

**Demography, Vital Rates, Habitat-Use, and Seasonal Movements of Greater  
Sage-Grouse in the Raft River Subunit Management Area,  
West Box Elder County, Utah - Phase 2  
WRI Project ID 2192:**

**2013 Annual Report**



Prepared By:

Avery Cook, Brian Wing, and Terry A. Messmer  
Jack H. Berryman Institute, Utah State University, Logan, UT

September 2013

**Demography, Vital Rates, Habitat-Use, and Seasonal Movements of Greater  
Sage-Grouse in the Raft River Subunit Management Area,  
West Box Elder County, Utah - Phase 2  
WRI Project ID 2192:**

**2013 Annual Report**

Cooperators:

Utah Watershed Restoration Initiative (WRI)

Ruby Pipeline and El Paso Corporation

Utah Division of Wildlife Resources

US Bureau of Land Management

Box Elder County Coordinated Resources Management

Box Elder County Adaptive Resources Management Sage-grouse Local Working  
Group

Prepared By:

Avery Cook, Brian Wing, and Terry A. Messmer  
Jack H. Berryman Institute, Utah State University, Logan, UT

September 2013

## Table of Contents

Introduction .....	5
Study Purpose .....	5
Objectives .....	6
Study Area .....	6
Methods .....	7
Lek Surveys and Searches .....	7
Capture and Marking .....	7
Radio Telemetry .....	8
Nest Monitoring .....	8
Brood Monitoring .....	8
Vegetation Surveys .....	8
Pellet Surveys .....	9
Results .....	9
Lek Surveys .....	9
Captures .....	9
Vital Rates.....	9
Survival Estimates .....	10
Seasonal Movements .....	10
Pellet Surveys.....	11
Plan of Work .....	11
Acknowledgements.....	11
Tables and Figures .....	12
Literature Cited .....	19

## List of Tables and Figures

Table 1. Greater Sage-grouse Nest and Brood Success Estimates: Raft River Subunit, West Box Elder County, Utah. 2012-2013 .....	12
Table 2. Greater Sage-grouse Survival Rates Estimate: Raft River Subunit, West Box Elder County, Utah 2012-2013 .....	12
Table 3. Greater Sage-grouse Seasonal Movement Summary: Raft River Subunit, West Box Elder County, Utah. 2012-2013 .....	12
Figure 1. 2002 BARM Greater Sage-grouse Management Area and Subunits Relative to the 2013 Utah Box Elder Sage-grouse Management Area .....	13
Figure 2. Long Distance Movement of Greater Sage-grouse Out of the Raft River Subunit of the 2002 BARM Greater Sage-grouse Management Area.....	14
Figure 3. Lek Count Trends in the Raft River and Pilot Mountain Subunits in Relation to Precipitation from 1959-2013.....	15
Figure 4. Lek to Nest Distance: Raft River Subunit, West Box Elder County, Utah 2013 .....	15
Figure 5. Nest Initiation by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013 .....	16
Figure 6. Nest Success by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013 .....	16
Figure 7. Brood Success by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013 .....	17
Figure 8. Mortality Rate by Age and Month: Raft River Subunit, West Box Elder County, Utah 2012-2013 .....	17
Figure 9. Greater Sage-grouse Sign and Telemetry Locations Relative to Pinyon-Juniper Removal Projects in the Box Elder SGMA.....	18

## **Introduction:**

Populations of greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) have been declining range-wide for the last century (Connelly et al. 2004). The range of sage-grouse has declined from an estimated historical pre-settlement distribution of 1.2 million square km to 668,000 square km as of 2000 (Schroeder et al. 2004). These declines have been largely attributed to the deterioration, loss, and fragmentation of the sagebrush (*Artemisia* spp.) habitats upon which they depend (Connelly et al. 2011). In Utah, sage-grouse were estimated to occupy 41% of historic habitats, with the largest populations inhabiting sagebrush areas in Box Elder, Garfield, Rich, Uintah, and Wayne Counties (Beck et al. 2003).

In response to population declines and the potential for the species being designated for protection under the Endangered Species Act, the Utah Division of Wildlife Resources (UDWR) developed a strategic statewide management plan in 2002 (UDWR 2002, 2009). The West Box Elder Adaptive Resource Management Local Working Group (BARM) incorporated the conservation strategies published in the state plan to develop and implement a conservation plan to manage sage-grouse populations and habitats at the regional scale (BARM 2007). The BARM sage-grouse conservation plan identified threats to the species, knowledge gaps, and conservation actions they believed could reverse the decline of sage-grouse.

In April 2013, Governor Gary Herbert signed Utah's Conservation Plan for Greater Sage-Grouse ([http://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater\\_sage\\_grouse\\_plan.pdf](http://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater_sage_grouse_plan.pdf)). The Utah Plan is a scientific-based strategy that establishes goals and measurable objectives for sage-grouse in Utah, and identifies how Utah will manage their habitat and populations to meet these objectives. The BARM plan conservation strategies were incorporated in the Utah Plan and used to refine the Box Elder Sage-grouse Management Areas (SGMAs). The Box Elder SGMA is one of the 11 described in the Utah Plan. The Box Elder SGMA incorporates all occupied and potential sage-grouse habitats in Box Elder County (Figure 1).

## **Study Purpose:**

This research is being conducted to address the knowledge gaps identified in the BARM and Utah Plan. Specifically, this research will use the Bureau of Land Management (BLM) habitat assessment framework to quantify sage-grouse habitat quality and use at multiple scales (i.e., landscape, population, and individual habitat-use levels) for the populations inhabiting the Raft River and Pilot Mountain subunits of the UDWR Sage-grouse Box Elder Management Unit (Unit 1) (Johnson 1980, Stiver et al. 2010). The UDWR Management Unit 1 lies within the Sage-grouse Snake River Plain management zone/ Management Zone IV as outlined in Connelly et al. (2004) and the Utah Plan Box Elder SGMA. This assessment will investigate the relationship between land ownership patterns, historic and contemporary land uses, sage-grouse vital rates, and seasonal habitat-use patterns.

This research is being conducted collaboratively by two Utah State University MS level graduate students. The students are using the same group of marked sage-grouse to answer both distinct and shared research questions. Specifically, Avery Cook is researching landscape level effects of human land use, and effects of habitat treatments to determine which habitat treatments are most

effective for conserving the species. Avery will also investigate how fragmentation relates to ownership patterns and subsequent land use. Brian Wing will determine how the structure, composition, and nutritional quality of vegetation may affect sage-grouse habitat-use, vital rates, and seasonal movements.

