2018 Annual Report

POPULATION DYNAMICS AND SEASONAL MOVEMENTS OF TRANSLOCATED AND RESIDENT GREATER SAGE-GROUSE (CENTROCERCUS UROPHASIANUS), SHEEPROCK SAGE-GROUSE MANAGEMENT AREA

Prepared by

Melissa Chelak, PhD Candidate and Graduate Research Associate

Terry Messmer, Principal Investigator, Jack H. Berryman Institute,

Department of Wildland Resources

Utah State University, Logan

February 2019

2018 Annual Report

POPULATION DYNAMICS AND SEASONAL MOVEMENTS OF TRANSLOCATED AND RESIDENT GREATER SAGE-GROUSE (CENTROCERCUS UROPHASIANUS), SHEEPROCK SAGE-GROUSE MANAGEMENT AREA

Cooperators

Utah Division of Wildlife Resources

Utah Public Lands Policy Coordination Office

US Bureau of Land Management

US Forest Service

US Geological Survey

West Desert Adaptive Resources Management Local Working Group

Utah State University Extension

Jack H. Berryman Institute

Yamaha Corporation

February 2019

Table of Contents

Executive Summary 6
Introduction 6
Utah sage-grouse populations 7
West Desert Adaptive Resource Management Local Working Group 8
Study Purpose 10
Study Area 11
Source Capture Areas 12
Methods 13
Translocations 13
Artificial Insemination 15
Lek Counts 15
Radio-telemetry 16
Vegetation Surveys 16
Predator Surveys 17
Avian predator surveys 17
Mammalian predator surveys 17
Off-Highway Vehicle Surveys 17
Preliminary Results 18
Translocations and resident sage-grouse captures 18
Lek Surveys 18
Radio-Telemetry Monitoring 20
Nest Initiation, Success and Brooding 22
Survival 28
Predator Surveys 29
Off-Highway Vehicle Recreational Use 30
Preliminary Conclusions 31
2019 Work Plan 32
Literature Cited 32

List of Figures

Figure 1. Delineation of Utah's 11 Sage-grouse Management Areas, 2019 Utah Conservation Plan for Greater Sage-grouse (*Centrocercus urophasianus*), Salt Lake City, Utah. 8
Figure 2. Average number of strutting greater sage-grouse (*Centrocercus urophasianus*) males in the Sheeprock Sage-Grouse Management Area from 2006 to 2018. Red areas indicate the years when translocations were completed (Utah Division of Wildlife Resources, unpublished data)..... 9
Figure 3. The 50-year average minimum and maximum temperatures per month in degrees Celsius for the Sheeprock Sage-Grouse Management Area as collected by Western Regional Climate Center in Vernon, Utah (Western Regional Climate Center 2016)..... 11
Figure 4. Average annual precipitation in inches in the Sheeprock Sage-grouse Management Area. This figure illustrates a bimodal distribution with peaks occurring during the spring and fall months (Western Regional Climate Center 2016)..... 12
Figure 5. The Sheeprock Sage-Grouse Management Area (SGMA) is the release site for the greater sage-grouse (*Centrocercus urophasianus*) translocation study. The sage-grouse were translocated from both Park Valley, located in the Box Elder SGMA, and Parker Mountain, located in the Parker Mountain-Emery SGMA. Resident sage-grouse within the Sheeprock SGMA are also monitored, Sheeprock SGMA, Utah. 13
Figure 6. Population growth rate (λ) of the Sheeprock Sage-Grouse Management Area greater sage-grouse (*Centrocercus urophasianus*) population for years 2006-2018. A growth rate value above 1 indicates that the population is increasing (Utah Division of Wildlife Resources, unpublished data). 19
Figure 7. A new greater sage-grouse (*Centrocercus urophasianus*) lek discovered in spring of 2018 in the Sheeprock Sage-Grouse Management Area less than 6 km north of the Benmore Pastures lek, Utah..... 20
Figure 8. Greater sage-grouse (*Centrocercus urophasianus*) general and brood location polygons from January through July 2018 in the Sheeprock Sage-grouse Management Area (SGMA). The general locations were determined by a location of non-breeding individual (i.e. not lekking, nesting, or brooding) either recorded in the field, in the case of very-high frequency (VHF) radio collars, or remotely by global position system (GPS) transmitters. Polygons were aggregated from points located within one km (0.6 mi) of each other..... 21
Figure 9. Movements of a juvenile female sage-grouse (Centrocercus urophasianus) translocated into Government Creek from Park Valley in 2018. Her movements show that she stayed within the western portion of the Sheeprock SGMA. For the winter, she traveled just south of the Simpson mountains, still within the SGMA. To date, we have not captured any individuals travelling and localizing around this portion of the study area. The blue circle indicates where she was released in spring of 2018 with blue arrows indicating her movements. The green circle is her current location as of January 2019. 22
Figure 10. Greater sage-grouse (*Centrocercus urophasianus*) nesting locations across the Sheeprock Sage-Grouse Management Area for 2018, Utah. 24

Figure 11. Survival probability (61.5%) of greater sage-grouse (*Centrocercus urophasianus*) broods across the brooding season for the 14 broods in 2018 in the Sheeprock Sage-Grouse Management Area, Utah. 25
Figure 12. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in Government Creek from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah. 26
Figure 13. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in Benmore Pastures lek area from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah. Grey points indicate failed nests..... 27
Figure 14. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in the McIntyre lek area from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah. Grey points indicated a failed nest. 28
Figure 15. Survival probabilities for translocated and resident greater sage-grouse (*Centrocercus urophasianus*) by month across years 2016-2018 in the Sheeprock Sage-grouse Management Area. Month 1 corresponds to March 2016, and Month 29 is August 2018. Sheeprock SGMA, Utah. 29
Figure 16. Data gathered from the predator surveys completed in May through July of 2017 and 2018 in the Sheeprock SGMA, Utah. 30
Figure 17. Spatial data of off-highway vehicle (OHV) recreational use from the visitors surveyed in Smith et al. (2018), Sheeprock Mountains Visitor Use Report, Utah State University, Utah. 31

List of Tables

Table 1. The dates of greater sage-grouse (*Centrocercus urophasianus*) translocations performed in 2018 and the number of individuals caught and released into the Sheeprock Sage-Grouse Management Area from their relative source populations in Utah. 18
Table 2. Status of greater sage-grouse (*Centrocercus urophasianus*) radio-marked from 2016-2018 in the Sheeprock Sage-Grouse Management Area, Utah. Undetected individuals have either emigrated from the study area, had collars detach or have had collars malfunction or deplete their batteries. 20
Table 3. Table showing the nest initiation, hatch dates, clutch sizes and 50-day post-hatch brood sizes for translocated and resident female greater sage-grouse (*Centrocercus urophasianus*) in the Sheeprock Sage-Grouse Management Area. Included is also information regarding source population for females: Park Valley (PV) or Parker Mountain (PM) and 2018 AI treatment (AI, SHAM, control). For resident birds, there is the capture lek: Government Creek (GOV), Benmore Pastures (BEN), and McIntyre (MCI). Sheeprock SGMA, Utah. 23
Table 4. Estimated number of predators taken (is this the number of predators taken/killed or the number of birds killed by predators?) through June of 2018 in the Sheeprock Sage-Grouse Management Area by species as reported by USDA-APHIS Wildlife Services, Sheeprock SGMA, Utah. 30

Executive Summary

Utah's 2019 Conservation Plan for Greater Sage-grouse (*Centrocercus urophasianus*; sage-grouse) reaffirmed the conservation goals of maintaining sage-grouse populations and their habitats in designated sage-grouse management areas (SGMAs; Utah Public Lands Policy Coordination Office [PLPCO 2019]). In support of this goal, we have completed 3 years of sage-grouse translocations to reverse the recorded long-term population declines in the Sheeprock SGMA. The translocations were conducted as part of an intensive management program, which included habitat and predation management. In 2018, over 60 male sage-grouse were counted on leks and the Utah Division of Wildlife Resources (UDWR) documented a new lek that was named the Fredrickson Pastures lek. Nest initiation rates and success rates were the highest ever reported in this population. In 2018, we recorded 14 of 17 nests successfully hatching. Eight broods survived to the 50-day, post-hatch survey. In 2018, we completed an assessment of off-highway vehicle (OHV) use and recreation users in the Sheeprock SGMA. This survey provided valuable information for application to management of OHV recreational use in the Sheeprock Mountains (Smith et al. 2018). We will be performing translocations in spring of 2019. In 2020, we will continue monitoring marked individuals and mark additional resident grouse.

Introduction

The estimated range-wide distribution and populations of sage-grouse have declined considerably compared to pre-settlement as well as recent estimates (Schroeder et al. 2004, Aldridge 2008, Garton et al. 2011). The prime factors contributing to the declines have been the loss and fragmentation of sagebrush habitat associated with the life history of the sage-grouse in addition to fire and invasive species (Aldridge et al. 2008, Miller et al. 2011).

Due to the range-wide population declines, the U.S. Fish and Wildlife Service (USFWS) has received multiple petitions to provide the sage-grouse protection under the Endangered Species Act (ESA). In 2010, the USFWS designated the sage-grouse as a candidate species for ESA protection (USFWS 2015). In September 2015, the USFWS reversed the 2010 decision when it announced that listing sage-grouse for ESA protection was unwarranted. The USFWS made this decision after evaluating on-going range-wide efforts by federal, state, and local partners and determined these actions had mitigated the threats to the species and provided for increased conservation certainty. The Bureau of Land Management (BLM), the U.S. Forest Service (USFS), and the western states with sage-grouse populations and habitats, had initiated land-use planning amendments and other actions designed to mitigate the identified threats, protect important sagebrush habitats, and develop adequate regulatory mechanisms to eliminate the need for a listing under the ESA. The USFWS requests annual updates from federal, state, and local partners regarding conservation plan implementation and population status. This information will be used by the USFWS to complete a 5-year status review of the population in 2020 to determine if the species may warrant ESA protection. The USFWS has emphasized the need to focus conservation efforts on protecting and enhancing the priority habitats as the essential mechanism for species conservation (USFWS 2013).

In response to USFWS guidance, the BLM and USFS revised their management plans for monitoring and managing sage-grouse populations and their habitats on public land (BLM 2015). In Appendix B of the BLM's adaptive management plan, they outlined a series of hard and soft population triggers as part of an integrated conservation strategy. The soft triggers designated population threshold levels which would require increased consultation with state partners (BLM 2015). The hard triggers were population thresholds that require immediate actions to protect the populations (BLM 2015).

Short-term Decline:

a) 4 consecutive years of 20% or greater annual decline in average males per lek
b) average males per lek, based on lek trends, drops 75% below the 10-year rolling average in any single year

Long-term Decline

c) Population growth rate is decreasing for 6 consecutive years
d) Population growth rate is decreasing for 8 years in a 10-year window

Utah sage-grouse populations

Utah's sage-grouse populations contribute 6-8% of the range-wide populations, and are discontinuous due to topographical features of Utah's landscape (PLPCO 2019). Population cycles vary from 9-12 years between peaks and troughs (Garton et al. 2011).

