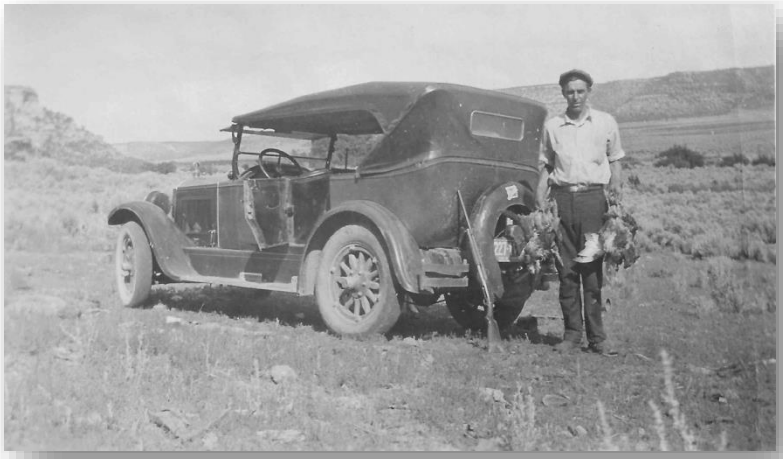
Transplant efforts and seasonal habitat use of Gunnison sage-grouse on Piñon Mesa: Recommendations for future conservation efforts



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Cover photos provided by: J. Van Loan, circa 1926 Van Loan family hunting grouse; D. Neubaum, 2009 release of transplanted Gunnison sage-grouse on Piñon Mesa.

Executive Summary

Translocation of individuals is one method of boosting a population that is in decline due to a host of factors such as population bottlenecks, habitat degradation, and catastrophic disturbance events. This report summarizes telemetry data from Gunnison sage-grouse (GuSG) transplanted to Piñon Mesa between 2010 and 2013. GuSG were transplanted from the Gunnison Basin to Piñon Mesa to boost population numbers, increase potential mating opportunities, and to address the threat of low genetic diversity. In addition, there is a need for better understanding all seasonal habitat use on Piñon Mesa and what characteristics designate these locations . We tracked radiotagged grouse from 2010–2015 to determine seasonal use, lekking, and nesting locations, investigate home range size, and monitor survival. Radiotracking results were used in concert with several land cover factors and surface variables to develop models of seasonal habitat use by GuSG. These delineations will be used to help guide future conservation efforts such as placement of treatments and easement acquisition, searching for new leks, or seasonal road closures among other actions.

In general, transplanted sage-grouse made small movements (<5 km) away from release sites and between lekking and nesting sites, remaining in the same area throughout the year. A few individuals made notable movements (e.g., Dominguez Canyon to Timber Ridge, 30.7 km). Hen movements, in relation to lekking and nesting, tended to be oriented around areas where they were released but some individuals did relocate to habitat that is farther away. Transplanted males of all ages were noted strutting on leks which they were released by in a previous year. If retention of transplant birds near release sites with smaller leks is desired, birds may need to be released in the spring when strutting activity is apparent as presence of other grouse alone may not hold them in that area during other times of the year. Transplanted birds were confirmed to have successfully bred and reproduced with resident GuSG on Piñon Mesa through genetic analysis. Feathers collected on leks show individuals with distinct genetic markers attributable to both transplant and resident grouse. These findings confirm that transplanted grouse successfully bred with resident grouse resulting in viable offspring who attended leks themselves in subsequent years.

Survival estimates and a home range analysis are presented to determine if the transplant efforts were successful. Survival of female transplant birds to 12 months (0.52 ± 0.08) in this study are remarkably similar to estimates collected in 2002 from resident grouse pooled across several satellite populations (0.52 ± 0.08). This trend was similar for males as well (0.46 ± 0.12 vs. 0.51 ± 0.09). Survival pooled across all transplant birds at one year varied slightly by season with spring transplants having slightly higher survival than birds released in the fall. Survival estimates by radio type were hampered by small sample size but suggest that males fitted with necklace

transmitters may have lower survival than rump mounted transmitters but confidence intervals largely overlapped. Home range analysis suggests that transplanted GuSG tended to settle within a couple kilometers to where they were released and generally adopted areas used by resident birds. Findings for resident birds tracked in 1995 (n = 5 males) and 2002 (n = 3 males, 6 females) with sufficient locations to develop home range polygons with 95% probability of use highly overlapped those of transplanted birds.

Occupied breeding, summer/fall brood-rearing, and winter range by Gunnison sage-grouse, as mapped by Colorado Parks and Wildlife, have been expanded significantly from areas previously classified as potential habitat based on telemetry results. Although marked grouse were transplanted from the Gunnison Basin to Piñon Mesa, our radiotracking suggests that transplanted grouse were regularly accompanied by unmarked resident grouse. Observations of incidental unmarked grouse in the proximity of birds being radiotracked were made for a minimum of 17% of all locations collected. Home range estimates for incidental bird observations collected in the field while conducting telemetry work were largely overlap those of transplanted birds. These findings suggest that transplant birds settled into and used habitat similar to those used by resident birds already established in the area.

Seasonal use maps developed using data collected from transplant grouse locations indicate that a number of areas with high probabilities of use on Piñon Mesa proper still remain that could benefit from protection of private lands to limit future development and fragmentation. Treatments conducted in areas previously mapped as potential habitat showed high probabilities of use by both transplant and resident grouse. Finally, we present vegetation characteristics tied to seasonal use in areas used by grouse on Pinon Mesa in an effort to supplement RSC Rangewide guidelines.

Table of Contents

Background

Historic records of sage-grouse harvested on Glade Park and Piñon Mesa by early settlers from the area exist from at least 1926 (pers. comm. J. Van Loan). Harvest of these birds was common throughout much of western Colorado at that time and had been occurring for nearly half a century before surveys were conducted with the first hunting season established in 1877. Grover (1942) conducted some of the first state surveys for sage-grouse and noted their occurrence from several areas in Mesa County including a population that covered Glade Park, Piñon Mesa, and extended onto the northern portion of the Uncompahgre Plateau. A more intensive effort to inventory sage-grouse populations and their strutting grounds throughout the state was initiated by Rogers (1964) starting in 1957. Seven leks were identified for the Glade Park/Piñon Mesa population by Rogers (1964) including four in the Glade Park area, two on Piñon Mesa, and one on the Uncompahgre Plateau near the headwaters of Dominguez Canyon (Anderson 1960). Lek counts at that time ranged from 0–6 in the Glade Park area and 0–17 on Piñon Mesa.

Sage-grouse were reported using the area by the historic Thompson leks on Glade Park as recently as the 1990's (Piñon Mesa Conservation Plan 2000). More intensive population monitoring of sage-grouse was implemented by the then Colorado Division of Wildlife (CDOW) with standardized lek counts beginning in 1995. A localized study of sage-grouse on Glade Park and Piñon Mesa was initiated in that year as well to identify active strutting grounds, track birds using telemetry to assess habitat use, and to map vegetation associated with areas of use (Woods and Braun 1995). Five active leks were confirmed to have strutting males in attendance during that year despite efforts to identify new sites and check historic ones (including the Thompson Reservoir area). The population was estimated to be somewhere between 75 and 150 birds in 1995. Telemetry work showed that the Luster Basin area was used for strutting, foraging, and nesting during the breeding and summer/fall periods but winter areas were considered unknown at the time of that study.

In 2000, the Gunnison sage-grouse (GuSG) was recognized as a distinct species (Young et al. 2000). A conservation plan for Piñon Mesa (PMCP) was finished that same year (PMCP 2000), and three conservation objectives were developed: 1) maintain and improve the quality of habitat, 2) reduce fragmentation of habitat, and 3) to identify and manage physical disturbances. Conservation actions were split into several categories: information and education, monitoring, avoiding and mitigating loss of habitat, restoring or improving the quality of grouse habitat and populations, reducing physical disturbances, and improving landowner and community support and participation. The Gunnison sage-grouse rangewide conservation plan (GUSG RSC 2005) continued these efforts by defining acres of occupied, potentially suitable, and

vacant/unknown habitat, identifying primary threats, and setting population targets for each GuSG population. Habitat loss from development and subdivision, changes in habitat type (ecological succession of open sagebrush to pinyon-juniper due to fire suppression), genetic isolation, and a lack of connectivity with other suitable habitats were noted for Piñon Mesa. By 2009, before the start of this study, over 39,073 acres of occupied or potentially suitable habitat on Piñon Mesa (34.4%) was held in easement to address habitat loss, and 9,549 acres treated to improve habitat quality, with an emphasis on removing pinyon-juniper. With lek counts at the lowest levels since standardized counts began in 1995, Colorado Parks and Wildlife (CPW) approved transplants to augment the population's low genetic diversity and boost population numbers.

Piñon Mesa is somewhat unique from most of the other GuSG populations in that it is typified by conspicuous canyon country and a broad range of elevations. Our understanding of how this diverse, naturally fragmented landscape is used by GuSG throughout the year varies widely by season. Initial studies by Woods and Braun (1995) and Wenger (2002) utilized radio telemetry to monitor grouse movements and habitat use. Woods and Braun (1995) marked 10 grouse, 2 males and 3 females from the Fish Park area, 3 males from the Luster Basin area, and 2 males from Payne Mesa. Three of these birds died during the summer and early fall with tracking discontinued by mid October. In general, birds marked near Fish Park and those from Luster Basin remained near the areas of capture. Even disturbance from the Triangle fire and its associated fire crews staging at the state line, where most marked birds in that area were using irrigated hay fields, did not cause them to leave. A yearling male marked on Payne Mesa moved regularly between that location and others along the middle level benches to the west. This bird also moved up on top of Piñon Mesa for much of the summer before returning to Payne Mesa in the fall. Sagebrush stands mixed with snowberry (*Symphoricarpos albus*) were regularly used by grouse on Piñon Mesa during that study. Gambel oak (*Quercus gambelii*) was widely distributed but reportedly avoided by marked birds. Areas with steep slopes and pinyon-juniper were not associated with grouse locations (Woods and Braun 1995). Birds were not tracked over the winter so areas of use during this period were considered unknown. Breeding habitat or lek sites were anecdotally noted to occur in clearings resulting from salt licks used by cattle. None of the female birds from this sample successfully nested that year, limiting further any conclusions about brood rearing habitat. Thus, some limited knowledge of movements and summer/fall habitat use was gained from this small sample of birds over a limited time frame (< 1 year).

Efforts to further investigate seasonal habitat use (particularly at the micro-habitat level), movements, and dispersal by Gunnison sage-grouse on Piñon Mesa, as well as other satellite populations in southwest Colorado, were conducted in 2002

(Wenger 2002, Apa 2004). Nineteen birds (12 males, 7 females) were captured on Piñon Mesa within 3.2 km of Luster Basin Lek and on Payne Mesa to be fitted with radio transmitters. Nest selection was documented for the first time but nest success could not be determined as all 4 nests initiated by females were depredated. Median distances moved by marked grouse from capture locations to nest sites were less than 1 km (0.86 ± 0.32 km) and ranged from 0.23 – 5.82 km (Apa 2004). It should be noted that tracking did not continue into winter when greater numbers and longer distances of movements might be expected. Survival estimates of 7 populations pooled from across GuSG range in this study were 0.48 and 0.57 for males and females respectively. Vegetation data collected at locations used by grouse were used to develop rangewide guidelines for GuSG related to sagebrush, forb and grass cover and height characteristics.

In 2010, efforts to transplant GuSG from capture locations in the Gunnison Basin to satellite populations were initiated to address concerns related to falling lek counts and the associated decline in populations. The goals of this effort were to boost population numbers to increase potential mating opportunities and to address the threat of low genetic diversity (see *Population Target* page 286, GUSG RSC 2005). Although grouse transplants have been deployed previously by CPW for other satellite populations, birds had never been moved to Piñon Mesa prior to this effort. Transplanted birds were equipped with radio transmitters to assess survival and success of the strategy. The opportunity to gain additional information on habitat use by GuSG on Piñon Mesa, particularly for winter use locations which were largely absent, simultaneous to assessing survival data, was added to the goals. Woods and Braun (1995) note "It is essential that annual patterns of movement and especially winter grounds for these grouse be identified." This concern was reiterated by the PMCP (2000) which stated "Little is known regarding winter habitat" and "nest site selection on Piñon Mesa." Efforts in 2002 (Wenger 2002, Apa 2004) added some new insight towards nest selection but stopped short of collecting winter locations. In addition to understanding winter habitat use, 9 new strutting locations have been confirmed since Wenger (2002) and Apa's (2004) efforts. Consequently, a need for better understanding use of all seasonal habitats and what characteristics help designate these locations on Piñon Mesa exists. These delineations will then be used to help guide future conservation efforts such as placement of treatments and easement acquisition, searching for new leks, or seasonal road closures to name a few.

