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Analyses of Greater Sage-Grouse (Centrocercus urophasianus) Translocation Release Methods and Chick Survival in Strawberry Valley, Utah

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ANALYSES OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*)

TRANSLOCATION RELEASE METHODS AND CHICK SURVIVAL IN

STRAWBERRY VALLEY, UTAH

by

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As chair of the candidate's graduate committee, I have read the thesis of Jordan P. Hennefer in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables, and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

ANALYSES OF GREATER SAGE-GROUSE (*CENTROCERCUS UROPHASIANUS*) TRANSLOCATION RELEASE METHODS AND CHICK SURVIVAL IN STRAWBERRY VALLEY, UTAH

Jordan P. Hennefer

Department of Plant and Animal Sciences

Master of Science

Manuscript No. 1

Recent research has indicated that low nest success and juvenile survival of Greater Sage-Grouse may be responsible for population declines. Recent technological advances in micro-transmitters have made radio-telemetry studies on Sage-Grouse chicks more common. Radio-telemetry enables monitoring of individual chicks and broods during a critical period of their life history. The exact cause of low chick recruitment in Strawberry Valley has not been well understood. In 2006, a chick mortality study using micro-transmitters was initiated to (1) determine the causes of chick mortality, (2) calculate overall chick survival, (3) compare chick survival in the Strawberry Valley

population to published reports, (4) monitor brood movements, and (5) suggest management strategies for mitigation of chick mortality. Survival data on radio-marked chicks were analyzed using a known fate model in program MARK. Chick survival in Strawberry Valley was greater than all reported estimates from other studies. Our study did not identify any unsuspected causes of chick mortality, and the cumulative effect of stressing chicks, hens, and broods was not deemed worth the benefit, especially in a population recovery setting like Strawberry Valley. We do not recommend the use of radio-telemetry on Sage-Grouse chicks in recovering or sensitive populations.

<u>Manuscript No. 2</u>

In 2003, we began translocating Greater Sage-Grouse into the Strawberry Valley of central Utah, in an attempt to recover the dwindling population found therein. Prior to 2006 all translocated Sage-Grouse were released within 250 m of the only active lek in Strawberry Valley while males were actively strutting. A prolonged winter in 2006 delayed normal lekking activity in Strawberry Valley. As a result 61 (59%) of the 103 sage-grouse translocated in 2006 were not released near an active lek. We analyzed the influence that release timing, hen age, body mass, and source population had on mortality, flocking, and dispersal distance of translocated hens in 2006. We found that mortality and flocking rates were not influenced by release timing, hen age, body mass, or source population. Dispersal distances for hens released near a lek with actively strutting males were significantly less than distances of hens released near an inactive lek. We believe that releasing translocated Sage-Grouse near a lek with actively strutting males is an essential technique for Greater Sage-Grouse translocations. We recommend that other Sage-Grouse translocation efforts employ this method to increase the likelihood of success.

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I would like to thank the Utah Reclamation, Mitigation, and Conservation Commission, Utah Division of Wildlife Resources, United States Forest Service and Sportsmen for Fish and Wildlife for their continued support of Greater Sage-Grouse research in the Strawberry Valley.

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Most of all I want to thank my beautiful wife Keri and daughter McKinlee for their continual love and support. My wife Keri has been optimistic and supportive throughout my schooling. Her belief in my abilities was contagious and in turn made be believe in myself. It hasn't always been easy, but it is now becoming worth it. I also thank all family members that offered support and encouragement of this degree.

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Manuscript No. 2

An analysis of release methods of translocated Greater Sage-Grouse (*Centrocercus urophasianus*) in Strawberry Valley, Utah.

Reduction of Greater Sage-Grouse (*Centrocercus urophasianus*) abundance throughout Western North America has been substantial with as much as a 47% decline in some areas of its range (Connelly and Braun 1997). Once found in 16 U.S. states and 3 Canadian provinces (Aldrich 1963, Johnsgard 1973), Sage-Grouse are now constricted to 11 states and 2 provinces (Braun 1998). The drastic decline has been linked to degraded Sage-Grouse habitat and anthropogenic factors (Braun 1998, Crawford et al. 2004). Low nest success and juvenile survival may also responsible for the population decline (Aldridge and Brigham 2001, Aldridge 2005, Beck et al. 2006).

Sage-grouse are relatively long-lived birds with females having a higher annual survival rate than males (Zablan 1993, Connelly et al. 1994). Survival to adulthood is the greatest challenge for Sage-Grouse chicks. Determining the causes of chick mortality has also proven difficult. Estimates of Sage-Grouse chick survival differ by time period (Beck et al. 2006) and methodology. In Wyoming, June (1963) estimated chick survival to early Fall by conducting brood surveys and counts. In Washington (Schroeder 1997) and Alberta (Aldridge and Brigham 2001) chick survival was estimated to 50 days by flushing radio-marked hens with broods. Recent technological advances in micro-transmitters have made radio-telemetry studies on Sage-Grouse chicks more common (Burkepile et al. 2002, Gregg et al. 2002, Huwer 2004, Aldridge 2005). Radio-telemetry enables monitoring of individual chicks and broods during a critical period of their life history. Identifying the causes of mortality and mitigating those causes where possible may help to increase chick survival and thereby benefit Sage-Grouse populations (Aldridge and Brigham 2001, Gregg 2002, Aldridge 2005, Beck et al. 2006).

Burkepile et al. (2002) sutured radio transmitters to chicks in Idaho and estimated chick survival to 21 days via daily monitoring. Gregg et al. (2002) also used the suture method to affix transmitters to chicks, and monitored radio-marked chicks daily over a 28 day period in Oregon. In Alberta, Aldridge (2005) estimated chick survival to 56 days using radio-equipped chicks and although not specifically studying chicks or using micro-transmitters Beck et al. (2006) classified chicks as 0-10 weeks of age and ≥10 weeks as juveniles in Idaho. There is an obvious need for standard methodology and length of study in order to facilitate comparisons between studies.

In Utah, Greater Sage-Grouse have experienced a trend similar to overall numbers across Western North America with a population decline of nearly 50%. This resulted in the Utah Division of Wildlife Resources (UDWR) classifying Greater Sage-Grouse as a "Sensitive Species of Concern" (Beck and Mitchell 1997). The Strawberry Valley of central Utah is an extreme example of population decline in Utah. In 1939 Griner, estimated the population to be about 3,500 Sage-Grouse (Griner 1939) the number eventually reduced to an estimated 150 breeding birds in 2000, a near 97% reduction (Bunnell 2000).

In March of 1998, the Strawberry Valley Greater Sage-Grouse Recovery Project was initiated to identify and remove or mitigate factors causing the decline of Sage-Grouse in the area. The specific objectives included population monitoring (i.e. lek counts, nest/brood counts, seasonal distributions, and identifying winter migration routes and destinations), identifying and quantifying biotic and abiotic components of seasonal and unoccupied habitat, and documenting factors affecting mortality. Extensive research in the Strawberry Valley has shown that available habitat is not likely a limiting factor to Sage-Grouse of any age class or reproductive status (Bunnell 2000, Bambrough 2002, Baxter 2003, Bunnell et al. 2004).

In 2003, we began translocating Sage-Grouse into the Strawberry Valley from stable populations in Utah in an attempt to reverse the downward trend and to increase the population. A total of 38, 34, 70, and 103 female Sage-Grouse were translocated to the Strawberry Valley in 2003, 2004, 2005, and 2006 respectively. The source populations include Parker Mountain (PM) which is primarily in Wayne County, Diamond Mountain (DM) in Uintah County, western Box Elder County (BEC), and Deseret Land and Livestock (DLL) in Rich County, Utah.

Prior to this study the exact cause of low chick recruitment in Strawberry Valley was not well understood (Baxter 2003). In 2006, this chick survival study was initiated, and our objectives were to (1) determine the causes associated with chick mortality, (2) calculate overall chick survival, (3) compare chick survival in the Strawberry Valley population to published reports, (4) monitor brood movements, and (5) suggest management strategies for mitigation of chick mortality. This effort was consistent with the specific overall project objective to identify and remove or mitigate causes of mortality effecting Sage-Grouse in Strawberry Valley.

