# 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**

**Prepared by:**


**[1]Kurt Smith, [1]Chad LeBeau, [1]Samantha Brown, and [2]Travis Runia**

[1]Western EcoSystems Technology, Inc.
1610 Reynolds Street
Laramie, Wyoming, 82072

[2]South Dakota Game Fish & Parks
895 3rd St. SW
Huron, SD 57350


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# 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 during the study period 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 to develop a prairie grouse research study plan 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; *Tympanuchus phasianellus jamesi*) from wind energy infrastructure. The presence of known STGR within CRI and CRII provides a valuable opportunity to evaluate the potential effects of wind energy development on STGR. In accordance with Permit Condition Number (No.) 45 of the South Dakota Public Utility Commission (Commission) order, CRI will undertake two years of independently conducted post-construction prairie grouse lek monitoring to evaluate the Project on the local prairie grouse populations. In addition, CRI worked collaboratively with South Dakota Game Fish and Parks (SDGFP) to develop a Grouse in Lieu Mitigation Plan (Mitigation Plan) that incorporates the 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 field season, lek counts and surveys were conducted within and around CRI and CRII to understand the extent of the local breeding STGR population. In addition, 61 STGR (10 males and 51 females) were marked with Global Positioning System (GPS) transmitters to collect information about habitat selection and demography in relation to wind energy infrastructure.

STRG lek surveys occurred at 13 of 19 historical leks where landowner access was obtained. Breeding activity was documented at eight of 13 historical leks and at 11 leks that were not previously documented. Thirty-six nests were documented, and 19 females had broods during the first study year. Nest and brood survival of GPS marked females during the 2020 breeding season was 57.1% and 57.9%, respectively. Female survival during the breeding season was 45.4% and overall survival of male and female STGR from April 01 to December 06, 2020, was 31.7%. Reported demographic rates were comparable to other studies evaluating STGR demography.

To date, 296,712 locations have been obtained from radio-marked STGR in this study (mean = 5,395 locations per individual). We identified potential movement pathways during the pre-nesting period that may be useful for identifying important features that facilitate movement between key habitats and may allow for further identification of potentially important movement corridors during

additional seasons once more location data becomes available. Marked individuals will be continually monitored to evaluate survival throughout the winter and we will begin field efforts for the 2021 field season in March 2021. An additional year of data collection (2021) will allow us to begin evaluating the potential effects of wind energy development on STGR and a cumulative report on all three years (2020–2022) of data collection following the 2022 field season.

## REPORT REFERENCE

Smith, K., C. LeBeau, S. Brown, and T. Runia. 2021. Sharp-Tailed Grouse Lek Survey and Capture 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 21, 2021.

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# INTRODUCTION

Crowned Ridge Wind I, LLC (CR I) 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 during the study period 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 the 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 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 and Solem 2018), 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 is to quantify the effects of wind energy development on STGR seasonal habitat selection and demography over a three-year period. Specifically, the study will analyze 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 over a period that includes 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 will provide 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 field season. In addition to lek survey and capture efforts, we summarize demographic rates (nesting, brood rearing, and survival), and telemetry location data collected during the 2020 breeding season at the Projects in accordance with reporting requirements of the Mitigation Plan.

## 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, ground or aerial, 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 historic lek locations provided by SDGFP revealed eight prairie grouse leks inside the Projects boundaries and 11 leks within six mi of the Projects boundaries (19 total leks). Biologists conducted ground-based lek counts during three to four occasions at these identified 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 and species 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.

Biologists traveled public roads stopping at survey points spaced at 0.5 mi (0.8 km) intervals to listen and visually scan for previously unidentified leks. Survey efforts first focused within the Projects' boundaries and then expanded up to six mi from the Projects (Figure 4). Surveys were limited to 30 minutes before sunrise until 90 minutes after sunrise. Surveys were not performed when wind speeds exceeded 20 mi/hour or during moderate to heavy precipitation. During each survey, observers visually scanned the ground using binoculars and unaided eyes for a period of five minutes. Observers simultaneously listened for vocalizations signifying the lekking behavior of male prairie grouse. Helicopter surveys were used to search for previously undocumented leks in areas with limited road access. Following detection of a potential lek, landowners were contacted to obtain verbal permission to access land, verify the lek location, and obtain accurate lek counts. Ground-based lek counts were similar to ones conduced at historical lek locations and occurred three to four times at newly identified leks. Active leks identified during the lek monitoring period were targeted for capturing and marking STGR.

### Sharp-tailed Grouse Capture

Sixty female STGR were targeted for captures. Males were targeted after peak female lek attendance passed. 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). 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; Figure 1). Travis Runia, the senior upland game biologist with SDGFP, reviewed and approved all capture and handling procedures and collection under a scientific collection permit (Permit No. 14).

**Figure 1. A female sharp-tailed grouse captured at the Projects and fitted with a Global Positioning System unit.**

## Sharp-tailed Grouse Monitoring

The solar-powered GPS units fit to each individual contained cellular uploads to an FTP website. This enabled near real-time assessment of location data. GPS units were programed 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, males and females 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 observer 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 the 249-day study period (April 01 to December 06). We excluded individuals that died within two days of capture ($n$ = 6) 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 Movements*

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 this first study year. Locations were removed from each individual less than three days after captured, 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.

To identify travel behaviors and movement paths of individual STGR, we used a segmentation clustering method with the 'segclust2d' package in Program R (Patin et al. 2019). This approach followed a modified version of Lavielle's method (Lavielle 1999) to detect change points between behavioral states in a time series of GPS locations for each individual (Ducros et al. 2020, Patin et al. 2020). We used speed and relative turning angle between successive locations to differential behavioral states. We considered three behavioral states, or clusters, in our models that were user-defined as stationary, loafing/foraging, or travel. The minimum number of locations for each segment, Lmin, was set to five (Patin et al. 2019). Locations identified as travelling were segmented into unique events for each individual, connected by subsequent GPS data time stamps, and then buffered by 200 meters to visually assess potential movement corridors near the Project. Analyses were restricted to locations collected between three days after capture and the date of initiation of the first STGR nest documented during 2020 (May 09).

# RESULTS

## Lek Counts and Surveys

We obtained landowner permission to survey 13 of the 19 historic leks (Table 1, Figure 2). Lek counts occurred between March 11 and April 17, 2020. Of the 13 leks where landowners granted access, eight leks were active during at least one visit. The mean count of STGR at historically active leks was seven individuals (Figure 3; range = 2–22). Leks 4 and 5, two historic leks within CRI were active during the 2020 lekking period (Figure 2).

We performed ground surveys at 1,382 points between March 17 and April 17, 2020, to locate leks within the Projects and the surrounding area out to 6 mi (Figure 2). In addition, helicopter surveys covered approximately 199 square mi ($mi^2$, 515 square km [$km^2$]) between March 29 and April 3, 2020. We located and confirmed 11 previously undocumented leks through these efforts. The mean count of STGR at previously undocumented leks was nine individuals (range = 4–23).

The majority of historically active leks occurred in the northern portion of the Projects and surrounding area. Previously undocumented leks were also located in this general region. The absence of historic and newly documented leks in the southern portion of the area is likely due to relatively small amounts of intact grasslands in this area. Because prairie grouse leks exhibit yearly movement (Hovick et al. 2015) and lek visitation is highly variable (i.e., leks disappear and/or reappear from year-to-year; Schroeder and Braun 1992), the status of the 11 previously undocumented leks may change in subsequent years.

