12-2015

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AVIAN CONSERVATION & ECOLOGY

VOLUME 10, ISSUE 2, ARTICLE 7

Lukacs, P. M., A. Seglund, and S. Boyle. 2015. Effects of Gunnison Sage-Grouse habitat treatment efforts on associated avifauna and vegetation structure. *Avian Conservation and Ecology* 10(2):7. http://dx.doi.org/10.5751/ACE-00799-100207

Research Paper

Effects of Gunnison Sage-Grouse habitat treatment efforts on associated avifauna and vegetation structure

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ABSTRACT. Conservation efforts over the last 20 years for the Gunnison Sage-Grouse (*Centrocercus minimus*) have involved extensive habitat manipulations done predominantly to improve brood rearing habitat for the grouse. However, the effects of Gunnison Sage-Grouse habitat treatments on sympatric avifauna and responses of vegetation to manipulations are rarely measured, and if they are, it is immediately following treatment implementation. This study examined the concept of umbrella species management by retrospectively comparing density and occupancy of eight sagebrush associated songbird species and six measures of vegetation in treated and control sites. Our results suggested that songbird densities and occupancy changed for birds at the extreme ends of their association with sagebrush and varied with fine-scale habitat structure. We found Brewer's Sparrows (*Spizella breweri*) decreased in density on treated sites and Vesper Sparrows (*Pooecetes gramineus*) increased. Occupancy estimation revealed that Brewer's Sparrows and Green-tailed Towhees (*Pipilo chlorurus*) occupied significantly fewer treated points whereas Vesper Sparrows occupied significantly more. Vegetation comparisons between treated and control areas found shrub cover to be 26% lower in treated sites. Lower shrub cover in treated areas may explain the differences in occupancy and densities of the species sampled based on known habitat needs. The fine-scale analysis showed a negative relationship to forb height and cover for the Sage Sparrow (*Amphispiza belli*) indicating, from vegetation measures showing grass and forb cover during a good precipitation year covered significantly more area in the treatment than the control sites, that Sage Sparrows may also not respond favorably to Gunnison Sage-Grouse habitat treatments. While the concept of an umbrella species is appealing, evidence from this study suggests that conservation efforts aimed at the Gunnison Sage-Grouse may not be particularly effective for conserving other sagebrush obligate species of concern. This is probably due to Gunnison Sage-Grouse habitat management being focused on the improvement of brood rearing habitat which reduces sagebrush cover and promotes development of understory forbs and grasses.

Effets des efforts d'aménagement de l'habitat du Tétras du Gunnison sur l'avifaune associée et la structure de la végétation

RÉSUMÉ. Les efforts de conservation du Tétras du Gunnison (*Centrocercus minimus*) au cours des 20 dernières années se sont transposés en d'importantes manipulations de l'habitat visant d'abord à améliorer l'habitat d'élevage des jeunes. Toutefois, les effets de l'aménagement de l'habitat du Tétras du Gunnison sur l'avifaune sympatrique et l'évolution de la végétation à la suite des manipulations sont rarement mesurés, et dans les cas où ils le sont, ces mesures sont prises immédiatement à la suite de l'aménagement. La présente étude examine le concept de gestion par espèces parapluie en comparant rétrospectivement la densité et l'occurrence de huit passereaux associés aux armoises et les valeurs de six paramètres de végétation dans des parcelles traitées et témoins. Nos résultats indiquent que la densité et l'occurrence ont changé pour les passereaux qui se situaient aux extrémités de leur association avec l'armoise et ont varié en fonction de la structure de l'habitat à petite échelle. Nous avons observé que la densité des Bruants de Brewer (*Spizella breweri*) a diminué dans les parcelles traitées et que celle des Bruants vespéraux (*Pooecetes gramineus*) a augmenté. Les estimations de l'occurrence ont révélé que le Bruant de Brewer et le Tohi à queue verte (*Pipilo chlorurus*) occupaient significativement moins de parcelles traitées comparativement aux parcelles témoins, tandis que les Bruants vespéraux en occupaient beaucoup plus. La comparaison de la végétation des secteurs traités et des secteurs témoins a permis de montrer que le couvert arbustif était inférieur de 26 % dans les parcelles traitées. Le couvert arbustif plus faible dans les secteurs traités pourrait expliquer les différences obtenues dans l'occurrence et les densités des espèces échantillonnées sur la base des besoins connus en matière d'habitat. L'analyse à petite échelle a montré qu'il existait une relation négative entre le Bruant de Bell (*Amphispiza belli*) et la hauteur et le couvert des plantes herbacées non graminoïdes; cette analyse indique aussi que, selon les mesures de végétation montrant que durant une bonne année de précipitation les graminées et les plantes herbacées non graminoïdes occupaient une superficie beaucoup plus grande dans les parcelles traitées que dans les parcelles témoins, le Bruant de Bell pourrait ne pas réagir favorablement à l'aménagement de l'habitat pour le Tétras du Gunnison. Bien que le concept de l'espèce parapluie soit attirant, les résultats de cette recherche laissent croire que les efforts de conservation destinés au Tétras du Gunnison ne sont peut-être pas très efficaces pour la

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conservation d'autres espèces préoccupantes spécialistes de l'armoise. Ce constat découle probablement du fait que l'aménagement de l'habitat du tétras cible l'amélioration de l'habitat d'élevage des jeunes, qui favorise la réduction du couvert d'armoises et le développement d'un sous-étage de plantes herbacées tant non graminoïdes que graminoïdes.

Key Words: *Colorado; distance sampling; Gunnison Sage-Grouse; occupancy; habitat treatments; sagebrush; umbrella species; sagebrush obligates*

INTRODUCTION

The concept of umbrella species management is the implementation of conservation efforts aimed at managing one focal species that will confer benefits to a broad suite of other species inhabiting similar ecosystems (Mills 2013). Umbrella species typically occupy large geographic areas that encompass a mosaic of habitats enabling the species to survive, reproduce, and maintain viable populations. The broad value of umbrella species management appears intuitively obvious, but its efficacy is rarely tested. Andelman and Fagan (2000) have suggested that actions taken for umbrella species management may fail to benefit associated species thought to be conserved through these focal species actions.

An example of umbrella species management would be the implementation of habitat treatments that alter a vegetative community to improve conditions for a focal species. With these alterations, it is thought that species with similar habitat requirements would likely benefit from treatments while species with less tightly associated habitat needs may gain little from these efforts, but would also not be harmed. However, to maintain a holistic management approach, it is imperative to recognize how habitat treatments directed at an umbrella species may impact other species occupying the same ecosystem.

