Greater Sage-Grouse
(*Centrocercus urophasianus*)
Movements, SNWA Ranchland and Rangeland Use, and Core Use Areas in Spring Valley, Nevada

SOUTHERN NEVADA WATER AUTHORITY

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ABSTRACT

The Southern Nevada Water Authority (SNWA) conducted a greater sage-grouse (*Centrocercus urophasianus*) radio-telemetry study from 2008-2010 in Spring Valley (Hydrographic Basin #184), Nevada. The primary goal of the study was to document greater sage-grouse use of SNWA deeded ranch properties and associated BLM grazing allotments, and interseasonal, intraseasonal, and daily movements between and within breeding sites and these lands. The study demonstrated that greater sage-grouse utilized SNWA deeded ranch properties largely for summer habitat (open meadows, shrubland patches, and occasionally alfalfa fields), and nearby BLM grazing allotments largely for winter and breeding habitat (shrublands). The study also demonstrated both migratory and non-migratory patterns, as well as site fidelity to seasonal ranges. This information can inform conservation efforts on SNWA deeded properties, and management strategies to protect and enhance Spring Valley's greater sage-grouse population.

INTRODUCTION

The greater sage-grouse (henceforth sage-grouse) is the largest grouse species in North America, and is limited to sagebrush habitat in the western U.S. and southwestern Canada. In the past few decades, sage-grouse populations have been declining throughout much of their range (Connelly and Knick 2011). Spring Valley, which is in White Pine and Lincoln counties in east-central Nevada, is near the southern limit of the species' distribution and supports a relatively small population compared to core areas within the species' range. Over the past decade, male attendance at trend leks suggests a decline in Spring Valley's sage-grouse population size (NDOW 2012).

In Nevada, the Bureau of Land Management (BLM) classifies the sage-grouse as a Nevada Special Status Species, and NDOW lists it as a state-protected game species. From 1999 – 2004, eight petitions were filed with the U.S. Fish and Wildlife Service (USFWS) to list greater sage-grouse as a threatened or endangered species. In 2005, USFWS found the listing not warranted; however, this finding was overturned by a federal court and the petition underwent a second review. In 2010, the USFWS ruled that the listing of the greater sage-grouse across its entire range was warranted, but precluded by higher priority listing actions (USFWS 2010). The greater sage-grouse is currently a candidate species under the Endangered Species Act.

In 2000, a sage-grouse conservation initiative was established in Nevada by the late Governor Guinn. In 2012, Governor Sandoval established the Greater Sage Grouse Advisory Committee (SGAC) that produced a strategic plan for sage grouse conservation in Nevada (SGAC 2012). As a result, national sage-grouse conservation plans have been adopted by county, state, and federal agencies (Governor's Sage Grouse Conservation Team 2004; Lincoln County Sage-Grouse Technical Review Team 2004; White Pine County; Bi-State Local Planning Group 2004; Sage-Grouse Technical Review Team 2004;

BLM 2004; NDOW Wildlife Action Plan Team 2006; and NDOW Sage-Grouse Conservation team 2007). In 2008, BLM began to implement the sage-grouse conservation plan for Lincoln County, including a sagebrush habitat restoration project in southeastern Nevada funded by a Southern Nevada Public Land Management Act (SNPLMA) grant.

Sage-grouse exhibit seasonal spatio-temporal variability in habitat use (Dalke et al. 1963; Beck 1975; Wallestad 1975; Hulet 1983; Connelly et al. 2000; Wakkinen 1990; and Fischer 1994). During the winter season, sage-grouse primarily use sagebrush habitat. During the breeding season sage-grouse use their typical sagebrush habitat, as well as leks characterized by open areas with low, sparse sagebrush vegetation. During the summer season sage-grouse are known to use not only sage-brush habitat, but also wet meadows and riparian areas, including irrigated pastures and cultivated fields (e.g., Berry and Eng 1985; Connelly et al. 1988). An understanding of interseasonal movements thus helps to spatially define seasonal area requirements, identify connectivity between habitats, and better manage sage-grouse populations (Fedy et al. 2012). Prior to the initiation of this study, aside from lek monitoring (NDOW 2012), limited telemetry data (NDOW 2007), and anecdotal observations in Spring Valley, little was known of sage-grouse movements and seasonal ranges within the basin.

In east-central Nevada, the Southern Nevada Water Authority (SNWA) currently holds deeds to approximately 23,500 acres of ranchland (over 95% of which are in Spring Valley), grazing permits on approximately 930,000 acres of associated Bureau of Land Management (BLM) and US Forest Service (USFS) grazing allotments, and approximately 66,000 acre feet per year (afy) of associated water rights (approximately 35,000 afy surface water, 7,000 afy groundwater, and 24,000 supplemental water rights). Approximately 40% (>4,000 acres) of the wetland/meadow habitats in the valley floor and valley floor / alluvial fan interface of Spring Valley occur within SNWA deeded properties, and another 40% (>4,500 acres) occur within the associated allotments (SNWA, 2004; SNWA et al., 2011). These resources (collectively known as SNWA Northern Resources) provide the ability to implement adaptive integrated resources management.

From 2008 through 2010, SNWA conducted a sage-grouse radio-telemetry study in Spring Valley, Nevada. The study was purposely biased toward SNWA deeded properties on the valley floor and valley floor-alluvial fan interface, and thus does not represent sage-grouse land use across the entire basin. Specific research objectives were to: (1) determine the spatio-temporal distribution of radio-collared sage-grouse on SNWA deeded land and associated grazing allotments in Spring Valley; (2) document their interseasonal and intraseasonal movements; (3) document their summer daily movements on SNWA deeded lands; (4) identify leks used by the radio-telemetry subjects tracked on SNWA deeded lands and associated grazing allotments; and (5) record the location of nesting sites of the female radio-telemetry subjects.

MATERIALS & METHODS

Study Area

The study was conducted in the southern three-quarters of Spring Valley in Lincoln and White Pine counties, Nevada, USA. Nearly 180 kilometers (km) (111 miles [mi]) in length, 24 km (14 mi) wide, and covering 4,315 km^2 (1,666 mi^2), the Spring Valley hydrographic basin is located in the Great Basin Desert, bordered by the Schell Creek Range to the west and Snake Range to the east. The valley floor elevation ranges between 1,676 meters (m) - 1,829 m (5,000 – 6,000 feet [ft]), and the bordering mountain ranges exceed 3,300 m (11,000 ft). Typical valley floor vegetation includes sagebrush (*Artemisia* spp.), greasewood (*Sarcobatus*), saltbush (*Atriplex* spp.), and rabbitbrush (*Chamisia* spp.). Although the lower elevations are largely shrubland, there are also spring systems, wetlands, and irrigated pastures dominated by grasses (i.e., *Muhlenbergia* and *Poa*), sedges (*Carex* spp.), and rushes (*Juncus* spp.) scattered across the valley. Several ranches in the valley also cultivate alfalfa (*Medicago sativa*). Higher elevation habitats are characterized by sagebrush, juniper (*Juniperus* spp.), single-leaf pinyon pine (*Pinus monophylla*), and quaking aspen (*Populus tremuloides*).

Subjects

Capture efforts were concentrated on SNWA deeded properties, areas adjacent to SNWA properties, and leks near SNWA properties. We initially located research subjects by searching five known leks during the breeding season (March-May) in 2008 and 2009. Additional research subjects were located by following the radio-collared individuals to their summer and winter ranges in 2008 and 2009. Captures were conducted under NDOW permit S31804, and before accessing private property we obtained landowner permission.

Recently captured male greater sage-grouse (926A) with radio-collar

We captured roosting individuals by spotlighting and netting, as described in Giesen et al. (1982) and Wakkinen et al. (1992) and per current NDOW protocol. We aged and sexed the subjects based on established criteria (Dalke et al. 1963). Under the guidance of an NDOW biologist, each sage-grouse was banded on the right leg with a uniquely numbered aluminum leg ring (size 14 for females and 16 for males) that NDOW provided. Subjects were fitted with a 22 g necklace-style radio transmitter (Advanced Telemetry Systems, Model # A4060) that operated on a unique frequency within a band range of 159-160 MHz, had an eight-hour mortality switch, and was designed to last approximately 870 days.

Tracking

We tracked subjects approximately every other week from April 2008 to August 2010 using Advanced Telemetry Systems receivers (Model # R410) and 3-element Yagi antennae. Upon locating a radio-collared sage-grouse, based on direct observation of the individual we recorded their approximate location with a Trimble GeoXH Global Positioning System (GPS) unit. We also recorded date, time, weather conditions, number of other sage-grouse present (both collared and uncollared), behavior, and general habitat description (including dominant plant species and visual estimate of average plant height within 100 m radius of the location point). Radio-collared individuals were tracked until their collars slipped off, mortality was determined, transmitter battery power ended, or the study was brought to a close.

We also collected three-point daily movement data on SNWA deeded properties for one to two days, every other week, for nine weeks in summer 2009. We located the sage-grouse in the morning, mid-day, and late afternoon at approximately five hour intervals. Upon locating a radio-collared sage-grouse, we recorded GPS location, date, time, weather conditions, number of other sage-grouse (collared and uncollared) present, behavior, and general habitat description as above. To avoid flushing the sage-grouse and altering movement behavior and distance, locations were estimated by distance and direction from a known GPS position.

Geodatabase

We created a final geodatabase in ArcGIS Software version 10.0 (Environmental Systems Research Institute [ESRI]). The geodatabase includes Universal Transverse Mercator (UTM) coordinates that were collected on the Trimble GPS units (North American Datum 83, Zone 11 North [NAD 83, Zone 11N]), as well as all other attributes collected in the field (date, time, weather, number of collared and associated uncollared sage-grouse, behavior, and general habitat descriptions). The final database underwent a rigorous Quality Assurance/Quality Control (QA/QC) by SNWA in order to ensure accuracy, consistency, transparency, and reliability. Detailed metadata are provided in the GIS database, and are best viewed in FGDC format. The geodatabase is stored in a secure SNWA data repository.

Movements

We measured interseasonal (migration) and intraseasonal (within season) movement distances of all radio-collared individuals from 2008-2010, and daily movement distances of all radio-collared individuals on SNWA deeded properties in summer 2009. Seasonal ranges were identified as summer, winter, and breeding ranges based on time of year, forage habitat, and breeding behavior (Connelly et al., 2011). We measured the distance (km) between GPS points using the measurement tool in ArcGIS Software version 10.0 (ESRI). Because we assumed linear movement between points, measurements represent minimum distances moved.

Movement distances were measured as follows:

- For interseasonal (migratory) movements, for each individual we measured the linear distance between the last point in one seasonal range and the first point within the next seasonal range. To distinguish migratory movements from intraseasonal movements, point locations and movement patterns were examined. For some individuals, the last point in one seasonal range directly preceded the first point in the next seasonal range. For others, intermediate migratory points were documented, and interseasonal distance was measured along the path of points.
- For intraseasonal movements, for each individual we measured the linear distance between every consecutive pair of points within each seasonal range. Of the daily movement locations, only non-consecutive days, and one point per day, were included in the intraseasonal movement analysis.
- For daily movements, for each individual we measured the linear distance between every consecutive pair of points within each day. The measurements were then summed to calculate the total daily movement for each individual. If during the daily tracking an individual was flushed at any time prior to documenting their last location (in late afternoon), we collected data for all three time periods but did not include its movements for that day in the three-point movement-day analysis.

Seasonal Activity Areas

To assess the use of seasonal habitats, we derived seasonal activity areas representing all tracked sage-grouse across 2008-2010. Seasonal activity areas are defined as general areas of use within each seasonal (winter, summer or breeding) habitat. General locations of seasonal activity areas were initially identified based on clustering of tracking points (2008-2010 combined) within each seasonal habitat. For each cluster, we created a minimum convex polygon by connecting the outermost tracking points (Burt 1943), and calculated the area with the measurement tool in ArcGIS Software version 10.0 (ESRI). Ranges and means were then calculated for the winter, breeding, and summer seasonal activity areas. Daily summer movement activity areas were derived using a similar approach, except they were derived for each individual (instead of across individuals) based on their locations during the nine week daily movement tracking period in 2009. A range and mean were then calculated across individuals for the daily summer movement activity areas.

Site Fidelity

We assessed seasonal site fidelity across 2008–2010 for the radio-collared sage-grouse. Site fidelity is defined as the tendency of a collared individual to return to a seasonal range that it had occupied in a previous year. Data were compared across the following seasonal time periods: breeding 2008, 2009, 2010; summer 2008, 2009, 2010; and winter 2008–2009 and 2009–2010. For each individual, we calculated the arithmetic means of their northing coordinates and of their easting coordinates within each season each year. Using the measurement tool in ArcGIS Software version 10.0 (ESRI), for each individual we then measured the distance between the derived mean GPS locations within each season across the years. A range and mean were then calculated across individuals for each season. Shorter distances signify greater seasonal site fidelity.

Core Use Areas

To assess areas of greater sage-grouse use, we derived core use areas representing all collared and associated uncollared grouse across 2008-2010. Core use areas are defined as areas of higher sage-grouse density. We performed a kernel density analysis of all telemetry GPS points representing 2,636 observations (1,088 location points of collared individuals plus 1,548 uncollared individuals documented at collard bird locations) collected from 2008-2010, using the "Kernel Density Tool" in ArcGIS Software version 10.0 (ESRI). This analysis considered both the distribution of location points and the number of individuals (collared and uncollared) recorded at each location point. Using a 1,609.344 m^2 (1 square mile) search area centered on each observation point, we produced a 10 m density surface raster with area units of 1 km^2. The symbology of the surface raster was produced as follows: Show = Classified; Classification = Natural Breaks (Jenks) with 7 classes; Excluded Values = 0 - 4.412379708 (156 outliers outside of clusters of more dense observations that were not removed from the raw analysis, but were not displayed in the map layer); and color representation of density classes (color gradation from tan [relatively low sage-grouse density] to red [relatively high sage-grouse density].

RESULTS

Capture and Telemetry Summary

We captured 35 sage-grouse (23 males and 12 females) from April 1, 2008 to September 16, 2009 in Spring Valley, Nevada and equipped them with radio-telemetry collars. Capture efforts focused on SNWA deeded properties and leks near SNWA properties. Nine sage-grouse (8 males, 1 female) were captured on or near four active leks (Lincoln Canyon, E. Kirkeby Knoll, Cleve Creek, and Piermont North) that were 1.2 – 14.2 km from an SNWA deeded property, 25 (14 males, 11 females) were captured on their summer range, and 1 male was captured on its winter range. Of the 25 sage-grouse captured on their summer range, 23 were on or near SNWA deeded properties. Specifically, we captured 13 on the SNWA El Tejón Ranch (Shoshone parcel), 7 on the SNWA Robison Ranch (Meadow Creek parcel), and 3 on the SNWA Robison Ranch (McCoy Creek parcel). The remaining two grouse were captured on privately owned ranches. **Figure 1** shows the initial capture locations of the 35 collared greater sage-grouse.