Study Area

The Pinon Mesa GuSG satellite population on Glade Park and Piñon Mesa encompasses a wide range of sagebrush habitats situated on the northern end of the

Uncompahgre Plateau. As of 2011, it was estimated that GuSG occupied approximately 38,904 acres on Piñon Mesa (Figure 1). Elevations range widely across the study area from approximately 6,500 to 9,800 feet resulting in a topography that varies widely from sandstone canyon country down low to rolling evergreen and aspen forest on top. Areas currently used by GuSG are generally composed of open mesas that drain in the northerly direction and are fragmented by deep canyons. Canyon bottoms and the flats around Glade Park typically contain big sagebrush (*Artemisia tridentata* subsp. *tridentata*), greasewood (*Sarcobatus vermiculatus*), and rabbitbrush (*Chrysothamnus nauseosus*). Pinyon-juniper (*Pinus edulis - Juniperous osteosperma*) dominates lower elevation slopes, intermixing with occasional stands of Gambel oak, and has encroached significantly into sagebrush stands in many areas of Piñon Mesa. Silver sagebrush (*Artemisia cana*) intermixed with Gambel oak, and snowberry (*Symphoricarpos rotundifolius*) is common at middle and higher elevations as are islands of aspen (*Populus tremuloides*) and some manzanita (*Arctostaphylos patula*). Landownership within the existing range is predominately private at 70%, with Bureau of Land Management comprising 28% and the U.S. Forest Service the remaining 2% (Figure 1). Private land is predominately rangeland used for livestock production with some irrigated hayfields scattered throughout the lower main drainages such as those along DS Road. Public land is leased for livestock grazing and used for various forms of recreation such as hunting.

Methods

Capture

Transplant efforts generally followed recommendations by Reese and Connelly (1997) including: captures made at leks at night, rapid transport of birds with morning releases, and releases at sites isolated from the Gunnison Basin (i.e. satellite populations). We did deviate from the recommendation of moving only reproductively active birds so we could investigate the survival and integration of younger individuals exposed to translocation activities. Gunnison sage-grouse were captured in the Gunnison Basin using the hand-held night spotlighting technique (Giesen et al. 1982, Wakkinen et al. 1994). The spotlight was scanned perpendicular to a patrolling vehicle and birds were detected when the light reflected from the eye. A combination of light and noise (loud music) were used by capture personnel to blind the bird and muffle footsteps as they moved towards the grouse on the ground. Upon reaching the bird a large hoop net was swung over the individual to capture them. Processing included recording weight and determining age and sex using wing and plumage characteristics (Beck et al. 1975). An aluminum leg band was affixed to the right leg and a radio transmitter attached. Most individuals received necklace transmitters (17.5 g, model A4050, Advanced Telemetry Systems, Isanti, Minnesota)

but some males were outfitted with backpacks (15 g, model A1260) later in the study in an attempt to reduce interference with the lekking behavior while not impacting survival (Bedrosian and Craighead 2010). Birds were placed in transport boxes that were composed of three to five compartments, with hay in the bottom to cushion the ride, and driven to a relay location where they were given to CPW personnel from Grand Junction. Upon arrival at the release location, typically near a lek site or where other resident unmarked birds were known to be in the area, the drop down exit door was lowered facing away from the transport crew so grouse had an unencumbered route in which to flush. In this report, any birds that were relocated to Pinon Mesa will be referred to as "transplants" and those that were born on and have always inhabited the area as "residents".

Radiotracking Movements

We tracked radiotagged transplant grouse to determine seasonal use, lekking, and nesting locations, investigate home range size, and monitor survival of these relocated birds. No resident grouse were marked with radios during the period that transplants were being moved to Pinon Mesa (2010–2013). However, resident grouse that were marked during previous efforts on Pinon Mesa in 1995 and 2002 are discussed for comparative purposes. Grouse referred to as "incidental" are resident birds sited while conducting radiotracking work. Scanning for marked transplant grouse generally was initiated at or near the release location. We initially searched for radio signals using scanning-telemetry receivers (R-1000, Communication Specialists, Inc., Orange, CA) and a roof-mounted whip antenna on vehicles when conditions allowed, or from snow machines and ATV's using a handheld 3-element antenna. In general, locations for individual marked grouse were acquired at least once a week during breeding and summer/fall seasons. Winter locations were collected once every week to two weeks as access became more challenging. Once signals were discovered, scanning commenced on foot to determine the bird's location. Degree of location accuracy was noted as one of three levels: 1) visual, 2) proximity, and 3) triangulation. The best method of getting close enough for a visual location was to flank the signal until the tracking route became a circle around the signal. On occasion, the perfect alignment between the shrubs and grass would allow for a view of the bird. Attempts to make visual locations often led to flushing of the bird. Consequently, in cases where the location of the bird was believed to be close, we made efforts not to flush them and collected a location in the immediate proximity by taking signals from several angles or circling the location. Proximity locations are thought to generally be within 10 m of the birds' actual location based were calculated using the Point Distance and Generate Near Table tools in ArcMap (ArcGIS, Idrisi, Redlands, CA).

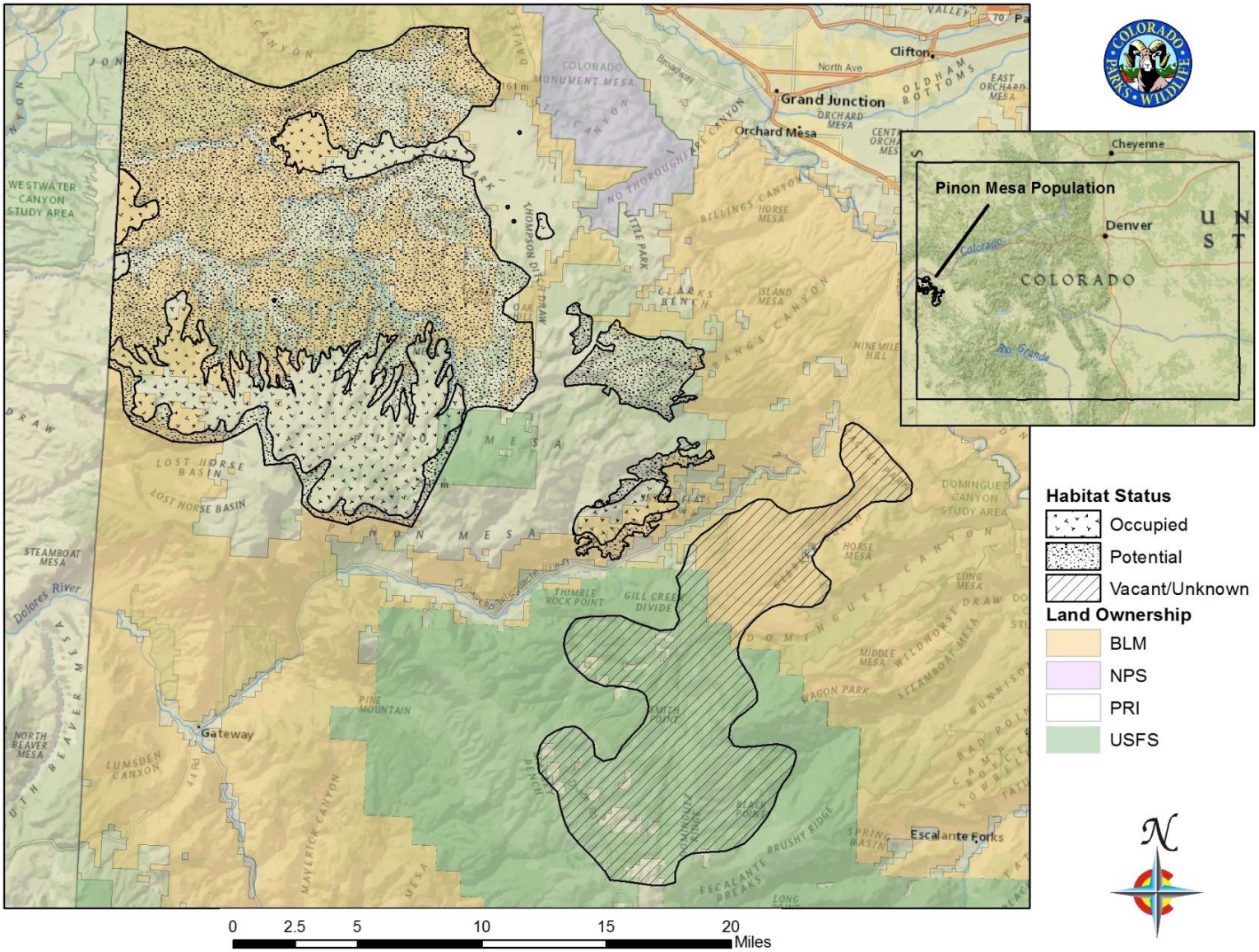


Figure 1. Land ownership and habitat status of the Pinon Mesa Gunnison sage-grouse population, Colorado as mapped by Colorado Parks and Wildlife at the start of transplant efforts in 2010.

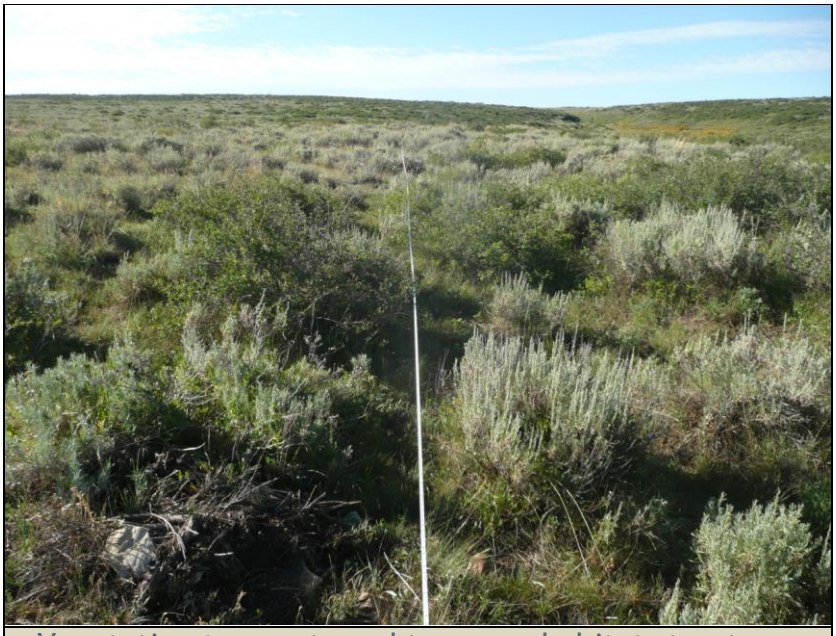
on the size of the circling radius. These locations were collected regularly in the summer/fall season when the grass and forb cover was especially tall.

Triangulations were made in cases where topography, accessibility (e.g. permission to access private lands was restricted during hunting season), and time limitations did not allow for a location to be collected in the immediate proximity. A global positioning system (GPS, Trimble Navigation Limited, Trimble Juno, Sunnyvale, CA) was used to calculate triangulations by utilizing the offset capability based on bearings taken from two or more positions. These short range triangulations were usually taken from county roads that allow public access on a year round basis and are considered to be reasonably accurate. If signals were missing or locations could not be located on the ground due to accessibility issues a fixed-wing aircraft was used in an attempt to find birds or improve location accuracy. Once a location was determined, Universal Transverse Mercator (UTM) coordinates (NAD 83, Zone 13) were collected with a GPS and a data dictionary populated. Variables in the data dictionary included animal ID, radio frequency, sex, observation (incidental, proximity, triangulation, visual), flush (yes or no), bearing (if triangulation taken), distance (if point was offset), date, season (breeding, summer/fall, winter), behavior (dead, flushed, foraging, lekking, resting, unknown), and comments. Data was periodically downloaded to a geographic information system (GIS) to update the location database.

Movement data for sage-grouse related to brood rearing habitat have generally reported distances birds moved from the lek of capture to the nest site. GuSG movements reported by Apa (2004) considered distances moved from the capture location to the nest by birds since they were often caught at locations other than leks. GuSG marked in this study were transplants brought from another population so we report the distances moved by birds from the release location on Piñon Mesa to nests and leks so that comparisons with movements made by resident birds could be made. In addition, we report distances birds moved from release locations to portions of their home range with a 95% probability of use. Home Ranges and 95% probability of use isopleth polygons were developed using the kernel density estimation (kde) and isopleths functions in Geospatial Modeling Environment (www.spatialecology.com). While recommended sample sizes of 30–50 points per individual is the most desirable (Seaman et al. 1999), our dataset consisted of very few individuals that met these specifications despite five years of tracking efforts. Consequently, only birds with 10 or more locations were considered for this analysis so results should be considered with this caveat in mind. The SCV bandwidth and 30 m cell size were selected for the kde analysis to maintain consistency with the seasonal habitat analysis (Carlson 2013) and a 0.95 quantile was used for the isopleths analysis. Distances between release sites and nests, leks, and home range polygons

Vegetation Characteristics

Vegetation characteristics were measured for a subset of general seasonal use, nesting, and brood-rearing locations in 2012. Transect locations were placed in the vicinity of locations where marked transplanted GuSG were sighted with unmarked resident grouse (referred to as incidental locations), and for locations of nesting or brood-rearing transplants collected between 2010 and 2012 (Table 1). Locations of transplanted birds found with resident grouse support the assumption that birds we moved to Pinon Mesa were utilizing the same habitat as the later. This data was intended to supplement the "Minimum structural vegetation collection guidelines for the Gunnison sage-grouse" created by the GuSG Rangewide Steering Committee (Appendix Table A1; GUSG RSC 2007) and was collected utilizing 10 Daubenmire frames along a 30 m transect and line intercept methods for foliar cover (Daubenmire 1959, Canfield 1941). Variables measured include cover percentages for sagebrush, non-sage shrubs, total shrubs, grasses, and forbs, and height in inches for sagebrush, grasses, and forbs. Transects began at the GPS point and proceeded in a randomly determined direction. One photo was taken by standing at the GPS point and pointing the camera down the transect line. The same procedure was followed for nest sites except that the beginning point was shifted so that the first Daubenmire plot at 3 m would coincide with the nest location in order to capture shrub heights and other data at the nest itself. Plant taxonomy and abbreviations used on transects is provided in the Appendix (Table A2).



