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Original Article

Greater Sage-Grouse Use of Mechanical Conifer Reduction Treatments in Northwest Utah

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ABSTRACT A potential consequence of climate change, altered fire regimes, and a legacy of resource exploitation in western North America is increased displacement of desirable sagebrush (*Artemisia* spp.) communities by invasive plant species. Annually, an estimated 90,000 ha of sage-grouse (*Centrocercus* spp.) habitat is degraded by pinyon (*Pinus* spp.) and juniper (*Juniperus* spp.; PJ) encroachment. Sage-grouse responses to conifer encroachment may include avoidance of otherwise available habitats, lek abandonment, and subsequent population declines. Thus, restoration of PJ encroached sage-grouse habitats that exhibit intact sagebrush understories is a priority conservation action. However, better information is needed regarding sage-grouse response to these management actions. We used sage-grouse fecal pellet surveys and radiotelemetry location data to identify vegetation and landscape attributes that may influence sage-grouse use of PJ removal treatments completed using mechanical methods. Use of PJ removal treatments by sage-grouse was positively associated with irrigated pasture and alfalfa (*Medicago sativa*) hay within 1 km ($\beta = 7.69$, $SE = 5.58$, $P = 0.17$) and negatively associated with PJ canopy cover ($\beta = -1.52$, $SE = 0.84$, $P = 0.07$) within 500 m of treatments. Percent cover of mesic habitats and sagebrush canopy were greater within 1 km of treatments where sage-grouse were detected; however, these relationships were weak because of large variability in conditions across sites. Our results document sage-grouse use of 9 of 16 mechanical PJ removal treatments examined in an encroached sagebrush landscape and suggest that mechanical PJ removal treatments should be sited adjacent to occupied sage-grouse habitat in areas that minimize surrounding PJ cover.

KEY WORDS *Centrocercus urophasianus*, fecal pellet surveys, greater sage-grouse, habitat management, juniper, *Juniperus* spp, mechanical treatments, *Pinus* spp, pinyon pine, Utah.

Prior to European settlement of the western United States, pinyon pine (*Pinus* spp.) and juniper (*Juniperus* spp.; PJ) woodlands were primarily located on rocky ridges and other areas exhibiting sparse vegetation (Miller et al. 2000). Expansion of PJ woodlands into sagebrush (*Artemisia* spp.) landscapes has accelerated over the past century (Miller et al. 2000), with PJ woodlands expanding at estimated rates greater than during previous climatic cycles (Weisberg et al. 2007, Sankey and Germino 2008, Miller et al. 2011). As PJ canopy cover increases in sagebrush communities, shrub canopy cover is displaced (Miller et al. 2000). Proximate causes of conversion of shrub-steppe communities to PJ woodlands include programmatic fire suppression resulting in reduced fire frequency, and unmanaged livestock grazing during the late 1800s and early 1900s (Miller et al. 2000).

Stiver et al. (2006) estimated that 60,000–90,000 ha of sagebrush habitat across the range of greater sage-grouse (*Centrocercus urophasianus*; sage-grouse) is lost annually to PJ encroachment. Sage-grouse population declines have also been partially attributed to conifer expansion (Beck et al. 2003, Schroeder et al. 2004). Previous research has reported that sage-grouse avoid PJ-dominated landscapes, with only occasional use of early successional stands (Doherty et al. 2008, Frey et al. 2013). Additionally, a sage-grouse lek may become inactive when PJ canopy cover exceeds 4% within 1 km of the lek, and nest sites may be avoided when conifer cover is >3% within 800 m (Baruch-Mordo et al. 2013, Severson et al. 2017).

Range-wide declines and habitat loss prompted the U.S. Fish and Wildlife Service (USFWS) to identify sage-grouse as a candidate species for protection under the Endangered Species Act of 1973 (USFWS 2010). The USFWS encouraged federal and state agencies to focus management actions in core

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conservation areas exhibiting the greatest potential for habitat conservation. Subsequently, the USFWS identified mitigating PJ expansion into occupied sage-grouse habitat in core conservation areas as a potentially important species conservation strategy (USFWS 2013).