STUDY AREA

The study area consists of Strawberry Valley and a migratory area known as Currant Creek. Strawberry Valley is in Wasatch County, south of the Uinta and east of the Wasatch mountain ranges. The valley is characterized as a montane sagebrush (*Artemisia tridentata*) steppe and has an elevation from 2280 to 2440 m. The climate is characterized by cool summers and cold winters with an annual precipitation of 41.8 cm. Mountain big sagebrush (*A.t. vaseyana*) dominates the area. The Current Creek study area is located approximately 18.5 km east of Strawberry Valley on the border of Wasatch and Duchesne Counties northwest of the town of Fruitland. The Current Creek area is dominated by an intermediate variety of mountain big sagebrush and Wyoming big sagebrush (*A.t. wyomingensis*) and ranges in elevation from 1981 to 2134 m respectively. The annual precipitation in this area is 31.5 cm (Bunnell et al. 2004).

METHODS

Resident and translocated hens with attached radio collars were located from the ground at nest sites via radio-telemetry using a 4-element Yagi antenna and an R - 1000 digital radio receiver (Communication Specialists Incorporated, Orange, CA). Hens on nests were monitored 3-4 times each week until eggs hatched. After the eggs hatched and the hen left with her brood we approached the hen and attempted to collect as many chicks as possible. Each chick was captured, placed in a cotton bag, and allowed to move freely within the bag until a transmitter was affixed. We captured chicks from translocated and resident hens and fitted them with radio transmitters.

We followed the methods of Burkepile et al. (2002) to attach radio transmitters. A 1.6 gm transmitter with 36 to 72 days of battery life (ATS Model A4320) was used to monitor each chick. To attach the transmitter, a sterile 20-guage hypodermic syringe needle pre-threaded with a monofilament suture through the needle barrel was inserted perpendicular to the midline of the back of the chick just under the loose layer of skin. The skin was pierced twice, once in the scapular region and the other was approximately 2 cm from the first insertion point on the lower back. The needle barrel was then removed leaving the suture thread in place. The suture was threaded through the transmitter and tied off using a square knot. A drop of cyanoacrylate glue (i.e. Super Glue®) was used to secure the knot.

A chick restraining board was also designed and used to facilitate single-person processing, while reducing handling time, movements, injury, and stress. It was a styrofoam board modified with a hole that allowed the researcher to put the chick's legs through the hole and secure their feet on the underside. This allowed the chick to sit on the dorsal side of the board (Figure 1). A rubber band was placed around the legs of each chick tight enough to secure the chick, but loose enough to allow it to struggle without injury and maintain normal circulation. The legs were then pulled back in a normal position and attached to a post on the underside of the board. The head of the chick was then restrained using a strip of Velcro attached to the board. The chick restraining board was designed by BYU researchers and was not used by Burkepile et al. (2002) or others.

Approximate age (in days) was assigned to each chick based on the time between capture and the last known date the hen was on a nest. The nesting locations of some hens were not known so chicks were assigned an age based on feather development and body mass. Body mass was measured using a Micro-line spring scale (Forestry Suppliers Inc., Jackson, MS). Universal Transverse Mercator (UTM) locations were also recorded at each capture site. Each chick was released individually into sagebrush cover immediately after the transmitter was secured in place. Handling time was also collected in order to determine the efficacy of the chick restraining board and to determine in our model whether stress associated with being captured increased mortality. Handling time was defined as the amount of time that it took to weigh each chick and attach the transmitter using the chick restraining board. Chick age in days was chosen over mass since other studies have shown a relationship between chick mass and age (Johnson and Boyce 1991, Huwer 2004) and recruitment was defined as 50 days post hatch (Schroeder 1997).

Chicks were monitored on an every other day basis until mortality or recruitment. When chick mortalities were discovered we used circumstantial evidence such as raptor feathers or whitewash, and mammal scat or tracks to determine the cause of death. There was generally very little chick remains and determining the cause of mortality was difficult. Chicks that survived past recruitment into the population were continually monitored, until the battery in the transmitter failed, to make comparisons to other reported time periods.

Survival data on radio-marked chicks were analyzed using a known fate model in program MARK (White and Burnham 1999). We created an encounter history for each radio-marked chick by dividing our proposed recruitment date of 49 days into seven 1-week intervals from capture to mortality or recruitment. The use of seven 1-week intervals was 1 day short of the standard of 50 days consistently used on this project. Adding or subtracting another 1-week interval however, would have made recruitment estimates in 2006 less consistent than data from previous years.

We established 10 *a priori* models that were used to explain variation in survival rates. Due to our small sample size, we were only able to use 4 covariates in our models. Each model represented survival as a function of a combination of the covariates and non-constant survival rates. We assumed that all influences affecting mortality were different for each chick in each time interval. The 4 covariates chosen were handling time, chick age, hen age, and hen experience in Strawberry Valley. The covariate 'hen age' was defined as juvenile or adult based on feather characteristics (Crunden 1963, Bihrle 1993). We collected these data before we placed the radio-transmitter on each hen. The covariate 'hen experience' was created to test the hypothesis that hen experience in Strawberry Valley would increase chick survival. Translocated hens from 2004 and 2005 were combined with resident hens and compared to hens translocated in 2006 to form this covariate. Definitions for the covariates 'chick age' and 'handling time' are described in the methods for attaching transmitters to chicks.

Models were ranked using Akaike's Information Criterion for small sample size (AIC_c; Burnham and Anderson 2002). A likelihood ratio test, using a Chi-square statistic in program MARK was used to determine the significance of the covariates. We used model averaging to estimate survival for chicks in the Strawberry Valley due to similar model weights.

UTM locations were collected using a Garmin eTrex Vista (Garmin International Inc., Olathe, KS) handheld Global Positioning System unit throughout the process of capturing and monitoring broods. Hens with radio-marked chicks were monitored on an every-other-day basis with waypoints taken at each brood location. These data were collected to test for differences in distances traveled by broods that died versus broods in which at least one chick was recruited into the population. Distance traveled successively between points was calculated using ArcView 3.3 (ESRI Redlands, CA). A Mann Whitney two-sample T-test was used to compare distances between broods. Non-parametric tests were used because the data did not meet normality assumptions.

RESULTS

We attached 42 transmitters to Sage-Grouse chicks captured from 20 different broods in 2006 (Table 1). There were 6 chicks from our sample radio-marked in the Currant Creek area; the remaining 36 were in Strawberry Valley. Two transmitters were attached to chicks >7 days old with a mean weight of 72 g. These chicks were not included in the survival analysis of program MARK because they were from a resident hen which was not radio-marked and the hen's age was unknown. The remaining 40 chicks from 19 different broods were ≤7 days old with a mean age of 2 days-old and body mass of 36 g. No chicks in the Currant Creek area survived to recruitment.

Mean handling time per chick was 10.6 minutes (SD ± 3.7). The maximum amount of time it took to weigh a chick and attach a transmitter on the chick restraint board was 19 minutes; this was also the first chick captured in the sample. The minimum time recorded to process a chick was 5 minutes. No chick died or was injured on the chick restraining board or at any point from capture through release.

Our comparison of *a priori* models in program MARK ranked the model containing the covariate chick age (AIC_c weight = 0.18632) as the best model, but it was only slightly better than the model for hen experience (AIC_c weight = 0.1857) (Table 2). AIC_c weights of models containing handling time and hen age were similar to the models mentioned above. Likelihood ratio tests revealed that no covariate had a significant effect on chick survival (Table 3). We observed that 9 (22.5%) of the 40 chicks survived to recruitment. Model averaging in program MARK estimated survival to 49 days to be 23.5% (Figure 2).

Determining cause specific mortality proved very difficult. We were unable to determine the fate of 23 (57.5%) chicks. Transmitters were found for 9 of the 23 (39%) chicks categorized as unknown, but an accurate identification of fate could not be made, and the remaining 14 (61%) were not found during multiple relocation attempts. Five of the 31 (16%) chicks that died were identified as avian predation, 2 (6.5%) mammalian predation, and 1 (3%) died due to observer error.