**Table 1. Summary of sharp-tailed grouse (STGR) lek attendance near the Projects during the 2020 breeding season.**

| Lek number | Status | Max STGR count[a] |
|---|---|---|
| 1 | Historic active | 2 (0–2) |
| 2 | Unknown (no access) | NA |
| 3 | Historic inactive | 0 |
| 4 | Historic active | 2 (0–2) |
| 5 | Historic active | 22 (18–22) |
| 6 | Historic active | 2 (0–2) |
| 7 | Historic inactive | 0 |
| 8 | Unknown (no access) | NA |
| 9 | Historic active | 5 (1–5) |
| 10 | Historic inactive | 0 |
| 11 | Historic active | 12 (0–12) |
| 12 | Unknown (no access) | NA |
| 13 | Historic inactive | 0 |
| 14 | Historic active | 3 (0–3) |
| 15 | Unknown (no access) | NA |
| 16 | Historic active | 11 (8–11) |
| 17 | Historic inactive | 0 |
| 18 | Unknown (no access) | NA |
| 19 | Unknown (no access) | NA |
| 20 | New active | 7 (5–7) |
| 21 | New active | 23 (18–23) |
| 22 | New active | 5 (3–5) |
| 23 | New active | 6 (1–6) |
| 24 | New active | 5[b] |
| 25 | New active | 9[b] |
| 26 | New active | 5[b] |
| 27 | New active | 4[b] |
| 28 | New active | 9[b] |
| 29 | New active | 5 (1–5) |
| 30 | New active | 16 (12–16) |

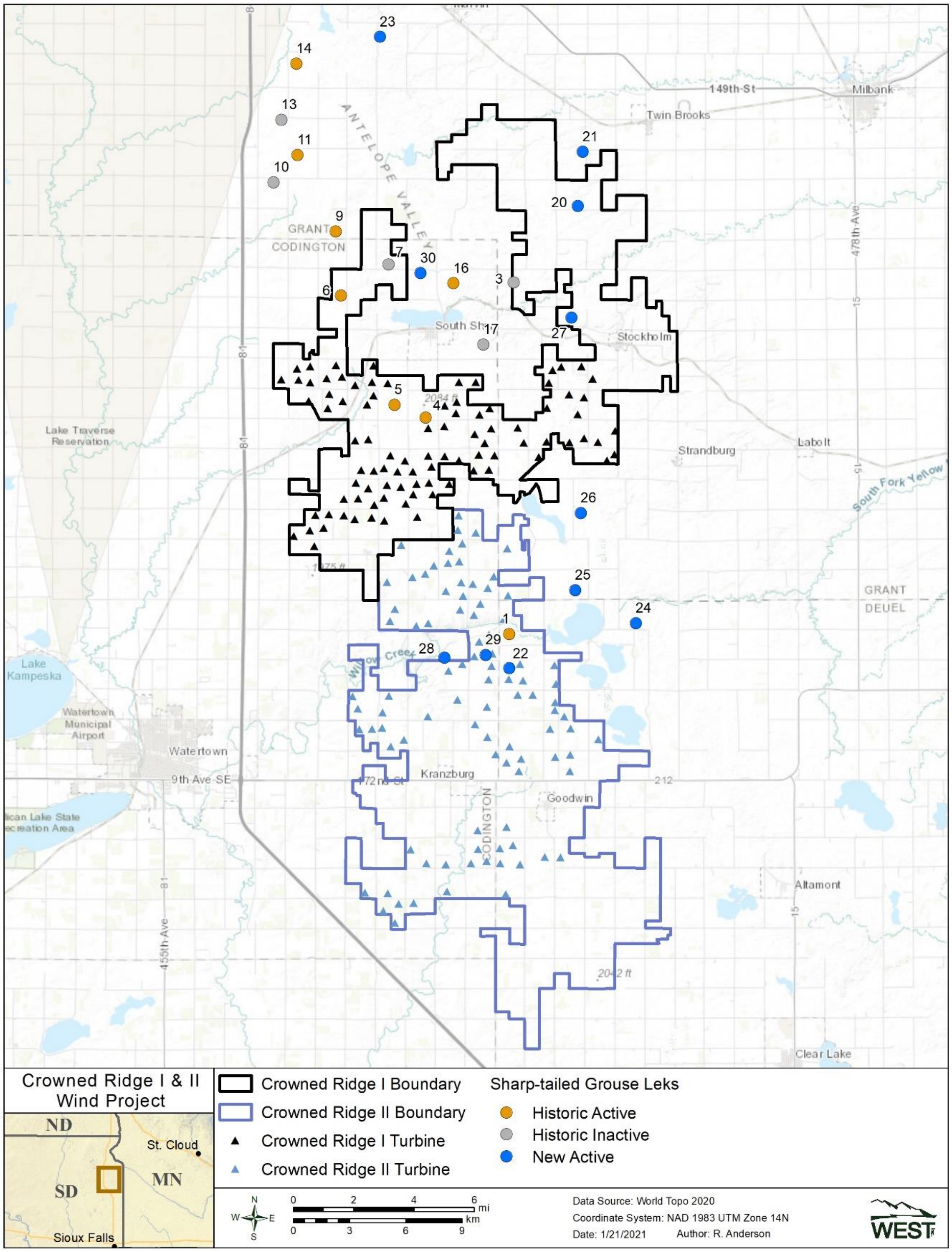


**Figure 2. Known historic active (orange circles), historic inactive (grey circles), and newly identified (green circles) sharp-tailed grouse leks within Crowned Ridge I and Crowned Ridge II Wind Energy Project boundaries surveyed during the 2020 breeding season.**

