Human–Wildlife Interactions 7(2):172–181, Fall 2013

Inter-seasonal movements in tri-state greater sage-grouse: implications for state-centric conservation plans

Jan S. Reinhart, Utah Department of Agriculture and Food, 350 North Redwood Road, Salt Lake City, Utah 84116, USA

Terry A. Messmer, Jack H. Berryman Institute, Department of Wildland Resources, Utah State University, Logan UT 84322-5230, USA

Todd Black, Deseret Land and Livestock, Woodruff, UT 84086, USA

Abstract: The U.S. Fish and Wildlife Service (USFWS) designated greater sage-grouse (*Centrocercus urophasianus*) as a candidate species to receive protection under the Endangered Species Act in 2010. Several states in the western United States have developed management plans to mitigate the listing factors identified by the USFWS. However, sage-grouse populations inhabit sagebrush (*Artemisia* spp.) ecosystems that may transcend multiple state boundaries. If sage-grouse inter-seasonal movements encompass habitats in multiple states and if state-centric wildlife management strategies differ, species conservation may be further complicated. Additionally, if these populations are located in peripheral state boundary areas, they may also receive less management focus both because of their remoteness and state agency emphasis on interior populations. The Grouse Creek sage-grouse population that inhabits extreme northwestern Utah where the state borders eastern Nevada and southern Idaho exemplifies this situation. We monitored 50 radio-collared sage-grouse from 2005 to 2006 to document inter-seasonal movements relative to sex and age and state boundaries. Radio-collared sage-grouse migrated an average of 13.1 km from breeding (range = 0.2 to 69.3, SE = 14.4) to summer range, 22.6 km from summer (range = 0.2 to 46.1, SE = 12.6) to winter range, and 25.4 km from winter (range = 1.1 to 37.2, SE = 13.4) to return to spring range. Ten radio-marked birds (20%) used seasonal habitats in Idaho, Nevada, and Utah. Males were more likely to engage in long-distance movements than females during the breeding season. We confirmed that within a geographically defined state population, individuals may exhibit diverse inter-seasonal migration strategies. Our results support the need for increased coordination among states that share occupied sagebrush habitats to develop interstate sage-grouse conservation plans.

Key words: *Centrocercus urophasianus*, conservation, greater sage-grouse, human–wildlife conflicts, Idaho, lek counts, migration, movement, Nevada, state management, Utah

Greater sage-grouse (*Centrocercus urophasianus*) depend on sagebrush (*Artemisia* spp.; Figure 1) habitats throughout the year for food, breeding, and cover (Patterson 1952, Braun et al. 1976, Connelly et al. 2011). Although most populations have been considered residents of the states where they occupy suitable habitats, wide variations in inter-seasonal movements may be common (Griner 1939, Dalke et al. 1963, Dunn and Braun 1986, Connelly et al. 1988, Fedy et al. 2012). Connelly et al. (2004) classified sage-grouse populations as nonmigratory (movements <6 km), 1-stage migratory (movements between 2 seasonal ranges: winter-breeding and summer), and 2-stage migratory (movements between 3 seasonal ranges [breeding, summer, and winter]). However, Fedy et al. (2012) reported wide variation in migratory behaviors exhibited by sage-grouse inhabiting core areas within Wyoming.

Because of continued sage-grouse population declines as a result of habitat loss and fragmentation, in 2010 the U.S. Fish and Wildlife Service (USFWS) designated sage-grouse as a candidate species to receive protection under the Endangered Species Act. Several western states in the United States have developed management plans to mitigate the listing factors identified by the USFWS. However, if sage-grouse use important habitats in other states during their seasonal migrations and the state plans do not account for these migrations and interstate habitat use, state-centric management strategies may not achieve the desired result. Additionally, if these populations are located in peripheral state boundary areas, they may also receive less management focus because of their remoteness and state agency emphasis on interior populations.

The extent and duration of sage-grouse

seasonal movements often are dictated by resource availability, but they also may differ based on age, sex, and breeding status (Knerr 2007, Thacker 2010, Connelly et al. 2011). For example, as sagebrush habitats desiccate, sage-grouse may move to areas with more succulent vegetation (Autenrieth 1981, Connelly et al. 1988, Fischer et al. 1996, Dahlgren 2006, Knerr 2007, Thacker 2010). These movements usually occur between early June and July (Patterson 1952, Fischer et al. 1996, Knerr 2007, Thacker 2010). During these movements, sage-grouse may continue to use sagebrush habitat but select areas with greater forb availability (Connelly et al. 2004, Dahlgren et al. 2006, Knerr 2007, Thacker 2010). Throughout the fall, sage-grouse may engage in slow, indirect movements toward wintering habitat (Connelly et al. 1988).

Figure 1. Three sage-grouse in the field. *(Photo courtesy Todd Black)*

Long-distance intra-state migratory movements previously have been documented in many sage-grouse populations when seasonal habitats are not contiguous (Connelly et al. 2011, Smith 2013). Males and hens without broods tend to move earlier and faster than brooding hens (Patterson 1952, Connelly et al. 1988, Fischer et al. 1996, Knerr 2007, Thacker 2010). Sage-grouse movements to summer ranges from 5 to 125 km have been documented (Dalke et al. 1960, Connelly et al. 1988, Fischer et al. 1997, Knerr 2007, Connelly et al. 2011).

