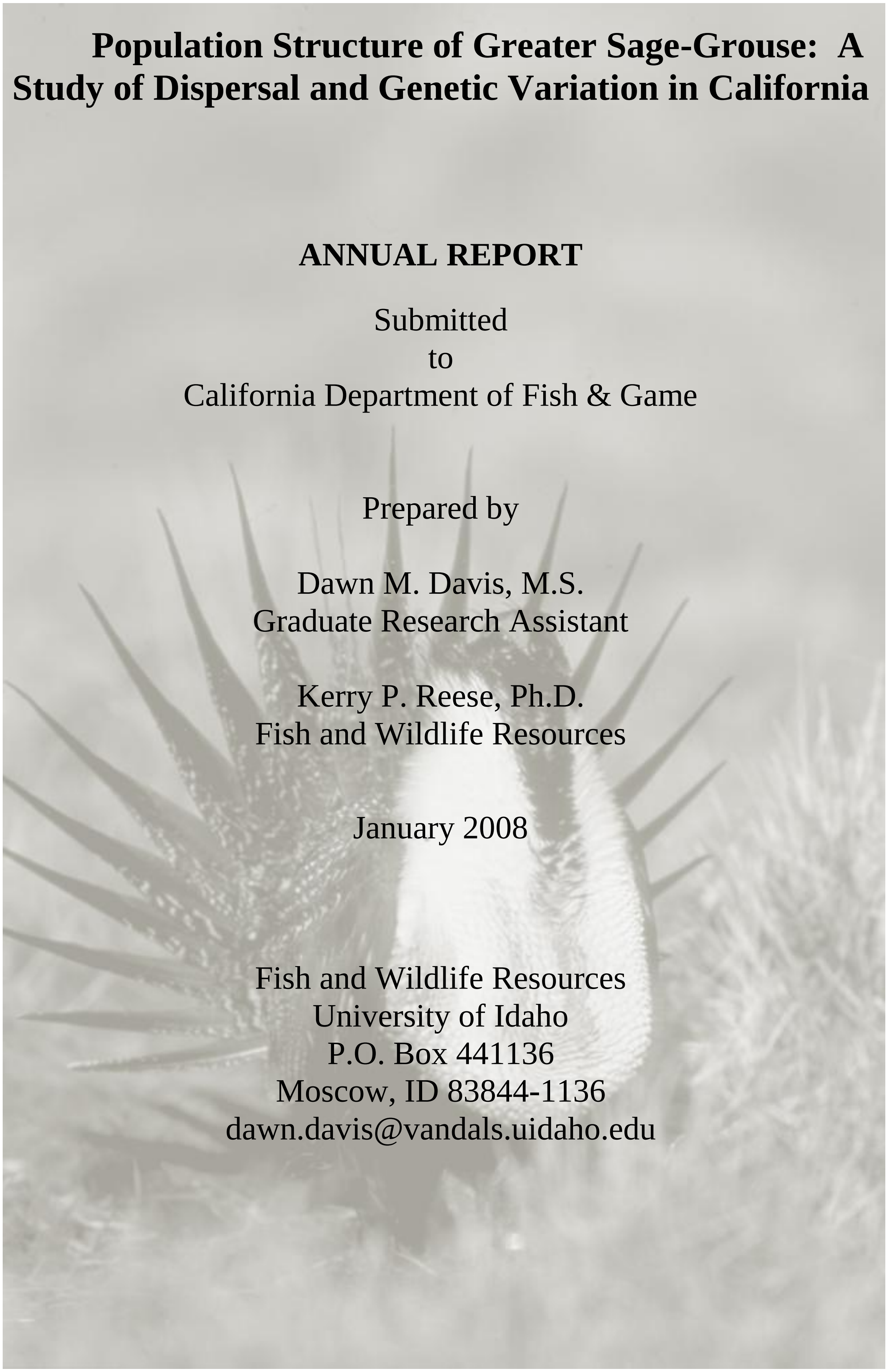

Population Structure of Greater Sage-Grouse: A Study of Dispersal and Genetic Variation in California

ANNUAL REPORT

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INTRODUCTION

Historically, the range of greater sage-grouse (*Centrocercus urophasianus*; hereafter sage-grouse) closely paralleled the distribution of sagebrush-steppe ecosystems (Beetle 1960, Autenrieth 1981); however, populations have declined throughout much of their range (Connelly and Braun 1997, Braun 1998). Alteration of sage-grouse habitats by expanding agriculture and urban development, sagebrush (*Artemisia* spp.) control programs, over-utilization of rangelands by domestic livestock, altered fire regimes, and prolonged drought throughout the sagebrush steppe in the 1930s and again in the late 1980s and early 1990s have been attributed to the decline in sage-grouse numbers (Crawford et al. 2004).

In California, two sage-grouse populations occupy the western periphery of the species' range: Lassen and Modoc counties in northeastern California and a genetically unique and relatively isolated population (Benedict et al. 2003) in Mono and Inyo counties to the south. Although little published information is available on California's sage-grouse population trends, sage-grouse appear to have lost a significant portion of their range in northern California over the past 35 years (Connelly et al. 2004, Schroeder et al. 2004, Hall et al. 2005), particularly in the most northern portion of the species' range in Modoc County. Invasion of western juniper (*Juniperus occidentalis*) and exotic annual grasses (cheatgrass [*Bromus tectorum*], medusahead rye [*Taeniatherum caput-medusa*]) have resulted in loss and degradation of sagebrush habitats and are considered the primary reason for the decline in sage-grouse populations in northeastern California (S. C. Gardner, personal communication).

Continued habitat loss and fragmentation may result in small, isolated sage-grouse populations at risk of losing genetic variation. Genetic diversity is necessary for a population to respond to environmental change, thus loss of genetic variation may jeopardize the persistence of fragmented sage-grouse populations (Shaffer 1981). Recent genetic work on sage-grouse populations has demonstrated that birds in Mono and Inyo counties are genetically unique, suggesting that they have no interchange with other sage-grouse populations and that they likely have been isolated for thousands of years (Benedict et al. 2003, Oyler-McCance et al. 2005). Additional genetic analyses of northern sage-grouse populations would allow us to evaluate the degree (if any) to which sage-grouse populations in California have experienced a loss of genetic diversity.

