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Response of a small population of greater sage-grouse to tree removal: implications of limiting factors

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Abstract: In Utah, greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) range has been reduced to 50% of what is considered historical availability due to habitat degradation and loss. In an effort to improve sage-grouse habitat in southern Utah, the U.S. Bureau of Land Management (BLM) conducted a tree-removal treatment in 2005. We conducted a study to determine if (a) the tree-removal treatment was effective at creating new sage-grouse habitat, and (b) if characteristics of used habitat were similar to those reported in previous literature. The treatment resulted in increased abundance of grasses and forbs. Additionally, shrub percentage cover and height was not negatively affected by the treatment. Sage-grouse used the treated areas more than expected based on availability within the first year of the treatment. The vegetation resulting from the treatment used by sage-grouse in all seasons was lower in percentage shrub, grass, forb composition, and average height than the range of previously reported habitats for late-brood rearing, fall and winter seasons of use. Sage-grouse's quick positive response to the treated area suggests that suitable habitat is limited in this region.

Key words: *Centrocercus urophasianus*, greater sage-grouse, habitat use, human–wildlife conflicts, juniper removal, pinyon removal, southern distribution, Utah, vegetation treatment

Greater sage-grouse (*Centrocercus urophasianus*; hereafter, sage-grouse) have been a species of concern in the West for more than a decade, and currently, they are a candidate species for listing under the Endangered Species Act. Throughout their range across the western United States and Canada, their distribution has been reduced (Connelly et al. 2004). In Utah, sage-grouse are found in 26 counties and are thought to occupy 50% of the habitat they once did (Utah Division of Wildlife Resources 2009). This decline is primarily attributed to habitat degradation and loss due to a wide variety of causes (Schroeder et al. 2004). In Utah, habitat change has been particularly evident in the southern portion of the sage-grouse distribution, where pinon pines (*Pinus edulus* and *P. monophylla*) and junipers (*Juniperus osteosperma* and *J. scopulorum*) have increased in areas that were once considered sage-brush steppe, and wildfires. Human disturbance also has increased abundance of cheatgrass (*Bromus tectorum*; Utah Division of Wildlife Resources 2009). With the conversion of sagebrush (*Artemisia* spp.) to juniper, Miller et al. (2000) found that herbaceous cover and herbaceous species diversity declined and bare ground increased. Within a juniper stand, shrub cover declines to <1%, forb availability declines, and the micro-climate of the habitat becomes more xeric (Bates et al. 2000) than a sagebrush community, eliminating both nesting habitat and food resources for sage-grouse.

Many studies have shown direct positive relationships between habitat characteristics and sage-grouse recruitment (see Crawford 2004, Knick and Connelly 2011). Therefore, to improve sage-grouse populations throughout their range, management agencies most often work to improve sagebrush-steppe habitat, creating environments suitable for nesting, brood-rearing, and winter survival (Utah Division of Wildlife Resources 2009). However, there are few planned experiments that document the response of sage-grouse

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to habitat treatments (Knick et al. 2003, Dahlgren et al. 2006). It is important that resource managers use their limited resources to produce the best possible result when conserving a sensitive species. Therefore, understanding the habitat requirements and habitat potential at the local scale is invaluable (Crawford et al. 2004). Further, populations exhibit unique spatial patterns within suitable habitat, a condition that should be taken into account to ensure the success of habitat management actions at the site level.

Very little is known about sage-grouse in southern Utah; anecdotal documentation from lifetime residents of the Alton area—the location of the southern-most sage-grouse lek within their distribution—suggests that sage-grouse populations have fluctuated over time and always persisted over the last 100 years, but they never reached extremely high numbers as they have in other areas (Frey et al. 2008). While sage-grouse habitat needs have been determined through numerous studies, the full range of conditions that can support sage-grouse populations, especially those on the edge of the distribution, remains unknown.

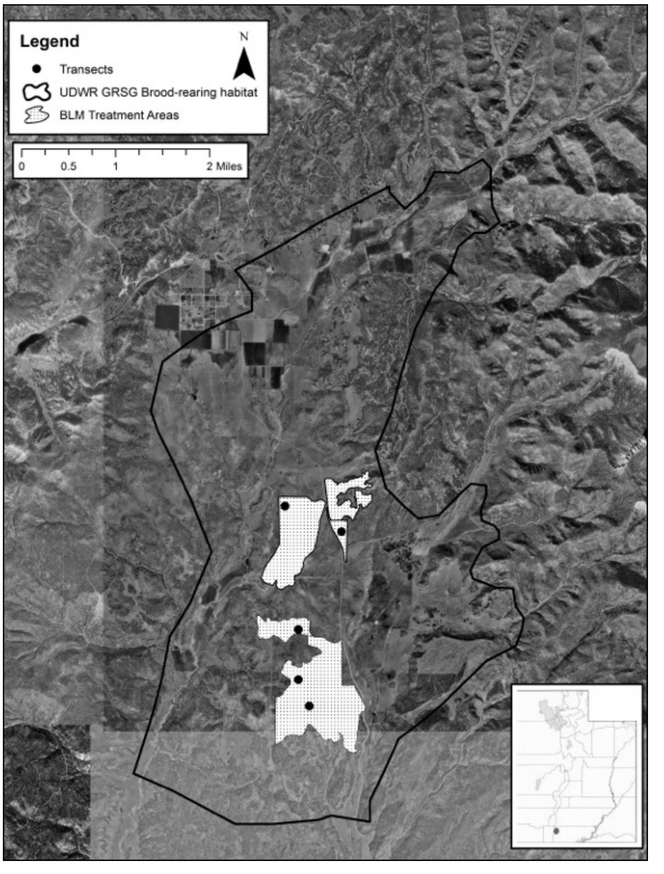

Figure 1: Location of the study area, indicating Alton, Utah, the vegetation treatment conducted by the Bureau of Land Management and the vegetation survey, Alton and Sink Valley, Utah, USA.

