2015 ANNUAL REPORT

GREATER SAGE-GROUSE RESPONSE TO SEASON-LONG AND PRESCRIBED GRAZING (NRCS CONSERVATION PRACTICE 528) ON PAIRED STUDY SITES IN RICH COUNTY, UTAH, USA

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Cooperators

Bureau of Land Management

Deseret Land and Livestock

Intermountain West Joint Venture

Natural Resources Conservation Service Sage-grouse Initiative

Pheasants Forever, LLC.

Rich County Commission

Rich County Coordinated Resources Management

US Fish & Wildlife Service

US Forest Service

Utah Department of Agriculture and Food

Utah Division of Wildlife Resources

Utah State University Extension

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Introduction

Background

The Utah Division of Wildlife Resources (UDWR) reported that sage-grouse (*Centrocercus spp.*) were historically found in all 29 of Utah's counties (UDWR 2009). In 2009, sage-grouse occupied habitats in only 26 of Utah's counties. The UDWR estimated that 13.6% or 11,514 mi^2 (29,821 km^2) of Utah provides habitat for sage-grouse. In 2003, Beck et al. reported that sage-grouse in Utah occupy just 41% of historical habitats.

The complex mosaic of land ownership, competing resource uses, and administration of the sagebrush habitats compound sage-grouse management and conservation in Utah. Because of this mosaic, sage-grouse may occupy seasonal habitats administered by several different federal and state agencies and private landowners. The UDWR (2009) estimated that privately owned lands provide 40.5% of the occupied sage-grouse habitat with Bureau of Land Management (BLM) lands second at 34%. The U.S. Forest Service (USFS) administers 10% of the currently occupied sage-grouse habitat and the State of Utah approximately 9.5%. Of this land base, Utah School and Institutional Trust Land Administration (SITLA) manages 8.0%, Utah Division of Parks and Recreation <1%, and UDWR 1.5%. Ute Tribal land comprises 5.2% and National Park Service and military reservations less than one percent each.

Declines in sage-grouse populations appear to parallel the loss and fragmentation of sagebrush (*Artemisia* spp.) habitats (UDWR 2009). The cause of this habitat loss and fragmentation include wildfire, urban expansion, development, agricultural conversion, herbicide treatments, rangeland seeding, noxious weeds/invasive species expansion, conifer encroachment, drought, and improper livestock grazing management (UDWR 2009). The primary land use of sage-grouse habitats in Utah is domestic livestock grazing.

Reported effects of grazing on greater sage-grouse (*C. urophasianus*: sage-grouse) and their sagebrush habitats differ (Beck and Mitchell 2000). The reason for this is that no before-after-control-impact (BACI) studies have been conducted to specifically document the long-term impacts on sage-grouse vital rates and the effects of specific grazing strategies on ecological site condition and trends. Changes to sagebrush steppe vegetation communities in response to management actions may also be manifested over decades (Connelly et al. 2004). Concomitantly, the prohibitive costs of meaningfully monitoring vegetation and sage-grouse population changes over extended time periods have precluded meaningful documentation of grazing effects on greater sage-grouse (Beck and Mitchell 2000, Connelly et al. 2004).

The Utah Sage-gGrouse Strategic Management Plan (UDWR 2009) has identified the following research priorities regarding livestock grazing and sage-grouse.

a) How does domestic grazing directly affect sage-grouse populations?

b) How does domestic grazing directly or indirectly affect sage-grouse habitats (all seasonal areas)?

c) How do water developments affect sage-grouse and their habitat (directly and indirectly)?

d) Does domestic livestock grazing alter behavior in seasonal habitat areas (including meadows/riparian areas)?

The Natural Resources Conservation Service (NRCS) Sage-Grouse Initiative (SGI) seeks to engage private landowners and other partners in cooperative efforts to reduce threats to sage-grouse populations. The SGI provides targeted technical and financial assistance through Farm Bill programs to assist cooperators with implementing sage-grouse conservation efforts.

The SGI focuses on implementing conservation practices on private and public lands as a means to: 1) improve sage-grouse habitat, 2) improve sage-grouse vital rates and increase population size, 3) prolong or enhance the desired effects of other land treatments, and 4) broader land management benefits to include other wildlife species and producers. By assisting land managers and livestock producers to improve range conditions in core sage-grouse population areas, SGI also seeks to improve sage-grouse habitat quality while ensuring the sustainability of working rangelands. An important component of the SGI is scientifically documenting the effectiveness of the conservation practices such as prescribed rotational grazing on sage-grouse habitat quality and populations.

Purpose

The purpose of this research is to scientifically document sage-grouse individual and population responses to habitat and vegetation differences that may occur under prescribed grazing and season-long grazing practices on paired study sites in Rich County, Utah. Specific questions to be addressed in our research objectives include:

1) Do sage-grouse vital rates differ between areas managed under prescribed rotational and more traditional season-long grazing practices?

2) Does sage-grouse habitat composition and quality differ based on prescribed rotational or season-long grazing practices?

3) Do sage-grouse seasonal habitat-use patterns differ under prescribed rotational and season-long grazing practices?

4) Does the quality of the seasonal habitats used by sage-grouse under prescribed and season-long grazing differ based on structure, composition, and nutrient analysis?

Study Area

The study area is located in Rich County, Utah, in the western United States. Rich County is located in northeastern Utah and constitutes the southwestern portion of the Wyoming Basin Sage-grouse Management Zone II (Knick and Connelly 2011). The research is being conducted on 2 paired study areas within Rich County. The first study area is Deseret Land and Livestock (Deseret L&L), an 86,900 ha privately owned ranch comprised of roughly 80,600 ha of private lands and 6,300 ha of federal BLM lands located in the eastern lower elevations. The Deseret L&L study area is managed as a cohesive unit and land managers there have used a system of rotational prescribed grazing practices since 1979. The second site, Three Creeks, is a 56,900 ha collection of BLM and USFS grazing allotments and private lands that are generally managed under season-long grazing practices. Three Creeks is located just west of the town of Randolph, Utah.

Both sites exhibit characteristic sagebrush steppe habitats dominated by Wyoming big sagebrush (*A. tridentata wyomingensis*) and an understory of bunchgrass species in the lower elevations. Stands of aspen (*Populus tremuloides*), fir (*Abies* spp.), and pine (*Pinus* spp.) are found at higher elevations. Elevation ranges from 1900 m in the eastern areas to 2600 m in the west. Mean annual precipitation ranges from 250 mm at lower elevation to 457 mm in the higher elevations. Roughly half of this precipitation occurs from December to March (Banner et. al 2009; Figure 1). Mean temperatures ranged from 28.7° C in July to -6° C in January (Western Regional Climate Center 2012).

Methods

Study Concepts

The research project was originally designed as a paired site study consisting of 2 distinct phases implemented over a 4 year period (2012-2015). Phase 1 was scheduled to begin in 2012 and continue through 2013 and evaluate the impacts on sage-grouse populations between the 2 grazing treatments under a paired site study design. In this phase Deseret L&L was the treatment site and Three Creeks the control site. Phase 2 was to begin in January 2014 when Three Creeks was scheduled to implement a grazing management change from a more traditional season-long to rotational prescribed grazing practice. This second phase would have applied a Before-After Control-Impact (BACI) study design where two years of pre-treatment data for Three Creeks would be compared to two years of post-treatment data. However the anticipated grazing management change in Three Creeks and the corresponding shift to Phase 2 of the study was delayed beyond the research timeline. This resulted in a shift in study design and it continued as a paired site study from 2012-2015 (Phase 1).

Lek Trends

Lek routes have been used as an alternative method for obtaining indices of breeding sage-grouse males. We surveyed lek routes and counted the number of males strutting on leks during the spring lekking season each year. The resulting indices were used to track sage-grouse population trends for each study area. Lek surveys followed UDWR (UDWR 2009) protocols and were conducted from late March through mid-May. Leks were visited a minimum of 3 times during the breeding season. All lek counts were conducted within 0.5 hour before to 1.5 hours after sunrise. Designated lek routes were counted on the same mornings. All counts were conducted on days when the weather conditions were favorable for lekking (i.e. no precipitation or strong winds). Observers used binoculars from >50 m and counted all males observed at the lek. Observing from this distance prevented observers from disturbing lekking activities. Peak attendance for each lek was calculated using the highest male count during the season.

Radio-telemetry

Initial sample size objectives for radio-collared sage-grouse was 60 juvenile and adult, male and female sage-grouse at each site (approx. 40♀ and 20♂, n =120). This initial goal was met at the beginning of the research project in spring 2012. Because we were interested in comparing sage-grouse vital rates between the treatments, we made efforts to increase nesting and brooding sample size by focusing exclusively on radio-collaring hens in the following years. Captured birds were fitted with a 19 g necklace style very high frequency (VHF) radio transmitter. Transmitters were equipped with a mortality sensor to assist in documenting mortalities.

All captured birds were aged, sexed, and weighed, with wing and tarsus measurements taken. Age and sex were determined based on feather characteristics and molt patterns (Eng 1955, Crunden 1963). All captured birds, including those not radio-collared, were marked with an aluminum leg-band (size 14 females, size 16 males) engraved with a unique identification number. These bands provided additional information on movements for birds that were recaptured or reported harvested by hunters. All birds were released at their point of capture.

To maintain desired sample size each year, new radio-collars were deployed on additional hens each spring to replace those that were missing or lost to mortality. Radio-marked birds were tracked to determine habitat use, home range and vital rates. Nests and broods were monitored from nest initiation until 50 days after hatch to quantify nest and brood-rearing success. Movement and home range estimates will be calculated during subsequent analyses using Spatial Analyst tools in ArcGIS Desktop (Environmental Systems Research Institute, Inc., Redlands, CA).