The U.S. Department of Agriculture Natural Resources Conservation Service, through its Sage-Grouse Initiative (www.sagegrouseinitiative.com), has provided cost-share to landowners to mechanically remove or reduce thousands of hectares of PJ on private lands in the western United States. Similar projects have been implemented range-wide on U.S. Department of the Interior Bureau of Land Management (BLM) and U.S. Forest Service-administered lands. In Utah, USA, alone, the Watershed Restoration Initiative (WRI), a multi-agency collaborative effort administered through the Utah Department of Natural Resources (UDNR), has removed PJ from >200,000 ha of sagebrush landscapes since 2006 (UDNR 2014). Large-scale mechanical PJ reduction projects are relatively low cost on a per hectare basis, and may have potential for increasing available habitat for sage-grouse and other sagebrush obligate species (Guthery 1997, UDWR 2009, Baruch-Mordo et al. 2013).

Few studies have evaluated sage-grouse use of PJ reduction projects completed using mechanical methods. Commons et al. (1999) reported that the number of Gunnison sage-grouse (*C. minimus*) males counted on leks doubled 3 years after conifer reduction by chaining. Frey et al. (2013) reported sage-grouse use of sites 1 year after hand thinning and mechanical mulching of PJ, but did not quantify habitat factors contributing to observed use. Knick et al. (2014) studied sagebrush-obligate birds, whose niches broadly overlapped with sage-grouse, to determine occupancy responses to habitat changes resulting from prescribed fire on 400–1,300-ha plots and smaller (<26-ha) adjacent plots where the PJ cover was removed using mechanical methods (i.e., hand-cutting and mastication). The authors concluded that prescribed fire and small-scale mechanical PJ treatments would not increase available habitat for the sagebrush bird community, including sage-grouse. However, posttreatment, their prescribed fire plots still exhibited 6–24% PJ canopy cover. Given current range-wide emphasis on implementation of large-scale mechanical PJ removal projects, it is necessary to evaluate sage-grouse responses to ensure appropriate project prioritization. Our objectives were to determine whether sage-grouse used areas where PJ was removed using mechanical treatments and, if so, identify vegetation and landscape factors associated with sage-grouse use.

STUDY AREA

We conducted our research in the Box Elder Sage-grouse Management Area (SGMA) as defined in the 2013 Utah Conservation Plan for Greater Sage-grouse (Utah Governor's Office 2013). In 2013, 577 male sage-grouse were counted on 42 active leks in this SGMA (J. Robinson, Utah Division of Wildlife Resources, unpublished data). The SGMA study area encompassed 566,117 ha of a mosaic of land ownership including private land (49.0%, 277,149 ha), and lands managed by the BLM (40.0%, 226,407 ha), Utah School and Institutional Trustlands Administration (SITLA, 5.9%, 33,447 ha), and U.S. Forest Service (5.1%, 29,114 ha; Utah Automated Geographic Reference Center [AGRC] 2013). The core of the study area where sage-grouse were captured was bounded by the Raft River Mountains to the north, Grouse Creek Mountains to the west and the hardpan of the Great Salt Lake to the southeast. The primary land use was grazing by domestic livestock and associated agricultural activities, which included irrigating pastures for summer livestock grazing and production of alfalfa hay (*Medicago sativa*) for livestock winter feed.

