EVALUATION OF ALTERNATIVE METHODS TO ESTIMATE GREATER SAGE-GROUSE POPULATIONS

Photo courtesy of Todd Black

State of Utah Contract Number #101567

Utah Division of Wildlife Resources

(Utah State University Account Number A-21980-124500)

Project Completion Report

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Submitted to

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INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) populations declined substantially during the 20th century (Connelly et al. 2004, Schroeder et al. 2004). These declines have been largely attributed to the loss and/or degradation of sagebrush (*Artemisia* spp.) habitats (Connelly et al. 2004). Unlike many rare or declining species, sage-grouse population trends can be easily monitored by counting the number of males attending display areas (i.e., leks) during the breeding season (Patterson 1952). Habitat around lek sites is typically low in visual obscurity. The lack of vertical obstruction around leks combined with the prominent visual and auditory displays of male sage-grouse make lek sites relatively easy to find (Schroeder et al. 1999). Additionally, lek locations tend to be static through time (Dalke et al. 1963). Male lek counts have been conducted by many western states since the mid-twentieth century, including the Utah Division of Wildlife Resources (UDWR).

The validity of using sage-grouse lek counts to estimate population size and trends has been questioned (Beck and Braun 1980, Walsh et al. 2004, Reese and Bowyer 2007). One issue confounding the use of lek counts to estimate population trends is individual male lek attendance rates. Emmons and Braun (1984) and Walsh et al. (2004) reported very different lek attendance rates. These differences may have been due to sample sizes and experimental approach (see Connelly and Schroeder 2007). However, both studies showed marked differences in yearling versus adult lek attendance rates. Additionally, each age class may attend leks during a different time within the breeding season. Johnson and Rowland (2007) reported that adult male sage-grouse typically attend leks early in the breeding season whereas yearlings attend late in the season. Furthermore, detection rates for attending males may vary by size of lek, individual behavior, and/or individual location on the lek. Moreover, it is likely that not all observers have the same ability to detect male sage-grouse. Thus the resultant population estimates may also reflect this bias. Using the above techniques to estimate numbers of male sage-grouse in a population is ineffectual given no valid technique to assess the precision of such estimates (Anderson 2001).

The use of lek routes (as defined in Connelly and Schroeder 2007) has been suggested as an alternative method for obtaining reliable indices to breeding male sage-grouse (Connelly et al. 2000a). The lek route count method involves: 1) locating (aerially or ground-based) all or a portion of leks within a breeding population, 2) identification of groups of leks that form a route, and 3) counting of males at each lek within a route during the same morning (0.5 hour before to 1.5 hour after sunrise) on at least four occasions throughout the spring breeding season (Connelly et al. 2003). The estimate used is the maximum number of males counted for each route. However, these counts may only provide an index to breeding population size, and may be termed "convenient sampling" (Anderson 2001).

Using lek route counts as an index is problematic given the following assumptions: 1) the sample is proportional to the population; 2) the proportion remains constant among years when trends are assessed; 3) the proportion remains constant among comparable sites; and 4) the detection probability is the same for all observers (Anderson 2001). The validity of these assumptions is questionable. Violation of these assumptions may result in significantly biased population estimates (White 2005). Additionally, lek route counts may be further biased by age class based on time of sampling, which may vary annually. Therefore obtaining reliable population estimates, rather than indices, will provide improved population assessment.

There is also a need to determine the breeding season sex ratio within populations. Currently, this statistic is unknown for sage-grouse populations across their range (personal communication, J. Connelly, Idaho Fish and Game). Male and female sage-grouse tend to segregate by sex throughout much of the year. However, during winter the sexes come together to form large flocks (Beck 1977). Winter pellet collection and subsequent DNA analysis may yield representative sex ratios for populations.