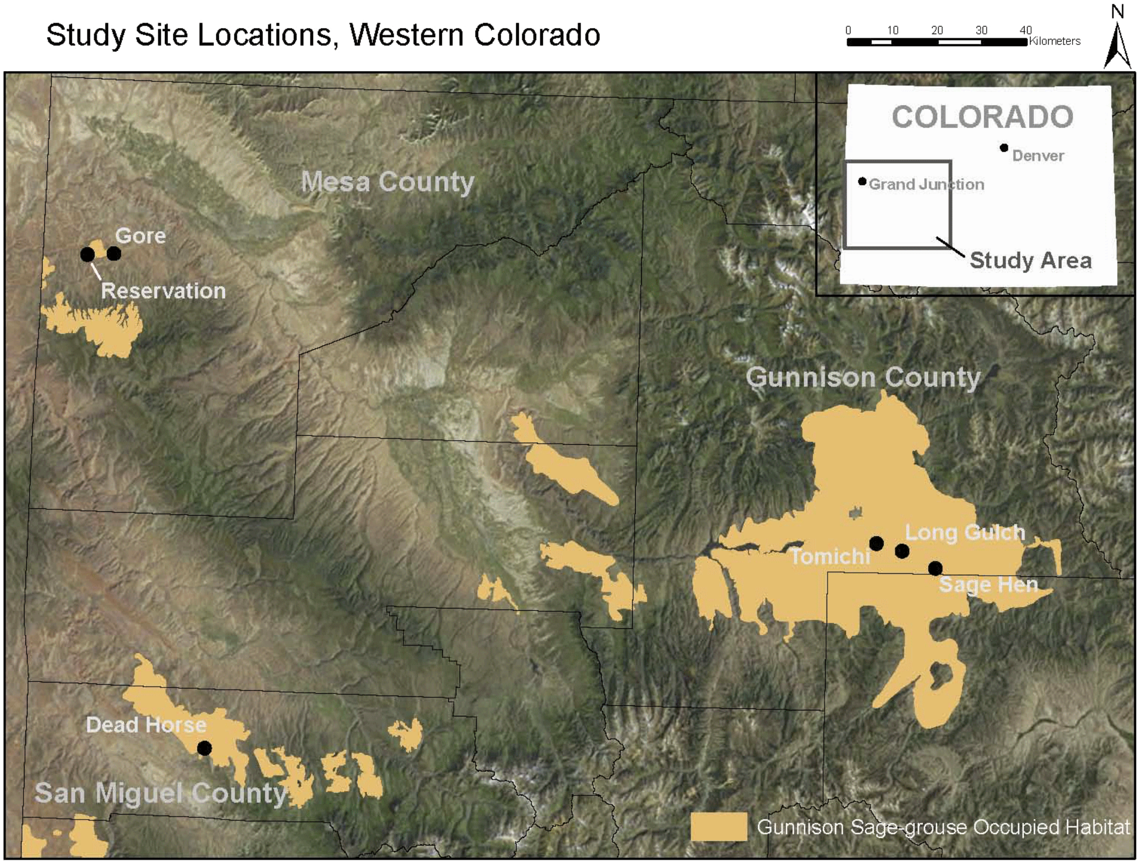
In this study we examined the use of the Gunnison Sage-Grouse (*Centrocercus minimus*) as an umbrella species for sagebrush communities in southwestern Colorado. The Gunnison Sage-Grouse is a sagebrush obligate that depends on intact, healthy sagebrush communities. Currently, the Gunnison Sage-Grouse occurs within seven distinct population areas across southwestern Colorado and southeastern Utah (Gunnison Sage-Grouse Rangewide Steering Committee 2005). Gunnison Sage-Grouse numbers and distribution have declined predominantly because of degradation, fragmentation and loss of sagebrush communities in western Colorado (Winward 2004, U.S. Fish and Wildlife Service 2013). These sagebrush systems have also seen population declines for associated sagebrush song birds (Paige and Ritter 1999, North American Bird Conservation Initiative 2014).

The concern for Gunnison Sage-Grouse populations led to the implementation of conservation efforts to protect remaining core population areas by trying to restore and improve sagebrush habitats. From 1994-2010 implementation of habitat treatments across the range of the Gunnison Sage-Grouse in Colorado were extensive with 16,000 ha being treated using several methods including mechanical, herbicides, and prescribed burning. A majority of these treatments were designed to reduce sagebrush cover and increase herbaceous understories to enhance brood rearing habitat (Connelly et al. 2000, Dahlgren et al. 2006). Treatments were also implemented to counteract encroachment of Colorado piñon pine (*Pinus edulis*) and juniper (*Juniperus* spp.) woodland stands into sagebrush ecosystems.

Habitat treatments implemented for Gunnison Sage-Grouse are routinely considered beneficial for other sagebrush associated species throughout southwestern Colorado (Rich and Altman 2001). However, how Gunnison Sage-Grouse habitat management affects other sagebrush associated bird species has not been tested (Rowland et al. 2006). The impacts to vegetation structure following treatments are immediately visible, but the response to treatments by avian species is rarely monitored. When avian response is monitored, it is typically immediately following treatment implementation (Knick et al. 2003, Magee et al. 2011). Because many avian species have high breeding site fidelity, this immediate post monitoring may not adequately reflect the long-term population level response of species to treatments (Wiens and Rotenberry 1985, Petersen and Best 1999, Norvell 2008). Given the cost and effort to implement habitat treatments and the high priority being given to Gunnison Sage-Grouse conservation, managers would benefit from understanding the effects of these treatments. However, data are currently lacking to evaluate the efficacy of the Gunnison Sage-Grouse habitat treatments for conserving other sagebrush associated avifauna.