To complete this work, vegetation characteristics will be compared between sage-grouse use and random sites to determine the habitat-use patterns and preferences in the study population and their relationship to structural or spatial habitat components. Overall, this research will assist land planners and government agencies on local and regional scales to identify land-use and management actions that will contribute to the long-term conservation of the sage-grouse meta-population in the Box Elder SGMA.

### **Objectives:**

1. To identify and map all leks and lek complexes in the designated study area.
2. To determine and compare sage-grouse vital rates in the Raft River and Pilot Mountain subunits to other areas of Utah and describe their relationship to habitat vegetation structure as affected by contemporary and historic land-uses.
3. To determine sage-grouse use of juniper removal projects areas in the subunits as a means of documenting the potential effects of SGMA habitat improvements on sage-grouse vital rates and habitat-use patterns.
4. To validate and refine Utah Plan occupied and potential sage-grouse habitat designations in the Raft River and Pilot Mountain subunits.
5. To determine if any relationship exists between the nutritional quality of sagebrush plants consumed and sage-grouse fitness.
6. To determine the extent of sage-grouse interseasonal movements and possible corridors between Nevada and Idaho populations.

### **Study Area:**

This study focuses on the Raft River and Pilot Mountain subunits of the West Box Elder Resource Area located in the north-west corner of Utah (Figure 1). The study area was based on the subunits of the Box Elder Management area outlined in the 2002 state plan, and resides within the Box Elder SGMA defined in the Utah Plan. Geographically, the core of the study area is bounded by the Raft River Mountains to the north, the Grouse Creek and Pilot Mountains to the west, by the Great Salt Lake to the east, and areas of salt flats to the south. The study area is primarily in the Northern Great Salt Lake Desert HUC 8 watershed (HUC #16020308), but also contains parts of the Curlew Valley HUC 8 watershed (HUC #16020309) on the eastern edge of the study area. Land ownership for the Pilot Mountain and Raft River subunits is a mix of public and private lands consisting of 51% private (676,483 ac, 273,764 ha), 37% BLM (483,035 ac, 195,478 ha), 6% School and Institutional Trust Lands Administration (SITLA) (76,099 ac, 30,796 ha), and 5% USFS (71,934 ac, 29,111 ha).

Vegetation composition and structure in the study area varies with elevation from salt desert scrub at low elevations, through various sagebrush communities, into juniper (*Juniperus spp.*)

and mahogany (*Cercocarpus ledifolius*) woodlands and coniferous forest at higher elevations. Elevation ranges from 4600-9800 ft. (1402-2987 m) above sea level.

Climate data for Park Valley, UT, from 1990 to 2012 shows annual precipitation averaged 8.9 in. (22.6 cm) in Park Valley (5000 ft. elevation), with 5.6 inches (14.2 cm) falling as snow between November and April. Temperatures range from a monthly average high of 86° F (30° C) in July to a monthly average low of 15° F (-9.4° C) in December and January (Western Regional Climate Center (WRCC) 2012). Snow does not typically persist through spring at lower elevations but can remain at high elevations over 8000 ft. (2438 m) into late summer. Greater levels of snowfall and colder temperatures exist at higher elevations. During the 2012 field season we had a dry winter and unusually early spring. The 2013 field season was preceded by a bitterly cold winter, also with below average precipitation, although there was an increase in summer moisture.

## **Methods:**

### *Lek Surveys and Searches*

We conducted aerial searches to look for new leks using a small single-engine fixed-wing aircraft. The surveys were conducted on clear, calm mornings with winds less than 15 mph (24 kph). Because of the difficulties in scheduling UDWR aircraft to conduct the searches, the Utah Community-Based Conservation Program (CBCP), Utah State University, contracted with Airmotive Service of Brigham City, Utah, for aircraft services to complete aerial surveys.

Lek searches were conducted from April 6<sup>th</sup> to April 19<sup>th</sup>, half an hour before to one hour after sunrise. Transects were flown at 300-450 ft. (91-137 m) above ground level as two observers and the pilot scanned the ground. Surveys began at the east edge of the survey area, working west to minimize the possibility of the plane flying over leks prior to them being observed.

Ground lek surveys were also conducted from March 1 to April 30 by single observers driving along roads in potential or known breeding habitat. The observers stopped every half mile or less to listen for sounds of lekking sage-grouse and to visually search using binoculars. Ground searches were conducted from an hour before to an hour after sunrise.

### *Capture and Marking*

Beginning in January of 2012, research teams captured and radio-collared sage-grouse using a spotlight and long handled net following protocols described by Connelly et al. (2003). Captured birds were fitted with a numbered leg band and a collar-type VHF radio transmitter, sexed, aged, weighed, and examined to determine general physical condition (Eng 1995). A contour feather, was collected from each bird for DNA analysis. Feathers were collected out of the capture net if they were lost or plucked from the breast below the air sacks if no feathers were lost during capture. All captured males that were not radio-collared were still equipped with a leg bands. The capture and capture location was recorded (UTM, 12N, NAD 83) and all birds were released on their capture site.

### *Radio Telemetry*

Following capture, all radio-collared sage-grouse were located using radio telemetry techniques to determine habitat use patterns, seasonal movements, nest success, brood success, and survival rates. Marked males were located biweekly from spring to late summer. Marked females were located two times each week during nesting and brood-rearing periods or weekly upon nest or brood failure. We attempted to locate any missing birds using a small fixed-wing aircraft fitted with radio telemetry equipment.

### *Nest Monitoring*

Sage-grouse nest initiations were determined when a hen was recorded using the same location on two consecutive visits during or following the breeding season. To mitigate nest abandonment, care was taken to not disturb nesting females. Nest locations were marked using a global positioning system (GPS) record and a discreet physical marker to aid researchers in returning to the located nest. Actively nesting females were observed carefully from a distance of 7 to 20 m at least two times weekly until the nest hatched or failed. A successful hatch was determined when egg halves were found intact in or near the nest bowl, and/or the inner membrane of the egg was separated from the shell (Wallestad and Pyrah 1974).

### *Brood Monitoring*

After hatching, females with broods were located twice weekly until they reached at least 50 days of age. Each brood was flushed and the number of chicks was recorded to determine brood success (Schroeder 1997). Due to the tall mixed mountain brush and big sagebrush vegetation communities in which broods were typically found in this study area, these flush counts were conducted in daylight to reduce the risk of missing birds that otherwise may not be visible using a spotlight count method. Radio telemetry was used to locate the adult hen, and the area of her flush was thoroughly searched using an outward spiral pattern until all chicks had flushed.