Vegetation transect used to assess habitat structure.

Table 1. Summary of Gunnison sage-grouse transplant and incidental telemetry points collected on Piñon Mesa, Colorado from 2010–2015 used for location of seasonal vegetation transects. Date the bird was located (Loc date) and transect run (Veg date), the season (Season) and behavior (Type of loc) associated with that location, the geographic area within the population (Geo loc), and averages for vegetative characteristics following the Gunnison Sage-grouse Rangewide Steering Committee (2007) guidelines.

ID	Loc date	Veg date	Season	Type of loc	Geo loc	Sage cover	Total shrub	Sage height	Grass cover	Forb cover	Grass height	Forb height
LF1105_nest	6/4/12	7/24/12	Breeding	nest	Luster Basin	18.4	42.6	16.9	37.5	34.7	6.9	5.5
LF1114_nest	6/15/12	7/13/12	Breeding	nest	Luster Basin	23.3	26.8	20.3	22.7	42.2	5.6	3.1
422	5/13/11	6/13/12	Breeding	nest	Timber Ridge	18.3	25.6	18.0	11.3	0.8	7.1	0.7
470	6/27/11	6/13/12	Breeding	nest	Timber Ridge	18.9	19.6	23.2	10.3	0.8	6.8	0.5
G1	4/3/12	8/2/12	Breeding	with incidental	Luster Basin	2.9	12.1	10.4	28.8	14.3	5.2	2.4
530	7/25/11	7/13/12	Summer/Fall	incidental brood	2V	5.4	18.7	15.4	20.2	27.5	4.6	3.1
245	8/17/10	8/7/12	Summer/Fall	incidental brood	2V	10.3	13.0	13.5	24.2	14.2	4.3	2.5
512	7/18/11	8/8/12	Summer/Fall	incidental brood	2V	13.1	29.1	16.9	21.7	19.2	7.8	4.1
566	8/8/11	8/15/12	Summer/Fall	Incidental brood	2V	6.4	19.7	14.7	22.1	46.9	6.3	3.4
LF1114_6-20	6/20/12	7/17/12	Summer/Fall	brood	Luster Basin	9.8	12.2	17.2	10.7	53.8	5.7	3.7
LF1114_6-28	6/28/12	7/17/12	Summer/Fall	brood	Luster Basin	7.4	11.2	21.3	21.0	38.4	4.0	3.1
LF1114_7-8	7/8/12	7/24/12	Summer/Fall	brood	Luster Basin	15.4	17.0	13.7	17.1	28.4	4.1	2.7
Incid_7-30	7/30/12	8/15/12	Summer/Fall	incidental brood	Luster Basin	14.9	25.3	14.7	23.0	19.5	5.5	3.4
451	6/15/11	6/13/12	Summer/Fall	possible brooding	Timber Ridge	21.2	24.1	19.4	6.1	0.0	4.5	0.0
471	6/27/11	6/19/12	Summer/Fall	hen with chick	Timber Ridge	13.6	13.6	19.2	11.6	0.5	4.1	0.5
480	6/30/11	6/19/12	Summer/Fall	possible brooding	Timber Ridge	30.5	30.5	17.7	9.6	5.7	4.9	2.5
503	7/14/11	6/19/12	Summer/Fall	possible brooding	Timber Ridge	5.6	20.7	11.8	17.7	4.7	5.9	2.5
47	7/15/10	7/3/12	Summer/Fall	incidental brood	Tipping Ridge	15.4	22.3	16.1	41.0	49.8	6.2	4.5
312	9/28/10	7/30/12	Summer/Fall	male, incidentals	2V	10.4	22.6	13.0	17.3	37.3	4.5	2.9
277	9/9/10	8/7/12	Summer/Fall	incidental	2V	13.5	23.8	15.1	27.6	25.8	6.0	4.4
8	6/29/10	6/27/12	Summer/Fall	location	Luster Basin	11.1	16.6	12.7	16.8	35.2	4.3	3.5
546	8/1/11	6/27/12	Summer/Fall	incidental hen	Luster Basin	13.7	19.8	16.3	12.4	34.8	4.9	3.5
556	8/4/11	6/26/12	Summer/Fall	w incidental	Luster Basin	20.0	20.0	15.6	12.6	47.6	3.8	3.9
G2	10/18/11	7/8/12	Summer/Fall	w incidental	Luster Basin	13.2	15.4	14.6	26.4	23.4	2.4	2.3
G3	10/25/11	7/8/12	Summer/Fall	w incidental	Luster Basin	16.1	17.0	16.3	8.2	30.4	3.7	3.4
G4	10/25/11	6/26/12	Summer/Fall	w incidental	Luster Basin	9.2	17.0	15.7	13.1	23.3	2.4	3.8
453	6/15/11	8/13/12	Summer/Fall	with incidental	Luster Basin	17.6	22.0	14.0	18.9	36.1	4.1	2.5
3	6/28/10	7/3/12	Summer/Fall	incidental hens	Luster Basin	12.5	19.0	16.6	26.0	36.5	7.0	4.9
15	6/30/10	7/10/12	Summer/Fall	incidental males	Luster Basin	17.3	30.7	16.6	23.9	53.8	7.7	5.7

Table 1. Continued.

ID	Loc date	Veg date	Season	Type of loc	Geo loc	Sage cover	Total shrub	Sage height	Grass cover	Forb cover	Grass height	Forb height
40	7/12/10	7/10/12	Summer/Fall	incidental	Luster Basin	9.6	12.1	16.5	20.4	60.7	5.4	3.7
49	7/15/10	7/26/12	Summer/Fall	incidental males	Luster Basin	2.4	49.2	17.3	35.8	46.7	8.2	5.9
247	8/19/10	7/3/12	Summer/Fall	incidental males	Luster Basin	23.2	27.1	16.8	11.1	40.6	3.6	2.9
578	8/10/11	7/9/12	Summer/Fall	location	Dominguez	3.2	3.9	11.7	12.3	17.9	2.5	1.3
617	8/23/11	7/9/12	Summer/Fall	location	Dominguez	5.1	16.5	14.4	9.6	13.6	3.1	2.4
633	8/30/11	7/9/12	Summer/Fall	location	Dominguez	9.9	18.0	10.9	4.8	18.0	2.5	2.6
Unc_R1	-	7/9/12	Winter	random point	Dominguez	33.7	33.7	28.2	11.3	21.6	4.5	3.0
357	1/28/11	8/14/12	Winter	with incidental	Payne Mesa	6.7	31.3	18.2	16.7	7.4	4.9	2.6
359	1/28/11	8/14/12	Winter	incidental	Payne Mesa	19.3	42.6	29.6	13.6	5.9	5.0	2.3
347	1/24/11	7/31/12	Winter	with incidental	Reservation	22.3	22.3	13.6	8.8	1.5	3.2	0.7
374	2/21/11	7/31/12	Winter	location	Reservation	16.3	16.3	10.6	4.4	0.3	3.9	0.0
RES2	2/3/11	7/31/12	Winter	location	Reservation	13.4	13.4	12.3	6.1	1.8	2.6	1.1
373	2/11/11	6/13/12	Winter	with incidental	Timber Ridge	16.8	16.8	13.0	10.2	0.5	4.3	0.4
381	3/14/11	6/19/12	Winter	three others	Timber Ridge	5.1	5.1	15.9	20.1	1.5	6.2	1.3
386	3/25/11	6/13/12	Winter	with incidental	Timber Ridge	11.6	20.1	12.8	6.9	1.8	4.5	0.9
LF1014_W	2/2/11	6/19/12	Winter	location	Timber Ridge	4.7	37.0	16.0	11.9	5.9	7.1	1.9

Seasonal Habitat Modeling

Seasonal habitat use models were developed in 2013 by graduate student A. Carlson using GIS data obtained from a number of sources including the CPW telemetry data described in this document (Carlson 2013). The modeling process is described in greater depth in this thesis but, in basic terms, utilized maximum entropy modeling (MaxEnt) and simultaneous autoregression (SAR) to create species distribution models (SDMs). Locations collected for 69 transplanted grouse from 2010 through 2013 were used in this two-step model process to identify which environmental variables were most important. MaxEnt models incorporated surface, anthropogenic, and course-scale landcover factors. Surface variables included elevation, slope, aspect, topographic roughness index (TRI), a compound topographic index (CTI) to investigate site wetness, and distance to woodlands. Anthropogenic variables such as linear road density, and distance to roads and buildings were also considered. Simultaneous autoregression (SAR) models used finer scale vegetation variables delineated in the GuSG Rangewide Conservation Plan (2005) that was collected from transect point data (e.g. percent cover of sagebrush) as previously described. Telemetry locations were split into three seasonal habitats defined as breeding (March 15th – May 31st), summer/fall (June 1st – October 31st), and winter (November 1st – March 14th) for the Piñon Mesa population. A total of 330 breeding, 597 summer/fall, and 247 winter locations were used as presence locations in the analysis. A raster map for each season was created from the models as a final product.

Statistical Analysis

Survival estimates were generated with Kaplan-Meier models using the survival package in Program R (ver. 3.1.3; R Foundation for Statistical Computing, Vienna, Austria), where age, sex, season, year, and radio type were covariates. Our data was right-censored for radios that failed or were dropped with unknown fates. Individuals with dropped collars where fate of the bird was unknown were run in three ways: all as mortalities, all as survivors, and as a ratio of mortalities and survivors determined from the known fate birds. We used this approach to examine how violation of the assumption that censoring is random with respect to fate affects survival estimates. To account for handling effects on survival, we did not consider data for any birds that died within one week of release. Encounter histories were created for each bird based on weekly time steps for an annual period that corresponded to the start of breeding season (March 15) starting in 2010 and running through the winter season (March 14) of 2015 so that 5 years of data for each season could be considered.

Results

Gunnison sage-grouse trap and transplant efforts were initiated in spring of 2010 to augment population numbers and genetic diversity on Piñon Mesa. Transplants were conducted again in the fall of 2010, 2011 and 2012, and spring of 2013. A total of 93 grouse were captured with one yearling hen succumbing to transplant myopathy during transport, resulting in a total of 92 live grouse successfully released during four years of capture work (Table 2). Sex ratios of transplants were purposely biased towards hens with 56 females, 33 males, and 4 unknown juveniles accounting for the released birds (Table 2). Eight birds were identified as "unknown" sex at time of capture, of which 3 were identified later as females and 1 as a male based on their plumage development and behavior. In addition, 1 bird originally classified as a yearling female was later determined to be a male. Birds were generally released at or near known leks including Luster Basin, 2V West, Payne Mesa Upper, and Timber Ridge (Table 3). Some fall transplants were released in areas of known resident grouse concentrations, such as the corrals off MS Road past Luster Basin, to encourage them to join resident birds there and follow them to suitable habitat.

Table 2. Total numbers of Gunnison sage-grouse, by year and age class, transplanted from the Gunnison Basin to Piñon Mesa between 2010 and 2013.

Sex/Age class	2010	2011	2012	2013	Total
Male					
Adult	7	0	1	6	14
Juvenile	1	3	4	0	8
Yearling	2	1	0	8	11
Female					
Adult	7	3	8	6	24
Juvenile	2	1	4	0	7
Yearling	8	4	1	11*	24
Unknown	0	1	0	0	1
Unknown					
Juvenile	1	3	0	0	4
Total	28	16	18	31	93

* One yearling hen died from transport myopathy.

Table 3. Gunnison sage-grouse transplanted from the Gunnison Basin to Piñon Mesa between spring of 2010 and fall of 2013.