Vegetation communities included salt desert shrub to mixed Wyoming and black sagebrush (*A. t. tridentata*, *A. nova*) communities and juniper woodlands at lower elevations along a fluvial bench. Mixed mountain shrub and aspen (*Populus tremuloides*) patches were present at mid elevations, with mountain mahogany (*Cercocarpus ledifolius*) and isolated Douglas fir (*Pseudotsuga menziesii*) forests mixed with mountain big sagebrush (*A. t. vaseyana*) at higher elevations. Elevations ranged from 1,400 m to 3,000 m above sea level. From 1990 to 2012, the weather station (1,732 m elevation) at Rosette, Utah, near the center of the study area, documented an average annual precipitation of 22.6 cm with 14.2 cm occurring as snow between November and April. Temperatures ranged from a monthly average high of 30° C in July to a monthly average low of −9.4° C in December and January (Western Regional Climate Center 2013).

METHODS

We evaluated 16 PJ removal treatments completed using mechanical methods in the study area between 2007 and 2013. Four treatments involved complete mastication (i.e., Fecon Bull Hog, Lebanon, OH, USA), and 12 were chained (Cain 1972). Treatments ranged in size from 57 ha to 547 ha ($\bar{x} = 274$ ha, median = 250 ha). Most treatments were located in the foothills of the Raft River and Grouse Creek Mountains between 1,654 m and 1,930 m above sea level, and near or adjacent to intact sagebrush communities.

Conifer Treatments

We mapped all known PJ treatment areas using data obtained from a combination of sources, including ground observations, aerial imagery and maps provided by Utah's WRI (WRI 2014). Eleven treatments were located on private land, 4 were on BLM-administered lands, and 1 on SITLA land. Because the treatments were conducted prior to the initiation of our research, we were unable to randomize the selection of treatment areas and, therefore, we assumed that treatment areas constituted a random and unbiased sample of sagebrush habitats with PJ encroachment in the study area. We established 14 reference plots in the closest sagebrush-dominated areas adjacent to the treatments; direction and distance from treatment area was not randomized (Fig. 1). Distance from edge of treatments to closest edge of reference plots ranged from 20 m to 1,800 m ($\bar{x} = 355$ m, median = 96 m).

Sage-Grouse Use

We used a combination of fecal pellet surveys and radiotelemetry to detect sage-grouse use in completed PJ treatments and