The long-term viability of sage-grouse populations also depends on the effects of landscape level habitat stability on dispersal rates and distances (Dale 2001). Grouse populations are particularly vulnerable to fragmentation of native rangelands (Woodward et al. 2001, Fuhlendorf et al. 2002, Schroeder and Robb 2003) and the ability of sage-grouse to move among suitable patches of habitat depends not only on the juxtaposition of such patches but also on the dispersal behavior of the species (Fahrig and Merriam 1994). Data on natal dispersal distances are important for understanding the genetic structure of populations, population regulation, and the effects of habitat fragmentation on metapopulation dynamics (Caizergues and Ellison 2002). Research that has been conducted on sage-grouse populations threatened by habitat fragmentation have traditionally reported on habitat use, breeding success, and survival (Homer et al. 1993, Schroeder 1997); however, few studies (e.g., Shepherd 2006) have documented the relationship between seasonal movement patterns and changes in landscape structure and little is known about the genetic effects of habitat fragmentation on sage-grouse populations.

Populations that have undergone large decreases in population size, such as sage-grouse in California, are likely to lose genetic variation (Nei et al. 1975, Maruyama and Fuerst 1985). Although no deleterious effects to demographic rates have been documented in California sage-grouse populations (CDFG, unpublished data), a loss in genetic diversity may be associated with inbreeding and a reduction in reproductive fitness (Bouzat et al. 1998a, b; Johnson et al. 2003, Johnson et al. 2004). Resistance to disease and the ability of populations to respond to stochastic events may also decrease with the loss of genetic variation (Lacy 1997). Thus, loss of genetic variation may negatively impact the long-term viability of sage-grouse populations in California.

Knowledge of natal dispersal is critical for understanding how sage-grouse populations expand and how this process can be augmented by relocation and re-introduction of sage-grouse into unoccupied habitats. In addition, statistical analysis of mitochondrial DNA (mtDNA) and microsatellite loci will provide measures of genetic variation within sage-grouse populations in northeastern California. Measures of genetic variation would permit evaluation of the degree to which sparse and scattered populations in northeastern California have experienced a loss of genetic diversity through processes such as genetic drift or inbreeding depression. Further, assessing the genetic variation of sage-grouse populations will assist managers in evaluating whether translocating birds from populations within California or supplementing California populations with birds from populations with higher genetic variability outside California (genetic introgression) is necessary. This may have practical management implications when making recommendations for conservation efforts, particularly when assessing landscape-level habitat change and its effects on sage-grouse population dynamics. Thus, the goal of this study is to develop a landscape-level, habitat-based approach to assess sage-grouse viability in northeastern California. Specifically, the objectives of this study are to:

1. Determine the productivity and survival of sage-grouse populations in northeastern California;
2. Investigate the natal dispersal patterns of sage-grouse among different subpopulations within the Lassen County study area;
3. Assess the sex-specific movement patterns of juvenile sage-grouse during natal dispersal including timing of brood break-up, directional preferences, seasonal habitat use, frequency of inter-lek movements, and factors influencing timings of these behaviors;
4. Predict how habitat loss and fragmentation affect dispersal;
5. Describe the molecular variance of sage-grouse populations within northeastern California;
6. Assess the degree of genotypic similarity between lek complexes; i.e., determine whether there is gene flow between subpopulations within the Lassen County study area; and
7. Link population viability analysis and information on sage-grouse habitat requirements to develop measures of habitat quality and quantity as a relative index to population size.

STUDY AREA

The Lassen County study area extends from Shaffer Mountain, in the south, to Dodge Springs, in the north, to the Madeline Plains in the west, to the Nevada border in the east (Figure 1). The size of the study area, defined by available sage-grouse habitat, comprises about 466,703 ha (S. C. Gardner, personal communication). The predominant sagebrush types include Wyoming big sagebrush (*A. tridentata wyomingensis*), mountain big sagebrush (*A. t. vaseyana*), and low sagebrush (*A. arbuscula*).

Lek Complexes

<u>Upper Smoke Creek/Hall Springs:</u> One of the largest lek complexes in Lassen County is found in the Upper Smoke Creek area on the Shinn Ranch, which is privately-owned. This area also contains significant wet meadows that are used by sage-grouse for brood-rearing, including Painter's Flat and Spanish Springs. Another large lek complex is found nearby to the west at Hall Springs. Both of these areas, located close to the Nevada border, contain a significant percentage of the breeding population of sage-grouse in Lassen County, and knowledge of movements and seasonal ranges of sage-grouse is lacking (S. C. Gardner, personal communication). Upper Smoke Creek and Hall Springs are the highest priority monitoring area for Lassen County (S. C. Gardner, personal communication).

<u>Dodge Springs:</u> The area around Dodge Springs, to the north of the Upper Smoke Creek area, contains a lek complex on the periphery of the Lassen County sage-grouse population, where populations have declined in recent years (S. C. Gardner, personal communication). Western juniper has encroached in recent years, particularly in the Dill Field area. Knowledge of the movements, survival, and productivity of sage-grouse in

this area is lacking and considered a high priority to help prevent further range contraction in Lassen County (S. C. Gardner, personal communication). Relatively low numbers of sage-grouse in the area will limit sample sizes.

Madeline Plains: The Madeline Plains lek complex is on the western edge of the Lassen County population and has declined significantly in the past 30 years (S. C. Gardner, personal communication). Little is known about movements and demographic rates of sage-grouse in this area, where habitat conditions are declining.

Shaffer Mountain/Chalk Bluff: Sage-grouse were previously studied in this area by Popham and Gutierrez (2003). This area contains one of the larger breeding concentrations of sage-grouse in Lassen County. Populations have remained relatively stable for the past 20 years (CDFG, unpublished data). Movements and demographic rates of sage-grouse are best known in this area of Lassen County. Additional birds will be marked in this area to better understand connectivity to surrounding breeding concentrations.