ID	Freq	Sex	Age	Year	Season	Release Date	Release Site
LM1001	166.955	Male	Adult	2010	Spring	4/15/2010	Kings Ridge
LF1002	166.283	Female	Yearling	2010	Spring	4/15/2010	Kings Ridge
LF1003	166.234	Female	Yearling	2010	Spring	4/15/2010	Kings Ridge
LF1004	166.196	Female	Adult	2010	Spring	4/15/2010	Kings Ridge
LM1005	166.084	Male	Adult	2010	Spring	4/16/2010	Tippings Gate
LM1006	166.359	Male	Adult	2010	Spring	4/16/2010	Tippings Gate
LM1007	166.023	Male	Adult	2010	Spring	4/19/2010	Luster Lek
LM1008	166.220	Male	Adult	2010	Spring	4/19/2010	Luster Lek
LF1009	166.396	Female	Adult	2010	Spring	4/19/2010	Luster Lek
LF1010	166.434	Female	Yearling	2010	Spring	4/27/2010	Luster Lek
LF1011	166.484	Female	Adult	2010	Spring	4/28/2010	Luster Lek
LF1012	166.258	Female	Adult	2010	Spring	5/6/2010	Luster Lek
LF1013	166.458	Female	Yearling	2010	Spring	5/6/2010	Luster Lek
LF1014	166.842	Female	Yearling	2010	Fall	9/16/2010	Bedford Road
LF1015	166.767	Female	Yearling	2010	Fall	9/16/2010	Bedford Road
LU1016	166.867	Unknown	Yearling	2010	Fall	9/16/2010	Bedford Road
LF1017	166.900	Female	Adult	2010	Fall	9/18/2010	2-V West Lek
LM1018	166.916	Male	Adult	2010	Fall	9/18/2010	2-V West Lek
LM1019	166.816	Male	Juvenile	2010	Fall	9/18/2010	2-V West Lek
LM1020	166.807	Male	Adult	2010	Fall	9/21/2010	Bedford Road
LF1021	167.334	Female	Yearling	2010	Fall	9/29/2010	Bedford Road
LM1022	167.170	Male	Yearling	2010	Fall	10/1/2010	Bedford Road
LM1023	167.180	Male	Yearling	2010	Fall	10/5/2010	Bedford Road
LF1024	167.426	Female	Adult	2010	Fall	10/5/2010	Bedford Road
LF1025	167.110	Female	Juvenile	2010	Fall	10/5/2010	Bedford Road
LF1026	167.100	Female	Juvenile	2010	Fall	10/5/2010	Bedford Road
LU1027	165.258	Unknown	Juvenile	2010	Fall	10/6/2010	Bedford Road
LF1028	167.610	Female	Adult	2010	Fall	10/13/2010	Bedford Road
LU1101	167.686	Male	Juvenile	2011	Fall	9/13/2011	Luster Lek
LF1102	167.260	Female	Yearling	2011	Fall	9/19/2011	Luster Lek
LF1103	167.120	Female	Yearling	2011	Fall	9/19/2011	Luster Lek
LM1104	167.628	Male	Yearling	2011	Fall	9/19/2011	Luster Lek
LF1105	167.448	Female	Adult	2011	Fall	9/19/2011	Luster Lek
LM1106	167.348	Male	Juvenile	2011	Fall	9/19/2011	Luster Lek
LF1107	167.042	Female	Unknown	2011	Fall	9/20/2011	Luster Lek
LU1108	167.066	Unknown	Juvenile	2011	Fall	9/20/2011	Luster Lek
LU1109	167.017	Unknown	Juvenile	2011	Fall	9/20/2011	Luster Lek
LM1110	167.142	Male	Juvenile	2011	Fall	9/20/2011	Luster Lek
LU1111	167.167	Unknown	Juvenile	2011	Fall	9/25/2011	Luster Lek
LF1112	167.426	Female	Yearling	2011	Fall	9/25/2011	Luster Lek
LU1113	167.117	Unknown	Juvenile	2011	Fall	9/25/2011	Luster Lek
LF1114	165.846	Female	Adult	2011	Fall	10/13/2011	Luster Lek
LF1115	167.200	Female	Yearling	2011	Fall	10/13/2011	Luster Lek
LF1116	165.421	Female	Adult	2011	Fall	10/13/2011	Luster Lek
LM1201	164.404	Male	Juvenile	2012	Fall	9/7/2012	Timber Ridge Lek
LM1202	164.180	Male	Juvenile	2012	Fall	9/7/2012	Timber Ridge Lek

Table 3. Continued.

ID	Freq	Sex	Age	Year	Season	Release Date	Release Site
LF1203	164.614	Female	Adult	2012	Fall	9/21/2012	Timber Ridge Lek
LF1204	164.664	Female	Adult	2012	Fall	9/22/2012	Timber Ridge Lek
LF1205	164.654	Female	Juvenile	2012	Fall	9/22/2012	Timber Ridge Lek
LF1206	164.724	Female	Adult	2012	Fall	9/23/2012	Timber Ridge Lek
LF1207	164.066	Female	Adult	2012	Fall	9/28/2012	Timber Ridge Lek
LM1208	164.743	Male	Juvenile	2012	Fall	9/28/2012	Timber Ridge Lek
LF1209	164.041	Female	Adult	2012	Fall	9/28/2012	Timber Ridge Lek
LF1210	164.181	Female	Juvenile	2012	Fall	9/30/2012	Timber Ridge Lek
LF1211	167.091	Female	Juvenile	2012	Fall	9/30/2012	Timber Ridge Lek
LM1212	167.014	Male	Adult	2012	Fall	10/4/2012	Luster Lek
LF1213	166.942	Female	Yearling	2012	Fall	10/5/2012	Luster Lek
LF1214	165.508	Female	Adult	2012	Fall	10/6/2012	Luster Lek
LU1215	166.630	Unknown	Juvenile	2012	Fall	10/6/2012	Luster Lek
LF1216	165.022	Female	Adult	2012	Fall	10/6/2012	Luster Lek
LF1217	164.956	Female	Adult	2012	Fall	10/11/2012	Luster Lek
LM1218	166.817	Male	Juvenile	2012	Fall	10/11/2012	Luster Lek
LM1301	165.182	Male	Adult	2013	Spring	4/8/2012	2-V West Lek
LM1302	164.134	Male	Juvenile	2013	Spring	4/8/2012	2-V West Lek
LM1303	164.274	Male	Adult	2013	Spring	4/8/2012	2-V West Lek
LM1304	165.071	Male	Juvenile	2013	Spring	4/8/2012	2-V West Lek
LM1305	164.753	Male	Juvenile	2013	Spring	4/8/2012	2-V West Lek
LF1306	164.145	Female	Juvenile	2013	Spring	4/9/2012	Payne Mesa Upper Lek
LM1307	166.993	Male	Adult	2013	Spring	4/9/2012	Payne Mesa Upper Lek
LM1308	167.955	Male	Adult	2013	Spring	4/12/2012	Luster Lek
LM1309	167.660	Male	Juvenile	2013	Spring	4/12/2012	Luster Lek
LF1310	167.190	Female	Juvenile	2013	Spring	4/12/2012	Luster Lek
LF1311	165.211	Female	Juvenile	2013	Spring	4/12/2012	Luster Lek
LF1312	164.425	Female	Juvenile	2013	Spring	4/22/2012	Luster Lek
LF1313	167.000	Female	Juvenile	2013	Spring	4/22/2012	Luster Lek
LM1314	164.762	Male	Juvenile	2013	Spring	4/22/2012	Luster Lek
LF1315	164.816	Male	Juvenile	2013	Spring	4/22/2012	Luster Lek
LF1316	167.149	Female	Juvenile	2013	Spring	4/22/2012	Luster Lek
LF1317	165.606	Female	Adult	2013	Spring	4/22/2012	Luster Lek
LF1318	165.232	Female	Juvenile	2013	Spring	4/23/2012	Luster Lek
LF1319	164.013	Female	Adult	2013	Spring	4/23/2012	Luster Lek
LF1320	164.165	Female	Adult	2013	Spring	4/23/2012	Luster Lek
LF1321	164.444	Female	Adult	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LM1322	167.350	Male	Adult	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LM1323	165.063	Male	Juvenile	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LF1324	167.210	Female	Adult	2013	Spring	4/23/2012	Payne Mesa Upper Lek
LF1325	164.695	Female	Adult	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LF1326	167.219	Female	Juvenile	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LM1327	164.772	Male	Adult	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LF1328	164.682	Female	Juvenile	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LM1329	167.790	Male	Juvenile	2013	Spring	4/24/2012	Payne Mesa Upper Lek
LF1330	166.841	Female	Juvenile	2013	Spring	4/25/2012	Timber Ridge Lek
LF1331	164.563	Female	Juvenile	2013	Spring	4/25/2012	Timber Ridge Lek

Radiotracking Efforts

Radio telemetry from the ground yielded 2,223 locations of transplanted grouse collected between 21 April, 2010 and 8 June, 2015 (Figure 2). Observations of incidental unmarked grouse were made at 17% of these locations while tracking marked birds (338 of 2,223 locations). An additional 175 locations of unmarked resident grouse (incidentals) were collected while technicians were in the field and not in the immediate proximity of a marked bird. Fixed-wing aerial tracking utilized to find missing birds and add winter records resulted in 313 additional locations. Expected life span of the radios was 18 months (547 days). Some radios showed clear signs of failure at around one year while others lasted over two years. Typically signs of radio failure included weak signals with a short range of detection, alternating between live and mortality signals, or projecting a thudding or ticking sound rather than a ping on the receiver. The longest lasting radio ran for 2 years and 4.5 months (868 days).

Most radio marked grouse concentrated their activity to relatively small areas as the clumped data suggests. Some birds wandered about soon after transplant, perhaps in search of their original home range. These movements, often long distance ones, sometimes resulted in mortalities and was more commonly detected by fixed-wing telemetry efforts. One female grouse transplanted in 2010 traveled 40 km down to the valley east of the Gunnison River to the area near Kannah Creek (Figure 2). She then returned to her place of release and remained in that area for the remainder of the study. Three birds transplanted during the spring of 2010 made long range movements south to the Uncompahgre Plateau soon after release on Piñon Mesa, all of which ended in mortalities. One hen travelled approximately 52 km south of Piñon Mesa before being depredated on Atkinson Mesa on the west side of the Uncompahgre Plateau. A hen that wintered near upper Dominguez Canyon made a series of movements back and forth to Piñon Mesa that added up to 93 km over a seven-month period. This bird likely traveled further as locations were only collected periodically. The greatest number of combined movements for a transplant grouse was made by a hen that traveled 201 km over her tracking history.

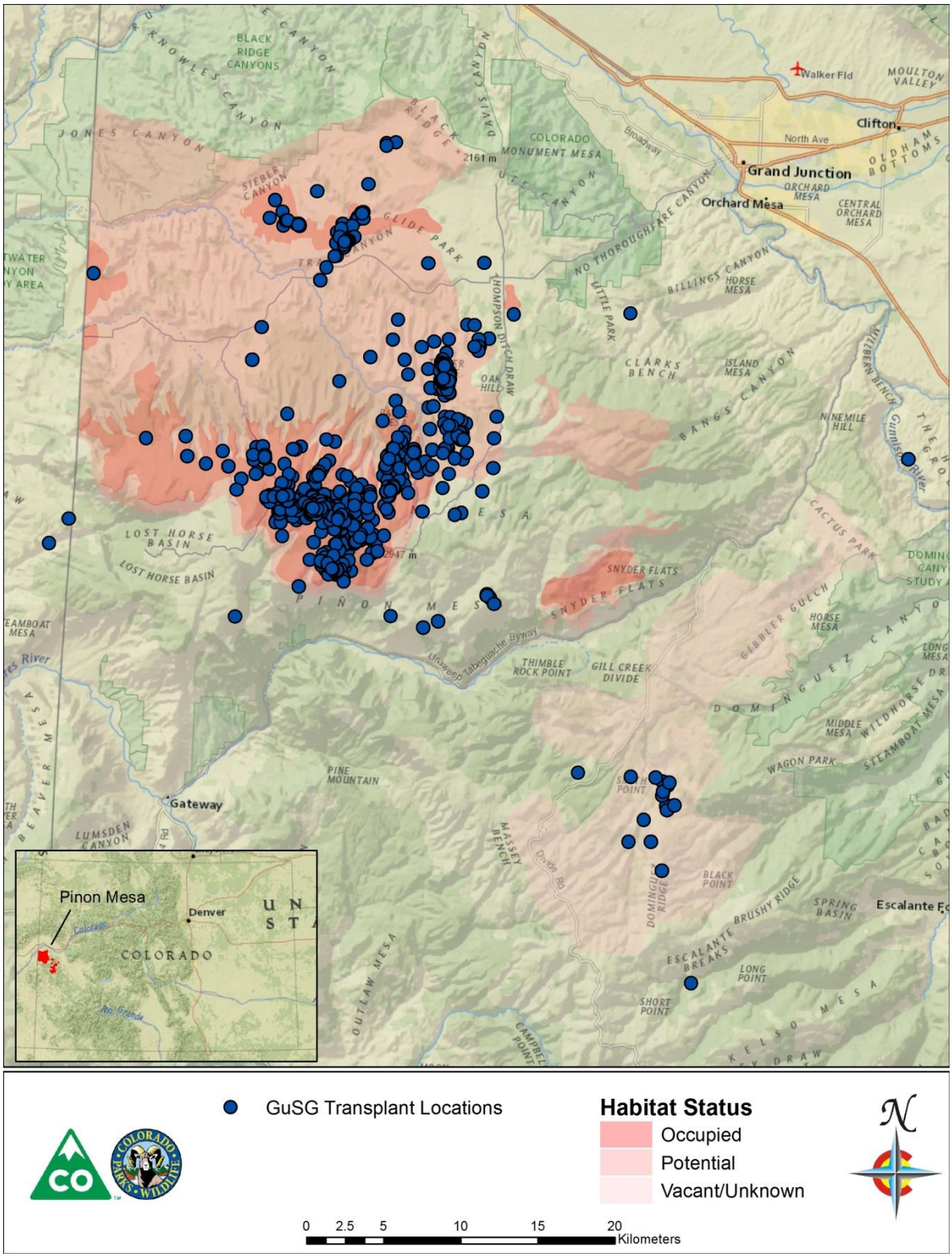


Figure 2. Telemetry locations of Gunnison sage-grouse transplanted to the Piñon Mesa population, Colorado between 2010–2013 in relation to habitat status as mapped at that time. Locations were collected between 2010 and 2015.