The West Box Elder County Adaptive Resource Management Local Working Group ([BARM] 2007) and the Utah Division of Wildlife Resources (UDWR) biologists believed that this population may seasonally use sagebrush habitats in Utah, Nevada, and Idaho. The Utah portion of the study area has been identified as a sage-grouse management area (SGMA) in the Conservation Plan for Greater Sage-grouse in Utah (Utah Governor's Office 2013). We studied the inter-seasonal movements of a sage-grouse population located in remote areas of extreme northwestern Utah where the state borders Nevada and Idaho to determine the spatial relationship between potential breeding, summer, and winter habitats. Our objectives included defining migration patterns relative to land use and state jurisdictions. If sage-grouse are engaging in long distance migrations and using seasonal habitats in multiple, this could have important ramifications for regional species conservation if state management priorities or strategies differ.

Study area

The study was conducted in the Grouse Creek subunit of the Box Elder Area Management Area (BARM 2007), located in the extreme northwestern corner of Utah (Figure 2). This area is included in SGMA boundaries in the Utah Plan. It is bounded by the Idaho border on the north, Nevada border on the west, Route 30 on the south, and the Grouse Creek Mountains on the east. The study area ranged from approximately 1,500 to 2,500 m in elevation and was characterized by varied topography, from sagebrush flats to steep, rocky drainages.

The area encompassed approximately 1,570 km^2 and exhibited a checkerboard pattern of land ownership, particularly at its southern end (Figure 2). Forty-seven percent of the land was privately owned, 46% administered by the Bureau of Land Management (BLM), and 7% owned by the Utah School and Institutional Trust Lands Administration. The primary land use in the study area was domestic livestock production, with grazing allotments consisting of a patchwork of public and private lands (BARM 2007). The average annual precipitation in the study area was 29 cm (Western Regional Climate Center 2007)

In both 2005 and 2006, more precipitation was recorded in April than in any other month. Long-term averages over 47 years indicate that precipitation was generally lowest in August

and greatest in May. Average snowfall in the study area was 95 cm. Total snowfall was greater during winter 2005 to 2006 than the previous winter. The average temperature in the study area was 7.2° C. January was typically the coldest month, with July being the warmest. The minimum average temperature for 2005 and 2006 was -12° C, and the maximum average temperature was 32° C.

The vegetation type in the study area consisted mainly of sagebrush intermixed with grassy meadows and woodlands. Common shrubs and trees included basin big sagebrush (*Artemisia tridentata* ssp. *tridentata*), mountain big sagebrush (*A. t.* ssp. *vaseyana*), black sagebrush (*A. nova*), low sagebrush (*A. arbuscula*), rabbitbrush (*Chrysothamnus* spp.), serviceberry (*Amelanchier utahensis*), snowberry (*Symphoricarpos oreophilus*), bitterbrush (*Purshia tridentata*), Utah juniper (*Juniperus osteosperma*), quaking aspen (*Populus tremuloides*), and chokecherry (*Prunus virginiana*). Common grasses included wheatgrasses (*Agropyron* spp., *Elymus* spp.), bluegrasses (*Poa* spp.), cheatgrass (*Bromus tectorum*), and Great Basin wildrye (*Elymus cinereus*). Common forbs included blue-eyed mary (*Collinsia parviflora*), phlox (*Phlox* spp.), astragalus (*Astragalus* spp.), arrowleaf balsamroot (*Balsamorhiza sagittata*), lupine (*Lupinus argenteus*), western yarrow (*Achillea millefolium*), prickly pear (*Opuntia* sp.), wild onion (*Allium* spp.), fleabane (*Erigeron* spp.), and buckwheat (*Eriogonum* spp.).

The lower-elevation, southern end of the study area also supported irrigated alfalfa (*Medicago sativa*) fields used for livestock production. These fields were surrounded largely by greasewood (*Sarcobatus vermiculatus*), hopsage (*Grayia spinosa*), gray rabbitbrush (*Chrysothamnus nauseosus*), Wyoming big sagebrush (*A. t.* ssp. *wyomingensis*), and black sagebrush.

