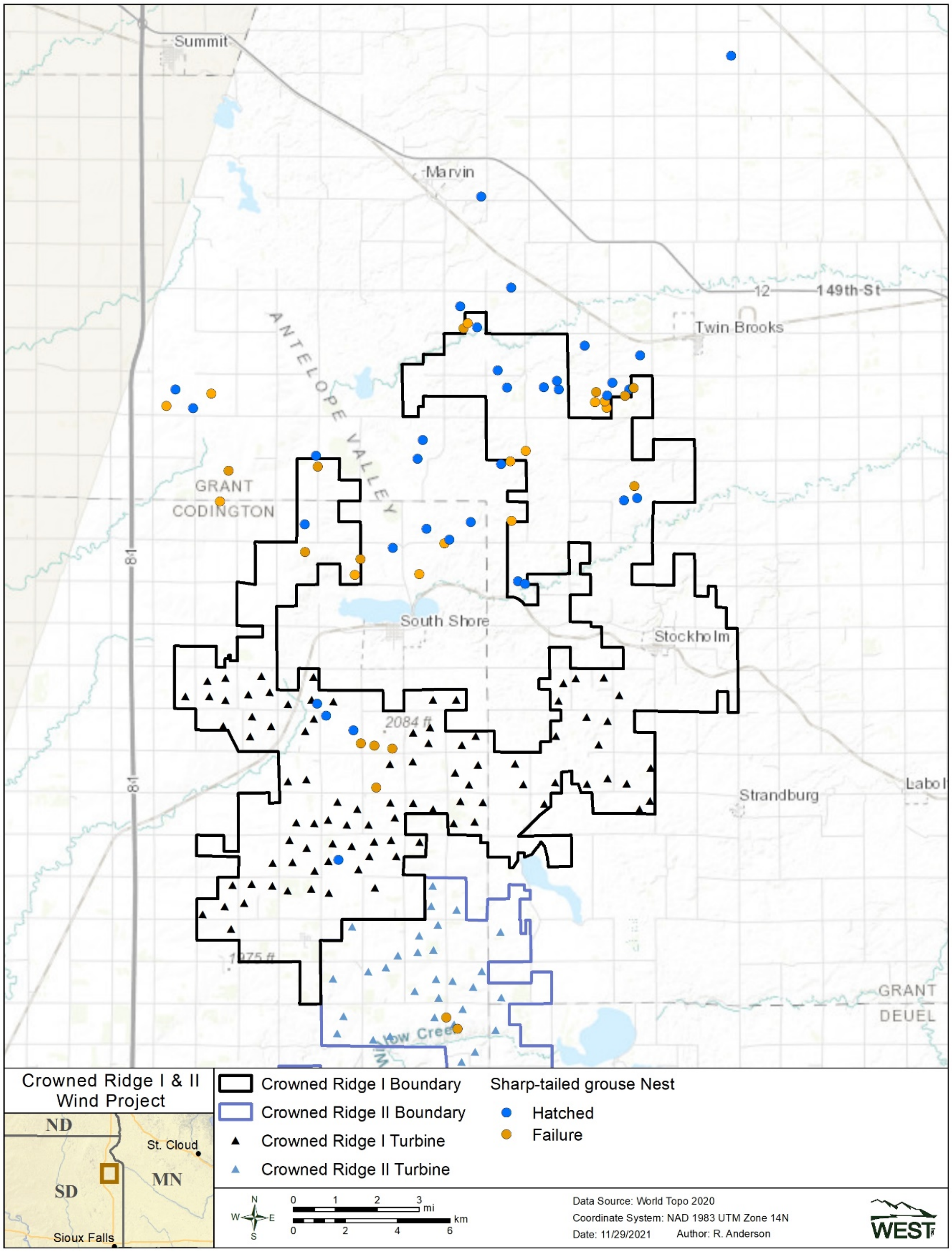

Figure 4. Locations of hatched and failed sharp-tailed grouse (STGR) nests near the Crowned Ridge 1 and Crowned Ridge II Wind Energy Projects during the 2020 and 2021 breeding seasons.