Currently, the UDWR uses a 0.75 male attendance probability and a 2:1 female to male ratio for sage-grouse breeding population estimation, and bases management on this estimation (personal communication, D. Olsen, UDWR Upland Game Program Coordinator). Based on the results of Emmons and Braun (1984), this assumption is conservative. However, these assumptions result in population estimates that are biased high according to the findings of Walsh et al. (2004). Additionally, the assumed 2:1 sex ratio is not scientifically founded (J. Connelly, Idaho Fish and Game, personal communication). Sex ratios may vary considerably between populations based on habitat quality (Swenson 1986) and harvest history (Connelly et al. 2000b). Therefore, there is no concrete evidence to support the above computation of population estimates for management purposes.

There is a clear need to rigorously document male lek attendance rates, sex ratios, and lek count error rates, and how these parameters may vary by population. Population estimation, with valid confidence intervals, will be possible once these objectives are met.

The major project objectives were to:

1. Assess male sage-grouse lek attendance rates.
2. Assess sex ratios for sage-grouse populations during the breeding season
3. Assess lek count error rates for observers

4. Calculate valid population estimates for two sage-grouse populations

STUDY SITES

This project took place on Deseret Land and Livestock (DLL) in Rich County and Parker Mountain (PM) in Wayne County, Utah (Figure 1). Both the Rich County and Parker Mountain sage-grouse populations exceed 500 breeding adults (Beck et al. 2003). Rich County, situated in extreme northeastern Utah, has elevations that range from ~6000-9500 feet. Lek locations typically occur at the lower elevations. Rich County is characterized by large contiguous tracts of sagebrush consisting of Wyoming big sagebrush (*A. tridentata wyomingensis*), basin big sagebrush (*A. t. tridentata*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), and mountain big sagebrush (*A. t. vaseyana*) from low to high elevations, respectively.

Parker Mountain is located in south-central Utah, and is on the extreme southern boundary of the range of greater sage-grouse. Parker Mountain is a unique high elevation sagebrush plateau (7000-10000 feet), which is dominated by black sagebrush with some mountain big sagebrush and silver sagebrush (*A. cana*) at higher elevations. Both areas contain stable sage-grouse populations and represent some of the largest contiguous tracts of sagebrush in Utah (Beck et al. 2003).

METHODS

Male lek attendance

We captured male sage-grouse on each study site during fall, winter, and early spring and marked them with necklace style radios and aluminum leg bands (Giesen et al. 1982). Capturing male sage-grouse that are unassociated with a particular lek (herein termed “unbiased”) is assumed to ensure unbiased results for attendance probabilities. A male captured during the lekking season (herein termed "biased") may already have a defined territory within the lek, and therefore may have a higher probability of attendance. When biased males were radio-marked their attendance rates were initially analyzed separately to test for differences. All birds were measured according to age, sex, weight, wing cord, and tarsus length.

Lek routes were delineated based on known lek locations in each study area. Sampling began around mid-March and continued through mid May. In 2010, DLL had 8 7-day sampling occasions (periods) and PM had 3 10-day sampling occasions. PM sampling periods were longer because PM has more leks and subsequently more lek complexes than DLL. PM climatic conditions (extreme snowpack) prevented access to leks prior to mid-April, precluding our observation of all leks on the study area until April 19. Leks were put into groups of 3 or 4 (according to proximity) allowing for sampling (15 minutes) of three leks per morning (1.5 hours) and travel time. A sampling period was defined as all leks within all lek routes being sampled once. Leks within groups were sampled in a random order. Sampling only occurred on days with relatively mild weather (low cloud cover and little wind). The observer counted the lek at the first location, recording the number of males and females on the lek. At each lek, the observer scanned through all available radio-collar frequencies to determine if marked males were attending the lek. If a collared male(s) was detected, the observer would check the signal from 2 other points to confirm that the bird(s) was in fact on the lek. Signals not detected or detected beyond lek boundaries were assumed to not be attending the lek. Additional data recorded included date, weather conditions, starting time, observer location, and observer's name for each count.