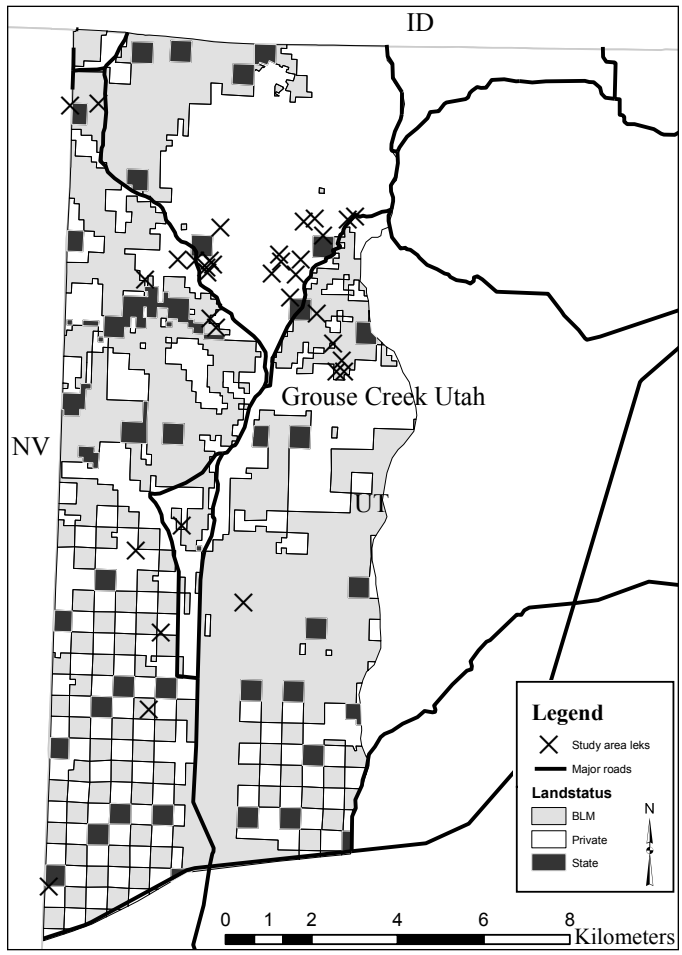

Figure 2. Utah's Grouse Creek Greater Sage-grouse (*Centrocercus urophasianus*) Management Area, Box Elder County, Utah, USA, 2005 to 2006.

Methods

Inter-seasonal movements

During the spring of 2005 and 2006, sage-grouse hens (n = 21) and males (n = 29) were captured near leks and fitted with radio-collars. Birds were located on or near leks during the night using a spotlight and binoculars. Sage-grouse were captured by study personnel riding in the back of pick-up trucks or on all terrain vehicles (ATVs) and using a long-handled net (Giesen et al. 1982, Connelly et al. 2003). In 2005, captured birds were fitted with a programmed (19 hours on, 5 hours off), 16.5-g ATS™ (Advanced Telemetry Systems, Isanti, Minn.) radio-collars (150.000 to 151.000 MHz). In 2006, we used 19-g collars (Holohil Systems Ltd., Carp, Ontario, Canada) that remained on

at all times (151.000 to 152.000 MHz).

The age of each bird (yearling or adult) was determined based on primary feather characteristics (Dalke et al. 1963). Each bird was weighed using a cotton bag and a Pesola™ (Pesola, Zug, Baar, Switzerland) 2,500-g spring scale. A Garmin™ (Garmin, Olathe, Kan.) global positioning system (GPS) unit set to Universal Transverse Mercator (UTM) NAD27 was used to record the location to the nearest 5 m. Birds were handled in accordance with protocol approved by the Institutional Animal Care and Use Committee at Utah State University, and with a UDWR certificate of registration.

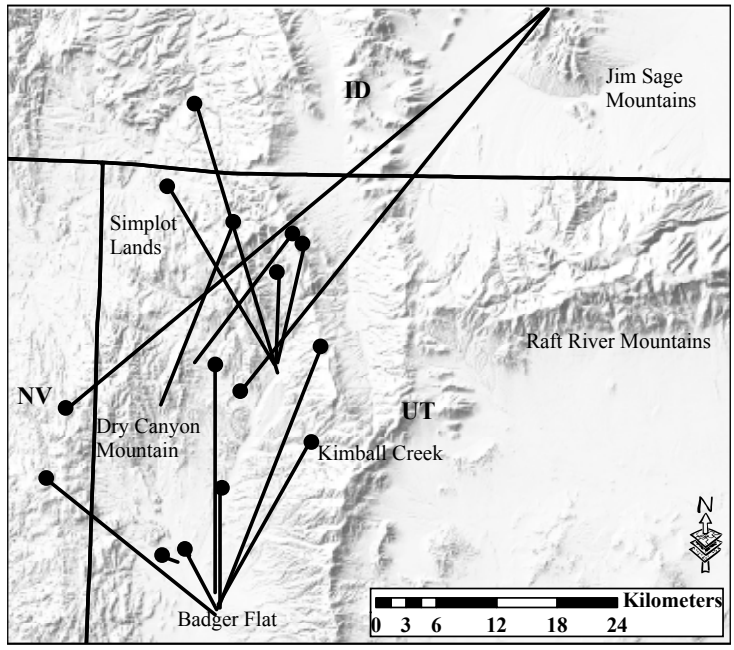

Figure 3. Representative summer movements of greater sage-grouse (*Centrocercus urophasianus*) in western Box Elder County, Utah, USA, 2005-2006. Darkened circles represent ending bird locations. One male moved 54.3 km south from Idaho to a drainage near to his trap location in Red Bank Springs, where his collar was found on mortality. The second male traveled 69.3 km southwest from Idaho into eastern Nevada between May and August.