We examined the effects of sagebrush habitat treatments implemented for Gunnison Sage-Grouse, hereafter referred to as treatments, on three sagebrush obligates, Brewer's Sparrow (*Spizella breweri*), Sage Sparrow (*Amphispiza belli*), and Sage Thrasher (*Oreoscoptes montanus*); two sagebrush associated species, Green-tailed Towhee (*Pipilo chlorurus*) and Lark Sparrow (*Chondestes grammacus*); and three species associated with more open arid shrublands and grasslands, Horned Lark (*Eremophila alpestris*), Western Meadowlark (*Sturnella neglecta*), and Vesper Sparrow (*Pooecetes gramineus*; Braun et al. 1976, Knick and Rotenberry 1995, Knick et al. 2003, Gilbert and Chalfoun 2011). The effects of treatments on these species were examined at two scales: the habitat treatment (site) and sampling locations (point) within the sites. The site-level effects represented the overall response of birds to the habitat treatment and the point-level effects represented how heterogeneity in vegetation structure within a site affects bird distributions. To account for the potential time lags in responses by avian species known to have high site fidelity, only treatments that were implemented a minimum of four to eight years prior to 2010 were examined (years were chosen based on available treatment data for Gunnison Sage-Grouse in southwestern Colorado). We hypothesized that vegetation structure influences bird distributions and manipulation of shrubs will reduce available shrub cover. From this hypothesis, we predicted that sagebrush obligate birds would decline in treated sites because of the reduction in shrub cover and height while those species associated with more open shrubland and grassland areas would increase. At the point-level, we predicted that variation in vegetation structure would drive local bird density and occupancy for each species according to their habitat preferences.

Fig. 1. Occupied Gunnison Sage-Grouse (*Centrocercus minimus*) range (shading) and sagebrush habitat treatment sites in Colorado (circles).



METHODS

Data on treatment types, dates, spatial extent of treatments, and locations are maintained by the U.S. Department of Interior, Bureau of Land Management and Colorado Parks and Wildlife. This database was used to select treatment sites based on relevant attributes including type of treatment, size of treatment, whether treatments were specifically implemented to improve habitat for Gunnison Sage-Grouse, and treatment dates. Treated sites selected from the database were evaluated on the ground to confirm treatment impacts and extent, and to identify if nearby control sites of similar size existed that had no sign of treatment impacts, but had similar topography, elevation, aspect and vegetation characteristics for comparison. We only considered mechanical treatments (roller chopping, disking, brush mowing, Dixie Harrow, and Lawson Aerator techniques) and those that were specifically implemented to benefit Gunnison Sage-Grouse.

Study areas

Study areas were located in southwestern Colorado within the known occupied range of the Gunnison Sage-Grouse (Fig. 1). The current occupied range is highly fragmented and individual study sites were selected within three population centers across the range: Gunnison Basin, Piñon Mesa, and San Miguel. The Gunnison Basin occurs at the highest elevation of the three sites, has the greatest expanse of relatively intact sagebrush habitat and the largest population of Gunnison Sage-Grouse. Piñon Mesa and San Miguel have much smaller populations of Gunnison Sage-Grouse and the extent and health of the sagebrush systems in these areas is limited. Piñon Mesa is noted for its canyon country and sites sampled in this area were at low elevations with piñon-juniper woodland intermixed within many sagebrush stands. The site sampled in San Miguel was a low elevation, dry site with dense and decadent sagebrush stands containing a poor herbaceous understory.

Study areas ranged in elevation from 1981-2651 m. Treated sites ranged in size from 61 ha to 131 ha. The vegetation communities at all sites were dominated by sagebrush (*Artemisia* spp.) and included Wyoming big sagebrush (*A. tridentata wyomingensis*), basin big sage (*A. t. tridentata*), and black sagebrush (*A. nova*) on the drier sites.

Deadhorse

Deadhorse is located in San Miguel County, about 19 km south of Naturita at an elevation of 1981-2402 m. The treatment site was situated on land managed by Colorado Parks and Wildlife in the Dry Creek Basin State Wildlife Area. The vegetation community was dominated by Wyoming big sagebrush and prior to treatment the stands were mostly tall and dense with little herbaceous vegetation. Mechanical treatment in 2002 removed nearly all sagebrush in numerous small patches and was followed by reseeding with native grasses and forbs. No livestock grazing has occurred for several decades in the treated site. The control site was about 3 km west of the treated site on land owned by the Town of Telluride and occurred at the same elevation. Vegetation in the control site was dominated by Wyoming big sagebrush and black sagebrush. Cattle and sheep have grazed the control site in the past, but no grazing occurred at the time of the field study.

Gore

Gore is located in Mesa County, about 12 km west of Glade Park at an elevation of 1981-2402 m. Both the control and treatment sites were on private land managed for cattle grazing. Vegetation on the treated site was dominated by Wyoming big sagebrush and black sagebrush. Mechanical treatment to reduce sagebrush cover and height was done by disking in 2003. This was followed by reseeding with native and non-native grasses and forbs. The control site was about 1.5 km west of the treated site with vegetation dominated by tall Wyoming big sagebrush with very little herbaceous understory.

Reservation

Reservation is located in Mesa County, about 15 km west of Glade Park at an elevation of 1950-2072 m. Both the control and treated sites were on lands managed by the Bureau of Land Management. Grazing by cattle occurred each year at both sites. Before treatment, the vegetation was a mosaic of small stands of piñon pine-juniper woodland and Wyoming big sagebrush. Mechanical treatment by roller chopping in 2006 eliminated most piñon pine and juniper trees and reduced sagebrush cover and height. The treatment was followed by reseeding with native grasses and forbs. The control site was about 0.1 km northwest of the treated site at an elevation of 1950 m and was dominated by Wyoming big sagebrush with stands of piñon pine-juniper woodland within the site.

Long Gulch

Long Gulch is located in Gunnison County, about 13 km southeast of Gunnison at an elevation of 2468-2560 m. Both the control and treatment sites were on lands managed by the Bureau of Land Management. Vegetation at both sites was dominated by Wyoming big sagebrush with black sagebrush on drier sites. Brush mowing in 2002 was completed across 100% of the treatment site. This treatment reduced sagebrush cover and height and was followed by reseeding with native grasses and forbs in all treated patches except one that was not reseeded.

Sage Hen

Sage Hen is located in Gunnison County, about 22 km southeast of Gunnison at an elevation of 2499-2560 m. Both the control and treatment sites were on lands managed by the Bureau of Land Management. Vegetation at both sites was dominated by Wyoming big sagebrush with black sagebrush on drier sites. Mechanical treatment patches covered about 50% of the site, and within treatment patches a mix of brush mowing, Dixie harrow, and Lawson aerator techniques were used in 2005 to treat either 30% or 70% of each patch. The treatments reduced sagebrush cover and height and were followed by reseeding with native grasses and forbs.