We radio-tracked the collared sage-grouse at intervals of approximately two weeks from April 2, 2008 to August 4, 2010. From June 3 to August 12, 2009, we also collected daily movement data (three location points daily) for 16 of the sage-grouse on SNWA ranches. During the course of the study, we recorded 2 to 66 location points for each sage-grouse being tracked. The total number of days from the date of collaring to the date last tracked ranged from 1 to 826 days (mean = 321 days). The total number of radio-telemetry points collected across 2008–2010 was 1,088. **Table 1** provides a summary of the number of days tracked and number of location points recorded for each individual.

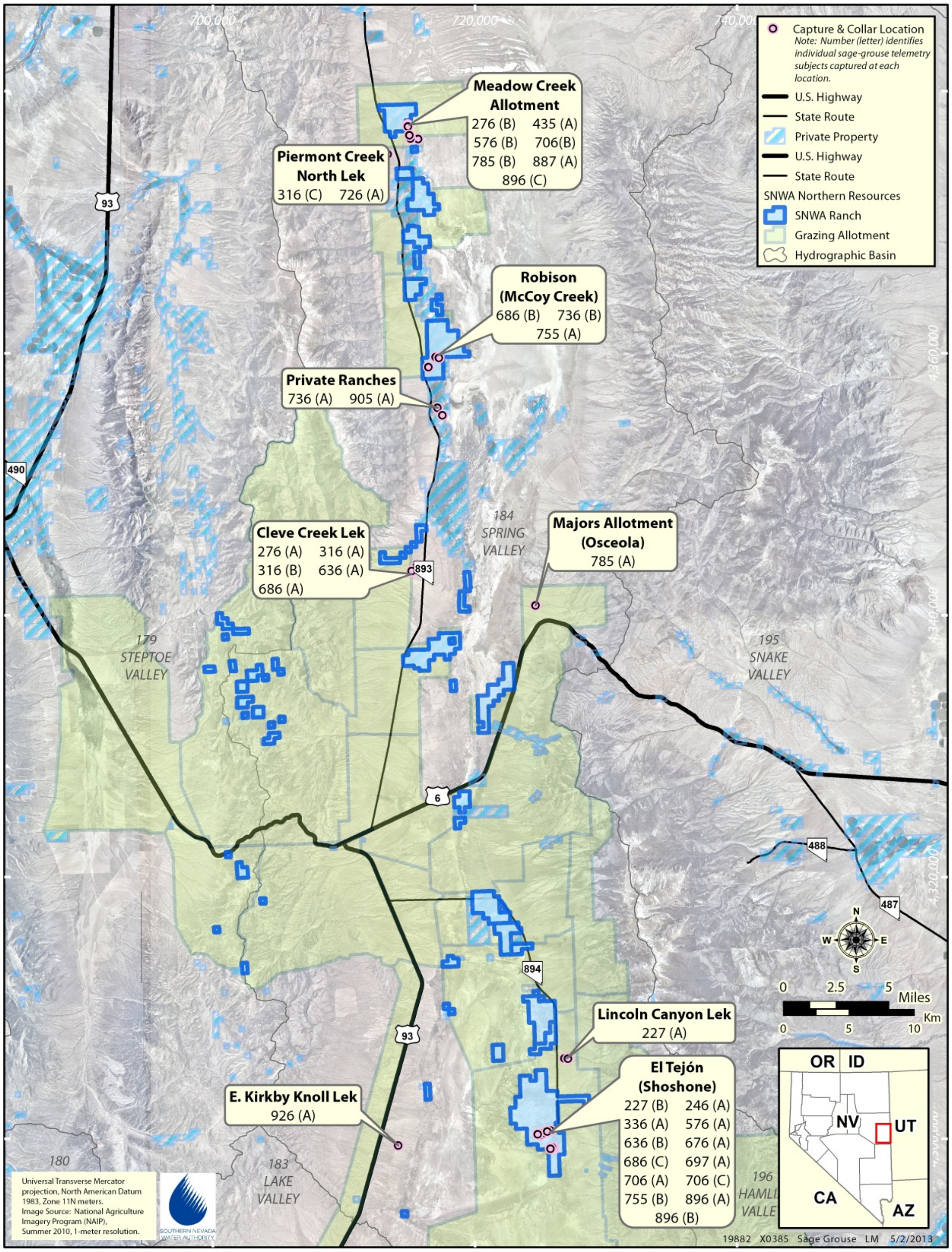

Figure 1. Capture locations of radio-collared sage-grouse, Spring Valley, Nevada, 2008-2009.

Table 1. A tracking summary of all radio-collared sage-grouse.

Bird ID#	Sex	Date Collared	Date Last Tracked	Number of Days Collared to Last Tracked	Number of Location Points
227A	M	4/23/08	9/10/08	141	14
227B	M	9/15/09*	5/27/10	255	11
246A	F	9/23/08	8/4/10	681	65
276A	F	4/2/08	6/24/09	449	45
276B	M	9/14/09	8/4/10	325	22
316A	M	4/1/08	5/7/08	37	8
316B	M	5/7/08	1/29/09	268	24
316C	M	4/20/09	6/22/10	429	47
336A	F	8/6/08	8/4/10	729	66
435A	M	6/16/09	4/20/10	309	39
576A	F	9/22/08	10/7/08	16	2
576B	F	6/16/09	5/27/10	346	31
636A	M	4/2/08	5/21/08	50	8
636B	M	8/6/08	3/1/10	573	63
676A	F	8/6/08	11/9/09	461	57
686A	M	4/1/08	5/28/08	58	11
686B	M	7/1/08**	7/10/08	10	3
686C	M	8/6/08	8/4/10	729	61
697A	M	8/6/08	3/24/10	596	63
706A	F	8/6/08	7/26/09	358	44
706B	F	9/4/09	9/15/09	1	2
706C	F	9/15/09	8/4/10	324	25
726A	M	4/20/09	8/4/10	472	54
736A	F	9/24/08	6/3/09	253	20
736B	M	9/16/09	4/20/10	217	15
755A	M	7/1/08	8/11/09	407	46
755B	F	9/15/09	6/22/10	281	20
785A	M	12/3/08	2/25/09	85	7
785B	M	9/14/09	8/4/10	325	22
887A	M	6/16/09	8/4/10	414	48
896A	M	8/6/08	9/24/08	19	6
896B	M	10/2/08	10/7/08	6	2
896C	F	9/14/09	1/13/10	122	7
905A	M	9/24/08	8/4/10	680	64
926A	M	4/30/08	8/4/10	826	66

*This bird was first captured on 5/7/08, but was only leg banded. It was recaptured over a year later and collared.
**This bird was first captured at a lek on 4/1/08, but it slipped off its collar by the next day. It was recaptured three months later and collared.

Seasonal Activity Areas, Interseasonal & Intraseasonal Movements

Throughout Spring Valley, we derived nine winter activity areas, seven breeding activity areas, and five summer activity areas representing radio-collared sage-grouse land use in 2008-2010 (**Figures 2a-c**). The collared sage-grouse generally occupied winter habitat from October to February, breeding habitat from late February through May, and summer habitat from late May to October. The winter activity areas ranged in size from 0.2 – 30.8 km^2 (mean = 13.0 km^2, standard error [SE] = 3.0), the breeding activity areas ranged in size from 0.2 – 9.3 km^2 (mean = 2.7 km^2, SE = 1.2), and the summer activity areas ranged in size from 1.8 – 11.7 km^2 (mean = 7.6 km^2, SE = 2.3). Sage-grouse were tracked to eight active leks (South Spring Valley #3, Lincoln Canyon, E. Kirkeby Knoll, Cleve Creek, Piermont, Piermont North, Kalamazoo, and North Creek) and five nest sites. Two of the eight active leks (South Spring Valley #3 and Kalamazoo) had not been previously documented, and have been added to NDOW's state-wide database.

We documented interseasonal movements between the seasonal activity areas for 26 of the collared sage-grouse. We monitored 22 of the sage-grouse long enough to document at least one full interseasonal movement cycle across winter, breeding, and summer habitats, and four long enough to document one interseasonal movement. In 2008-2009 the sage-grouse were tracked moving from summer to winter habitat in late September through late October; from winter to breeding habitat in late February to early March (males) and in March and April (females); and from breeding to summer habitat generally in May and June. In 2008 and 2009, most of the tracked sage-grouse settled in summer habitat by early June; however, in 2010 many of the tracked sage-grouse delayed arrival to their summer habitat until late June to early August. Summer to winter habitat movement distances ranged from 0.05 – 48.4 km (mean = 14.2 km, SE = 1.7), winter to breeding habitat movement distances ranged from 0.5 – 46.3 km (mean = 12.1 km, SE = 2.3), and breeding to summer habitat distances ranged from 0.8 – 29.7 km (mean = 14.9 km, SE = 1.7).

We documented intraseasonal movements within the seasonal activity areas for 31 of the radio-tracked individuals. Twenty-five individuals were tracked for at least one summer season, 27 individuals were tracked for at least one winter season, and 27 individuals were tracked for at least one breeding season. Movements between consecutive points (approximately 2 weeks apart) within winter habitat ranged from 0.0 – 15.6 km (mean = 1.9 km, SE = 0.2 km); within breeding habitat ranged from 0.0 – 9.7 km (mean = 1.0 km, SE = 0.2 km); and within summer habitat ranged from 0.2 – 4.9 km (mean = 1.0 km, SE = 0.1). Intraseasonal movement distances during the breeding season differed slightly based on the sex of the individual: male movements ranged from 0.0 – 7.6 km (mean = 0.6 km, SE = 0.1 km), and female movements ranged from 0.1 – 9.7 km (mean = 1.9 km, SE = 0.4 km).

During the breeding season, the collared males generally occupied the areas around active leks from late February to middle May. During this period, we regularly observed them strutting at leks in the early morning. The collared females were observed at lek sites in March to middle May, but less regularly than the males. Females that had mated moved to nest sites in late April and early May, and generally occupied their nests

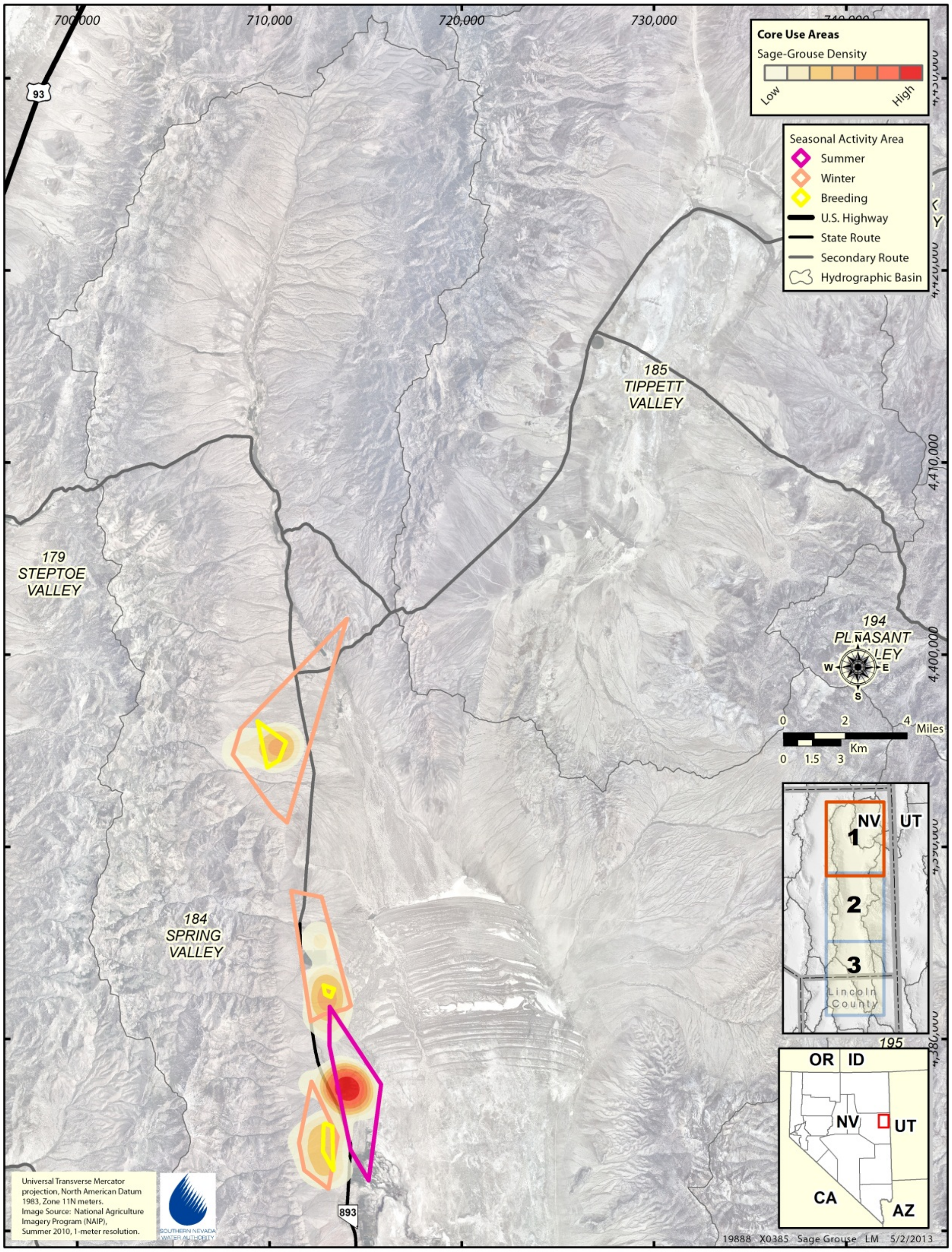

Figure 2a. Seasonal activity areas and core use areas of radio-collared sage-grouse, Spring Valley, Nevada, 2008-2010. Map 1 (north Spring Valley) of 3.