Radio-marked birds were located using Communications Specialists (Orange, Cal.) and Telonics (Mesa, Ariz.) receivers, Yagi hand-held 3-element antennas, and vehicle-mounted omni antennas. Visual locations on females that were nesting or rearing broods were acquired approximately 3 times a week, and nonbrooding females and males once a week between April and September. Nonbrooding females, males, and brooding females with juveniles >3 weeks old were flushed to determine flock or brood size. Sage-grouse wintering areas were determined from a fixed-wing aircraft by flying at least 3 times between December and April.

Data analysis

Summer movements were defined between breeding areas and summer habitat from April to September. Winter movements were defined as travel from summer to wintering habitat between October and February. Spring movements were defined between wintering areas and breeding areas in March and April. Geographic information system (ArcView GIS 3.3) software was used to analyze movement data. Movement distance was calculated as a minimum, straight-line distance between 2 locations. We used a 1-way analysis of variance to determine differences between the seasonal movements of females and males, yearlings and adults, and brooding females and nonbrooding females. Residuals were assessed for normality and homogeneity of variances using graphical methods. Square root transformations of the distance data were used to meet the assumptions of the analysis where needed. We used descriptive statistics to summarize movement patterns. Data analyses were conducted using the SAS-STAT software (SAS Version 9.1, 2002-2003). The GLM procedure was used for ANOVA. The MEANS procedure was used to obtain descriptive statistics.

Results

Fifty greater sage-grouse were captured and radio-marked over the period of this study (2005 to 2006). Twenty-one of the captured birds were female; sixteen of these were yearlings, and five were adults. Twenty-nine of the captured birds were male; three of these were yearlings, and twenty-six were adults. Summer movements of radio-collared birds ranged from 0.2 to 69.3

km, with a mean distance of 13.1 km (SE = 14.4; Table 1). Adult sage-grouse traveled farther than yearling birds ($F_{1, 45}$ = 9.47, SE = 2.84, P = 0.004). Male sage-grouse moved farther than females ($F_{1, 45}$ = 16.67, SE = 2.51, $P \leq 0.001$). Movement distances for yearling and adult females did not differ. Ten (20%) of the sage-grouse used seasonal habitats in Idaho and Nevada.

Most of the radio-collared sage-grouse that were captured at the lower elevation lek in Utah during the spring moved north during the summer to higher elevations in either near or in Idaho ($\bar{x}$ = 22.3 km). However, there were some notable exceptions where an adult female engaged in long-distance movements that encompassed habitats in Utah and Idaho during the breeding season (Figure 3). The round-trip distance for this hen's movements was 143 km. These movements were completed in <60 days.

Additionally, 3 radio-marked birds (1 female and 2 males) also exhibited extensive summer movements that included habitats in Idaho and Nevada. The adult female traveled 49 km in May to Idaho and in June returned to her original capture location. One male that also moved to Idaho during May, traveled 54.3 km south from Idaho to a drainage near the lek he was captured on where his collar was found on mortality. The second male traveled 69 km southwest from Idaho into eastern Nevada between May and August (Figure 4).

Successful brooding females moved a maximum distance of 1.4 to 9.8 km from their nest sites during the 50 days of brood-rearing. The mean elevation gain of these movements was 270 m (SE = 59.7). Movement distances of brooding and non-brooding females did not differ.

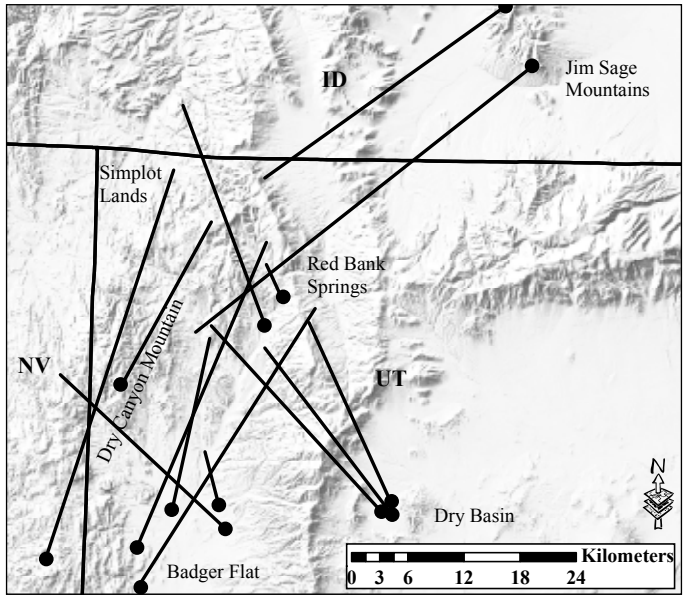

Figure 4. Representative winter movements of greater sage-grouse (*Centrocercus urophasianus*) that were radio-collared near leks in western Box Elder County, Utah, USA, 2005 to 2006. Darkened circles represent bird winter locations. These movements highlight the importance of documenting seasonal movements in developing conservation plans for multi-state populations.