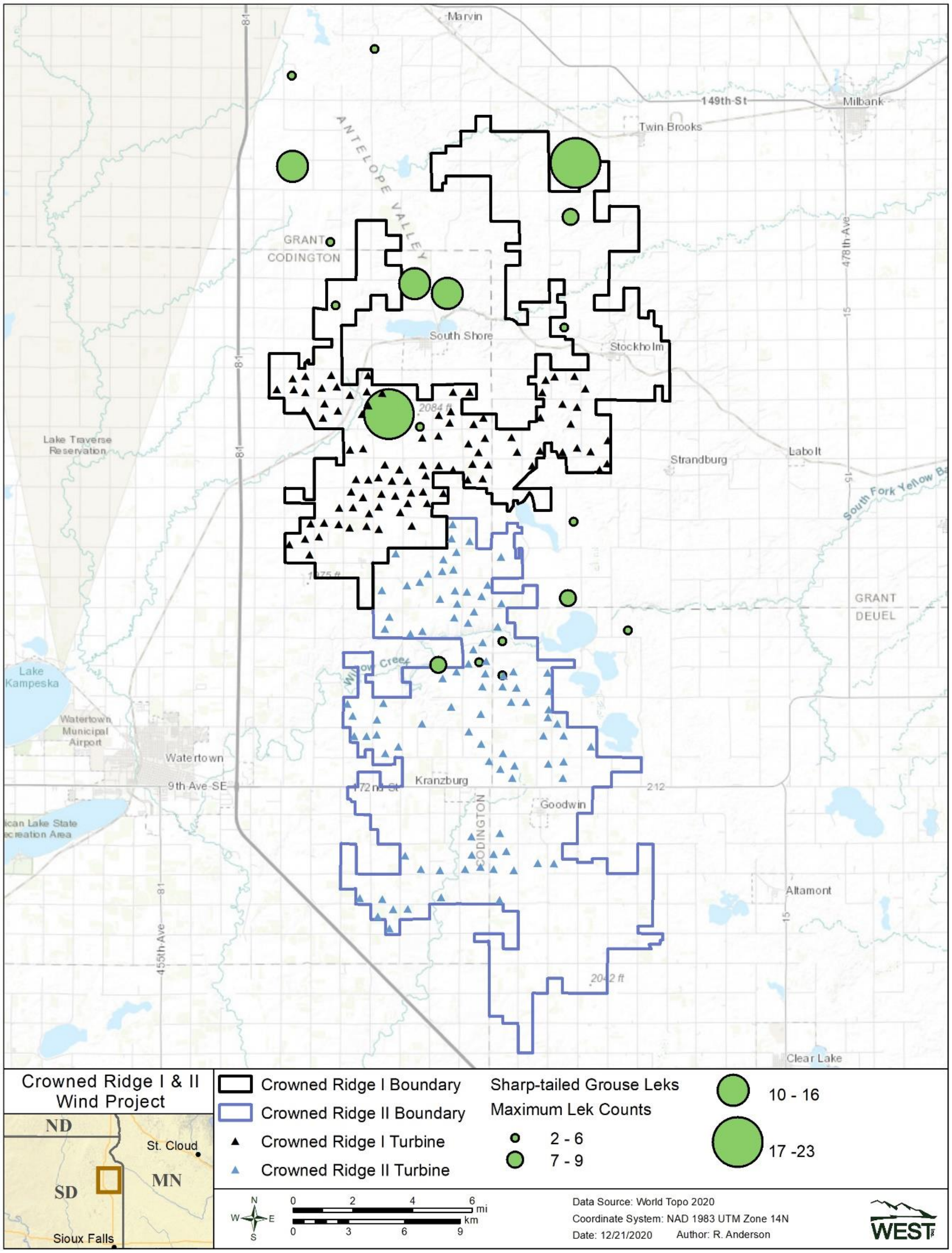


**Figure 3. Maximum lek counts at historic and newly identified sharp-tailed grouse leks within Crowned Ridge I and Crowned Ridge II Wind Energy Project boundaries surveyed during the 2020 breeding season.**

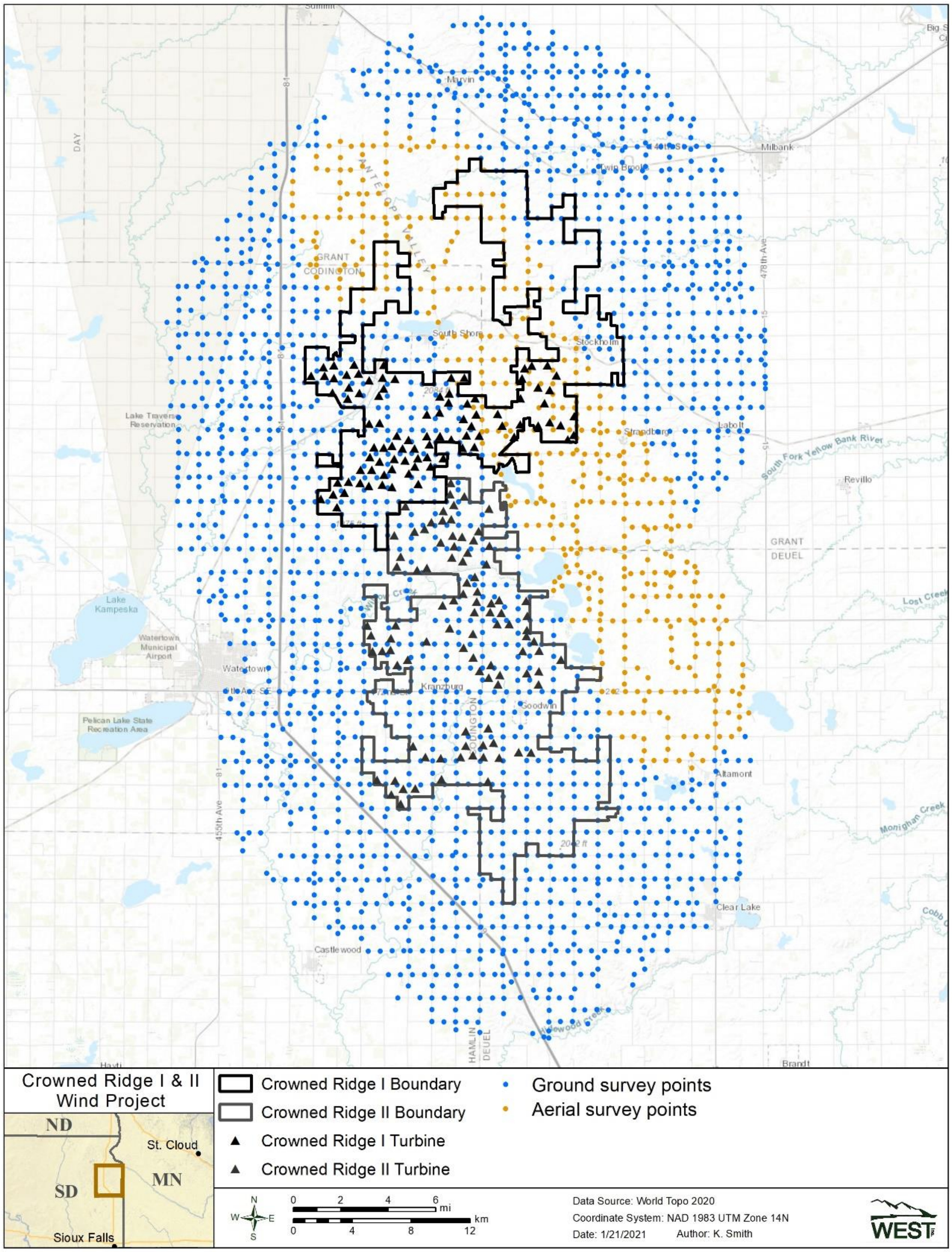


**Figure 4. Locations of ground (blue circles) and aerial (orange circles) survey efforts for sharp-tailed grouse leks.**

Note: aerial surveys were not restricted to survey points and surveyed locations near survey points.

### Sharp-tailed Grouse Captures

We captured STGR at six lek locations (three of the 8 historically active leks with landowner permission and three of the 11 newly identified leks) between March 29 and April 24, 2020 (Table 2, Figure 5). We targeted leks that had at least five individuals present and were within a reasonable proximity to roads. For example, lek number 11 had a maximum count of 12 individuals, but was located greater than one mile from an accessible road (Table 1, Figure 2), so we did not attempt to capture individuals at lek 11. 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. Overall, we placed 61 telemetry units on 51 females and 10 males.