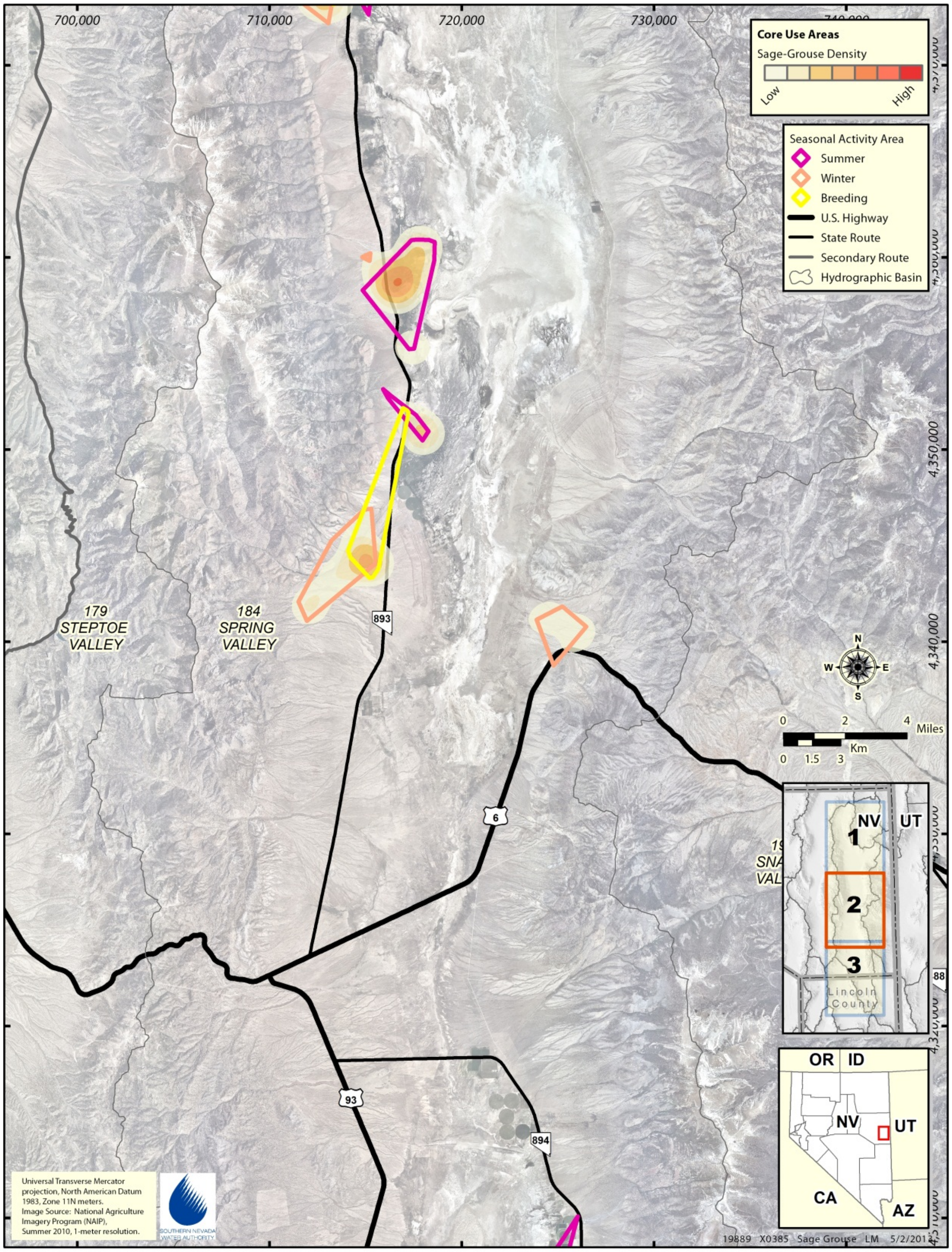

Figure 2b. Seasonal activity areas and core use areas of radio-collared sage-grouse, Spring Valley, Nevada, 2008-2010. Map 2 (central Spring Valley) of 3.

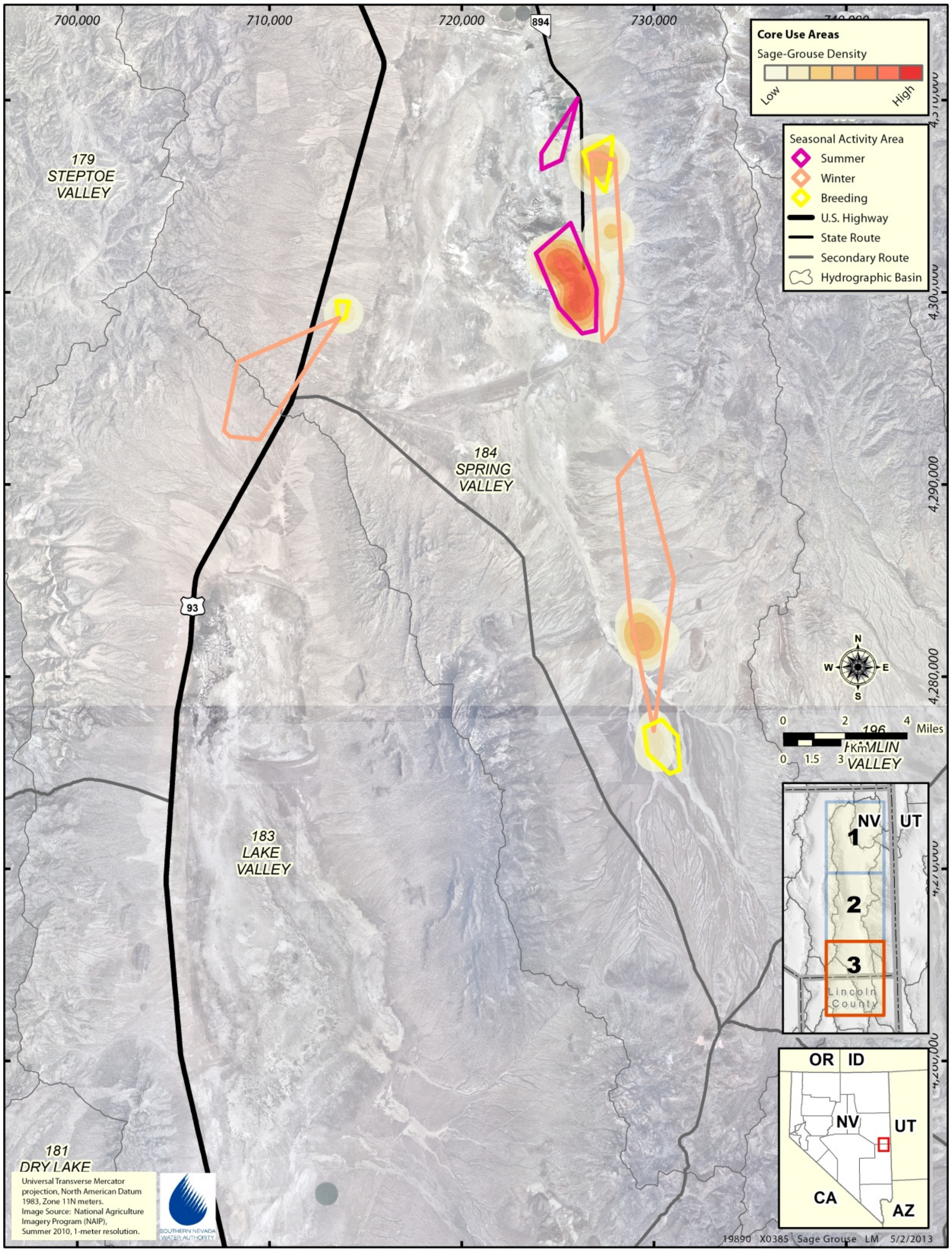

Figure 2c. Seasonal activity areas and core use areas of radio-collared sage-grouse, Spring Valley, Nevada, 2008-2010. Map 3 (south Spring Valley) of 3.

through late May. The nest sites were located 1.0 - 8.6 km (mean = 2.8 km; SE = 1.4) from the leks where, based on tracking data, the females presumably bred.

Radio-collared and uncollared male greater sage-grouse displaying on a lek

General Habitat Use

Annual habitat use ranged from sagebrush habitat in winter to sagebrush and open meadow habitat in summer. Shrubland (e.g., sagebrush, greasewood, rabbitbrush) use occurred throughout the year, but level of use varied by season. Meadow habitat (e.g., wet meadows, grassland, alfalfa field) was most heavily utilized from late May to late September. **Figure 3** depicts the monthly percent of sage-grouse locations found in shrubland and meadow habitats.

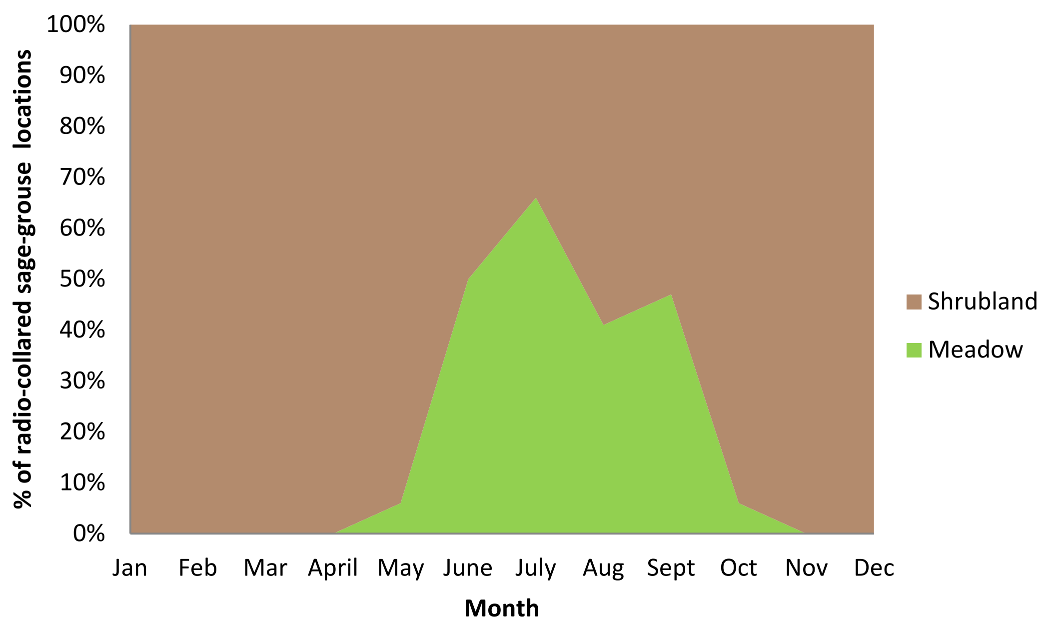

Figure 3. The percent of all sage-grouse radio-telemetry locations documented in shrubland and meadow habitats by month across 2008-2010, Spring Valley, Nevada.

Tracked locations within winter habitat occurred in valley bottoms and on low benches of Spring Valley at elevations ranging from 1726 – 2006 m, and were dominated by one or more sagebrush (*Artemisia*) species, usually black sagebrush (*Artemisia nova*) and Wyoming big sagebrush (*Artemisia tridentata wyomingensis*). Estimated shrub height ranged from 0.1 – 0.7 m, but was generally observed to be in the 0.2 – 0.4 m height range.

Greater sage-grouse winter habitat

The leks where the collared sage-grouse were located occurred in valley bottoms and on low benches of Spring Valley at elevations ranging from 1,752 – 1,932 m, and were characterized by low growth vegetation comprised of winterfat (*Krascheninnikovia*), rabbitbrush (*Chamisa* spp.), sagebrush (*Artemisia* spp.), and/or saltbush (*Atriplex*), with shrub height generally < 0.1 m. Males tended to stay within an approximate 1 km radius of the active leks. These adjacent areas were subsets of the broader winter habitat and dominated by sagebrush (*Artemisia* spp.). Shrub height at tracked locations around the leks ranged from 0.2 – 0.4 m. Nest sites of the collared females were documented in valley bottoms and on low benches at elevations ranging from 5,588 – 6,146 m. General areas where the nests were documented were subsets of the broader winter habitat and dominated by sagebrush (Artemisia spp.), with an estimated height ranging from 0.3 – 0.4 m. All five nests were placed beneath Wyoming big sagebrush shrubs 0.4 –- 0.8 m tall (mean = 0.7 m) with a canopy cover of 50 – 80% (mean = 71%).

Tracked locations with summer habitat occurred in the valley bottoms of Spring Valley at elevations ranging from 1,646 – 1,777 m, and centered on active ranch properties that had natural or irrigated meadows and, in some cases, alfalfa fields. The habitat at the tracked locations consisted of: wetland meadows dominated by sedges (*Carex* spp.), rushes (*Juncus* spp.), and grasses (e,g., *Muhlenbergia* sp.); grasslands dominated by several grass species (e.g., *Poa* sp.); and shrublands dominated by rabbitbrush (*Chamisa* spp.), greasewood (*Sarcobatus*), and sagebrush (*Artemisia* spp.). Plant height in the wet and dry meadows reached up to 1.5 meters, but was generally under 0.7 meters. Shrub height ranged from 0.25 – 0.8 meters.

Greater sage-grouse summer habitat

To further explore the habitat at the tracked locations, we overlaid the points on mapped vegetation community polygons in ArcGIS Software version 10.0 (ESRI). The digital polygons were created as part of a 2008-2009 high-resolution plant community mapping effort focusing on springs, wetlands and meadows in Spring Valley; each polygon was attributed by its three most dominant plant taxa and a classification system of plant community, association, alliance, and biome (McLendon et al., 2011; SNWA et al., 2011). Of the 1,088 radio-telemetry points, 276 (25%) were located within mapped vegetation polygons (approximately 95% on SNWA Robison Ranch [McCoy Creek parcel] and SNWA El Tejón [Shoshone parcel], and the 5% on a privately owned ranch). Thirty-nine percent of those points were within polygons classified in the wetland biome (defined as an area where the soil is saturated for most of the year, but not perennially covered by water, and not dominated by grasses; McLendon et al., 2011). Of these: 86 percent were within polygons dominated or sub-dominated by sedge or rush (*Carex* spp. or *Juncus* spp.), 8 percent were within polygons dominated by *Iris* spp., and 6 percent were within polygons associated with various other types of vegetation. Sixty-one percent of the points were within polygons classified in the grassland biome (defined as an area dominated by grasses and not perennially covered by water; McLendon et al., 2011). Of these: 77 percent were within polygons dominated or sub-dominated by sedge or rush (*Carex* spp. or *Juncus* spp.), and 23 percent were within polygons dominated by grass species (including *Distichlis*, *Muhlenbergia*, *Poa*, *Agrostemma*, *Spartina*, and *Deschampsia* spp.). The plant taxa and biome attributes of the digital vegetation database aligned well with the habitat attributes documented at the radio-telemetry points.