Tomichi

Tomichi is located in Gunnison County, about 8 km southeast of Gunnison at an elevation of 2499-2651 m. Both the control and treatment sites were on lands managed by the Bureau of Land Management. Vegetation at both sites was dominated by Wyoming big sagebrush with black sagebrush on drier sites. Brush mowing narrow strips in 2005 and 2006 covered about 30% of the treatment site. Treatments reduced sagebrush cover and height and were followed by reseeding with native grasses and forbs.

Avian point counts

Mapped boundaries of control and treatment sites were uploaded into ArcGIS and 20-29 random points were generated in a systematic grid at 200 m spacing for vegetation and avian sampling using spatial analysis tools in ArcMap GIS. Point locations were adjusted to maintain at least a 100 m buffer from the study site boundary edge.

Avian populations were sampled by a point count method in each study site. In 2010 and 2011, three counts were made at each site spanning the nesting season (one count in April, May, and June). Three counts were completed to accommodate the different timing in breeding for each species because some species arrive at the breeding sites earlier and begin to sing as other arrive at a later date. It also allowed us to detect birds during multiple breeding attempts. Counts were initiated in mid-April at the lowest elevation sites followed by the higher elevation sites. Surveys were conducted by observers experienced with point counts and identification of birds of the region by sight and sound. Two observers worked concurrently at each study site; one observer in the treatment site and the other in the control site. On subsequent visits to the same study site in the same year, observers switched sites to reduce effects of observer bias. The order in which points were completed also varied between visits in the same year to reduce time of day effects. Counts were conducted 15 minutes before local sunrise and ended four hours later. Counts were not conducted during unsuitable weather, i.e., persistent rain or strong winds.

At each point count location the birds were allowed to settle for several minutes while observers prepared gear and recorded start time, cloud cover, wind speed, and temperature on data sheets. Six minute point counts were conducted using the removal method for each 1-minute interval allowing for estimation of detection probabilities (Farnsworth et al. 2002, Alldredge et al. 2007). For all birds detected by sight or sound, the species, detection type (visual, aural, or flyover), and distance (not recorded for birds flying over) were recorded. Distance was defined as the horizontal measurement from the sample point to the location of the bird when it was first detected, and was measured using a rangefinder. Distances to birds were recorded in 2010 as one of six distance intervals (bins): bin 1: 0-20 m; bin 2: 20-40 m; bin 3: 40-60 m; bin 4: 60-100 m; bin 5: 100-200 m; and bin 6: > 200 m. Data analysis after the first field season showed evidence of "heaping" at short distances, which impaired the calculation of detection probabilities. In 2011 distance intervals were changed to bin 1: 0-10 m; bin 2: 10-20 m; bin 3: 20-40 m; bin 4: 40-60 m; bin 5: 60-100 m; and bin 6: > 100 m. The potential for minimizing overlapping sampling of neighboring points was done by truncating observations > 100 m at the time of data analysis.

Vegetation structural characteristics

Vegetation structural characteristics were measured following the guidelines established for Gunnison Sage-Grouse by the Gunnison Sage-Grouse Rangewide Steering Committee (2007). At each of the six study sites, 15 of the 20-29 original sample points were randomly selected and a vegetation transect was completed at the same point locations in 2010 and 2011. In a few cases, sample points were omitted because the transect was not typical of the area, e.g., rock outcrops, and replaced with a different randomly chosen sample point. Transects were completed during the bird nesting season and when the vegetation growing season was underway (May to July). Transects occurring at the lowest elevation sites were completed first followed by the higher elevation sites. Transects were only completed one time during the breeding season so the full spectrum of plant growth and senescence was not evaluated. Transects allowed one measurement to evaluate differences between control and treated sites.

At each sample point a 30-m line transect was oriented at a random bearing and a photo was taken from the origin looking along the transect. Daubenmire plots (20 cm x 50 cm; Daubenmire 1959, USDI-BLM 1996) placed along transects were used to estimate cover and height of grasses and forbs and height of shrubs. Grasses and forbs were identified to species where possible and broken into two categories: native and non-native. Plots were placed every 3 m along transects beginning 3 m from the origin, with 10 frames per transect.

A line intercept method (Canfield 1941) was used to measure cover of sagebrush and other shrubs. Intercepts were measured to the nearest cm. Intercepts recorded for shrubs included all live canopy material. Canopy gaps greater than 5 cm were excluded and overlapping canopies of different shrubs were ignored.

Statistical analysis

We estimated density (birds/hectare) at the site-level for eight passerine species on treated and control sites using distance sampling methods (Buckland et al. 2001). We estimated density separately by site, year, and visit within year. A common detection function was used for each species across sites to provide a more precise estimate of detection probability. We fit three detection functions (half-normal, hazard rate, and uniform) for each species and used AIC corrected for small sample size, AIC_c, to select the best model for detection (Table 1; Burnham and Anderson 2002). Observations of birds at outlying distances (> 100 m) were truncated to improve detection function fit (Buckland et al. 2001). Analyses were performed in the program Distance version 6.1 (Thomas et al. 2009).

We estimated occupancy within 100 m of each sampling point for the same eight passerine birds on treated and control sites (MacKenzie et al. 2005). Occupancy was estimated based on removal in time with birds recorded at 1-minute intervals used for repeated observations at a point. We considered four models representing hypotheses about year, treatment, and site effects. These models represent a difference between treated and control sites, variation by site with an additive effect of the treatment, variation by site with an additive effect of the treatment and year, and an interaction of site and year (Table 2). All models had a constant detection probability for each species. We used AIC_c to select among models (Burnham and Anderson 2002).

Table 1. Numbers of birds detected, best fitting detection functions, truncation distance (*w*), detection probability (*p*), and its standard error for eight species of passerine birds surveyed on treated and control sagebrush sites in western Colorado. Birds species are Brewer's Sparrow (*Spizella breweri,* BRSP), Green-tailed Towhee (*Pipilo chlorurus,* GTTO), Horned Lark (*Eremophila alpestris*, HOLA), Lark Sparrow (*Chondestes grammacus,* LASP), Sage Sparrow (*Amphispiza belli,* SAGS), Sage Thrasher (*Oreoscoptes montanus,* SATH), Vesper Sparrow (*Pooecetes gramineus,* VESP), and Western Meadowlark (*Sturnella neglecta,* WEME).