In 2019, Utah released their sage-grouse conservation plan that updated its goals developed in 2013. The plan supported sustaining the eleven Sage-Grouse Management Areas (SGMAs, Figure 1) within the state of Utah, which represent the highest sage-grouse breeding density areas and support more than 90% of the combined Utah population of sage-grouse (PLPCO 2019). The plan also identified two primary objectives with subsequent strategies to meet those objectives. The objectives identified include efforts to:

1) Maintain and increase sage-grouse populations statewide and within each SGMA.
    a. Monitor sage-grouse population trends annually. If necessary, implement adaptive management strategies to support viable and stable populations
2) Maintain, protect, and increase sage-grouse seasonal habitats within SGMAs through the following actions:
    a. Identify highest-priority sage-grouse habitats and migration corridors
        i. Protect at least 5,000 acres of these habitats annually
    b. Improve and increase sage-grouse seasonal habitats by 75,000 acres annually
    c. Coordinate with local, state, and federal fire-fighting jurisdictions to include sage-grouse habitats as a priority during pre-fire planning and suppression

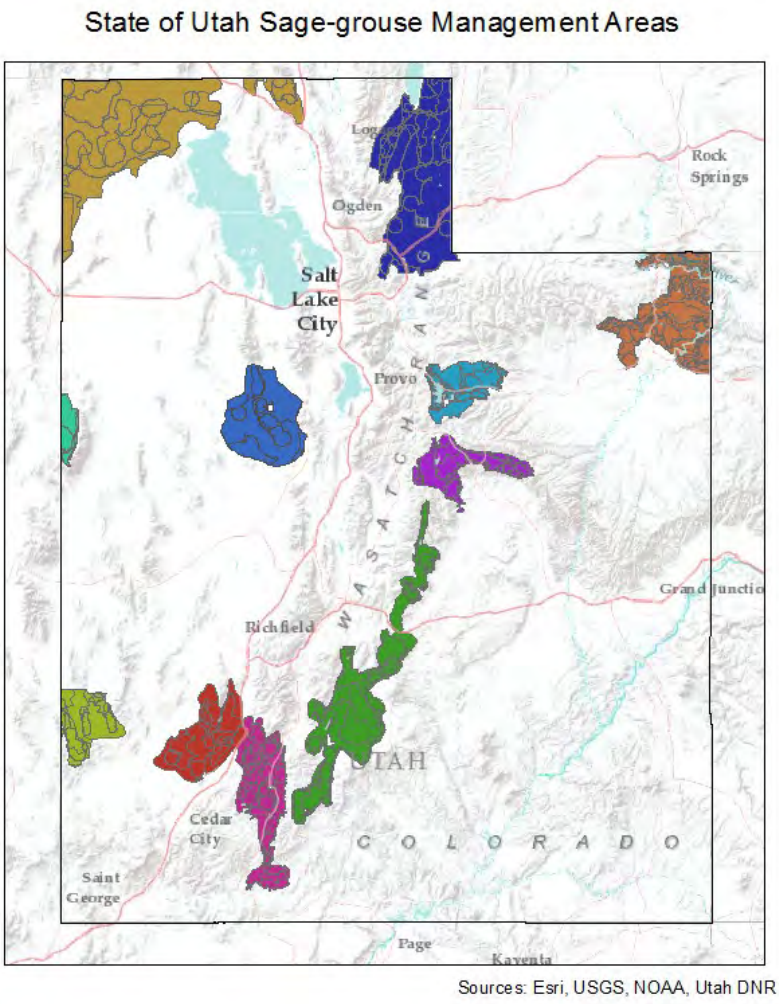

Figure 1. Delineation of Utah's 11 Sage-grouse Management Areas, 2019 Utah Conservation Plan for Greater Sage-grouse (*Centrocercus urophasianus*), Salt Lake City, Utah.

West Desert Adaptive Resource Management Local Working Group

The West Desert Adaptive Resource Management (WDARM) local working group encompasses the Sheeprock SGMA (WDARM 2007). The WDARM (2007) identified conservation strategies to mitigate the declines in the Sheeprock sage-grouse population. These strategies included evaluating population trends, identifying research needs and knowledge gaps, determining population and habitat needs for the future, and identifying threats that have potential to impact sage-grouse in the West Desert (WDARM 2007). The strategies included:

1. Incorporate management strategies from state and federal agency partners, local governments, and established range-wide conservation and management guidelines (Connelly et al. 2004)
2. Increase effective communication with all potential stakeholders in the West Desert and the state of Utah, through outreach, information distribution, and education

3. Address and prioritize threats to aid in prioritizing management solutions

During the normal population cycles, all 11 Utah SGMA's showed gradual declines in their populations (Garton et al. 2011). However, the Sheeprock SGMA population has continued to decline while others showed increasing population levels. Figure 2 illustrates the active male lek counts for the Sheeprocks in 2006, when 190 males were observed across the SGMA (Robinson 2007). In 2015, the number of active males counted on leks was 23 (UDWR, unpublished data).

Given these trends, the population unofficially hit the hard trigger outlined in the BLM Adaptive Management Plan (BLM 2015). During 2015, the WDARM met and discussed avenues for immediate action required to prevent extirpation of the Sheeprock population including: translocations, predator control, habitat restoration, and a long-term research project to study the population. In 2017, the BLM officially stated that the Sheeprock population reached the hard triggers outlined above. As a result, they have outlined adaptive management strategies to prevent future declines: prioritizing habitat restoration efforts, making the area the focal point for fire suppression, and seeking to minimize impacts from rights-of-way developments (BLM 2017).

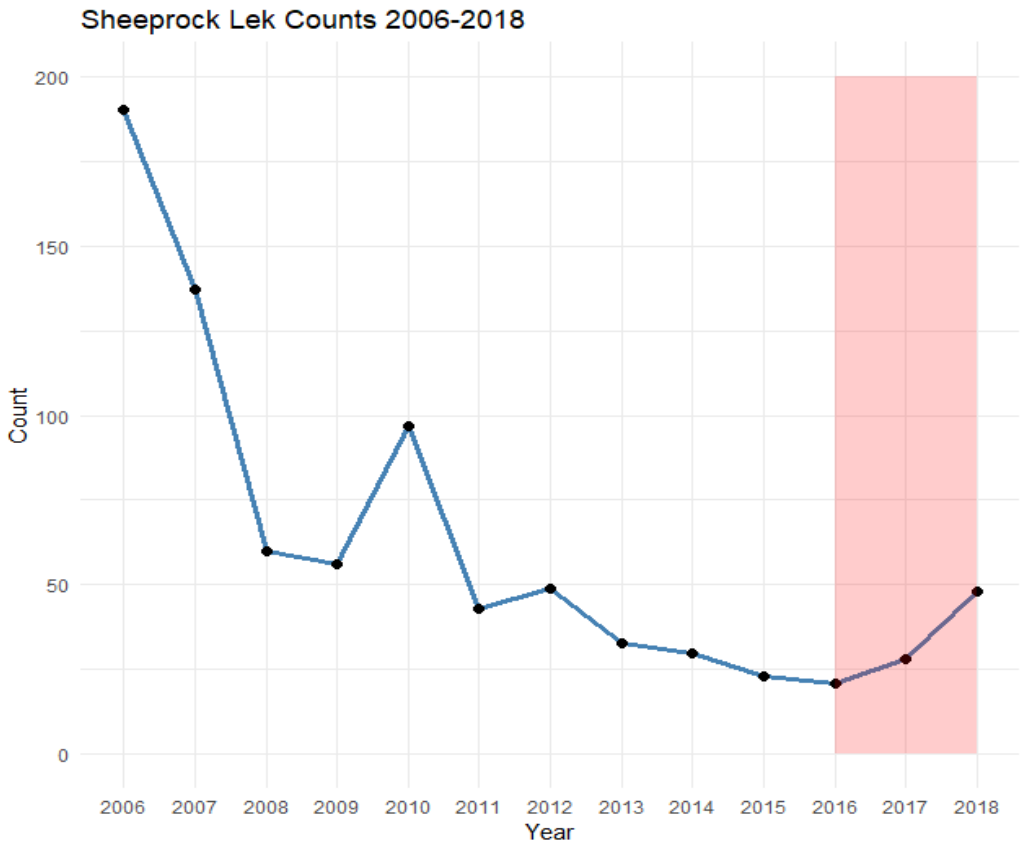

Figure 1: Average number of strutting greater sage-grouse (*Centrocercus urophasianus*) males in the Sheeprock Sage-Grouse Management Area from 2006 to 2018. Red areas indicate the years when translocations were performed (Utah Division of Wildlife Resources, unpublished data).

Translocations have been used to establish, reestablish, or prevent extirpation of populations of various species with the ultimate goal being to create self-sustaining populations (Griffin et al. 1989, Dickens et al. 2009). Success of translocations is contingent upon the methods and protocol of capture. Wild and native game bird species have been reported to exhibit the highest success rate for translocations (Griffin et al. 1989). The quality of habitat will also influence the success, with higher quality habitats leading to higher success; however, in areas with lower quality habitat, ongoing habitat restoration projects aid in success (Dickens et al. 2009). In areas where predation was implicated as a factor in the population declines, predator control has increased success (Baxter 2008). Translocating birds overnight during the breeding season and releasing them on an active lek the morning of capture has also increased survival rates (Reese and Connelly 1997, Baxter 2008).

Study Purpose

The purpose of this study is to evaluate if translocations could augment the population of sage-grouse located within the Sheeprock SGMA. The specific objectives of this study are to:

1. Estimate vital rates for marked birds and determine if they differ between radio-marked translocated and resident sage-grouse.

2. Determine if the translocations increase population growth rate in years 2 and 3.

3. Evaluate habitat-use (breeding, winter), responses to habitat management actions, seasonal movements and travel corridors for marked birds, and if these variables differ between radio-marked translocated sage-grouse and resident sage-grouse.

    a. Develop specific disturbance and habitat management recommendations for the USFS, BLM, and other partners based on marked sage-grouse vital rates and habitat-use patterns. These recommendations will include the prioritization and placement of habitat restoration projects to increase mesic habitats, usable space, development and placement of migration corridors, and actions to mitigate the potential effects of dispersed recreation on sage-grouse seasonal habitats.

4. Determine predator occupancy across the study area and if it affects sage-grouse habitat selection.

5. Determine if employing the use of artificial insemination on translocated females presents a possible option for improving the outcome of future translocations through improving nest initiation rates and decreasing homing (the action of returning to the individual's source population).

6. Quantify off-highway vehicle (OHV) recreation abundance throughout the Sheeprock SGMA and determine if it affects sage-grouse habitat selection or reproductive success.

Study Area

The Sheeprock SGMA is located near Vernon, Utah in central Utah's West Desert. It is an area comprised of 611,129 acres located in both Tooele and Juab counties. The BLM and the USFS manage 325,280 and 92,328 acres of the SGMA, respectively. The remaining acres are divided as follows: private ownership (82,740 acres), Utah School and Institutional Trust Lands (SITLA; 34,131acres), and the Utah Department of Natural Resources (UDNR; 684 acres).

This area is characterized by warm, dry summers and cool winters. The 50-year average maximum summer temperature is 32.4 ˚C in July, and the minimum winter temperature is -10.4 ˚C in January (Figure 3). The average annual precipitation is 10.24 inches, with the highest amount being in the spring and fall months (Figure. 4). Average snowfall is 36.2 inches (Western Regional Climate Center 2016).

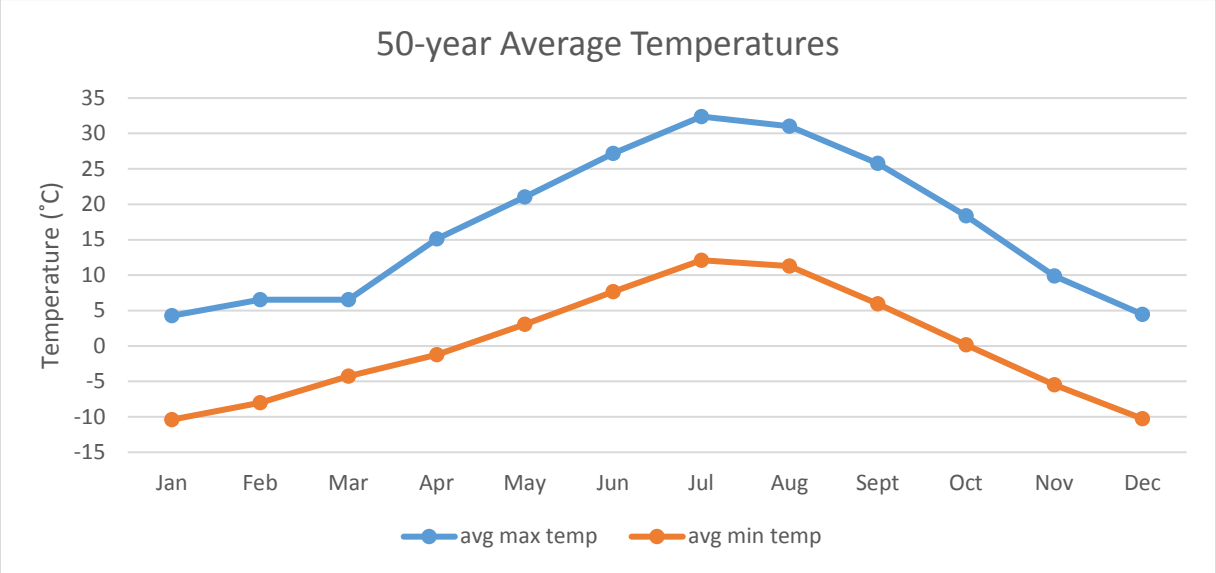

Figure 2. The 50-year average minimum and maximum temperatures per month in degrees Celsius for the Sheeprock Sage-Grouse Management Area as collected by Western Regional Climate Center in Vernon, Utah (Western Regional Climate Center 2016).