While monitoring a brood, one chick that was not equipped with a radio-transmitter and therefore not in the sample, was observed running from sagebrush cover into a grass meadow where it died. A necropsy performed by the Central Utah Veterinary Diagnostic Laboratory in Lehi, Utah determined that the chick likely died of exposure and/or stress. This was the only intact chick recovered during our study.

Broods were located every 2.5 days on average. The average distance traveled by all broods over a 2.5 day period was 394 m with distances ranging from 24 m to 2.9 km. A Mann-Whitney test concluded that there was no difference between distance traveled by broods in which all radio-marked chicks died and broods that recruited at least one chick equipped with a transmitter ($Z = -0.3491$; p-value = 0.73). Five (25%) of the 20 broods raised at least one chick to recruitment into the population.

DISCUSSION

We experienced several setbacks in our efforts to capture chicks. Twelve nests were lost to nest predation or abandonment, and one hen lost her entire brood shortly after successfully hatching. This reduced the number of potential broods by 37.5% forcing us to be more opportunistic in radio-marking efforts. Other studies (Gregg et al. 2002, Burkepile et al. 2002, Aldridge 2005) claim that using micro-transmitters on Sage-Grouse chicks have not increased mortality rates. We could not add support to this claim based on our chick survival data via brood flush counts prior to this study. Chick survival in Strawberry Valley was estimated at 51.8% from 2003-2005 using brood flush counts. After weighing the cost-benefit ratio of this study we decided to discontinue further research on chick survival through use of micro-transmitters. The study did not identify any unsuspected causes of chick mortality, and the cumulative effect of stressing chicks, hens, and broods was not deemed worth the benefit, especially in a population recovery setting like Strawberry Valley. As a result only one year of chick survival data was available and our sample size was probably not sufficient enough to detect differences due to the aforementioned variables. However, results from this study will still be compared to other studies across the species range.

Chick survival in Strawberry Valley was greater than all reported values from other studies (Table 4). Burkepile et al. (2002) and Gregg et al. (2002) both estimated survival based on the lifespan of radio-transmitter batteries. Schroeder (1997) established 50 days as the standard age of chick independence, which was the standard followed using micro-transmitters in the Strawberry Valley. Initially, Aldridge and Brigham (2001) used methods described by Schroeder (1997) to flush radio-marked hens with broods, but later Aldridge (2005) used 56 days to define recruitment age. Beck et al. (2006) did not use transmitters on chicks or report chick survival making comparisons impossible. In order to compare survival in Strawberry Valley to all other available published estimates and time periods we reported survival to 10 weeks which was the standard survival estimation period used by Beck et al. (2006). Inferences had to be made for a 10 week survival period in the Strawberry population since only 2 radio-transmitter batteries lasted ≥10 weeks (70 days). For 7 chicks surviving to battery depletion the batteries lasted an average of 67 days (SD ± 4.8).

Analyses in program MARK revealed that handling time, chick age, hen age, and hen experience in the Strawberry Valley population may not be good indicators of chick survival. Error could have resulted from small sample size or when estimating chick age, hen age, and handling time causing the covariates to appear less valuable. Models that analyzed each covariate separately were very similar (Table 2) indicating that no one variable was more important than another when estimating survival. In addition, models consisting of combinations of the covariates were ranked lower. It may be possible in this given year that chick mortality was influenced by general Sage-Grouse biology and life history characteristics more than any other measured variable. However, it is more likely that our sample size was insufficient. It may also be possible that the covariates chosen were not good indicators of survival. Survival estimates for each time interval from program MARK did not illustrate continually increasing survival rates over time (Figure 2).

Our observed chick survival estimate of 22.5% was less than the estimate of 23.5% from program MARK. This discrepancy is likely do to the precision of estimating survival differently for each chick in each time interval in program MARK. It may also be a result of observations to the 50^{th} day when MARK was estimating to 49 days.

Our higher observed chick survival rates in Strawberry Valley can most likely be attributed to high quality habitat and an abundant suite of insects (Bunnell 2000, Bambrough 2002, Baxter 2003, Bunnell et al. 2004). However, we cannot discount the predator control by U.S.D.A. Wildlife Services as a factor in chick survival. Heavy rainfall or unseasonably cold temperatures are also suspected to decrease Sage-Grouse productivity (Connelly et al. 2000). Young broods would be most vulnerable in these conditions. The only indication that climatic factors affected chicks in the Strawberry Valley population in 2006 was the chick, not included in our sample that we observed dying, but necropsy results were inconclusive. Cold weather or heavy rains were not the cause of this mortality because it died in July during a period of hot, dry weather.

The chick restraining board proved to be a valuable tool in the field. Burkepile et al. (2002) reported that it took less than 30 minutes to weigh an entire brood and attach 3 transmitters. Aldridge (2005) reported 15-45 minutes to process an entire brood with approximately 10 minutes to affix the micro-transmitters. The number of researchers required to capture and radio-mark chicks was not reported in other studies. It is assumed that at least two people would be required under normal circumstances. Broods were processed in about 15-45 minutes in this study with an average of 10.6 minutes to attach each transmitter to each chick. The greatest benefit of the chick board was that it enabled a single person to search for chicks, capture chicks, and attach transmitters to chicks. It was lightweight and easily manageable in the field.

Although radio-telemetry enables researchers to locate chicks to attempt to determine proximate and ultimate causes of mortality, it still left many questions unanswered in this study. There were 23 chicks whose fate was unknown representing the majority of the sample. The most likely explanation for chicks with unknown fate is predation (Gregg et al. 2002). Chicks this age are small and before ≤21 days unable to fly; therefore the likelihood of the chick traveling out of range of the receiver is minimal. Fourteen chicks were not relocated and transmitter signals could not be detected. This indicates that a predator likely carried the chick and transmitters a great distance; this indicates a mortality possibly caused by a canid or raptor. Transmitter failure is also a possible explanation for chicks of unknown fate, although we witnessed no evidence of this.

We recommend that predator control be continued in the Strawberry Valley and that it be focused on critical times of lekking, nesting, and brood rearing to benefit Sage-Grouse. Our mortality data in 2006 suggests that raptors are becoming an increased cause of adult and chick mortality in Strawberry Valley. Federal regulations prohibit lethal control of raptors, so control efforts should be focused on unprotected mammals and target specific avian species such as the common raven (*Corvus corax*) and black-billed magpie (*Pica hudsonia*) to minimize overall pressure on Sage-Grouse during the sensitive reproductive period. In addition, habitat restoration is desperately needed in the Currant Creek area. In 2001, big sagebrush was decimated by herbicide treatment of large areas of former Sage-Grouse habitat. All chicks in the Currant Creek area were in or near these treatment areas and all 6 of these chicks died before recruitment into the population. Poor condition habitat is the most likely contributing factor for chick mortality in Currant Creek. Without adequate cover, chicks are far more susceptible to predation. In addition, crested wheatgrass (*Agropyron cristatum*) was planted in these treated areas to enhance forage for livestock creating very poor brood rearing conditions for Sage-Grouse.

We decided to discontinue further research on chick survival via the use of radio-telemetry since we found no evidence of unsuspected causes of chick mortality. However, we did find possible evidence of stress related mortality in the chick that was not in our sample, but was in the same brood as a radio-equipped chick. The decision to discontinue radio-telemetry studies on chicks creates an insufficient sample for more reliable inferences. In addition, chicks were not randomly collected or randomly assigned to treatment groups therefore no inferences to other populations or of cause and effect can be made to other populations. Radio-telemetry studies of chicks from Sage-Grouse populations with sensitive or recovering status should be considered with great caution. It is our opinion based on evidence provided by this study that the benefits associated with the minimal amount of information gathered were not worth the costs associated with increased stress of a recovering population such as the Greater Sage-Grouse population in Strawberry Valley.

LITERATURE CITED

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management 27:529-545.

Aldridge, C.L. 2005. Identifying habitats for persistence of Greater Sage-Grouse (*Centrocercus urophasianus*) in Alberta, Canada. Doctoral dissertation. University of Alberta, Edmonton, Alberta, Canada. 250 p.

Aldridge, C.L., and R.M. Brigham. 2001. Nesting and reproductive activities of Greater Sage-Grouse in a declining northern fringe population. Condor 103:537-543.