Survival Analysis

Tracking duration in number of days varied by sex, age, season, and radio type for transplant birds (Table 4, Figure 3). These days don't represent survival but rather the number of days the radio was carried before the bird was predated, the radio was dropped, or some other type of known fate was noted. Our ability to determine the cause of confirmed mortalities were variable. In some cases, evidence in the form of a pile of feathers or a part of the bird remained to confirm the mortality. Anecdotal evidence such as coyote tracks in the dirt or snow and white wash suggest the mortality was caused by a given predator but generally these assumptions could not be confirmed. One transmitter located in a golden eagle nest and the sighting of a red-tailed hawk departing from a freshly killed bird provided direct evidence of raptor caused mortalities.

The cause of other mortalities was more ambiguous with only the radio present, a chewed antenna, or presence of blood. One hen was found frozen under a log and a second, upon necropsy, is likely to have flushed into a cliff face where it broke its neck. Some dropped radios may actually be mortalities if cinches (crimps that hold the radio harness at the right size) remained intact. The fate of other radios was more apparent with the cinch of the collar undone and no sign of mortality or a struggle at the location where it was collected. One backpack radio was found tangled up in the branch of a sagebrush suggesting it got hooked and the grouse pulled out of the harness. Initially, dropped radio collars from males often had harnesses with large leg loops and were found soon after release. For example, three collars were dropped by males in the transport box before release. Two collars were constructed with rubber tubing so that they would release on their own. One of these collars came loose within days of release while the other lasted approximately 70 days. In total, 77 necklace radios were deployed with birds carrying them for an average of 250 days (Min=0, Max=868, Med=173), while 13 backpacks were carried for an average of 232 days (Min=0, Max=651, Med=81).

Table 4. Sex and age class of transplanted Gunnison sage-grouse in relation to the final fate of birds on Piñon Mesa between 2010 and 2014. Number of transplants (n), those that died (Mortality), radios that were dropped, battery died (Battery), or were unknown, and those still being tracked at the time of analysis.

Sex/Age class	n	Mortality	Dropped	Battery	Unknown	Tracking
Male						
Adult	14	6	3	1	4	0
Juvenile	8	5	1	2	0	0
Yearling	11	5	1	2	2	1
Female						
Adult	24	15	2	6	0	1
Juvenile	7	4	0	3	0	0
Yearling	24	13*	1	6	2	2
Unknown	1	0	0	0	1	0
Unknown						
Yearling	4	2	0	1	1	0
Total	93	50	8	21	10	4

* One yearling hen died from transport myopathy

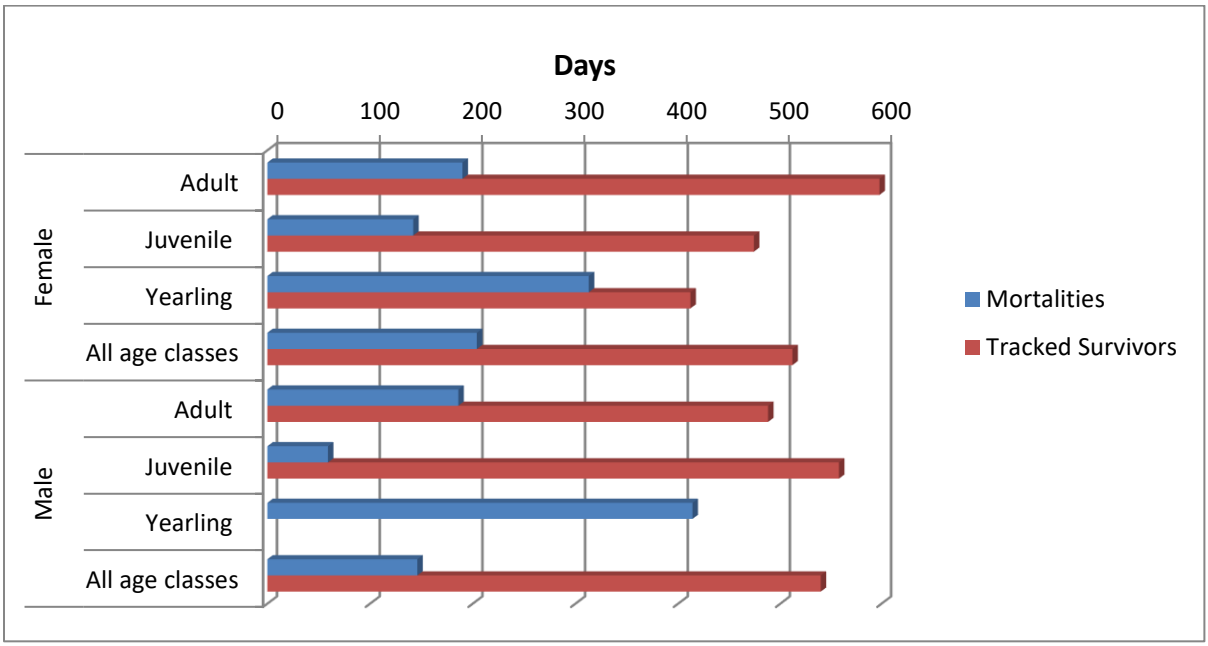
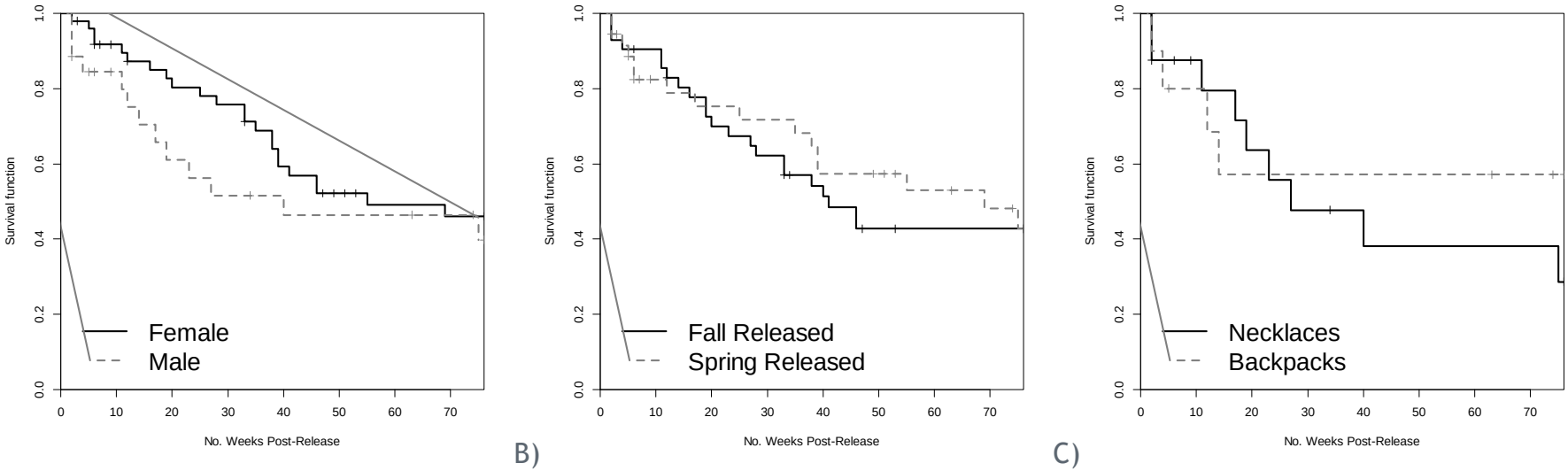


Figure 3. The average number of days' grouse were tracked from the time of release to last-heard-alive for each sex and age class at Piñon Mesa between 2010 and 2014. Known fate for birds includes categories of failed radios, missing birds, and those still being tracked up to the cut-off date of August 31, 2014. Data from dropped radio birds was excluded because loss of radio was an arbitrary factor to survival.

Attempts to analyze survival of sage-grouse transplanted to Piñon Mesa using Kaplan Meier models in Program R were hindered by small sample sizes when interactions of multiple variables such as season, age, and sex were considered. Consequently, sex and season alone were analyzed independently with samples pooled across both year and age. Annual survival of female and male transplant birds was 0.52 ± 0.08 and 0.46 ± 0.11 respectively (Table 5, Figure 4). Estimates of annual survival considering only a seasonal effect showed slightly higher survival for birds transplanted in the spring (0.57 ± 0.09) versus fall (0.43 ± 0.08; Table 5, Figure 4). Birds fitted with rump mounted transmitters had higher annual survival estimates (0.57 ± 0.16) than those fitted with necklace transmitters (0.38 ± 0.14). Only male grouse were fitted with rump mounted transmitters resulting in a small sample size for comparison and large 95% confidence intervals (Table 5).

Table 5. Estimates of average annual survival by sex, season, and transmitter type for Gunnison's sage-grouse transplanted to Piñon Mesa, Colorado from 2010 and 2013.

				95% CI	
Survival	**n**	**Estimate**	**SE**	**Lower**	**Upper**
Sex					
Female	49	0.522	0.076	0.392	0.694
Male	27	0.464	0.108	0.295	0.731
Season					
Spring	37	0.573	0.091	0.420	0.783
Fall	42	0.428	0.081	0.295	0.620
Radio Type					
Necklace	17	0.382	0.140	0.186	0.784
Rump mount	10	0.571	0.164	0.326	1.000



A) B) C)

Figure 4. Survival of Gunnison sage-grouse transplanted to Piñon Mesa, Colorado from 2010–2013 by A) sex, B) season, and C) transmitter type.

Home Range Analysis

Home range size with 95% probability of use by GuSG transplant birds averaged 9,663 hectares (23,878 acres) and ranged from 1,043 to 43,362 hectares (2,576—114,564 acres) in size. GuSG hens transplanted to Piñon Mesa (n = 36) established home ranges that encompassed the site at which they were released on 89% of occasions (Table 6). Home ranges of male GuSG (n = 15) encompassed release sites 93% of the time. Of the hens that did not establish home ranges where they were released, they settled an average distance of 2.4 km (range = 0.6 to 4.7 km) from release locations (Table 6). One male established a home range that did not encompass its release site. However, the distance of the release location was only 12 m outside of the home range which could be accounted for by the model variance.

The average size of a home range for five resident birds marked in 1995 was 3,838 acres (Range 483 – 7,104 acres) and for 9 birds marked in 2002 was 2,457 acres (199 – 10,556 acres). All but two birds from 1995 had home ranges that encompassed the areas where they were originally captured. Two males tracked during the summer/fall of 1995 established home ranges that were 0.6 and 1.2 km away from their capture sites. Overlap of home ranges by resident birds tracked in 1995 and 2002 with transplant birds from 2010–2015 was widespread with a few notable exceptions (Table 7). Birds tracked in 1995 with home ranges in the Fish Park area were not overlapped by either of the subsequent telemetry efforts (Figure 5). Conversely, the overall home range of transplant birds, considered across all seasons, used a number of lower elevation areas around Glade Park such as Timber Ridge, the Reservation/Bunkers, and upper Dominguez Canyon. Home ranges of transplant birds largely overlapped those of incidental birds documented during the study (Figure 6).

Gunnison sage-grouse hen and chicks.

Table 6. Number and percentage of Gunnison's sage-grouse transplanted to Piñon Mesa, Colorado between 2010 and 2013 with release sites encompassed by their 95% probability home range polygons (# In/%) or were outside of home ranges (# Out/%). In cases where release sites were outside of home range polygons, the average, minimum and maximum distances (km) between the two are provided. Only individuals with 10 or more locations were considered for this analysis.