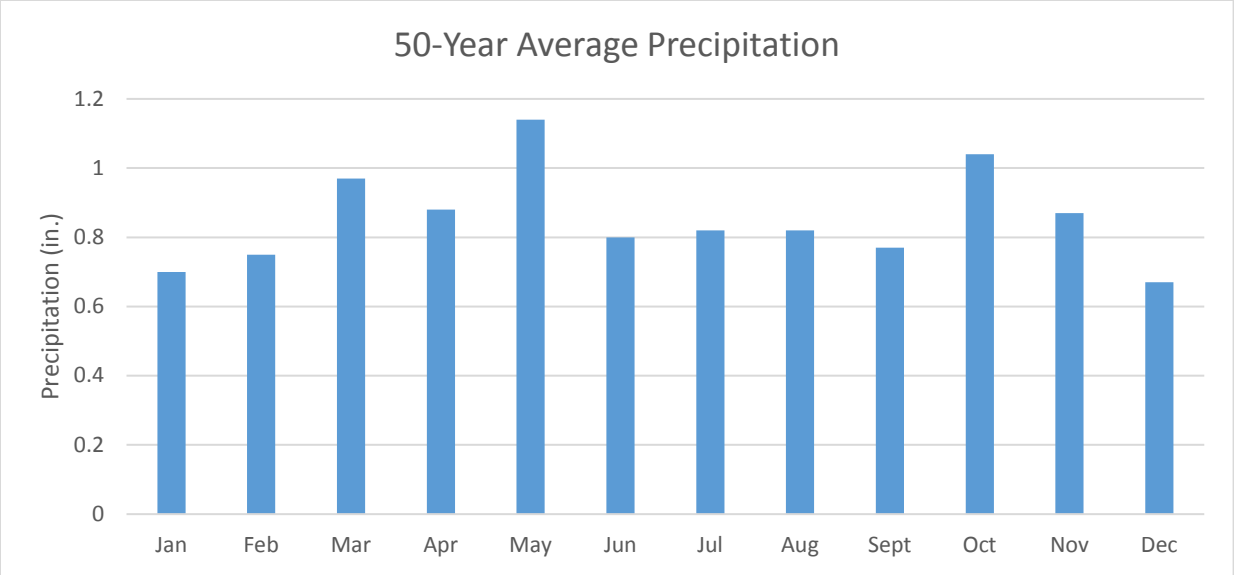

Figure 3: Average annual precipitation in inches in the Sheeprock Sage-grouse Management Area. This figure illustrates a bimodal distribution with peaks occurring during the spring and fall months (Western Regional Climate Center 2016).

Elevation ranges from 1500m in the lower valleys to 2950m at the tallest peaks. The lower elevation vegetation is comprised of Wyoming big sagebrush (*A. tridentata* spp *wyomingensis*), crested wheatgrass (*Agropyron cristatum*), and bulbous bluegrass (*Poa bulbosa;* Robinson 2007). Invasive vegetation located in the lower elevation includes cheatgrass (*Bromus tectorum*) and knapweed (*Centaurea* spp.; Robinson 2007). As elevation increases, shrubs such as the following become more prevalent: serviceberry (*Amelanchier alnifolia*), common snowberry (*Symphoricarpos albus*), antelope bitterbrush (*Purshia tridentata*), mountain big sagebrush (*A. t. vaseyana*), and juniper (*Juniperus* spp.) stands (Robinson 2007). Higher elevations, along ridgelines, are dominated by black (*A. nova*) and low sagebrush (*A. arbuscula*; Robinson 2007). Rubber rabbitbrush (*Ericameria nauseosa*) and Douglas rabbitbrush (*Chrysothamnus viscidiflorus*) are also prevalent in lower and mid elevations (Robinson 2007).

Source Capture Areas

Parker Mountain (PM) is part of Utah's Parker Mountain-Emery SGMA (Figure 5) located in south-central Utah and contains one of the largest sage-grouse populations in the state. It is located within the Great Basin Desert and characterized by mostly black sagebrush on the ridges and slopes and big sagebrush in the drainages (Baxter et al. 2008). Elevation ranges from 2,140 m to 3,000 m (Chi 2004; Baxter et al. 2008). Average annual precipitation is 567 mm with the highest precipitation in fall, winter, and spring as is characteristic of cold deserts (Dulfon 2016).

Park Valley (PV) is located in northwestern Utah in the Box Elder SGMA (Figure 5). It contains predominately big sagebrush and black and low sagebrush similar to that of the Sheeprock SGMA (Sanford et al. 2017). It is on the edge of the Snake River plain and the Great Basin

Desert. Elevation ranges from 1,350 m to 2,950 m with average annual precipitation ranging from 177 mm to 783 mm from low elevation to high elevation, respectively (Sanford et al. 2017).

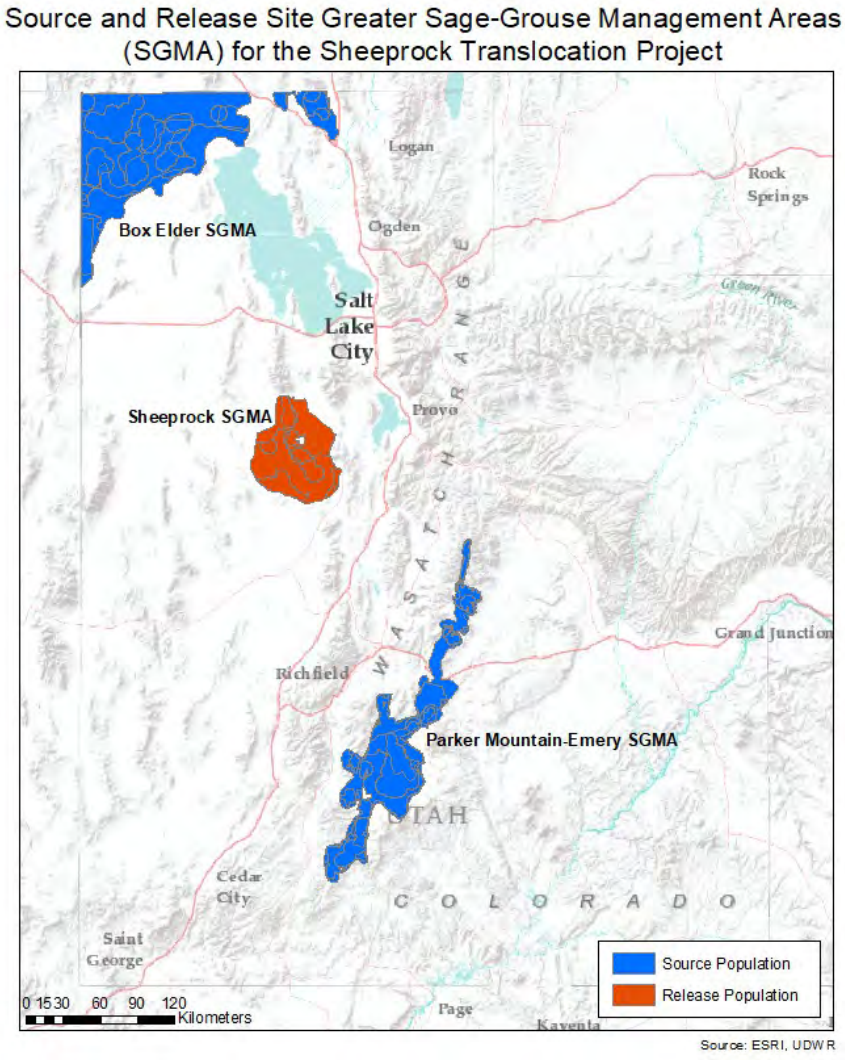

Figure 5. The Sheeprock Sage-Grouse Management Area (SGMA) is the release site for the greater sage-grouse (*Centrocercus urophasianus*) translocation study. The sage-grouse are translocated from both Park Valley, located in the Box Elder SGMA, and Parker Mountain, located in the Parker Mountain-Emery SGMA. Resident sage-grouse within the Sheeprock SGMA are also monitored, Sheeprock SGMA, Utah.

Methods

Translocations

Translocation methods follow guidelines outlined by Connelly et al. (1997) and Baxter et al. (2008). We have performed translocations from 2016-2018 and plan to translocate more individuals in 2019. During the lekking period, 30 females and 10 males are translocated

annually from genetically-compatible populations of sage-grouse located in Park Valley and on Parker Mountain (Reese and Connelly 1997, Oyler-McCance et al. 2005). Source populations are greater than 50km away from the Sheeprock SGMA, where the birds are released (Reese and Connelly 1997, Oyler-McCance et al. 2005). Park Valley and Parker Mountain source populations were approved by the Regional Advisory Councils, the Wildlife Board, the Resource Development Coordination Council (RDCC), the Utah State University Institutional Animal Care and Use Committee (IACUC), and the West Desert, Parker Mountain and West Box Elder SGMA local working groups.

Sage-grouse are captured at night using all-terrain vehicles, spotlights, and long handled nets near active leks (2100hr to 0200hr; Connelly et al. 2003). Sage-grouse are brought to the trucks and processed—i.e. fitted with transmitters, weighed, aged, etc.—there before leaving the capture site. Most of the females and males are fitted with an 18-gram necklace-style very high frequency (VHF) radio transmitter (Advanced Telemetry systems, Insanti, MN and American Wildlife Enterprises, Monticello, FL). Some females and males are fitted with camouflaged solar-powered GPS satellite transmitters mounted on the rump of the grouse. The GPS transmitters include Ultra High Frequency (UHF) capabilities to allow for relocating marked birds in the field. Processing includes mounting the transmitter, ageing, sexing, weighing, leg banding, and recording the capture locations (UTM, 12N, NAD 83).

Beginning in 2017, we collaborated with two other sage-grouse translocation studies out of North Dakota and California on improving translocation protocols to improve post-release survival of translocated individuals. Under the new current protocol, birds are placed in wooden remote-release boxes that contain 5 individual compartments with ventilation and transported overnight (0200hr -0530hr) in a pickup truck to the release site. At sunrise (0600hr-0630hr), radio-marked sage-grouse are released the morning following capture, within 200m of an active lek site. The boxes are lined up with the opening facing the lek, and grouse are released after the immediate area is scanned for predators.

In the Sheeprock SGMA, up to 10 resident sage-grouse (8 females and 2 males) are captured annually. Some individuals, both male and female, are marked with GPS transmitters, with the remaining individuals being fitted with the VHF radio-collars. All sage-grouse are weighed and aged, with age being determined by characteristics of the P9 and P10 wing feathers. The birds are immediately released following processing. With the Sheeprock SGMA population being so low, capturing 10 grouse represents a realistic goal (Robinson and Messmer 2013). Data gathered from these birds provides information on the habitat use, seasonal movements, and habitat corridors of the resident population, as requested by the WDARM.

Feathers are collected from both resident and translocated grouse during processing for genetic analysis. Clean feathers lost incidentally during the capture are collected; if clean feathers are not present or no feathers are lost during the capture, feathers are plucked from the breast. Feather samples are placed in small paper envelopes, sealed, and labeled with the date, sex, collector's name, bird ID, and the UTM coordinates. Samples are stored in desiccant for tissue preservation.

Artificial Insemination

Developed by Steven Mathews (ISU), Dr. Pete Coates (USGS), and Dr. David Delehanty (ISU) for a sharp-tailed grouse (*Tympanuchus phasianellus*) translocation study, we have implemented the use of artificial insemination for 2017 and 2018 translocations to assess its effect on nest initiation and homing behavior. The artificial insemination procedure has three treatments to which females are randomly assigned:

1. Artificial Insemination (AI): females receive a sample that includes a recorded volume of semen and an avian semen extender buffer at a ratio that depends on the quality and quantity of sperm cells extracted from the male.
2. Avian Semen Extender Buffer (SHAM): females receive a sample of a recorded volume of only the semen extender.
3. Control: females of this treatment group do not receive any sample and are translocated normally

Semen samples are collected by capturing males on leks at night (see capture methods above). Males are transported to a central location where researchers can easily and efficiently extract samples. This process is called desemenation. Upon extraction from the male, the sample is observed underneath a microscope and three characteristics are assessed: 1) Number of sperm, 2) Speed that sperm are moving in the sample, and 3) Appearance of sperm, i.e. whether they are fully developed or underdeveloped. After the sample is assessed based on these three criteria, it is given a rating. Depending on that rating, it is then buffered with avian semen extender to aid in keeping the sperm alive until insemination in the female.

After the sample has been assessed and buffered, the females are brought in, mounted with GPS or VHF transmitters, leg banded, feather samples taken, and, lastly, a semen sample is inserted into the vaginal opening in the cloaca using a rubber-tipped syringe to prevent injuring the female. The ID of the contributing male, band number, sample quality, and female treatment type are all recorded in an artificial insemination database as well as the capture database for the female.

Lek Counts

Lek counts are conducted according to the procedures outlined in the UDWR protocol. A minimum of three counts are made in weekly intervals beginning in mid-March and ending May 7. The counts begin 30 minutes before sunrise and end 1 hour and 30 minutes after sunrise, counting 3 to 5 times during that time period and recording the maximum number of males that visit the lek. To record whether translocated males visit the lek, the observer uses radio telemetry equipment to listen for the translocated males' frequencies. Radio-marked translocated males are excluded from population calculations based on lek attendance during lek counts within the year they are translocated.