METHODS

Capture and Handling – We trapped sage-grouse opportunistically on or near spring lek sites using spotlighting techniques (Giesen et al. 1982, Wakkinen et al. 1992) and following established California Department of Fish and Game (CDFG) protocol for trapping, handling, and marking of greater sage-grouse (CDFG 2003). We classified gender and age of captured birds by plumage characteristics and wing molt (Crunden 1963, Dalke et al. 1963). Birds were affixed with a serially-numbered aluminum leg band and were fitted with a ≤ 20-g necklace configuration radio collar (Connelly et al. 2003). We recorded mass and unflattened wing chord for all birds upon capture.

Tissue Collection – Blood samples for genetic analyses were collected from 4 lek complexes (Upper Smoke Creek/Hall Springs, Dodge Springs, Madeline Plains, Shaffer Mountain/Chalk Bluff) within the Lassen County study area (Figure 1). A genetic sample was acquired by collecting approximately 3 drops of blood from a slightly over-clipped hallux nail and was stored in Queen's lysis buffer (Seutin et al. 1991) or a microfuge tube previously coated with EDTA (Oyler-McCance et al. 1999). Where possible, approximately equal proportions of males and females were sampled in each lek complex.

Demographic Variables – We assessed demographic variables (e.g., nest initiation rate, apparent nest success, clutch size, renesting rate, brood success, and survival) from locations of radio-collared females. Females were monitored 1-3 times per week with a hand-held antenna and portable receiver throughout the breeding season to determine nesting chronology and ascertain habitats used for nesting. Positions of radio-collared females were determined by circling the estimated location of the female, indicated by the loudest signal strength (Springer 1979). When monitoring revealed a female had initiated a nest (i.e., 2-3 locations near the same spot), the female was approached until observed on the nest and the nest location was marked with a Global Positioning System (GPS) unit and recorded in Universal Transverse Mercator (UTM) coordinates. Nesting females were monitored remotely (> 60 m) to avoid disturbance (Holloran and Anderson 2005). Once monitoring revealed a female had moved away from the nest and incubation had likely ceased, we examined the nest to ascertain fate. We classified nests as successful if $\geq$ 1 egg hatched. Depredated nests were distinguished from successful nests by the presence of a firmly attached shell membrane in broken eggs (Wallestad and Pyrah 1974).

Date of first day of nest incubation was estimated as the midpoint between consecutive observations (Schroeder 1997). Nest initiation rates were defined as the number of radio-collared females that initiated nests divided by the total number of radio-collared females alive at the onset of the nesting season. Apparent nest success was calculated by dividing the number of successful nests by the total number of nesting females. Clutch size was assessed for successful nests after hatching by examination of the eggshell fragments. Females were considered successful if ≥ 1 chick was recruited into the fall population (≥ 60 days). Brood success was obtained by dividing the number of females that recruited ≥ 1 chick to independence (≥ 60 days) divided by the total number of successful nests.

Chick Capture and Monitoring – Chicks were captured 1-2 days after hatch and marked with an 11 x 2 mm, 0.078 g subcutaneous passive integrated transponder (PIT) tag inserted mid-dorsally just above the wings via a 16-gauge syringe (Carver et al. 1999). We collected genetic samples (through removal of a growing secondary feather) from each chick to determine the gender of each bird. We recaptured broods at 31-64 days of age and fitted each chick with a 3.9 g radio transmitter sutured along the dorsal midline between the chick's wings (Burkepile et al. 2002). At ≥ 90-days post-hatch chicks were re-captured and fitted with a serially numbered aluminum leg band and 18-gram necklace style transmitter. Broods were monitored every 1-3 days until a breakdown in brood integrity or if the brood was lost. Brood locations were determined by locating the radio-marked female and circling within 25 m to avoid disturbance. Juveniles (≥ 90-days post-hatch) were monitored once per week to record seasonal movements related to fall migration. We did not monitor sage-grouse in November. Birds were monitored aerially in December. UTM coordinates were recorded for all locations with a GPS unit.

Home Range Analysis – We calculated home ranges for all females with sample sizes $\geq$ 20 locations and males with sample sizes $\geq$ 10 locations using the fixed kernel method with the least squares cross-validation smoothing parameter (LSCV). Seasons were defined as spring (Mar-May), summer (June-Aug), and fall (Sept-Oct) following Leonard et al. (2000). We calculated distance from the lek of capture to initial nest sites for all nesting females. The central tendency in locations (e.g., mean center) for each individual was computed using CrimeStat III (2004) to examine the spatial distribution of seasonal locations. The linear distance (km) sage-grouse moved was assessed by calculating the straight line distance from the lek of capture to mean center of the spring seasonal ranges. In addition, we computed linear distances sage-grouse moved between both spring and summer and summer and fall ranges, respectively, from UTM coordinates calculated for each seasonal range mean center. Composite home ranges of all marked birds within the study area were used to delineate the study area boundary and estimate seasonal ranges (spring, summer, fall) using a 100% minimum convex polygon. Home range estimates were mapped using the Animal Movement Analysis extension (Hooge and Eichenlaub 2000) in ArcView 3.2a (Environmental Systems Research Institute, Inc., Redlands, CA, USA).

Survival Analysis – Seasonal (Mar-Oct) survival of females and males, and brood survival to 25 weeks, were estimated using Kaplan-Meier survival rates (Kaplan and Meier 1958) modified for staggered entry (Pollock et al. 1999). We estimated apparent brood survival using spotlighting techniques (B. L. Walker pers. comm.) at 28-, 60-, and 90-days post-hatch, respectively. Probable causes of mortality were classified as predation, legal harvest, other anthropogenic-related factors, or unknown.