To estimate sage-grouse vital rates across each study area, we attempted to radio-mark and track individuals from leks within the 2 study areas. Capture techniques included night spotlighting and long-handled hoop nets as described by Giesen et al. (1982) and Wakkinen et al. (1992). All-Terrain Vehicles (ATV) were used to capture birds.

Data obtained by tracking radio-collared grouse were used to assess vital rates and habitat use. When possible, radio-marked females were located a minimum of twice weekly during the spring until time of nest initiation. We also used telemetry software (LOAS) to estimate hen locations at the start of the nesting season. Calculated locations allowed us to monitor females that were in the process of initiating nests without disturbing them. We assumed a female was nesting after she was located in the same spot as indicated by the VHF signal for a period >3 days. After determining that a female was nesting we verified her presence by homing in on the transmitter to locate her nest without disturbing it. Because of the predation risk to sage-grouse and their nests from both avian and mammalian predators, nest verification occurred only after the area was visually checked for predators. A GPS point was recorded for all nests with the nest being remotely monitored ≥3 times a week until hatch or failure could be determined.

Once a female was detected at a distance from the nest, it was checked to determine nest fate. Eggshell fragments with separated membranes and typical hatching pattern on the shell (Rearden 1951) were used to indicate a successful hatch. We attempted to record all unhatched and depredated eggs observed.

Nesting effort or initiation was estimated as the proportion of hens that attempted to nest divided by the total hens closely monitored within that study area during the nesting period. Re-nesting effort was estimated from the proportion of hens that re-nested divided by total hens that survived an initial nest failure. Nests were considered successful if at least one egg in the nest hatches successfully (Connelly et al. 2003).

Nest survival was calculated using the Nest Survival model with the RMARK package in R. This model takes into account both the time of first detection and the total number of days the nest was monitored. Hatching success was determined for each nest, as the proportion of all eggs laid in successful nests that hatch. Hen success was calculated for each study area as the proportion of hens that hatch at least one egg, regardless of the number of nesting attempts.

When broods were estimated to be approximately 50 days of age, we located, flushed and counted the total number of chicks to determine brood success. Brood size was calculated as the mean number of chicks per hen at 50 days of age, using all hens alive at the onset of nesting. At each site, chick survival was calculated as the number of chicks that survive to 50 days of age from all eggs that hatched in successful nests. Dahlgren et al. (2010) documented a high rate of brood-hopping (chicks are adopted by females that are not their mother) in some populations. If brood-hopping occurs, this may bias estimates of chick survival and brood success if the chicks that brood-hopped are presumed mortalities.

Sage-grouse populations often engage in seasonal movements over large annual ranges composed of differing seasonal habitats. To determine the extent that these two populations engaged in such activity, we : 1) defined the second-order selection of habitat based on home ranges of individuals or subpopulations (e.g., birds associated with a lek or lek complex), 2) assessed the condition of various seasonal habitat components (e.g., breeding and winter habitats), within the home range (third-order selection), and 3) described the quality and quantity of food or cover at particular use sites (fourth-order selection) (Johnson 1980). To accomplish these objectives, sage-grouse seasonal movements/migrations were spatially plotted in subsequent analysis to identify important seasonal habitats. Aerial photos, satellite imagery, and digitized maps were used to measure the size and juxtaposition of these habitats. The term ‘condition’ referred to above relates to landscape characteristics such as habitat patch sizes, measures of habitat quality (structure, percent cover), connectivity (availability of corridors connecting patches), amount of edge and distance between habitat patches.

Vegetation and Habitat Monitoring

Habitat quality and vegetation composition responses to the respective grazing treatment were assessed with vegetation/habitat surveys in each study area. Because the research was focused on hens and their reproductive success, vegetation surveys were based on the location of nesting sites and brood locations of radio-collared hens. Each vegetation survey location was paired with a random site generated using the 'gencondrandompnts' command builder in Geospatial Modeling Environment (GME; Beyer 2012). Each paired random site was generated within the same pasture as the actual nest or brood location. This ensured that random sites occur within areas that are subject to the same potential grazing pressure of the actual nest or brood location. To avoid sampling inappropriate random sites (roads, bodies of water, cliffs, etc.) all generated paired random points were overlaid on satellite imagery and censoring those points determined not appropriate for sampling.

Vegetation surveys were conducted along 4 transects laid out in the cardinal directions. Transect length varied based on location type. Nest location transects were 15 m in length while transects at brood sites 25 m. The longer transect length at brood sites was to reflect the larger areas selected by hens and their broods.

To assess habitat characteristics at each survey location, several methods were employed. Because visual obstructive cover can help limit nest predation risk, Robel pole measurements (Robel et al. 1970) were recorded at each nest and random nest site. The pole was centered in the nest bowl and measurements were taken from a height of 1 m and at a distance of 4 m. At randomly generated nest sites the pole was centered in the canopy of the closest shrub that appeared large enough to conceal a nesting hen.

To estimate canopy cover for all shrub species at each site we used measurement techniques based on the canopy line intercept method described by Canfield (1941). The ability of the line intercept method to converge on the actual shrub cover at lower sample sizes when compared to Daubenmire plots makes it a better choice for our sites (Hanley 1978). Measurements included both length of the canopy intercept and height of shrub next to the transect. Because of the open nature of shrub canopies in sagebrush steppe, gaps in foliage that were <5 cm were considered continuous.

High food forb cover has been associated with both early- and late-season brood habitat in Wyoming (Holloran 1999). Feeding trials of sage-grouse chicks conducted by Johnson and Boyce (1990) found insects to be an essential component of their diet for both survival and development. The abundance of insects is influenced to a degree by the amount of forb cover. Brood locations occur in areas with less sagebrush cover when compared to nest sites (Holloran 1999). A reduction in brush cover might be mitigated by increased forb cover in these locations from June to September.

Forb cover was estimated using methods outlined by Daubenmire (1959). Plots were read at 3, 6, 9, 12, and 15 m along each transect at nest sites (n=20/site). Longer transect lengths for brood sites accommodated additional plots at both 18 and 21 m (n=28/site). When possible all forbs and grasses within the plot were identified to species level. Specimens that are unidentifiable to species level in the field were recorded as A=annual or P=perennial, G=grass or F=forb and assigned a number based on the sample order (e.g., PF1, AF2). The percent cover for each species was assigned using Daubenmire's class system. The use of classes in cover estimations reduces bias and error between observers to a point lower than the normal variation within the site (Daubenmire 1959). Height for each species in the plot was measured using the individual of that species closest to the bottom right corner of the plot. Bare ground, rock, and litter cover was also estimated for each plot.

The mean percentage of cover for species in each plot was calculated using the cover class midpoint (Daubenmire 1959). Percentages for each species was summed for all plots at each site then divided by total number of plots. The resulting value will be used as the estimation of total percentage of cover for each species at that site. Species mean height will also be calculated for each site.

Viewsheds for nest and brooding locations (Aspbury and Gibson 2004) will be calculated to determine long-range visibility at these sites. We will use the viewshed tool in the Spatial Analyst tools of ArcGIS to generate each viewshed. Viewsheds will be calculated from 10 m Digital Elevation Models (DEM) layers available from the State of Utah's Automated Geographic Reference Center (AGRS 2012).

Nutritional Analysis

Sage-grouse habitat has historically been evaluated in terms of structure (e.g., vegetation cover, height, density, etc.). By describing vegetation characteristics associated with sage-grouse use and random sites, inferences can be drawn regarding relationships of habitat quality and selection to productivity (Connelly et al. 2003). Vital rates may differ even though no observable difference in vegetation structure of habitat-use areas exists at either site. Thus, there still would be biological costs to different grazing regimes, but they may be underestimated by relying solely on vegetation structural measurements. Expanding the traditional definitions of sage-grouse habitat quality to include the nutritional make-up of sagebrush and other important forage plants may provide greater insights into the biological costs of displacing birds from traditional seasonal habitats.

We will assess nutritional and chemical components of sagebrush preferred by sage-grouse in both treatment and control to determine if dietary constituents can be used to predict diet selection and how diet might impact productivity. Where possible, we will attempt to monitor dietary selection of individually radio-marked sage-grouse and collect samples of sagebrush eaten by that individual. To conduct this analysis, we collected samples from February to March from browsed and random non-browsed shrubs (within 1 m) of the same subspecies and analyze for nitrogen (protein) digestibility, amino acids, and chemical composition following techniques outlined by Remington and Braun (1985). These results may be used to develop alternative metrics to identify, map, and conserve high quality sage-grouse habitat. A map of the most palatable sagebrush plants could identify key foraging sites across landscapes and predict important winter and early spring use areas for sage-grouse (J. Connelly, Idaho Department of Fish and Game, personal communication).

Predator surveys

Increased predation of sage-grouse is perceived as a major threat to the species by private land owners (Belton et al. 2009). Connelly et al. (2000) found predation to be the leading cause of mortality for a sage-grouse population in SE Idaho. In that same study hunting was identified as the second leading cause of mortality. Hagen (2011) reported that range wide sage-grouse nest success rates and adult survival are relatively high and that few studies have demonstrated a link between habitat quality, predation, and mortality rates. However, in fragmented native habitats or areas where anthropogenic activities sustain higher levels of native or invasive predator populations, predation may limit population growth (Bui et al. 2010).

Coates and Delehanty (2010) hypothesized that the potential risk for increased raptor and corvid predation on sage-grouse could be mitigated by maintaining and restoring sagebrush canopy cover. Additional threats to sage-grouse and their young include ground squirrels (*Spermophilus* spp.), badgers (*Taxidea taxus*), coyotes (*Canis latrans*), red fox (*Vuples vulpes*), weasels (*Mustela* spp.), and skunks (*Mephitis* spp.) (Coates et al. 2008).