Radio-telemetry

To monitor sage-grouse vital rates and habitat-use, locations are recorded for all radio-marked grouse using UTM's in NAD83. For the VHF transmitters, birds are located with VHF receivers and VHF antennas. The data for the GPS-marked birds has a duty cycle of 5 days, so data are uploaded at the end of each duty cycle. Five-six locations are recorded per day for the GPS transmitters at different times depending on the time of year. For each location for VHF-marked individuals, the date, time, observer, UTM, group size, flocking with resident birds, nearest lek, habitat type, nearest disturbance, and survival status are recorded. Mortality for the VHF radio-collared birds is determined by a mortality signal (faster pulse), which initiates after the collar has remained in the same location for 8 or more hours. Mortality for the GPS transmitters is determined using the data, which detects a mortality mode after several fixes at the same location. After a mortality signal is detected, the observer locates the transmitter and determines the cause of mortality, if possible.

During the nesting season, all radio-marked females are located 2 to 3 times per week to determine the date of nest initiation. Once a nest has been confirmed by visually seeing a female on a nest without flushing her, it is checked 2 to 3 times a week from 30-50 m away to determine the fate. Once the eggs hatch and the hen and brood leave the nest area, the clutch size is estimated by counting the number of egg shells. If a nest fails, the observer attempts to identify the cause and the female is again monitored 2 to 3 times a week to document re-nesting attempts. Broods are located 3 times a week until the brood reaches 50 days old. Females that do not have broods are located 1 to 2 times per week.

During the fall and winter, collared sage-grouse are located bi-monthly using ground telemetry. Periodic flights in a fixed-wing aircraft are also used to locate grouse that are undetectable from the ground. Locations of the GPS birds are downloaded after each 5-day duty cycle to determine movement corridors and fall and winter ranges. All research activities are completed in accordance with Utah State University IACUC approved protocol.

Vegetation Surveys

For each nest and one location weekly per brood (up to 50 days of age for the brood), vegetation measurements are recorded using a line intercept method to determine shrub cover, height and species (Connelly et al. 2003). Each location consists of four, 15m transects for nest sites and four, 10m transects for brood sites. A random compass bearing is used to determine the direction of the initial transect. Daubenmire frames (20 x 50 cm) are read every 3m for nests and 2.5m for broods along each transect to determine the percent cover of forbs and grasses at each site (Daubenmire 1959). A Robel pole is used at each vegetation plot to assess visual obstruction, which is assessed at 4m along each transect at 100 cm high, looking both into and out from the Robel pole (Robel 1970).

Predator Surveys

Predator surveys were initiated in 2017 and will be conducted through 2020 concurrent with predator control efforts by U.S. Department of Agriculture (USDA) Animal and Plant Health Inspection Service (APHIS) Wildlife Services. The purpose of these surveys is to develop an index of the predator species abundance and how it may change in response to predator control in the Sheeprock SGMA. We will estimate predator occupancy across the SGMA by species. These predator survey methods were adapted from methods developed in Rich County, Utah (Dettenmaier and Messmer 2013).

Avian predator surveys

We are recording avian predator abundance weekly beginning in May through July from points located on scat transects. Counts include ravens (*Corvus corax*), black-billed magpies (*Pica hudsonia*), golden eagles (*Aquila chrysaetos*), red-tailed hawks (*Buteo jamaicensis*), ferruginous hawks (*Buteo regalis*), northern harriers (*Circus hudsonius*), and other raptors during a 10-minute period. Counts are restricted to days with light winds (<19 kph) and little or no precipitation (Luginbuhl et al. 2001). At each survey point, avian predators are counted by visually searching the area with the aid of binoculars and listening for bird calls. The species code and count are recorded along with the time, weather, behavior (flying or perched), and estimated distance at time of first detection. To mitigate double counting, survey points are separated by more than 5 km and previously recorded birds will be tracked prior to moving to the next survey point. The survey routes are located both near and away from lek sites across the SGMA. Using a modification of the method created by Somershoe et al. (2006), we will use annuli between <100 and >500 meters from the survey point to give us an estimated density of the avian predator species when combined with the point count data. These distance annuli reflect the open sagebrush habitats and relative ease of detecting larger avian predator species.

Mammalian predator surveys

Scat surveys are inexpensive and noninvasive while still providing information on abundance (Shauster et al. 2002, Kamler et al. 2013), patterns and occupancy (Long et al. 2011), and diet (Kitchen et al. 1999, Losinger et al. 2016). Thirty, 1km transects are located on two-track and maintained (gravel) roads across the SGMA. Scat survey transects are initially cleared of all scat and surveyed every 4 to 7 days beginning in May and continuing to the end of July. Roads are driven on an ATV to maximize detection of scat presence while minimizing time spent on the transects. Similar to the avian predator surveys, transects are 5 km apart. Species identification include red fox (*Vulpes vulpes*), coyote (*Canis latrans*), American badger (*Taxidea taxis*), and other mammalian predators.

Off-Highway Vehicle Surveys

In 2018, we received funding from the Yamaha Outdoor Access Initiative to initiate a needs assessment of recreational users in the Sheeprock SGMA. We collaborated with researchers, Dr. Jordan Smith and Ben Muhlestein, to develop and implement these surveys during high, medium, and low use days during the summer of 2018 from May to September (Smith et al.

2018). Willing participants were asked to participate in a short questionnaire and, if they agreed, a Garmin GPS device was attached to their off-highway vehicle (OHV) to register use of the area. The study will assess recreationalists' use based on motivations gathered from the survey as well as assess impact on habitat fragmentation.

Preliminary Results

Translocations and resident sage-grouse captures

The 2018 translocations were completed on March 20th and 24th and April 6th. Table 1 illustrates the source populations, dates, and number of individuals trapped by sex. Forty sage-grouse (30 females and 10 males) were transported to the Sheeprock SGMA using specially-constructed wooden release boxes. The artificial insemination experiment was set up to give the 30 females one of three treatments: AI (artificial insemination from males of the location from which they were translocated), SHAM (receiving a control of the avian semen extender buffer), or control (no treatment). Due to logistics in acquiring viable semen from males during the translocations this year, 2 females received the AI treatment, 11 received the SHAM treatment, and 12 received the control.

Table 1. The dates of greater sage-grouse (*Centrocercus urophasianus*) translocations performed in 2018 and the number of individuals caught and released into the Sheeprock Sage-Grouse Management Area from their relative source populations in Utah.

Translocation dates	Date	Number of Males,Females
Parker Mountain	3/20/2018	7 Males, 21 Females
Park Valley	3/24/2018	3 Males, 4 Females
Park Valley	4/6/2018	5 Females

In the resident Sheeprock population, we radio-marked 3 males and 5 females in 2018. Two females were fitted with a GPS PTT transmitter and 3 with VHF collars, and 2 males were fitted with GPS, and 1 was marked with a VHF radio collar.

Lek Surveys

Lek surveys are conducted in the spring of this year by technicians and UDWR biologists. We counted over 60 males on leks this year for the peak count (PLPCO 2019). Figure 6 illustrates the population growth rate from 2006-2018. In an aerial infrared survey performed by the UDWR, a new lek was found north of the Benmore Pastures lek (Figure 7). We noted that the location of the Benmore lek moved several times between March-May of 2018. It is important to note that lek sites are chosen by males based on the proximity to nesting habitat as well as areas through which females travel from wintering habitat to breeding habitat (Gibson 1996).

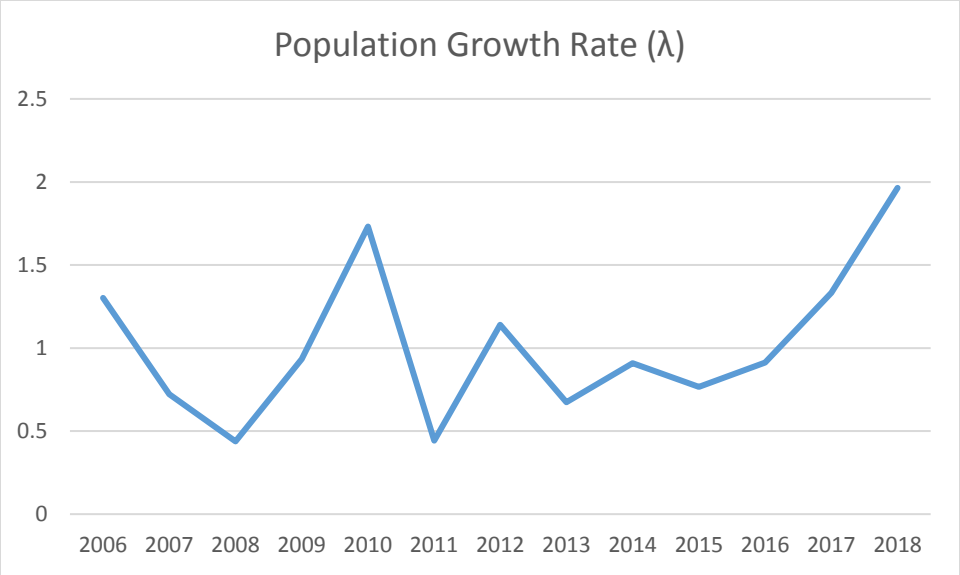

Figure 6. Population growth rate (λ) of the Sheeprock Sage-Grouse Management Area greater sage-grouse (*Centrocercus urophasianus*) population for years 2006-2018. A growth rate value above 1 indicates that the population is increasing (Utah Division of Wildlife Resources, unpublished data).

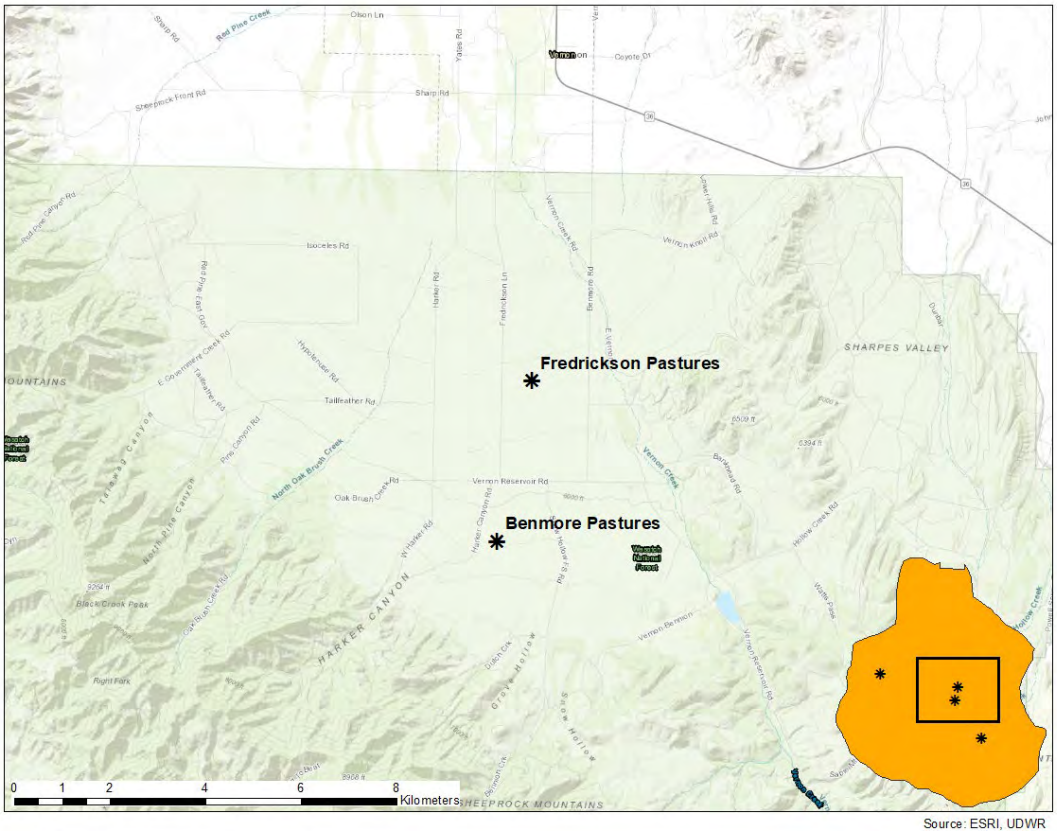

Figure 7. A new greater sage-grouse (*Centrocercus urophasianus*) lek discovered in spring of 2018 in the Sheeprock Sage-Grouse Management Area less than 6 km north of the Benmore Pastures lek, Utah.

Radio-Telemetry Monitoring

In 2018, translocation efforts combined with trapping efforts in the Sheeprock SGMA resulted in 48 birds being radio-marked: 40 translocated and 8 resident birds (10 translocated males, 30 translocated females, 3 resident males, 5 resident females). As of 2018, there have been 140 individuals (120 translocated and 20 resident) marked and monitored in the Sheeprock SGMA.

Table 2. Status of greater sage-grouse (*Centrocercus urophasianus*) radio-marked from 2016-2018 in the Sheeprock Sage-Grouse Management Area, Utah. Undetected individuals have either emigrated from the study area, had collars detach or have had collars malfunction or deplete their batteries.