**Table. 2. Summary of sharp-tailed grouse captures during the 2020 breeding season**

| Lek number | Number of Females | Number of Males | Capture Dates |
|---|---|---|---|
| 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 |

### Nest, Brood, and Seasonal Survival

Thirty-one of 34 (91%) females available to nest (i.e., those alive or with functioning transmitters after May 10), initiated a nest (Figure 6). We documented 31 first nests, and five re-nesting attempts. We were unable to access land to determine the fate of one first nest attempt, so inference was made from 35 nests. Kaplan-Meier nest survival estimate to 23 days for all nests was 57.1% (95% confidence intervals [CI] 42.9 to 76.1%; $n$ = 20 successful nests). Estimates differed by nest attempt and were 60% (95% CI, 44.8 to 80.4%; $n$ = 18 successful first nests), and 40% (95% CI 13.7 to 1.00%; $n$ = 2 successful second nests) for first and second nest attempts, respectively.

Of the 20 successfully hatched nests, we determined brood success of 19 females with hatched nests (Figure 7). We were unable to determine the fate of 1 female with a hatched nest due to lack of access. Eleven of 19 females had at least one chick at 35 days post-hatch. Kaplan-Meier brood survival estimates from hatch to 35 days post-hatch was 57.9% (95% CI 39.5 to 85.0%).

We estimated survival of females during the breeding season (April 01 to August 15) from 46 individuals (five of 51 were excluded due to potential capture related mortality). Twenty-three 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 45.4% (95% CI 32.5% to 63.3%; Figure 8). We estimated survival of males during the breeding season from nine individuals (one of 10 was excluded due to suspected capture related mortality). Two 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 75.0% (95% CI 50.3 to 100%).

Overall, Kaplan-Meier survival estimates of all marked individuals during the study period (April 01 to December 06) was 31.7% (95% CI 20.8% to 48.3%). Survival estimates varied by month and were lowest in May (72.9%) and highest in July (96.2%; Table 3). One male and one female were harvested by hunters on September 19 and November 27$^{th}$, respectively.

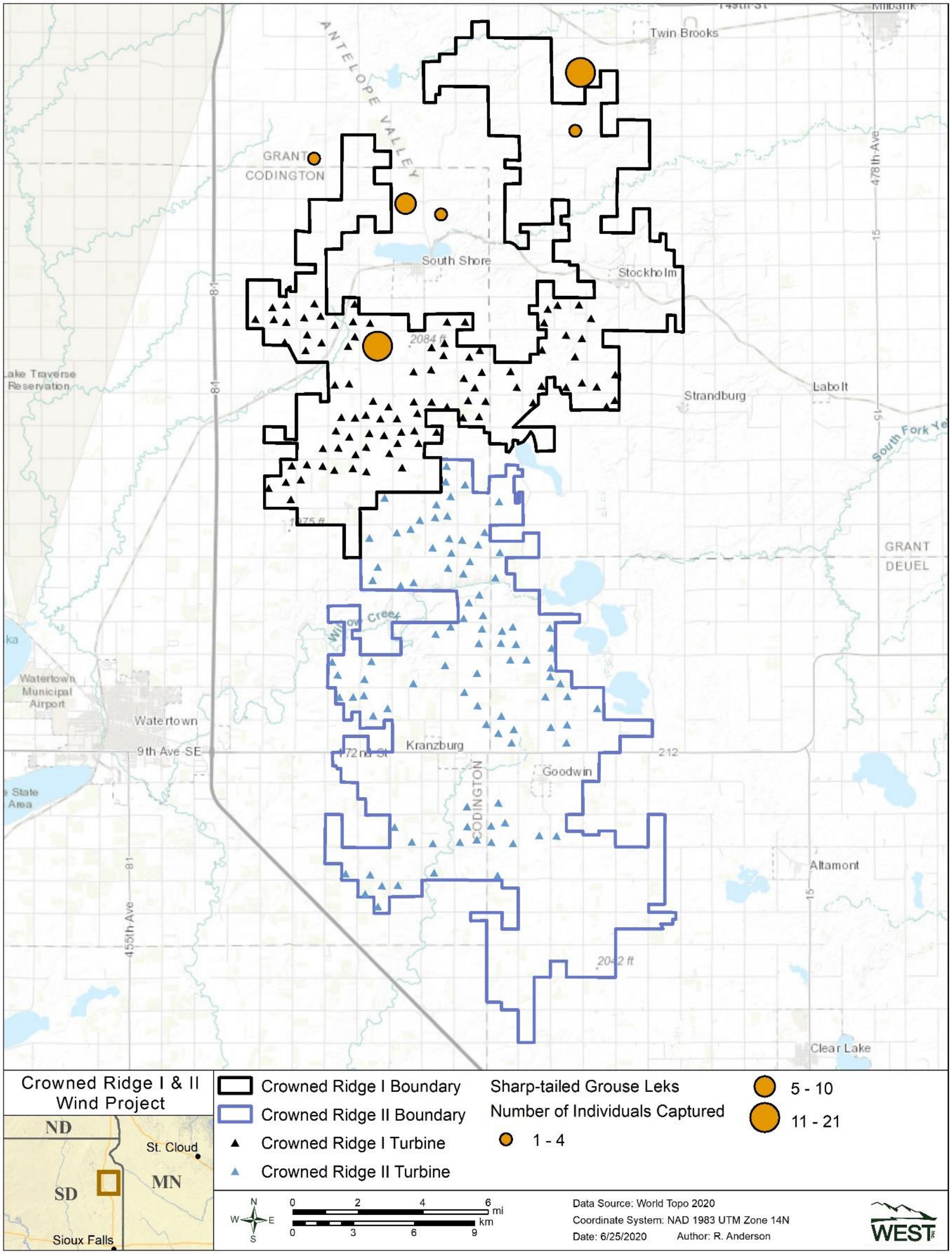


**Figure 5. Number of individual sharp-tailed grouse captured within the Crowned Ridge I Wind Energy Project March 30 – April 24, 2020.**