Group	n	# In/%	# Out/%	Average (km)	Minimum	Maximum
Transplants	51	46/90%	5/10%	1.88	0.01	4.67
Female	34	30/88%	4/12%	2.35	0.57	4.67
Male	14	13/93%	1/7%	-	-	-
Unknown	3	3	0	-	-	-

Table 7. Area in acres of overlap for home ranges of Gunnison's sage-grouse transplanted to Piñon Mesa, Colorado between 2010 and 2013 with resident sage-grouse marked in 1995 (Woods and Braun 1995) and 2004 (Wenger 2004). Percent overlap of home ranges is provided below the diagonal with amounts for the column group given first followed by the row group. Only individuals with 10 or more locations were considered for this analysis.

Group (n)	Transplants	1995	2002
Transplants (51)	-	14,199	4,426
1995 (5)	49%/50%	-	4,320
2002 (9)	15%/99%	15%/96%	-

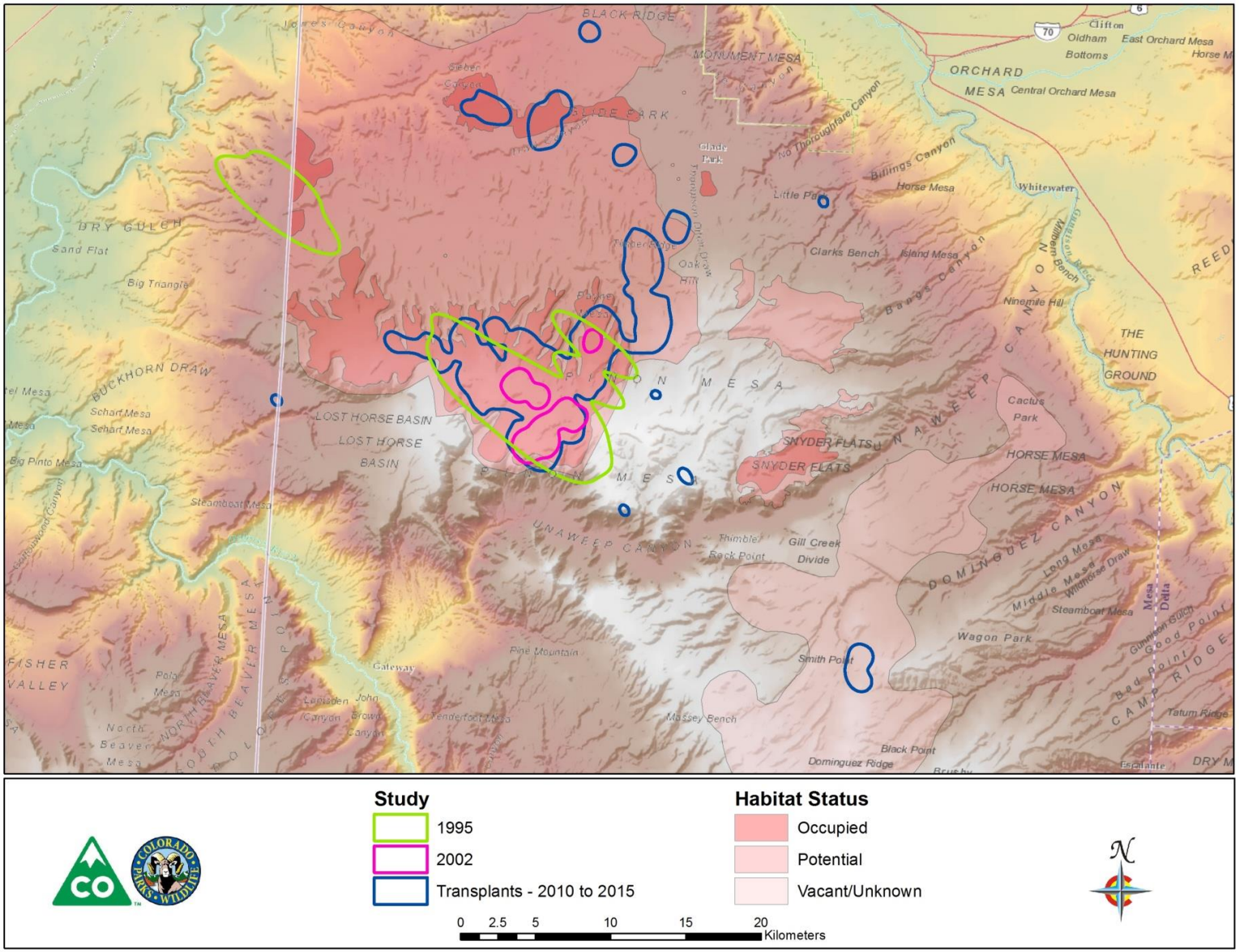


Figure 5. Home ranges for Gunnison sage-grouse radiotracked on Piñon Mesa, Colorado during 1995, 2002, and transplanted birds from 2010–2015. Home ranges are based on 95% probability of use isopleth polygons developed in Geospatial Modeling Environment (www.spatialecology.com).

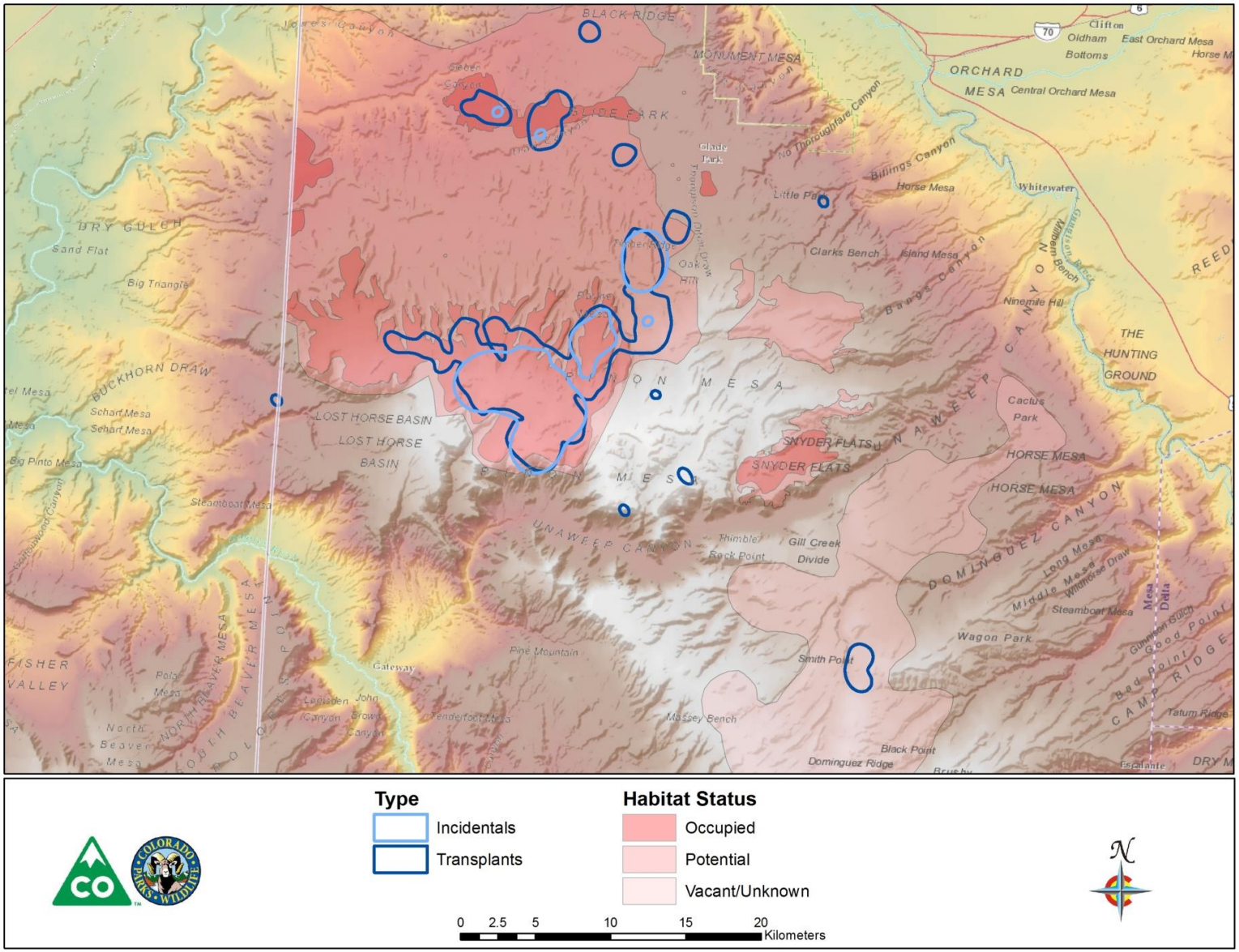


Figure 6. Home ranges for Gunnison sage-grouse transplanted (Transplants) to Piñon Mesa, Colorado from 2010–2013 and incidental birds (Incidentals) located during the same radiotracking efforts. Home ranges are based on 95% probability of use isopleth polygons developed in Geospatial Modeling Environment (www.spatialecology.com).

Seasonal Habitat Use and Distance Analysis

Breeding Habitat and Lek Attendance

Attendance of marked birds was confirmed at active, inactive, historic, and new leks during this study. Of the 93 marked sage-grouse, thirteen male and 7 female radiotagged transplants were confirmed on or near leks during strutting hours in the breeding season from 2010—2015. An additional male with only leg bands but no transmitter was viewed strutting on a lek as well. Four transplant males and one hen were confirmed using two lek locations. Two males made small movements of 0.3 km between Luster Basin and Tipping Ridge leks. Other individuals moved farther distances of 3.9 km (Luster Basin to 2V), 5.6 km (Luster Basin to Payne Mesa Pond), and 12.0 km (Timber Ridge to Luster Basin) both within and between years. Telemetry work also drew attention to a potential new lek site on Timber Ridge. Further observation at this lek confirmed strutting activity and lek attendance by resident hens. Male Gunnison sage-grouse attendance on Timber Ridge increased from 0 to 5 over this 4-year period and a transplanted male that had dropped its radio (leg band observed) occupied the dominant spot on the lek in 2014.

Strutting male Gunnison sage-grouse. Photo by S. Wenger

Average distances moved by male transplants from release sites to lekking locations was 2.5 km (range = 0.0 to 12.1 km; Table 8). Two adult, three yearling, and two juvenile males released near Luster Basin lek were documented strutting on that lek on one or more of the following years. One juvenile male released near the Timber Ridge lek was subsequently documented lekking at Luster Basin lek, a movement of 12.1 km. Females noted on leks during the breeding season moved 1.6 km from original release locations on average (range = 0.0 to 10.9 km; Table 8). One hen wintering on the Uncompahgre Plateau near upper Dominguez Canyon returned to Timber Ridge (30.7 km) during breeding season where she attended the lek briefly before moving to the Luster Basin lek the following week.

Table 6. Number of transplanted Gunnison's sage-grouse (n birds), along with average ($\bar{X}$ and *SE*), minimum, and maximum distances (km) moved from release sites to leks (both sexes) and to nests (females) transplanted to Piñon Mesa, Colorado between 2010 and 2013. Number of locations used for the estimates (n loc) is provided for lek distances as some birds attended more than one lek location. Estimates for resident sage-grouse captured on Piñon Mesa in 2002 (Apa 2004) are provided for comparison but with distances from capture sites used instead of release locations.

		n	n	*Distance*		
Group	**Sex**	**birds**	**loc**	**$\bar{X}$ (*SE*)**	**Minimum**	**Maximum**
Transplants						
Release site to lek(s)	male	11	45	2.5 (3.2)	0.0	12.1
Release site to lek(s)	female	9	19	1.6 (2.8)	0.0	10.9
Release site to nests	female	14	-	4.9 (5.4)	0.1	14.6
2004						
Release site to nests	female	6	-	0.9 (0.3)	0.2	5.8

Summer/Fall Habitat and Nesting Documentation

Of the 57 female GuSG transplanted to Piñon Mesa and tracked over 5 breeding seasons, 11 radio collared hens were confirmed to have initiated nesting on at least 14 occasions. These hens hatched a minimum of 47 chicks (this number is likely higher as fate of some eggs could not be accounted for), not counting three of the nests that were depredated, for an overall nest success across all years of 71% (n=10/14). After fledging, two broods consisting of 8 to 10 chicks were likely lost to predation. Nest initiation and success varied by area within the population. Radio marked hens nested on Timber Ridge 6 times. In 2011, two hens nested on Timber Ridge and each successfully hatched 5–6 eggs. In 2012, two hens nested in the vicinity of Luster Lek with one nest hatching 6 chicks and the other being depredated by a mammal before hatching. In 2013, five hens nested with all successfully hatching chicks. One of the successful hens from 2011 nested again near Luster lek within 200

meters of her previous nest and was seen with 2 chicks. Two hens transplanted in the fall 2012 nested on Timber Ridge in 2013 and hatched 5–6 chicks each. One of these hens was later depredated before her brood was old enough to be fully independent so their survival is questionable. One hen transplanted in 2012 nested on Payne Mesa and hatched 4–5 chicks. A hen, transplanted in spring of 2013, nested on Timber Ridge soon after transplant, indicating that she may have bred in the Gunnison Basin prior to being captured. This hen hatched 3–4 chicks and soon after moved several kilometers, leaving survival of her brood as unknown. One hen laid an egg in the transport box that spring but did not attempt to nest again. In 2014, 3 hens were confirmed to have nested. One hen, transplanted in 2012, nested on the rim of Unaweep Canyon near the highest elevation on the summer range and was depredated along with her nest by a mammal. The hen that nested on Timber Ridge in 2013 nested there again in 2014 and hatched 6 chicks. A second hen transplant from 2013 nested near the 'Bunkers' and hatched 6 chicks with 1 sterile egg. This bird was later seen on the north Unaweep rim on Piñon Mesa's highest ridge with 3 chicks, a movement of 21 km from her nest site. In 2015, 1 of the 3 hens still being tracked was confirmed nesting within 300 meters from her nest site in 2014. Four hens and one male were located south of upper Dominguez Canyon as well. This area was primarily used in winter but one hen remained there through the summer, fall, and winter of 2011. During the summer/fall in drought years GuSG, particularly hens with chicks, in peripheral areas of occupied habitat were noted using intact forbs and grasses under mature Gambel oak as the forbs and grasses under open sagebrush stands were desiccated. These findings suggest that mature savannah Gambel oak may provide a buffer against drought, particularly for areas that are already considered arid environments.