### *Vegetation Surveys*

Vegetation was measured at sage-grouse use and paired random sites. Use sites included nest locations, brood locations, and general habitat use areas. Random site locations were selected from 3 broad vegetation strata consisting of sagebrush, agriculture, and other. Random vegetation plots were selected from each strata using a generalized random-tessellation stratified sampling design (Stevens 2004). This method of random sample selection produces more spatially balanced samples and a reduction of clumping relative to simple random sampling. Each survey was conducted using four transects; the first directed toward a random bearing and the others at 90 degree increments radiating from a central point. Nest surveys consisted of 15 m transects, and all other surveys consisted of 10 m transects. Along each transect, a line-intercept method was used to evaluate ground cover density and height of shrub species (Canfield 1941). The height and species composition of forbs and grasses were evaluated along each transect using the Daubenmire frame technique (Daubenmire 1959). Five frames were placed on each nest survey transect at 3 m intervals, and four frames were placed at 2.5 m intervals on all other



surveys. Nest surveys also included measurements of the nest bush by species, height, length, width, and visual obstruction (Robel 1970).

### *Pellet Surveys*

Pinyon-juniper treatment sites were evaluated for habitat use using pellet surveys (Dahlgren et al. 2006). Fourteen treatment areas were evaluated by walking four, 600 m transects per treatment area. The number, type (roost, cecal), distance along and distance from the center line of the transect was recorded for each pellet or pellet group detected. Paired transects were also evaluated in adjacent untreated habitat.

## **Results:**

### *Lek Surveys*

During the spring of 2013, 80 leks were surveyed in West Box Elder County in cooperation with UDWR biologists for a total count of 559 males. The number of males counted in 2013 was higher than 2011 and 2012 with 237 and 531 respectively (Figure 3). In 2012 and 2013, we located eight previously unreported leks ranging in size from 3 to 39 males. These leks were located in the Raft River subunit. We did not find any leks in the Pilot Mountain subunit (Figure 1).

### *Captures*

In 2012 and 2013 we captured 14 hens and 49 males, and 54 hens and 6 males, respectively. To date, we have captured 123 sage-grouse, of which 68 were hens and 55 were males. In addition, 11 males were banded without radio collars.

Sage-grouse captured in the fall, winter, and early spring of 2012/2013 were found in flocks located by tracking previously radio marked birds. Most birds captured in the spring were located on or adjacent to known leks in the study site.

### *Vital Rates*

We are still analyzing 2012-2013 vital rate data. We however report apparent vital rates calculated with simple descriptive statistics. **These data should be considered preliminary and subject to revision.**

Of the 57 hens that were marked with radio collars, we were able to determine nesting status for 37. Six hens were not accessible due to private land access being denied, and the other 14 were inaccessible due to steep and snowy terrain or inability to locate them because of quick and distant movements. Ninety-two percent (n=34) of accessible hens initiated nests. The mean clutch size was 6.9 eggs. In 2013, 65% (n=22) of the nests successfully hatched, with 77% (n=17) producing successful broods with an average brood size of 3.8 chicks at 50 days of age. 2012 results were similar with 60% (n=6) of the nests successfully hatching; 50% (n=3)

producing successful broods with an average brood size of 2.3 chicks at 50 days of age (Table 1; Figures 5, 6, and 7).

Distances from lek of capture to nest locations varied quite a bit between individual hens. The shortest distance travelled was 0.1 km and the longest distance was 28 km. Most hens nested less than 15 km from capture leks and the average distance was 9.3 km (Table 3; Figure 4).

### *Survival Estimates*

The apparent survival rate was 57% with 70 of 123 birds collared surviving through mid August 2013. From 2012-2013, radio-collared males had a higher apparent mortality rate than hens with 61% (34 of the 55 males) mortality rate through the course of the study. Nineteen of 68 hens died, giving the hens an apparent survival rate of 72% over the study period (Table 2; Figure 8). We were not able to positively identify the cause of most mortalities.

We are currently completing data quality checks on vegetation data and importing into our database for analysis. Currently, summary statistics and analysis of preferred habitat is not available; however this population appears to show similar preferences as other populations in the literature, favoring taller stands of sagebrush for nesting cover and mesic areas within contiguous sagebrush habitat for late brood rearing and summer habitats.

### *Seasonal Movements*

Through the spring and summer, birds moved within and out of the study area, with a general trend of moving to the north and northwest toward higher elevations and more mesic areas. During the study from January of 2012 to August of 2013 we did not have any birds move south into the Pilot Mountain subunit.

Twelve radio marked birds moved north from the Park Valley, Warm Springs, and southern areas of the study site to the top of the Raft River Mountains, and remained to late summer. Two of the birds who moved to the top of the Raft Rivers did so with a brood in late June and early July. One male continued over the Raft Rivers to the northern foothills of the mountain. We also found three birds that traveled north past Lynn and settled at the Idaho border, as well as five others who left the state all together, ending up as far as 15 miles (24 km) into Idaho. These birds came from Dove Creek and Dry Basin with movements exceeding 41 miles (66 km) (Figure 2). The majority of birds leaving the study area were located via aerial telemetry. We had eight telemetry flights over the two years of the project ranging in duration from two to three hours over the study area, in which time we were able to locate from 42 (winter – not all lost birds) to 6 birds.

The mean distance travelled from lek of capture to summer range was 17.9 km, minimum distance was 1.9 km, and maximum distance was 58.2 km. The average seasonal movements varied very little between sexes and age classes. However, the greatest movements were made by females with a maximum of 58.2 km as compared to a maximum of 35.3 km for males (Table 3).

## *Pellet Surveys*

We are currently analyzing pellet count data. Our preliminary analysis suggests that sage-grouse have moved into the Pinyon-Juniper treatment areas. It appears the birds are using the areas within a few years of treatment when the treatments are adjacent to occupied habitats (Figure 9).

## **Plan of Work**

For the remainder of 2013 and into 2014, we will continue to monitor radio-marked birds to determine survival rates and seasonal movements. In particular, we will monitor winter range use patterns. In 2014, we will monitor nesting effort of existing radio-marked birds, capture new hens, and investigate the use of GPS collars on birds which engaged in long distance movements in 2013. The use of these collars will help us define movement corridors and important seasonal habitats in adjacent states.

All data collected during the 2012-2014 field seasons will be analyzed for inclusion in MS theses. The theses will be defended in the spring of 2014.