Bambrough, D.J. 2002. Greater Sage-Grouse winter and male and female summer habitat selection in Strawberry Valley, Utah. M.S. Thesis. Brigham Young University, Provo, Utah, USA.

Baxter, R.J. 2003. Greater Sage-Grouse brood and non-reproductive female habitat selection and population dynamics in Strawberry Valley, Utah. M.S. Thesis. Brigham Young University, Provo, Utah, USA.

Beck, J.L., and D.L. Mitchell. 1997. Brief guidelines for maintaining and enhancing sage grouse habitat on private lands in Utah. Utah technical notes: UT 190-1-3. U.S. Natural Resources Conservation Service, Salt Lake City, Utah.

Beck, J.L., K.P. Reese, J.W. Connelly, and M.B. Lucia. 2006. Movements and survival of juvenile Greater Sage-Grouse in Southeastern Idaho. Wildlife Society Bulletin 34(4):1070-1078.

Bihrle, C. 1993. Upland game identification: a basic guide for aging and sexing the bird in your hand. North Dakota Outdoors 56(3):9-23.

Braun, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139–156.

Bunnell, K.D. 2000. Ecological factors limiting sage grouse recovery and expansion in Strawberry Valley, Utah. M.S. Thesis. Brigham Young University, Provo, Utah, USA.

Bunnell, K.D., J.T. Flinders, D.L. Mitchell, and J.H. Warder. 2004. Occupied and unoccupied sage grouse habitat in Strawberry Valley, Utah. Journal of Range Management 57(5) 524-531.

Burkepile, N.A., J.W. Connelly, D.W. Stanley, and K.P. Reese. 2002. Attachment of radiotransmitters to one-day-old sage grouse chicks. Wildlife Society Bulletin 30(1):93-96.

Burnham K. P., and Anderson D. R. 2002. Model selection and multimodel inference: a practical information-theoretic approach. Second edition. Springer-Verlag. New York, New York, USA.

Connelly, J.W., and C.E. Braun. 1997. Long-term changes in sage grouse (*Centrocercus urophasianus*) in western North America. Wildlife Biology 3/4:123-28.

Connelly, J.W., K.P. Reese, W.L. Wakkinen, M.D. Robertson, and R.A. Fischer. 1994. Sage grouse ecology report. Idaho Department of Fish and Game, Job Completion Report W-160-R-19, Subproject 9, Boise, Idaho, USA.

Connelly, J.W., M.A. Schroeder, A.R. Sands, and C.E. Braun. 2000a. Guidelines to manage sage grouse populations and their habitats. Wildlife Society Bulletin 28(4):967-985.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-10.

Crunden C. W.1963. Age and sex of sage grouse from wings. Journal of Wildlife Management. 27:846–850.

Gregg, M.A., M, Pope, and J.A. Crawford. 2002. Survival of sage grouse chicks in the northern Great Basin. 2002 Annual Report. Department of Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.

Griner, G.L. 1939. A study of sage grouse (*Centrocercus urophasianus*), with special reference to life history, habitat requirements, and numbers of distribution. Thesis. Utah State Agricultural College, Logan, Utah.

Huwer, S.L. 2004. Evaluating Greater Sage-Grouse brood habitat using human-imprinted chicks. Thesis. Department of Fishery and Wildlife Biology, Colorado State University, Fort Collins, Colorado, USA.

Johnsgard, P.A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln. 553pp.

Johnson, G.D., and M.S. Boyce. 1991. Survival, growth, and reproduction of captive-reared sage grouse. Wildlife Society Bulletin 19(1):88-93.

June, J.W. 1963. Wyoming sage grouse population measurement. Proceedings of the Western Association of State Game and Fish Commissioners 43:206-211.

Schroeder, M.A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. Condor 99:933-941.

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

Zablan, M.A. 1993. Evalutation of sage grouse banding program in North Park, Colorado. Thesis, Colorado State University, Fort Collins, USA.

Table 1. A comprehensive list of all chicks, handling time, body mass in grams, age in days, and known-fate.

Chick Frequency	Handling Time (minutes)	Weight (g)	Age (days)	Chick Fate
149.9396	19	30.5	1	Unknown
150.3689	18	30	1	Avian Predation
148.9681	18	32	1	Unknown
148.7901	15	30.5	1	Unknown
148.8500	7	32	1	Recruited
151.0990	17	33	1	Unknown
148.7297	18	36	2	Recruited
150.0393	9	36	2	Recruited
150.1399	10	33	2	Recruited
148.6688	13	30	2	Unknown
148.9107	10	29	2	Avian Predation
148.6999	8	28	2	Unknown
149.8895	11	37	3	Unknown
151.1104	11	47	4	Avian Predation
149.9207	10	40	3	Recruited
150.0083	10	28	1	Unknown
150.0919	9	28	1	Unknown
151.1708	8	30	1	Unknown
151.0202	11	30	1	Recruited
148.9801	12	36	3	Unknown
151.1291	12	32	1	Avian Predation
151.1191	8	30	1	Mammalian Predation
151.0289	8	28	1	Unknown
151.0595	7	25	1	Unknown
148.8185	9	40	3	Observer Error
150.2893	12	30.5	2	Unknown
148.7618	10	26.5	1	Unknown
149.8808	5	26.5	1	Unknown

149.8400 [1]	10	74	8	Mammalian Predation
149.8997 [1]	11	74	8	Mammalian Predation
149.8592	6	64	6	Unknown
150.1986	5	62	6	Unknown
148.9898	12	59	6	Avian Predation
151.1493	11	68	7	Unknown
148.9605	10	62	6	Mammalian Predation
152.2589	9	30	1	Recruited
152.2686	7	33	1	Recruited
152.2786	7	31.5	1	Unknown
152.2185	11	31	1	Recruited
152.2499	10	31	2	Unknown
150.3493	18	37.5	3	Unknown
148.8187	5	39.5	3	Unknown
Averages:	11	37.88	2.5	

[1]Chicks were not included in Program Mark analysis, because they were from an un-collared resident hen.

Table 2. Known-fate candidate models (using Akaike's Information Criterion corrected for small sample size[AICc]) for weekly Sage-Grouse chick survival in Strawberry Valley, 2006.

Model	AICc	Delta AICc	AICc Weights	Model Likelihood	Num. Par	Deviance
{S(t) chickage}	149.5	0.00	0.19	1.0	8	132.3
{S(t) experience}	149.5	0.01	0.19	1.0	8	132.3
{S(t) handtime}	149.5	0.10	0.18	1.0	8	132.4
{S(t) henage}	150.1	0.69	0.13	0.7	8	133.0
{S(t) handtime + chickage}	151.0	1.51	0.09	0.5	9	131.5
{S(t) chickage + henage}	151.4	1.97	0.07	0.4	9	131.9
{S(t) henage + experience}	151.5	2.01	0.07	0.4	9	132.0
{S(t) chickage + henage + experience}	152.4	2.90	0.04	0.2	10	130.5
{S(t) handtime + chickage + experience}	152.8	3.35	0.03	0.2	10	131.0
{S(t) handtime + chickage + henage + experience}	154.5	5.08	0.01	0.1	11	130.3

Table 3. Likelihood ratio tests used to determine the effect of each covariate in the model of Sage-Grouse chick survival in Strawberry Valley, 2006.

	Chi-square	Degrees of Freedom	P-value
Chick age	1.02	1	0.31
Handling time	0.79	1	0.37
Hen age	0.65	1	0.42
Hen experience	1.42	1	0.23

Table 4. A comparison of observed chick survival in Strawberry Valley to survival periods and survival estimates based on use of radio transmitters reported in other studies.