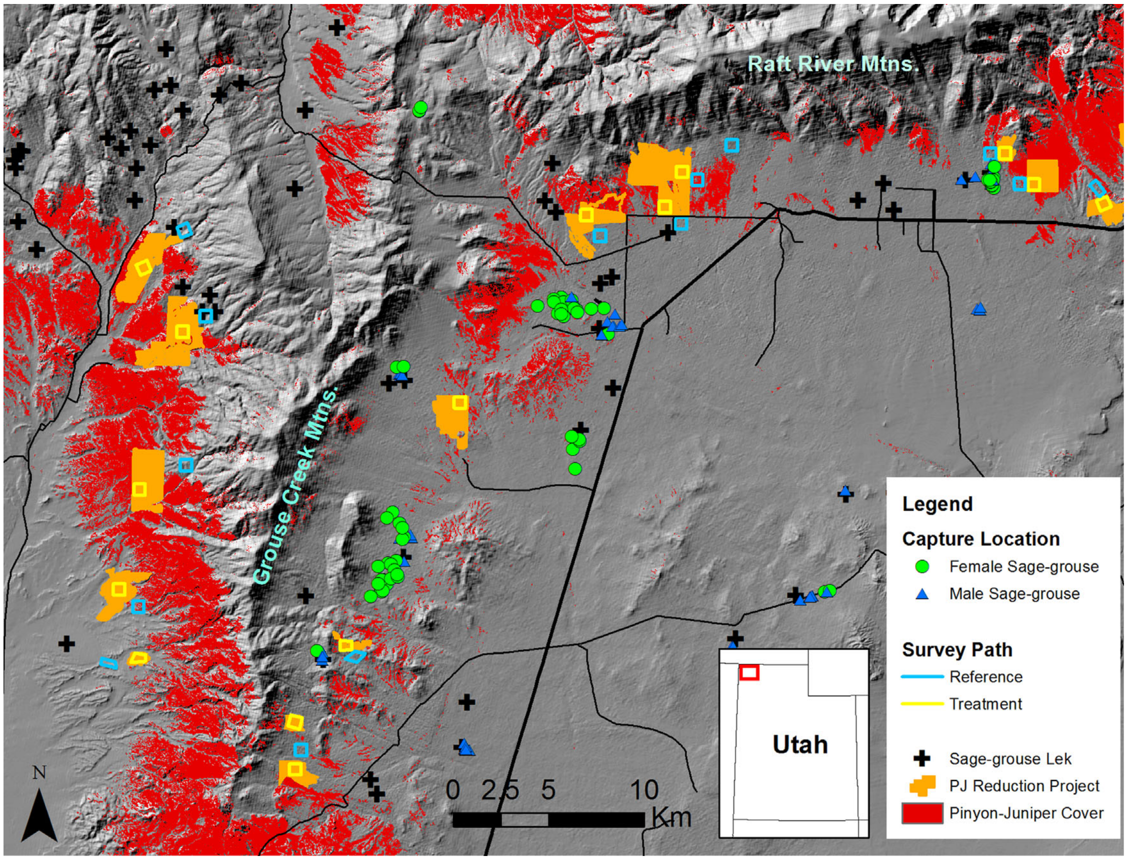

Figure 1. Mechanical conifer-removal treatments and reference plots surveyed in 2013 to evaluate greater sage-grouse ("sage-grouse") use in response to landscape and habitat vegetation characteristics in Utah, USA, West Box Elder Sage-grouse Management Area relative to pinyon–juniper (PJ; *Pinus* spp.–*Juniperus* spp.) vegetation cover (LANDFIRE 2010), capture locations for radiomarked sage-grouse, and active sage-grouse leks (Utah Division of Wildlife Resources 2015).

reference plots (Dahlgren et al. 2006). To conduct fecal pellet surveys, we placed one rectangular 2,400-m survey transect centered within each treatment and reference plot in July and August of 2013. A single observer walked each transect with the guidance of a handheld Global Positioning System receiver. Observers visually scanned for fecal pellets and cecal droppings, focusing on the area within 2 m of the transect center line. However, observers also recorded fecal pellets and cecal droppings observed farther than 2 m from the transect center line (Dahlgren et al. 2006). In addition to sage-grouse pellets, we also recorded number and density of domestic cattle pats along transects as a proxy for grazing intensity (Jankowski et al. 2014).

We also used radiotelemetry locations within treatments and reference plots as a measure of sage-grouse use. To obtain telemetry locations, we captured and radiomarked sage-grouse from January 2012 to March 2013 using the nocturnal spotlight method (Giesen et al. 1982, Wakkinen et al. 1992, Connelly et al. 2003). We equipped individual sage-grouse with a very-high-frequency radiocollar (Advanced Telemetry Systems, Isanti, MN, USA; Model A4050) weighing approximately 22 g with necklace (1–2% of body wt). We visually located radiomarked females 2–3 times/week from mid-March to early August in 2012 and 2013 to monitor movements. We located males biweekly throughout spring, summer, and autumn field seasons. We located radiomarked sage-grouse 1–2 times during the winter season via ground and aerial telemetry. Research protocols were approved by the Utah State University Institutional Animal Care and Use Committee permit #1547, and UDWR Certificate of Registration Number 2BAND8743.

Habitat Vegetation Classification and Attributes

We used 2010 LANDFIRE Existing Vegetation Type data to determine vegetation types adjacent to and surrounding treatment areas (LANDFIRE 2010). Little information is known about sage-response to PJ removal treatments, so we buffered treatments areas at multiple scales: 40 m, 500 m, 1 km, and 2 km. We categorized vegetation types within buffers into PJ (Great Basin Pinyon Juniper Woodland and Inter Mountain Basins Juniper Savanna), sagebrush (sagebrush and shrub-steppe classifications), mesic (riparian and mesic classifications), agriculture (i.e., irrigated pasture and alfalfa hay), and other (all other classifications). We calculated percent land cover classified as PJ, sagebrush, mesic, and agriculture for each treatment buffer. We acquired stream and spring locations and calculated distance to nearest water feature from the closest edge of each treatment area (Utah AGRC 2014).