## **Acknowledgements**

This project was made possible by the support of landowners throughout the study area in addition to the following agencies and organizations:



**Table 1.** Greater Sage-grouse Nest and Brood Success Estimates: Raft River Subunit, West Box Elder County, Utah. 2012-2013

		Marked Hens	Accessible Marked Hens	Hens Nested	Re-nest Attempts	Mean Clutch Size	Nests Hatched	Successful Broods	Mean Brood Size
2012	Adult	10	9	8 (89%)	0	6.5	5	2 (40%)	2
	Juvenile	4	3	2 (67%)	0	7	1	1 (100%)	3
	Total	14	12	10 (83%)	0	6.6	6 (60%)	3 (50%)	2.3
2013	Adult	29	23	23 (100%)	0	7	14	12 (86%)	3.5
	Juvenile	27	14	11 (79%)	1	6.7	8	5 (63%)	4
	Total	57	37	34 (92%)	1	6.9	22 (65%)	17 (77%)	3.8

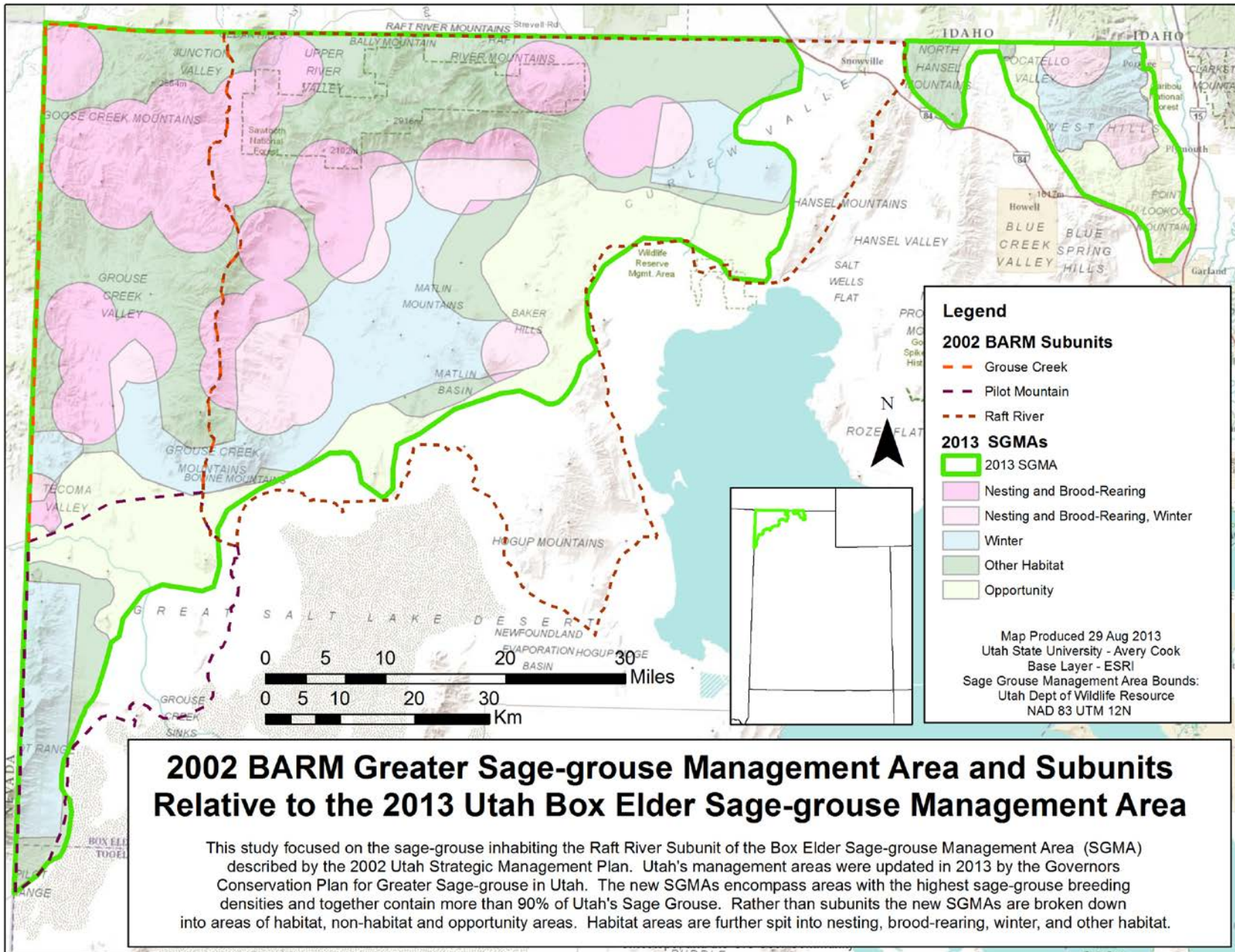
**Table 2.** Greater Sage-grouse Survival Rates Estimate: Raft River Subunit, West Box Elder County, Utah. 2012-2013

	Sage-Grouse Radio Marked	Total Mortalities	Percent Mortality
Adult Male	38	29	76.3
Adult Female	36	9	25.0
Juvenile Male	15	5	33.3
Juvenile Female	32	10	31.3
Total	123	53	43.1