Habitat Characteristics – Stand characteristics were described at selected radio-locations to assess seasonal habitat use during nesting and brood-rearing. Habitat sampling at nest sites was performed after hatching for successful nests and after the predicted hatch date for depredated or abandoned nests. Because of logistical constraints, not all brood locations marked were sampled. We measured vegetative attributes at nest sites and brood locations along two, 10-m perpendicular transects intersecting at the nest bowl or center of use. Species composition and percent cover of grasses, forbs, bare ground, and litter were estimated at five, 50- x 50-cm quadrat frames spaced equidistantly along each transect (Daubenmire 1959). Shrub canopy cover was quantified using the line intercept method (Canfield 1941). Vegetative attributes at paired random points within 500 m of each nest site or brood location were sampled using the techniques just described. Random points within 100 m of nests and brood locations were excluded to reduce the potential of dependence among samples.

RESULTS AND DISCUSSION

Capture and Demographic Parameters – We captured greater sage-grouse opportunistically on or near leks sites using spotlighting techniques from 16 March – 19 April 2007. Twenty-seven females and 16 males were captured and fitted with serially-numbered, aluminum leg bands and ≤ 20 g necklace-mounted ATS radio transmitters at 12 lek locations within the Lassen County study area (Table 1). The age ratio by gender was: 13 adult female:14 yearling female; 13 adult male:3 yearling male. In addition, 6 adult males and 4 yearling males were fitted with leg bands. Blood samples for genetic analysis were acquired from all birds captured (n = 53).

Table 1. Lek complex, lek site, age, and gender of sage-grouse trapped in Lassen County, California, 2007.

Lek complex	Adult female	Yearling female	Adult male	Yearling male
Shaffer Mtn./Chalk Bluff	--	--	--	--
Little Black Mtn.	--	1	--	--
Shaffer Mtn.	2	2	2	--
Chalk Bluff	2	3	1	1
Gilman Springs	1	--	2	--
Skedaddle	2	--	--	--
Upper Smoke Creek/Hall Springs	--	--	--	--
Spanish Springs	1	3	1	1
Rush Creek	1	--	--	--
Hall Springs	--	2	2	--
Shinn Ranch	1	2	1	--
Madeline Plains	--	--	--	--
Grasshopper	1	--	--	--
Madeline	1	1	4	1
Dodge Springs	--	--	--	--
Dill Field	1	--	--	--
Totals	**13**	**14**	**13**	**3**

We initiated re-locations of radio-marked sage-grouse in mid-late April. Nest initiation rate was 61% (14/23); this sample does not include 1 female killed before the onset of the breeding season and 3 females that disappeared due to a damaged radio transmitter and/or undetected movement outside the study area, which precluded our ability to detect and monitor the female. Gibson and Bachman (1992) found that females localize to within 500 m of their nest site approximately 4 days after mating and began incubation as early as 20 days later. Thus, some nesting attempts in our study may not have been detected because monitoring of radio-marked sage-grouse was initiated > 20 days after capture. Average date of initiation for nest incubation was 13 April 2007 (range = 25 March – 1 May; *n* = 12). Overall apparent nest success was 57% (8/14). The locations of 3 nests were unknown; 1 hen had a brood patch at the time of capture and was assumed to have initiated a nest and we observed 2 females in June with a brood. Clutch size varied from 5 to 8 eggs for successful nests (*n* = 6). Renesting rate was 20% (1/5) and renest success was 0% (0/1); 1 female killed on its initial nest was not included in calculations of renest initiation. The renesting female moved 1.8 km to renest and established the second nest within 15 days of the loss of her first nest. Four females (50%) were known to recruit ≥ 1 chick to independence (i.e., chick(s) surviving ≥ 60 days post-hatch).

Diagnostic sign at depredated nests was unreliable for indentifying nest predators of sage-grouse. However, potential nest predators (Schroeder and Baydack 2001) observed on the study area included ground squirrels (*Spermophilus* spp.), badgers (*Taxidea taxus*), coyotes (*Canis latrans*), bobcats (*Felis rufus*), and common ravens (*Corvus corax*).

<u>Chick Capture and Monitoring</u> – We captured 29 chicks from 6 broods, 1-5 days after hatch and marked each individual with a PIT tag inserted mid-dorsally just above the wings. In July, we recaptured 4 chicks from 4 broods at 31-64 days of age and fitted each chick with a 3.9 g radio transmitter sutured along the dorsal midline between the chick's wings (Table 2). At 112- to 135-days post-hatch, 2 radio-marked juveniles were re-captured and fitted with a serially numbered aluminum leg band and 18-gram necklace style transmitter.

Table 2. Age and weight (mean ± SE) of greater sage-grouse chicks captured in Lassen County, California, 2007.

	Age (days)	Weight (g)
Initial capture	3.4±0.3 range = 1-5 *n* = 29	31.5±1 range = 23-39 *n* = 27
First recapture	48.3±7.1 range = 31-64 *n* = 4	514.5±130.3 range = 220-785 *n* = 4
Second recapture	123.5 ± 11.5 range = 112-135 *n* = 2	1083.5 ± 78.5 range = 1005-1162 *n* = 2

Survival Analysis – Sage-grouse for which the exact time of death was unknown (*n* = 1 female) and missing birds (*n* = 2 females; 4 males) were not included in survival analysis. In addition, those sage-grouse where fate of the individual was unknown due to a damaged radio transmitter and/or undetected movement outside the study area (*n* = 1) were right-censored on the date the individual was last known alive.

We recorded 17 deaths (11 females; 6 males) from March–October, 2007. The majority of mortalities were attributed to predation (*n* = 14), 1 female was dismembered by farm machinery, 1 male was recovered at a residence and mortality was attributed to either a domestic dog (*C. familiaris*) or cat (*F. domesticus*), and 1 intact female carcass was recovered. Potential mammalian and avian predators (Schroeder and Baydack 2001) observed on the study area included coyotes, bobcats, red-tailed hawks (*Buteo jamaicensis*), rough-legged hawks (*B. lagopus*), northern harriers (*Circus cyaneus*), golden eagles (*Aquila chrysaetos*), Swainson's hawks (*B. swainsoni*) and ferruginous hawks (*B. regalis*). Predators killed 1 incubating female and 3 females with broods (1 female died approximately 37 days after hatch and 2 females died >100 days after hatch).