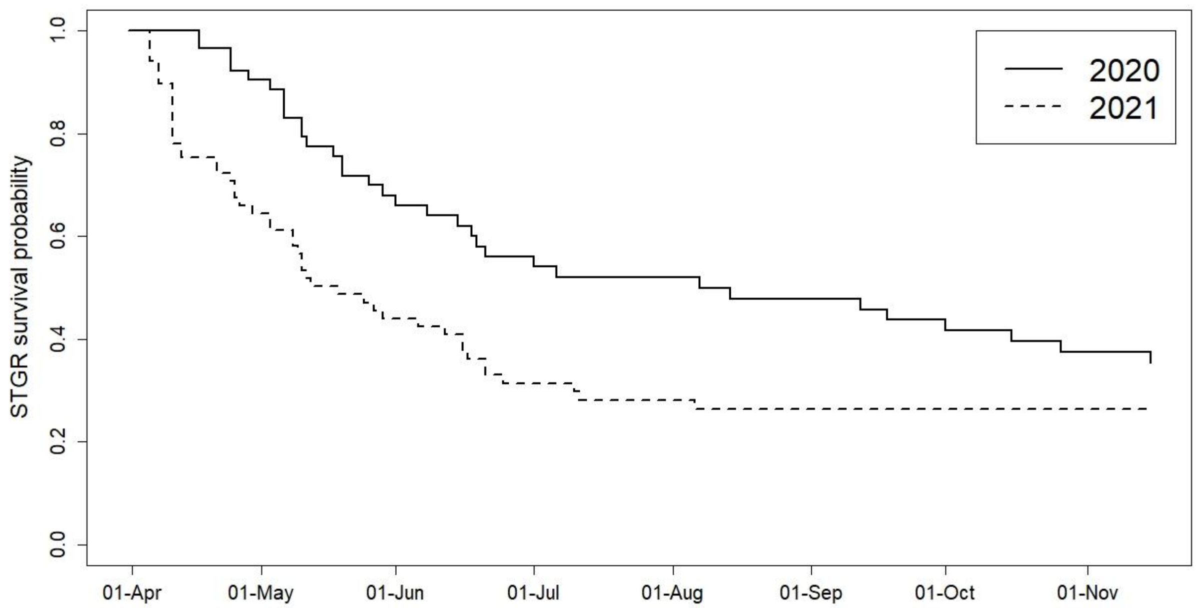

Figure 5. Kaplan-Meier survival estimates and 95% confidence intervals for female sharp-tailed grouse (STGR) near the Crowned Ridge 1 and Crowned Ridge II Wind Energy Projects during the 2020 and 2021 breeding season.

Habitat Use and Movements

To date, we have collected 629,126 locations from radio-marked STGR. The average number of locations per individual is 6,108 (range: 25 to 36,515; Figure 6). Seasonal ranges during the breeding season were calculated from 20 individuals (19 females and one male; Figure 7). Breeding season range size averaged 1.0 mi^2 (2.7 km^2, range: 0.2 to 4.2 mi^2 [0.4 to 10.8 km^2]), and were similar to the size of breeding season ranges in 2020 (0.9 mi^2 [2.3 km^2], range: 0.3 to 2.5 mi^2 [0.7 to 6.4 km^2]). We excluded one female (ID ‘S43’) from these calculations because this individual had a breeding season range size estimate of 37.8 mi^2 (97.8 km^2). This was similar to female ‘S07’ during 2020, which had a breeding season range size estimate of 82.6 mi^2 (214 km^2) and made a large and unique movement during the middle of the breeding season. On average, breeding season ranges during 2021 were 3.8 mi (6.1 km, range: 0.1 to 25.4 mi [0.2 to 40.8 km]) from lek of capture and were similar to the distance between lek of capture and breeding season ranges in 2020 (4.3 mi [6.9 km], range: 0.2 to 36.1 mi [0.3 to 58.1 km]).