Estimated Survival Period	% Chick Survival Reported	% Survival in Strawberry Valley
21 days (Burkepile et al. 2002)	22.0%	37.5%
28 days (Gregg et al. 2002)	19.0%	30.0%
50 days (Schroder 1997)[1]		22.5%
49 days (Estimated from program MARK)		23.5%
56 days (Aldridge 2005)	12.3%	17.5%
10 weeks (Beck et al. 2006)[2]		17.5%[3]

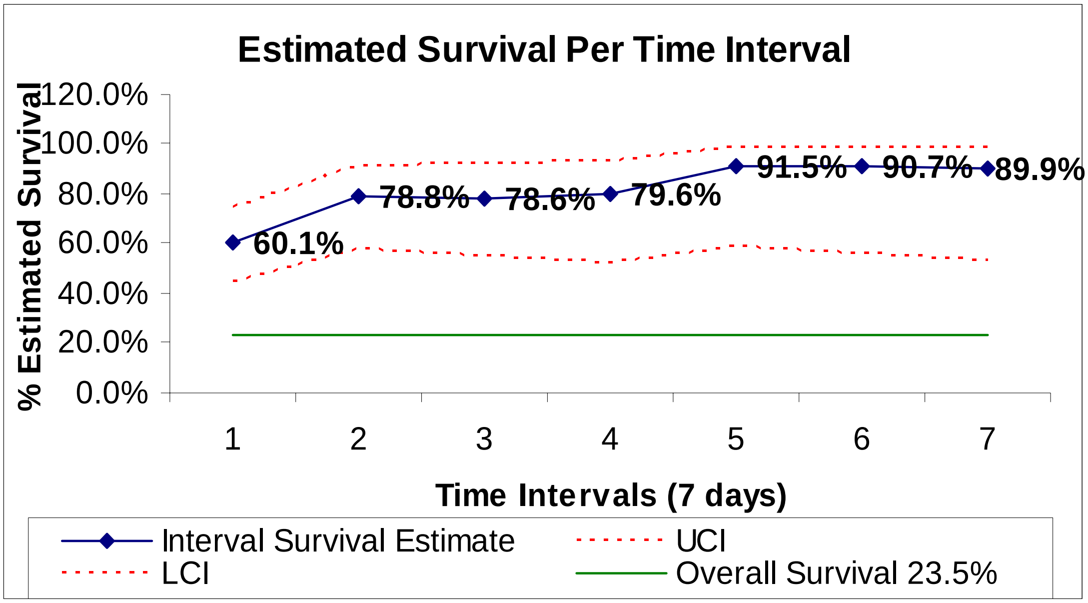
[1] This study reported survival, but did not use radio-marked chicks; 50 days was the standard time period used in Strawberry Valley

[2] This study did not report chick survival, it only specified the survival estimate period

[3] Many radio-transmitter batteries failed, this estimate assumes that chicks near 10 weeks survived

Figure 1. A 1 day-old chick restrained on the chick board while sutures are being inserted for attachment of a radio transmitter.

Figure 2. Survival estimates for Sage-Grouse chicks for each 7 day interval with 95% upper and lower confidence intervals and overall estimated survival in Strawberry Valley, 2006.



Reduction of Greater Sage-Grouse (*Centrocercus urophasianus*) abundance throughout Western North America has been considerable with as much as a 47% decline in some areas of its range (Connelly and Braun 1997). Once found in 16 U.S. states and 3 Canadian provinces, (Aldrich 1963, Johnsgard 1973) Sage-Grouse are now constricted to 11 states and 2 provinces (Braun 1998). The drastic decline has been linked to degraded Sage-Grouse habitat and anthropogenic factors (Braun 1998, Crawford et al. 2004). Low nest success and juvenile survival may also be responsible for the population decline (Schroeder 1997, Aldridge and Brigham 2001, Aldridge 2005, Beck et al. 2006).

In Utah, Greater Sage-Grouse have experienced a trend similar to overall numbers across Western North America with a population reduction by nearly 50%. This resulted in the Utah Division of Wildlife Resources (UDWR) classifying Greater Sage-Grouse as a "Sensitive Species of Concern" (Beck and Mitchell 1997). An example of extreme population decline in Utah has occurred in the Strawberry Valley of central Utah. In 1939 Griner, estimated about 3,500 Sage-Grouse (Griner 1939) in the Strawberry Valley. The population eventually diminished to an estimated 150 breeding birds in 2000, a near 97% reduction (Bunnell 2000).

In March 1998, the Strawberry Valley Greater Sage-Grouse Recovery Project was initiated to identify and remove or mitigate factors causing the decline of Sage-Grouse in the area. The specific objectives included population monitoring (i.e. lek counts, nest/brood counts, seasonal distributions, and identifying winter migration routes and destinations), identifying and quantifying biotic and abiotic components of seasonal and unoccupied habitat, and documenting factors affecting mortality.

Translocations have commonly been used as a method to recover or augment wildlife populations and are not new to Sage-Grouse management. Reese and Connelly (1997) cited at least 56 attempts to augment or reestablish Sage-Grouse populations via translocations since 1933. The majority of translocation attempts yielded little long-term beneficial results (Reese and Connelly 1997).

In 2003, we began translocating Sage-Grouse into the Strawberry Valley from stable populations in Utah in an attempt to reverse the downward trend and to recover the population. A total of 38, 34, 70, and 103 female Sage-Grouse were translocated to the Strawberry Valley in 2003, 2004, 2005, and 2006 respectively. The source populations include Parker Mountain (PM) primarily in Wayne County, Diamond Mountain (DM) in Uintah County, western Box Elder County (BEC), and Deseret Land and Livestock (DLL) in Rich County, Utah. Prolonged winter weather in 2006 created an unexpected opportunity to test translocation release methods. We hypothesize that Sage-Grouse released prior to resident lekking activity will not display similar movements to those released during lekking activity. We also hypothesize that translocated hens released before the lek was active will not display flocking rates similar to those hens released near an active lek. Finally, we hypothesize that hens released prior to lekking activity will experience higher mortality than those that were released during lekking activity.

STUDY AREA

The study area consists of Strawberry Valley, and two migratory areas known as Currant Creek and Lower Red Creek. Strawberry Valley is in Wasatch County, south of the Uinta and east of the Wasatch mountain ranges. The valley is a montane sagebrush (*Artemisia tridentata*) steppe and has elevations from 2280 to 2440 m. Climatic data show cool summers and cold winters, with an annual precipitation of 41.8 cm. Mountain big sagebrush (*A.t. vaseyana*) dominates the area. Included in the study area is a property owned by the UDWR known as the Wildcat Wildlife Management Unit. Wildcat is positioned to the east of the main Strawberry Valley. It is a plateau slightly higher in elevation with sagebrush dominated valleys interspersed with aspen (*Populus tremuloides*).

The Current Creek study area is approximately 18.5 km east of Strawberry Valley on the border of Wasatch and Duchesne Counties northwest of the town of Fruitland. The Lower Red Creek area is located on private land approximately 32.2 air kilometers east of Strawberry Valley in Duchesne County east of Fruitland, north of Highway 40, and west of Highway 208. Lower Red Creek and Current Creek are similar in vegetation type dominated by an intermediate variety of mountain big sagebrush and Wyoming big sagebrush (*A.t. wyomingensis*) and range in elevation from 1981 to 2134 m respectively. The annual precipitation in these areas is 31.5 cm (Bunnell 2000).

METHODS

During spring 2006, we trapped Sage-Grouse hens via the spotlighting method (Giesen et al 1982) on and around leks at PM, BEC, and DLL. Each hen was placed in an individual cardboard box and transported overnight to the Strawberry Valley. Upon arrival, each bird was taken from the box, weighed, aged according to feather characteristics (Crunden 1963, Bihrle 1993), fitted with a necklace style radio transmitter (Advanced Telemetry Systems, Inc., Isanti, MN), placed back in a box and transported to the release site. The release site was within 250 m of the only known active lek in

Strawberry Valley. We released all hens from the cardboard boxes ≤12 hours after capture.

Ours has been the first translocation effort to release all Sage-Grouse near an active lek with strutting male grouse. Since 2003, we have followed this release protocol without exception. We believe this method was one of the primary reasons for the success of translocations in Strawberry Valley, since it allowed translocated hens to immediately associate with resident grouse. A prolonged winter in 2006 delayed normal lekking activity in Strawberry Valley. In addition, the logistics of moving such a large number of birds, and trying to coordinate lekking activity in Strawberry Valley with source populations created problems. In order to reach translocation objectives for 2006 it became necessary to translocate hens before the lek was active. Source populations began strutting several weeks before the Strawberry Valley population. As a result 61 (59%) of the 103 Sage-Grouse translocated in 2006 were not released while males were actively strutting. This created an unplanned opportunity to test the method of releasing translocated hens over an active lek.