Seasonal survival (Mar-Oct) was 54% (SE = 0.01) and 50% (SE = 0.02) for females and males, respectively. No differences in survival were detected between yearling and adult females (48%, SE = 0.01 and 56%, SE = 0.01, respectively; Log rank χ^2_1 = 0.13, *P* = 0.72). Due to small sample sizes, age classes for males were pooled. Monthly mortalities were centered around late spring and summer (i.e., May-July) and were highest during June for females (Table 3).

Eight broods were produced from the 14 nests (57% apparent nest success) that were initiated within the Lassen County study area during 2007. One female from the radio-marked sample apparently lost her brood within 1 week post-hatch. We captured 29 chicks from 6 broods, 1-5 days after hatch and marked individuals with a PIT tag (Table 4). One chick was subsequently caught and fitted with a 3.9 g radio transmitter during the first recapture at approximately 64 days of age. In addition, 3 non-PIT tagged chicks were marked with a transmitter. From the 4 radio-marked chicks captured at 31-64 days of age, 2 chicks survived to ≥ 90-days post-hatch and were re-captured and fitted with a serially numbered aluminum leg band and 18-gram necklace style transmitter. Survival rate of broods to 25 weeks was 42% (SE = 0.05).

A limited entry hunt was conducted in Lassen County the second Saturday in September extending for 2 consecutive days. Daily bag and possession limits were 2 sage-grouse per day, 2 per season in the East Lassen and Central Lassen zones. Number of permits issued was 20 and 15 for the East and Central Lassen zones, respectively. No band returns or radio-marked sage-grouse were reported at check stations located in the East and Central Lassen zones.

Table 3. Timing of sage-grouse mortalities from 15 March – 31 October, 2007 in Lassen County, California.

Month of death	Females (n = 24)	Males (n = 12)
March	1	0
April	1	0
May	2	2
June	4	0
July	2	2
August	1	1
September	0	0
October	0	1
Totals	**11**	**6**

Table 4. Status of broods and chicks of radio-marked female greater sage-grouse in Lassen County, California, 2007.

Parameter	Status
Number of broods	8
Number of chicks PIT-tagged	29[1]
Number of chicks radio-marked at 60 days	4
Number of chicks radio-collared at ≥ 90 days	2
Brood success at 28 days	88% (*n* = 7/8)
Brood success at 60 days	57% (*n* = 4/7)[2]
Brood success at 90 days	57% (*n* = 4/7)

[1]Sample size includes 1 chick that died from exposure after capture.
[2]This sample does not include one brood hen that was killed, precluding our ability to monitor the brood.

Home Range Analysis – We collected 1,181 diurnal and nocturnal locations from 67 sage-grouse. The annual range (Mar-Oct) of sage-grouse in Lassen County comprised 2,639 km^2 (Figure 2). Spring range (Mar-May) for both males and females (*n* = 145 locations) was 2,479 km^2. Both the summer (June-Aug) and fall (Sept-Oct) seasonal home range largely overlapped the spring range and encompassed 2,282 km^2 (*n* = 454 locations) and 1,954 km^2 (*n* = 585 locations), respectively.

We examined the home ranges and seasonal movement patterns for 22 sage-grouse (*n* = 14 female, 8 male; Table 5). Mean number of observations per female was 39.14 ± 2.80 (SE; range = 20–55 observations per female). In comparison, mean number of observations per male was 21.5 ± 3.01 (SE; range = 11-34 observations per male). Mean home range size was 108.26 km^2 ± 50.00 (SE; range = 5.39-671.25 km^2) and 45.87 ± 14.94 (SE; range = 3.31-139.155) for females and males, respectively. However, differences in home range size between females and males may have been confounded by sample size and the statistical properties of the home range estimator. Sample sizes did not warrant separate analyses of home ranges delineated by lek complex; therefore, female and male locations were pooled. Mean home range size was lower for sage-grouse monitored in the Madeline Plains lek complex (23.23 km^2 $\pm$ 8.58 (SE); n = 6) than the Upper Smoke Creek (43.62 km^2 $\pm$ 17.62 (SE); n = 6) and Shaffer Mountain (148.15 km^2 $\pm$ 66.89 (SE); n = 5) lek complexes.

Male and female sage-grouse captured in the Upper Smoke Creek/Hall Springs lek complex exhibited similar directional movements to the Madeline Plains area, generally moving north from the Upper Smoke Creek to Coyote Flat. Sage-grouse from the Madeline Plains lek complex appeared to be non-migratory and remained on the Alturas Ranch, which is privately-owned. Sage-grouse captured from the Shaffer Mountain/Chalk Bluff lek complex showed greater directional variability. Although some sage-grouse moved north to the Madeline Plains and Upper Smoke Creek area, most birds remained in the Lower Smoke Creek area and were located from the Tablelands north of Shaffer Mountain, east to the Nevada border.

The average distance females moved from lek sites of capture to initial nest locations was 3.38 km $\pm$ 2.47 (SD); n = 12. The straight-line distance of movements from lek of capture to spring ranges ranged from 0.6-18.7 km (n = 14), and 2.1-32.0 km (n = 8) for females and males, respectively (Table 6). The mean distance sage-grouse moved between spring and summer ranges was 19.5 km ± 13.9 (SD) for females and 18.3 km for males (Table 6). The largest straight-line distance movement we observed between spring and summer ranges (48.3 km) was made by a broodless female, which made a unidirectional movement from Skedaddle Mountain within the Shaffer Mountain lek complex, north to Observation Peak approximately 25 days after losing her brood.

Distances of female and male movements from summer to fall ranges were 3.1-16.3 km (n = 5) and 7.8-8.7 km (n = 2), respectively (Table 6).