Year marked	# Mortality	Undetected	Currently Monitoring	Total Marked
2016	22	23	2	47
2017	22	11	12	45
2018	15	5	28	48
Total	59	39	42	140

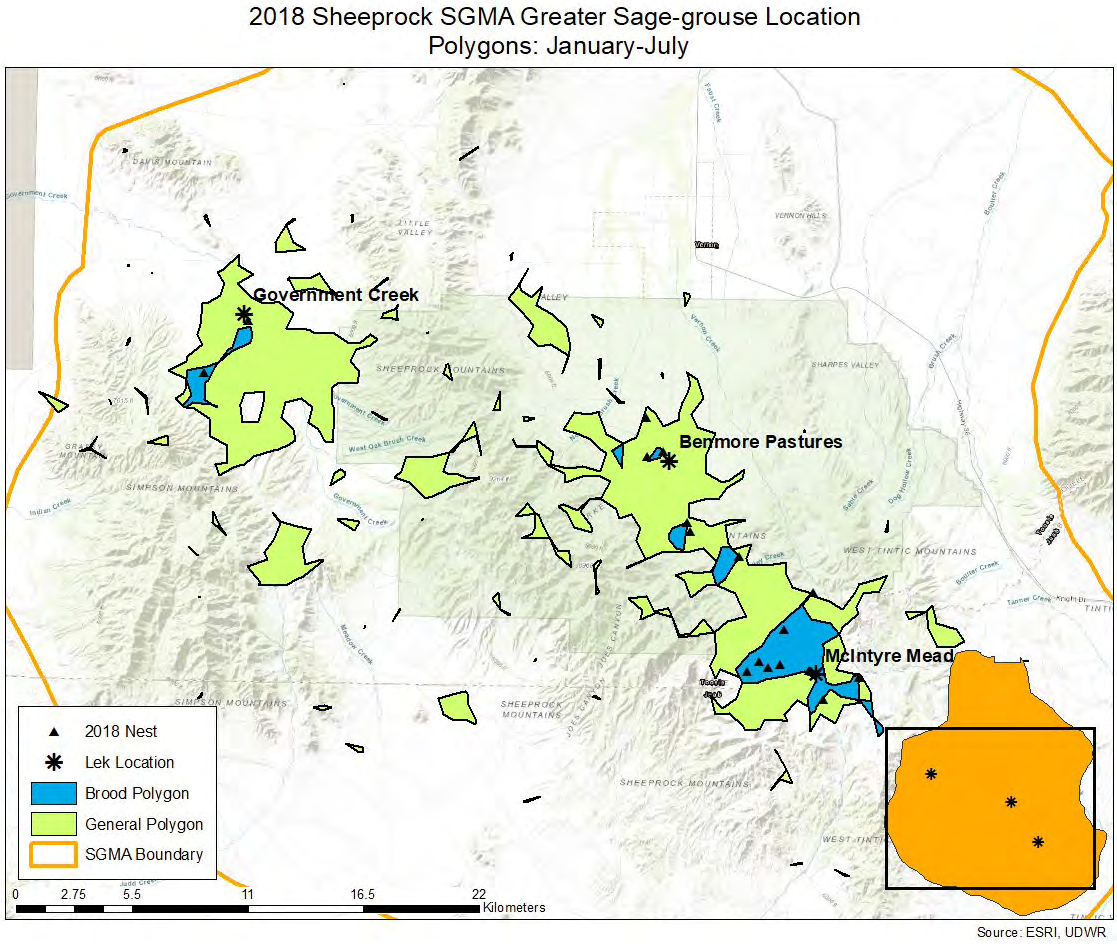

Figure 8. Movements of a juvenile female sage-grouse (*Centrocercus urophasianus*) translocated into Government Creek from Park Valley in 2018. Her movements show that she stayed within the western portion of the Sheeprock SGMA. For the winter, she traveled just south of the Simpson mountains, still within the SGMA. To date, we have not captured any individuals travelling and localizing around this portion of the study area. The blue circle indicates where she was released in spring of 2018 with blue arrows indicating her movements. The green circle is her current location as of January 2019.

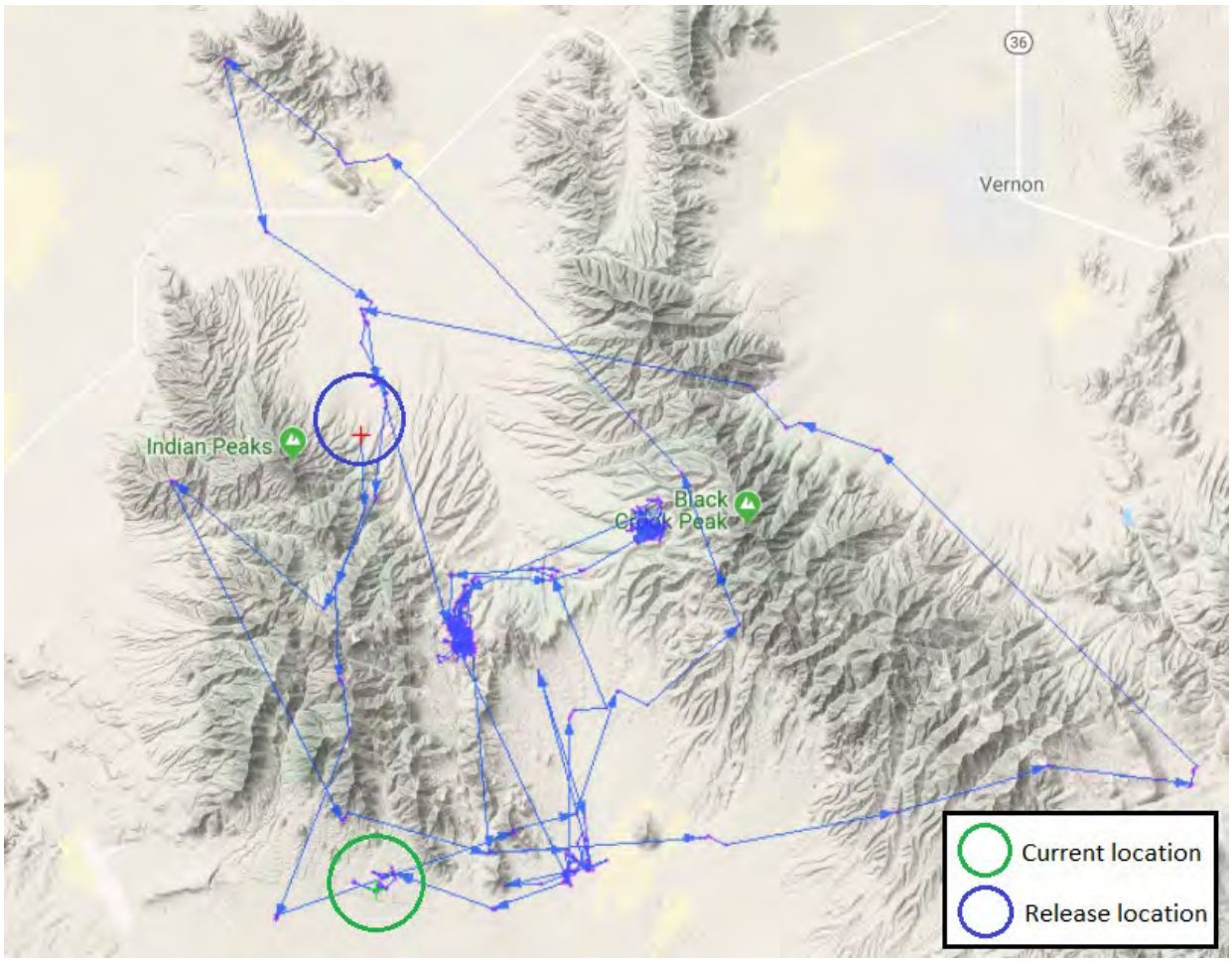

Figure 9. Movements of a juvenile female sage-grouse (*Centrocercus urophasianus*) translocated into Government Creek from Park Valley in 2018. Her movements show that she stayed within that western portion of the Sheeprock SGMA. For the winter, she has traveled just south of the Simpson mountains, still within the SGMA. To date, we have not captured any individuals travelling and localizing around this portion of the study area. The blue circle indicates where she was released in spring of 2018 with blue arrows indicating her movements. The green circle is her current location as of January 2019.

Nest Initiation, Success and Brooding

Of the 40 marked, live females detected during nesting season, 14 nest initiations were detected. This gives an apparent nest initiation rate of 35%. The 17 nest initiations were from the following females: 2 from 2016 resident females, 6 from 2017 translocated females, 1 from a 2017 resident female, 6 from 2018 translocated females and 2 from 2018 resident females. At least 92 chicks were successfully hatched from these nests; one GPS female's transmitter stopped transmitting during her nesting period due to lack of sun and could not be found post-hatch. Figure 10 shows the nesting locations of all 17 nests in the Sheeprock SGMA and Table 3 summarizes the nesting and brooding results.

Of the 17 nests, 14 hatched and 8 successfully reached the 50-day brood survey performed to assess brood success. By the end of the 50-day brooding period, apparent brood survival was estimated to be 61.5%, higher than last year's estimated 40% (Figure 11). Nineteen chicks were present from these 8 broods, yielding an apparent chick survival of 20.7%. Figures 12-14 show the brood locations of each brood with their nesting locations. Various studies found chick survival, whether either apparent or estimated, to be: 39% at 28 days posthatching (Gregg 2006); 44% at 18 days posthatch in Nevada (Reholz 2007); 34% to 42% in North Dakota and 32%-50% in South Dakota, respectively at 21 days posthatch (Herman-Brunson 2007, Kaczor 2008); and 50% at 42 days in Utah (Dahlgren et al. 2010).

Table 3. Table showing the nest initiation, hatch dates, clutch sizes and 50-day post-hatch brood sizes for translocated and resident female greater sage-grouse (*Centrocercus urophasianus*) in the Sheeprock Sage-Grouse Management Area. Included is also information regarding source population for females: Park Valley (PV) or Parker Mountain (PM) and 2018 AI treatment (AI, SHAM, control). For resident birds, there is the capture lek: Government Creek (GOV), Benmore Pastures (BEN), and McIntyre (MCI). Sheeprock SGMA, Utah.

Nest Number	Year Caught, Res/Trans	Source Population/Lek for SR	2018 AI treatment	Estimated Initiation Date	Hatch Date /Fail	Initial Brood Size	50-day Brood Survey: # of Chicks
1	2017 Res	GOV	--	4/4/2018	5/4/2018	6	--
2	2018 Res	BEN	--	4/21/2018	**FAIL**		--
3	2017 Trans	PM	--	4/18/2018	5/12/2018	7	1
4	2018 Trans	PV	AI	4/24/2018	**FAIL**		--
5	2017 Trans	PM	--	4/20/2018	5/19/2018	7	--
6	2017 Trans	PM	--	4/20/2018	5/20/2018	8	4
7	2017 Trans	PM	--	4/22/2018	5/20/2018	8	--
8	2018 Trans	PM	Control	4/24/2018	5/20/2018	7	4
9	2018 Trans	PM	SHAM	4/23/2018	5/22/2018	5	--
10	2017 Trans	PV	--	4/24/2018	5/22/2018	7	2
11	2016 Res	MCI	--	4/24/2018	5/21/2018	7	--
12	2016 Res	MCI	--	4/29/2018	5/29/2018	--	2
13	2018 Trans	PV	--	4/28/2018	5/28/2018	7	--
14	2018 Trans	PM	SHAM	4/29/2018	5/27/2018	7	3
15	2017 Trans	PM	--	4/30/2018	5/31/2018	7	2
16	2018 Res	BEN	--	5/1/2018	6/2/2018	9	1
17	2018 Trans	PM	Control	5/15/2018	**FAIL**		--
					Total:	92	19