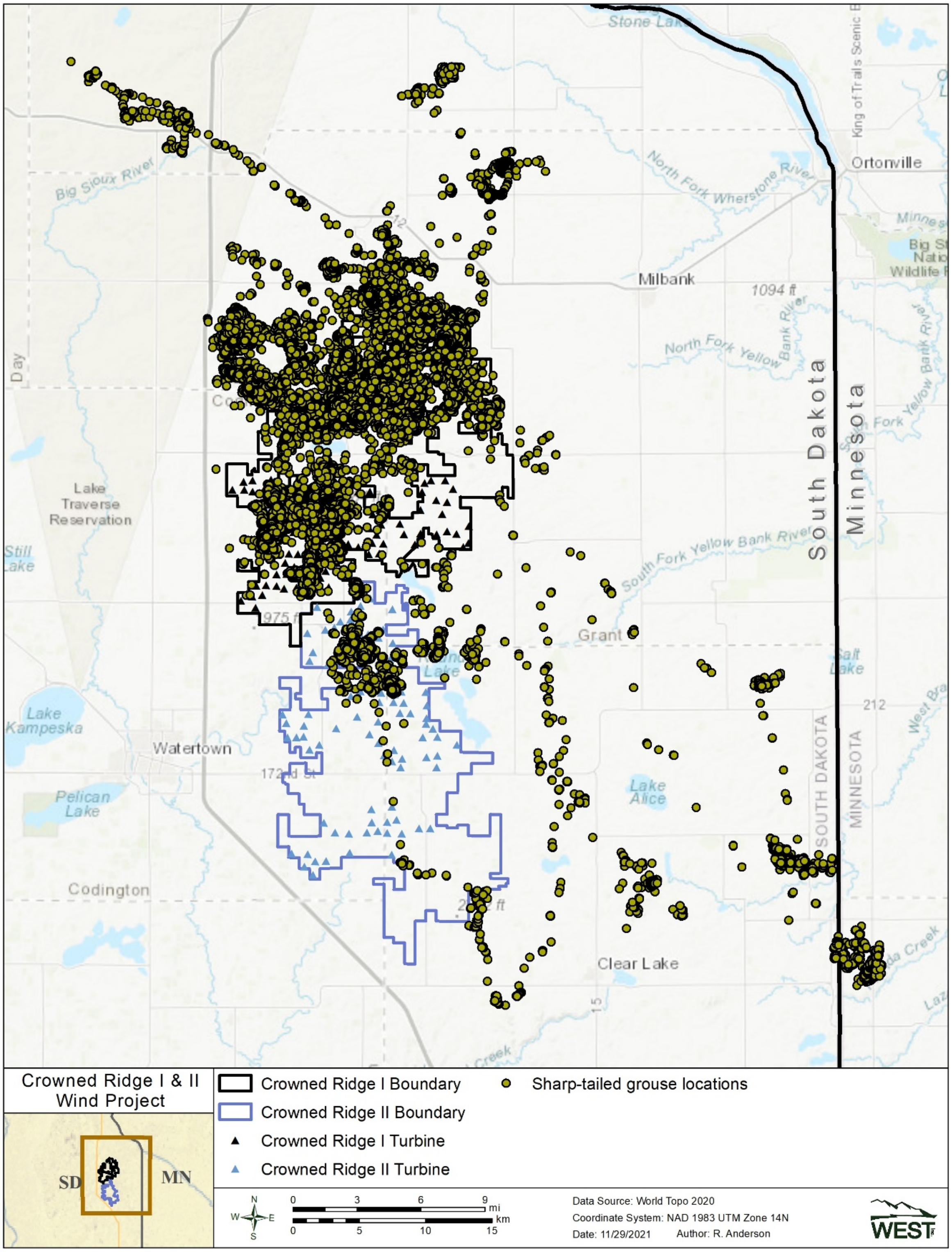

Figure 6. All telemetry locations obtained from GPS marked sharp-tailed grouse between capture and November 15, 2021 near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects.