To improve sagebrush-steppe habitat management efforts, and, thus, improve and support the sage-grouse populations in southern Utah, we studied the southern-most population of sage-grouse in Alton and Sink Valley, Kane County, Utah, during a tree-removal project. Our goal was to monitor sage-grouse use of habitat that had been treated recently by the U.S. Bureau of Land Management (BLM) to reduce juniper and pinyon density and, thus, to determine how the landscape would respond to treatment and how greater sage-grouse would use an area after tree removal.

Study area

Our study focused on a population of sage-grouse associated with the only known active lek in Sink Valley, Kane County, Utah, which is the southernmost lek of sage-grouse distribution (Figure 1). The Sink Valley study area was 8.6 km long and on average 2 km wide, situated on a SE-NW trajectory, surrounded by small hills ranging in elevation from 2,072 to 2,194 m. Situated at the north end of Sink Valley is the small town of Alton (37°26′24″N, 112°28′55″W). Alton is a small rural town with approximately 55 to 130 permanent residents (U.S. Census Bureau 2010). The area of town itself is 1.0 km^2; however, agricultural practices occupy fields adjacent to it and south into Sink Valley. During this study, monthly mean winter temperatures (November to February) ranged from -5.7 to 5.4° C. Summer temperatures (June to September) ranged from 13 to 25° C (Utah Climate Center 2012*a*). Alton receives more precipitation than many southern Utah towns. The average annual precipitation from 1915 to

2012 was 41 cm and ranged from 27 to 64 cm during our study (Utah Climate Center 2012*b*). Alton receives most of its precipitation in February, with an annual average snowfall of 55.8 cm, most falling in February (Utah Climate Center 2012*c*).

The study area is characterized by 4 plant associations: pinyon-juniper woodlands, sagebrush-steppe, pasture grasslands, and irrigated croplands. In the woodlands, species include juniper, pinyon pine, big sagebrush (*Artemisia tridentata* var. *tridentata* and var. *vaseyana*), black sagebrush (*Artemisia nova*), and antelope bitterbrush (*Purshia tridentata*), with predominant grasses of bluebunch wheatgrass (*Pseudoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), and needlegrass (*Stipa* spp.). In the sagebrush steppe, predominant species include big sagebrush, black sagebrush, and antelope bitterbrush, with predominant grasses of bluebunch wheatgrass, Idaho fescue, and squirreltail (*Sitanion hystrix*). Pasture grasslands include Kentucky bluegrass (*Poa pratensis*), timothy (*Phleum pratense*), intermediate wheatgrass (*Thinopryum intermedium*) and several *Carex* species, as well as a variety of forbs, such as lomatium (*Lomatium* spp.) and western yarrow (*Achillea millefolium*). Irrigated crops are predominantly alfalfa (*Medicago sativa*) and cereal grain crops, which are harvested for hay.

Methods

Grouse habitat use and movements

We began sage-grouse trapping in March of 2005 using an all-terrain vehicle to access roosting locations, a spotlight to locate sage-grouse, and handheld nets to capture sage-grouse; this was repeated each fall and spring to maintain a population of ≥12 birds during the rearing and dispersal seasons (Utah State University IACUC #1322). The attending male population at the Sink Valley lek was 6 to 12 individuals during the time of this study; thus, we may have been sampling a much as one-third of the population at any 1 time (D. Schaible, Utah Division of Wildlife Resources, personal communication, 2008). Captured sage-grouse were sexed, assessed for injuries, fitted with a necklace radio-transmitter (Holohil Systems Ltd., Carp, Ontario, Canada), and released on site.

During the summer, sage-grouse were visually located at least twice a week with the use of a 3-element Yagi antenna and a hand-held radio receiver (Communications Specialists Inc., Orange, Calif.). From September to April, we visually located sage-grouse at least once a week. Efforts were made to get only as close as needed for a visual sighting without flushing the birds. At each sighting, the GPS coordinate was recorded (GARMIN Etrex Legend H), along with the habitat characteristics at the location, flock size, and activity.

Vegetation treatment

In Fall 2005, the BLM initiated a tree-removal project in our study area to improve sagebrush-steppe habitat, and, thus, improve sage-grouse brood-rearing habitat. The project involved removing invading pinyon and juniper trees from areas that were once sagebrush-steppe habitat. The trees were cut down using mechanical methods and hand-thinning. Cut trees were mulched and the mulch spread on the ground as cover for seed. After tree removal, the BLM reseeded the area with seed provided by the Great Basin Research Center (Utah Division of Wildlife Resources, Ephraim, Utah). The seed mix was a standard one for southern Utah sagebrush-steppe rehabilitation and consisted of native forbs and grasses, including crested wheatgrass (*Agropyron cristatum*), intermediate wheatgrass, Russian wildrye (*Psathyrostachys juncea*), Indian ricegrass (*Achnatherum hymenoides*), western yarrow, Rocky Mountain beeplant (*Cleome serrulata*), blue flax (*Linum perenne lewisii*), yellow sweetclover (*Melilotus officinalis*), alfalfa, sainfoin (*Onobrychis viciifolia*), and small burnet (*Sanguisorba minor*). We measured the vegetation response to the treatment to determine what plants become established in the seeded area and if sage-grouse utilized these treated areas.