Gunnison sage-grouse transplant's nest.

Average distances moved from release sites to nest sites used by female transplants was 5.0 km (Table 8). The smallest movement distance from a release to nest site, 0.1 km, was by a hen released near Luster Basin lek in the heart of occupied habitat. The two largest movement, 14.6 km, was by a hen that was released on Payne Mesa but was found nesting on the mesa to the north of DS road in a detached occupied area referred to as the Bunkers. This nest site, at 2,026 m elevation, was one of the lowest documented during the study.

Winter Habitat

The lower elevation benches north of Piñon Mesa (Figure 1, reflected by fingers running north off the central occupied polygon), such as Payne Mesa, have generally been considered winter range and telemetry points from this study partially confirmed this assumption. The resident GuSG population on Piñon Mesa is seasonally migratory depending on the severity of the winter. The high elevation summer range occupied by the majority of the grouse can receive enough snow to completely cover the sagebrush. In winters with deep snow accumulations, grouse typically move north short distances (1.6–4.8 km) to lower elevation benches and mesas. In winters with more moderate snow pack (0.5–1.0 m), grouse appear to remain on the top of Piñon Mesa where they use taller sagebrush stands within the same habitat occupied during the summer/fall season. Telemetry work also revealed previously undocumented winter range use of the "Reservation/Bunkers" area, Timber Ridge, and Dominguez Canyon/Smith Point flats on the Uncompahgre Plateau. Timber Ridge was formerly mapped as potential habitat and Dominguez Canyon/Smith Point as unknown status of use (Figure 1). Timber Ridge winter range is approximately 11 km northeast and the 'Reservation' area approximately 18 km from heavily occupied breeding and summer habitat on Pinon Mesa. The upper Dominguez Canyon area on the Uncompahgre Plateau is approximately 27 km from Luster Basin which is within movement distances noted elsewhere for other Gunnison sage-grouse populations (Apa 2004). If used, habitat connections such as Snyder Flats would reduce single distance movements needed to reach this area from Piñon Mesa. Movements to the upper Dominguez Canyon area using such a route would extend to approximately 32 km with a 3 km flight across the Unaweep Canyon. Winter access to this area for monitoring purposes is difficult so locations during that season were mostly collected from the air. However, during the winter of 2013–2014 three unmarked birds were observed, from the ground, flushing with a hen transplanted to the Luster Basin lek release site in spring of 2013.

In years of moderate snow fall, birds appear to winter on top of Piñon Mesa with some individuals moving to the aforementioned outlier locations. If snow levels

become deep enough to cover sagebrush completely on Piñon Mesa the grouse remaining on top will shift down to lower areas but this occurred infrequently (i.e., 2011) during the winters of 2010 to 2015. It is unclear why some birds move off Piñon Mesa early in the winter while others stay throughout the season baring deep snow accumulations. Grouse use of sagebrush mixed with Gambel oak during the winter months was commonly observed, particularly on middle elevation benches. On several occasions, marked birds were accidentally flushed from snow caves as well.

Vegetation Measurements

Forty line transects were measured on Piñon Mesa proper, Payne Mesa, Timber Ridge, the Reservation, and upper Dominguez Canyon to capture vegetation measurements for locations used by transplanted and incidental resident grouse for the Piñon Mesa population (Appendix Table A3). Species composition and cover averaged across these geographic areas show interesting differences and illustrate that the area can be quite heterogeneous due to its notable elevational gradient and associated moisture levels (Table 7). The majority of transects fall within guidelines recommended by the GuSG Rangewide Steering Committee (Appendix Table A1; GUSG RSC 2007). In some cases, measurements outside of RSC guidelines may reflect areas of use on Pinon Mesa that could be incorporated into the dataset referenced to develop the guidelines so that they better reflect the diverse spectrum of sagebrush habitat used by grouse across the satellite populations.

Table 7. Vegetation characteristics for transects measured during the summer of 2012 at radiotelemetry and incidental locations for Gunnison sage-grouse collected during breeding, summer–fall, and winter across the Piñon Mesa population (*n* = 40). Average and range measures of percent cover (%) for sagebrush, non-sagebrush, total shrubs, grasses, and forbs as well as heights (inches) of sagebrush, grass and forbs are presented.

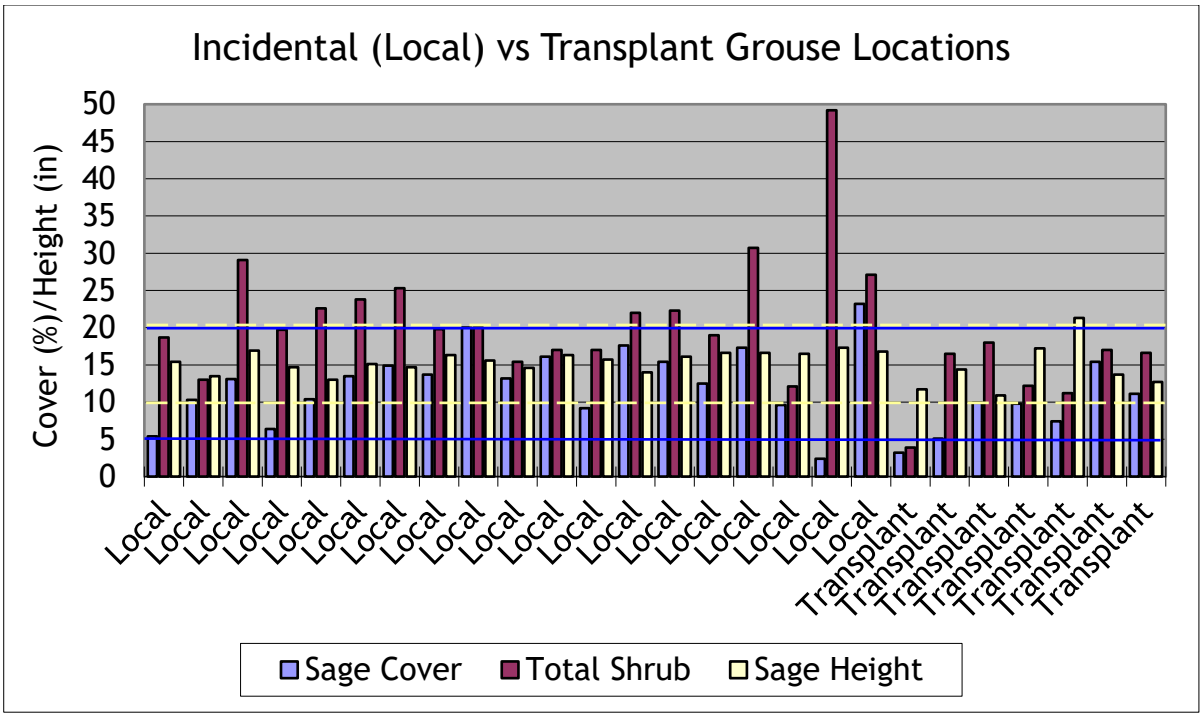
	Breeding		Summer–Fall		Winter	
Vegetation Variable	$\bar{X}$	**Range**	$\bar{X}$	**Range**	$\bar{X}$	**Range**
Sagebrush Cover (%)	16.4	2.9–23.3	12.6	2.4–30.5	15.0	4.7–33.7
Non-Sage Cover (%)	8.9	9.2–19.3	7.7	1.5–18.7	8.9	0.4–8.9
Total Shrub Cover (%)	25.3	12.1–42.6	20.3	3.9–49.2	23.9	5.1–42.6
Sagebrush Height (in)	17.8	10.4–23.2	15.5	10.9–21.3	17.0	10.6–29.6
Grass Cover (%)	22.1	10.3–37.5	18.1	4.8–41.0	11.0	4.4–20.1
Forb Cover (%)	18.6	0.8–42.2	29.7	0.0–60.7	4.8	0.3–21.6
Grass Height (in)	6.3	5.2–7.1	4.8	2.4–8.2	4.6	2.6–7.1
Forb Height (in)	2.4	0.5–5.5	3.2	0.0–5.9	1.4	0.0–3.0

When transects for marked transplant birds were compared to those based on locations for incidental unmarked birds differences between the two tended to be within a couple percentages or inches of each other (Table 8, Figure 4) and both met RSC guidelines (Table A1). In general, measurements in these areas fell within GuSG RSC guidelines (Table A1). Two transects had slightly low sage cover and one had very high total shrub cover (Table 8, Figure 4). On portions of Piñon Mesa used by GuSG, non-sagebrush cover, including snowberry (SYRO) and Gambel oak (QUGA), can be the dominant shrub cover. Grass cover was lower than RSC guidelines for half of transects during breeding season but nearly all met them for the Summer/Fall season. Conversely, forb cover nearly always met guidelines and in some cases were 10–20 % higher.

Table 8. Vegetation characteristics for transects conducted on Piñon Mesa in 2012 at 7 transplanted (Trans) and 25 incidental (resident) locations collected for Gunnison sage-grouse during the summer–fall, 2010–2012. Average percent cover (%) for sagebrush, non-sagebrush, total shrubs, grasses, and forbs as well as heights (inches) of sagebrush, grass and forbs are presented. All sites met mesic conditions as noted in the GuSG RSC (2005).

	Summer–Fall		
Vegetation Variable	**Transplant**	Resident	**RSC**
Sagebrush Cover (%)	8.8	12.9	5–20
Non-Sage Cover (%)		9.4	5–15
Total Shrub Cover (%)	13.6	22.3	10–35
Sagebrush Height (in)	14.6	15.6	10–20
Grass Cover (%)	13.2	21.4	10–35
Forb Cover (%)	21.3	27.8	15–35
Grass Height (in)	3.7	5.2	4–6
Forb Height (in)	2.8	3.7	2–6

A)



B)