To determine year of treatment implementation when not documented, we reviewed annual Landsat 5 Thematic Mapper images from 2000 to 2011, Landsat 5 Multispectral Scanner images from 2012, and Landsat 8 Orbital Land Imager images from 2013 (Path 39 Row 31) collected from the U.S. Geological Survey Global Visualization Viewer (glovis.usgs.gov). We did not evaluate successional stages of PJ communities prior to treatments; however, we visually estimated degree of encroachment from National Agriculture Imagery Program aerial imagery and categorized it as phase I, II, or III (datagateway.nrcs.usda.gov, Miller 2005).

Statistical Analyses

Our primary objective was to evaluate whether sage-grouse used PJ removal treatments at levels similar to adjacent sagebrush habitats. We combined detection data from pellet surveys and telemetry monitoring in treatment and reference plots: if sage-grouse was detected using either method it was designated as a detection plot; if use was not detected it was designated as a nondetection plot. We used a generalized linear regression model with a logit link in Program R (version 3.2.0, www.r-project.org; accessed 4 Jun 2015) to test the statistical null hypothesis that probability of use did not differ between treatment and reference plots. To address our second objective, to identify vegetation and landscape factors associated with sage-grouse use, we compared the mean percentage of LANDFIRE vegetation types within treatment buffers of varying widths to determine the spatial scale at which each vegetation type had the greatest effect on plot use by sage-grouse and determine the overall most influential vegetation type and scale combination. We compared vegetation and landscape factors between plots where sage-grouse use was or was not detected using a generalized linear regression model with a logit link in Program R (version 3.2.0, www.r-project.org; accessed 4 Jun 2015), and we ranked competing models for each of 4 buffer widths using Akaike Information Criterion corrected for small-sample-size scores (AIC_c; Akaike 1973). Finally, to determine strength and magnitude of effects of other landscape features on sage-grouse patch use, we modeled use (detection or nondetection) as a function of distance to water, years since PJ removal treatment, patch size, and cow pat density using generalized linear regression with a logit link.

RESULTS

We captured and radiomarked 123 sage-grouse (68 F, 55 M) from 7 leks and 4 non-lek areas during our study (Fig. 1). The combination of pellet surveys and telemetry monitoring resulted in sage-grouse use being detected in 9 of 16 (56.3%) treatment plots, 4 by pellet surveys, 2 using radiotelemetry, and 3 using both radiotelemetry and pellet surveys. We detected sage-grouse use in 11 of 14 (78.6%) reference plots, 7 by pellet surveys and 4 using radiotelemetry. We failed to detect a difference in probability of sage-grouse use between treatment and reference plots ($\beta = 0.25$, $SE = 0.50$, $P = 0.62$).

Models examining the relationships between percent coverage of vegetation types at various scales and sage-grouse use indicated that the 1-km scale was most informative for 3 of the 4 cover types (Table 1). Models for the effect of PJ at various scales indicated that the 500-m scale was influential in determining whether sage-grouse would use a site ($\beta = -1.52$, $SE = 0.84$, $P = 0.07$; Table 1). Sage-grouse use was not detected in treatment areas that exhibited >44% of land cover classified as PJ within 500 m.

Table 1. Generalized linear regression results examining relationships between proportion cover within buffers surrounding mechanical conifer reduction treatments implemented between 2007 and 2013 and greater sage-grouse detections from 2012 and 2013 (fecal pellet or telemetry presence within a treatment area) in Box Elder County, Utah, USA.