Species	Observations	Detection Function	*w*	*p*	SE(*p*)
BRSP	670	Hazard Rate	60	0.204	0.144
GTTO	183	Hazard Rate + Simple Poly	100	0.247	0.211
HOLA	180	Hazard Rate	100	0.030	0.155
LASP	64	Half-normal	100	0.429	0.078
SAGS	159	Half-normal	100	0.705	0.099
SATH	99	Uniform	60	0.683	0.128
VESP	1039	Hazard Rate	100	0.318	0.088
WEME	166	Uniform	100	1.000	0.000

Table 2. Occupancy model selected representing constant detection probability (*p*(.)) occupancy varying by site and year (psi(g)), detection probability during a 1-minute interval (*p*), and its standard error for eight passerine species surveyed on treated and control sagebrush sites in western Colorado. Bird species are Brewer's Sparrow (*Spizella breweri,* BRSP), Green-tailed Towhee (*Pipilo chlorurus,* GTTO), Horned Lark (*Eremophila alpestris*, HOLA), Lark Sparrow (*Chondestes grammacus,* LASP), Sage Sparrow (*Amphispiza belli,* SAGS), Sage Thrasher (*Oreoscoptes montanus,* SATH), Vesper Sparrow (*Pooecetes gramineus,* VESP), and Western Meadowlark (*Sturnella neglecta,* WEME).

Species	Occupancy Model	*p*	SE(*p*)
BRSP	{p(.) psi(g)}	0.205	0.006
GTTO	{p(.) psi(g)}	0.155	0.008
HOLA	{p(.) psi(g)}	0.008	0.007
LASP	{p(.) psi(g)}	0.108	0.014
SAGS	{p(.) psi(g)}	0.108	0.007
SATH	{p(.) psi(g)}	0.168	0.005
VESP	{p(.) psi(g)}	0.247	0.006
WEME	{p(.) psi(g)}	0.241	0.008

We estimated the change in vegetation structure by treatment site using a linear mixed-effects model (Zuur et al. 2009). We included treatment, year, and a year by treatment interaction as fixed effects and site, transect, and plot as random effects. We included a year effect because precipitation, as measured at the Grand Junction, Colorado airport, was substantially different between the two-year surveys we conducted. Precipitation in Grand Junction highlighted the large difference between the two years, but was not sufficiently representative of the sites to use as a covariate. We used parameter estimates and their precision (SE) to measure the magnitude of the treatment and year effects.

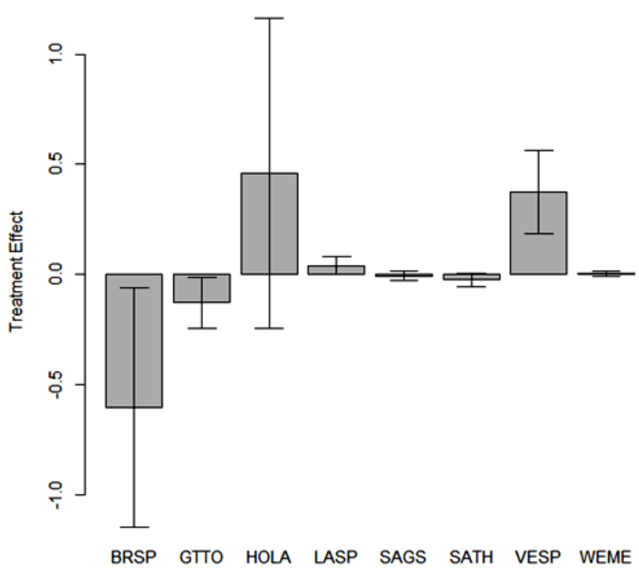
To examine habitat relationships at the point-level, we fit distance sampling models including covariates on abundance (Royle et al. 2004) in the R package *unmarked* (Fiske and Chandler 2011). For each species, the same detection function and truncation distance were used as was best in the site-level density estimation. We fit models considering additive effects of forb height, grass height, sage height, forb cover, shrub cover, and grass cover. AIC was used to select the best model (Burnham and Anderson 2002).

RESULTS

In 2010, data were collected at all control and treatment sites within the six designated study sites. In 2011, data collection was restricted to five of the six study sites because access permission was withheld at one of the sites in Piñon Mesa.

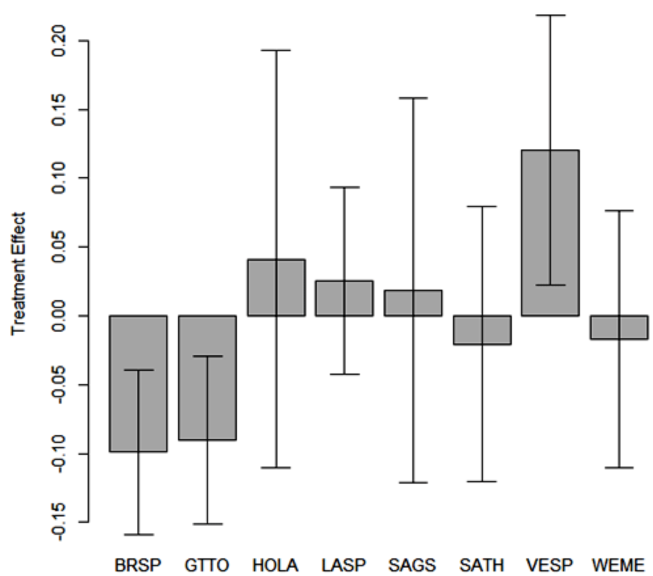
A total of 2560 observations of the 8 songbird species of interest were made on 11 treatment and control sites across 2 years (Table 1). Detection probability varied substantially across species from < 0.05 (Horned Lark) to 1.0 (Western Meadowlark). Comparisons of density at treated versus control sites showed significantly lower density for Brewer's Sparrow on treated sites while the Vesper Sparrow showed significantly higher densities (Fig. 2). The remaining species showed no measureable differences in density on treated and control sites (Fig. 2). Average bird density at the site scale was not related to any of the vegetation measures. A positive relationship existed between Western Meadowlark density and shrub height ($\beta = 0.02$, SE = 0.01) and a negative relationship existed between Vesper Sparrow and grass cover ($\beta = -0.19$, SE = 0.05).