**Table 3.** Greater Sage-grouse Seasonal Movement Summary: Raft River Subunit, West Box Elder County, Utah. 2012-2013

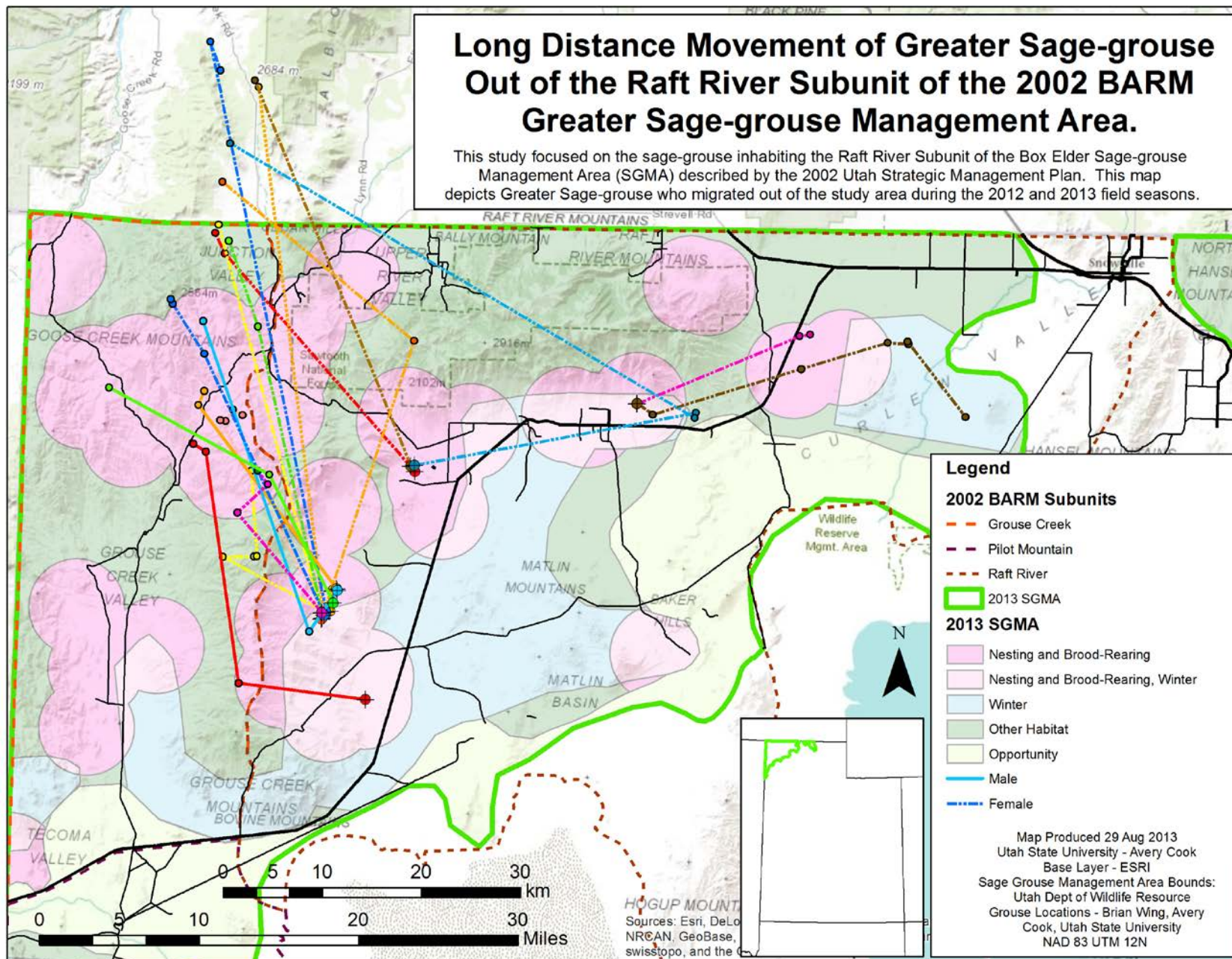
	Lek to Summer Range Movement					Lek to Nest Site Movement		
	All	Male	Female	Adult	Yearling	All	Adult	Yearling
Average Seasonal Movement (km)	17.9	18.4	17.6	17.7	18.4	9.3	8.6	10.4
Min Seasonal Movement (km)	1.9	1.9	1.9	1.9	2.9	0.1	0.3	0.1
Max Seasonal Movement (km)	58.2	35.3	58.2	58.2	38.6	28.1	27.9	28.1
Num Moving less than 10 km	30	10	20	22	8	27	27	9
Num Moving more than 10 km	90	43	47	57	33	13	7	6
Total Number	120	53	67	79	41	40	34	15

**Figure 1. 2002 BARM Greater Sage-grouse Management Area and Subunits Relative to the 2013 Utah Box Elder Sage-grouse Management Area.**