Little information has been reported about the movement tendencies of Sage-Grouse in PM, BEC, or DLL. We know that each source population is among the most abundant in Utah (Beck et al. 2003), but reports of migratory behaviors or movements are not available.

All translocated hens were tracked via radio-telemetry from the ground using a 4-element Yagi antenna and an R - 1000 digital radio receiver (Communication Specialists Incorporated, Orange, CA). Fixed-wing aircraft flights were also used to search for birds which could not be located from the ground. Radio-telemetry facilitated year-round monitoring of movements, survival, reproductive effort, and seasonal habitat use. Whenever a hen was located Universal Transverse Mercator (UTM) coordinates were recorded using a Garmin eTrex Vista (Garmin International Inc., Olathe, KS) handheld Global Positioning System.

Translocated Sage-Grouse were followed during the summer (April 1 to September 30) of 2006 to document dispersal, flocking, reproductive effort and mortality. Reproductive effort will not be addressed in this manuscript. Using the point distance tool of ArcMap 9.1 (ESRI, Redlands, CA) a value was calculated for each GPS waypoint by measuring the distance from the release site to each summer location. Median distance traveled by each hen was calculated and used for distance analysis.

We monitored and recorded flocking and interactions of translocated hens with resident birds. Flocking was defined as an instance when a translocated hen was observed grouped or flocked two consecutive times with at least one resident bird (male or female). Monthly flocking will be reported for hens translocated from each location in 2006. We also located all translocated Sage-Grouse mortalities and determined the cause of death, based on circumstantial evidence, whenever possible.

Statistical analyses were performed using NCSS® 2001. We used hen age, body mass, release time (i.e. prior to lekking activity versus during lekking activity), and source population (i.e. PM, BEC, and DLL) as independent variables to determine the influence they may have had on median distance traveled, flocking, and survival. Body mass was measured in grams, and age was categorized as juvenile or adult. Median distances were tested using multiple regression. Both mortality and flocking were binary response variables since the hens either did or did not flock or die and were tested using logistic regression. Stepwise variable selection was used to determine the most influential variables in each test of distance, mortality, and flocking. In addition, we used an analysis of covariance (ANCOVA) for distance traveled to determine the relationship of hen age, body mass, release time, and source population. ANCOVA was not used on mortality and flocking because the responses were discrete.

A Kruskal-Wallis non-parametric ANOVA was used to test for differences in age and body mass between source populations since assumptions of a normal distribution or equal standard deviations were violated. A Bonferroni Multiple Comparisons test was used to adjust our alpha level for multiple tests on the same data when comparing hen age and body mass between the 3 source populations. The resulting alpha level was set at 0.017 for significance. A Mann-Whitney test was used to test median distances of hens released near an inactive lek and those released during activity. It was also used to compare median dispersal distances of 2006 PM hens and PM hens translocated prior to 2006. All statistical tests, excluding those specified with Bonferroni corrections, were considered significant at an alpha level of 0.05.

RESULTS

During the spring of 2006 we trapped 35 Sage-Grouse (13 adults, 22 juveniles) from PM, 34 (14 adults, 20 juveniles) from BEC, and 35 (24 adults, 10 juveniles) from DLL. For the first time since translocations began in 2003 a hen died in the box before arrival into Strawberry Valley. Another hen was euthanized shortly after release because of apparent injuries sustained while in the box. Both hens were eliminated from the sample. Also 2 different hens from DLL laid eggs in the box while in transit.

As of 30 September 2006 there were 15 hens (7 PM, 3 BEC, 5 DLL) that had not been located since their release (active and inactive lek). To avoid bias to movement, flocking, and mortality data these hens were removed from the sample. The most likely explanation for the loss of these hens is transmitter failure. In an effort to preserve funding, all radio transmitters for PM hens were re-used from previous years of the study. The transmitters were thought to have had at least 1 year of battery life remaining, but 8 of the 15 lost birds were wearing re-used transmitters.

We found that there was a difference in the age (P-value = 0.011, Chi-square = 9.04, D.F. = 2) and body mass (P-value = 0.0002, Chi-square = 33.16, D.F. = 2) between source populations using nonparametric ANOVA. DLL hens were significantly older than PM hens (P-value = 0.013, Z = -2.49), and very near being significantly older than BEC hens (P-value = 0.026, Z = 2.23) with alpha set at 0.017 for significance. DLL hens also had significantly greater body mass than hens from PM (P-value < 0.0001, Z = -5.19) and BEC (P-value = 0.0006, Z = 3.42) (Table 1).

All of the 35 hens from PM and 26 hens from BEC were released before lekking activity. The remaining 7 BEC hens along with all 34 DLL hens were released when males were actively strutting. The mean distance traveled by PM hens was 6.3 km (SD ± 5.8 km) with an average of 3 locations per hen over the summer. Overall PM movements ranged from 0.1 km to 28 km. BEC distances had a mean dispersal distance of 7.5 km (SD ± 9.88 km). There was an average of 4 locations per hen from BEC and distance traveled ranged from 0.54-59.75 km. Mean dispersal distance for DLL was 6 km (SD ± 7.55 km) and overall distances ranged from 0.8-53 km with an average of 4.3 locations per hen.

Hen age, body mass, timing of release, and source did not create a good predictive model of median distance traveled (P-value = 0.15, R^2 = 0.08, F = 1.735, D.F. = 4). However, stepwise regression selected release time as an influential variable in dispersal distance (P-value = 0.011, T = 2.6). ANCOVA testing revealed that release time was significantly different (P-value = 0.04, F = 4.25, DF = 1) than the other covariates when testing dispersal distance. To further test median distances we used a Mann-Whitney test which showed that hens released near an inactive lek traveled significantly greater median distances (6.3 km) than hens released over an active lek (2.6 km) (P-value = 0.007, Z = -2.71)

Mortality did not appear to be influenced by hen age, body mass, release time, or source (P-value = 0.79, R^2 = 0.02, Chi-square = 1.73, D.F. = 4). Although mortality was not significantly different for hens released near an inactive lek versus those released during lek activity; it was higher for hens released before lekking activity (Figure 1). Mortality was high over the summer with only 46% of PM, 60% of BEC, and 62% of DLL surviving from the time of release through the summer. Predation was the primary cause of mortalities of translocated hens.

Flocking appeared to be influenced by the combination of hen age, body mass, release time and source (P-value = 0.038, R^2 = 0.11, Chi-square = 10.12, D.F. = 4). Stepwise selection found that source population had a significant influence on flocking (P-value = 0.004, T = 2.99). DLL hens were found flocked sooner and at a higher rate than PM and BEC (Figure 2). By the end of the summer 83%, 53%, and 50% of translocated hens were flocked for DLL, BEC, and PM respectively. Although flocking was not significantly different between hens released before the lek was active and those released near an active lek, the flocking rate was higher for hens released during lekking activity (Figure 3).

All 2006 PM hens were released over an inactive lek. In the 3 years prior to 2006, all PM hens were released over an active lek. A Mann-Whitney test was used to compare median distances of 2006 PM hens to those from previous years released near an active lek. There was no difference between 2006 PM movements and previous years (P-value > 0.9, Z = 0.003).

DISCUSSION

The results from the summer of 2006 provide validation to the method of releasing translocated Sage-Grouse hens near an active lek. Hens released near an inactive lek in 2006 dispersed significantly greater distances than those released over an active lek. No other translocation efforts (Musil et al. 1993, Reese and Connelly 1997) have released Sage-Grouse over an active lek in the way we have in Strawberry Valley. Our data suggest that releasing hens near an active lek will influence the distance hens travel. Mortality rates were not significantly influenced by release time, hen age, body mass, or source population. However, mortality was higher (Figure 1) for hens released before lek activity. Flocking appeared to be influenced by source population. Flocking with resident birds was delayed for hens released before lekking activity (Figure 3). Although it was not found to be statistically significant, hens released before lekking activity flocked less and had higher mortality than those released during lekking activity (Figure 4). We are persuaded that non-flocking hens will travel greater distances and therefore be more susceptible to predation. Further research is needed to test this hypothesis.