Fig. 2. Estimated differences in density (birds/hectare) of eight passerine birds on treated versus control sagebrush sites in western Colorado. Birds species are Brewer's Sparrow (*Spizella breweri,* BRSP), Green-tailed Towhee (*Pipilo chlorurus,* GTTO), Horned Lark (*Eremophila alpestris*, HOLA), Lark Sparrow (*Chondestes grammacus,* LASP), Sage Sparrow (*Amphispiza belli,* SAGS), Sage Thrasher (*Oreoscoptes montanus,* SATH), Vesper Sparrow (*Pooecetes gramineus,* VESP), and Western Meadowlark (*Sturnella neglecta,* WEME). Vertical lines represent 95% confidence intervals.



Occupancy estimation revealed that Brewer's Sparrow and Green-tailed Towhee occupied significantly fewer treated than control sample points whereas Vesper Sparrow occupied significantly more treated points (Fig. 3). Across all species, a model with occupancy varying across all sites had the best support suggesting substantial variation in occupancy of each species among sites.

Fig. 3. Estimated differences in occupancy of eight passerine birds on treated versus control sagebrush sites in western Colorado. Birds species are Brewer's Sparrow (*Spizella breweri,* BRSP), Green-tailed Towhee (*Pipilo chlorurus,* GTTO), Horned Lark (*Eremophila alpestris*, HOLA), Lark Sparrow (*Chondestes grammacus,* LASP), Sage Sparrow (*Amphispiza belli,* SAGS), Sage Thrasher (*Oreoscoptes montanus,* SATH), Vesper Sparrow (*Pooecetes gramineus,* VESP), and Western Meadowlark (*Sturnella neglecta,* WEME). Vertical lines represent 95% confidence intervals.



At the point-level, all species except the Brewer's Sparrow showed at least one significant relationship with a vegetation variable (Table 3). Green-tailed Towhee and Sage Sparrow were negatively related to forb height whereas Vesper Sparrow and Western Meadowlark were positively related to forb height. Western Meadowlark was also positively correlated with grass height. Green-tailed Towhee showed a positive relationship with shrub height, but Sage Thrasher and Vesper Sparrow showed a negative relationship. Lark Sparrow was positively related to forb cover whereas Sage Sparrow and Western Meadowlark were negatively related. Horned Lark demonstrated a negative correlation with grass cover. Shrub cover was uncorrelated with all species.

Grass and forb cover differed between treated and control sites during the high precipitation year (2010), but not in the low precipitation year (2011). All sites had increased grass and forb coverage in 2010, but it was significantly greater in the treatment sites than in the control sites (grass $\beta = 5.8$, SE = 1.6, forb $\beta = 4.1$, SE = 0.7). Shrub coverage was lower, but imprecisely estimated in the treatment sites ($\beta = -2.3$, SE = 1.89). Average shrub cover was 26% lower in the treated sites than in control sites, but the

Table 3. Habitat relationships for eight sagebrush associated songbirds in western Colorado from AIC selected best models of density for each species. Percent grass cover was not included in any of the best models and is therefore not included in the table. Bird species are Brewer's Sparrow (*Spizella breweri,* BRSP), Green-tailed Towhee (*Pipilo chlorurus,* GTTO), Horned Lark (*Eremophila alpestris*, HOLA), Lark Sparrow (*Chondestes grammacus,* LASP), Sage Sparrow (*Amphispiza belli,* SAGS), Sage Thrasher (*Oreoscoptes montanus,* SATH), Vesper Sparrow (*Pooecetes gramineus,* VESP), and Western Meadowlark (*Sturnella neglecta,* WEME).

Species	Model	Forb Height	SE	Grass Height	SE	Sage Height	SE	Forb Cover	SE	Grass Cover	SE
BRSP	Intercept only										
GTTO	Forb Height + Sage Height	-0.018	0.006			0.003	0.001				
LASP	Forb Cover							0.021	0.005		
SAGS	Forb Height + Forb Cover	-0.014	0.007					-0.009	0.004		
SATH	Sage Height					-0.004	0.002				
VESP	Forb Height + Sage Height	0.005	0.003			-0.003	0.001				
WEME	Grass Height + Forb Cover	0.010	0.004	0.007	0.003			-0.013	0.003		
HOLA	Grass Cover									-0.005	0.002

differences were not statistically significant. Shrub cover was similar across years and was not impacted by precipitation patterns. Forb and grass height were similar in treated and control sites, but differed between years. Shrub height was similar across sites and years. Plant species diversity was higher on treatment sites with most of the effect coming from native species.

DISCUSSION

Gunnison Sage-Grouse management in southwestern Colorado has predominantly focused on implementing habitat treatments that cause a reduction of shrub cover and promotes development of forbs and grasses in the understory to restore critical brood rearing areas. These management objectives are readily implemented across the landscape with little associated monitoring to evaluate long-term impacts to vegetation structure and composition, success of project to improving Gunnison Sage-Grouse population viability, and demographic parameters or impacts to associated species inhabiting the sagebrush ecosystem. Implementing broad conservation measures for a focal species raises concern about the impacts to other sympatric avifauna and impacts to overall vegetative communities. This project was not designed to evaluate success of habitat treatments on conserving Gunnison Sage-Grouse populations, but was a retrospective evaluation of actual on the ground management practices and their effect on sagebrush obligate birds and vegetation structure. Our original prediction for the study was that sagebrush obligate birds would decline in treated sites because of a reduction in shrub cover and height whereas those species associated with more open shrubland and grassland areas would increase. The results from this study did document a reduction in density and occupancy of Brewer's Sparrow and a reduction in occupancy of Green-tailed Towhee on habitat treatment sites. Conversely, Vesper Sparrow occupancy and density increased on treated sites.

Our results are similar to other habitat manipulation studies in sagebrush systems that found Brewer's Sparrow and Green-tailed Towhee populations declined and Vesper Sparrow increased when treatments reduced sagebrush cover (Schroeder and Sturges 1975, Wiens and Rotenberry 1985, Kerley and Anderson 1995, Petersen and Best 1999). However, of the three sagebrush obligate species we evaluated, only the Brewer's Sparrow displayed this response. Though the Sage Sparrow and Sage Thrasher are considered to have similar habitat preferences as the Brewer's Sparrow for shrub cover and bare ground (Wiens and Rotenberry 1985, Kingery 1998), these sagebrush obligates did not demonstrate the same treatment effect. Two reasons may help explain the differences in responses measured. First, Brewer's Sparrows were much more abundant (n = 698) across the study sites sampled whereas sample sizes for Sage Sparrow (n = 228) and Sage Thrasher (n = 99) were relatively small. Sage Sparrows were found to be rare in the Gunnison Basin probably because of the higher elevation of this sagebrush system and though Sage Thrashers were more common in the Gunnison Basin, they were much less numerous in San Miguel and Piñon Mesa. Larger sample sizes and a more even distribution for these two species may have provided the statistical power needed to detect differences between occupancy and densities at treated and control sites as we did for the more abundant Brewer's Sparrow.