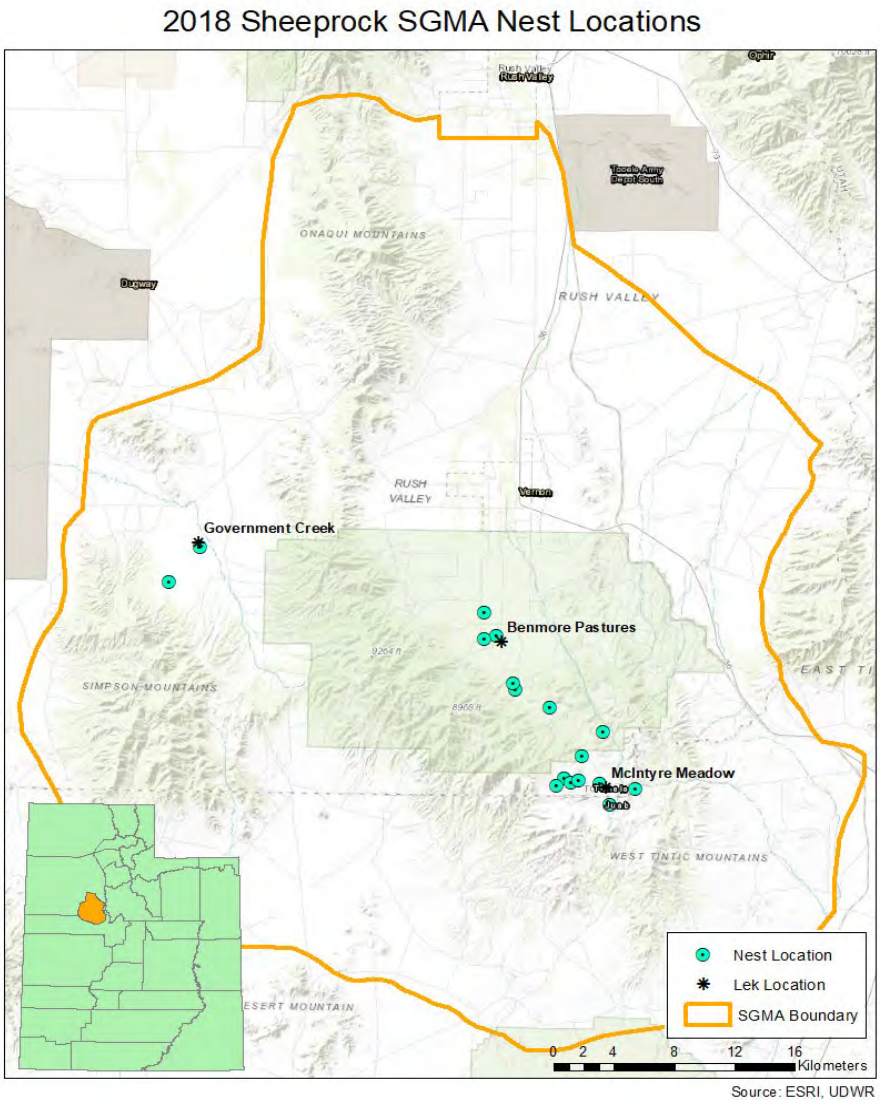

Figure 4. Greater sage-grouse (*Centrocercus urophasianus*) nesting locations across the Sheeprock Sage-Grouse Management Area for 2018, Utah.

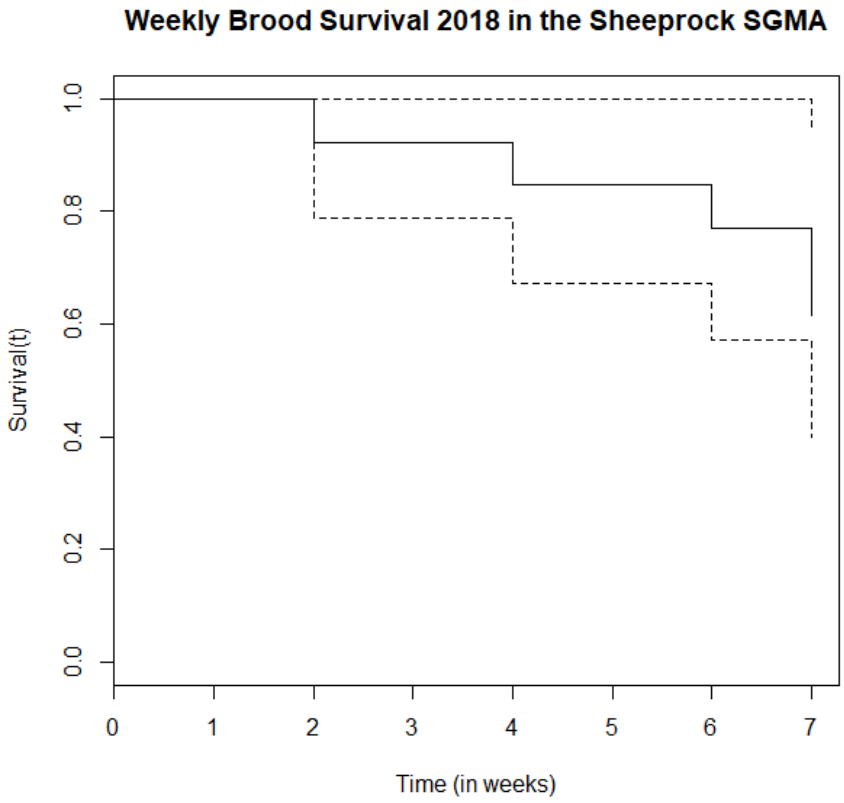

Figure 11. Survival probability (61.5%) of greater sage-grouse (*Centrocercus urophasianus*) broods across the brooding season for the 14 broods in 2018 in the Sheeprock Sage-Grouse Management Area (SGMA), Utah.

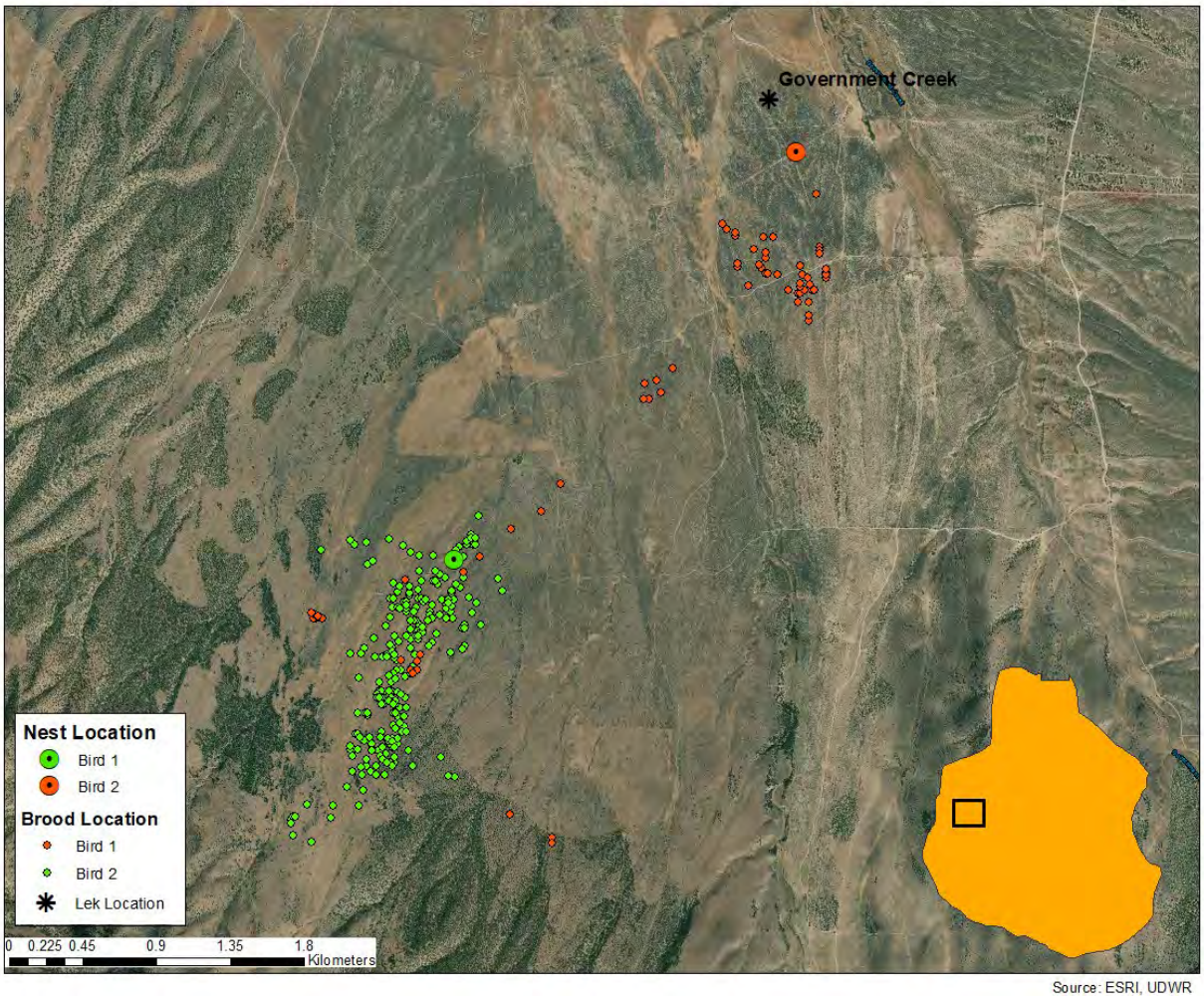

Figure 5. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in Government Creek from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah.

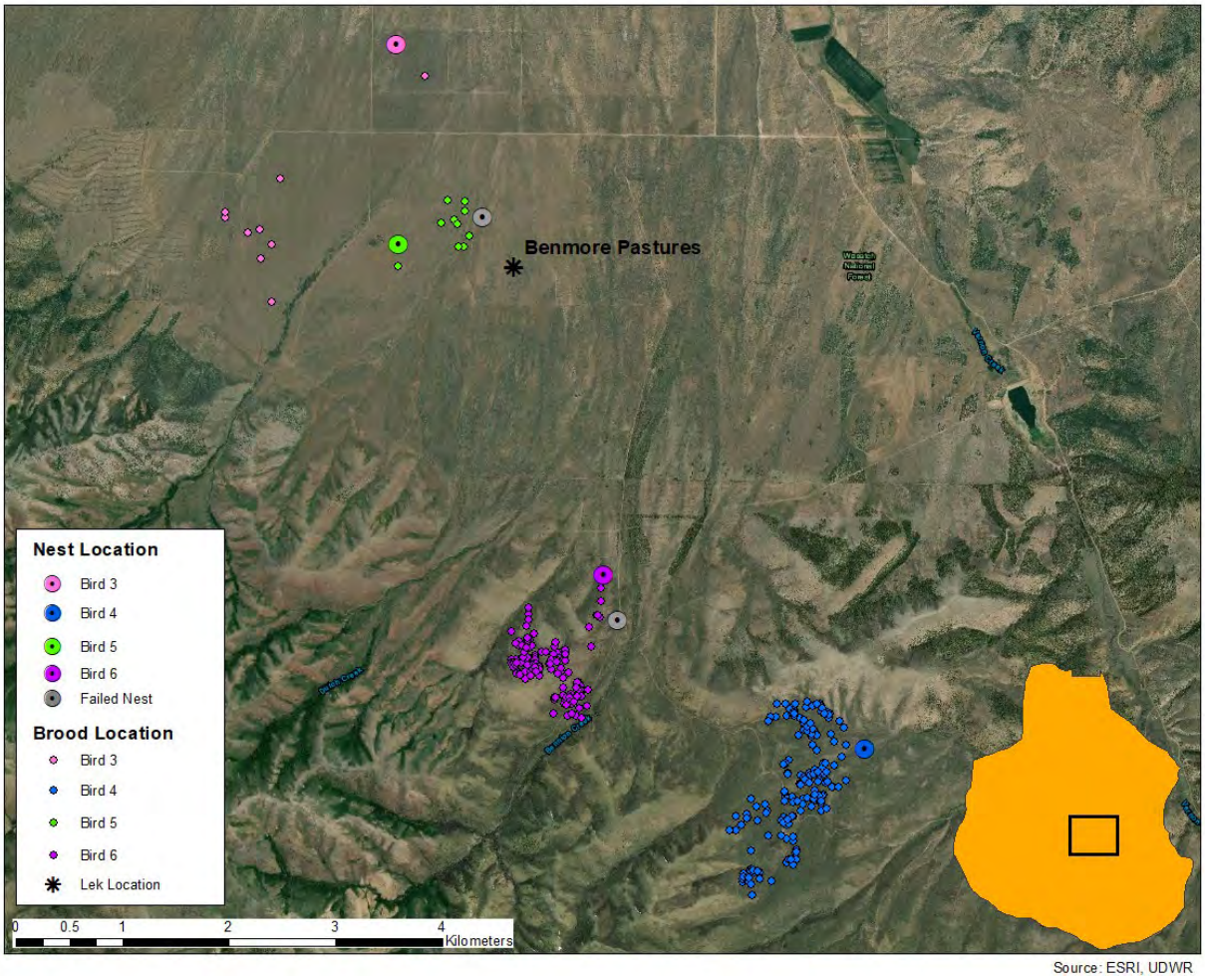

Figure 6. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in Benmore Pastures lek area from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah. Grey points indicate failed nests.