Daily Movements and Habitat Use

The daily movement tracking efforts focused on SNWA deeded properties. We recorded daily movements for 16 collared greater-sage grouse (10 male and 6 female) from June 3, 2009 to August 12, 2009 on summer habitat within ranches. Fifteen of the 16 sage-grouse were tracked within SNWA deeded properties (eight on El Tejón Ranch [Shoshone parcel], and seven on Robison Ranch [four on Meadow Creek parcel and three on McCoy Creek parcel), and one was tracked within a privately owned ranch. The span between tracking days ranged from one to thirteen days, and time between consecutive morning (6:00 - 10:00 am), mid-day (11:00 - 2:30pm), and late afternoon (4:00 - 7:30pm) locations ranged from 3 – 6.5 hours (mean = 5 hours). The total number of daily tracking points recorded was 334. **Table 2** provides a radio-telemetry summary of the number of days tracked and number of location points recorded.

Table 2. A summary of radio-collared sage-grouse with daily tracking movements on ranches, Spring Valley, Nevada, summer 2009.

Bird ID#	Sex	Date Range	# of Days Tracked	# of Location Points*	# of 3-Point Movement-Days**
SNWA El Tejón Ranch (Shoshone parcel)					
246A	F	6/4-8/12	7	21	5
336A	F	6/3-8/12	8	23	6
636B	M	6/3-8/12	10	27	6
676A	F	6/3-8/12	10	26	5
686C	M	6/3-8/12	10	19	3
697A	M	6/3-8/12	10	26	5
706A	F	6/3-7/29	8	20	5
926A	M	6/30-8/12	7	17	4
SNWA Robison Ranch (Meadow Creek parcel)					
435A	M	6/16/8/12	7	21	7
576B	F	6/16-8/12	5	14	3
726A	M	6/4-8/12	9	25	7
887A	M	6/16-8/12	8	22	7
SNWA Robison Ranch (McCoy Creek parcel)					
316C	M	6/3-8/12	9	24	4
755A	M	6/3-8/11	9	17	0
905A	M	6/3-8/12	9	21	0
Privately Owned Ranch (Non-SNWA Property)					
276A	F	6/3-6/24	4	11	1

* Also included in the number of location points presented in Table 1.

** If during the daily tracking an individual was flushed at any time prior to documenting their late afternoon location, we collected data for all three time periods but did not include its movements for the day in the three-point movement-day analyses.

We recorded a total of 68 movement-days (i.e., days with morning, mid-day, and late afternoon location points, and no flushing events prior to the late afternoon location). We recorded one to seven movement-days for 14 individuals, and no movement-days for two sage-grouse due to consistent flushing behavior. Using the nine week period of daily movement-day data, we derived one summer movement activity area for each individual, which ranged in size from 0.3 – 3.5 km^2 (mean = 1.8 km^2, SE = 0.3). Total movements among consecutive points within movement-days (morning to mid-day plus mid-day to late afternoon distances) ranged from 0.09 – 2.67 km (mean = 0.61 km, SE = 0.06).

Two general habitats, open meadow and shrubland, were utilized by the sage-grouse during their documented summer daily movements. **Figure 4** shows the percent of sage-grouse location points found in meadow and shrubland habitat for each time period (morning, mid-day, and late afternoon) across the 64 movement-days. Both meadow and shrubland habitat were used during all three time periods, although at different frequencies, and individuals were not necessarily located in both habitat types within a specific movement-day. Individual birds were located in meadow habitat for all three time periods in 55% of the movement-days, and in shrubland habitat for all three time periods in 8% of the movement-days. The sage-grouse tended to be in meadow or grassland habitat throughout the day, but would often shelter in patches of shrubland when not foraging. When sheltering in shrub patches, they were generally 100 meters or less from open meadow/grassland.

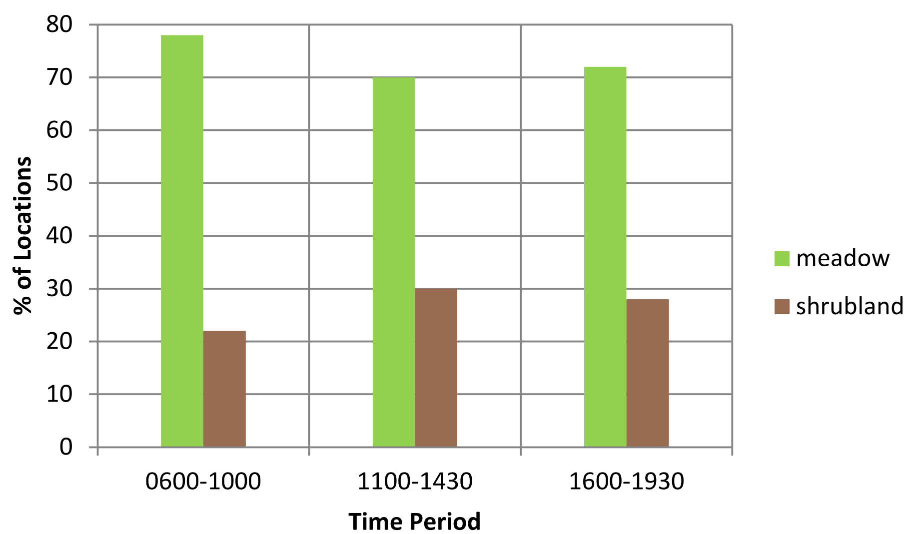

Figure 4. The percent of radio-collared sage-grouse locations found in meadow and shrubland habitat by time period.

To further explore the habitat at the daily tracking locations, we overlaid the points on mapped vegetation community polygons (described above) in ArcGIS Software version 10.0 (ESRI). Because the mapped polygons focused on springs, wetlands and meadows, this summary describes sage-grouse radio-telemetry points located in wetland and grassland areas and ignores points located in shrubland areas. Of the 338 daily tracking radio-telemetry points, 172 (51%) were located within mapped vegetation polygons in wetland and grassland areas on SNWA Robison Ranch (McCoy Creek parcel) and SNWA El Tejón Ranch (Shoshone parcel). Forty-four percent of those points were within polygons classified in the wetland biome. Of these, 100 percent were within polygons dominated or sub-dominated by sedge and/or rush (*Carex* spp. and/or *Juncus* spp.). Fifteen percent of the points were within polygons also sub-dominated by grasses (i.e. *Poa* sp. and *Muhlenbergia* sp.), and 8 percent were within polygons also sub-dominated by *Iris* spp. Sixty-six percent of the points were within polygons classified in the grassland biome. Of these, 100 percent were within polygons dominated or sub-dominated by grasses (including *Distichlis* sp., *Poa* sp, *Muhlenbergia* sp., and

Agrostemma sp.). Seventy-four percent of the points were within polygons also dominated or sub-dominated by sedge and/or rush (*Carex* spp. and/or *Juncus* spp.). The plant taxa and biome attributes of the digital vegetation database aligned well with the habitat attributes documented at the radio-telemetry points.

Nesting and Brood Care

We documented five nesting events over two breeding seasons (three in 2009 and two in 2010). In three of the five nests for which we were able to count eggs, the eggs numbered from five to eight. Four of the five nests failed (one abandoned and three depredated), and one was successful.

The successful nest was initially discovered on May 5, 2009, when we located female # 276A on her nest. By May 28, based on hatched egg shells documented at the nest on this date, we assume that all five eggs successfully hatched. The female was located on May 28 0.8 km away from her nest in an open burn area dominated by grass and patches of black sagebrush, with large numbers of grasshoppers present. We did not observe any chicks at the time. On June 3, 1.3 km away from her previous location in the burn area, the female was located in an irrigated meadow on a privately owned ranch. At that time we observed at least two chicks with her. On June 16, the female was located back on the burn area, but we did not observe any chicks at the time. We discovered the depredated remains of the female on June 24 in a patch of juniper within the burn area, but had no further sightings of the chicks. It is unknown whether the chicks survived.

To follow a hen and her female chick on their summer range, on September 15, 2009 we attached transmitters to a female (# 755B) and her chick (# 706C, 3 – 4 months of age) on the SNWA El Tejón Ranch (Shoshone parcel). They remained on the Shoshone parcel until September 29, 2009, at which time they moved together to their winter range. The telemetry data revealed that the chick and hen were consistently located together until April 20, 2010 when the chick, now a yearling, was tracked to a location separate from the hen. In March and April the yearling and hen were both in the vicinity of the Lincoln Canyon lek, where we presume the yearling bred, on May 4, 2010, the yearling was located on a nest with eight eggs. We located the yearling on the nest multiple times until May 26, at which time we located her off of the nest and determined the nest to be abandoned with no signs of the eggs. On June 8 and June 22, 2010, the yearling and hen were once again located together, and on June 22, 2010 they were at a location halfway between the nest site and the SNWA El Tejón Ranch (Shoshone parcel). We lost battery power on the hen’s collar after June 22. The yearling was located back on the SNWA El Tejón Ranch (Shoshone parcel) in July and August of 2010, at which time the study ended.

Seasonal Site Fidelity

We tracked 19 greater sage-grouse (12 males and 7 females) long enough to assess seasonal site fidelity. All 19 birds exhibited strong site fidelity to the same winter, breeding, and summer ranges. Of the 19 sage-grouse, we tracked 16 through at least two summers, and each individual returned annually to its respective summer range. The linear distance between the derived mean summer range locations each consecutive year for each of the 16 individuals ranged from 0.2 – 2.0 km (mean = 0.9 km, SE = 0.1). In several cases, we tracked individuals to within 0.1 km of where we had located them on the same date the previous summer. We also tracked seven of the sage-grouse through at least two winters, and each individual returned annually to its respective winter range. The linear distance between the derived mean winter range locations each consecutive year for each of the seven individuals ranged from 0.2 – 6.9 km (mean = 2.5 km, SE = 1.1). We tracked 10 of the sage-grouse through at least two breeding seasons, and each bird returned annually to its respective breeding area(s). The linear distance between the derived mean breeding range locations each consecutive year for each of the 10 individuals ranged from 0.1 – 2.5 km (mean = 0.8 km, SE = 0.2). Male individuals were often observed on leks at exactly the same spot we had observed them the previous year. Also, in the one case where a female nested in consecutive years, the nests were 2.4 km apart and within the same breeding activity area.

Strong fidelity to a specific breeding location was observed for four radio-collared individuals that were located overwintering in the vicinity of a known active lek, but were tracked migrating to a different lek to breed. Two males (# 905A and # 755A) were located overwintering directly adjacent to a known active lek site, but traveled 37 km at the onset of the breeding season to utilize a different lek. We were able to track # 905A long enough to document this site fidelity in two consecutive breeding seasons. Similarly, another collared male (# 736B) traveled 15 km and a collared female (# 276A) traveled 39 km at the onset of the breeding season to utilize a lek, although there was a lek closer to their winter range.

Fidelity to specific leks during the breeding season was not always confined to the use of a single lek. We documented three collared males and one female visiting two different leks during the span of a single breeding season. One male (# 887A) was found to utilize two leks, 1.9 km apart, within the same breeding activity area. Although not directly observed on either lek, the female (# 576B) was found near (<200 m) two different leks that were 4.5 km apart. The other two males (#726A and #926A) were each documented utilizing leks that were 20.0 km and 15.0 km apart, respectively, and which were located in two different breeding activity areas. Male #926A was tracked over three breeding seasons and was found to utilize both leks in 2008 and 2009, but only one in 2010.

Core Use Areas

We derived 18 core use areas depicting areas of highest sage-grouse densities. The core use areas reflect the intensity of use by incorporating both the distribution of location points, and the number individuals (collared and uncollared) recorded at each location point. Of the 2,636 location points (1,088 location points of collared individuals plus 1,548 uncollared individuals documented at collard bird locations) collected from 2008-2010, 2,480 points were encompassed by the core use areas. The relative kernel density estimates within the core use areas ranged from 4.8 - 110.3 sage-grouse/ km^2, which are displayed in raster form in **Figures 2a-c** and **Figures 5a-h** (from high [red] to low [tan] relative density). It is important to note that these are estimates from the kernel density analysis, and not actual recorded densities. **Figures 2a-c** show the core use areas in relation to the seasonal activity areas, and **Figures 5a-h** show the core use areas, seasonal activity areas, and telemetry points in relation to SNWA deeded ranch properties and associated grazing allotments.

Fate of Radio-Collared Individuals

Of the 35 collared birds, 17 (12 males, 5 females) were alive at their last location point, and 18 (11 males, 7 females) were confirmed mortalities during the study. Of the 17 birds that were alive at their last location point: nine were alive at the end of the study (6 males, 3 females; August 2010); four were alive at their last collar transmission (2 males, 2 females, January-June 2010, lost transmission likely due to low battery power); and four were alive prior to finding their slipped collar on the ground (4 males, no sign of depredation or injury). Of the 18 confirmed mortalities during the study, 16 (10 males, 6 females) appeared to have been depredated, and two (1 male, 1 female) died of unknown causes. Twelve of the depredation incidents took place on their summer range, two on their winter range, and two on their breeding range. In most cases, the predators responsible for mortalities could not be determined. However, there were four cases where the predators were apparent: in two cases, coyote (*Canis latrans*) tracks and scat were found next to sage-grouse remains; in one case, the transmitter signal came from a kit fox (*Vulpes macrotis*) burrow; and in one case, an impact depression was observed in a shrub next to the remains of a sage-grouse suggesting an aerial attack by a large raptor. It was noted that on two other occasions, we observed a golden eagle (*Aquila chrysaetos*) unsuccessfully attempt to take a sage-grouse we were tracking. Of the 17 birds that were alive at their last location point, we tracked them for 122 – 826 days (mean = 451 days, SE = 59). Of the 18 sage-grouse that were confirmed dead during the study, we tracked them for 1 – 729 days (mean = 220 days, SE = 56).