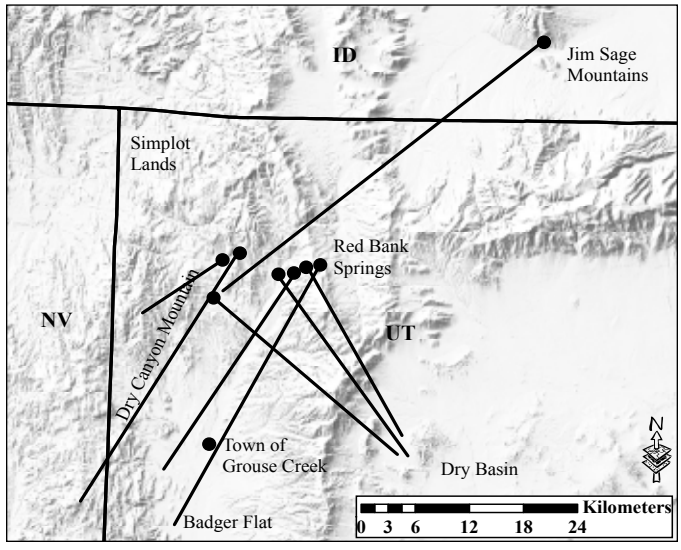

Figure 5. Spring movements of greater sage-grouse (*Centrocercus urophasianus*) from leks where they were radio-collared in western Box Elder County, Utah, USA, 2005 to 2006. Darkened circles represent final distance locations. The line with a darkened circle at both ends represents the straight line distance for one radio-collared hen that traveled 143 km between Idaho and Utah in less than 60 days.

Spring movements ranged from 1.1 to 45.9 km, with a mean distance of 25.4 km (SE = 13.4). Spring movements of yearlings and adults, or males and females did not differ.

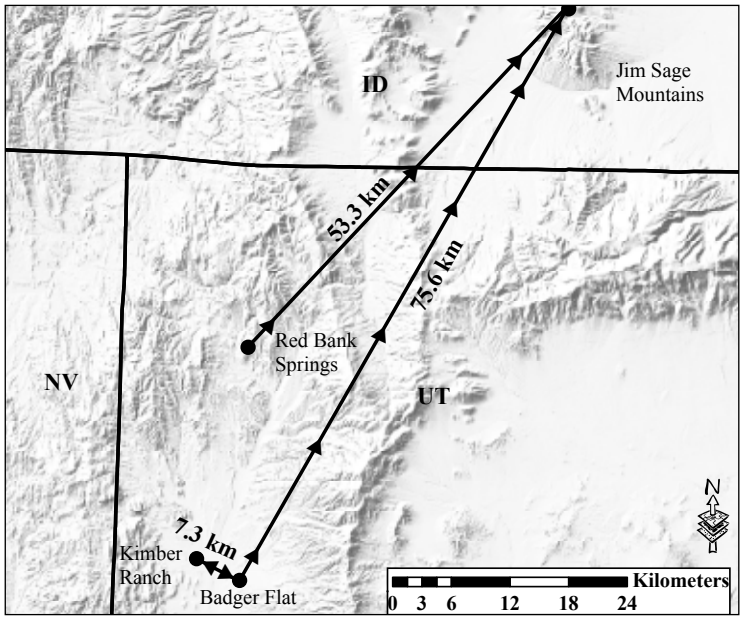

Figure 6. Movements of radio-collared male greater sage-grouse (*Centrocercus urophasianus*) during the lekking period in western Box Elder County, Utah, USA, 2005-2006. Such long distance and between-lek movements in multi-state populations could constitute a source of bias in state-centric species conservation plans and lek trend surveys.

We tracked 30 greater sage-grouse movements from summer habitat to wintering areas (Table 1). Winter movements ranged from 0.2 to 46.1 km, with a mean distance of 22.6 km (SE = 12.6). Movement distances of yearlings and adults, males and females, or yearling females and adult females did not differ (Figure 5). The area surrounding the Badger Flat lek provided wintering habitat to a large number of birds. All located birds captured on this lek returned to the area to winter, traveling 8 to 25 km from the alfalfa fields in Utah and eastern Nevada. In addition, 2 females that summered south in Utah moved 4 and 20 km, respectively, to winter in eastern Nevada. Three females traveled a mean distance of 34.4 km (SE = 3.0) from summer to winter habitats. Another male followed the same path, but continued into winter habitats in eastern Nevada, a distance of 44 km (Figure 5).

We tracked movements of 6 female and 3 male sage-grouse returning from their wintering locations to breeding areas in spring 2006 (Figure 6; Table 1). All of these birds, with the exception of 1 female, returned to the lekking areas where they were captured. Another female traveled 46 km from her wintering location in southern Idaho back to the area of her capture. Two weeks later, she had moved 48 km north, returning to Idaho. Based on annual euclidean distances from the leks where the sage-grouse studied were captured to winter ranges, we calculated that 56% of the population moved >10 km (Table 1).