Secondly, we did not detect any relationship between bird density and occupancy to vegetation measures. The sites selected for sampling occurred across southwestern Colorado within the range of the Gunnison Sage-Grouse and variation in site characteristics, precipitation patterns, and elevation were apparent. This level of variation may have created difficulties when determining impacts of treatment on species and the association of vegetation dictating relationships. In addition, the magnitude of treatment and size of area treated may have been too low in severity and scale to show clear responses by avian species. Other studies have found that sagebrush obligate species differ in their response to mechanical treatments depending on the scale and timing that can make evaluation of impacts difficult (Norvell 2008).

Point-specific variation in songbird occupancy and density helped add additional insight into what impacts sagebrush treatments may be having on associated avifauna. Sage Sparrows were found to have a negative relationship with forb height and cover. This response could impact occupancy on a larger scale by this species if habitat treatments for Gunnison Sage-Grouse are designed to reduce sagebrush cover and increase forb understory. The reason for the negative relationship measured is probably due to Sage Sparrows being ground foragers with abundant ground cover impacting their ability to feed (Kingery 1998, Martin and Carlson 1998, Paige and Ritter 1999). Wiens and Rotenberry (1985) found after a habitat treatment reduced sagebrush cover and increased the understory of grasses, Sage Sparrow abundance declined. This differs from the Vesper Sparrow where we found a positive relationship with forb height and a negative relationship with shrub height. Vesper Sparrows are known to prefer more open areas with little shrub cover (Boyle and Reeder 2005, Jones and Cornely 2002). Though the point-specific relationships fit within the knowledge of the life history of the Vesper Sparrow and Sage Sparrow, other point-specific variation results were unclear and not easily explained. For example, the Brewer's Sparrow showed no response to vegetation variables measured and the Sage Thrasher showed a negative relationship to shrub height. Wiens and Rotenberry (1981) found that habitat associations and community structure of birds in sagebrush habitats is not always easy to interpret and is highly dependent on the scale and measurement taken. Thus, it was important for this study to analyze both the point and site-level with each scale providing information to help evaluate how bird communities are using habitats and how treatments may impact species.

The most substantial vegetative difference between treatment and control sites appeared in shrub cover. Four to eight years after a habitat treatment, shrub cover remained 26% lower in treated sites than in control sites. Grass and forb coverage also differed, but the relationship was more complicated. Precipitation varied substantially between years; the study area received twice as much moisture in 2010 as it did in 2011. In 2010, grasses and forbs covered significantly more area in the treatment than the control sites. Limited precipitation in 2011 may have prevented grass and forb growth to an extent that it masked the treatment effect. Therefore, some treatment effects may have been hidden by variation in precipitation. It does appear however, that treatments to increase herbaceous understory and reduce shrub cover have been successful at least in normal to high precipitation years. Meanwhile, the other vegetation structure measured varied little between control and treatment sites.

Obligate sagebrush songbirds have been declining throughout their breeding range since 1968 (North American Bird Conservation Initiative 2014). These declines highlight the need to understand the potential ramifications of implementing conservation measures under an umbrella species concept and the effects on associated sagebrush species. Our results suggest that manipulating vegetation structure and composition to manage the Gunnison Sage-Grouse correlated with a change in density and occupancy of Brewer's Sparrow and Vesper Sparrow and occupancy of the Green-tailed Towhee. In addition, the point-level analysis showed a negative relationship to forb height and cover for the Sage Sparrow. Understanding the needs of all species within an ecosystem is important for mangers so that conservation of one high profile species does not result in the detriment of another.

On the other hand, our results suggest that habitat manipulations of the magnitude implemented here had little effect on a range of other species that use sagebrush habitats (Sage Thrasher, Horned Lark, Lark Sparrow, and Western Meadowlark). The lack of response at the site-level demonstrates some resiliency of these species. Therefore, managers may have some flexibility in manipulating vegetation to benefit Gunnison Sage-Grouse without too much risk of negatively affecting the breeding songbirds that use sagebrush systems.

One big question still lingering is if the treatments being implemented are really having the outcome managers would like for the Gunnison Sage-Grouse. Though it is used as an umbrella species, information is needed to evaluate how habitat treatments are impacting this species as well. If mounting evidence suggests that conservation efforts aimed at the Gunnison Sage-Grouse may not be particularly effective for conserving sagebrush associated species, perhaps habitat treatments are not effective for Gunnison Sage-Grouse either. Or perhaps the Gunnison Sage-Grouse are using sagebrush habitats in a different manner than other species and that the focus of managing habitats for one life cycle (brood rearing) makes for ineffectual umbrella species management and/or our ability to manipulate sagebrush habitats is not providing desired outcomes. Understanding the ramification of these hypotheses as continued conservation efforts move forward will be a crucial step toward conserving sagebrush communities and the species that rely on them in the future. Continued work to evaluate and monitor habitat treatments and the long-term impacts to sagebrush avifauna is imperative to increase our understanding and management of this crucial ecosystem.

Responses to this article can be read online at:
http://www.ace-eco.org/issues/responses.php/799

Acknowledgments:

This project was funded by Colorado Parks and Wildlife through the Species Conservation Trust Fund program. Data were collected by BIO-Logic, Inc. We would like to thank biologists Jim LeFevre, Ron Lambeth, Adam Petry, and Andrew Keaveney for their excellent field data collection and Linda Thompson for spending many long hours quality checking data. Jim Garner, Nathan Seward, and Dan Neubaum provided guidance and information on treatments at each study site. We thank two anonymous reviewers for their comments.

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Editor-in-Chief: Keith A.Hobson

Sponsored by the Society of Canadian Ornithologists and Bird Studies Canada
Parrainée par la Société des ornithologistes du Canada et Études d`oiseaux Canada

APPENDIX 1. Model selection results for habitat relationships for eight sagebrush associated songbirds in western Colorado. Bird species are Brewer's Sparrow (BRSP), Green-tailed Towhee (GTTO), Horned Lark (HOLA), Lark Sparrow (LASP), Sage Sparrow (SAGS), Sage Thrasher (SATH), Vesper Sparrow (VESP), and Western Meadowlark (WEME). Parameter estimates for the AIC selected best model are provided in Table 3.