Prior to tree removal, we created 5 survey lines in areas where the treatment would occur (Figure 1). We intended for 2 lines to be used as controls where no treatment would occur; however, when the project was completed, we found that all survey lines were treated. The survey lines were created by randomly selecting a UTM coordinate near (for control survey lines) or within the proposed treatment area. We randomly selected a compass bearing and walked 30 m on that bearing. This became the origin of the survey line. Next, we randomly selected another bearing. This became the direction of the 100-meter survey line. Along each survey line, we also created 5 perpendicular arms, 60 m wide, bisected by the survey line. One arm was at each end of the survey line; the other three were randomly located along the 100-m section with ≥20 m separating any 2 arms.

During June to July 2005, we collected information on the vegetative community and structure before the tree-removal began. We repeated the process in 2006, 2007, and 2009 to determine changes to the vegetative cover and composition immediately after the treatment. On each arm, we measured percentage vegetative cover, line-intercept, and average vegetative height, which are common measurements collected when assessing sage-grouse habitat (Connelly et al. 2003).

Rather than using the standard-sized Daubenmire frame, we measured percentage vegetative cover using a (1 m x 1 m) frame due to the scarcity of understory vegetation in the pinyon-juniper stands and the level of vegetation expected post-treatment. For each arm, we placed the frame at 10, 20, and 30 m from the survey line for 6 measurements per arm and 30 measurements per transect. We calculated percentage cover for trees, shrubs, forbs, and grasses, as well as percentage cover for the dominant species in each class.

To determine line-intercept, we pulled a meter-tape along the 30-m line of each arm, or 10 measurements per transect. We calculated the proportion of the tape covered by trees, shrubs, and grasses-forbs (#m covered÷30 m), and the species of vegetation that covered the tape (Connelly et al. 2003). We calculated the average shrub height along each transect arm, making 10 measurements per transect. Most studies on sage-grouse do not calculate the line-intercept of grasses and forbs; however, we felt that this measurement was necessary to estimate the response of grasses and forbs to tree removal. For this measurement, we calculated the intercept by holding the tape approximately 30 cm above the ground, which was just below the seed-head of the predominant grass prior to treatment. Although trees are not usually considered in most sage-grouse habitat studies, sage-grouse in our study area were documented using stands of trees, perhaps for cover. Therefore, we also measured the average height of trees that intercepted the survey line. Using Systat 11 (Systat Software Inc., Richmond, Calif.), we conducted analyses of variances to determine the differences in percentage vegetation cover, line-intercept, and vegetation height among years, with a significance noted at $P \leq 0.05$.

Sage-grouse use of vegetation treatment

We used ArcGIS (ESRI 2009) to determine habitat use in our study area. To analyze sage-grouse locations we imported GPS locations into ArcGIS (Environmental Systems Resource Institute [ESRI], Redlands, Calif.). Using a 1-m resolution vector data layer, we attributed vegetation type descriptions (Utah Automated Geographic Reference Center 2009) to the sage-grouse locations. We then calculated average sage-grouse habitat use by activity season, using the seasons as delineated above.

Our study included monitoring sage-grouse use of the vegetation treatment. Therefore, we adjusted the vegetation data in our attribute table to account for the changes that resulted by the treatment. To do so, we imported color photography at 1-m resolution, available through Utah Automated Geographic Reference Center (2009), of the study area after the treatment. We overlaid the sage-grouse GPS data that contained the vegetation attribute information for each sage-grouse location onto this coverage. We then reclassified the vegetation category for each GPS point located within the treated area during the time period after treatment had occurred. Further, based on the vegetation surveys, we coded the vegetation to reflect the actual vegetation available in the area at the time of the observation, rather than the vector data classification. We considered an area mulched immediately after treatment in 2005 and before spring growth in 2006. After spring growth began, these areas were considered seeded, indicating a newly growing habitat type, rather than an established habitat. Once vegetation was established, the treated area was classified as corresponding vegetation community (sagebrush, grassland, etc.). To determine annual use of a habitat type, we categorized a year as 1 breeding season to the next breeding season (March 1 to February 28), which coincided with the growing season better than the calendar year.

Using Systat 11, we conducted a chi-square analysis to determine differences in frequency of vegetation use annually and seasonally and the interaction of these 2 factors. Additionally, we determined if sage-grouse were selecting a particular habitat by first determining the percentage of total study area each vegetation type represented. Then, using a chi-square analysis, we compared the relative sage-grouse use (number of telemetry locations of all birds) of each vegetation type to the available amount of that vegetation type.

Results

Vegetation treatment

The BLM treatment resulted in tree removal and seeding in 358 ha (3.6 km^2). Our study design proposed 2 control transects and 3 treated transects; however, all transects in the study received treatment. Consequently, we were able to compare only the vegetation post treatment to the surveys conducted prior to treatment (2005; Figure 2). Forb species present included yarrow, annual mustards, great rushy milkvetch (*Astragalus lonchocarpus*), sego lily (*Calochortus nuttallii*), lambsquarters (*Chenopodium album*), thistle (*Cirsium* spp.), wallflower (*Erysimum asperum*), daisy (*Erigeron* spp.), sweet yellowclover, several penstemon species (*Penstemon* spp.), lobeleaf groundsel (*Packera multilobata*), sainfoin, and small sagebrush sprouts. Grasses present in the transects included: cheatgrass (*Bromus tectorum*), squirreltail, and bluegrass species (*Poa* spp.). Shrubs