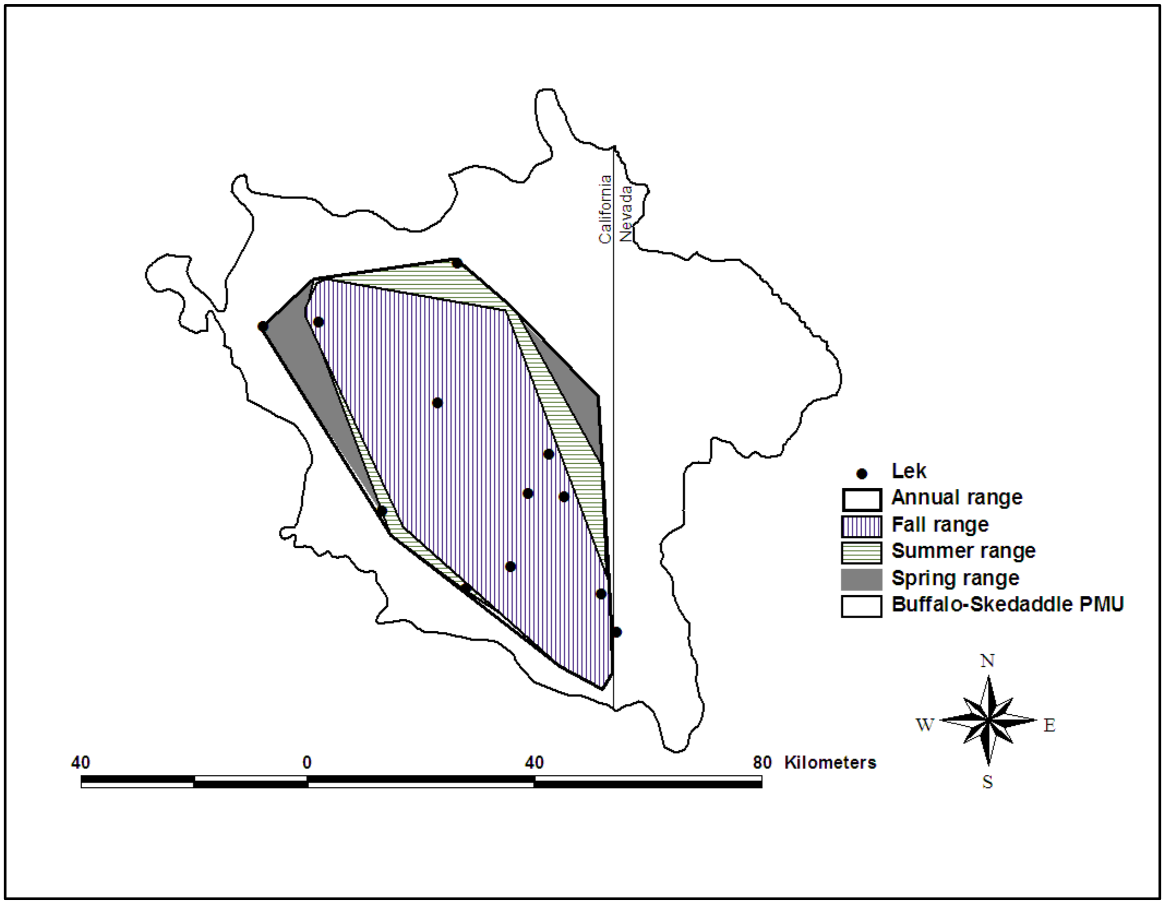

Figure 2. Annual and seasonal ranges of sage-grouse in Lassen County, California, 2007.

Table 5. Home range estimates (km^2) for 22 sage-grouse in Lassen County, California, March- October, 2007.

Lek complex	Frequency	Gender	Number of locations	Home range (km^2)
Upper Smoke Creek/Hall Springs	160.026	F	41	61.03
	160.265	F	29	122.69
	159.390	F	41	22.49
	159.865	F	24	20.05
	160.176	M	28	3.31
	160.326	M	24	32.16
Madeline Plains	160.036	F	53	15.25
	159.000	F	55	5.39
	159.886	F	48	12.65
	160.115	M	11	28.78
	159.906	M	34	14.10
	159.200	M	26	63.22
Shaffer Mtn./Chalk Bluff	159.010	F	42	20.79
	159.047	F	20	6.81
	159.180	F	40	50.00
	159.210	F	42	64.28
	159.307	F	27	368.27
	159.876	F	44	671.25
	159.896	F	42	74.71
	160.085	M	14	139.15
	160.127	M	11	52.54
	159.857	M	24	33.69

Table 6. Mean distances (km) sage-grouse moved between seasonal ranges, Lassen County California, 2007.

	Spring			Summer			Fall		
Gender	Mean	Range	n	Mean	Range	n	Mean	Range	n
Female	6.5	0.6-18.7	14	19.5	7.2-48.3	7	11.4	3.1-16.3	5
Male	14.3	2.1-32.0	8	18.3	--	1	8.3	7.8-8.7	2
Totals	**9.3**	**0.6-32.0**	**22**	**19.4**	**7.2-48.3**	**8**	**10.5**	**3.1-16.3**	**7**

Fall Trapping – We captured greater sage-grouse opportunistically using spotlighting techniques from 7 August – 22 October 2007. Twenty-four females within the Lassen County study area were captured and fitted with serially-numbered aluminum leg bands and ≤ 20 g necklace-mounted ATS radio transmitters. The age ratio by sex was: 13 adult female:6 yearling female:5 juvenile female. In addition, 6 juvenile males were fitted with leg bands. Blood samples for genetic analysis were acquired from all birds captured (n = 30).

Habitat Structure – We measured vegetative characteristics at 13 nest sites and at 13 paired random points during the nesting period. Females used a variety of plants as nesting cover (Table 7) including: silver sagebrush (*A. cana*), Wyoming big sagebrush, mountain big sagebrush, low sagebrush, littleleaf horsebrush (*Tetradymia glabrata*), and green rabbitbrush (*Chrysothamnus viscidiflorus*). Habitat sampling was completed for 28 brood sites and 28 paired random sites, respectively.

Table 7. Nest success and nest cover used by radio-collared female sage-grouse, Lassen County, California, 2007.

	Nest Cover					
Fate	ARCA	ARAR	ARWY	ARVA	TEGL	CHVI
Successful	2	0	1	1	1	1
Depredated	0	2[a]	1	2	0	2
Totals	**2**	**2**	**2**	**3**	**1**	**3**

[a]Includes 1 renest.