Initial plans called for the use of mark-recapture methods to be used to model lek attendance rates. However, this approach was abandoned when a preliminary inspection of the data revealed that some of our marked birds were never documented on a lek. This resulted in empty encounter histories. As a result of not having encounter data for some birds, mark-recapture methods were not applicable (Cooch and White 2011).

Given this situation, we opted to use multi-state models to estimate lek attendance (Cooch and White 2011). During each sampling period, marked birds could be in one of 3 possible states: attending a lek, on the study site but not attending a lek, or not detected on the study site. Multi-state models can be used to directly estimate survival rates, recapture rates, and state transition rates (i.e., the probability of a bird that was found on the site but not at a lek during sampling period t being found on a lek during sampling period $t+1$). The probability of remaining in a given state can then be calculated as (1 - probability of transitioning from that state to the alternative state). Therefore, lek attendance for a given sampling period would be calculated as the probability of being found on a lek during sampling periods t and $t+1$ plus the probability of transitioning from not on a lek during period t to attending a lek in period $t+1$. This approach would accommodate birds never found on a lek by allowing them to be specified as either not detected or detected but not attending a lek.

Because multi-state models estimate multiple parameters, they require large amounts of data to consider informative models (Cooch and White 2011). Unfortunately, our data sets were not large enough to allow us to develop useful models of lek attendance. Also, because the number of sampling periods varied between years and sites we could not combine data sets for pooled analyses. Therefore, we report "apparent" lek attendance rates. Apparent lek attendance was calculated by dividing the number of marked males detected on a lek by the total available during a sampling period.

Lek Count Error Rates

All leks on each study site were classified as large, medium, or small based on the average number of males attending the lek in recent years. One lek from each size class at each site was randomly chosen to receive an observation blind. Blinds were erected near the edge of a lek and were used to compare counts conducted during lek routes. All blinds were erected prior to the breeding season to allow adequate habituation by the birds. Observers entered the blinds two hours prior to sunrise to avoid disturbing lekking birds. Sampling from the blinds began at 0.5 hours before sunrise and birds were counted every 15 minutes until 1 hour after sunrise. During the 1.5 hour observation period, a second observer would approach in a vehicle to within sight of the lek. All birds were then simultaneously counted by the observer in the blind (blind count) and the observer in the vehicle (standard count). Data recorded included observer's name, date, general weather conditions (temperature, wind speed, cloud cover), time of each count, number of attending males and female, number of displaying males, and number and frequency of radios heard. Observers did not exit blinds until lekking activities had ceased.

To determine if standard counts differed from blind counts, we analyzed the difference of the 2 counts conducted at the same lek on a given morning (Blind Count_{ij} - Standard Count_{ij}) using a normal error model in PROC GLIMMIX (SAS 9.2). This analytical framework also allowed us to consider the influence of covariates on the difference of the counts. Covariates considered were temperature, wind speed, cloud cover, precipitation, and lek size.

We expected that blind counts would represent the true number of birds attending leks and that these counts would always be ≥ standard counts. Had this assumption held true, our response variable (i.e., Blind Count - Standard Count) would have been a natural number with value ≥ zero. Under these conditions, it would have been more appropriate to analyze the data using a Poisson or negative binomial distribution rather than a normal distribution. However, there were occasions when standard counts exceeded blind counts. Therefore, we chose to use a normal distribution. Residual diagnostics were performed to ensure that the models met the standard parametric assumptions of normality and homoscedasticity. We used Akaike's Information Criterion with a small sample size adjustment (AICc) to select the best model from a set of candidate models.

Sex ratios

We followed radio-marked sage-grouse of both sexes from December to mid-March to locate roost sites. We then systematically searched roost sites for sage-grouse pellets to obtain a sample by selecting pellets from separate roost piles. Fresh pellets were collected and dried to ensure sample quality. Preliminary efforts by the Utah State University Conservation Genetics Laboratory to extract viable DNA from sage-grouse feces were unsuccessful. Additionally, while this procedure could yield valid sex ratio estimates, the requirements to ensure that estimates are unbiased (i.e., genotyping each sample to avoid double sampling individuals) exceeded our time and financial constraints. Therefore, we were not able to accomplish this objective.