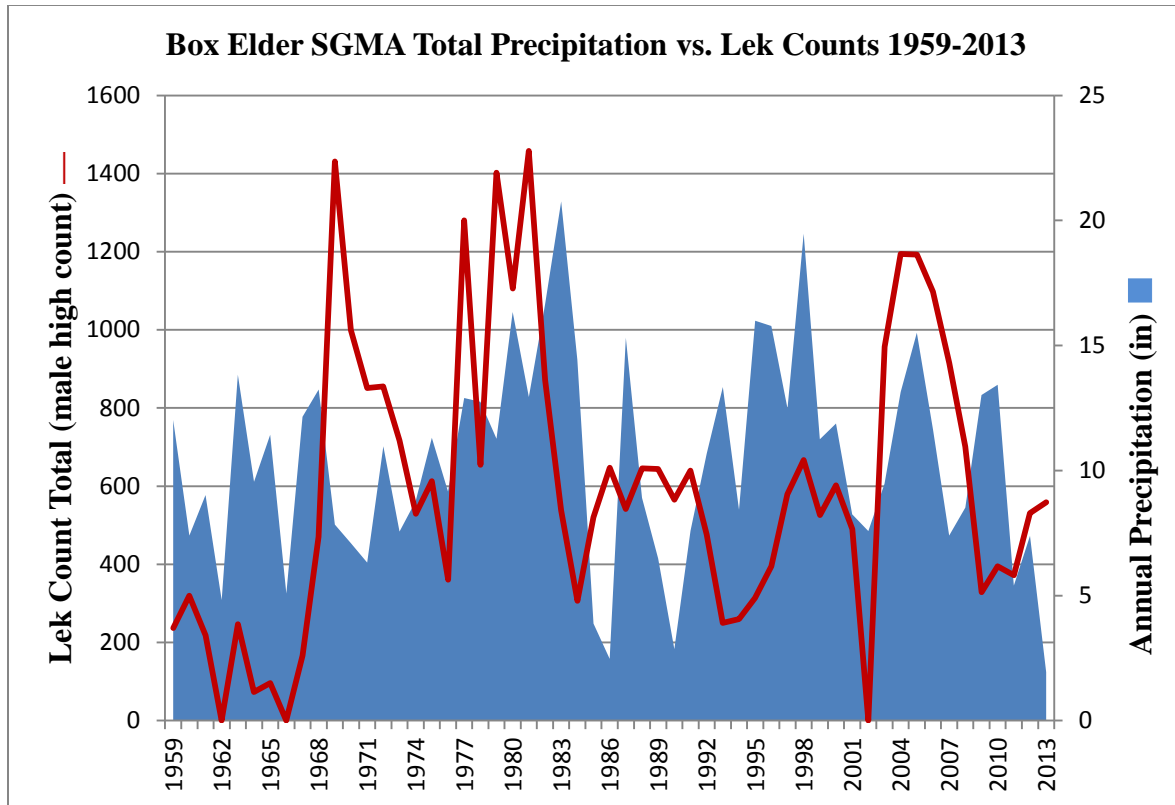




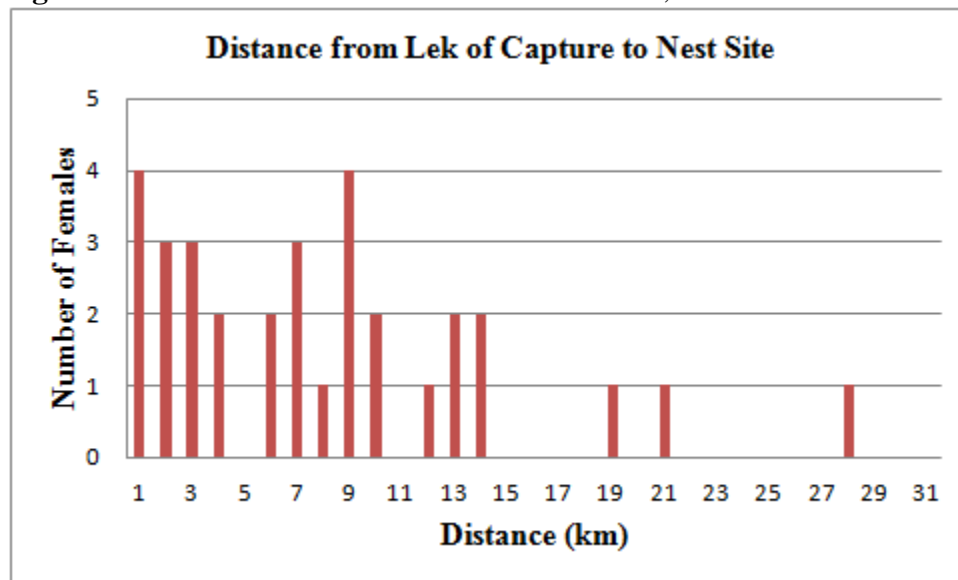
**Figure 2.** Long Distance Movement of Greater Sage-grouse Out of the Raft River Subunit of the 2002 BARM Greater Sage-grouse Management Area.



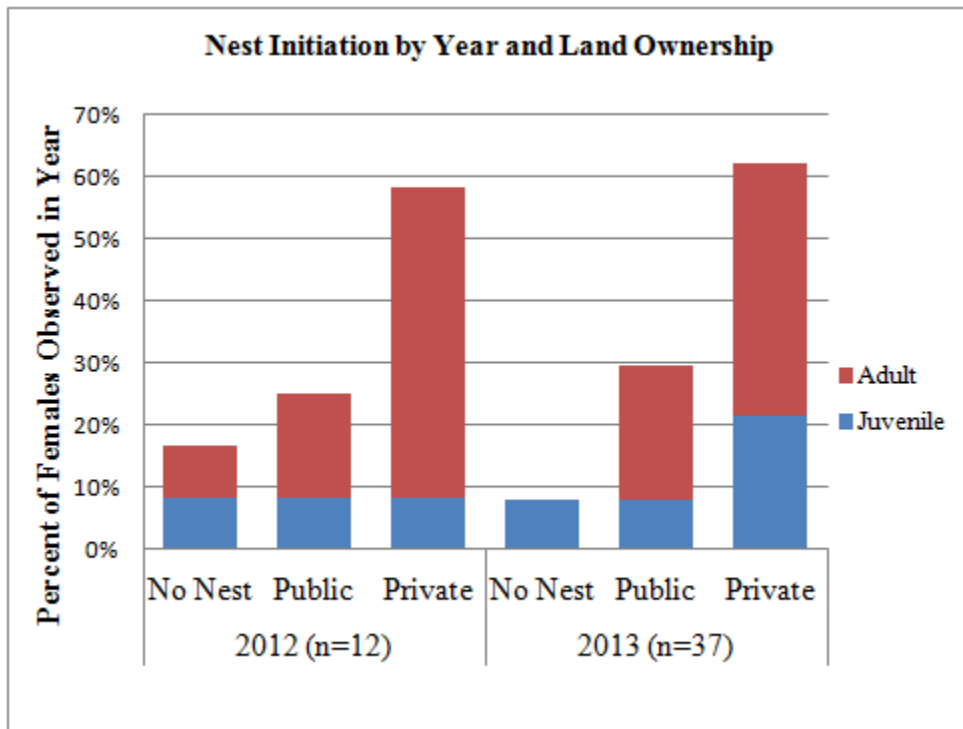
**Figure 3.** Lek Count Trends in the Raft River and Pilot Mountain Subunits in Relation to Precipitation from 1959-2013.



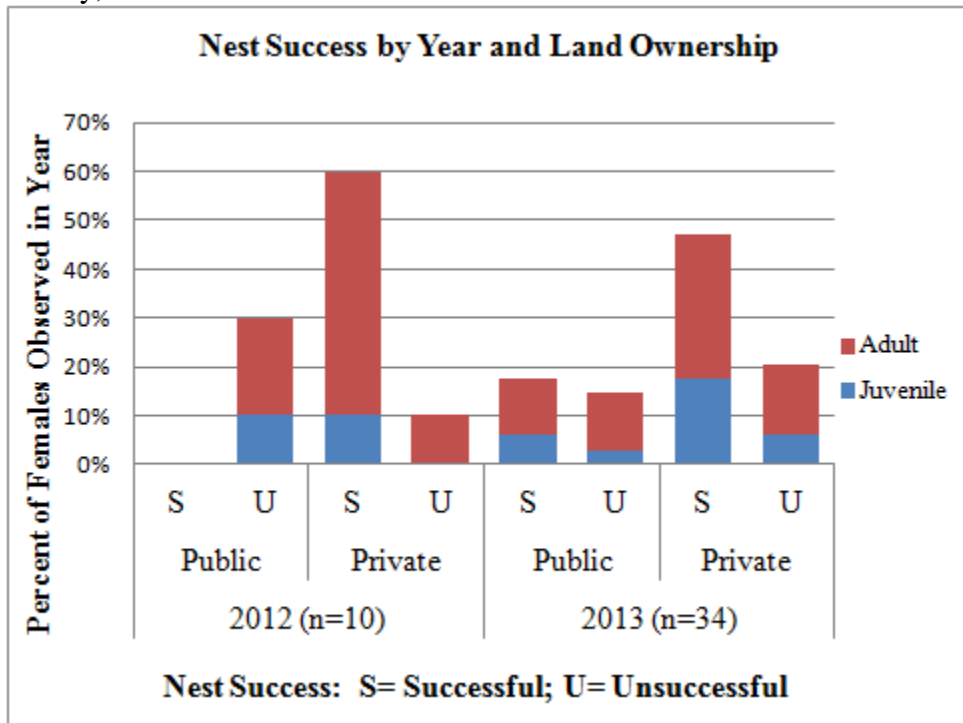
**Figure 4.** Lek to Nest Distance: Raft River Subunit, West Box Elder County, Utah 2013