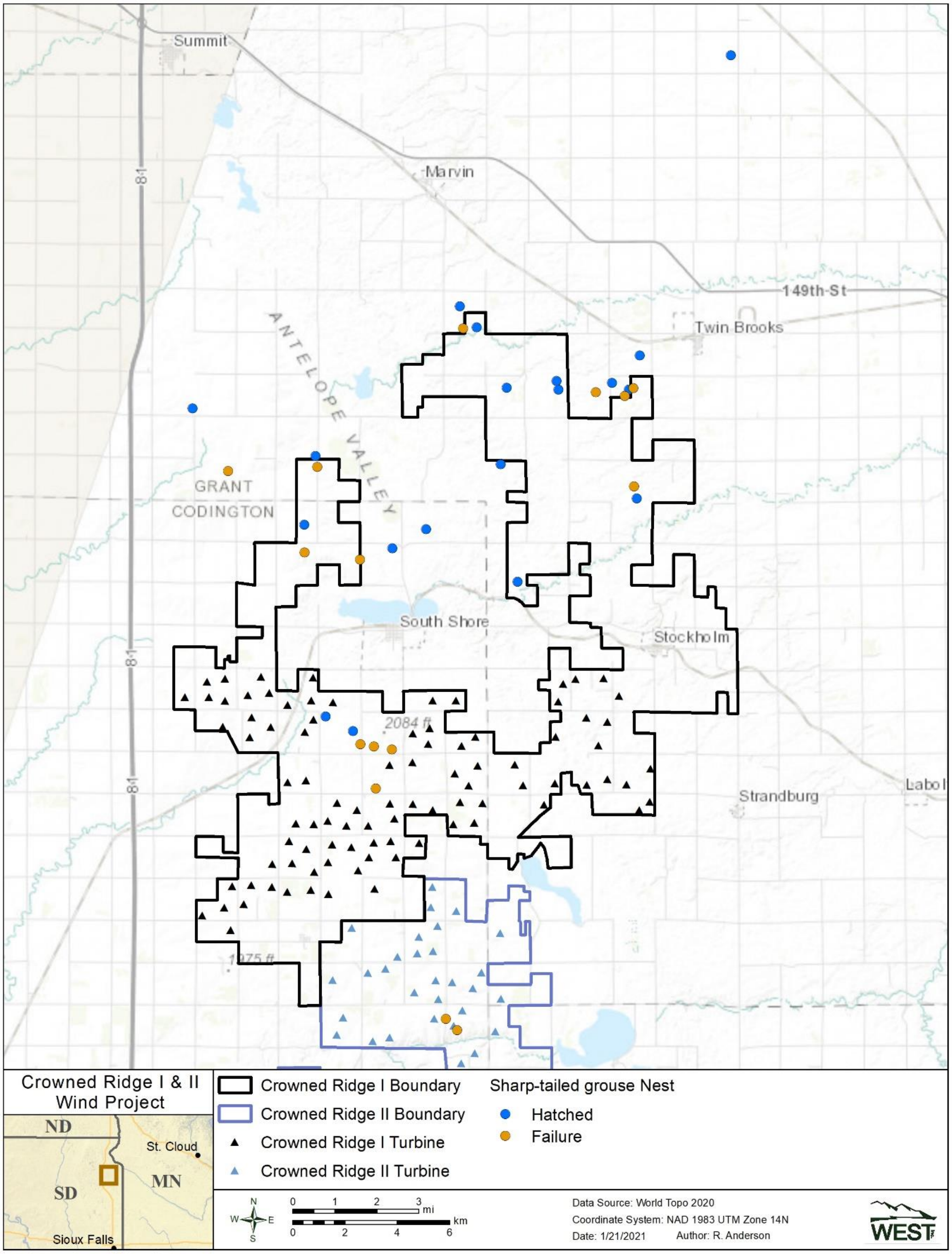


**Figure 6. Locations of hatched (blue circles) and failed (orange circles) sharp-tailed grouse (STGR) nests near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects during the 2020 breeding season.**

Note: Individual 'S30' which moved southeast of the Projects to Minnesota is not include in this figure.

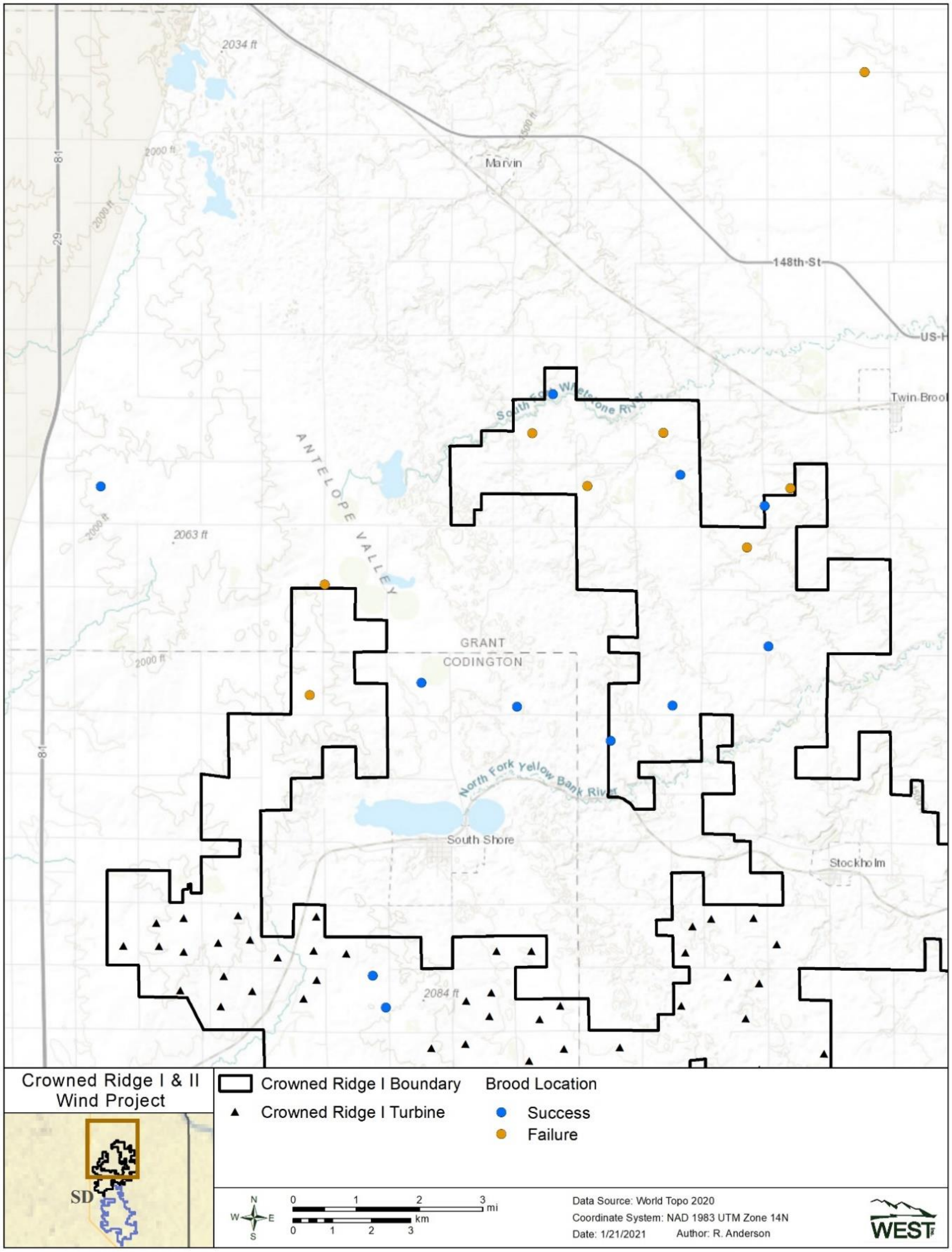


**Figure 7. Locations of successful (blue circles) and unsuccessful (orange circles) brood-rearing female sharp-tailed grouse (STRG) during 35 day brood checks near the Crowned Ridge 1 and Crowned Ridge II Wind Energy Projects during the 2020 breeding season.**