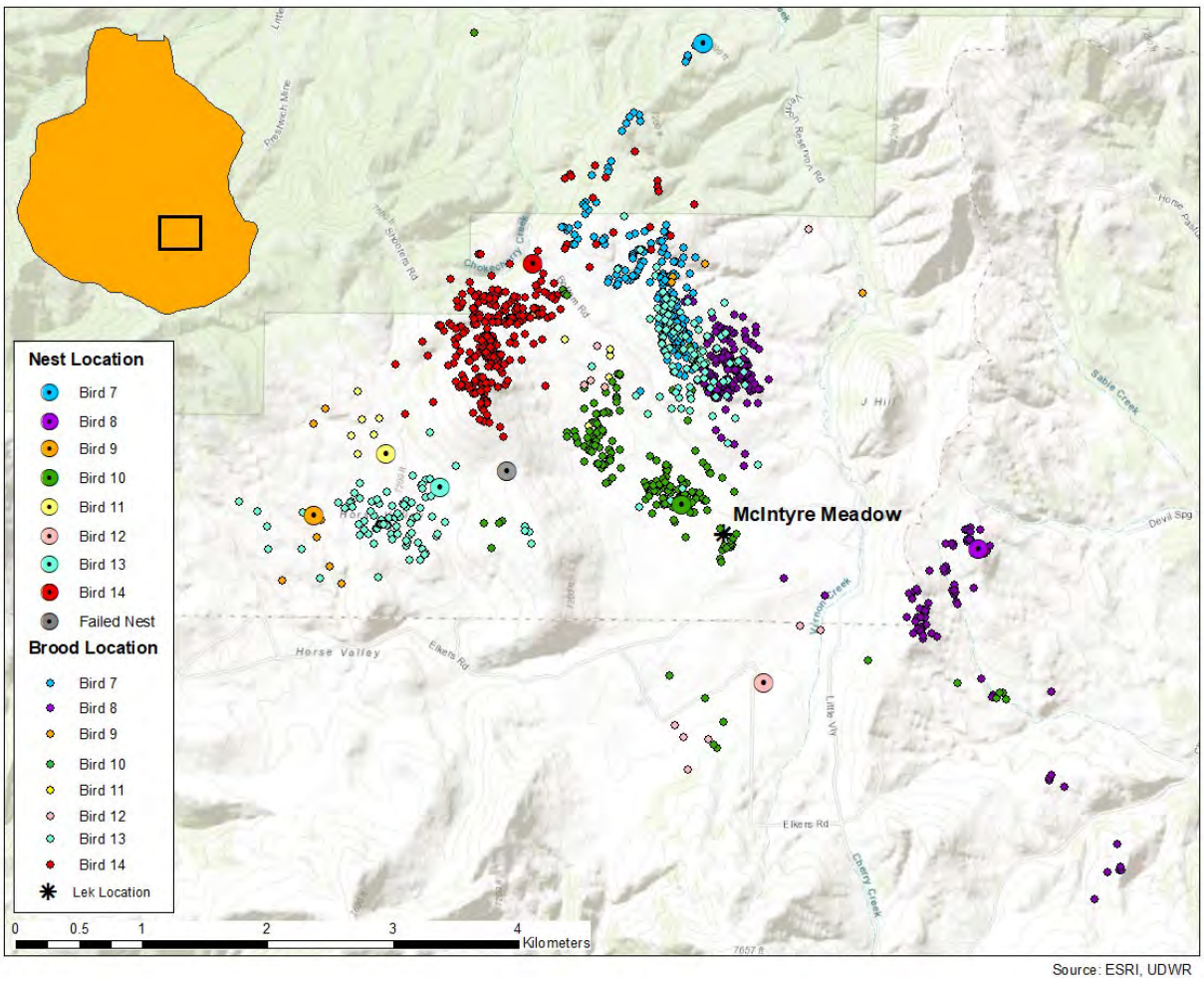

Figure 7. Greater sage-grouse (*Centrocercus urophasianus*) brooding and nesting locations in the McIntyre lek area from the 2018 breeding season in the Sheeprock Sage-Grouse Management Area, Utah. Grey points indicated a failed nest.

Survival

This year, we detected 23 mortalities: 4 translocated 2017 females, 2 translocated 2017 males, 1 resident 2017 female, 1 resident 2017 male, 11 translocated 2018 females, 3 translocated 2018 males , and 1 resident 2018 female. There have been 59 mortalities detected to date (Table 2).

Using a Cox Proportional Hazard model (Cox 1972), we have compared the monthly survival across years for all birds monitored from 2016 to 2018. Figure 15 illustrates the survival probabilities of 52.5% (CI 37.9%-72.8%), 58.6% (CI 46.0%-74.6%), and 68.8% (CI 58.1%-81.6%) for 2016, 2017, and 2018, respectively.

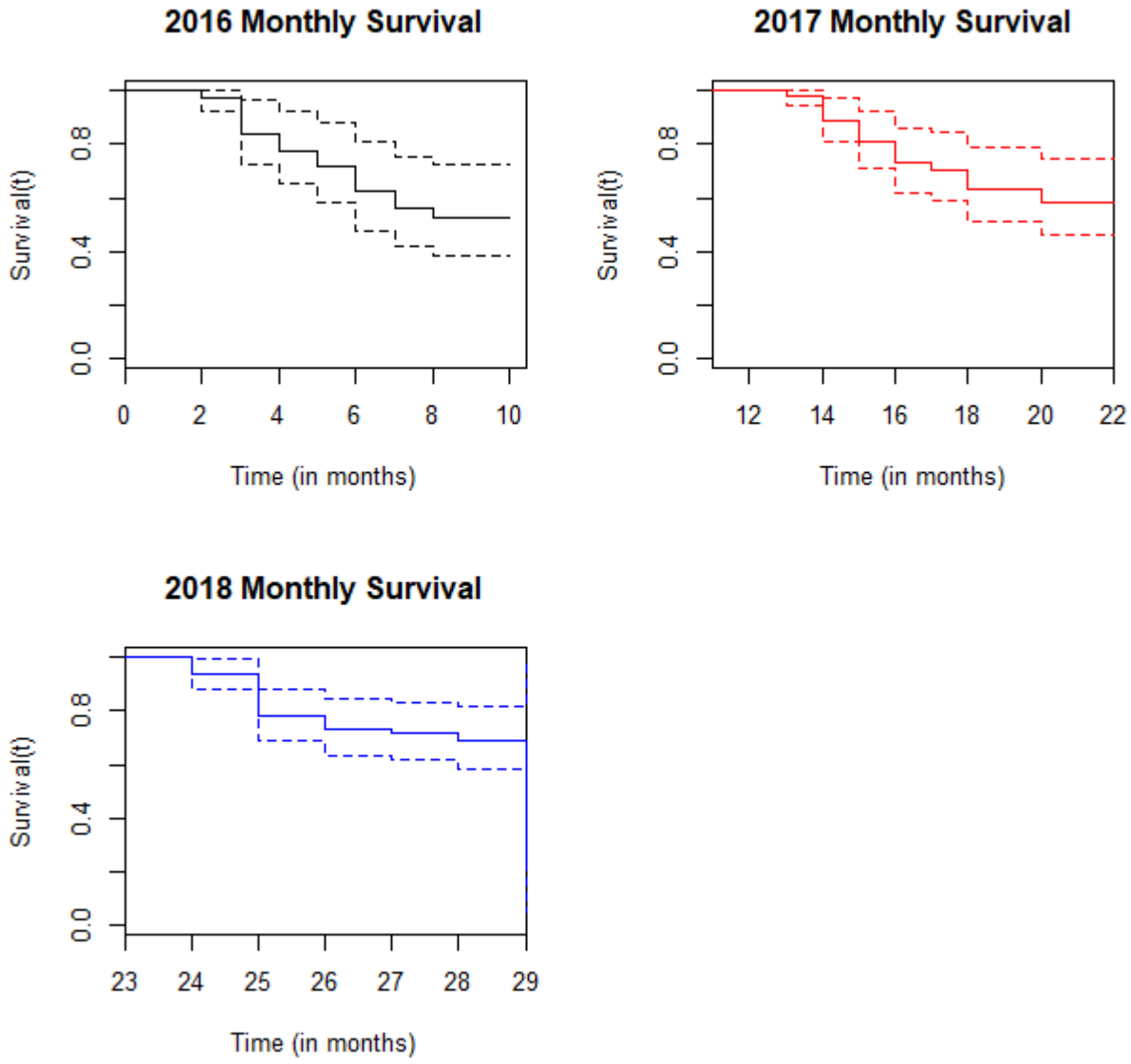

Figure 15. Survival probabilities for translocated and resident greater sage-grouse (*Centrocercus urophasianus*) by month across years 2016-2018 in the Sheeprock Sage-grouse Management Area. Month 1 corresponds to March 2016, and Month 29 is August 2018. Sheeprock SGMA, Utah.

Predator Surveys

We have included some preliminary numbers on how many individuals we observed per species on our avian and mammalian surveys for both 2017 and 2018. Figure 16 illustrates the overall counts of predators in the study area from May through July. In addition to our predator surveys, we also have provided the estimated predator take numbers provided by the USDA-APHIS Wildlife Services from 2018.

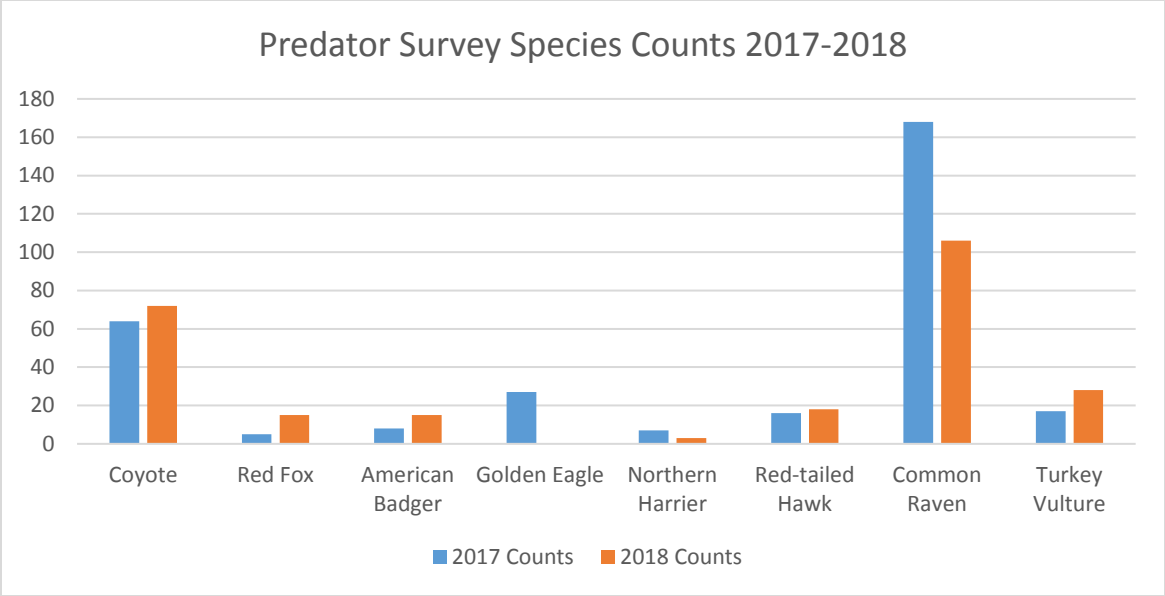

Figure 16. Data gathered from the predator surveys performed in May through July of 2017 and 2018 in the Sheeprock Sage-grouse Management Area, Utah.

Table 2. Estimated number of predators taken through June of 2018 in the Sheeprock Sage-Grouse Management Area by species as reported by USDA-APHIS Wildlife Services, Sheeprock SGMA, Utah.

2018 USDA-APHIS Wildlife Services Sheeprock SGMA Predator Take Numbers (through June)	
Target Species	**# Estimated Individuals Taken**
American Badger (*Taxidea taxus*)	2
Common Raven (*Corvus corax*)	680
Coyote (*Canis latrans*)	73
Red Fox (*Vulpes vulpes*)	4
Raccoon (*Procyon lotor*)	1

Off-Highway Vehicle Recreational Use

Smith et al. (2018) reported that the average group size of visitors to the Sheeprocks was slightly over 7 people, and the average distance from the Sheeprocks to their home was 58 miles. Of the groups sampled, 65% brought at least one OHV with them on their trip (Smith et al. 2018). The spatial data illustrated in Figure 17 show that visitors used existing roads; few visitors used single track and two track trails (Smith et al. 2018).