Population Estimates

Because we were unable to estimate valid lek attendance rates or breeding season sex ratios, we were also unable to calculate defensible population estimates.

RESULTS

In 2010 we trapped 71 males on DLL, of which 29 were adults (10 unbiased, 19 biased) and 20 were yearlings (15 unbiased; 5 biased). We trapped 39 males on PM, of which 26 were adults (all biased) and 10 yearling males (all unbiased). Because of inclement weather and apparent poor production in 2010, trapping for the 2011 field season was impeded on both study sites. On DLL, 15 additional males were captured and radio-collared during Fall 2010 and Spring 2011. Of these 15, only 5 were unbiased and only one was a yearling. On PM, 24 additional males were captured and radio-collared in the 2011 field season. Eight of the 24 were yearlings and all 24 were biased.

Objective 1 - Male Lek Attendance Rates

Our efforts to develop valid models of male lek attendance rates were unsuccessful because our data was not compatible with the intended modeling approach (mark-recapture) and our data set was too small for the alternative approach (multi-state). However, we were able to calculate apparent lek attendance rates by study site, year, and sampling period. The overall average attendance rate was 0.561 (SE=0.041). Attendance rates varied by site, year, and sampling period (Figure 2). When averaged across years, attendance rates were higher on PM (0.626 ± 0.061) than on DLL (0.513 ± 0.054). Within mornings, lek attendance by male sage-grouse tended to be highest prior to sunrise (Figure 3) and declined steadily with time (Figure 4).

Objective 2 - Breeding Population Sex Ratio

Our efforts to obtain valid breeding season sex ratio estimates were unsuccessful because of potentially biased sampling procedures and time and financial constraints. Our sampling methodology did not allow us to guarantee that individuals were not sampled on multiple occasions. Repeated sampling of individuals could result in biased sex ratios. The Utah State University Conservation Genetics Laboratory estimated a cost of approximately $25,000 to determine the sex of the roughly 300 sage-grouse fecal samples we collected in 2010 and 2011. A more detailed genetic analysis would allow for individual birds to be identified, thereby allowing us to calculate valid sex ratios. However, the cost of this analysis would have likely exceeded $100,000.

Objective 3 - Lek Count Error Rates

Analysis of lek count error rates indicated that blind counts did differ from standard counts ($P = 0.0221$) and that lek size was the primary factor contributing to the difference in the 2 types of counts ($P = 0.0193$). Overall, blind counts detected an average of 1.96 ($SE = 0.52$) more male sage-grouse than did standard counts. On small leks the difference was negligible (0.37 ± 0.35), but was more substantial on median sized and large leks (3.69 ± 1.01 and 2.15 ± 1.18, respectively).

Objective 4 - Population Estimation

Because of our inability to complete objectives 1 and 2, we were unable to calculate defensible estimates of the breeding season population for either site.

DISCUSSION

Although we were not able to thoroughly achieve all of our stated objectives, our results reinforce the suspicion that lek-count based population estimates are likely invalid. The UDWR assumes a 75% detection rate for male sage-grouse on leks and a 2:1 female biased sex ratio. Our results indicate that the standard counts which are used to monitor most sage-grouse leks may omit, on average, 2 males. Additionally, only 56% of all available males will actually be attending leks at any given time. Our estimates of lek attendance are similar to the findings of Walsh et al. (2004) but well below the estimates provided by Emmons and Braun (1984). It should be noted that the springs of 2010 and 2011 were unusually severe in terms of lower seasonal temperatures with substantial snow pack. These conditions may have resulted in lower than normal lek attendance rates.