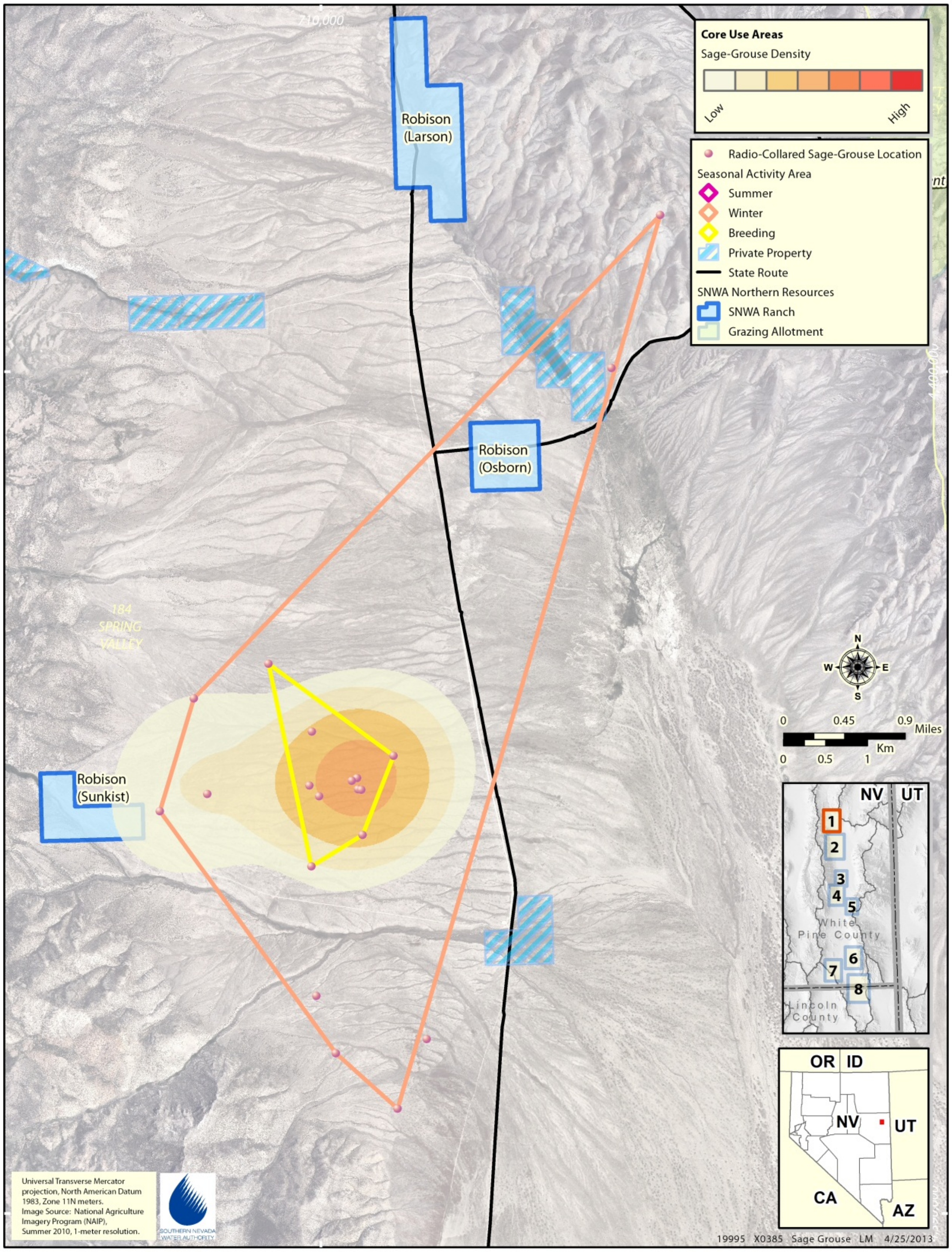

Figure 5a. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 1 of 8.

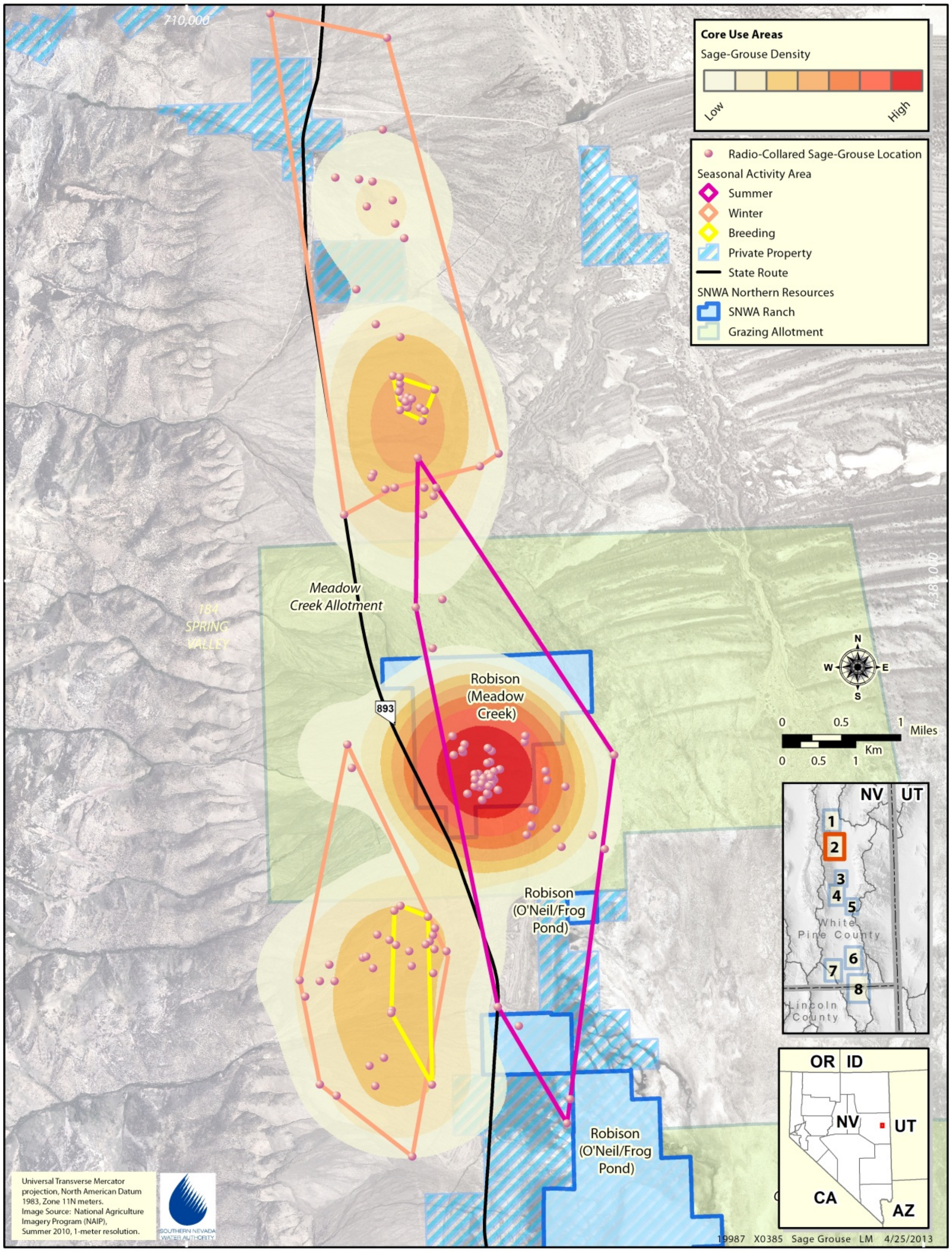

Figure 5b. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 2 of 8.

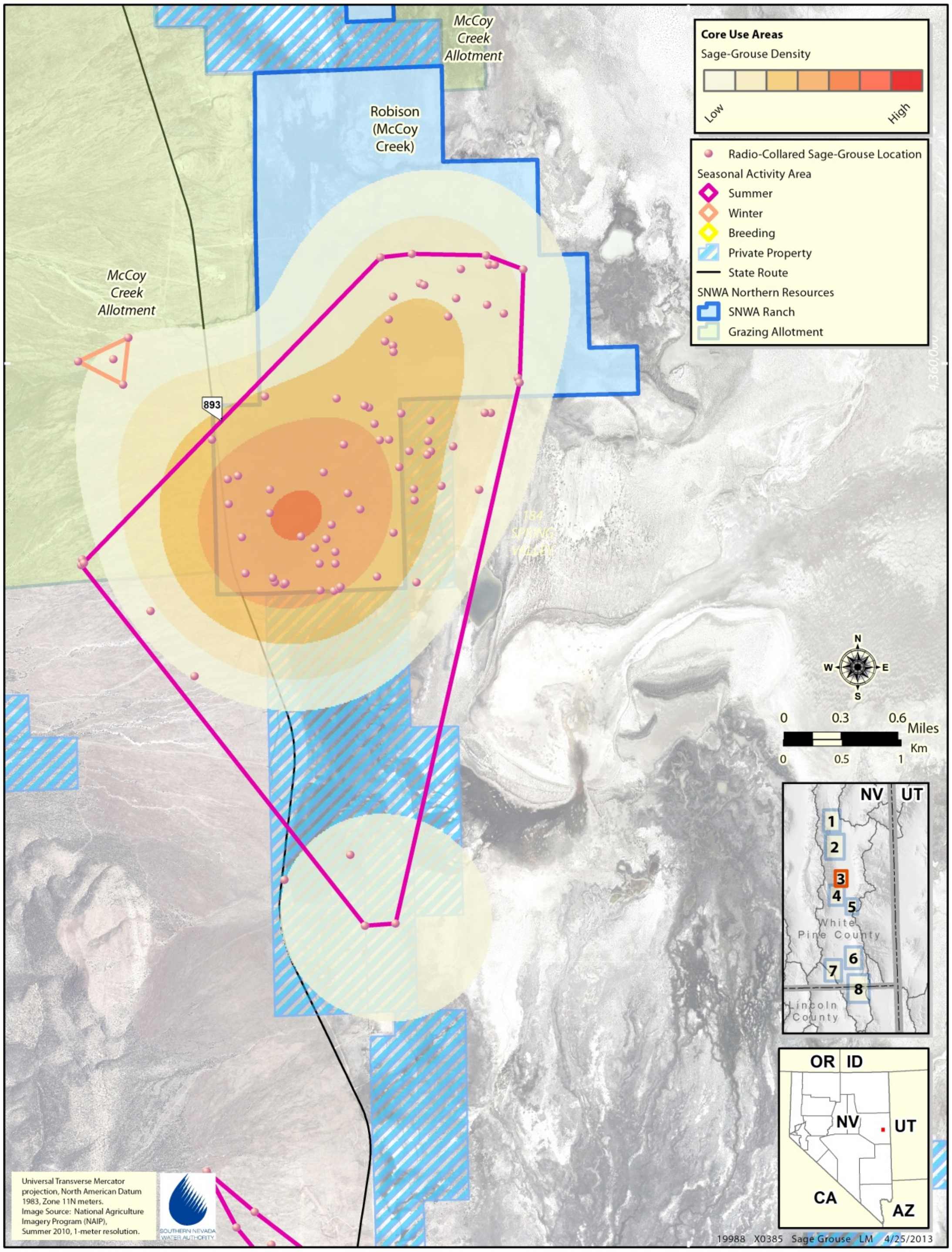

Figure 5c. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 3 of 8.

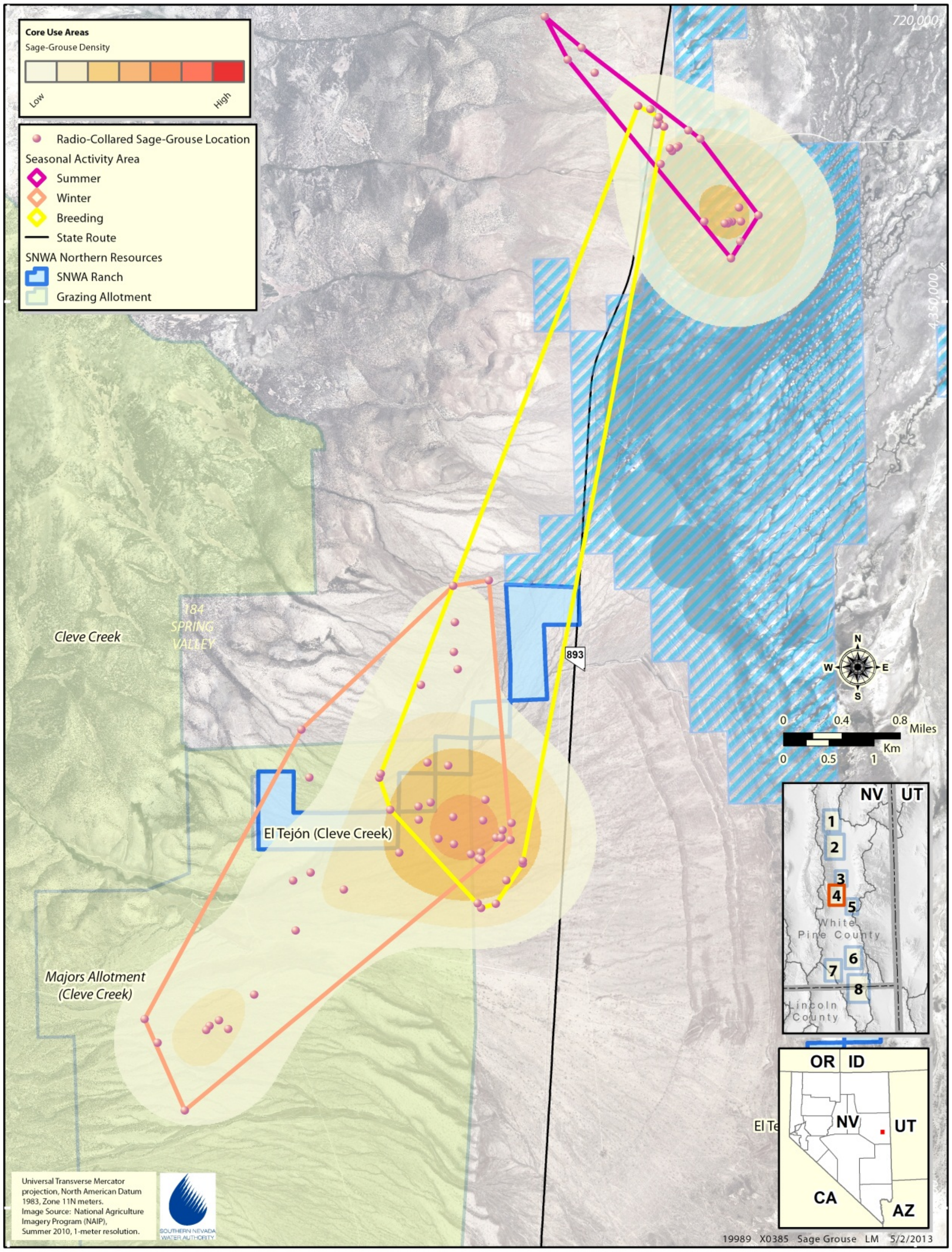

Figure 5d. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 4 of 8.