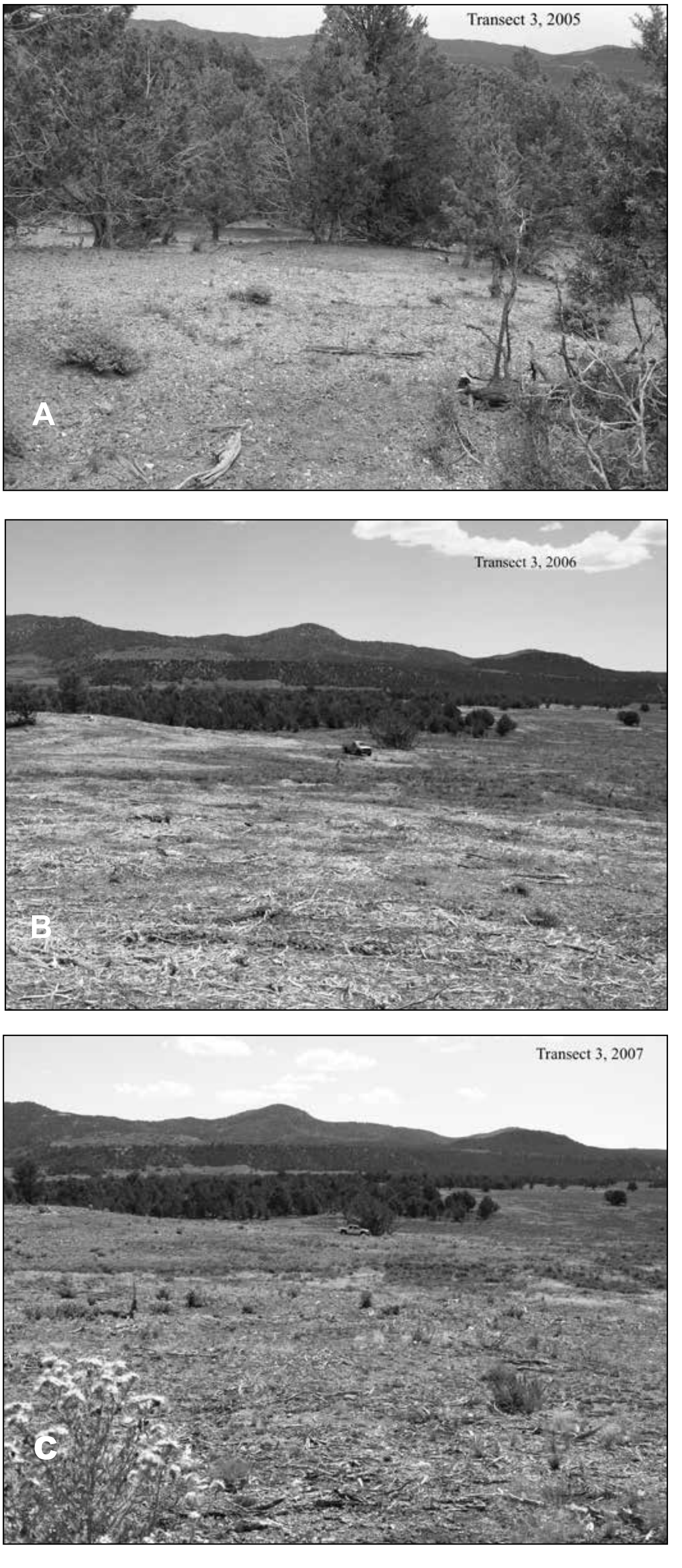

Figure 2: Pictures of vegetation survey transect (A) 3 before (2005) and (B, C) after (2006, 2009) tree removal, Alton, Utah.

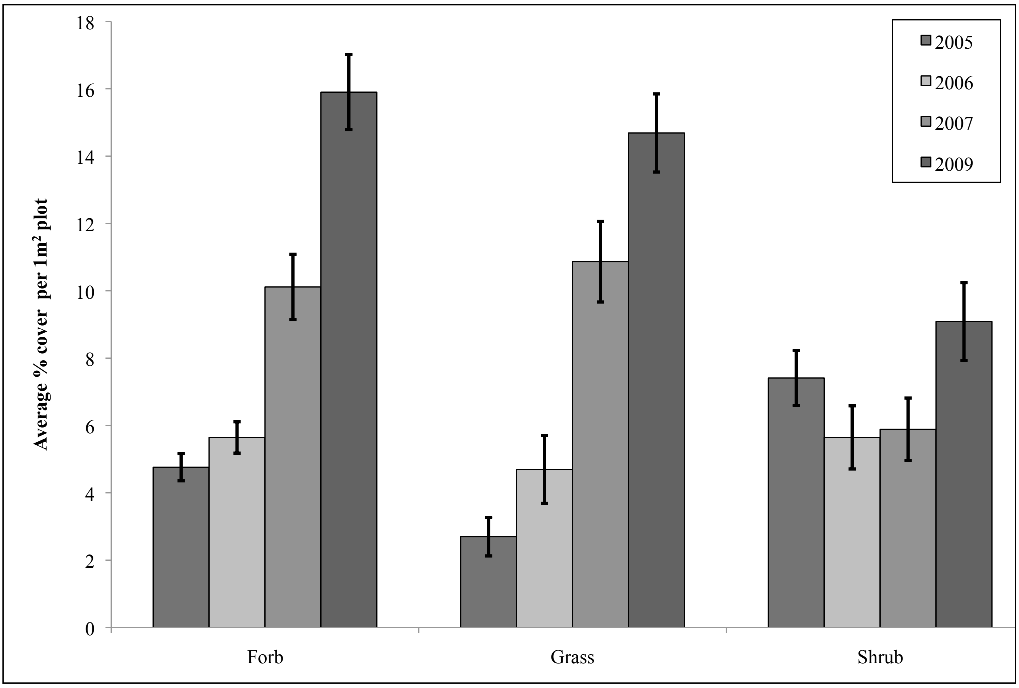

Figure 3: Average percentage cover (± standard error) of vegetation plots 2005 to 2007, and 2009, Alton, Utah.

present in the transects included Wyoming big sagebrush (predominant species present), rubber rabbitbrush (*Chrysothamnus nauseosus*), viscid rabbitbrush (*C. viscidiflorus*), cactus (*Opuntia* spp.), wild crab apple (*Peraphyllum ramosissimum*), and a few antelope bitterbrush.