Although it is often assumed that sage-grouse exhibit a female biased sex ratio, no valid estimates of sage-grouse sex ratios currently exist. Atamian and Sedinger (2010) found no evidence of biased sex ratios at hatching for one population in Nevada. Similarly, Guttery et al. (in preparation) found balanced sex ratios at hatching for 3 Utah sage-grouse populations, including the PM population. Further, Guttery et al. found that survival of chicks to 42-days of age was not influenced by sex on PM. Finally, Guttery et al. analyzed harvest data for the PM sage-grouse population and found that it indicated that a 3:2 female biased sex ratio was more probably than a 2:1 ratio.

The assumptions used to extrapolate lek counts to population estimates can have drastic effects on the resulting estimates. If we consider an area with 5 leks having high male counts of 10, 15, 20, 25, and 30 we can easily see the consequences of different assumption. Under the current UDWR equation (75% detection and 2:1 sex ratio), this population would be estimated at 399 total individuals. Increasing each lek count by 2 and assuming 56% detection and a 2:1 sex ratio yields a population estimate of 589 individuals. Maintaining this detection rate and assuming a 1:1 sex ratio gives an estimate of 393 individuals whereas a 3:2 ratio yields an estimate of 510 birds.

MANAGEMENT IMPLICATIONS

Despite the fact that there are theoretical reasons why sage-grouse grouse may exhibit female biased sex ratios (Trivers and Willard 1973), we suggest that the more conservative ratios of either 1:1 or 3:2 be adopted until better data is available. Additionally, any estimates of lek attendance using our results should be interpreted with caution. As noted, unusually harsh climatic conditions during both years of this study may have influenced lek attendance rates. We suggest that the more conservative assumption of 75% detection be used until more data becomes available concerning the factors which influence lek attendance rates. Our results do show that while attendance rates do fluctuate throughout the breeding season, attendance rates appear to peak at or before sunrise. As such, counts should be conducted as early as possible in order to obtain the most accurate counts possible. This may result in fewer leks being counted per morning but will provide more representative data.

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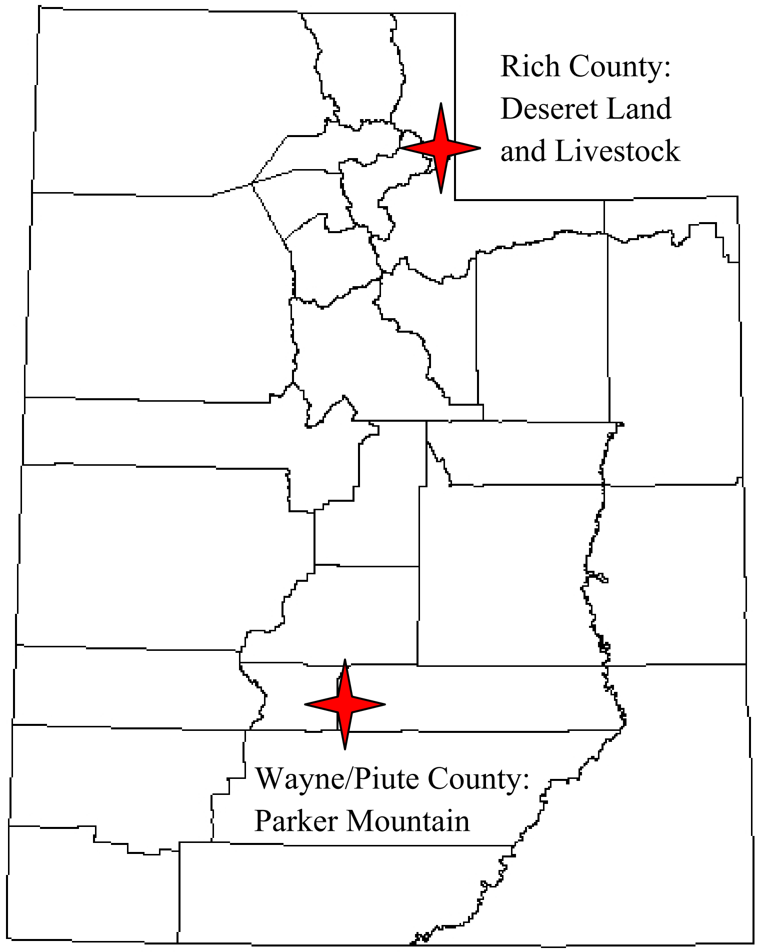

Figure 1. Study sites for greater sage-grouse lek attendance rate study.