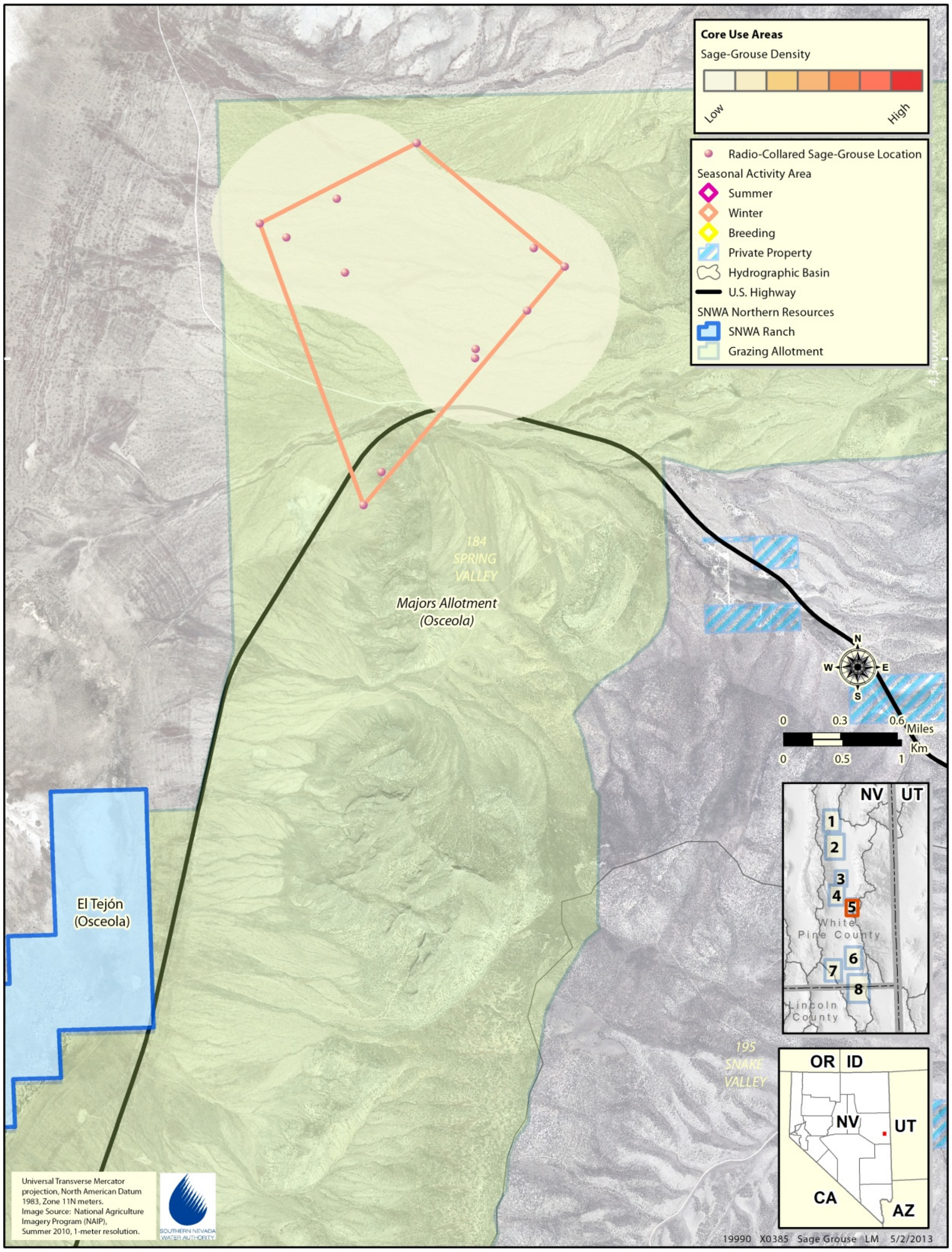

Figure 5e. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 5 of 8.

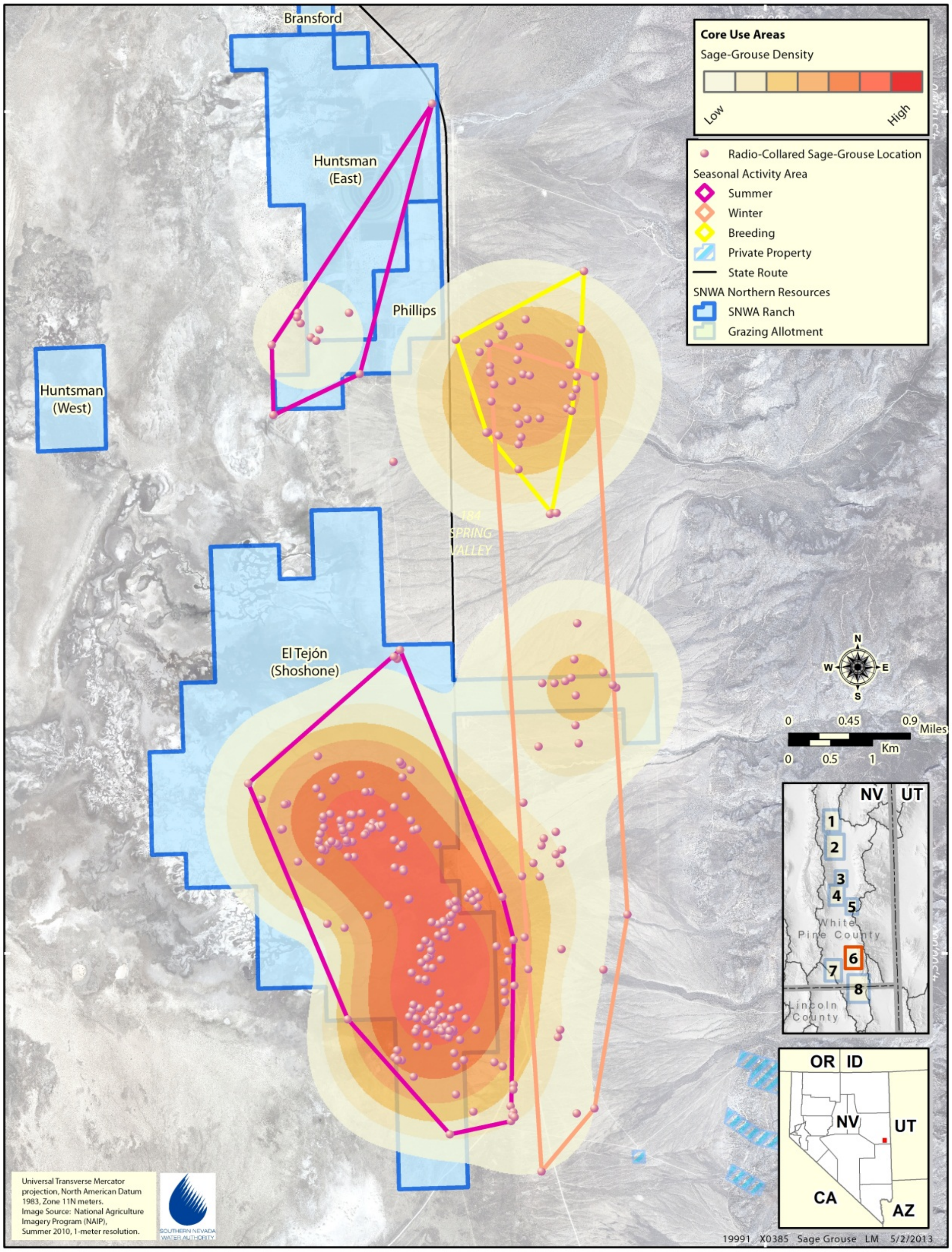

Figure 5f. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 6 of 8.

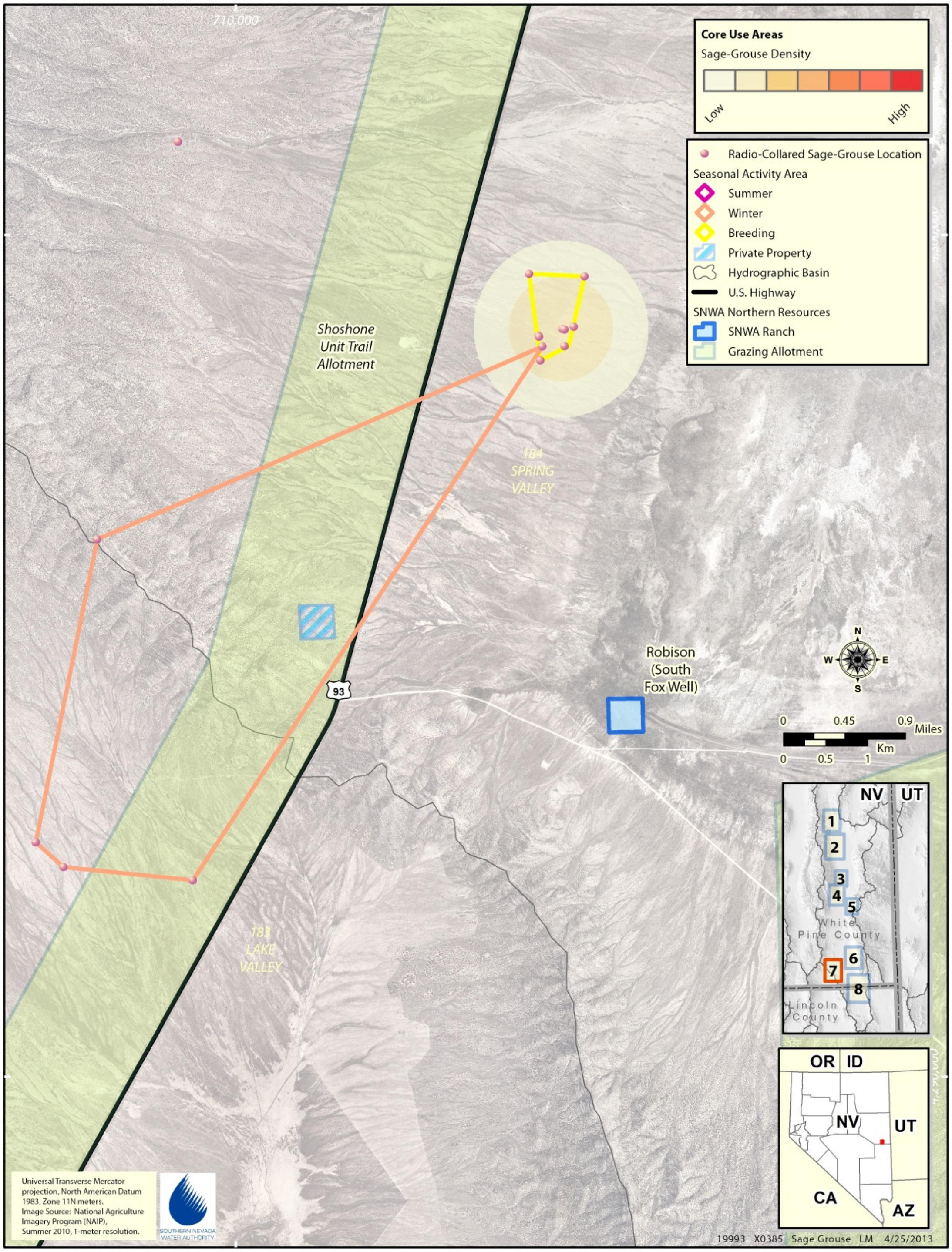

Figure 5g. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 7 of 8.

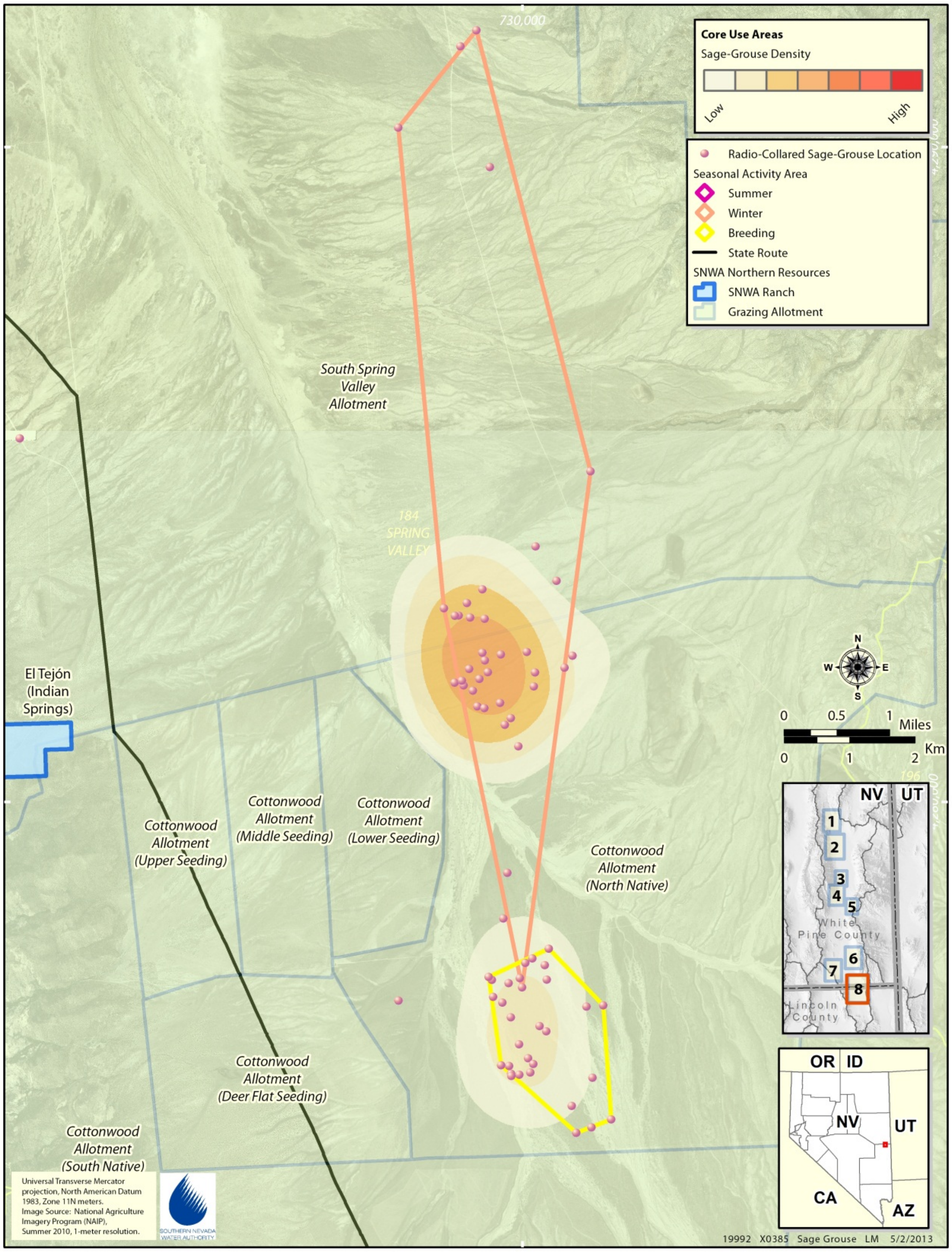

Figure 5h. Radio-collared sage-grouse core use areas in Spring Valley, Nevada, shown in relation to radio-collared sage-grouse location points, seasonal activity areas, SNWA deeded properties, and associated grazing allotments. Map 8 of 8.