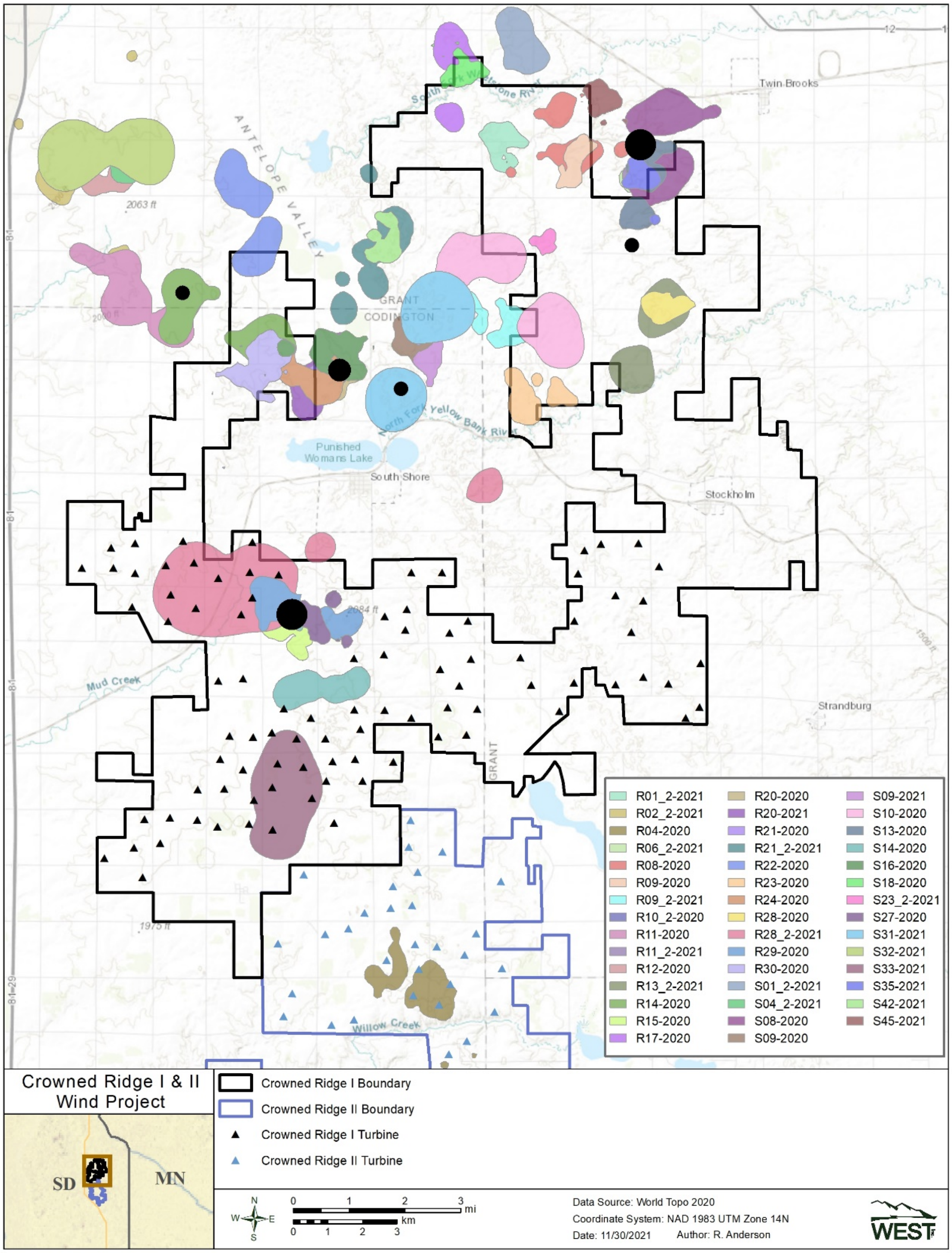

Figure 7. Breeding season ranges of sharp-tailed grouse estimated from Kernel Utilization Distributions near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects during the 2020 and 2021 breeding seasons.

Note: Individuals 'S30' and 'S07' are not included in this figure. 'S30' moved southeast of the Projects to Minnesota.

DISCUSSION AND CONTINUING EFFORTS

This report is intended to provide a progress update and satisfy reporting requirements outlined in the Mitigation Plan for the Projects. This report has addressed the 2020 and 2021 lek survey and capture efforts, and summarizes breeding metrics (nesting, brooding, and survival) and telemetry data collected during both years to address objectives of the Mitigation Plan. We will continue to closely monitor marked individuals to evaluate survival throughout the winter and will begin field efforts for the 2022 field season in March 2022.

We found that nest survival of radio-marked females was approximately 52% during 2021 near the Projects. Nest survival was similar to estimates reported by other studies in eastern Montana and western North Dakota (Burr et al. 2017, Milligan et al. 2020a), as well as in British Columbia (Goddard and Dawson 2009a), and was lower than reported in central (72%; Norton 2005) and northeast South Dakota (59%; Klostermeier 2019). Nest success during 2021 was approximately 5% lower than estimated nest success in 2020.

Similarly, we found that brood survival to 35 days was approximately 46%, and this was within the range of estimated brood survival reported elsewhere (Bouaquet and Rotella 1998, Connolly 2001, Goddard and Dawson 2009b, Geaumont and Graham 2020). Reported female STGR survival during the breeding season was 65% in Montana and North Dakota (Milligan et al. 2020b), and 53% in Alberta, Canada (Manzer and Hannon 2008). We found that female survival during the 2021 breeding season was lower than these reported rates, but overall survival rates fall within the range of those reported elsewhere (Robel et al. 1972, Milligan et al. 2020b, Moyles and Boag 1981). Maximum male lek counts were approximately 24% higher in 2021 compared to 2020, suggesting that reproduction and survival during 2020 led to a higher number of STGR counted at leks in this area during spring 2021. However, all demographic estimates were lower in 2021 compared to 2020. It was generally hotter and drier near the Projects during 2021 compared to 2020. STGR productivity is influenced by temperature and precipitation (Flanders-Wanner et al. 2004, Milligan and McNew 2021), offering a potential explanation for lower demographic rates during the 2021 breeding season.

To date, we have not explicitly evaluated the objectives of the study in context with potential STGR responses to the Projects' infrastructure. An additional year of data collection (2022) will allow us to develop a cumulative report on all three years (2020–2022) of data collection following the 2022 field season.

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