Because predator populations may change in response to changing grazing practices, continuous monitoring is important to explain any observed differences in sage-grouse vital rates. If sage-grouse nest and adult predation rates are lower in areas under prescribed grazing, this practice may constitute a best management practice to mitigate the effects of other anthropogenic disturbances (e.g., power lines and roads). Because the dynamics of a predator population and its primary food source can also impact sage-grouse populations (Schroeder and Baydack 2001), data regarding the relative abundance of potential sage-grouse predators and possibly their common prey will be incorporated into our analysis.

In the case of adult sage-grouse mortalities we examined the condition of the remains to determine if death was caused by a mammalian or avian predator or from other causes (e.g., power lines, human interaction, capture myopathy, disease, etc.). In the event that bones and feathers are broken or matted (i.e., chewed), cause of death was attributed to a mammalian predator. If a mammalian predator is implicated, the surrounding area was searched for sign of hair, scat, tracks or evidence of a den to help identify the specific predator. If the remains consist of the entire carcass with feathers intact, partially plucked, or if only the breast is consumed, the cause of death was attributed to an avian predator. In cases of avian predation, known raptor nests and perches were searched for the remains of sage-grouse. Pellet analysis can provide additional insights into the diets of raptors that use tall structures for perching or nesting (Prather and Messmer 2010). If the evidence or information at the mortality site was insufficient to determine the cause of death, the event was designated as unknown.

Our objective for the predator aspect of this study was to document the relative effect of prescribed and season-long grazing on sage-grouse predation rates. This information may be more important than documenting the specific predator. Changes in abundance of avian, mammalian, and primary prey are being monitored using standardized transects in the treatment and control areas using methods outlined by Garton et al. (2005). Monitoring trends of potential sage-grouse predators in concert with changes in vital rates in the study areas may provide data to corroborate any observed differences in vital rates between treatment and control sites.

Coates and Delehanty (2010) compared a priori models of sage-grouse nest survival (microhabitat variables) to models of sage-grouse nest survival that included raven abundance as covariates. They focused on ravens, because the species has been identified as a major synanthropic predator (Boarman and Heinrich 1999). They conducted strip transect surveys (Garton et al. 2005) of ravens at sage-grouse lek complexes every 3–7 days during morning (0600–1200 hr) from March to June to investigate the impact of raven abundance on sage-grouse nest success in Wyoming. Their best model at predicting nesting success included day of incubation and raven abundance. Luginbuhl et al. (2001) took a slightly different approach to look at the effects of corvid abundance on sage-grouse. They assessed the relationship between predation on artificial nests and corvid abundance using a variety of techniques including point-count surveys, transect surveys, and the broadcast of corvid territorial and predator attraction calls. Point counts of corvid abundance had the strongest correlation with predation of artificial nests.

We monitored avian predator abundance annually from April through mid-July from specific points along transects in the treatment and control sites. Counts were restricted to days with light winds (<19 kph) and little or no precipitation (Luginbuhl et al. 2001). At each survey point, birds were counted by visually searching the area with the aid of binoculars while also listening for bird calls. Counts included ravens, other corvids, and raptors, either flying or perched, during a 10 minute period. The species code and count was recorded along with the time, weather, behavior, and distance at time of first detection. To mitigate double counting, survey points are separated by >2 km distance and previously recorded birds will be tracked prior to moving to the next survey point. The survey routes are located along unimproved or gravel roads within each study area. These routes were surveyed annually using the same methodology.

Somershoe et al. (2006) combined point count data and distance sampling to estimate the density of 14 bird species. Combining these two techniques was beneficial because density and relative abundance could be estimated. This is advantageous compared to relative abundance indices that cannot be compared among species due to differences in detectability (Norvell et al. 2003). Using Somershoe's (2006) technique we used distance annuli of 0-50 m, 51-100 m, 101-250 m, 251-500 m, 501-1000 m, and >1000 m. These distance annuli are larger than those used by Somershoe (2006). We increased distances to reflect the open sagebrush habitat of the study areas and the ease of detection for our species of interest due to larger body sizes. In accordance with the recommendations from program DISTANCE, we recorded a minimum of 60-100 detections for calculating detection probabilities. If detections at the species levels did not meet this requirement, species may be binned into guilds to increase the number of detections (J. Dinkins, Utah State University personal communication, April 2012).

Spotlight surveys are considered a practical method for assessing relative abundance of nocturnal animals. We conducted spotlight surveys to determine the relative abundance of mammalian predators of sage-grouse; and to obtain indices of lagomorph populations. The surveys followed protocols outlined by Gese (2001) where two observers used a 3 million candle power spotlight to scan the area while the vehicle is driven at (16-24 km/hr). Observers detected animals by observing eye shine. When an animal was detected, the vehicle was stopped and a visual identification was obtained using binoculars. The mileage and time of detection was recorded for each sighting. This information will be used to calculate an index of animals/km (Gese 2001).

Spotlight counts were used to estimate population size with line-transect methodology by recording the perpendicular distance to the sighted animal. Transects were > 10 km in length and conducted in similar habitats. These surveys were repeated over several nights (repeated counts) to obtain a measure of sampling error (Gese 2001).

Scat transects are a practical method for determining coyote abundance (Henke and Knowlton 1995). No special equipment is necessary and technicians can be easily trained in proper protocol. Schauster et al. (2002) found scat transects more effective than scent station surveys and second only to mark recapture estimates when determining abundances of swift fox (*Vulpes velox*). Knowlton (1984) reported a high correlation ($r^2 = 0.97$) between scat deposition rates and coyote density estimates when compared to mark-recapture methods using radioisotope detection of feces.

For this study 20 one km scat transects were distributed across each study area. Transects were read each July and initially cleared of all scats. Transects were read again at 14 days for one sampling occasion. Knowlton and Gese (1995) identified potential biases associated with scat transects. These biases included an estimated 0.7 detection probability for transects walked once and destruction of scats on heavily travelled roads. Efforts to reduce this bias included walking transects both directions increasing the detection probability. Transects were located along two-track roads to reduce the potential destruction of scats by vehicle traffic.

To calculate the coyote density for each site we used the same equation Gese (2009) used in Wyoming: coyotes/km^2 = 4.9052* scats/km/day.

Data Analysis

Annual survival of radio-marked sage-grouse for this report was calculated using the known fate model within Program MARK (White and Burnham 1999). The sage-grouse included in survival estimates survived for at least one week after being radio-collared to ensure that mortalities were not related to capture myopathy (Spraker et al. 1987). Radio-collared sage-grouse harvested during upland game bird hunting seasons, or found to be illegally taken, were included in the survival estimates. Nest survival was modeled using the Nest Survival models described by Dinsmore et al. (2002) within Program MARK.

At the conclusion of the study in fall 2015, population vital rates (i.e., survival, recruitment and λ) will be compared for the study areas and other areas in Utah using various landscape and environmental parameters (e.g., vegetation, cover type, patches size, relative to distance from tall structures). Identification of unique relationships between vital rates and environmental parameters such as distances from roads, electric transmission and distribution power lines, and residences can provide insights regarding potential effects of land uses on sage-grouse local populations.

Gradient analysis will be used in subsequent analyses to assess if relationships exist between distance from landscape features and sage-grouse abundance (via lek surveys) and seasonal habitat-use patterns. The relationship between sage-grouse habitat use patterns (i.e., time of, duration, and frequency of movements and distance moved), and distance from anthropogenic activities will be calculated. The averages of these differences by distance gradient can be compared against the null hypothesis (H_o=0) using *t*-tests and confidence intervals to test whether a reduction in sage-grouse density different from what would be expected under normal distribution (P=0.05) and to identify the distance at which it occurred.

Preliminary Results and Discussion

Lek Surveys

In 2015 USU technicians conducted surveys of 10 known leks in the Three Creeks study area from 27 March to 22 April. During approximately the same period 20 leks within the Deseret L&L study area were being surveyed by Deseret L&L staff. No new leks were discovered within either study area in 2015.

The calculated average number of males per lek on Deseret L&L (18) for 2015 was higher than the previous 4 years. These counts also represent an approximate 50% increase from 2014 estimates. Average counts for Three Creeks (16) were also higher in spring 2015. We observed an increase in males per lek in this study area of roughly 43% from our 2014 estimates. The trend in increasing numbers is promising after observing very low counts in recent years. However, the overall counts in 2015 for both study areas were still below estimated 10-year averages (~28 Deseret L&L, ~18 Three Creeks).