DISCUSSION

This study investigated the movements of sage-grouse in Spring Valley, Nevada, with particular focus on the use of SNWA ranches and associated rangelands. The study was purposely biased toward SNWA deeded properties, where the majority of capture efforts took place (71% of subjects were captured on SNWA deeded properties, and 25% were captured at leks on BLM-managed land in the vicinity of SNWA deeded properties). Of the 33 sage-grouse tracked during at least one summer season, 31 (94%) used SNWA deeded properties as their primary summer range. Of the 25 sage-grouse tracked during at least one winter season, 19 (76%) were documented on BLM grazing allotments associated with SNWA deeded properties. The following discussion presents information regarding tracked movements and areas of use that can be applied to sage-grouse conservation in Spring Valley and on SNWA property.

Interseasonal Movements and Migration

The sage-grouse that we tracked in Spring Valley exhibited various migratory tendencies. Connelly et al. (2000) defined nonmigratory and migratory populations based on a temporal and geographic basis: (1) nonmigratory populations do not move ≥ 10 km between or among seasonal ranges; (2) one-stage migratory populations move between two distinct seasonal ranges; and (3) two-stage migratory populations move among three distinct seasonal ranges. Using this definition, we did not see one consistent migratory pattern for the Spring Valley population segment, but rather different migratory patterns across individuals. Of the 22 sage-grouse (14 males, 8 females) that we tracked long enough to document at least one full interseasonal movement cycle, seven were nonmigratory and 15 were migratory. Of the migratory individuals, seven exhibited one-stage migration between a distinct summer range and an integrated winter and breeding range, and eight exhibited two-stage migration among distinct summer, winter, and breeding ranges. Although sample size is small, there may have been a difference in tendency for males and females to migrate: of the eight females, 50% (4) were nonmigratory, 25% (2) exhibited one-stage migration, and 25% (2) exhibited two-stage migration; and of the 14 males, 21% (3) were nonmigratory, 36% (5) exhibited one-stage migration, and 43% (6) exhibited two-stage migration.

The timing of migrations between seasonal ranges in Spring Valley in 2008-2010 fell within the general periods reported range-wide by Schroeder et al. (1999). Summer to winter range migrations typically occurred in late September to late October; winter to breeding range migrations typically occurred in late February to early March (males) and March and April (females); and breeding to summer range migrations typically occurred from May to June. In 2010, however, many of the individuals delayed movement into summer habitat until late June at the earliest. This delay may have been due to the higher densities of forage insects present in the sagebrush habitat that the sage-grouse continued to occupy (discussed in more detail below).

The distances traveled between seasonal ranges (winter to breeding, breeding to summer, and summer to winter ranges) averaged 12.1 km, 14.9 km, and 14.2 km, respectively.

The collared sage-grouse in this study that exhibited two-stage migrations traveled the longest distances. The longest interseasonal distance travelers were female # 276A (**Figure 6)** and male # 905A **(Figure 7**), which covered 91 km and 74 km (respectively) roundtrip across distinct winter, breeding, and summer ranges. **Figure 6** and **Figure 7** demonstrate their interseasonal and intraseasonal movements over an approximately one year period. Breeding movements for female 276A (**Figure 6**) include post-mating movements in 2008 that center on the area of her 2009 nest site, although we did not document a nesting event for her in 2008. Given this, it is possible that she had a failed nesting attempt in 2008 that was missed. Breeding movements for male 905A (**Figure 7**) are not detailed in the map, but centered on and around the lek that he utilized.

The migration distances that we observed were likely influenced by a variety of factors, including experience, site fidelity and traditional site learning. Of the seven sage-grouse that we tracked long enough to document at least two winter, summer, or breeding seasons, all seven returned to the same seasonal ranges each year. Of these, one male (# 926) was captured on a lek in 2008, and subsequently tracked to the same lek in 2009 and 2010. We also documented individuals bypassing apparently suitable habitat and active lek sites to travel up to 48 km to reach seemingly similar habitat, suggesting that they were selecting sites not only based on habitat, but also experience. The bypassing of active lek sites can be seen in the examples shown in **Figures 6** and **7**. Traditional site learning was also documented when a yearling female (# 706) followed its mother (# 755B) to the vicinity of a lek, where the yearling presumably bred (her nest was later documented nearby). That summer the yearling returned to within as little as two kilometers of where it was located during its first summer as a chick. These findings are consistent with the literature (e.g., Connelly et al. 2011) in which site fidelity is reported to be quite strong in sage-grouse populations.

Seasonal Activity Areas, Intraseasonal & Daily Movements

Winter, breeding, and summer activity areas (general areas of use) derived from the tracking data provide a conservative estimate of the boundaries and size of areas utilized by the radio-collared sage-grouse in each season **(Figures 2a-c** and **Figures 5a-h**). Seasonal activity areas were largest in the winter season (mean = 13.0 km^2), reduced in the summer season (mean = 7.6 km^2), and smallest in the breeding season (mean = 2.7 km^2). We attribute this pattern to the broader availability of wintertime forage and loafing habitats, more limited availability of summertime mesic habitats, and specific habitat conditions and behaviors (e.g., congregations at leks, nest establishment after mating) that define breeding areas.

All seasonal activity areas had some overlap with the core use areas. In most cases the activity areas covered larger areas, as they included those points which were removed as outliers in the kernel density analysis that derived the core use areas. The seasonal activity areas overlapped with the same SNWA deeded properties and associated BLM grazing allotments that the core use areas overlapped with (see below), but also overlapped with SNWA Robison Ranch (Osborn parcel) the BLM Shoshone Unit Trail Allotment.

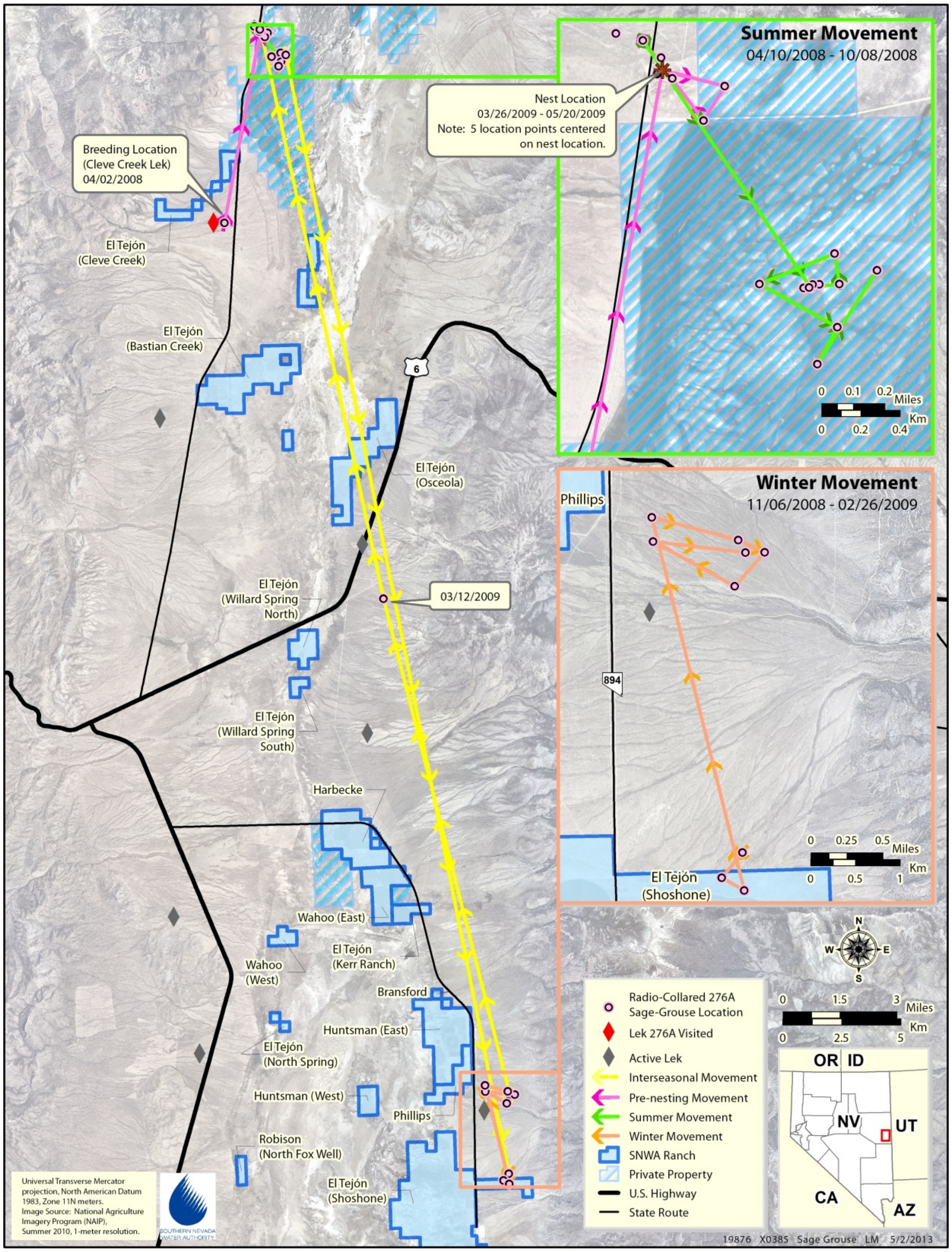

Figure 6. Interseasonal and intraseasonal movements of radio-collared female sage-grouse 276A from April 02, 2008 to May 20, 2009.

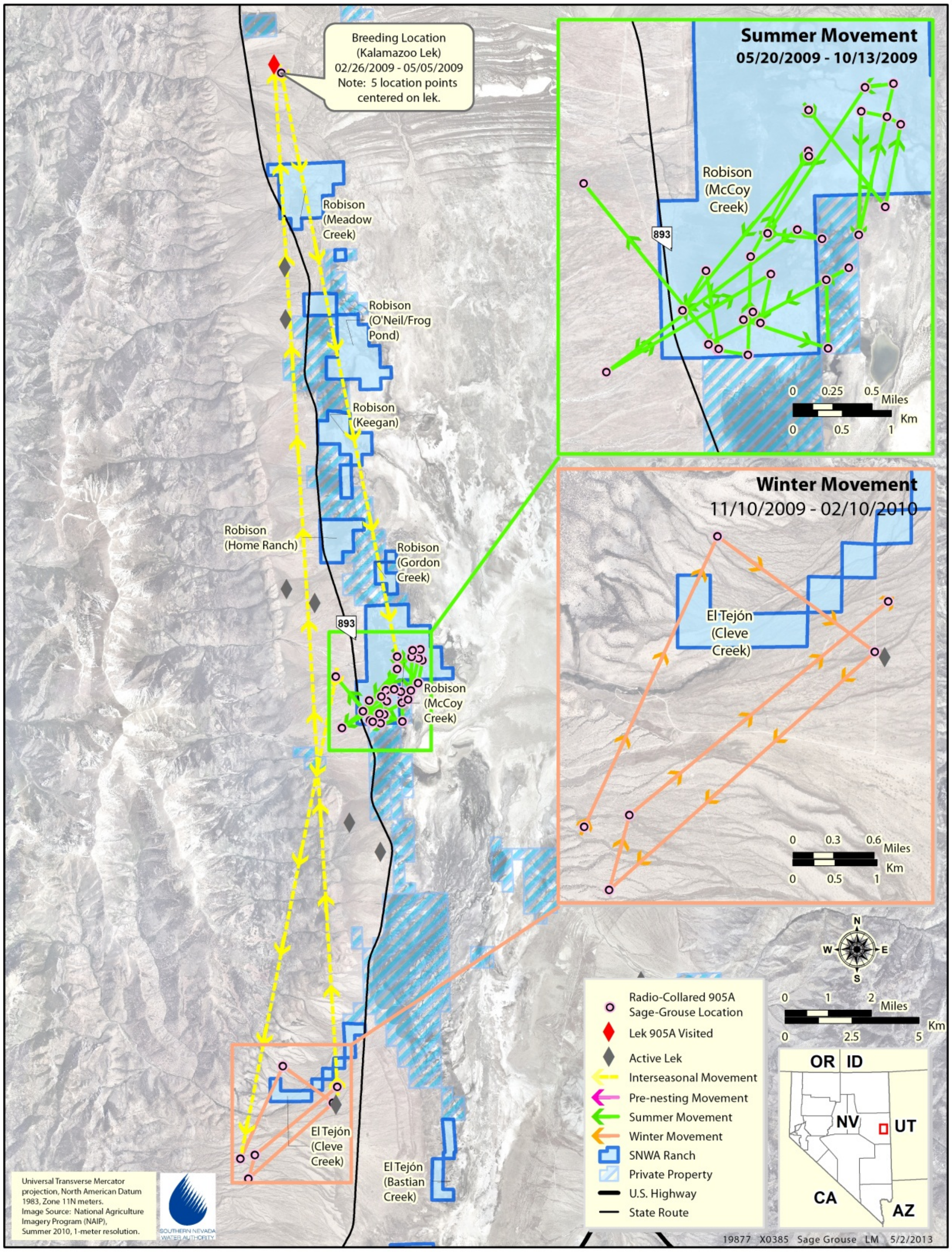

Figure 7. Interseasonal and intraseasonal movements of radio-collared male sage-grouse 905A from February 26, 2009 to February 10, 2010.

The intraseasonal movements that we tracked offer indications of general movement distances within seasons, and help define the availability of resources (e.g., food and cover). Although actual movements were greater than calculated (we only tracked movements between consecutive points approximately 2 weeks apart), the linear movement distances between points provide a relative measure of intraseasonal movement behavior. Movement distances between consecutive points were longest in the winter range (mean = 1.9 km), as well as in the breeding range for females (due to greater stray from leks and movements to nest sites; mean = 1.9 km). Movement distances were relatively moderate in the summer range (mean = 1.0 km), and shortest for males in their breeding range (mean = 0.6 km). The limited distance traveled by males during the breeding season is consistent with other studies. In one study, Wallestad et al. (1974) documented radio-collared male sage-grouse moving $\leq$ 1.8 km from a lek to forage, returning to the lek each morning (central place foraging). In another study, Eng (1963) documented 75% of radio-collared males moving $\leq$ 1.2 km from their lek during the daytime, and $\leq$ 2.5 km when including movements to roosting sites. Relatively shorter distances traveled within a season likely suggests more concentrated use of a limited resource (e.g., mesic summer habitats and lek sites), or a greater reluctance to leave a particular location site for an extended time period (e.g., collared males tended to stay within 1 km of leks during the breeding season).