**Figure 5.** Nest Initiation by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013

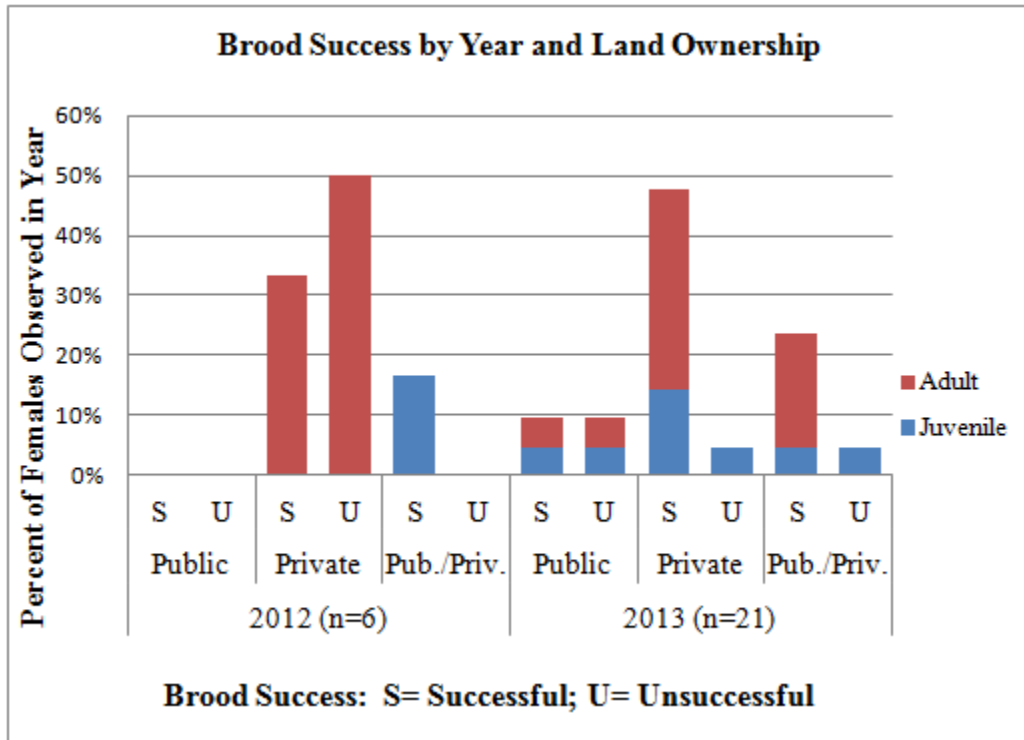


**Figure 6.** Nest Success by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013

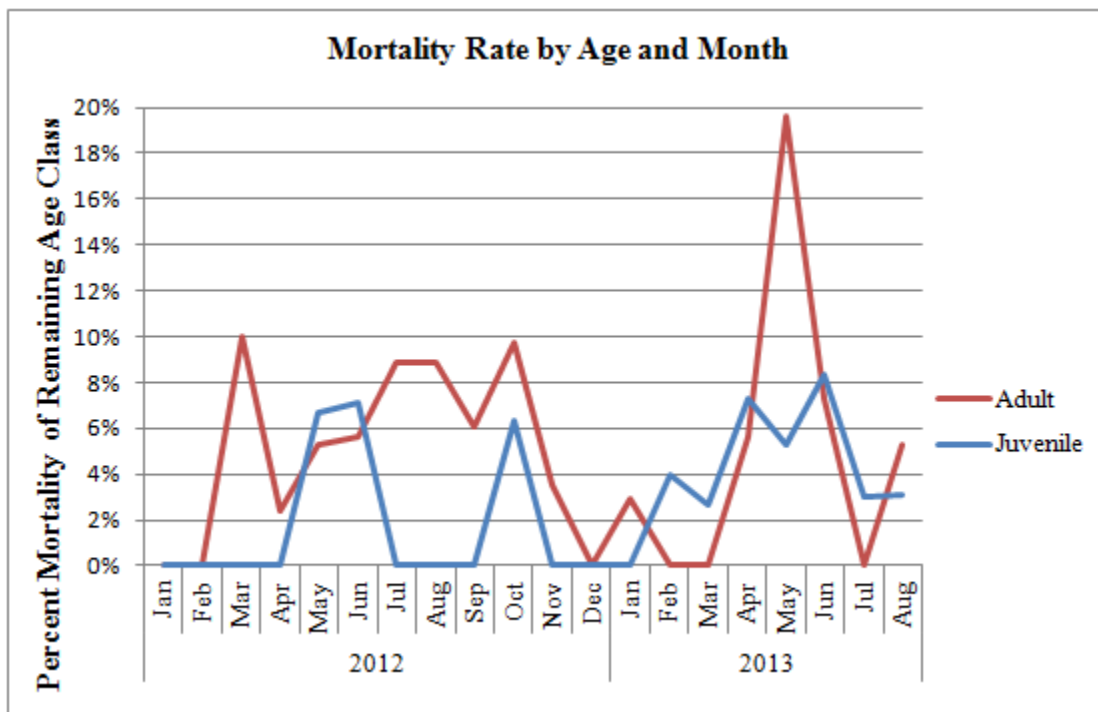




**Figure 7.** Brood Success by Year and Land Ownership: Raft River Subunit, West Box Elder County, Utah 2012-2013



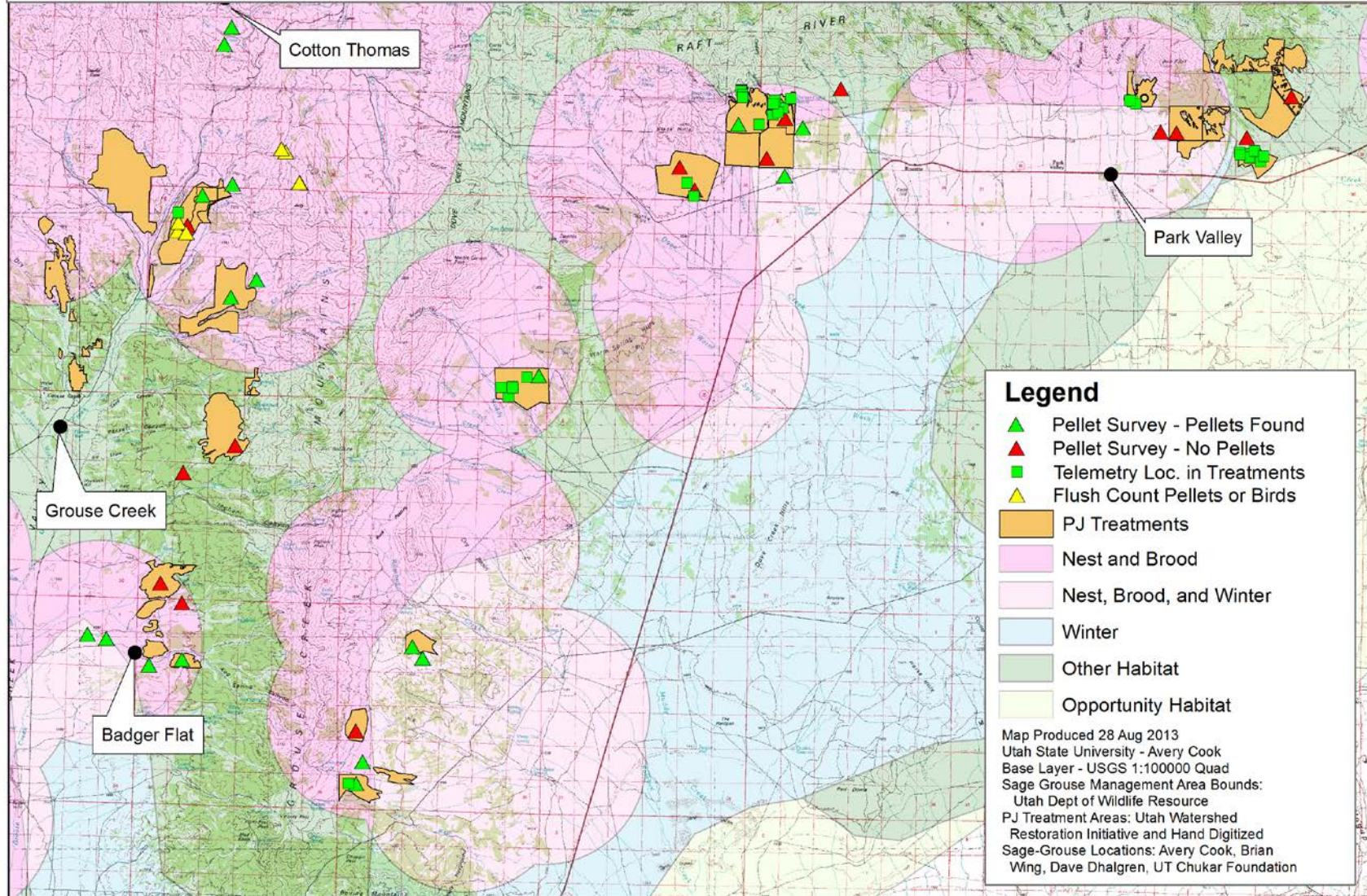
**Figure 8.** Mortality Rate by Age and Month: Raft River Subunit, West Box Elder County, Utah 2012-2013



**Figure 9.** Greater Sage-grouse Sign and Telemetry Locations Relative to Pinyon-Juniper Removal Projects in the Box Elder SGMA

## Greater Sage-grouse Sign and Telemetry Locations Relative to Pinyon-Juniper Removal Projects in the Box Elder SGMA

A Component of Utah State University's 2013 Research in the Box Elder SGMA  
 Avery Cook, Dave Dhalgren, and Terry Messmer



## Literature Cited:

- Beck, J.L., D.L. Mitchell, and B.D. Maxfield. 2003. Changes in the distribution and status of sage-grouse in Utah. *Western North American Naturalist* 63:203-214.
- Canfield, R.H. 1941. Application of the line interception method in sampling range vegetation. *Journal of Forestry* 39:388-394.
- Connelly, J.W., C.A. Hagen, and M.A. Schroeder. 2011. Characteristics and dynamics of greater sage-grouse populations. In *Greater Sage-Grouse: ecology and conservation of a landscape species and its habitats*. Studies in Avian Biology. University of California Press, Berkeley, California. pp. 53–67.
- Connelly, J.W., S.T. Knick, M.A. Schroeder, and S.J. Stiver. 2004. Conservation assessment of greater sage-grouse and sagebrush habitats. Western Association of Fish and Wildlife Agencies. Unpublished Report. Cheyenne, Wyoming.