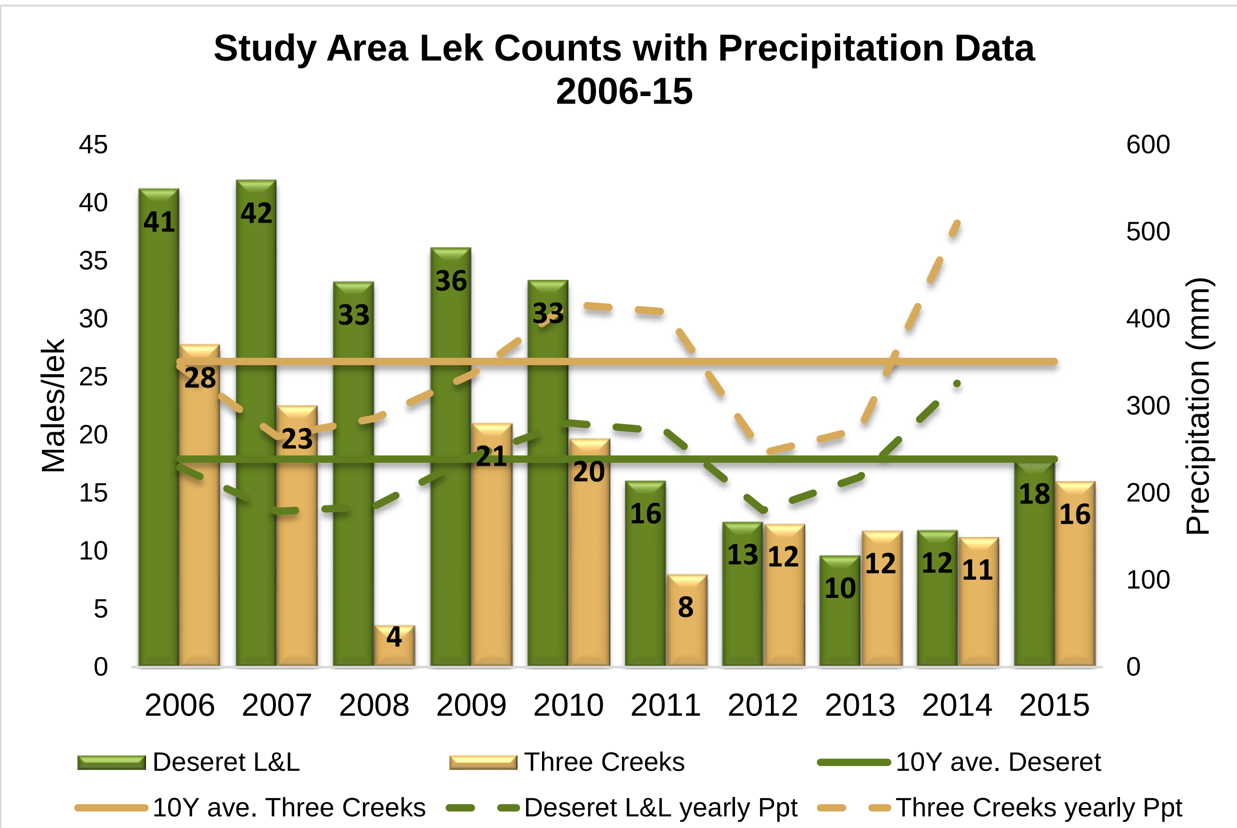

Figure 1. Project area lek counts from 2006-15 overlaid with annual and 10-year average precipitation data for each study area. In 2015 counts were conducted for 20 leks in Deseret L&L and 10 leks within the Three Creeks study area. Lek count data was provided by the UDWR. Climatic data was collected at GHCN stations in Woodruff and Randolph, Utah, and accessed through the Utah Climate Center website (https://climate.usurf.usu.edu/).

In sagebrush-steppe ecosystems, precipitation plays a large role as a driver of plant species abundance and composition. This affects sage-grouse habitat quality and ultimately sage-grouse population vital rates (Guttery et al. 2013). Thus, we have included local precipitation data for each of our study areas in this report (Figure 1).

Trapping and Radio-Collaring Efforts

In 2015, we focused trapping efforts to known lekking sites in both study areas starting in late February and continuing until mid-April. We had 2 personnel stationed in Rich County full-time in February to aid in trapping efforts. Additional help was provided by Deseret L&L wildlife manager Todd Black and USU graduate student Ben Davis who conducted the majority of trapping efforts on Deseret ranch. Crews attempted to trap every night that had both favorable weather and moonlight conditions. These efforts provided us an additional 19 radio-collared hens on Deseret L&L and 9 on the Three Creeks study area.

To maximize nest and brood sample sizes within each study area we focused capturing efforts to hens roosting near leks. All birds, including males, captured in 2015 were fitted with leg bands but only the hens were fitted with radio transmitters. To distribute collars more equally across each study area, we spent at least one night trapping on all accessible leks during the trapping season. Capture success in 2015 varied by study area, lek, and night. The highest number of birds radio-collared in a single night was 6 on the Deseret L&L.

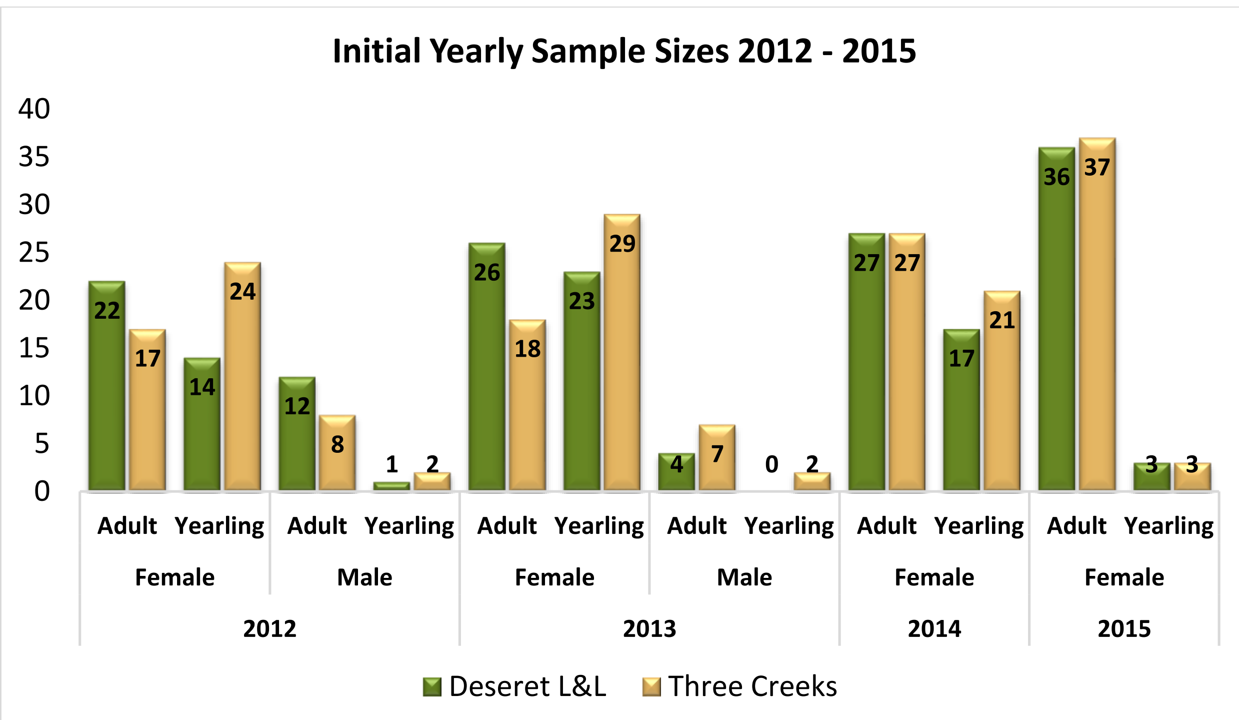

Figure 2. Initial yearly sample sizes by sex and age class for 2012-15. Totals may include birds that were missing and/or previously undetected mortalities.

Nest Initiation and Nest Survival

The start of each nesting season was determined as the date of the first verified nest that year. In 2012, 2013, 2014 and 2015 the start of the nesting season occurred on 18 April, 28 April, 12 April, and 10 April respectively. The 2015 nesting season was the earliest recorded during the study.

To be included in our calculations of nest initiation rates, a hen had to be monitored ≥2/week to ensure a high likelihood of detecting nest initiation before a possible nest failure occurred (Connelly et al. 2003). In 2015, 15 hens in Three Creeks met this requirement and 10 on Deseret L&L could be consistently located at this frequency. In Three Creeks 13 of these hens initiated nests for an initiation rate of 87%. Seven of these hens were successful in hatching ≥1 egg for an apparent nest survival of 54%. In Deseret L&L 9 of 10 (90%) radio-collared hens closely monitored in the study area initiated nests this year. Of the 9 monitored nests 5 hatched successfully (56%). No hens were observed re-nesting on either study area in 2015.

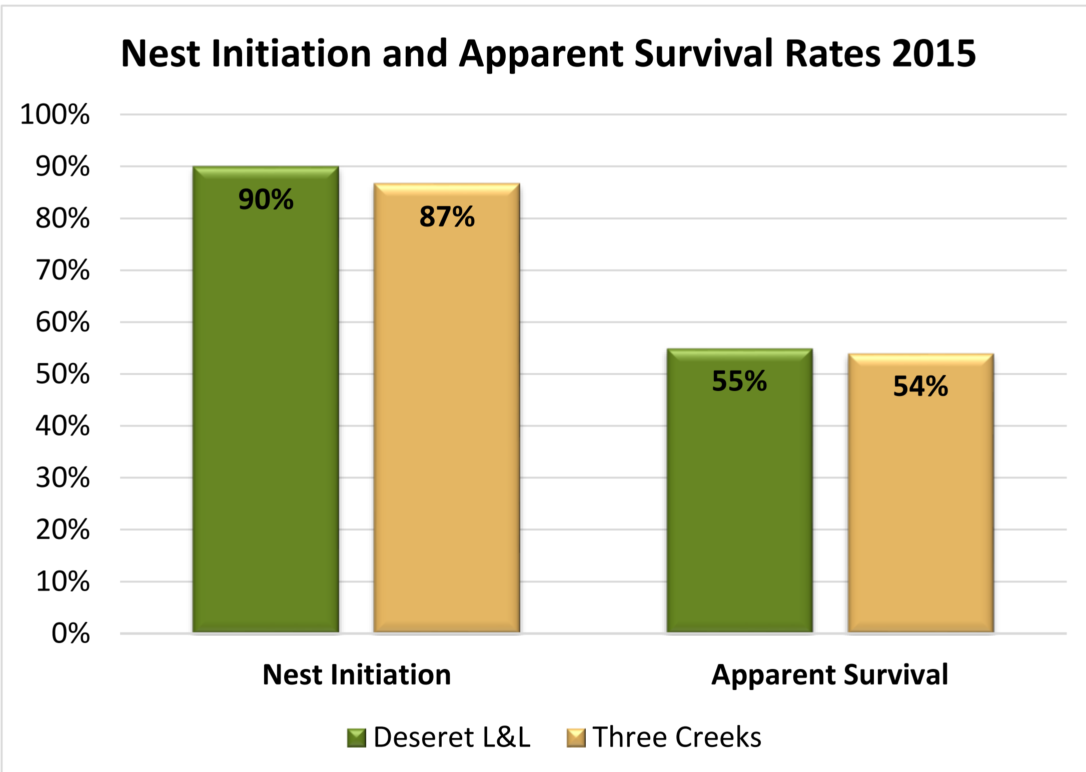

Figure 3. Nest initiation and apparent survival rates for Three Creeks and Deseret L&L study areas in 2015.