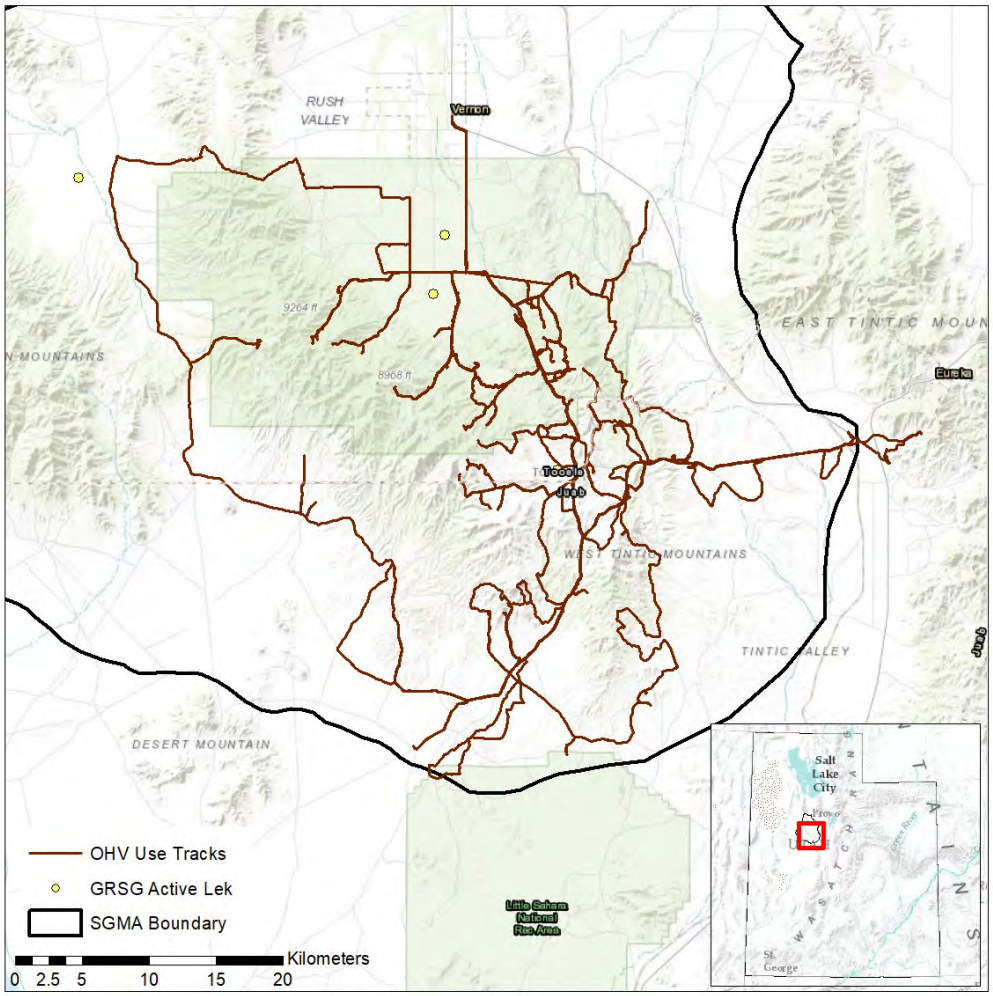

Figure 8. Spatial data of off-highway vehicle (OHV) recreational use from the visitors surveyed in Smith et al. (2018), Sheeprock Mountains Visitor Use Report, Utah State University, Utah.

Preliminary Conclusions

The Sheeprock SGMA sage-grouse population appears to be responding to the translocations. However, it is premature to attribute our positive results to any strategies employed thus far. We will conduct another year of translocations and monitor the vital rates of the populations through 2020 to determine population responses to the various management strategies.

2019 Work Plan

Jan-March: Field preparations to include finalizing research-funding plan, hiring technicians, purchasing radio-transmitters and field equipment, and participation in local working group and related meetings.

March-May: Sage-grouse capturing, radio-marking, translocations and participation in local working group and related meetings. We will be hiring four technicians this field season. More effort will be put into trapping in Government Creek and Fredrickson Pastures to acquire better data of resident birds' movements. Predator surveys will also be conducted during the field season to estimate predator abundance.

May-August: Monitoring radio-marked sage-grouse vital rates and habitat-use, predator surveys, and participation in local working group and related meetings. In order to better estimate chick survival during the brooding season, we will employ the use of pointing-dogs to detect females with their chicks for their 50-day brooding surveys. Dahlgren et al. (2010) found that spotlight and pointing-dog surveys detected 96% of chicks that were marked in the study, and found no significant difference between the use of pointing-dogs and spotlight surveys.

August- December: Monthly monitoring of population, data analysis and reporting, and participation in local working group and related meetings.

We plan to continue with another field season in 2020 to monitor individuals marked and translocated this spring.

Literature Cited

Aldridge, C.L, S. E. Nielson, H. L. Beyer, M. S. Boyce, J. W. Connelly, S. T. Knick, and M. A. Shroeder. 2008. Range-wide patterns of greater sage-grouse persistence. Diversity and Distributions 14: 983-994.

Baxter, R.J., J.T. Flinders, and D.L. Mitchell. 2008. Survival, movements, and reproduction of translocated greater sage-grouse in Strawberry Valley, Utah. Journal of Wildlife Management 72:179-186.

Bureau of Land Management (BLM). 2015. Utah Greater Sage-Grouse Proposed Land Use Plan Amendment B/ Final Environmental Impact Statement. http://www.blm.gov/ut/st/en/prog/planning/SG_RMP_rev/FEIS.html. Accessed December 3rd, 2016.

Bureau of Land Management (BLM). 2017. BLM Implements Measures to Restore and Maintain Habitat for the Sheeprocks Greater Sage-Grouse Population in Central Utah. Press Release. https://www.blm.gov/press-release/blm-implements-measures-restore-and-maintain-habitat-sheeprocks-greater-sage-grouse. Accessed December 13, 2017.

Chi, R.Y., 2004. Greater sage-grouse reproductive ecology and tebuthiuron manipulation of dense big sagebrush on Parker Mountain. Ph.D. Dissertation, Utah State University.

Connelly, J.W., M. A. Schroeder, A. R. Sands, and C. E. Braun. 2000. Guidelines to manage sage-grouse populations and their habitats. Wildlife Society Bulletin 28:967-985.

Connelly, J.W., K.P. Reese, and M.A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. College of Natural Resources Experiment Station, Moscow, Idaho. Station Bulletin 80.

Connelly, J. W., S. T. Knick, M. A. Schroeder, and S. J. Stiver. 2004. Conservation Assessment for Greater Sage-grouse and Sagebrush Habitats. Western Association of Fish And Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming, USA.

Connelly, J.W., C.A. Hagen, M.A. Schroeder. 2011. Characteristics and dynamics of greater sage-grouse populations, in: S. T. Knick and J. W. Connelly (Eds.), Greater sage-grouse:Ecology and conservation of a landscape species and its habitats. Greater Sage-Grouse: Ecology and Conservation f a Landscape Species and Its Habitats, Edition: Studies in Avian Biology (vol 38), University of California Press, Berkeley, pp. 53-67.

Cox, D.R. 1972. Regression models and life tables (with discussion). Journal of the Royal Statistics Society, Series B 34: 187–220.

Dahlgren, D.K., T.A. Messmer, E.T. Thacker, and M.R. Guttery. 2010. Evaluation of Brood Detection Techniques: Recommendations for Estimating Greater Sage-Grouse Productivity. Western North American Naturalist 70:233-237.

Dahlgren, D.K., T.A. Messmer, D. N. Koons. 2010. Achieving Better Estimates of Greater Sage-Grouse Chick Survival in Utah. Journal of Wildlife Management 74:1286-1294.

Daubenmire, R.F. 1959. A canopy-coverage method of vegetation analysis. Northwest Science 33:43-64.

Dettenmaier, S.J., and T.A. Messmer. 2013. Greater sage-grouse response to season-long and prescribed grazing (NRCS conservation practice 528) on paired ecological sites (phase 1). Annual Report. Utah State University. Logan, UT.

Dulfon, N.E., 2016. Sagebrush Ecology of Parker Mountain, Utah. Master's Thesis, Utah State University. Logan, UT.

Garton, E.O., J.W. Connelly, J.S. Horne, C.A. Hagen, A. Moser, and M.A.Schroeder. 2011. Greater Sage-Grouse population dynamics and probability of persistence, in: S. T. Knick and J. W. Connelly (Eds.), Greater Sage-Grouse: Ecology and Conservation f a Landscape Species and Its Habitats, Edition: Studies in Avian Biology (vol 38), University of California Press, Berkeley pp.293-382

Gibson, R.M. 1996. A re-evaluation of hotspot settlement in lekking SageGrouse. Animal Behaviour 52:993-1005.

Gregg, M.A. 2006. Greater Sage-Grouse reproductive ecology: linkages among habitat resources, maternal nutrition, and chick survival. Ph.D. dissertation, Oregon State University, Corvallis, OR.

Herman-Brunson, K.M. 2007. Nesting and broodrearing success and habitat selection of Greater Sage-Grouse and associated survival of hens and broods at the edgeo f their historic distribution. M.S. thesis, South Dakota State University, Brookings, SD.

Kaczor, N.W. 2008. Nesting and brood-rearing success and resource selection of Greater Sage-Grouse in northwestern South Dakota. M.S. thesis, South Dakota State University, Brookings, SD.

Luginbuhl, J. M., J. M. Marzluff, J. E. Bradley, M. G. Raphael, and D. E. Varland. 2001. Corvid survey techniques and the relationship between corvid relative abundance and nest predation. Journal of Field Ornithology 72:556–572.

Miller, R.F, and L.L. Eddleman. 2000. Spatial and temporal change of sage grouse habitat in the sagebrush biome. Oregon State University Aricultural Experiment Station Technical Bulletin 151. Corvallis, Oregon, USA.

Miller, R. F, T.J. Svejcar, and J. A. Rose. 2000. Impacts of western juniper on plant community composition and structure. Journal of Range Management 53: 574-585.

Norvell, R. E., F. P. Howe, J. R. Parrish, and F. R. Thompson III. 2003. A seven-year comparison of relative-abundance and distance-sampling methods. The Auk 120:1013–1028.

Oyler-McCance, S.J., S.E. Taylor, and T.W. Quinn. 2005. A multilocus population genetic survey of greater sage-grouse across their range. Molecular Ecology 14:1293-1310.

Rebholz, J.L. 2007. Influence of habitat characteristics on Greater Sage-Grouse reproductive success in the Montana Mountains, Nevada. MS. thesis, Oregon State University, Corvallis, OR.

Reese, K.P. and J.W. Connelly. 1997. Translocations of sage grouse Centrocercus urophasianus in North America. Wildlife Biology 3:852-864.

Robel, R.J., J.N. Briggs, A.D. Dayton, and L.C. Hulbert. 1970. Relationships between visual obstruction measurements and weight of grassland vegetation. Journal of Range Management 23:295-297.

Robinson, J. D. 2007. Ecology of two geographically distinct greater sage-grouse populations inhabiting Utah’s West Desert (Master of Science Thesis). Utah State University, Logan, Utah, USA.

Robinson, J.D. and T.A. Messmer. 2013. Vital rates and seasonal movements of two isolated greater sage-grouse populations in Utah's West Desert. Human Wildlife Interactions 7:182-194.

Schauster, E. R., E. M. Gese, and A. M. Kitchen. 2002. An evaluation of survey methods for monitoring swift fox abundance. The Wildlife Society Bulletin 30:464–477.

Schroeder, M.A., J.R Young, and C.E. Braun. 1999. Sage Grouse (Centrocercus urophasianus). In A. Poole and F. Gill (editors). The birds of North America. No. 425. The Academy of Natural Sciences, Philadelphia, PA, and the American Ornithologists Union, Washington, D.C.

Schroeder, M.A., C. L. Aldridge, A. D. Apa, J. R. Bohne, C. E. Braun, S. D. Bunnell, J. W. Connelly, P. A. Deibert, S. C. Garnder, M. A. Hilliand, G. D. Kobriger, S. M. McAdam, C. W. McCarthy, J. J. McCarthy, D. L Mitchel, E. V. Rickerson, and S. J. Stiver. 2004. Distribution of sage-grouse in North America. Condor 106: 363-376.

Smith, J.W., B. Muhlestein, M. Chelak, L. Belton and T. Messmer. 2018. Sheeprock Mountains Visitor Use Report. Institute of Outdoor Recreation and Tourism, Utah State University, Logan, Utah, USA.

Somershoe, S. G., D. J. Twedt, and B. Reid. 2006. Combining breeding bird survey and distance sampling to estimate density of migrant and breeding birds. The Condor 108:691–699.

U.S. Fish and Wildlife Service (USFWS). 2015. Endangered and Threatened Wildlife and Plants; 12-Month Finding on a Petition To List Greater Sage-Grouse (Centrocercus urophasianus) as an Endangered or Threatened Species; Proposed Rule. Web. Accessed January 24, 2016. https://www.gpo.gov/fdsys/pkg/FR-2015-10-02/pdf/2015-24292.pdf

Utah Department of Natural Resources. 2011. Utah's Watershed Restoration Initiative. Utah Department of Natural Resources, Salt Lake City, Utah, USA. Accessed December 15, 2017. https://wildlife.utah.gov/pdf/fact_sheets/watershed_restoration.pdf

Utah Public Lands Policy Coordination Office. 2019. Utah Conservation Plan for Greater Sage-grouse in Utah. Salt Lake City, Utah, USA.

West Deseret Adaptive Management Resources Working Group (WDARM). 2007. Accessed August 17, 2015. http://utahcbcp.org/files/uploads/westdesert/WDARMSAGRPlanFinal.pdf.

Western Regional Climate Center. 2016. Vernon, Utah (429133). Period of record:8/1/1953 to 6/10/2016, http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut9133. Accessed November 06, 2016.