Discussion

The sage-grouse we monitored exhibited wide variation in seasonal migration patterns. The studied population did not fit the migration categories as described by Connelly et al. (2004), but rather exhibited migratory behaviors reported by Fedy et al. (2012). Of the birds monitored for >1 full year, most females moved between 2 seasonal ranges and most of the males moved among 3 ranges. However, other females that were captured near the same leks were non-migratory or 2-stage migratory, and some males were 1-stage migratory. These movement patterns suggest that local resource availability influenced bird movements (Knerr 2007, Thacker 2010).

Resource availability in the study area reflected settlement patterns and contemporary land uses. This land use is the result of a historical pattern of public and private landownership BARM 2007). The northern portion of the study area consisted mainly of higher elevation sections of public and private rangelands. These areas were seasonally grazed by domestic cattle from summer to early fall. The southern portion of the study area consisted of sections of irrigated private hayfields interspersed with public rangelands that could be described as sagebrush flats. This unique combination provided our study population year-round access to suitable resources.

For example, hens captured near lower elevation leks used the surrounding sagebrush flats for both nesting and wintering habitats. The leks were on private land, and the sagebrush flats were on public rangelands. After the

nesting season, hens with and without broods moved to spend the summer in alfalfa fields on private lands that were within 2 km of their capture sites. These fields remained succulent throughout the summer and exhibited high arthropod abundance (Knerr 2007). Because of their close proximity to these resources, the birds spent their entire life cycle within

Table 1. Greater sage-grouse seasonal movement distances (km) by season and percentage of movements >10 km in the Grouse Creek Watershed, Box Elder Sage-grouse Management Area, Utah, USA, 2005 to 2006.

		Seasonal distances (km)		
Breeding	n	$\bar{x}$ (SD)	Range	% > 10 km
Summer				
Male, adult	18	15.3 (7.4)	2.8 – 26.1	72
Male, yearling	1	21.2		100
Female, adult	10	7.4 (8.7)	0.8 – 25.8	20
Female, yearling	13	4.7 (4.4)	0.6 – 15.3	15
All males	19	15.6 (7.3)	2.8 – 26.1	74
All females	23	5.9 (6.6)	0.6 – 25.8	17
All adults	28	12.5 (8.6)	0.8 – 26.1	54
All yearlings	14	5.8 (6.1)	0.6 – 21.2	21
Summer–winter				
Male, adult	13	23.4 (11.4)	8.1 – 46.1	8
Male, yearling	1	21.3		100
Female, adult	4	33.3 (12.7)	22.3 – 50.0	100
Female, yearling	10	28.0 (14.2)	6.0 – 47.1	80
All males	14	23.2 (11.0)	8.1 – 46.1	93
All females	14	29.5 (13.6)	6.0 – 50.0	86
All adults	17	25.7 (12.1)	8.1 – 50.0	94
All yearlings	11	27.4 (13.6)	6.0 – 47.1	82
Winter–breeding				
Male, adult	13	11.2 (16.1)	1.4 – 53.0	31
Male, yearling	1	1.2		0
Female, adult	3	14.2 (19.0)	2.9 – 36.2	33
Female, yearling	9	17.3 (12.0)	3.5 – 35.8	67
All males	14	10.5 (15.7)	1.2 – 53.0	29
All females	12	16.5 (13.1)	2.9 – 36.2	58
All adults	16	11.8 (16.1)	1.4 – 53.0	31
All yearlings	10	15.7 (12.4)	1.2 – 35.8	60
Annual movements				
All males	47	16.3 (12.2)	1.2 – 53.0	66
All females	49	15.2 (14.5)	0.6 – 50.0	47
All adults	61	16.0 (13.2)	0.8 – 53.0	59
All yearlings	35	15.4 (13.9)	0.6 – 47.1	51
All birds	96	15.8 (13.4)	0.6 – 53.0	56

approximately 7 km^2 of the lek on which they were captured.

However, this relationship was not as clear for birds captured on the higher elevation, northern leks. Although some of these birds remained within 5 km of their capture sites throughout the summer, more engaged in long-distance seasonal movements. The birds that remained closer to their capture sites were frequently found in close association with riparian areas, including wet meadows and semi-permanent streams. These areas exhibited greater juniper encroachment than the southern sites.

The range of seasonal movement distances we recorded was similar to those reported of sage-grouse populations in Idaho (Dalke et al. 1960, Connelly et al. 1988, Fischer et al. 1997). In these studies, as in ours, bird movements were initiated when vegetation began to desiccate in response to increasing ambient temperatures.

Patterson (1952) and Klebenow (1969) observed that sage-grouse tended to move higher in elevation throughout the summer in search of adequate resources. Some of the birds we monitored used higher elevation aspen and chokecherry stands later in the season. These areas had a succulent, herbaceous understory. Patterson (1952) and Connelly et al. (1988) reported that grouse did not seek higher elevation in the summer months because the birds found adequate habitat in irrigated agricultural fields. The population we studied exhibited similar patterns. The birds' timing and distance traveled were predicated on their ability to find suitable resources.