To estimate actual daily nest survival we used the nest survival model in package RMark within Program R. To get the total estimated survival rate the daily survival estimate was raised to the power of 34 to account for a 7 day laying cycle and 27 day incubation time. Despite a slightly lower apparent nest survival rate, estimated actual nest survival in Deseret L&L (31%) was roughly 38% higher than that of Three Creeks (21%).

Brood Success

In 2015, we monitored 10 radio-collared hens with broods across both study areas. Of these broods, 6 were located in Three Creeks and 4 in Deseret L&L. We monitored 4 successful broods, surviving to independence (≥50d), in Three Creeks (67%) and 3 successful broods in Deseret L&L (75%). This represents the highest observed rates of brood success in Deseret L&L and the second highest in Three Creeks for the duration of the study.

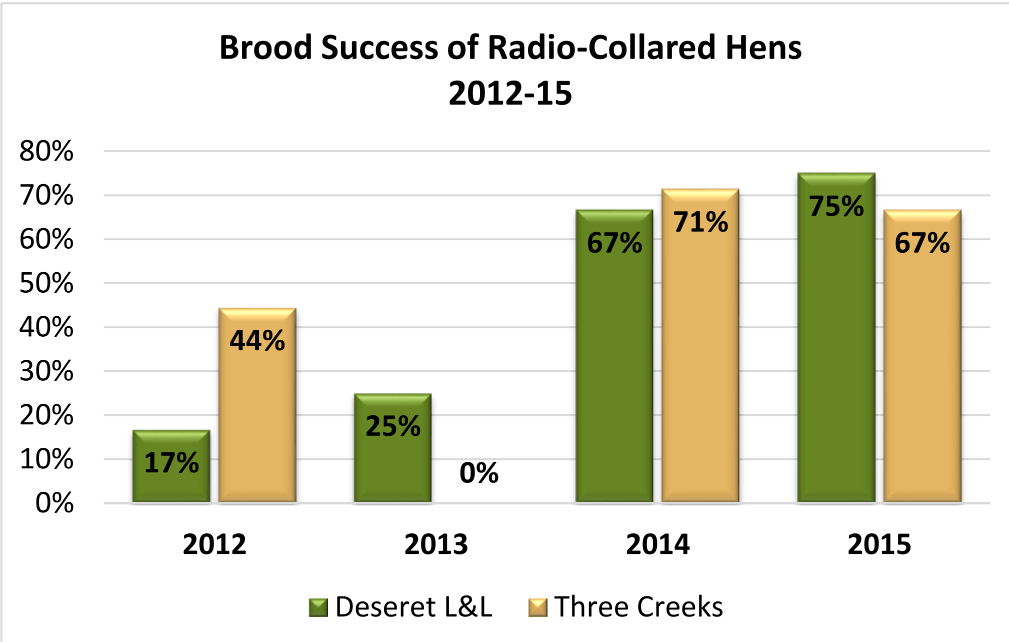

Figure 4. Brood success of radio-collared hens by study area for 2012-15.

Survival

We calculated sage-grouse survival rates in each study area for the spring (01 March – 31 May) and summer (01 June – 31 August) time periods for 2012-15. Limited field access and monitoring efforts in winter have made it difficult to report accurate survival rates for the winter period. For this analysis, we combined both sexes and all age classes. We plan to conduct a more complex analysis using RMark later this year, which will investigate a multitude of covariates.

We calculated 2015 survival rates for Deseret L&L near 90% for spring and 94% for the summer period. This is slightly below 2014 estimated rates of survival. Three Creeks had a slightly higher calculated spring survival rate at 94% and 100% for the summer period (Figure 5).

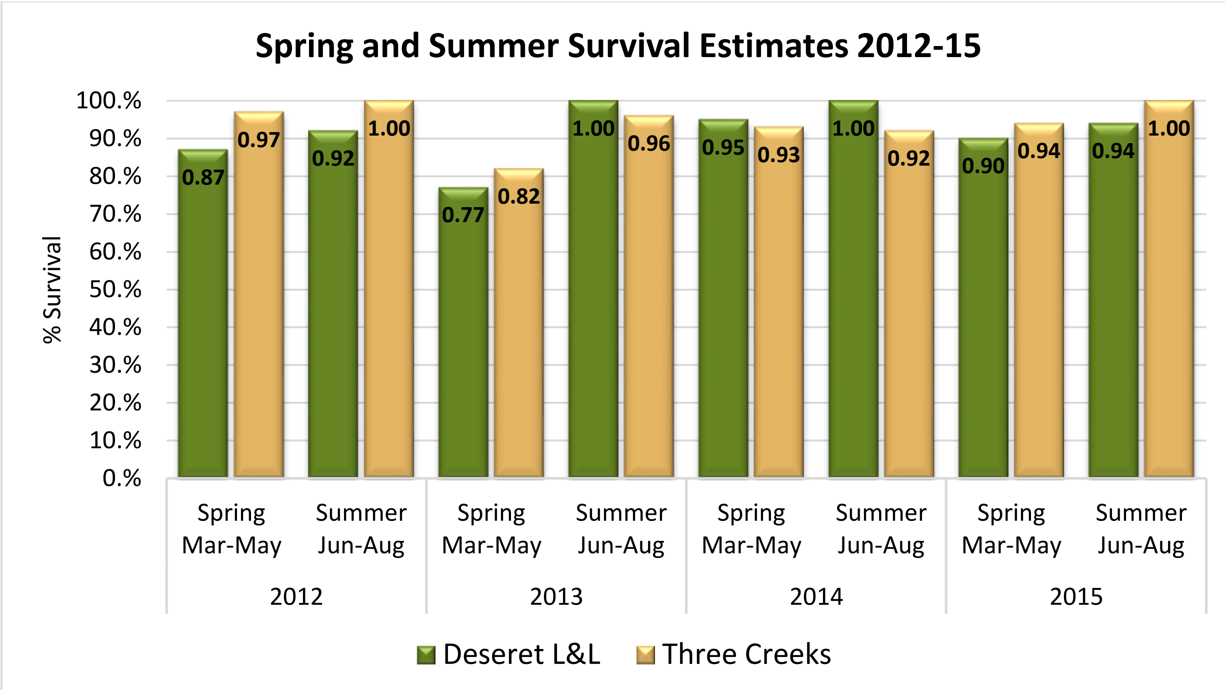

Figure 5. Sage-grouse spring and summer survival rates for Three Creeks and Deseret L&L 2012-15.

Vegetation Habitat Metrics

In 2015, we monitored 22 nest sites for radio-collared hens across both study areas (Deseret L&L n=9, Three Creeks n=13). Nest site sample size was lower than expected due to the low number of radio-collared hens that were detected on the study areas during the nesting period. We completed vegetation surveys at all nest sites to determine habitat vegetation structural and compositional characteristics. Each nest site was also paired with a randomly generated site occurring within the same pasture. We assume since each paired nest and random site are located in the same pasture, they are theoretically subject to the same potential level of grazing pressure. We will use the data collected on randomly generated (paired) sites in determining differences in both hen selected nesting and brood rearing sites versus randomly generated sites.

In 2015, we conducted vegetation surveys at 28 brood sites in Deseret L&L and 25 in Three Creeks. Methods for surveying brood sites were similar to those of nests. Similar to nest sites, each brood site was also paired with a randomly generated survey site within the same pasture. Broods were subsequently located 2-3 times each week. The amount time required to survey a particular brood site was highly variable. Brood sites in more open and grassy habitat were surveyed relatively quickly. In the later brood-rearing season many broods were located at higher elevations in sites dominated by thick stands of mountain brush and occasionally aspen. These sites were both difficult to access and time consuming to read. Given the difficulty experienced surveying many of these sites, it was not possible to conduct vegetation sampling for every known brood location. Technicians were also tasked with multiple predator surveys, brood counts, and monitoring of other radio-collared hens throughout the season. This also limited the time available for vegetation surveys.

For the analysis reported here, we grouped vegetation data by site type and study area. The results presented in the following table are representative of the duration of the study, 2012-15. A MANOVA was performed using the vegan package in R to determine statistical significance in our data. When we compared mean perennial grass heights at actual nest sites between study areas we found Deseret L&L had 22% taller grass heights. In a comparison of actual brood sites Three Creeks exhibited higher sagebrush cover but Deseret L&L had greater forb and perennial grass heights. Overall Deseret L&L had greater grass heights in every site type that we compared and was a statistically significant difference for both actual nest and brood sites.

We will continue to analyze the vegetation data and link it with vital rate data. These results should become available in early 2016.

Table 1. Mean percent cover and heights for greater sage-grouse nest and broods sites and paired random sites, Deseret L&L and Three Creeks Allotment, Rich County, USA, 2012-2015.

	Deseret Land & Livestock				**Three Creeks**			
	Nest Actual	Nest Paired	Brood Actual	Brood Paired	Nest Actual	Nest Paired	Brood Actual	Brood Paired
%Cover								
Sagebrush	21.2	18.6	12.8	17	19.3	19.5	20.5	21.2
All Shrubs	33.9	28.2	27	30	28.8	27.3	31.2	30
Grass	18.7	17.6	26.6	22.7	20.1	22.2	24.1	15.8
Forb	15.7	17	15.5	12.1	13.1	11.5	17	13.9
Litter	74.1	70.5	77.5	74.6	70.3	69.4	72.7	68
Bare Ground	21.4	23.7	18.9	21	17.4	17.9	18.7	20.1
Height (cm)								
Shrub	43.9	38.8	51.1	45.8	38.6	35.5	41.8	34
Grass	14.1	12.7	18.4	18.9	11.3	10.8	12.9	12.2
Forb	6.2	5	8.8	7.8	4.7	4.4	5.9	5.1
Robel	63	49.7	-	-	51.66	44.86	-	-

Table 2. Total vegetation sites sampled for each study area broken down by year and site type.