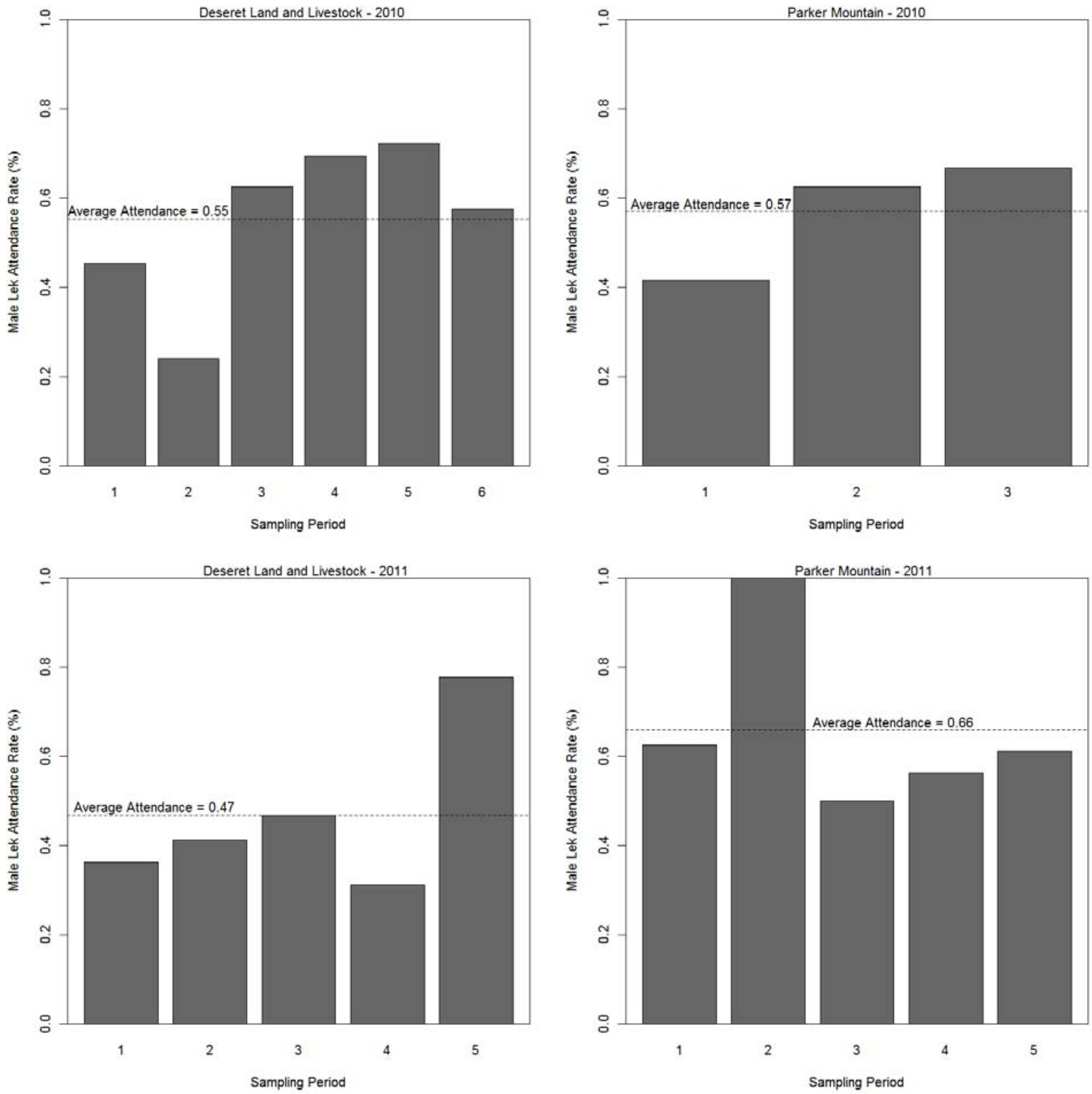

Figure 2. Male greater sage-grouse apparent lek attendance rates by study site, year, and sampling period. Apparent attendance for a given sampling period was calculated as the number of radio-collared male sage-grouse documented on a lek divided by the