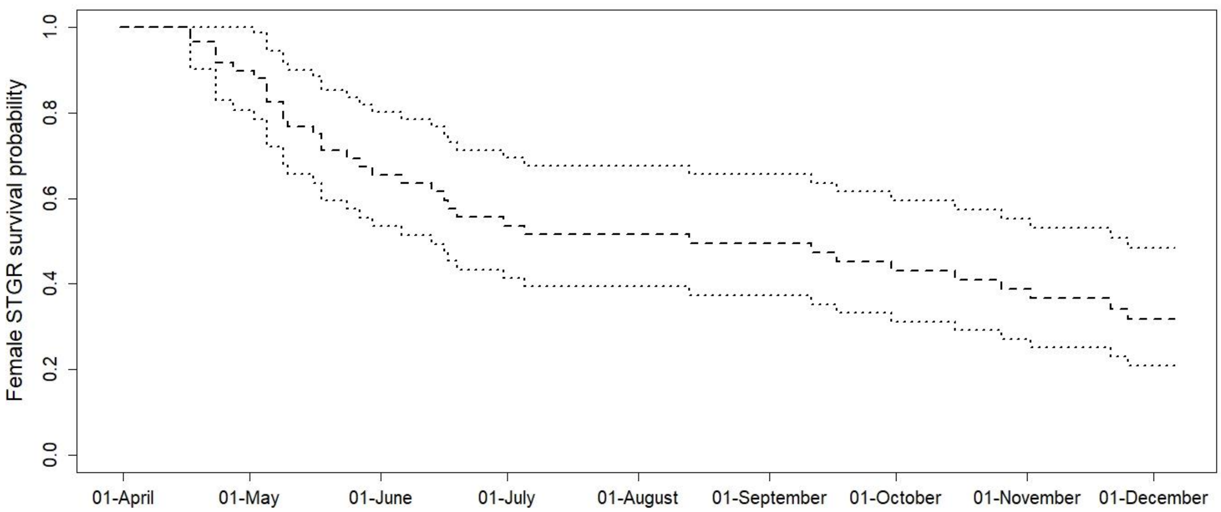


**Figure 8. Kaplan-Meier survival estimates and 95% confidence intervals for female sharp-tailed grouse (STGR) during the 2020 breeding season.**

**Table 3. Monthly Kaplan-Meier sharp-tailed grouse (STGR) survival estimates from radio-marked individuals near the Projects, April through November, 2020**

| Month | Survival Estimate (%) | Lower 95% CI | Upper 95% CI |
|---|---|---|---|
| April | 89.8 | 80.6 | 100 |
| May | 72.9 | 61.4 | 86.7 |
| June | 81.8 | 69.7 | 96.1 |
| July | 96.2 | 89.0 | 100 |
| August | 95.8 | 88.2 | 100 |
| September | 87.0 | 74.2 | 100 |
| October | 90.0 | 77.8 | 100 |
| November | 81.2 | 64.2 | 100 |

CI = confidence interval

## Habitat Use and Movements

To date, we have collected 296,712 locations from radio-marked STGR. The average number of locations per individual is 5,395 (range: 25 to 22,028; Figure 9). Seasonal ranges during the breeding season were calculated from 26 individuals (20 females and 6 males) that survived through August 15 (Figure 10). Breeding season range size averaged 0.8 $mi^2$ (2.1 $km^2$, range: 0.2 to 2.2 $mi^2$ [0.6 to 5.8 $km^2$]), and was larger on average for males (1.1 $mi^2$ [2.8 $km^2$], range: 0.5 to 2.1 $mi^2$ [1.2 to 5.6 $km^2$]) compared to females (0.7 $mi^2$ [1.9 $km^2$], range: 0.2 to 2.2 $mi^2$). We excluded one female (ID 'S07') from these calculations because this individual had a breeding season range size estimate of 82.6 $mi^2$ (214 $km^2$). This individual made a large and unique movement between June 16 and June 19 that was approximately 13 mi (21 km) to the southwest

(Figure 11). This movement by S07 roughly coincided with a failed nest attempt (June 13). Following this movement, S07 has remained in this area through present. On average, breeding season ranges were 3.7 mi (6.0 km, range: 0.1 to 36.0 mi [0.2 to 58 km]) from lek of capture. Removing one individual (S30, which moved southeast to Minnesota) with a breeding season range 36.0 mi from lek of capture, the average breeding season ranges were 2.4 mi (3.9 km, range: 0.1 to 10.2 mi [0.2 to 16.4 km]) from lek of capture. The segmentation cluster method appears to fit the data well in identifying potential movement pathways during the pre-nesting period (Figure 12). Visual inspection of potential pathways suggest that this information may be useful for identifying key features that facilitate movements between important seasonal habitats.

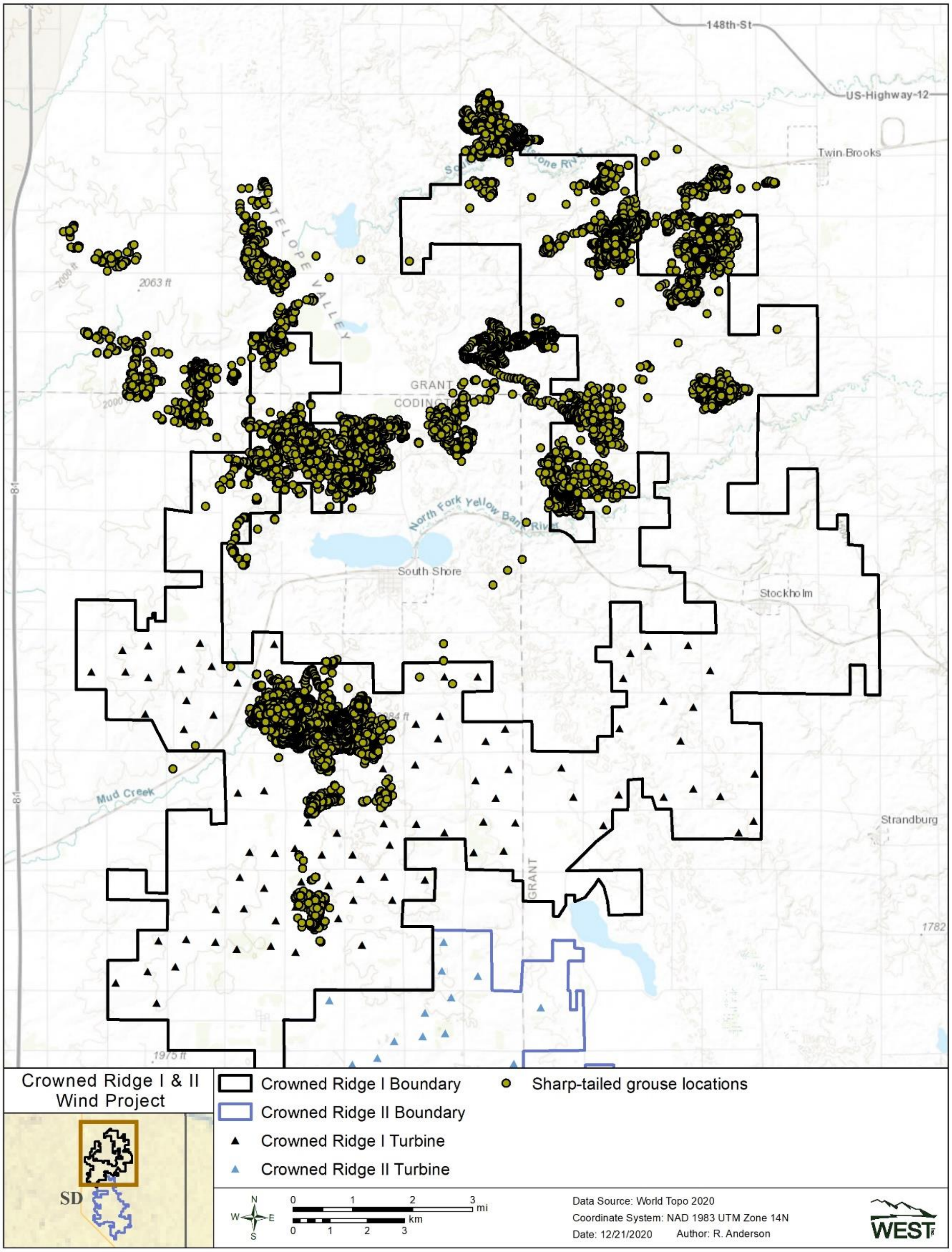


**Figure 9. All telemetry locations obtained from GPS marked sharp-tailed grouse (STGR) between capture and December 5, 2020 near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects.**

Note: Individual ‘S30’, which moved southeast of the Projects to Minnesota is not included in this figure.