The average percentage of area covered by forbs, grasses, and shrubs differed over the course of the study (F = 78.67, df = 3, *P* = 0.00; Figure 3). Further analysis determined that the percentage cover of shrubs was similar in 2005 to 2007 but increased in 2009. The percentage cover of grass and forbs significantly increased from 2005 to 2009 (Figure 3).

The line-intercept of grasses and forbs increased from 2005 to 2007 (F = 33.38, df = 2, *P* = 0.0; Figure 3). The line-intercept of shrubs did not change from 2005 to 2007 (F = 2.36, df = 2, *P* = 0.098; Figure 3). The elimination of trees from many of the transects prevented us from transforming the data for line-intercept of trees per 30 m to a normal distribution. Therefore, we conducted a Kruskal-Wallis 1-way analysis of variance for this variable. There was a significant decrease in the line-intercept of trees from 2005 to 2006; however, 2006 and 2007 were similar (*t* = 126.246, *P* = 0.00; Figure 4). Line-intercept data were not collected in 2009.

The average height of shrubs changed after treatment, with an initial decrease from 2005 to 2006, followed by a significant increase by 2009 (F = 8.86, df = 3, *P* = 0.00; Figure 5). Grass and forb height increased from 2005 to 2007 each year of the study (F = 53.3, df = 2, *P* = 0.00; Figure 5). The elimination of trees from many of the transects prevented us from transforming the data for the average height of trees per 30 m to a normal distribution. Therefore, we conducted a Kruskall-Wallis one-way analysis of variance for this variable. As expected, the average height of trees declined significantly after the first year (treatment) but was similar in subsequent years (K = 122.1, df = 3, *P* = 0.00; Figure 6). The variance in this value was an effect of 1 transect receiving only 75% treatment; thus, there were a few small trees remaining on this transect.

Sage-grouse use of vegetation treatments

During the study, sage-grouse used habitat preferentially (χ^2 = 1453.57, df = 7, *P* = 0.00). Sage-grouse selected sage-brush steppe habitat (42% of total habitat used) and agricultural lands (28% of total habitat used, Figure 6). However, 21% of the locations were within areas that were recently mulched and re-seeded (Figure 6).

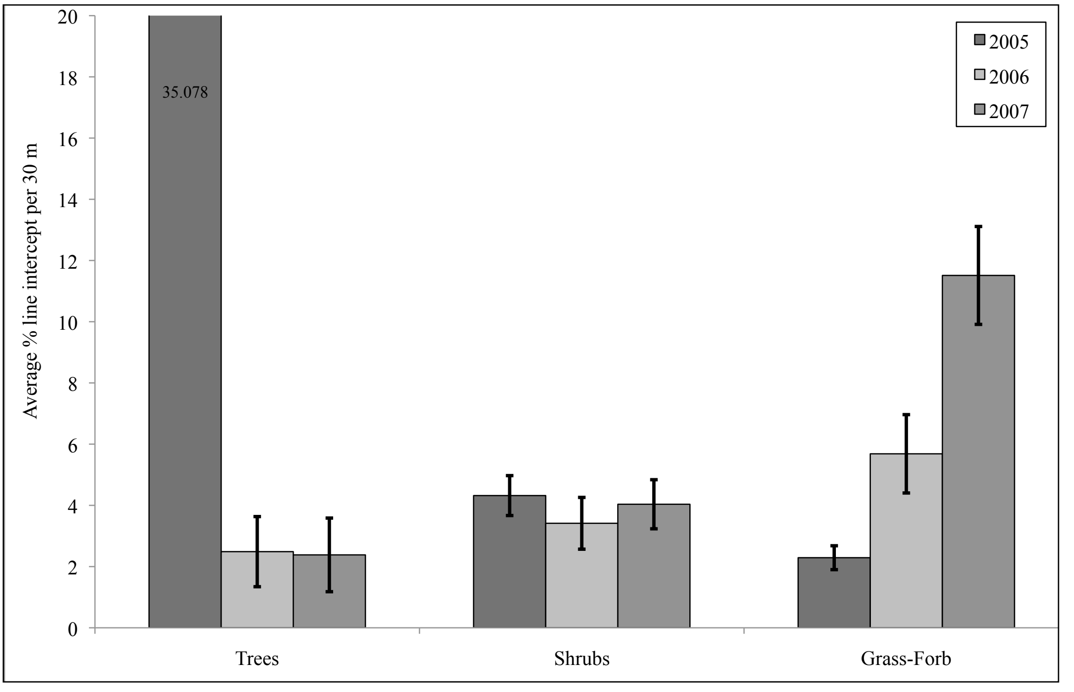

Figure 4: Average percentage of 30-m transect (± standard error) intercepted by each vegetation type, 2005 to 2007, Alton, Utah. Grasses are combined due to low frequency. The average peercentage intercept of trees in 2005 is labled rather than shown to allow for representation of shrubs and grass-forbs.