total number of radio-collared males detected on the study site.

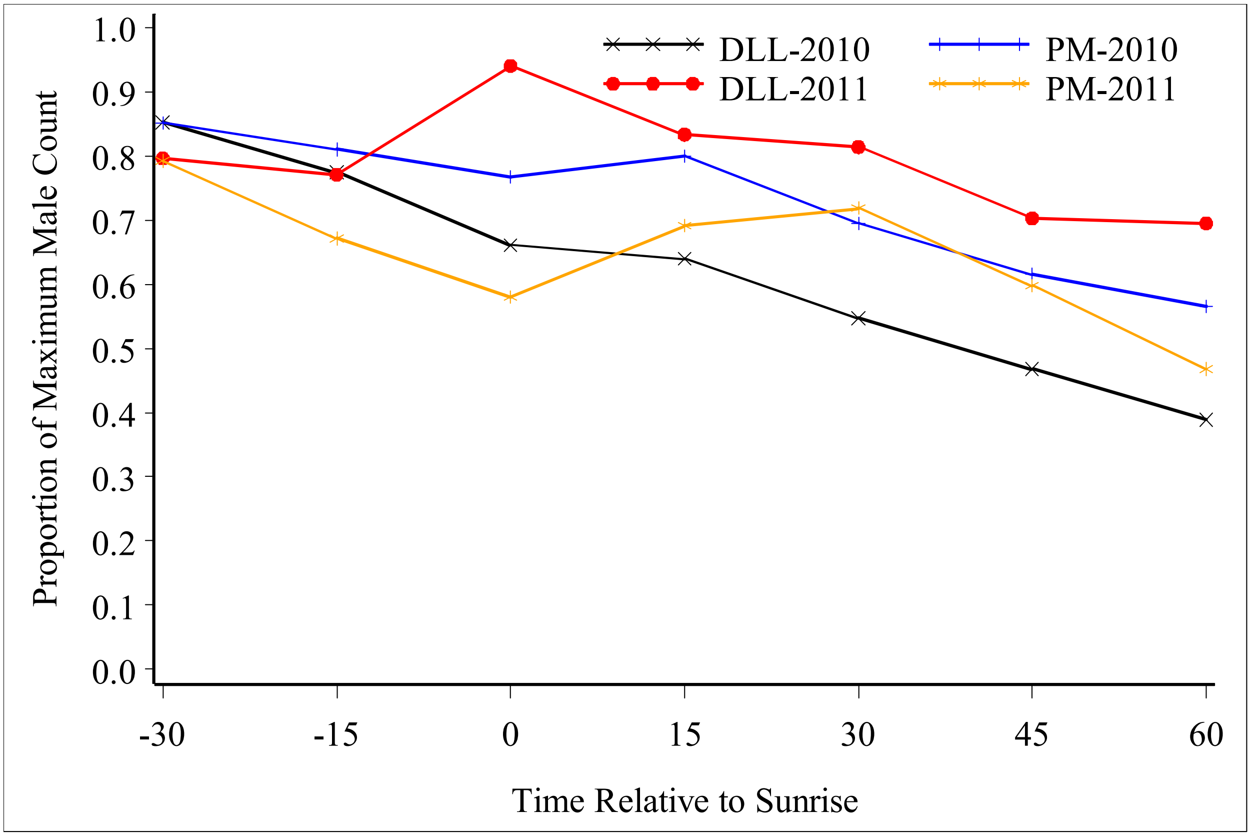

Figure 3. Observed number of male greater sage-grouse attending leks at various time throughout observation mornings on Deseret Land and Livestock and Parker Mountain, Utah, 2010-2011.