Hens from PM, BEC, and DLL did not display any significant difference (P-value = 0.1502) in movements over the summer of 2006. In an effort to further account for source effects we analyzed all summer movement data from PM hens. PM has been a source population since the beginning of translocations and we have 3 years of movement data prior to 2006, and every PM hen prior to 2006 was released over an active lek. Analysis revealed that median distances of PM hens translocated prior to 2006 did not differ from those released in 2006. This may seem contradictory to our hypothesis that hens released near an active lek will move shorter distances than those released near an inactive lek. There are several lurking variables that need to be addressed. Year effects were not tested. Translocated hens from 2003-2005 were released into a much smaller Strawberry Valley Sage-Grouse population, and the likelihood of encountering resident grouse was much lower. Therefore, we believe, the tendency to continue to disperse was likely higher as a result. In addition, very little sagebrush habitat was exposed when PM hens were released in 2006 because of deep residual snow, creating a greater likelihood that newly released hens would encounter residents when suitable habitat was found, thereby decreasing likelihood of continued dispersal. Further analysis of source effects for BEC and DLL are not possible since this was the first year of translocations from these areas.

We believe the influence that the source population had on flocking was most likely the result of release time, although release time was not found to have a statistically significant influence. All DLL hens were released near an active lek and that is the group that displayed the greatest flocking rate (Figure 2). We maintain that flocking with residents is very important to newly translocated Sage-Grouse since associations with residents may transfer valuable spatial information of locations of suitable habitat for reproduction and other essential life processes for in Strawberry Valley. Hens released during lekking activity flocked with residents sooner than those hens released prior to lek activity (Figure 3). Although not found to be significant these results provide support for the protocol of our method of release.

DLL hens were older and heavier (Table 1) than those trapped from BEC and PM, but this did not appear to impact survival, flocking or dispersal distance. Proportionately more hens died in the study area this year. The percent mortality of hens released during lekking activity were lower than those of hens released prior to lek activity (Figure 1). Although greater flocking and mortality rates were not found to be significant we believe that this provides valuable evidence that hens should be released near an active lek. Mortality data have not been analyzed completely but observations appear to show an increase in avian predation. We postulate that raptors have discovered the more adequate food base of Sage-Grouse in Strawberry Valley and can now profitably focus hunting efforts on these grouse. Further research is needed to clarify this hypothesis.

Timing translocations of Sage-Grouse from 3 different locations to Strawberry Valley was difficult, and we observed several deviations from patterns of previous years. Although there were a few hens in years prior to 2006 that injured themselves in the box and were then euthanized soon after release, this is the first year that a hen died in the box.

Another anomaly was the 2 DLL hens that laid eggs in the boxes while in transit. This is an indication of the difficulty of timing reproductive activities of separate populations. We likely missed prime translocation time in DLL by 1-2 weeks. Ideally, hens should be trapped before initiating a clutch so that they initiate nesting in Strawberry Valley. One hen that laid an egg in the box was a part of the group of 15 that were never located. It is possible she and others left the study area in attempts to return to initiated clutches. Radio-telemetry flights from a fixed-wing aircraft near DLL have failed to locate her or any other radio-marked hens in that area.

Two of the 3 hens dispersing the maximum distances from each group initiated movements never before observed. The BEC hen that traveled nearly 60 km from the release site was found on the Ute-Ouray Indian Reservation northwest of the town of Mountain Home, Utah. She was one of the 61 hens released before the lek was active. This is the greatest distance traveled by one of our translocated hens, and it is the first time a hen from our research effort (resident or translocated) was found in this area. There is a healthy Sage-Grouse population in this area and several active leks. This presents evidence of possible future connectivity between this population and the Strawberry Valley population. Such connectivity between populations will be important in maintaining genetic diversity. It is also possible that some of the 15 un-located hens also moved to the area where she was found; although she was the only radio-collared hen found in this area.

The movement of the DLL hen which traveled 53 km was very uncharacteristic. She was located northwest of the release site in the backyard of a private residence in Orem, Utah. The hen was in very poor body condition with several open wounds and was euthanized as a result of her injuries. It is unclear why this hen traveled this direction or what route she took to get there. The main spine of the Wasatch Mountains separates the Strawberry Valley and the location where she was found with very little suitable Sage-

Grouse habitat in between. This movement can only be classified as an anomaly. Incidentally this hen was released when the lek was active. Her movements may be a result of missing the prime trapping period in DLL.

From our results in 2006 we conclude that releasing translocated grouse near an active lek is an essential technique for moving Sage-Grouse. Our sample was not randomly selected and there was no random assignment of treatment groups, therefore we cannot infer cause and effect or make inferences to other populations. We acknowledge that our R^2 values are quite low indicating potential influences not measured in our testing. We cannot discount the potential influences of weather, stress, predators, habitat, and individual hen behavior. However, within the Strawberry Valley population in 2006 there is valuable evidence that supports our hypothesis that releasing Sage-Grouse near an active lek will increase the likelihood of a successful translocation. Further testing of this hypothesis is needed, but we recommend that other Greater Sage-Grouse translocation projects employ the method of releasing grouse very near a lek where males are actively strutting.

LITERATURE CITED

Aldrich, J.W. 1963. Geographic orientation of American Tetraonidae. Journal of Wildlife Management. 27:529-545.

Aldridge, C.L. 2005. Identifying habitats for persistence of Greater Sage-Grouse (*Centrocercus urophasianus*) in Alberta, Canada (dissertation). Edmonton, Canada: University of Alberta. 250 p.

Aldridge, C.L., and R.M. Brigham. 2001. Nesting and reproductive activities of Greater Sage-Grouse in a declining northern fringe population. Condor 103:537-543.

Beck, J.L., and D.L. Mitchell. 1997. Brief guidelines for maintaining and enhancing sage grouse habitat on private lands in Utah. Utah technical notes: UT 190-1-3. U.S. Natural Resources Conservation Service, Salt Lake City, Utah.

Beck, J.L., D.L. Mitchell, and B.D. Maxfield. 2003. Changes in Distribution and status of sage-grouse in Utah. Western North American Naturalist 63(2):203-214.

Beck, J.L., K.P. Reese, J.W. Connelly, and M.B. Lucia. 2006. Movements and survival of juvenile Greater Sage-Grouse in Southeastern Idaho. Wildlife Society Bulletin 34(4):1070-1078.

Bihrle, C. 1993. Upland game identification: a basic guide for aging and sexing the bird in your hand. North Dakota Outdoors 56(3):9-23.

Braun, C. E. 1998. Sage grouse declines in western North America: what are the problems? Proceedings of the Western Association of State Fish and Wildlife Agencies 78:139–156.

Bunnell, K.D. 2000. Ecological factors limiting sage grouse recovery and expansion in Strawberry Valley, Utah. M.S. Thesis. Brigham Young University, Provo. UT.

Crawford, J.A., R.A. Olson, N.E. West, J.C. Mosley, M.A. Schroeder, T.D. Whitson, R.F. Miller, M.A. Gregg, and C.S. Boyd. 2004. Ecology and management of sage-grouse and sage-grouse habitat. Journal of Range Management 57:2-10.

Connelly, J.W., and C.E. Braun. 1997. Long-term changes in sage grouse (*Centrocercus urophasianus*) in western North America. Wildlife Biology 3/4:123-28.

Crunden C. W.1963. Age and sex of sage grouse from wings. Journal of Wildlife Management 27:846–850.

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

Griner, G.L. 1939. A study of sage grouse (*Centrocercus urophasianus*), with special reference to life history, habitat requirements, and numbers of distribution. Thesis, Utah State Agricultural College, Logan.

Johnsgard, P.A. 1973. Grouse and quails of North America. University of Nebraska Press, Lincoln. 553pp.

Musil, D.D., J.W. Connelly, and K.P. Reese. 1993. Movements, survival, and reproduction of sage grouse translocated into Central Idaho. Journal of Wildlife Management 57(1):85-91.

Reese, K. P., and J. W. Connelly. 1997. Translocations of Sage Grouse (Centrocercus urophasianus) in North America. Wildlife Biology 3: 235–241.

Schroeder, M.A. 1997. Unusually high reproductive effort by sage-grouse in a fragmented habitat in north-central Washington. Condor 99:933-941.