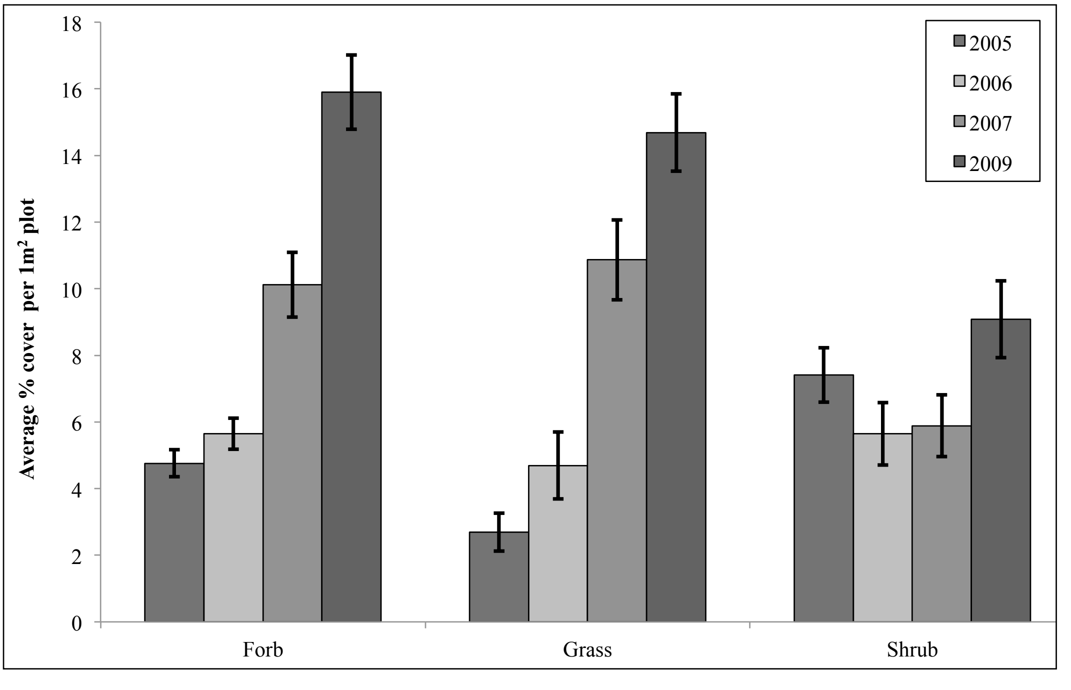

Figure 5. Average percentage cover (± standard error) by each vegetation type, 2005 to2009, Alton, Utah.

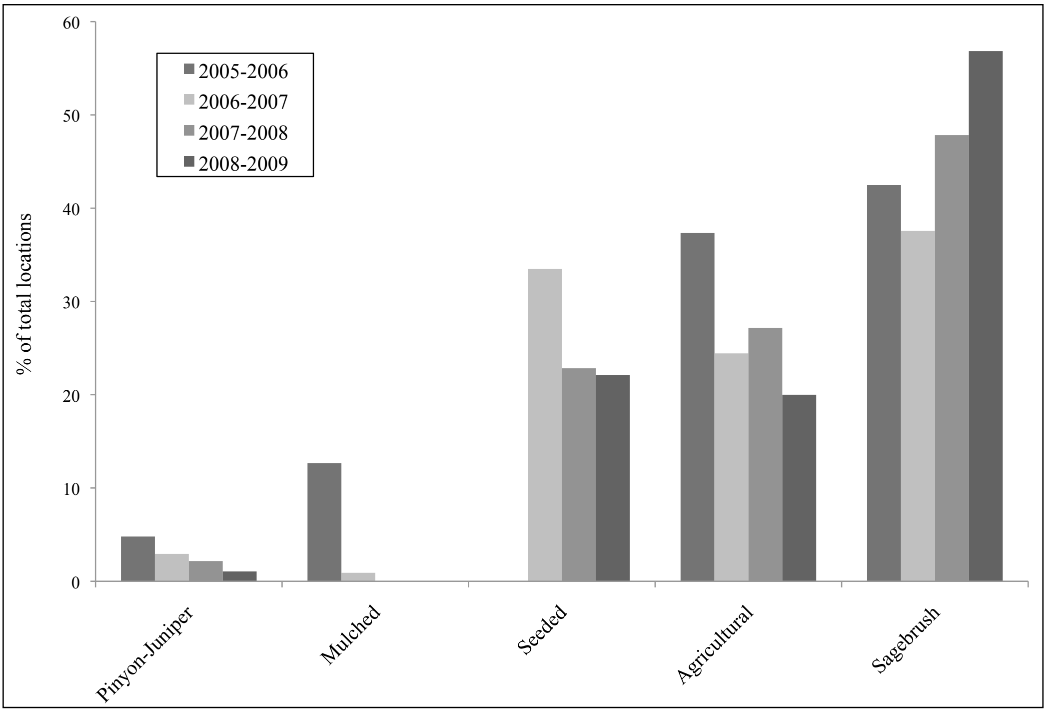

Figure 6: Overall vegetation use by sage-grouse for each available habitat type. Mulched includes the treated areas immediately pos-treatment in 2005. Seeded areas represent the treated areas once vegetation began to grow in the spring of 2006.

To conduct the chi-square analysis of yearly differences, we post-priori removed the developed, oak-mahogany, and riparian vegetation types, which together constituted only 0.4% of all locations. In the first year (March 2005 to February 2006), sage-grouse were usually found in agricultural lands (37%) and sage-brush steppe habitat (42%). After the treatment, there was a significant change in habitat use (χ^2 = 207.9, df = 15, P = 0.00). We found that sage-grouse used the treated areas (i.e., mulched) immediately after treatment; these areas had virtually no cover and very little vegetation growing (Figure 6). Once the first growing season after the treatment began (March 2006) there was a shift in use away from sagebrush and agriculture into the treated areas (i.e., seeded); the decrease in the use of agricultural fields continued throughout the study. Additionally, there was a trending decline in the percentage of use of pinon-juniper stands (Figure 5). To put habitat-use percentages in perspective, we also evaluated habitat-use with respect to habitat availability. With this analysis, it is clear that, while sage-grouse used pinyon-juniper and agricultural lands more than expected by their availability prior to treatment, their use was the opposite after the vegetation treatment (Figure 7). Sage-grouse were found in the seeded areas much more than expected based on habitat availability during the first growing season, and all other habitats less than expected. This preference for the treated areas was not apparent in subsequent years (Figure 7).