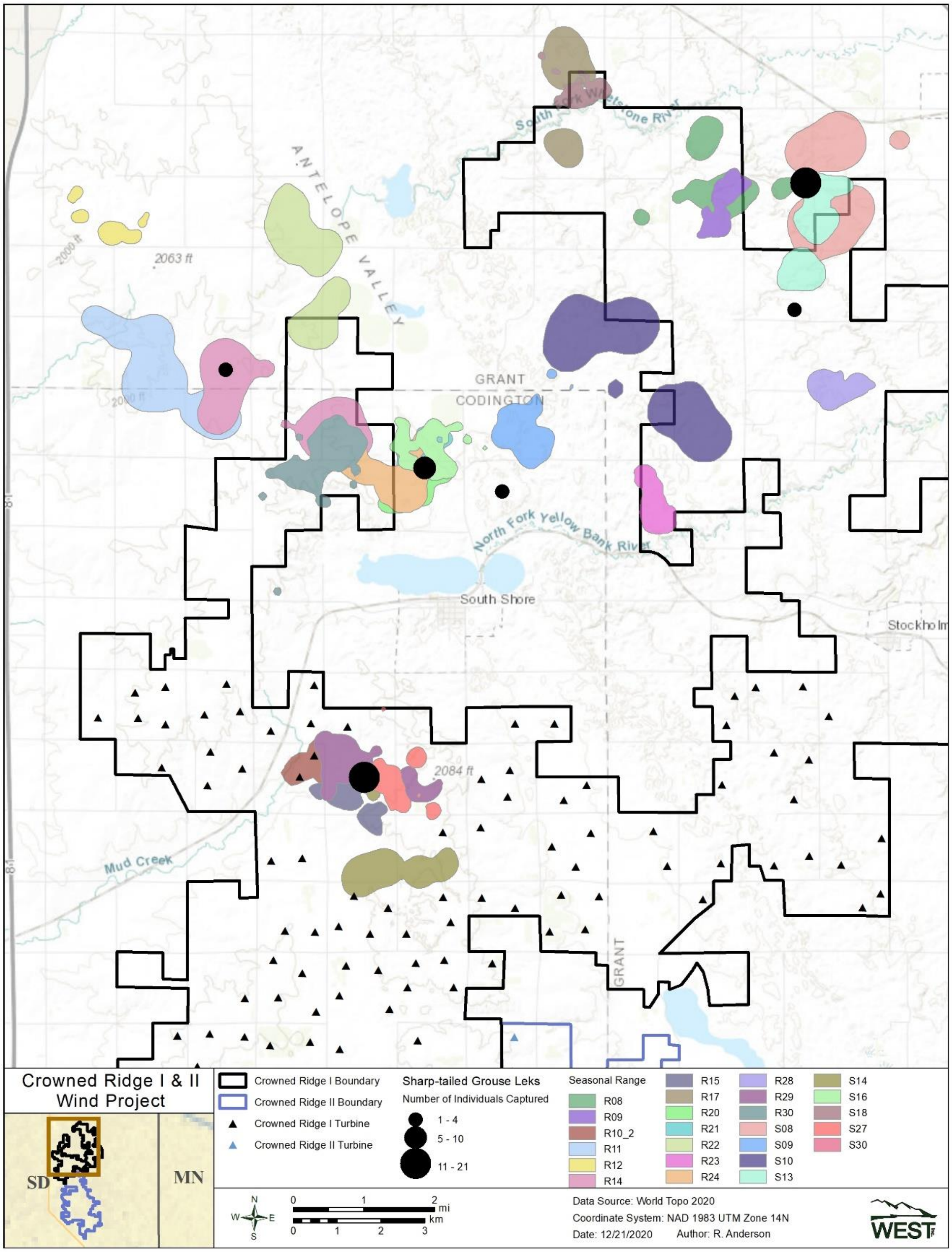


**Figure 10. Breeding season ranges of sharp-tailed grouse (STGR) estimated from Kernel Utilization Distributions (KUDs) near the Crowned Ridge I and Crowned Ridge II Wind Energy Projects during the 2020 breeding season**

Note: Individuals ‘S30’ and ‘S07’ are not included in this figure. ’S30’ moved southeast of the Projects to Minnesota .and ‘S07’ is highlighted in figure 11.