The daily movement telemetry data we collected provided supplemental summer movement information on individual collared sage-grouse utilizing SNWA ranchland. The data collected from tracking a given sage-grouse three times per day exhibit details of movements and habitat use that could not be obtained from the bi-weekly tracking alone. The daily movement data reveal more frequent movements and intricate spatial use than the biweekly data suggest, and provide additional information about land use that can inform management on local scale.

Core Use Areas

The kernel density analysis derived seasonal core use areas, which are areas of relatively higher sage-grouse densities based on the tracking data. Because the core use areas were derived using both the distribution of location points and the number individuals (collared and uncollared) recorded at each location point, the core use area rasters depicted in **Figures 2a-c** and **Figures 5a-h** reflect the relative intensity of sage-grouse use. **Figures 2a-c** and **Figures 5a-h** also demonstrate how core use areas generally fell within activity areas, although it is noted that the core use areas extend beyond actual location points due to the kernel density analysis. The highest density areas occurred on and around active leks and within summer ranges. Leks concentrated sage-grouse, particularly males, over a two to three month period, and summer ranges tended to have discrete resource areas that concentrated sage-grouse for a three to four month period. This concentrated long-term use equates to higher densities in the kernel density analysis. In contrast, winter range generally provided a widespread resource (sagebrush) that allows sage-grouse to utilize a broader geographic area over time.

The core use areas highlight which SNWA deeded properties and associated BLM grazing allotments were more intensely used by sage-grouse recorded during the study. As shown in **Figures 5a-h**, nine (50%) core use areas overlapped with SNWA deeded properties, and fifteen (83%) overlapped with associated BLM grazing allotments. In particular, core use areas overlapped with the following SNWA deeded properties, which were largely used by sage-grouse for summer range: Robison Ranch (Meadow Creek and McCoy Creek parcels), El Tejón Ranch (Shoshone parcel), Phillips Ranch, and Huntsman Ranch. Core use areas also overlapped with the following SNWA deeded properties and associated BLM grazing allotments used by sage-grouse for winter range: Robison Ranch (Sunkist parcel) and El Tejón Ranch (Cleve Creek parcel), and the BLM Cottonwood Allotment, South Spring Valley Allotment, Majors Allotment (Osceola and Cleve Creek pastures), and McCoy Creek Allotment. Three of these grazing allotments (Majors Allotment [Cleve Creek pasture], South Spring Valley Allotment, and Cottonwood Allotment) also included three active leks (Cleve Creek, Lincoln Canyon, and South Spring Valley #4). The highest sage-grouse densities occurred on the SNWA Robison Ranch (Meadow Creek and McCoy Creek parcels) and the SNWA El Tejón Ranch (Shoshone parcel) during the summer.

Although no core use areas overlapped with the SNWA Harbecke Ranch, sage-grouse use of that ranch property is known. During this study we observed several uncollared adult sage-grouse in the alfalfa fields on the SNWA Harbecke Ranch, and we attempted to capture a group of four sage-grouse on Harbecke Ranch in summer 2009. In 2007, NDOW documented summer use of the SNWA Harbecke Ranch and the adjacent BLM Willard Creek Allotment by two radio-collared male sage-grouse (NDOW, unpubl. data). These data and observations suggest the possibility of higher sage-grouse densities on SNWA Harbecke Ranch than depicted by the tracking data.

Tracking data also demonstrated sage-grouse use of SNWA Wahoo Ranch and the SNWA Robison Ranch (O'Neal/Frog Pond parcel). Female #246A was located on the SNWA Wahoo Ranch on a single occasion outside of her normal summer range. While she moved off by the next tracking session, this data suggests that the Wahoo alfalfa fields are at least occasionally used by sage-grouse. Female # 576B was located on and near the SNWA Robison Ranch (O'Neal/Frog Pond parcel) for a three week period in late summer, suggesting that sage-grouse may also use this parcel for summer range.

Habitat Use and Foraging

Seasonal habitat use by sage-grouse in Spring Valley was similar to use documented range-wide (Connelly and Knick 2011). Generally, in 2008-2010 the radio-collared sage-grouse used sagebrush in winter and a meadow and shrubland mix in summer. The winter ranges used by the collared sage-grouse in 2008-2010 were dominated by black sagebrush and Wyoming sagebrush, both of which were found to comprise > 90% of sage-grouse winter diet in south-central Utah (Thacker et al. 2011). The shrub height we reported at tracked sage-grouse winter locations of 0.2 – 0.4 m was similar to the average of 0.32 m reported by Eng et al. (1972) in central Montana. Breeding habitat utilized by the radio-collared individuals appeared to be similar to the general breeding habitat described by Connelly and Knick (2011), with leks occurring in openings within shrubland habitats and nesting taking place in sagebrush communities. The summer ranges had forbs and insects, both of which have been found to comprise sage-grouse summer diet (Martin 1970; Peterson 1952; Wallestad et al. 1975).

The spatio-temporal movements of the sage-grouse in 2008-2010 appeared to be predicated in-part upon the availability of forage. Sage-grouse migrations from summer to winter habitat appeared to be associated with the onset of forb (including cultivated alfalfa) dormancy / die-off and a concomitant switch to a winter diet of sagebrush. Similarly, migrations from breeding habitat to summer habitat in May/June appeared to be associated with the general lack and/or desiccation of forbs in sagebrush habitat, and the increasing availability of forbs in meadow habitat.

Radio-collared female greater sage-grouse (# 246A) feeds on sagebrush in winter habitat

A small percentage of forb species growing on the summer ranges likely make up a critical part of sage-grouse diet. Dandelions appeared quite abundant in several of the 2008-2010 summer activity areas. We also tracked sage-grouse to alfalfa fields on two ranches (SNWA Robison Ranch [Meadow Creek parcel] and a privately owned ranch), and NDOW has documented use of alfalfa fields on the SNWA Harbecke Ranch (NDOW 2007). In another study, Martin (1970) reported that dandelion (*Taraxacum* spp.) comprised 45% of sage-grouse summer diet, but also included legumes (i.e., *Astragalus* spp.) and sagebrush.

Insects also comprise a portion of sage-grouse diet. Peterson (1952) documented that insects comprised up to 60% of a 1 week old sage-grouse chick's diet, but that the percentage dropped to approximately 5% in 12 week old chicks. In another study, Wallestad et al. (1975) reported that 42% of greater sage-grouse crops collected in July contained grasshoppers. This suggests that the radio-collared sage-grouse we located in open summer habitat with few noticeable forbs, but high densities of grasshoppers (*Melanoplus* sp. or *Camnula* sp.), were likely foraging on the insects.

In 2010, the timing of migration of tracked sage-grouse onto their summer ranges appeared to have been influenced by insect availability. Approximately 80% of the collared sage-grouse (sample size [n] = 9) delayed movement onto their summer range until late June to early August. Of these, 45% (n = 5) lingered near their breeding areas where large numbers of cicadas (*Okangana* sp.) or grasshoppers were observed, and 36% (n = 4) stopped in sagebrush habitat adjacent to their summer range where large numbers of cicadas (*Okangana* sp.) were emerging. The other two collared sage-grouse (18%) did not delay their movements onto their summer range, where large numbers of grasshoppers were observed. The delay in seasonal habitat change, in conjunction with the presence of high insect numbers, suggests that the sage-grouse may have modified their interseasonal migrations to capitalize on insect food sources.

The movements of sage-grouse in summer range also appeared to be predicated upon the availability of cover. The 2008-2010 summer range and daily movement data we collected suggested heavy use of ranchland areas dominated by grasses, sedges, and rushes. These plant types are not known to comprise a large percentage of sage-grouse diet, but can provide cover to sage-grouse foraging on associated forbs. We also documented radio- roosting in dense sedge and rush which afforded some cover while still allowing the birds to see approaching predators. The data also reveal the use of shrub cover near or within meadow habitat, suggesting the importance of shrub patches in the daily routine of sage-grouse in meadows.

Although we occasionally located radio-collared individuals during summer close to water (e.g. springs or diversion ditches), it is possible they were not directly using the water resources, but rather foraging on the forbs that were supported by the mesic conditions. Connelly et al. (2011) suggest that sage-grouse obtain needed water from succulent forbs, and do not commonly rely upon water developments even during relatively dry years. Connelly et al. (2011) conclude that "movements to irrigated agricultural lands are probably a response to a lack of forbs rather than a lack of [standing] water." Thus, it appears that water availability to support forbs, and not direct sage-grouse use of standing water, was an important component of the ranch habitat.

In a telemetry study of sage-grouse in north-central Nevada, Oakleaf (1971) reported heavy summer use of upland meadows by sage-grouse, but also recognized that, when available, native and alfalfa hay fields may be similarly used in other parts of their range. Although we did not detect upland meadow use by the radio-collared subjects, the data cannot preclude its use. In general, the patterns of ranchland meadow use by the radio-collared sage-grouse in this study paralleled Oakleaf's (1971) observations of radio-collared sage-grouse in a natural upland meadow setting. This suggests that the observed sage-grouse behaviors on summer habitat in this study represent what is generally considered normal for the species.

Nesting

We documented nests for 50% percent of the females that we tracked during the 2009 and 2010 breeding seasons (2009: 6 females tracked, 3 nests documented; 2010: 4 females tracked, 2 nests documented). Given that the percent likelihood of a female nesting in any given year is known to range from 55 – 100% (Connelly and Knick 2011), the number of nests that we documented appears low. However, it is possible that by tracking sage-grouse every 10 – 15 days, we missed nesting attempts. The laying period lasts only 7 – 10 days, and the average likelihood of re-nesting is only 30% if the first nesting attempt fails (Connelly and Knick 2011). In addition, of the five nests we documented, the 20% success rate fell within the low end of the reported range of 15 – 86% (Connelly and Knick 2011). We were unable to determine what predator(s) were involved in nest depredation events, and were unable to determine the cause of nest abandonment. Given the small sample size (n = 5 across two years), it is unknown whether these nesting and success rates are reflective of typical sage-grouse nesting in Spring Valley.

Fate of Radio-Collared Individuals

The longevity of the collared sage-grouse tracked from 2008-2010 ranged from 3 months to at least 3.2 years old (mean = at least 2 years old), although it is quite possible that some individuals lived longer. These calculated ages are based on two assumptions, as follows. 1) If individuals did not show juvenile morphology, they were assumed born as late as the nesting season the year prior to collaring. Thirty-three of the 35 collared individuals (94%) did not have juvenile morphology, and based on date collared were assumed to be at least 0.9-1.5 years old. Given that sage-grouse have an average life span of 1.5 years but may live up to 9 years (Macias 2011), however, it is possible that some of these individuals had been born in previous years and were older than one year at collaring. 2) It was assumed that the last day of life for all 35 individuals was their last day tracked. However, for 17 of the 35 individuals (50%) that were alive at their last tracking observation, it is highly likely that they lived longer than documented. Approximately 40% of the individuals survived at least one year with collars on (range for all 35 individuals = 1 day – 2.3 years, mean = 0.9 years), although again it is likely that the 17 individuals that were alive at their last tracking survived longer with their collars on. These data suggest that the radio-collars did not significantly impact an individual's chances of survival.

Of the 18 mortality events that we recorded during the course of the study, direct or indirect evidence suggest that 89% (n = 16) were the result of predation. Analyses of spatio-temporal mortality rates revealed that 72% mortalities took place in summer, 17% took place during the breeding season, and 11% took place in winter. This is consistent with published reports of high overwinter survival and lower survival over the summer (Connelly et al. 2011). Higher summer mortality may be due to increased exposure to predators while foraging on open meadows, coupled with increased predation pressure. A concentration of resources (e.g., prey and water) may draw in predators to the same mesic meadow conditions that attract the sage-grouse. A similar situation may develop around leks where male sage-grouse may be especially vulnerable to predation (Connelly et al. 2011). As such, annual male survival has been documented to range from 46 – 54%, whereas annual female survival has been documented to range from 68 – 85% (Connelly et al. 2000). On winter range, birds may be more dispersed over a larger area with more consistent cover, snow may offer additional protection, and predators may be less concentrated.

CONCLUSION

A radio-telemetry survey of 35 sage-grouse in Spring Valley between 2008-2010 documented sage-grouse use of SNWA deeded properties, associated BLM grazing allotments, and leks near SNWA properties in Spring Valley, Nevada. The study was purposely biased toward SNWA deeded properties on the valley floor and valley floor-alluvial fan interface where the majority of capture efforts took place, and thus does not represent sage-grouse land use across the entire basin. Of the 33 sage-grouse tracked during at least one summer season, 31 (94%) used SNWA deeded properties as their primary summer range. Of the 25 sage-grouse tracked during at least one winter season, 19 (76%) were documented on BLM grazing allotments associated with the SNWA ranches. The tracked sage-grouse exhibited both migratory and non-migratory patterns, and all individuals exhibited site fidelity to their seasonal ranges. All individuals tracked to primary summer range used ranchland managed for livestock and/or agriculture.

We identified three SNWA deeded land parcels that were used predominantly by the collared and associated uncollared sage-grouse in summer: Robison Ranch (Meadow Creek and McCoy Creek parcels), and El Tejón Ranch (Shoshone parcel). Collared and associated uncollared sage-grouse use was also observed on SNWA Huntsman Ranch and SNWA Phillips Ranches, although to a lesser degree. A small number of collared sage-grouse points were located on the SNWA deeded properties of Robison Ranch (O'Neal/Frog Pond parcel) and Wahoo Ranch. The summer use of ranch properties generally began in late May and often lasted until mid-October each year. Daily summer movement data on these ranches suggest that sage-grouse concentrate their activities within smaller areas compared to winter habitat, and that they utilize shrubland patches, open meadows, and occasionally alfalfa fields.

We also identified BLM grazing allotments associated with SNWA properties that were used by the collared sage-grouse in winter: Cottonwood Allotment, South Spring Valley Allotment, and Majors Allotment (Cleve Creek and Osceola pastures). The winter use of these areas in southern Spring Valley generally began in October and lasted through the breeding season to mid-May each year. The collared sage-grouse were tracked predominantly in shrub habitat dominated by black sagebrush and Wyoming sagebrush.

The documentation of sage-grouse seasonal activity areas, core use areas habitat use, and interseasonal, intraseasonal, and daily movements can inform future management strategies to protect and enhance Spring Valley's sage-grouse population. This information can inform biological and hydrologic monitoring of sage-grouse groundwater-dependent habitats on BLM-managed lands, which is required in areas that may be affected by groundwater pumping for the Clark, Lincoln and White Pine Counties Groundwater Development Project (GWD Project) (BLM, 2012 at page 14: conservation measure GW-WL-10). This information can also aid in the development of a Candidate Conservation Agreement and Candidate Conservation Agreement with Assurances (CCAA) (SNWA, 2012), which is planned to provide benefit to sage-grouse that occur on SNWA deeded properties in Spring Valley.

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