2008 LASSEN COUNTY PROJECT GOALS AND EXPECTATIONS

March of 2008 will mark the second year of a 3 year research project to develop a landscape-level, habitat-based approach to assess sage-grouse viability in northeastern California. Our objectives for the 2008 field season will include: 1) capturing additional female ($n \geq 50$) and male ($n \geq 15$) sage-grouse to account for mortalities and/or losses over the previous field season; 2) to monitor successfully nesting females during the breeding season until a breakdown in brood integrity or if the brood is lost; 3) to assess lek attendance, natal dispersal distance, and movement patterns for all known yearling sage-grouse marked as juveniles during the fall of 2007; 4) to collect DNA from approximately 100 greater sage-grouse; 6) to monitor brood and chick survival from successfully nesting females until a breakdown in brood integrity; and 7) to examine seasonal movement patterns, including movements from fall to winter range.

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LITERATURE CITED

Autenrieth, R. E. 1981. Sage grouse management in Idaho. Idaho Department of Fish and Game. Wildlife Bulletin 9.

Beetle, A. A. 1960. A study of sagebrush. The section Tridentata of *Artemisia*. University of Wyoming Agricultural Experiment Station Bulletin 368.

Benedict, N. G., S. J. Oyler-McCance, S. E. Taylor, C. E. Braun, and T. W. Quinn. 2003. Evaluation of the eastern (*Centrocercus urophasianus urophasianus*) and western (*C. u. phaios*) subspecies of sage-grouse using mitochondrial control-region sequence data. Conservation Genetics 4:301-310.

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

Bouzat, J. L., H. H. Cheng, H. A. Lewin, R. I. Westemeier, J. D. Brawn, and K. N. Paige. 1998a. Genetic evaluation of a demographic bottleneck in the greater prairie-chicken. Conservation Biology 12:836-849.

Bouzat, J. L., H. A. Lewin, and K. N. Paige. 1998b. The ghost of genetic diversity past: historical DNA analysis of the greater prairie-chicken. American Naturalist 152:1-6.

Burkepile, N. A., J. W. Connelly, D. W. Stanley, and K. P. Reese. 2002. Attachment of radio transmitters to one-day-old Sage Grouse chicks. Wildlife Society Bulletin 30: 93-96.

California Department of Fish and Game. 2003. California Department of Fish and Game trapping, handling, and data collection protocol for greater sage-grouse. Sacramento, California, USA.

Caizergues, A., and L. N. Ellison. 2002. Natal dispersal and its consequences in black grouse *Tetrao tetrix*. Ibis 144:478-487.

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

Carver, A. V., L. W. Burger Jr., and L. A. Brennan. 1999. Passive integrated transponders and patagial tag markers for northern bobwhite chicks. Journal of Wildlife Management 63:162-166.

Connelly, J. W., and C. E. Braun. 1997. Long-term changes in sage grouse *Centrocercus urophasianus* populations in western North America. Wildlife Biology 3:229-234.

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

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, USA.

Crawford, J. A., R. A. Olson, N. E. West, J. C. Mosely, 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 57:2-19.

CrimeStat III. 2004. A spatial statistics program for the analysis of crime incident locations. National Institute of Justice, Washington, D.C.

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

Dale, S. 2001. Female-biased dispersal, low female recruitment, unpaired males, and the extinction of small isolated bird populations. Oikos 92:344-356.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1963. Ecology, productivity, and management of sage grouse in Idaho. Journal of Wildlife Management 27:811-841.

Daubenmire, R. F. 1959. A canopy coverage method of vegetation analysis. Northwest Science 33:224-227

Fahrig, L., and G. Merriam. 1994. Conservation of fragmented populations. Conservation Biology 8:50-59.

Fuhlendorf, S. D., A. J. W. Woodward, D. M. Leslie Jr., and J. S. Shackford. 2002. Multi-scale effects of habitat loss and fragmentation on lesser prairie-chicken populations of the US Southern Great Plains. Landscape Ecology 17:617-628.

Gibson, R. M., and G. C. Bachman. 1992. The cost of female choice in a lekking bird. Behavioral Ecology 3:299-309.

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

Hall, F. A., S. C. Gardner, and D. S. Blankenship. 2005. Greater Sage-Grouse *in* D. Shuford, ed. California Birds Species of Special Concern. Draft in press. CDFG, Sacramento, California, USA.

Holloran, M. J. and S. H. Anderson. 2005. Spatial distribution of greater sage-grouse nests in relatively contiguous habitats. Condor 107:742-752.

Homer, C. G., T. C. Edwards, R. D. Ramsey, and K. P. Price. 1993. Use of remote sensing methods in modeling sage grouse winter habitat. Journal of Wildlife Management 57:78-84.

Hooge, P. N., and B. Eichenlaub. 2000. Animal movement extension to ArcView. Ver. 2.0. Alaska Science Center – Biological Science Office, USGS, Anchorage, Alaska, USA.

Johnson, J. A., J. E. Toepfer, and P. O. Dunn. 2003. Contrasting patterns of mitochondrial and microsatellite population structure in fragmented populations of greater prairie-chickens. Molecular Ecology 12:3335-3347.

Johnson, J. A., M. R. Bellinger, J. E. Toepfer, and P. Dunn 2004. Temporal changes in allele frequencies and low effective population size in greater prairie-chickens. Molecular Ecology 13:2617-2630.

Kaplan, E. L., and P. Meier. 1958. Nonparametric estimation for incomplete observations. Journal of American Statistical Association 53:457-481.

Lacy, R. C. 1997. Importance of genetic variation to the viability of mammalian populations. Journal of Mammalogy 78:320-335.

Leonard, K. M., K. P. Reese, and J. W. Connelly. 2000. Distribution**,** movements and habitats of sage grouse *Centrocercus urophasianus* on the Upper Snake River Plain of Idaho: changes from the 1950s to the 1990s. Wildlife Biology 6:265-270.

Maruyama, T., and P. A. Fuerst. 1985. Number of alleles in a small population that was formed by a recent bottleneck. Genetics 111:675-689.