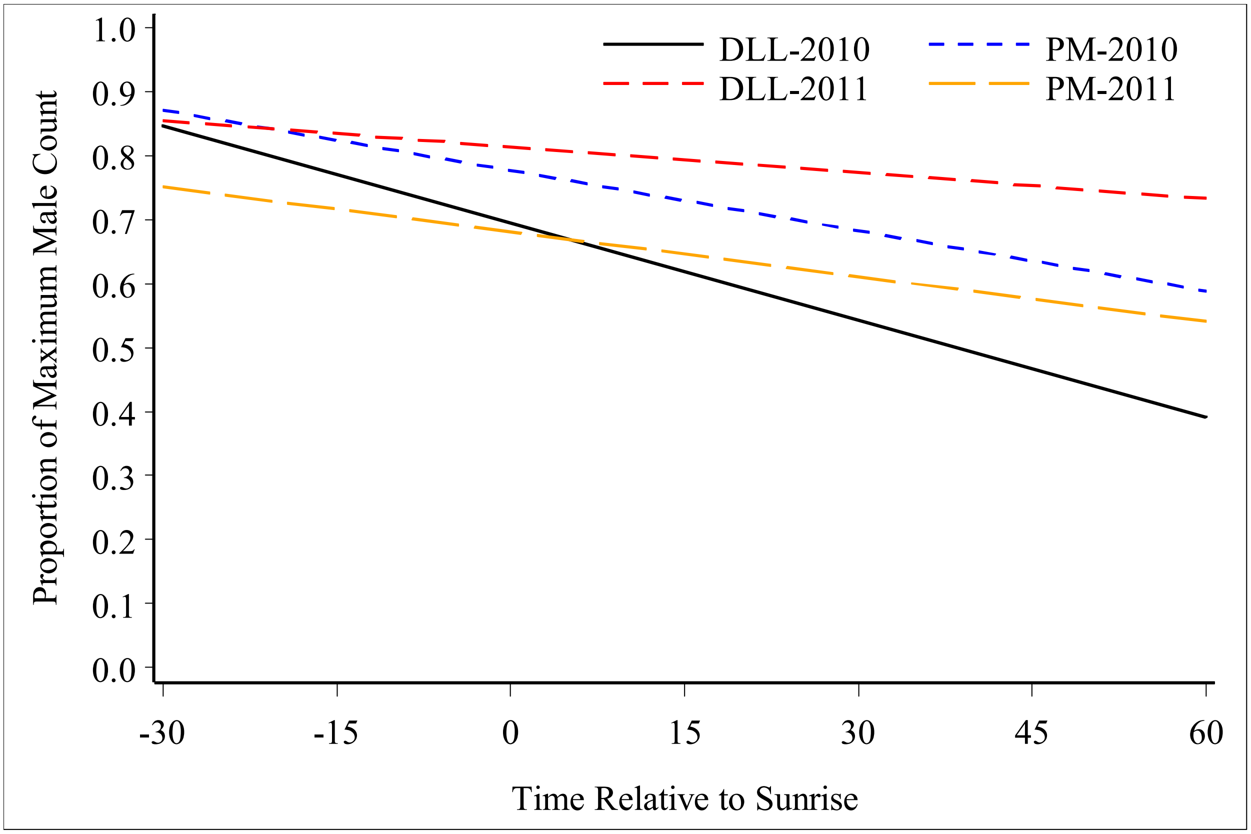

Figure 4. Trends in the number of male greater sage-grouse attending lek throughout observation mornings on Deseret Land and Livestock and parker Mountain, Utah, 2010-2011.