Model	K[a]	AIC_c[b]	Category ΔAIC_c[c]	Overall ΔAIC_c[d]	w_i[e]	Dev[f]
Agriculture 1,000 m	2	19.18	0.00	0.00	0.33	14.25
Agriculture 500 m	2	21.67	2.49	2.49	0.09	16.75
Agriculture 2,000 m	2	22.83	3.65	3.65	0.05	17.91
Agriculture 40 m	2	26.54	7.36	7.36	0.01	21.61
Pinyon juniper 500 m	2	21.57	0.00	2.39	0.10	16.65
Pinyon juniper 1,000 m	2	21.72	0.15	2.54	0.09	16.79
Pinyon juniper 2,000 m	2	23.11	1.54	3.94	0.05	18.19
Pinyon juniper 40 m	2	24.90	3.33	5.72	0.02	19.97
Mesic 1,000 m	2	22.12	0.00	2.94	0.08	17.20
Mesic 2,000 m	2	24.65	2.10	5.47	0.02	19.72
Mesic 500 m	2	24.74	2.53	5.56	0.02	19.81
Mesic 40 m	2	26.54	2.62	7.36	0.01	21.61
Sagebrush 1,000 m	2	23.50	0.00	4.33	0.04	18.58
Sagebrush 500 m	2	23.80	0.30	4.63	0.03	18.88
Sagebrush 2,000 m	2	24.23	0.73	5.05	0.03	19.31
Sagebrush 40 m	2	26.12	2.61	6.94	0.01	21.19
Null	1	24.22		5.04	0.03	21.93

[a] No. of estimated parameters in the model.
[b] Akaike's Information Criterion corrected for small sample size.
[c] Delta AIC_c relative to top model within land-cover category candidate model set.
[d] Delta AIC_c relative to top model in overall candidate model set.
[e] Akaike model wt.
[f] Model deviance.

The presence of sagebrush canopy cover within 1 km of treated sites was positively associated with the probability that the site would be used by sage-grouse ($\beta = 1.07$, $SE = 0.66$, $P = 0.10$), with used sites having, on average, greater sagebrush canopy cover ($\bar{x}_{used} = 71.2\%$, $SE = 4.5$; $\bar{x}_{used} = 55.9\%$, $SE = 6.6$). Similarly, mesic habitats were most influential at the 1 km scale ($\beta = 1.61$, $SE = 0.98$, $P = 0.10$). Percent mesic areas within 1 km of treatments was greater ($\bar{x}_{used} = 1.9\%$, $SE = 0.5$) in areas where sage-grouse use was detected than areas where use was not detected ($\bar{x}_{used} = 0.5\%$, $SE = 0.2$). Across all models, percent agriculture land use within 1 km had the greatest effect on whether PJ removal treatment areas were used by sage-grouse ($\beta = 7.69$, $SE = 5.58$, $P = 0.17$; Table 1). Although agricultural land use was low in all cases, treatments where we detected sage-grouse use had, on average, 22.5 times more agriculture land use within 1 km than did treatments where we did not detect any sage-grouse use ($\bar{x}_{used} = 1.2\%$, $SE = 0.5$; $\bar{x}_{used} = 0.1\%$, $SE < 0.0$).

Sage-grouse were detected on 7 phase II and 2 phase III PJ treatments and not detected on 3 phase II and 4 phase III PJ treatments. All treatment areas had sagebrush cover remaining after PJ removal. Sage-grouse use was positively related to age of PJ treatments ($\beta = 1.15$, $SE = 0.66$, $P = 0.08$). Treatments where sage-grouse use was detected were older ($\bar{x}_{used} = 3.6$ yr, $SE = 0.67$) than treatments where use was not detected ($\bar{x}_{used} = 1.6$ yr, $SE = 0.60$). More cattle pats were recorded in treatment plots where sage-grouse use was detected ($\beta = 1.30$, $SE = 0.80$, $P = 0.10$; $\bar{x}_{used} = 41.9$ pats/km, $SE = 7.0$) than not detected ($\bar{x}_{used} = 20.4$ pats/km, $SE = 14.7$). We found no relationships between sage-grouse detection or nondetection and distance to water ($\beta = 0.21$, $SE = 0.54$, $P = 0.69$), or treatment size ($\beta = 0.08$, $SE = 0.52$, $P = 0.87$).