	Year	Broods Actual	Broods Paired	Nests Actual	Nests Paired
Three Creeks	2012	26	26	20	17
	2013	26	26	11	11
	2014	22	22	24	25
	2015	25	25	13	13
	Total	**99**	**99**	**68**	**66**

	Year	Broods Actual	Broods Paired	Nests Actual	Nests Paired
Deseret	2012	23	21	8	7
	2013	24	23	11	11
	2014	25	25	11	11
	2015	28	25	9	9
	Total	**100**	**94**	**39**	**38**

Predator Surveys

In 2012, to estimate coyote abundance we established 5 scat transects in each study area and surveyed each transect on 2 occasions. This initial sampling was based on an effort to achieve transect densities greater than those used by Gese (2009) for estimations of coyote densities in Wyoming.. In a subsequent discussion with Dr.Gese regarding sampling design he recommended that a more accurate coyote density estimation could be achieved by increasing transect density and reducing sampling occasions to once per season. Starting in 2013 we implemented this change by increasing the number of scat transects in each study area to 20 and only sampling on one occasion per year.

Estimates of coyote densities in 2015 on Three Creeks (0.37/km^2) were at the lowest levels during the research study period. The USDA Wildlife Services conducts a predator removal program within the county that might explain some of our observed decline in densities. Coyote densities on Deseret L&L (0.54/km^2) were up slightly from the previous year but still 25% lower than our highest estimates observed in 2013.

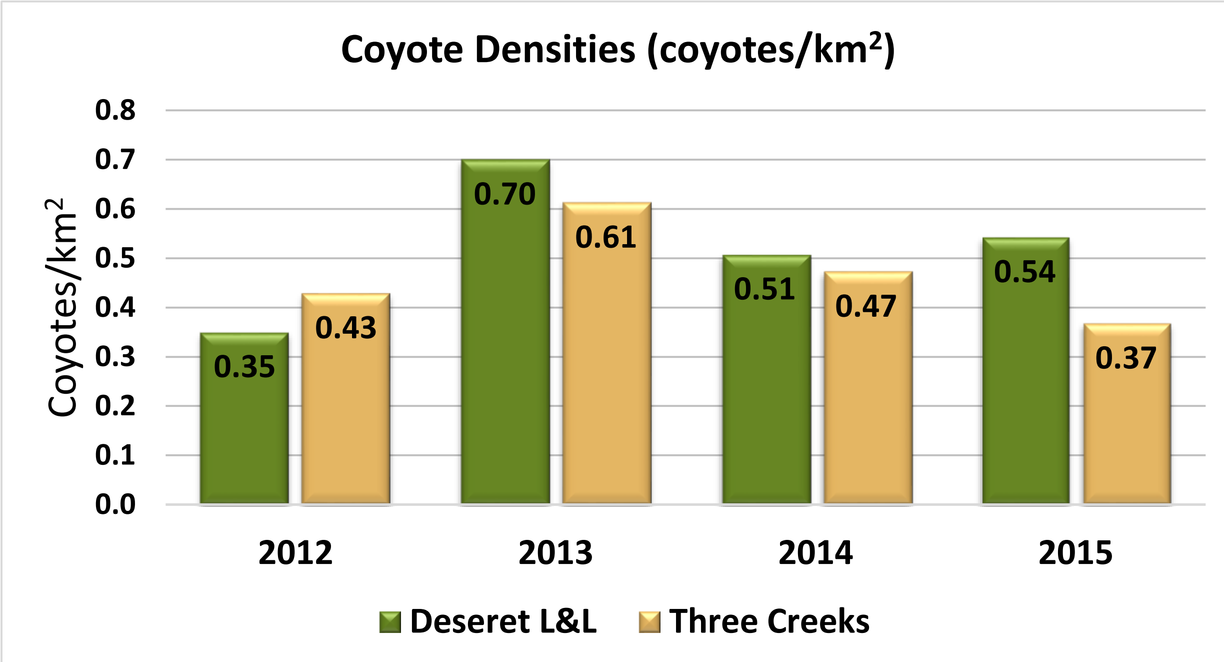

Figure 6. Comparison of estimated coyote densities between study areas for 2012-15. In 2012 5 transects within each study area were surveyed. For 2013-15 estimates, the number of transects for each study area was increased to 20.

Avian predator surveys were conducted following protocols outlined in the methods section. For 2012 and 2015 7 avian point count sampling periods were completed in each study area. In 2013-14 Three Creeks was sampled on 7 occasions and Deseret L&L on 5. Avian point counts are conducted bi-weekly beginning in mid-April and continuing to late July of each year. Yearly corvid (raven/crow) averages were calculated by summing the number of corvid observations for each study area and dividing by the total number of sampling days for that year (Figure 10). To aid in our analysis, when an audio detection was observed in the field we applied a value of one to that detection. This prevented detections from being completely omitted from the calculation even though the true number of individuals could not be verified.

We observed a 61% decrease in corvid detections in the Three Creeks study area for 2015 compared to 2014 estimations. However, detections in Deseret L&L increased 50% during that same period. Until 2015 Deseret L&L had averaged corvid detections levels near 3.2 corvids per survey day over the previous 3 years. The high corvid detection in 2015 was surprising given control efforts by Deseret L&L in spring 2014 and again in 2015 to reduce corvid populations.

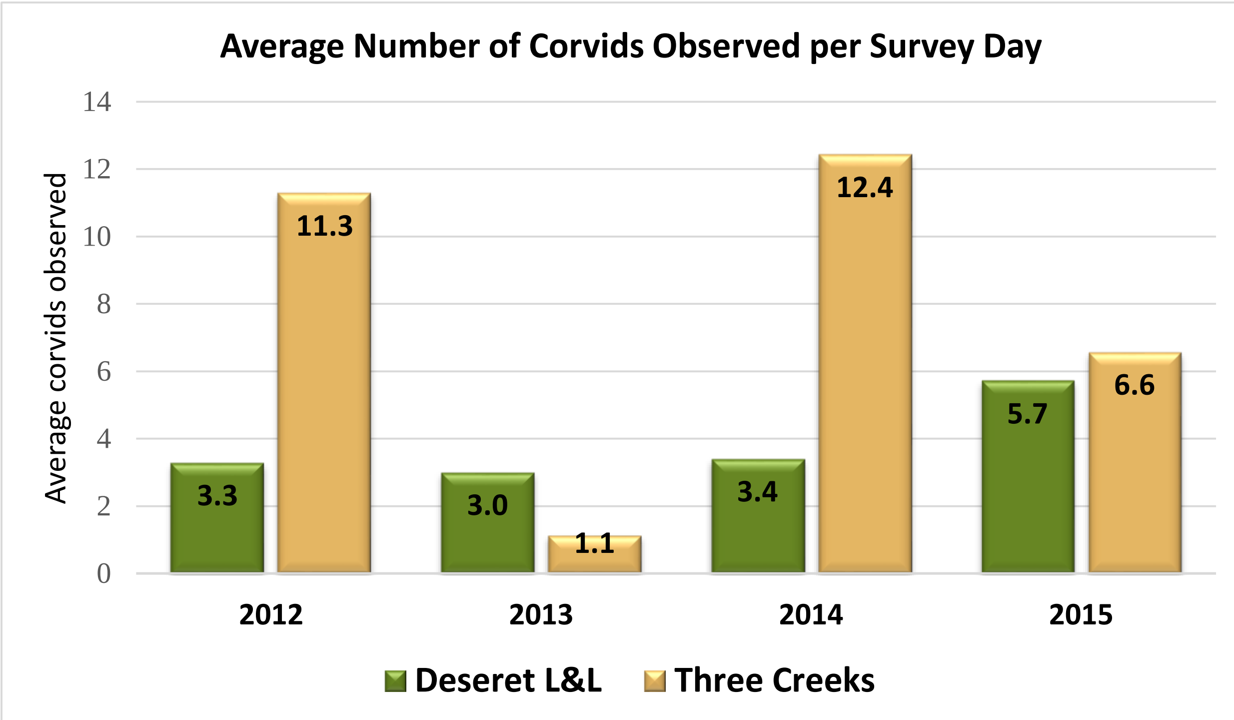

Figure 7. Average number of corvids (raven/crow) observed per survey day in each study area in 2015.

Preliminary Conclusions

Overall lek counts in terms of total males and males per lek counted increased across the project area in 2015. Annual precipitation has increased in the project area following 2012, which was one of the lowest recorded annual precipitation years in the past decade.

Radio-collaring efforts in spring 2015 successfully fitted another 19 hens with radio transmitters in Deseret L&L and 9 hens in Three Creeks. These newly radio-collared hens helped to increase our sample size while entering the final year of the study. Unfortunately, many of the radio-collared hens could not be consistently located/detected throughout the nesting and brood rearing season. This was likely the result of both the tendency of hens in Rich County to disperse from their early season breeding areas (Dettenmaier and Messmer 2013, 2014) as well as 8 mortalities that occurred during in the nesting season.

Nest initiation rates in 2015 were at very high levels with 90% of hens initiating nests in Deseret L&L and 87% in Three Creeks. Estimates of nest initiation rates in our previous reports were reported as being very low. This was likely the result of an over estimation of hen totals appropriate for the analysis. To reduce the issue of technicians not detecting a nest before failure all hens that are included in the estimate need to be monitored a minimum of ≥2x/week. In previous estimates we had included hens that did not meet this minimum level of monitoring.

Previous estimates are being revised and will be reported in the final project report (Ph.D. dissertation).