Species	Model	AIC	Delta AIC
BRSP	Forb Height	1455.984	0.262
BRSP	Grass Height	1457.021	1.299
BRSP	Sage Height	1455.722	0
BRSP	Forb + Grass	1457.899	2.177
BRSP	Forb + Sage	1457.336	1.614
BRSP	Grass + Sage	1457.661	1.939
BRSP	Forb + Grass + Sage	1459.295	3.573
BRSP	Grass Cover	1455.962	0.24
BRSP	Forb Cover	1457.148	1.426
BRSP	ShurbCover	1456.999	1.277
BRSP	ForbC + SageC	1458.735	3.013
BRSP	ForbC + GrassC	1459.141	3.419
BRSP	Forb + ShrubC + Grass	1459.995	4.273
BRSP	ShrubC+ Grass	1458.981	3.259
GTTO	Forb Height	1166.748	2.394
GTTO	Grass Height	1171.488	7.134
GTTO	Sage Height	1171.111	6.757
GTTO	Forb + Grass	1168.742	4.388
GTTO	Forb + Sage	1164.354	0
GTTO	Grass + Sage	1172.978	8.624
GTTO	Forb + Grass + Sage	1165.828	1.474
GTTO	Grass Cover	1171.891	7.537
GTTO	Forb Cover	1168.646	4.292
GTTO	ShurbCover	1172.071	7.717
GTTO	ForbC + SageC	1170.703	6.349
GTTO	ForbC + GrassC	1169.447	5.093
GTTO	Forb + ShrubC + Grass	1171.525	7.171
GTTO	ShrubC + Grass	1170.489	6.135
HOLA	Forb Height	987.4356	7.2434
HOLA	Grass Height	987.2863	7.0941
HOLA	Sage Height	986.0657	5.8735
HOLA	Forb + Grass	989.2066	9.0144
HOLA	Forb + Sage	988.3616	8.1694
HOLA	Grass + Sage	987.5504	7.3582
HOLA	Forb + Grass + Sage	989.4867	9.2945
HOLA	Grass Cover	980.1922	0
HOLA	Forb Cover	981.1993	1.0071
HOLA	ShurbCover	986.287	6.0948
HOLA	ForbC + SageC	981.8497	1.6575
HOLA	ForbC + GrassC	983.9922	3.8
HOLA	Forb + ShrubC + Grass	984.1438	3.9516
HOLA	ShrubC + Grass	990.0609	9.8687
LASP	Forb Height	490.4499	14.3504
LASP	Grass Height	489.7867	13.6872
LASP	Sage Height	482.3521	6.2526
LASP	Forb + Grass	491.7845	15.685
LASP	Forb + Sage	480.861	4.7615
LASP	Grass + Sage	481.4088	5.3093
LASP	Forb + Grass + Sage	481.653	5.5535

(con'd)

LASP	Grass Cover	486.3902	10.2907
LASP	Forb Cover	476.0995	0
LASP	ShurbCover	487.869	11.7695
LASP	ForbC + SageC	476.5806	0.4811
LASP	ForbC + GrassC	479.0351	2.9356
LASP	Forb + ShrubC + Grass	479.1229	3.0234
LASP	ShrubC + Grass	490.1691	14.0696
SAGS	Forb Height	986.4831	2.0894
SAGS	Grass Height	996.6541	12.2604
SAGS	Sage Height	996.758	12.3643
SAGS	Forb + Grass	986.6868	2.2931
SAGS	Forb + Sage	986.7508	2.3571
SAGS	Grass + Sage	999.6229	15.2292
SAGS	Forb + Grass + Sage	987.073	2.6793
SAGS	Grass Cover	996.5696	12.1759
SAGS	Forb Cover	987.2851	2.8914
SAGS	ShurbCover	996.6816	12.2879
SAGS	ForbC + SageC	989.2577	4.864
SAGS	ForbC + GrassC	984.3937	0
SAGS	ForbH + ForbC	984.415	0.0213
SAGS	Forb + ShrubC + Grass	986.3857	1.992
SAGS	ShrubC + Grass	988.5055	4.1118
SATH	Forb Height	455.8808	2.5693
SATH	Grass Height	455.9662	2.6547
SATH	Sage Height	453.3115	0
SATH	Forb + Grass	457.8141	4.5026
SATH	Forb + Sage	455.3054	1.9939
SATH	Grass + Sage	455.3673	2.0558
SATH	Forb + Grass + Sage	457.198	3.8865
SATH	Grass Cover	454.9673	1.6558
SATH	Forb Cover	455.9896	2.6781
SATH	ShurbCover	455.6908	2.3793
SATH	ForbC + SageC	457.5903	4.2788
SATH	ForbC + GrassC	459.7706	6.4591
SATH	Forb + ShrubC + Grass	461.0766	7.7651
SATH	ShrubC + Grass	459.0799	5.7684
VESP	Forb Height	3211.281	13.236
VESP	Grass Height	3209.889	11.844
VESP	Sage Height	3198.244	0.199
VESP	Forb + Grass	3212.125	14.08
VESP	Forb + Sage	3198.045	0
VESP	Grass + Sage	3200.774	2.729
VESP	Forb + Grass + Sage	3198.88	0.835
VESP	Grass Cover	3208.494	10.449
VESP	Forb Cover	3204.557	6.512
VESP	ShurbCover	3209.371	11.326
VESP	ForbC + SageC	3204.62	6.575
VESP	ForbC + GrassC	3206.054	8.009
VESP	Forb + ShrubC + Grass	3203.499	5.454
VESP	ShrubC + Grass	3211.115	13.07
WEME	Forb Height	1717.577	16.744
WEME	Grass Height	1715.055	14.222
WEME	Sage Height	1715.37	14.537
WEME	Forb + Grass	1715.622	14.789
WEME	Forb + Sage	1706.701	5.868

(con'd)

WEME	Grass + Sage	1707.699	6.866
WEME	Forb + Grass + Sage	1703.147	2.314
WEME	Grass Cover	1720.264	19.431
WEME	Forb Cover	1710.705	9.872
WEME	ShurbCover	1715.508	14.675
WEME	ForbC + SageC	1708.109	7.276
WEME	ForbC + GrassC	1700.833	0
WEME	Forb + ShrubC + Grass	1702.082	1.249
WEME	ShrubC + Grass	1715.227	14.394