Discussion

Vegetation treatment

Grass and forb cover and height. The vegetation treatment conducted by the BLM was effective at removing trees in such a way that forbs, grasses, and shrubs were able to quickly become established in the treated areas. The vegetation treatment succeeded in increasing forb and grass cover; however, the average percentage cover and line-intercept for the forb-grass component in the study plots was very low at the end of the second year of growth compared to what is usually considered optimal for late summer habitat (see Connelly et al. 2011). However, this has been reported as acceptable early brood-rearing (early summer) habitat in central Wyoming (Holloran 1999).

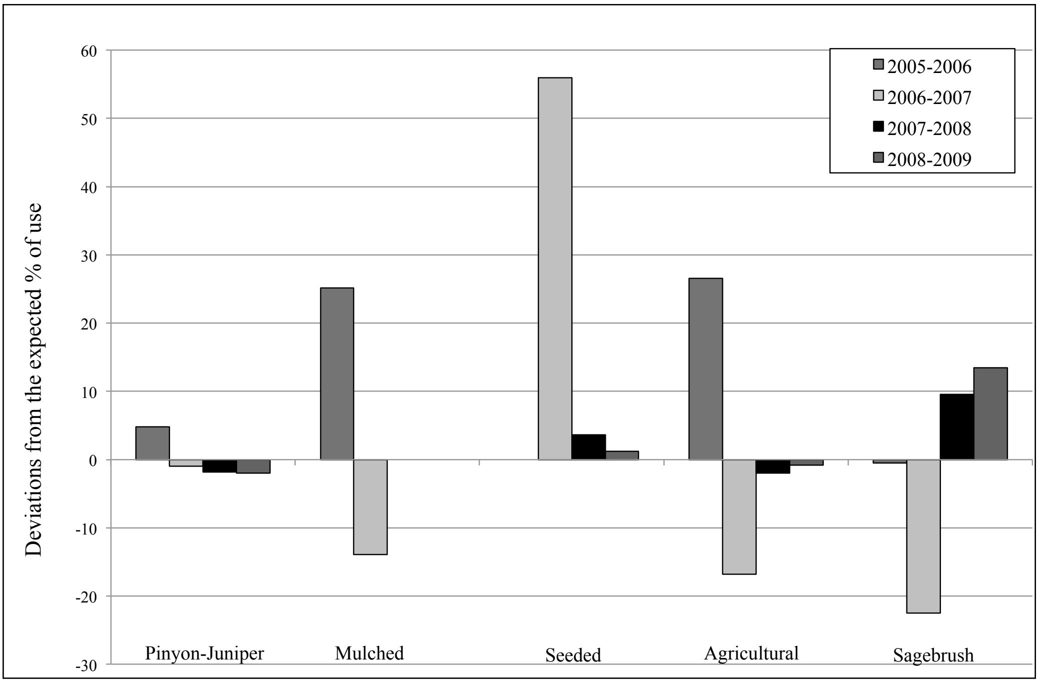

Figure 7. Deviations from the expected value of use, based on the amount of each habitat type available versus the percentage of the time sage-grouse were found in that habitat type. Bars above the line indicate use greater than expected. Mulched existed only in areas immediately after treatment in 2005 and before the first spring growth in 2006. After spring growth in 2006, these areas were considered seeded.

The average height of the forb-grass component did not increase with the vegetation treatment. We can deduce that this height is the average height to be expected, given the moisture and temperature regimes of the study area. Previous studies do not indicate a desired forb-grass height for optimum sage-grouse habitat; however, a forb-grass height similar to shrub height seems like a logical desired condition for providing cover. The vegetation treatment did result in forb-grass height similar to shrub height, which would provide sage-grouse broods with some visual cover from ground predators throughout the summer.

Shrub cover and height. The underlying objective of the vegetation treatment was to remove trees while keeping the shrub community as intact as possible. We consider it a success that shrub canopy cover was not negatively affected by the treatment methods and eventually began to increase in the area. Wallestad (1971) found a range of sagebrush canopy cover of 1 to 25% used in early brood-rearing habitat. Therefore, our low level of shrub cover may be acceptable for this life-stage. However, this is lower than the percentage canopy cover determined by Homer et al. (48 cm; 1993) as necessary for winter habitat in Utah. Eng and Schladweiler (1972) reported that sage-grouse used canopy cover of 20 to 30% in an area with a reported 25 cm of snow depth. From 1928 to 2005, Alton had an average monthly snow depth maximum of 20 cm (Utah Climate Center 2011). Perhaps 9% canopy cover is sufficient with this average snow depth; however, a study focusing on winter habitat needs would be necessary before making any conclusions regarding this interaction. The average shrub height was 25 cm; although this height is lower than the average reported for sage-grouse winter habitat, shrubs of this height would be able to provide cover throughout the winter for most years, given the average monthly snow depth reported in 2011. However, this height would not be suitable for cover in heavy snowstorms, and, therefore, could be a limiting factor for sage-grouse winter survival.

Shrub height was initially decreased by the vegetation treatment, most likely due to direct damage from the treatment itself; however, shrub height increased over the course of the study to a level similar to pre-treatment. Holloran (1999) found that sage-grouse used areas with similar shrub canopy height to our study area for early brood-rearing habitat. In Utah, Homer et al. (1993) determined that sage-grouse preferred medium to tall shrub height (40 to 60 cm), which is much higher than the shrub height we estimated in our study transects. Homer et al. (1993) conducted their study in northern Utah, with a different temperature and moisture regime than southern Utah, which may account for the differing results.