Apparent nest survival rates in 2015 were similar between study areas. Estimated daily survival rates calculated in RMark were 31% for Deseret L&L and 21% for Three Creeks. To elucidate the potential causes of the higher nesting survival in Deseret L&L we will be conducting a more thorough analyses in the future using habitat as a predictor variable.

Observed brood success was also near the highest levels since 2012 for both study areas. Three Creeks brood success rates were 67% and Deseret L&L was even higher at 75%. The highest calculated brood success rates in the previous years were 71% and 67% for Three Creeks and Deseret L & L, respectively. Both of these estimated success rates were observed in 2014. The high rates of nest initiation, nest success, and brood success are promising for the future success and sustainability of sage-grouse populations in Rich County, Utah.

Overall sage-grouse survival rates were slightly higher in Three Creeks (95%) compared to Deseret L&L (93%) in our analysis that grouped all sexes and ages together. Seasonal trends are apparent in both study areas and are generally similar. Estimated survival rates for radio-collared birds for spring 2015 were between 90%-94% with summer survival ranging from 94%-100%.

Cursory vegetation data analysis has indicated a few differences between study areas. Mean perennial grass heights were higher in Deseret L&L at both actual brood and nest sites. The mean perennial grass heights at Deseret L&L were higher on every site type that we tested. This result is congruent with our expectations that Deseret L&L's grazing system should produce taller grass heights. However, total sagebrush cover was lower in Deseret L&L at actual brood sites. This might be the result of Deseret L&L's ability to more easily apply sagebrush treatments.

Coyote densities on both study areas have decreased since our highest observed estimates in 2013 (~0.7/km^2). Respective calculated coyote densities were higher in Deseret L&L (0.54/km^2) than those measured in Three Creeks (0.37/km^2). Estimates have slightly increased on Deseret L&L compared to the consistent decline observed in Three Creeks. That contrasts with differences in detected raven numbers observed during each of the 4 study years. In 2015, the number of ravens observed during avian surveys was slightly higher in Three Creeks compared to Deseret L&L. This is consistent with 2012 and 2014 estimates where corvid detections were nearly 4x higher on Three Creeks compared to Deseret L&L. Raven numbers are influenced by a multitude of factors including the density and proximity of anthropogenic features and local control efforts. We are obtaining more data regarding each of these factors to analyze the potential causes of these differences.

2015-2016 Work Plan

In the fall/winter of 2015 we will begin a more detailed analysis of the vegetation and habitat data that was collected over the duration of the project. Using the programs outlined in the methods section, we will estimate vital rates for each study area and explore potential correlations between these rates and the corresponding habitat characteristics of each area. Efforts will be focused on writing thesis chapters and preparing manuscripts for publication. We anticipate that these products will begin to become available summer/fall of 2016.

As 2015 was our final field season there are no current plans for continued fieldwork for this specific project. However, a new master's student at Utah State University, Wayne Smith, will be heading another sage-grouse research project in Rich County. His research will be focused on the geospatial interactions of greater sage-grouse and livestock on Deseret L&L.

In 2015 we had the opportunity to present the study and our preliminary results to several groups and agencies. We plan to continue to take advantage of these opportunities in the coming year.

Literature Cited

Aspbury, A. S., and R. M. Gibson. 2004. Long-range visibility of greater sage grouse leks: a GIS-based analysis. Animal Behaviour 67:1127–1132.

Atamian, M. T., and J. S. Sedinger. 2010. Balanced sex ratio at hatch in a greater sage-grouse (*Centrocercus urophasianus*) population. The Auk 127:16–22.

Banner, R. E., B. D. Baldwin, and E. I. Leydsman McGinty. 2009. Rangeland resources of Utah. Utah State University Cooperative Extension.

Belton, L. R., D. B. Jackson-Smith, and T. A. Messmer. 2009. Assessing the needs of sage-grouse local working groups: final technical report. Unpublished report prepared for the USDA Natural Resources Conservation Service., Institute for Social Science Research on Natural Resources, Utah State University, Logan, Utah. <https://utahcbcp.org/files/uploads/Sage-Grouse%20LWG%20Technical%20Report.pdf>. Accessed 26 Nov 2012.

Beyer, H. L. 2012. Geospatial Modeling Environment. <http://www.spatialecology.com/gme>.

Boarman, W. I., and B. Heinrich. 1999. Common raven (*Corvus corvax*). Pages 1–32 *in* A. Poole and F. Gill, editors. The Birds of North America. 476, The Birds of North America, Inc., Philadelphia, PA.

Bui, T. D., J. M. Marzluff, and B. Bedrosian. 2010. Common raven activity in relation to land use in western Wyoming: implications for greater sage-grouse reproductive success. The Condor 112:65–78.

Canfield, R. H. 1941. Application of the line interception method in sampling range vegetation. Journal of Forestry 39:388–394.

Coates, P. S., J. W. Connelly, and D. J. Delehanty. 2008. Predators of greater sage-grouse nests identified by video monitoring. Journal of Field Ornithology 79:421–428.

Coates, P. S., and D. J. Delehanty. 2010. Nest predation of greater sage-grouse in relation to microhabitat factors and predators. The Journal of Wildlife Management 74:240–248.

Connelly, J. W., A. D. Apa, R. B. Smith, and K. P. Reese. 2000. Effects of predation and hunting on adult sage grouse *Centrocercus urophasianus* in Idaho. Wildlife Biology 6:227–232.

Connelly, J. W., K. P. Reese, and M. A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations.
Crunden, C. W. 1963. Age and sex of sage grouse from wings. The Journal of Wildlife Management 846–849.
Dahlgren, D. K., T. A. Messmer, and D. N. Koons. 2010. Achieving better estimates of greater sage-grouse chick survival in Utah. The Journal of Wildlife Management 74:1286–1294.

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.

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

Dinsmore, S. J., G. C. White, and F. L. Knopf. 2002. Advanced techniques for modeling avian nest survival. Ecology 83:3476–3488.

Dettenmaier, S. J., and T. A. Messmer. 2014. Greater Sage-Grouse Response to Season-Long and Prescribed Grazing (NRCS Conservation Practice 528) on Paired Ecological Sites. Utah State University, Logan, Utah.

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). Utah State University, Logan, Utah. <http://utahcbcp.org/files/uploads/rich/2013RichCountyAnnualReport.pdf>. Accessed 9 Sep 2015.

Eng, R. L. 1955. A method for obtaining sage grouse age and sex ratios from wings. The Journal of Wildlife Management 19:267–272.

ESRI. 2012. ArcGIS Desktop: Release 10.1. Environmental Systems Research Institute, Redlands, CA.

Garton, E. O., J. T. Ratti, and J. H. Guidice. 2005. Research and experimental design. Pages 43–71 *in* C. E. Braun, editor. Techniques for wildlife investigations and management. 6th edition. The Wildlife Society, Bethesda, MD.

Gese, E. M. 2001. Monitoring of terrestrial carnivore populations. USDA National Wildlife Research Center-Staff Publications 576.

Gese, E. M. and P. J. Terlesky 2009. Estimating coyote numbers across Wyoming: a geospatial and demographic approach.

Giesen, K. M., T. J. Schoenberg, and C. E. Braun. 1982. Methods for trapping sage grouse in Colorado. Wildlife Society Bulletin 10:224–231.

Guttery, M. R., D. K., Dahlgren, T. A. Messmer, J. W. Connelly, K. P. Reese, P. J. Terlesky, and D. Koons. 2013. Effects of Landscape-Scale Environmental Variation on Greater Sage-Grouse Chick Survival. PLoS ONE 8(6): e65582. doi:10.1371/journal.pone.0065582

Hagen, C. A. 2011. Predation on greater sage-grouse: facts, process, and effects. Pages 95–100 *in* S. T. Knick and J. W. Connelly, editors. Greater sage-grouse: ecology and conservation of a landscape species and habitats. Volume 38. Studies in Avian Biology, University of California Press, Berkeley, CA.

Hanley, T. A. 1978. A comparison of the line-interception and quadrat estimation methods of determining shrub canopy coverage. Journal of Range Management 31:60–62.

Henke, S. E., and F. F. Knowlton. 1995. Techniques for estimating coyote abundance. Pages 71-78 *in* Symposium Proceedings – Coyotes in the Southwest: A Compendium of our knowledge. University of Nebraska – Lincoln, USA.

Holloran, M. J. 1999. Sage grouse (*Centrocercus urophasianus*) seasonal habitat use near Casper, Wyoming. University of Wyoming. <http://search.proquest.com/docview/304541114>.

Johnson, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61:65–71.

Johnson, G. D., and M. S. Boyce. 1990. Feeding trials with insects in the diet of sage grouse chicks. The Journal of Wildlife Management 54:89–91.

Knick, S. T., and J. W. Connelly. 2011. Greater Sage-Grouse: Ecology and Conservation of a Landscape Species and its Habitats. Volume 38. University of California Press.

Knowlton, F. F. 1984. Feasibility of assessing coyote abundance on small areas. Denver Wildlife Research Center, Denver, Colorado.

Knowlton, F. F., and E. M. Gese. 1995. Coyote population processes revisited. Pages 1-6 *in* Symposium Proceedings – Coyotes in the Southwest: A Compendium of our knowledge. University of Nebraska – Lincoln, USA.

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.

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.

Prather, P. R., and T. A. Messmer. 2010. Raptor and corvid response to power distribution line perch deterrents in Utah. The Journal of Wildlife Management 74:796–800.

Rearden, J. D. 1951. Identification of waterfowl nest predators. The Journal of Wildlife Management 15:386–395.

Remington, T. E., and C. E. Braun. 1985. Sage grouse food selection in winter, North Park, Colorado. The Journal of Wildlife Management 49:1055–1061.

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.

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., and R. K. Baydack. 2001. Predation and the management of prairie grouse. Wildlife Society Bulletin 29:24–32.

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.

Spraker, T. R., W. J. Adrian, and W. R. Lance. 1987. Capture myopathy in wild turkeys (*Meleagris gallopavo*) following trapping, handling and transportation in Colorado. Journal of Wildlife Diseases 23:447–453.