DISCUSSION

Our study demonstrated extensive sage-grouse use of mechanical PJ removal treatments that were previously phase II and early phase III PJ stands and exhibited a residual sagebrush understory (Miller 2005). Because of the retrospective nature of our study, we were not able to collect pretreatment data for study plots to determine whether they were used by sage-grouse prior to PJ removal. However, because sage-grouse avoidance of PJ woodlands has been previously reported, we assumed a similar response for our study area (Commons et al. 1999, Doherty et al. 2010, Baruch-Mordo et al. 2013, Frey et al. 2013, Wing 2014).

The completed treatments in our study area exhibited habitat characteristics that have previously been reported as desirable for sage-grouse (i.e., increased sagebrush canopy and herbaceous cover, mesic areas; Connelly et al. 2011, Cook 2015). The PJ removal projects may have also increased the amount of useable sagebrush habitat space available to sage-grouse by reducing the PJ cover to <4% (Baruch-Mordo et al. 2013). Guthery (1997) used the northern bobwhite (*Colinus virginianus*) as a case study to advance the concept of useable habitat space. He argued that increasing habitat quality does not necessarily lead to an increase in total population or densities, but increasing usable space can increase total population. Management actions implemented to remove or reduce PJ in areas where the sagebrush understory still provides potentially available habitat may increase the amount of useable space available for sage-grouse, which could lead to increased local populations in areas where sagebrush habitat is a limiting factor (Dahlgren et al. 2016).

Frey et al. (2013) reported immediate sage-grouse use of conifer removal treatments in areas occupied by sage-grouse. In their study, adjacent areas occupied by sage-grouse were subjected to increased disturbance because of coal mining activities (S. Frey, Utah State University personal communication). This ongoing disturbance may have accelerated sage-grouse use of the conifer removal treatments as birds abandoned previously occupied habitats. Lyon and Anderson (2003) reported sage-grouse moving farther from leks to nest in areas in Wyoming, USA, disturbed by energy development. In our study area, the land use in areas adjacent to study plots did not change over the period from treatment implementations to sage-grouse use data collection; therefore, sage-grouse movement into treatment areas cannot be attributed to increased disturbance resulting from changes in land use.

In contrast to Knick et al. (2014), we found that PJ reduction projects did lead to increased use by a sage-brush obligate species. Knick et al. (2014) concluded that, 3–5 years posttreatment, few if any of their treatments conducted in juniper woodlands would increase available habitat for the sagebrush bird community and concluded that the immediate habitat benefits for sage-grouse from conifer removal treatments would also be limited. However, use of prescribed fire by Knick et al. (2014) to remove PJ canopy cover would likely have a negative effect on shrubs and herbaceous understory plants important for sage-grouse (Connelly et al. 2011, Beck et al. 2012, Roundy et al. 2014). Additionally, prescribed fire treatments studied by Knick et al. (2014) still exhibited 6–24% PJ cover and woodland canopy cover; >4% has been implicated as being associated with sage-grouse lek extirpation and avoidance (Baruch-Mordo et al. 2013, Fedy et al. 2014). Further, scales of the mechanical PJ treatments we studied were larger than those studied by Knick et al. (2014). Sage-grouse, a landscape-species, use a variety of seasonal habitats distributed over large areas and scale of treatments may affect probability of sage-grouse use (Doherty et al. 2010, Frey et al. 2013), although we did not find any relationship between the size of treatments and their probability of being used by sage-grouse. Lastly, conifer removal treatments we studied were completed in an SGMA that exhibited some of the greatest sage-grouse densities reported in Utah (UDWR 2009). Knick et al. (2014) did not describe the level of sage-grouse occupancy in terms of active leks in areas adjacent their study area.