Sage-grouse use of vegetation treatment

In our study, we were unable to track birds for a full year prior to the vegetation treatment, so we can discuss only how their use of vegetation changed from year to year (i.e., their annual reference) as the treatment took effect, rather than what their preferred habitat was in a stable environment. However, the change in habitat use that we documented does provide some insight into sage-grouse habitat use in the Alton area.

Prior to treatment, sage-grouse in the Alton area used pinyon-juniper stands and agricultural fields. They used agricultural areas nearly as much as sagebrush habitat. Connelly and Doughty (1989), who reported similar use of agricultural areas, suggested that the use of agricultural areas was indicative of a lack of succulent forbs in the brood-rearing season. Looking at the vegetation treatment data, it is clear that there was very little understory or cover for sage-grouse in the pre-treatment habitat, limiting both food and shelter availability, and resulting in the use of habitat not normally associated with sage-grouse. Data collected in the study area in conjunction with another project registered ground temperatures of 41° C during the summer of 2005 (N. Frey, Southern Utah University, 2009, unpublished data), in untreated habitat. We suspect the high ground temperature was a result of the amount of bare ground combined with soil type. We did not do a comparison of cover type, cover density, or soil type to investigate these ground temperatures. However, they are an indicator of possible conditions in the study area. During times of high ground temperatures, such as this, pinyon-juniper stands may have been providing supplemental shade, which would explain the continued use of pinyon-juniper stands throughout the study. Similarly, with little understory available in their native habitat, as indicated by the pre-treatment vegetation surveys, alfalfa fields provided grouse with moisture and food during the summer months.

We were surprised to document sage-grouse using the treated areas immediately after treatment (Fall 2005), because there was no cover and often no vegetation in these areas. Additionally, it appears that the birds preferred the treated areas more than sagebrush habitat in the summer months. Most of our locations occurred during the day, rather than at dawn or dusk; the locations we documented were most likely due to foraging activity, rather than roosting activity. The newly treated areas would provide access to invertebrates in the mulch, and forbs would increase invertebrates and provide succulent vegetation in subsequent years. We did observe birds foraging in these treated areas but were unable to determine precisely what they were eating. We hypothesize that the birds were foraging in the mulch for grubs and other invertebrates, yet, using sagebrush habitat along the perimeter for cover. Similarly, Dahlgren et al. (2006) noticed sage-grouse using newly treated areas while staying close to the edge of the untreated sagebrush habitat.

The preference for the treated areas during the first growing season (early brood-rearing 2006) was also unexpected. We had hypothesized that these areas would not be used until a forb understory was established. The quickness of their use may be explained by the style of the treatment. As the data show, shrub cover may have slightly decreased, but it was not eliminated in the treated areas. Often the body of the shrub remained, but pieces had been broken off. Thus, the shrubs were still able to provide some cover for birds that were foraging in the new grass and forb vegetation. Their quick response might also be a reaction to what one might call a habitat release, or a sudden availability of limited habitat. In other words, the availability of suitable habitat was so low that any increase in even moderately desirable habitat resulted in a quick response.

While the use of treated areas happened sooner than expected, we did predict that the use of this habitat would minimize the use of what is commonly considered to be sub-optimal habitat, such as pinyon-juniper stands.

We found that after the seeded treatment areas began to grow, sage-grouse use of agricultural fields and pinyon-juniper stands was less than would be expected by availability; the proportion of locations found in these habitat types decreased each year.

Our telemetry results determined that sage-grouse in this study area used the area of the transects, which had a similar shrub height before and after the treatment, during the winter, although the shrub height and percentage cover was lower than reported as suitable in other studies (Eng and Schladweiler 1972, Homer et al. 1993). Sage-grouse in this study area may be capable of using (and persisting with) sagebrush canopy cover of this lower percentage and height given the shallow snow depth of Sink Valley in average years. However, our data of sage-grouse movements did record sage-grouse using small pinon-juniper stands throughout the winter. We suggest that sage-grouse in this area are most likely using pinyon-juniper stands for cover during heavy snow storms, when the shrub canopy cover and height are not sufficient to provide protection from the elements. Whether or not this adaption is a successful strategy remains to be determined.

We were not able to follow sage-grouse broods during our study; therefore, we cannot determine if female sage-grouse used these areas for early brood-rearing, as would be expected based on the habitat characteristics. However, we do know that the 2 females that we were able to track did not spend the summer in the area of Alton, but stayed in the proximity of the treatments. Additionally, not all sage-grouse used the agricultural areas in the summer and fall in the years after the treatment, suggesting that a portion of the sage-grouse in Sink Valley was able to meet its needs in the sagebrush habitat and treated areas rather than move north to the agricultural fields.

In conclusion, many habitat characteristics of the treated areas were below the characteristics that are considered average or optimal for different activity seasons. Habitat improvements to reduce tree cover and improve grass-forb densities in this region can quickly result in a positive change in sage-grouse habitat use in their southern distribution. The quick response of sage-grouse to habitat treatments in this study may be an indicator that habitat quality is a limiting factor in this region.

Management implications

This study suggests that suitable habitat is limited for greater sage-grouse in this study area. Sage-grouse responded quickly to treatments to remove trees in areas better suited for shrubs and grasses, thereby creating more foraging opportunities. It is worth noting that sage-grouse in this area are using areas for winter habitat with characteristics of cover and height much lower than recommended. Future studies might investigate if this use is a successful adaptation to the local climate or if winter habitat may be a limiting factor in this area.

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