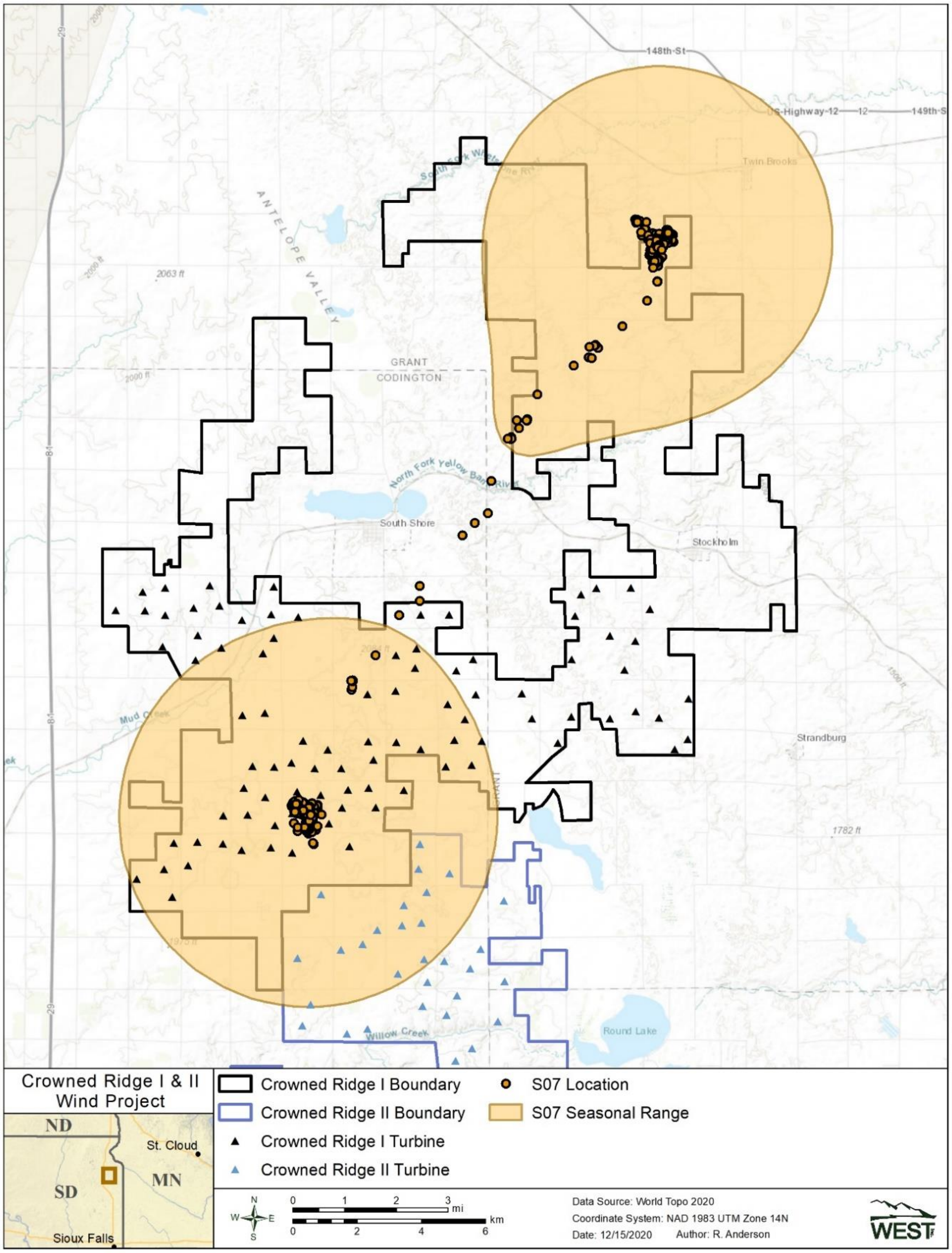


**Figure 11. Estimated Breeding season range of GPS marked female sharp-tailed grouse (STGR) ID 'S07' within the Crowned Ridge I and Crowned Ridge II Wind Energy Projects during the 2020 breeding season. This individual made a unique movement approximately 21 km southwest between June 16 and June 19, 2020.**

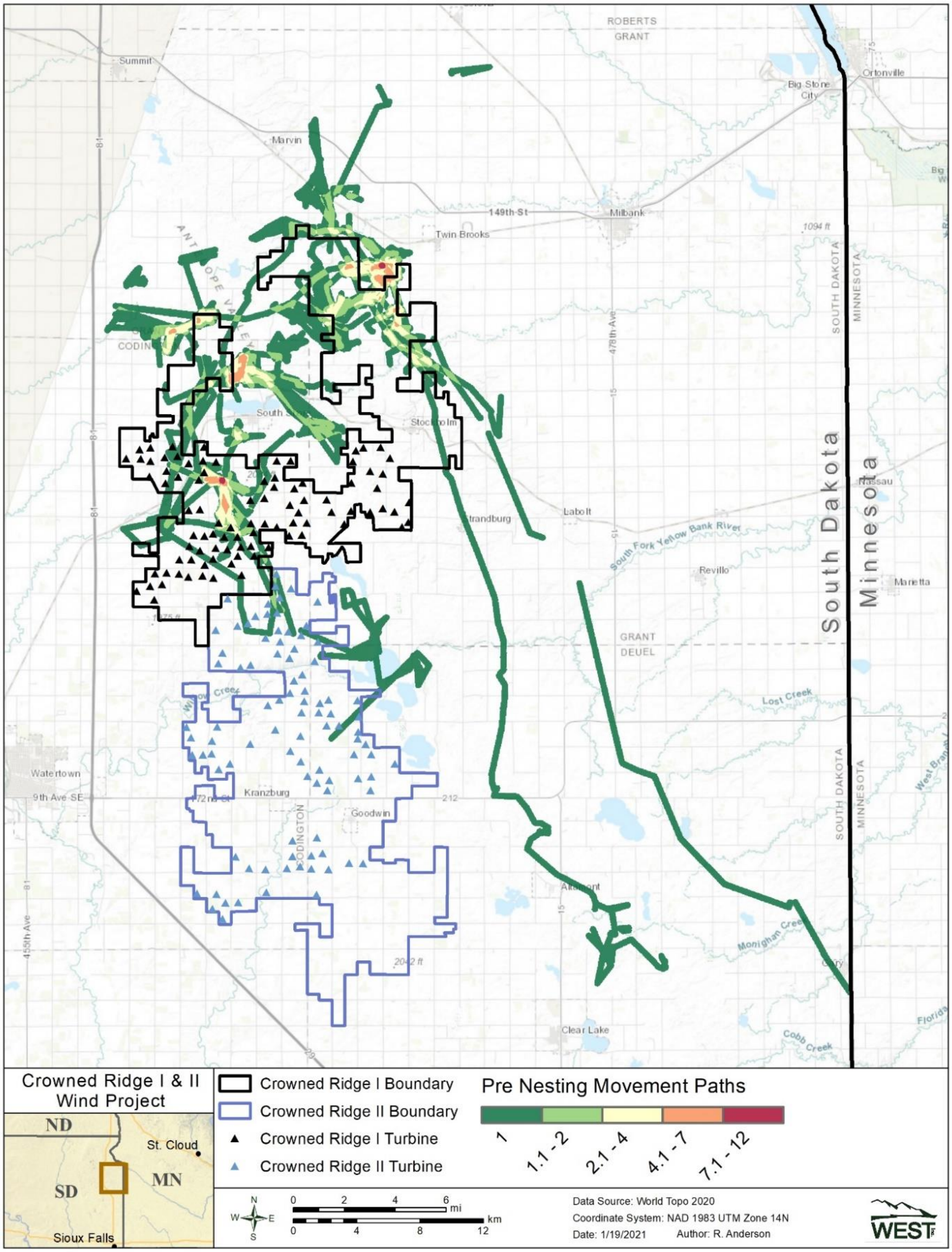


**Figure 12. Movement paths of sharp-tailed grouse (STGR) during the pre-nesting period, 2020 at the Crowned Ridge I and Crowned Ridge II Wind Energy Projects. Individual paths were overlaid to identify areas where one or multiple paths occurred in the same areas (number of overlapping paths depicted as increasing from cool to warm colors).**

## 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 2020 lek survey and capture efforts, and summarizes breeding metrics (nesting, brooding, and survival) and telemetry data collected during 2020 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 2021 field season in March 2021. To date, we have not evaluated the objectives of the study in context with potential STGR responses to the Projects' infrastructure. An additional year of data collection (2021) will allow us to begin evaluating these objectives prior to developing a cumulative report on all three years (2020–2022) of data collection following the 2022 field season. Nonetheless, we can begin compare our general findings to those reported elsewhere.

We found that nest survival of radio-marked females was approximately 57% during 2020 near the Projects. Nest survival was generally higher than 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 slightly lower than reported in northeast South Dakota (59%; Klostermeier 2019). Similarly, we found that brood survival to 35 days was approximately 58%, and this was within the range of estimated brood survival reported elsewhere (Bouaquet and Rotella 1998, Connolly 2001, Geaumont and Graham 2020, Goddard and Dawson 2009b). 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 breeding season was lower than these reported rates, but confidence intervals surrounding our survival estimates overlapped with rates reported elsewhere. Estimated annual survival rates have been reported between 17 and 50% (Robel et al. 1972, Milligan et al. 2020b, Moyles and Boag 1981). While not directly comparable because a full annual cycle is not complete, our estimate of 31.7% survival to date falls within this range.

To our knowledge, movement ecology of STGR has not been previously evaluated. We identified potential movement pathways during the pre-nesting period that may be useful for identifying important features that facilitate movement between key habitats. While determining potential movement pathways during the pre-nesting period was intended to provide a proof of concept, evaluation of STGR movements may allow us to identify potentially important movement pathways during additional seasons once more data becomes available.

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