The male grouse that we monitored traveled the farthest. Connelly et al. (1988) also noted that males in Idaho moved farther to summer range than females. Additionally, adult birds moved farther than yearlings. However, the movement differences between adults and yearlings may be questionable because most of the yearling birds tracked were female.

Movement distances of brooding and nonbrooding females did not differ. Three of the successfully brooding hens stayed within 2.7 km of their nests, making small daily movements. Most nonbrooding females stayed in the same area throughout the summer months, while others made one major movement, usually in late June or early July. All of the areas that these birds used tended to be more mesic than either the site they originally used or the surrounding landscape.

Sage-grouse that were trapped on different leks and that used different areas in the summer moved to use the same areas in the winter. These wintering areas differed both in proximity and in habitat type from summer areas. Most of the birds we monitored moved to lower elevations in the winter, using areas dominated by black sagebrush. A few birds used more mountainous areas as wintering habitat, but the exact habitat type they used is unknown. Sage-grouse that we tracked for 2 consecutive winters tended to move to the same general areas both years.

The winter movements of the birds we monitored appeared to be similar to those of sage-grouse populations in southeastern Idaho (Connelly and Markham 1983), southwestern Wyoming (Berry and Eng 1985), and on Cold Spring Mountain, Colorado (Dunn and Braun 1986). The movements of yearling birds were comparable to those of adults, as was observed by Connelly et al. (1988).

The distances of movements from winter habitat to breeding areas in our population were greater than those noted by Schoenberg (1982) in North Park, Colorado. Most of our monitored sage-grouse moved 11.4 to 45.9 km to return to breeding areas. Dalke et al. (1960) noted that 70% of marked grouse returned to the same strutting ground each spring for 3 consecutive years.

Management implications

Our results confirmed that the sage-grouse population we studied constituted a tri-state population. Our radio-marked birds were capable of long-distance movements during the lekking, breeding, and winter season. The Utah SGMA that included our study area encompassed all of the in-state inter-seasonal movements of this population. However, it did not include important seasonal habitats used in Idaho and Nevada. This could impede conservation efforts if the important habitats used by this population during interstate inter-seasonal movement are not afforded similar priorities and protection strategies. Additionally, extensive inter-seasonal movements during the lekking season could bias lek counts that are used to estimate population trends.

Important wintering areas of the study population included sagebrush flats in Utah, Idaho, and Nevada. These areas are at increased risk of wildfires because invasive species, such as cheatgrass, may constitute >50% of the ground cover (UDWR 2002, BARM 2007). Protection of these areas from wildfires will ensure adequate sagebrush cover for sage-grouse wintering habitat.

The brood-rearing habitats used by our study populations were largely privately-owned, ≥2,000 m in elevation, and were grazed by domestic livestock. Each area exhibited riparian habitats, with streams, wet meadows, and scattered aspen (*Populus tremuloides*) stands. Managing these areas for increased water availability will help to maintain brood-rearing habitats for this tri-state population of sage-grouse.

Connelly et al. (1988) argued that sage-grouse populations should be defined on a temporal and geographic basis, and this is true of the population in northwestern Utah. There were numerous movements not only into southern Idaho, but also into eastern Nevada. Because some of the these birds inhabit portions of 3 states, the future of the sage-grouse in this area may depend upon local working groups from Utah, Idaho, and Nevada joining forces and striving to attain common landscape-based conservation goals.

Literature cited

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

Berry, J. D., and R. L. Eng. 1985. Inter-seasonal movements and fidelity to seasonal use areas by female sage grouse. Journal of Wildlife Management 49:237–240.

Braun, C. E., M. F. Baker, R. L. Eng, J. S. Gashwiler, and M. H. Schroeder. 1976. Conservation committee report on effects of alteration of sagebrush communities on the associated avifauna. Wilson Bulletin 88:165–171.

Connelly, J. W., H. W. Browers, and R. J. Gates. 1988. Seasonal movements of sage grouse in southeastern Idaho. Journal of Wildlife Management 52:116–122.

Connelly, J. W., C. A. Hagen, and M. A. Schroeder. 2011. Characteristics and dynamics of greater sage-grouse populations. Pages 53–67 in S. T. Knick and J. W. Connelly, editors. Greater sage-grouse: ecology and conservation of a landscape species and its habitats: studies in avian biology. University of California Press, Berkeley, California, 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.

Connelly, J. W., and O. D. Markham. 1983. Movements and radionuclide concentrations of sage-grouse in southeastern Idaho. Journal of Wildlife Management 47:169–177.

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.

Dahlgren, D. K. 2006. Greater sage-grouse reproductive ecology and response to experimental management of mountain big sagebrush on Parker Mountain, Utah. Thesis, Utah State University, Logan, Utah, USA.

Dalke, P. D., D. B. Pyrah, D. C. Stanton, J. E. Crawford, and E. F. Schlatterer. 1960. Seasonal movements and breeding behavior of sage grouse in Idaho. Transactions of the North American Wildlife Conference 25:396–407.