- Connelly, J.W., K.P. Reese, and M.A. Schroeder. 2003. Monitoring of greater sage-grouse habitats and populations. Station Bulletin 80. University of Idaho College of Natural Resources Experiment Station, Moscow, Idaho.
- Dahlgren, D.K., R. Chi, and T.A. Messmer. 2006. Greater sage-grouse response to sagebrush management in Utah. *Wildlife Society Bulletin* 34:975–985.
- Daubenmire, R.F. 1959. A canopy-coverage method of vegetation analysis. *Northwest Science* 33:43-64.
- Eng, R.L. 1955. A method for obtaining sage grouse age and sex ratios from wings. *Journal of Wildlife Management* 19:267-272.
- Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. *Ecology* 61:65-71.
- 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.
- Schroeder, M.A. 1997. Unusually high reproductive effort by sage grouse in a fragmented habitat in north-central Washington. *The Condor* 99:933-941.
- Stevens, Jr., D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262–278.
- Stiver, S.J., E.T. Rinkes, and D.E. Naugle. 2010. Sage-grouse habitat assessment framework. Unpublished Report. U.S. Bureau of Land Management, Idaho State Office, Boise, Idaho.

Utah Governors Office. 2013, Conservation Plan for Greater Sage-grouse in Utah. <[http://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater\\_sage\\_grouse\\_plan.pdf](http://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater_sage_grouse_plan.pdf)>. Accessed 29 August 2013.

Utah Division of Wildlife Resources. Strategic Management Plan for Sage-Grouse. 2002. Publication 02-20.

Utah Division of Wildlife Resources. Utah Greater Sage-Grouse Management Plan. 2009. Publication 09-17.

Wallestad, R.O. and B.D. Pyrah. 1974. Movement and nesting of sage grouse females in central Montana. *Journal of Wildlife Management* 38:630-633.

WRCC (Western Regional Climate Center), 2012. ROSETTE, UTAH - Climate Summary. <<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?ut7408>>. Accessed July 5, 2012.