Utah Division of Wildlife Resources (UDWR). 2009. Utah Greater Sage-grouse Management Plan. Utah Division of Wildlife Resources.

Wakkinen, W. L., K. P. Reese, J. W. Connelly, and R. A. Fischer. 1992. An Improved Spotlighting Technique for Capturing Sage Grouse. Wildlife Society Bulletin 20:425–426.

White, G. C., and K. P. Burnham. 1999. Program MARK: Survival estimation from populations of marked animals. Bird Study 46:120–138.

Appendix A.

```
--- 2012-15 VEGETATION DATA MANOVA ANALYSIS RESULTS ---
```

-- Actual Nest Sites by Study Area --

```
 Response SBcover :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   60.2  60.215  0.7871 0.3771
Residuals   100 7650.2  76.502

 Response Forbheight :
             Df  Sum Sq Mean Sq F value  Pr(>F)
StudyArea     1   36.57  36.569  3.5546 0.06228 .
Residuals   100 1028.79  10.288
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Forbcover :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1    138  138.02  0.9322 0.3366
Residuals   100  14806  148.06

 Response PGheight :
             Df  Sum Sq Mean Sq F value  Pr(>F)
StudyArea     1  152.67 152.665  5.6726 0.01912 *
Residuals   100 2691.27  26.913
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGcover :
```

```
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1     12  12.032  0.0833 0.7735
Residuals   100  14443 144.427

 Response Litter :
             Df  Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   348.1  348.09  1.2599 0.2644
Residuals   100 27628.0  276.28

 Response Bare :
             Df  Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   364.2  364.25  2.2703  0.135
Residuals   100 16043.9  160.44

 Response Rock :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   49.4  49.429  1.3817 0.2426
Residuals   100 3577.4  35.774
```

-- Actual Brood veg by Study Area --

```
 Response SBcover :
             Df  Sum Sq Mean Sq F value    Pr(>F)
StudyArea     1  2654.5 2654.46  22.532 4.005e-06 ***
Residuals   194 22854.8  117.81
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Forbheight :
             Df Sum Sq Mean Sq F value    Pr(>F)
StudyArea     1  405.1  405.06  18.009 3.405e-05 ***
Residuals   194 4363.6   22.49
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Forbcover :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1    101  100.60  0.5865 0.4447
Residuals   194  33274  171.51

 Response PGheight :
             Df  Sum Sq Mean Sq F value    Pr(>F)
StudyArea     1  1470.4 1470.36   24.75 1.434e-06 ***
Residuals   194 11525.2   59.41
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGcover :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1    238  237.96  0.6254   0.43
Residuals   194  73816  380.49

 Response Litter :
             Df Sum Sq Mean Sq F value Pr(>F)
```

```
StudyArea     1   1191 1191.25  5.7335 0.0176 *
Residuals   194  40307  207.77
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Bare :
             Df  Sum Sq Mean Sq F value Pr(>F)
StudyArea     1     0.4   0.398   0.003 0.9565
Residuals   194 25868.2 133.341

 Response Rock :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   18.0  18.037  0.4656 0.4959
Residuals   194 7516.1  38.743
```

-- Random/Actual Nest Sites in Deseret --

```
 Response SBcover :
            Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1  122.2  122.20  1.1634 0.2843
Residuals   74 7772.9  105.04

 Response Forbheight :
            Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1  16.27 16.2661  1.7137 0.1946
Residuals   74 702.39  9.4918

 Response Forbcover :
            Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1    23.3  23.332  0.1051 0.7468
Residuals   74 16434.1 222.082

 Response PGheight :
            Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1   27.55  27.552  1.0535  0.308
Residuals   74 1935.24  26.152

 Response PGcover :
            Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1    47.2  47.211   0.285  0.595
Residuals   74 12256.2 165.625

 Response Litter :
            Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1   238.5  238.49  1.1537 0.2863
Residuals   74 15297.1  206.72

 Response Bare :
            Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act     1   106.9  106.86  0.7531 0.3883
Residuals   74 10500.7  141.90

 Response Rock :
            Df  Sum Sq Mean Sq F value Pr(>F)
```

```
Rand_Act     1   20.66  20.665  1.2708 0.2633
Residuals   74 1203.33  16.261
```

-- Random/Actual Nest Sites in Three Creeks --

```
 Response SBcover :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     0.8   0.774  0.0089 0.9248
Residuals   127 11002.2  86.631

 Response Forbheight :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   1.93  1.9338  0.3237 0.5704
Residuals   127 758.78  5.9747

 Response Forbcover :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   162.8  162.82  1.4491 0.2309
Residuals   127 14269.7  112.36

 Response PGheight :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   10.18  10.181  0.5044 0.4789
Residuals   127 2563.31  20.183

 Response PGcover :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   184.4  184.40  1.2784 0.2603
Residuals   127 18319.8  144.25

 Response Litter :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     34  33.795  0.1242 0.7251
Residuals   127  34559 272.114

 Response Bare :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1    10.9  10.947  0.0728 0.7877
Residuals   127 19098.5 150.382

 Response Rock :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   54.6  54.588  0.9959 0.3202
Residuals   127 6961.0  54.811
```

-- Random/Actual Brood Sites in Deseret --

```
 Response SBcover :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   776.3  776.29  6.3872 0.01232 *
Residuals   187 22727.6  121.54
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
 Response Forbheight :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   44.1  44.072  1.5362 0.2167
Residuals   187 5364.7  28.688

 Response Forbcover :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   515.7  515.70  3.1081 0.07954 .
Residuals   187 31027.3  165.92
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGheight :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1    13.3  13.334  0.1605 0.6892
Residuals   187 15535.6  83.078

 Response PGcover :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1    622  621.57  2.1177 0.1473
Residuals   187  54887  293.51

 Response Litter :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   458.4  458.44  2.8266 0.09438 .
Residuals   187 30328.7  162.19
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Bare :
             Df  Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   238.5  238.45  2.0451 0.1544
Residuals   187 21803.6  116.60

 Response Rock :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   46.6  46.561  1.6898 0.1952
Residuals   187 5152.5  27.553
```

-- Random/Actual Brood Sites in Three Creeks --

```
 Response SBcover :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     21  20.765  0.1281 0.7208
Residuals   196  31775 162.117

 Response Forbheight :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   35.25  35.247  5.6024 0.01891 *
Residuals   196 1233.12   6.291
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
 Response Forbcover :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   460.4  460.38  3.4823 0.06352 .
Residuals   196 25912.4  132.21
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGheight :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   26.2  26.211  1.1135 0.2926
Residuals   196 4613.6  23.539

 Response PGcover :
             Df Sum Sq Mean Sq F value   Pr(>F)
Rand_Act      1   3431  3430.8  13.662 0.000284 ***
Residuals   196  49222   251.1
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Litter :
             Df Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   1078 1078.33  4.2848 0.03977 *
Residuals   196  49326  251.66
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Bare :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     97  96.559  0.5824 0.4463
Residuals   196  32493 165.780

 Response Rock :
             Df  Sum Sq Mean Sq F value    Pr(>F)
Rand_Act      1  1318.2 1318.17  13.352 0.0003313 ***
Residuals   196 19349.7   98.72
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

-- Random Brood Sites by Study Area --

```
 Response SBcover :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     21  20.765  0.1281 0.7208
Residuals   196  31775 162.117

 Response Forbheight :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   35.25  35.247  5.6024 0.01891 *
Residuals   196 1233.12   6.291
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
 Response Forbcover :
             Df  Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   460.4  460.38  3.4823 0.06352 .
Residuals   196 25912.4  132.21
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGheight :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1   26.2  26.211  1.1135 0.2926
Residuals   196 4613.6  23.539

 Response PGcover :
             Df Sum Sq Mean Sq F value   Pr(>F)
Rand_Act      1   3431  3430.8  13.662 0.000284 ***
Residuals   196  49222   251.1
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Litter :
             Df Sum Sq Mean Sq F value  Pr(>F)
Rand_Act      1   1078 1078.33  4.2848 0.03977 *
Residuals   196  49326  251.66
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Bare :
             Df Sum Sq Mean Sq F value Pr(>F)
Rand_Act      1     97  96.559  0.5824 0.4463
Residuals   196  32493 165.780

 Response Rock :
             Df  Sum Sq Mean Sq F value    Pr(>F)
Rand_Act      1  1318.2 1318.17  13.352 0.0003313 ***
Residuals   196 19349.7   98.72
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

-- Random Nest Sites by Study Area --

```
 Response SBcover :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1     15  15.039  0.1365 0.7125
Residuals   101  11125 110.148

 Response Forbheight :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   7.47  7.4684  1.7446 0.1895
Residuals   101 432.38  4.2810

 Response Forbcover :
             Df  Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   795.9  795.92  5.0567 0.0267 *
```

```
Residuals   101 15897.5  157.40
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGheight :
             Df  Sum Sq Mean Sq F value  Pr(>F)
StudyArea     1   85.49  85.486  4.7774 0.03115 *
Residuals   101 1807.28  17.894
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response PGcover :
             Df  Sum Sq Mean Sq F value  Pr(>F)
StudyArea     1   524.8  524.78  3.2853 0.07287 .
Residuals   101 16133.3  159.74
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Litter :
             Df  Sum Sq Mean Sq F value Pr(>F)
StudyArea     1    40.6  40.634  0.1846 0.6683
Residuals   101 22227.6 220.075

 Response Bare :
             Df  Sum Sq Mean Sq F value  Pr(>F)
StudyArea     1   778.5  778.45  5.8002 0.01784 *
Residuals   101 13555.3  134.21
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

 Response Rock :
             Df Sum Sq Mean Sq F value Pr(>F)
StudyArea     1   69.1  69.140  1.5224 0.2201
Residuals   101 4586.9  45.415
```