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.

Dunn, P. O., and C. E. Braun. 1985. Natal dispersal and lek fidelity of sage grouse. Auk 102:621–627.

Dunn, P. O., and C. E. Braun. 1986. Late summer-spring movements of juvenile sage grouse. Wilson Bulletin 98:83–92.

Fedy, B. C., C. L. Aldridge, K. E. Dougherty, M. O'Donnell, J. L. Beck, B. Bedrosian, M. J. Holloran, G. D. Johnson, N. W. Kaczor, C. P. Kirol, C. A. Mandrich, G. McKee, C. Olson, C. C. Swanson, and B. L. Walker. 2012. Inter-seasonal movements of greater sage-grouse, migratory behavior, and an assessment of the core regions concept in Wyoming. Journal of Wildlife Management 76:1062–1071.

Fischer, R. A., K. P. Reese, and J. W. Connelly.

1996. Influence of vegetal moisture content and nest fate on timing of female sage grouse migration. Condor 98:868–872.

Fischer, R. A., W. L. Wakkinen, K. P. Reese, and J. W. Connelly. 1997. Effects of prescribed fire on movements of female sage grouse from breeding to summer ranges. Wilson Bulletin 109:82–91.

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

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

Klebenow, D. A. 1969. Sage grouse nesting and brood habitat in Idaho. Journal of Wildlife Management 33:649–662.

Knerr, J. S. 2007. Ecology of greater sage-grouse in Western Box Elder County, Utah. Thesis, Utah State University, Logan, Utah, USA.

Patterson, R. L. 1952. The sage grouse in Wyoming. Wyoming Game and Fish Commission. Sage Books Inc., Denver, Colorado, USA.

Schoenberg, T. J. 1982. Sage grouse movements and habitat selection in North Park, Colorado. Thesis, Colorado State University, Fort Collins, Colorado, USA.

Smith, R. E. 2013. Conserving Montana's sagebrush highway: long-distance migration in sage-grouse. University of Montana, Missoula, Montana, USA.

Thacker, E. T. 2010. Greater sage-grouse seasonal ecology and responses to habitat manipulations in northern Utah. Dissertation, Utah State University, Logan, Utah, USA.

Utah Division of Wildlife Resources (UDWR). 2002. Strategic management plan for sage-grouse. State of Utah Department of Natural Resources, Division of Wildlife Resources. Publication 02-20. Salt Lake City, Utah, USA.

Utah Governor's Office. 2013. Conservation plan for greater sage-grouse in Utah, <http://wildlife.utah.gov/uplandgame/sage-grouse/pdf/greater_sage_grouse_plan.pdf>. Accessed July 22, 2013.

West Box Elder Adaptive Resource Management Local Working Group (BARM). 2007. West Box Elder greater sage-grouse (Centrocercus urophasianus) local conservation plan. Unpublished Report. Utah State University Extension, Jack H. Berryman Institute, and Utah Division of Wildlife Resources. Salt Lake City, Utah, USA.

Western Regional Climate Center. 2007. Monthly climate summary for Grouse Creek, Utah, <http://www.wrcc.dri.edu/summary/climsmut.html> . Accessed July 9, 2013.

Jan S. Reinhart is a rangeland biologist with the Utah Department of Agriculture and Food.

She holds a B.S. degree in biology from Muhlenberg College and an M.S. degree in wildlife biology from Utah State University. Her primary focus is monitoring vegetation response to changes in grazing management.

Terry A. Messmer (photo unavailable) is a professor and extension wildlife specialist in the Department of Wildland Resources, Utah State University (USU), where he is the director of the Jack H. Berryman Institute. He holds the Quinney Professorship of Wildlife Conflict Management in USU's Quiney College of Natural Resources, and he is the director of USU's Utah Community-Based Conservation Program (CBCP). He received a B.S. degree in fisheries and wildlife management and in biology from the University of North Dakota–Grand Forks, an M.S. degree in regional and community planning and a Ph.D. degree in animal and range science from North Dakota State University–Fargo. His research, teaching, and extension activities include identification, implementation, and evaluation of conservation strategies, technologies, and partnerships that can benefit agriculture, wildlife, and resource stakeholders. As CBCP director, he, his staff, and graduate students work closely with Utah's sage-grouse local working groups to identify, implement, and evaluate the effects of management actions on sage-grouse conservation.

Todd Black (photo unavailable) is wildlife manager for Deseret Land and Livestock Ranches/AgReserves Inc., a cattle-agricultural cooperation that has several large ranches located throughout the United States. Prior to his current position, he worked for over 15 years as an extension specialist for Utah State University in the community based conservation program; he worked with landowners, agencies, and other interested publics on sage-grouse research and conservation efforts throughout Utah. He has has worked for state wildlife agencies, federal land management agencies, county governments, and private consulting companies. He owns a successful guiding-outfitting business with his brothers in San Juan County, Utah (Blacktimberoutfitters). He and his wife Pat have 3 children who all are tolerant enough of him to allow him to work and play in the field he loves.