Table 1. The number of adults and juveniles as well as mean body mass (in grams) for 2006 translocated sage-grouse hens from PM, BEC, and DLL.

	Adults	Juveniles	Mean Body Mass (g)
PM	13	22	1193 (SD ± 243)
BEC	14	19	1271 (SD ± 266)
DLL	24	10	1540 (SD ± 122)

Figure 1. The percent total mortality for hens released before and after the lek was active in Spring 2006.

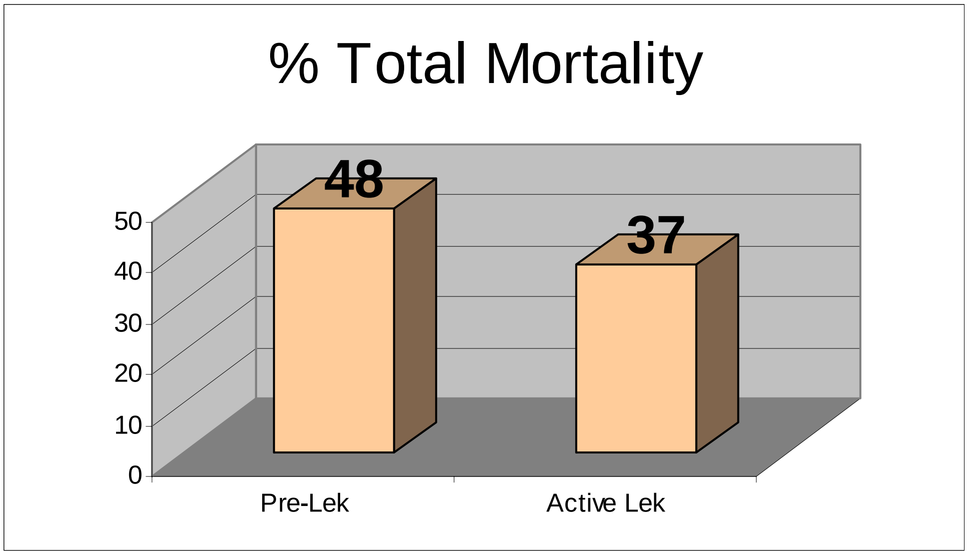


Figure 2. The percent of translocated sage-grouse flocked with residents for PM, BEC, and DLL by month over the summer of 2006.

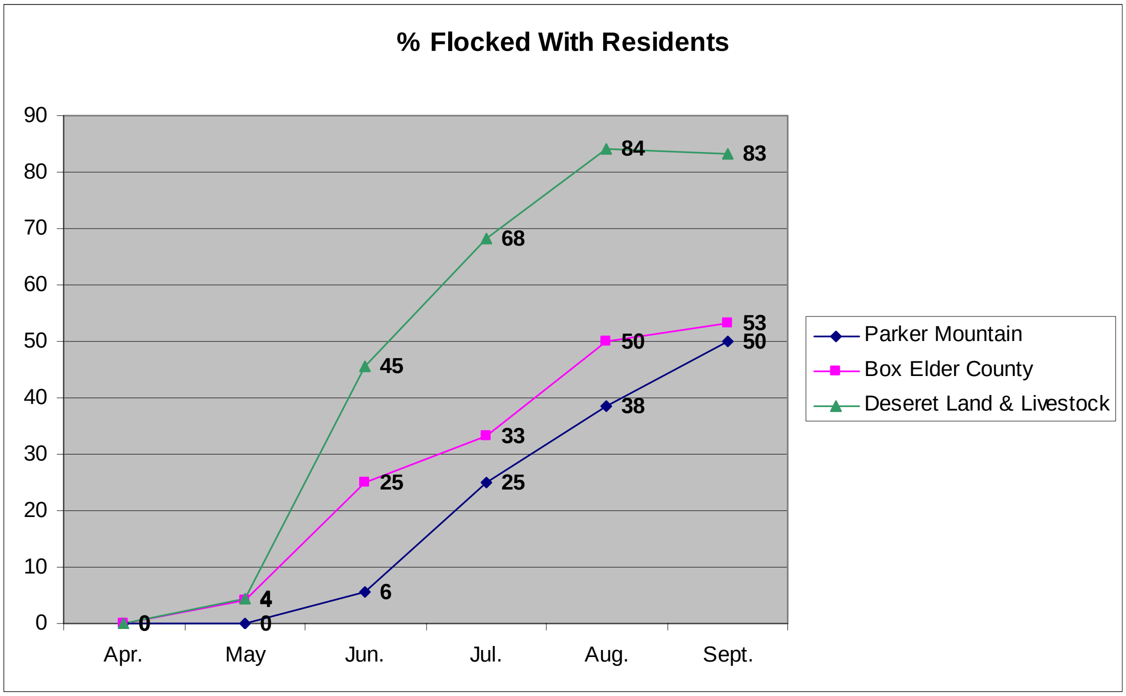


Figure 3. The percent of translocated sage-grouse flocked with residents throughout the summer of 2006 divided into hens released before and those released after lekking activity.

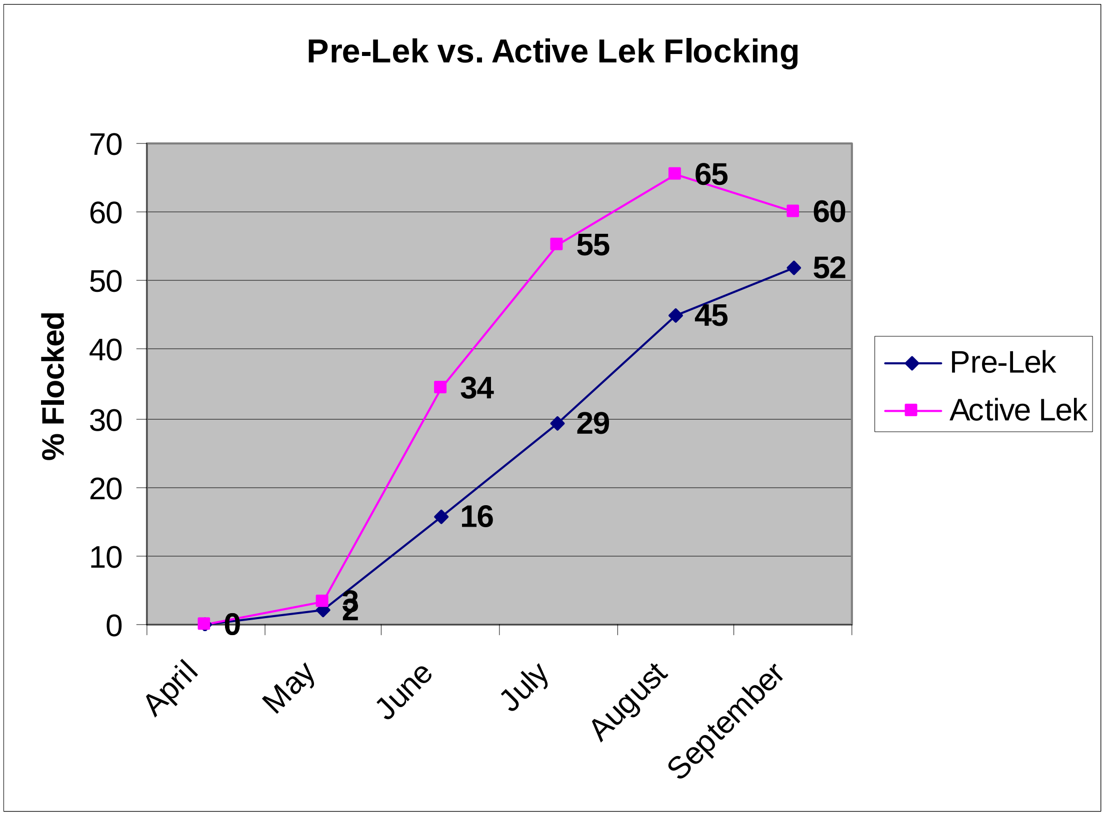


Figure 4. A comparison of mortality and flocking for hens released before lekking activity and those released during lekking activity in Strawberry Valley, Utah.