The relationship we detected between mesic and agriculture land use at the 1-km spatial scale and sage-grouse use provides guidance to help prioritize PJ removal projects intended to benefit sage-grouse. In buffer areas surrounding treatments used by sage-grouse, mesic patches, which are often associated with sage-grouse brood use (Klebenow 1969, Wallestad 1971, Atamian et al. 2010, Connelly et al. 2011, Dzialak et al. 2011), exhibited nearly 4 times the cover relative to treatments where sage-grouse use was not detected. This 4-fold magnitude of difference and known importance of mesic habitat to sage-grouse suggests that the relationship may be ecologically important and should be taken into consideration when planning habitat improvement projects and investigated further in future research. Although the area classified as agriculture land use was limited, it was an important effect in the top model at 1 km. Agriculture land use in our study area consisted of irrigated pastures and alfalfa hay; therefore, these results may not apply to other forms of agriculture. Patterson (1952), Donnelly et al. (2016) and others (see Connelly et al. 2011 for a review) reported sage-grouse use of irrigated pasture and alfalfa fields on private land during the brood-rearing period. As such, the agricultural land uses in our study area may have constituted surrogate mesic brood habitat.

Our results also corroborate other studies reporting that conifer removal improves habitat quality for sage-grouse or leads to an increase in sage-grouse use (Commons et al. 1999, Coultrap et al. 2008, Frey et al. 2013, Roundy et al. 2014). Coultrap et al. (2008) found that removing junipers from the landscape resulted in increased grass cover and herbaceous productivity and reduced bare ground. Roundy et al. (2014) demonstrated that shrub and perennial grass cover can be maintained when PJ woodlands are removed before displacing desired understory species (Phases I and II), but that treatments implemented when PJ was the dominate vegetation (Phase III) resulted in herbaceous-dominated plant communities (Miller 2005). The positive relationship between sage-grouse occupancy and cattle pat density suggests that sage-grouse and cattle were attracted to similar areas where herbaceous vegetation may have been enhanced because of the treatments (Roundy et al. 2014). However, we did not have information on stocking rates in surveyed areas and were not able to survey more broadly for cattle densities in the study area, and therefore cannot draw definitive conclusions on relationships between stocking rates and sage-grouse use.

The relationship we observed between sage-grouse use and age of PJ treatments may also reflect an increase in herbaceous vegetation. Roundy et al. (2014) reported that older PJ treatments generally exhibited better shrub, forb, and grass cover depending on pretreatment conditions. Concomitantly, as vegetation responds over time to management treatments, sage-grouse may move into these areas because of increased resource availability (Dahlgren et al. 2006, 2016; Fedy et al. 2012).

We acknowledge that the sample sizes we used to make inferences in this study were small, and likely contribute to imprecise estimates of some of the parameters we examined. However, we argue that the associations we report are biologically important and as such should not be discounted based solely on imprecise estimates (Cohen 1995, Johnson 1999, Guthery 2008). Additional research will be needed to determine how sage-grouse use conifer-removal treatment areas in various seasons (i.e., nesting, brood-rearing, and winter habitat), and whether this use translates into increased vital rates and more stable populations.

MANAGEMENT IMPLICATIONS

Pinyon–juniper removal increases usable habitat space for sage-grouse. Future PJ-removal treatments should be located near areas that exhibit relatively extensive sagebrush canopy cover and in locations with increased availability to mesic areas, which could provide potential brood-rearing habitats. Although larger scale mechanical PJ-removal treatments similar to those we studied may add to the amount of useable habitat space available for sage-grouse (Dahlgren et al. 2016), understanding the effects of these treatments on stabilizing sage-grouse populations will require further study.

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