Nei, M., T. Maruyama, and R. Chakraborty. 1975. The bottleneck effect and genetic variability in populations. Evolution 29:1-10.

Oyler-McCance, S. J., N. W. Kahn, K. P. Burnam, C. E. Braun, and T. W. Quinn. 1999. A population genetic comparison of large- and small-bodied sage grouse in Colorado using microsatellite and mitochondrial DNA markers. Molecular Ecology 8:1457-1465.

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

Pollock, K.H., S.R. Winterstein, C.M. Bunck, and P.D. Curtis. 1989. Survival analysis in telemetry studies: the staggered entry design. Journal of Wildlife Management 53: 7-15.

Popham, G. P., and Gutierrez, R. J. 2003. Greater sage-grouse (*Centrocercus urophasianus)* nesting success and habitat use in northeastern California. Wildlife Biology 9:327-334.

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

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

Schroeder, M. A., and L. A. Robb. 2003. Fidelity of greater sage-grouse *Centrocercus urophasianus* to breeding areas in a fragmented landscape. Wildlife Biology 9:291-299.

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

Seutin, G., B. N. White, and P. T. Boag. 1991. Preservation of avian blood and tissue samples for DNA analyses. Canadian Journal of Zoology 69:82-90.

Shaffer, M. L. 1981. Minimum population sizes for species conservation. Biosciences 31:131-134.

Shepherd, J. F. III. 2006. Landscape-scale habitat use by greater sage-grouse (*Centrocercus urophasianus*) in southern Idaho. Dissertation. University of Idaho, Moscow, Idaho, USA.

Springer, J. T. 1979. Some source of bias and sampling error in radio triangulation. Journal of Wildlife Management 43:926-935.

Wakkinen, W. L., K. P. Reese, J.W. Connelly, and R. A. Fischer. 1992. An improved spotlighting technique for capturing sage grouse. Wildlife Society Bulletin 20: 425-426.

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

Woodward, A. J. W., S. D. Fuhlendorf, D. M. Leslie Jr., and J. Shackford. 2001. Influence of landscape composition and change on lesser prairie-chicken (*Tympanuchus pallidicinctus*) populations. American Midland Naturalist 145:261-274.

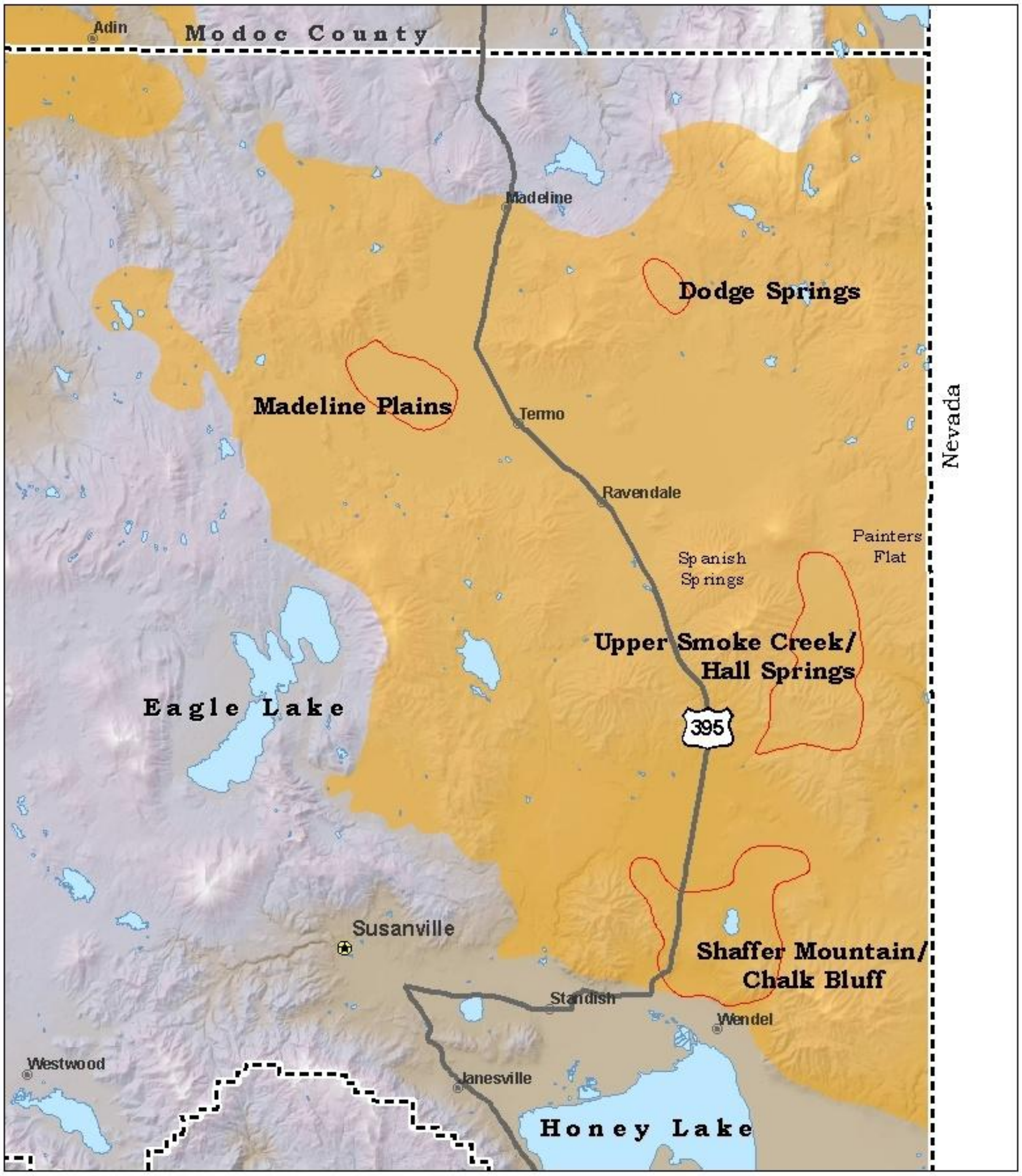

Fig. 1 Lassen County Greater Sage-Grouse Study Area