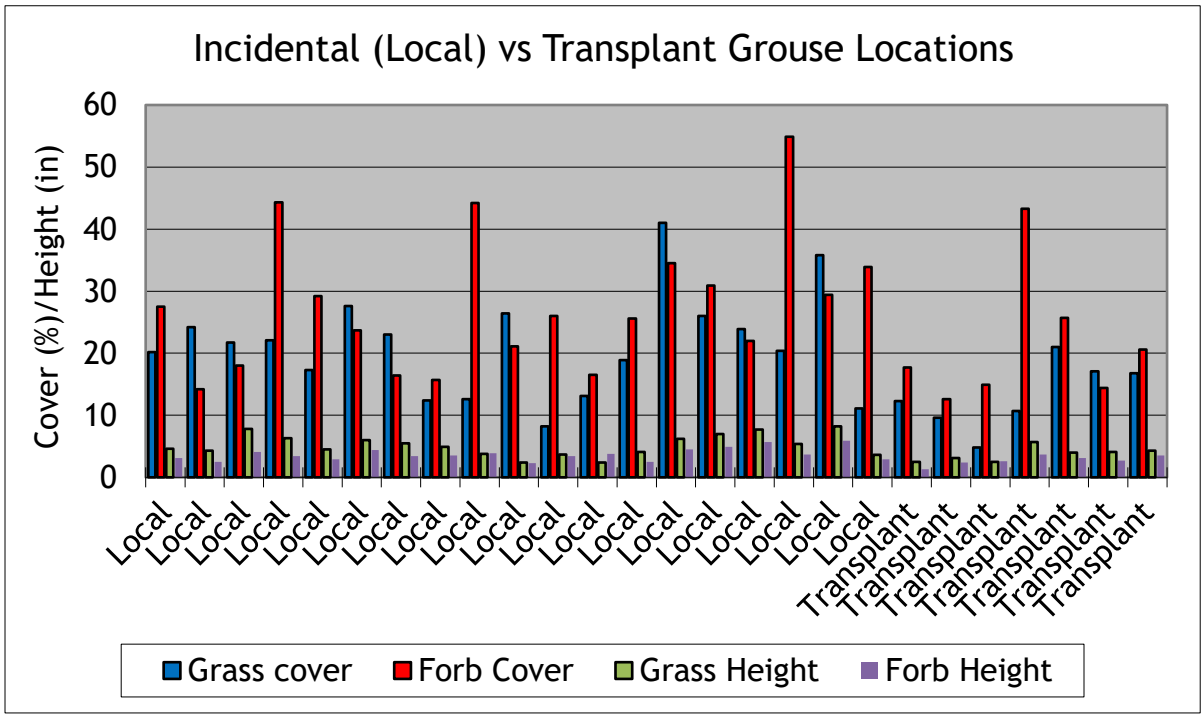


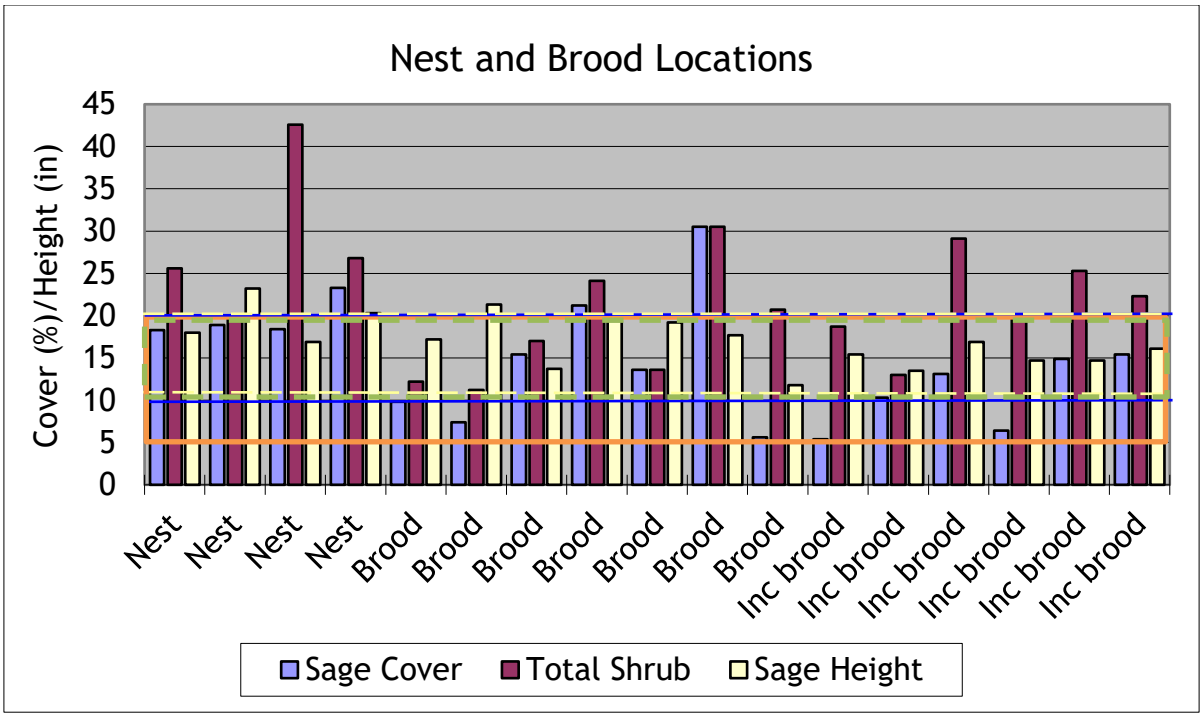
Figure 7. Average percent cover (%) and height (inches) for A) sagebrush and total shrub, and B) grasses and forbs collected in 2012 at locations for 19 incidental (resident) and 7 transplanted Gunnison sage-grouse using summer–fall habitat on Piñon Mesa from 2010–2012. All sites met mesic conditions as noted in the GuSG RSC (2005). Sage cover and height guidelines from the GuSG RSC (2005) are indicated by solid blue and dashed yellow lines respectively.

Four nest and 13 brood sites were included in these measurements and correspond well with mesic GUSG RSC guidelines (Table 9, Figure 8) despite six of the transects being located in the more arid moisture zone on Timber Ridge. Most noteworthy departures from the GUSG RSC guidelines (2005) were at winter use sites with both sagebrush cover and heights below or at the bottom limit of recommended measures (Table 10, Figure 9). These winter measurements collected from winter habitat with arid conditions correspond more closely with Connelly et al. (2003). Vegetation data used to construct winter habitat guidelines in the GuSG RSC (2005) was limited in its availability of locations to reference and may better reflect satellite populations through the addition of data collected during this study and others as they become available.

Table 9. Vegetation characteristics for transects conducted at 4 nest and 13 brood locations for marked and incidental Gunnison sage-grouse on Piñon Mesa in 2012 compared to those from the Gunnison sage-grouse rangewide conservation plan (GuSG RSC 2005) for mesic breeding and summer/fall habitat. Average percent cover (%) for sagebrush, non-sagebrush, total shrubs, grasses, and forbs as well as heights (inches) of sagebrush, grass and forbs are presented.

	Breeding		Summer-Fall	
Vegetation Variable	**2012**	**RSC**	**2012**	**RSC**
Sagebrush Cover (%)	19.7	10-20	13.0	5-20
Non-Sage Cover (%)	9.0	5-15	6.8	5-15
Total Shrub Cover (%)	28.7	15-35	19.8	10-35
Sagebrush Height (in)	19.6	12-20	16.3	10-20
Grass Cover (%)	20.5	20-40	18.9	10-35
Forb Cover (%)	19.6	20-40	23.7	15-35
Grass Height (in)	6.6	4-6	5.2	4-6
Forb Height (in)	2.5	2-6	2.8	2-6

A)



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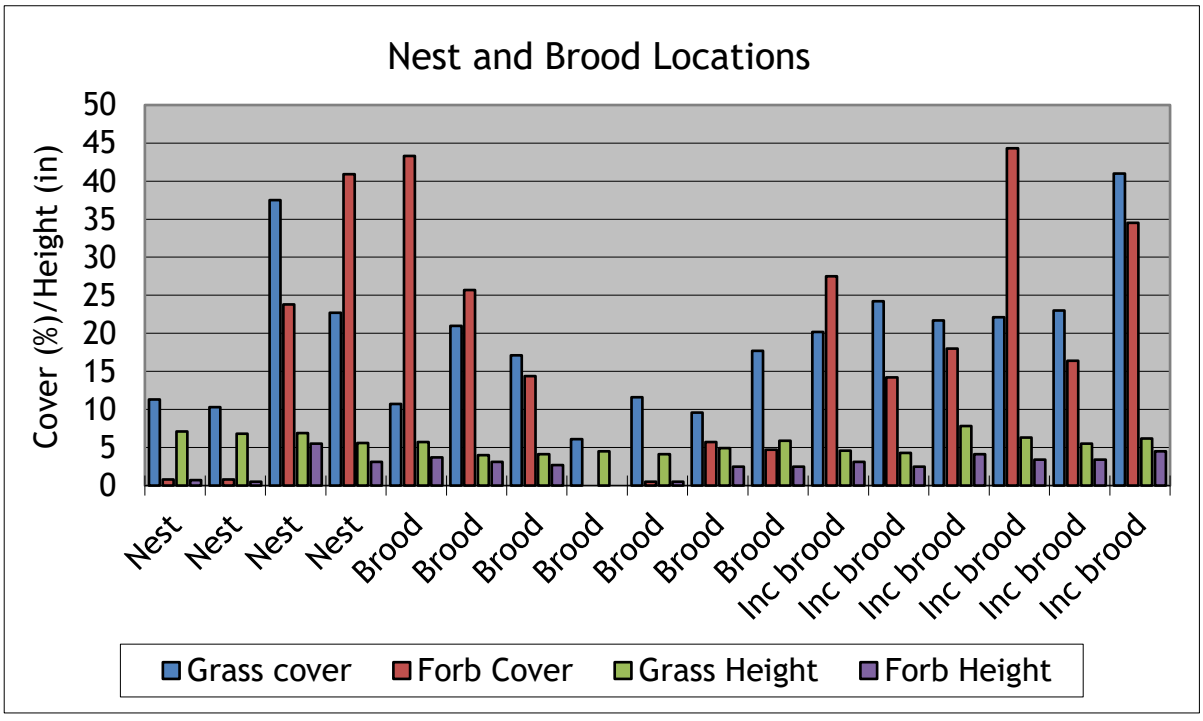


Figure 8. Average percent cover (%) and height (inches) by transect type for A) sagebrush and total shrub, and B) grasses and forbs collected at nests and brood locations during breeding and summer–fall on Piñon Mesa in 2012. Incidental broods belonging to resident unmarked birds are shown as Inc brood. Sage cover and height guidelines from the GuSG RSC (2005) are represented by solid blue and dashed yellow lines respectively for breeding, and solid orange and dashed green for summer/fall.

Table 10. Vegetation characteristics for transects conducted in 2012 at 9 locations for Gunnison sage-grouse within winter habitat from 2010–2012 compared with the Gunnison sage-grouse rangewide conservation plan habitat guidelines (GuSG RSC 2005) and Connelly (2003). Average percent sagebrush cover, non-sagebrush cover, total shrub cover, grass cover, and forb cover as well as heights in inches of sagebrush, grass and forbs.

Vegetation Variable	Winter				
	This study		RSC (2005)	Connelly et al. (2003)	
	$\bar{X}$	Range	Arid	Arid	Mesic
Sagebrush Cover (%)	12.9	4.7–22.3	30–40	10–30	10–30
Sagebrush Height (in)	15.8	5.1–42.6	16–22	10–14	10–14

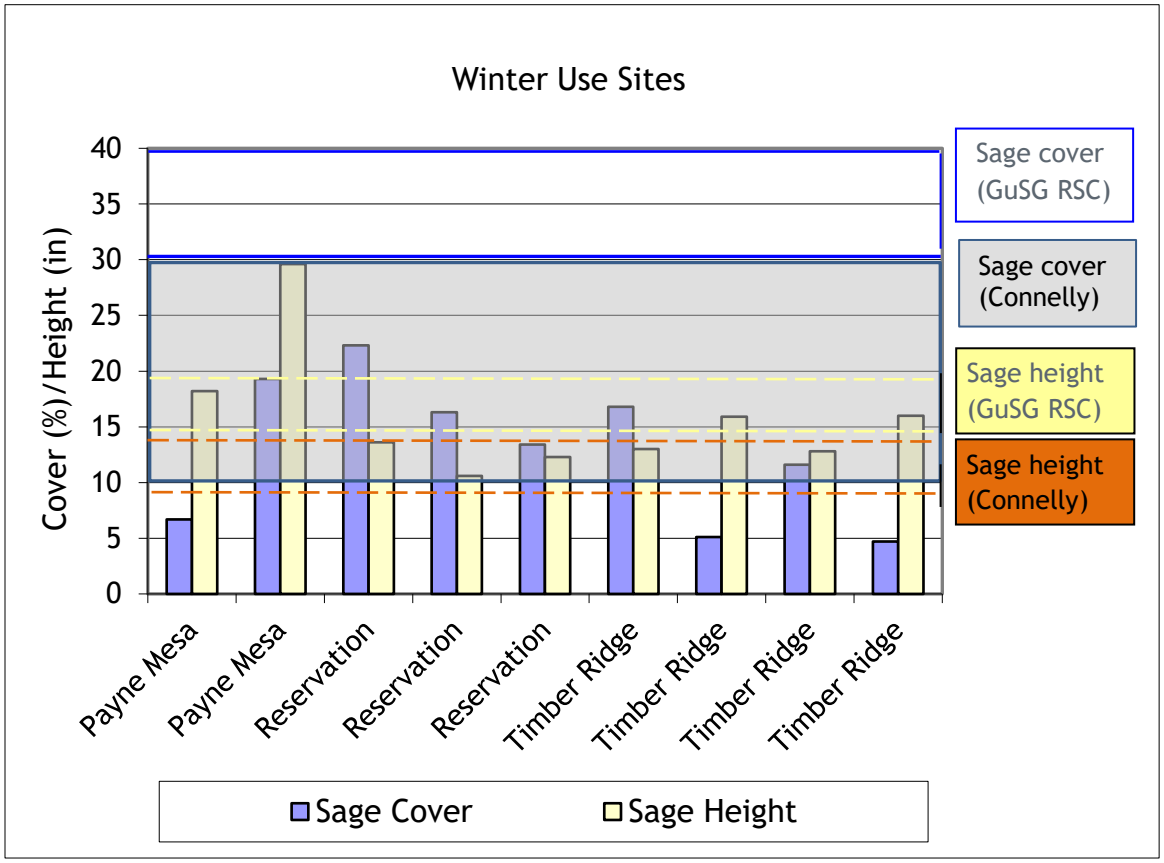


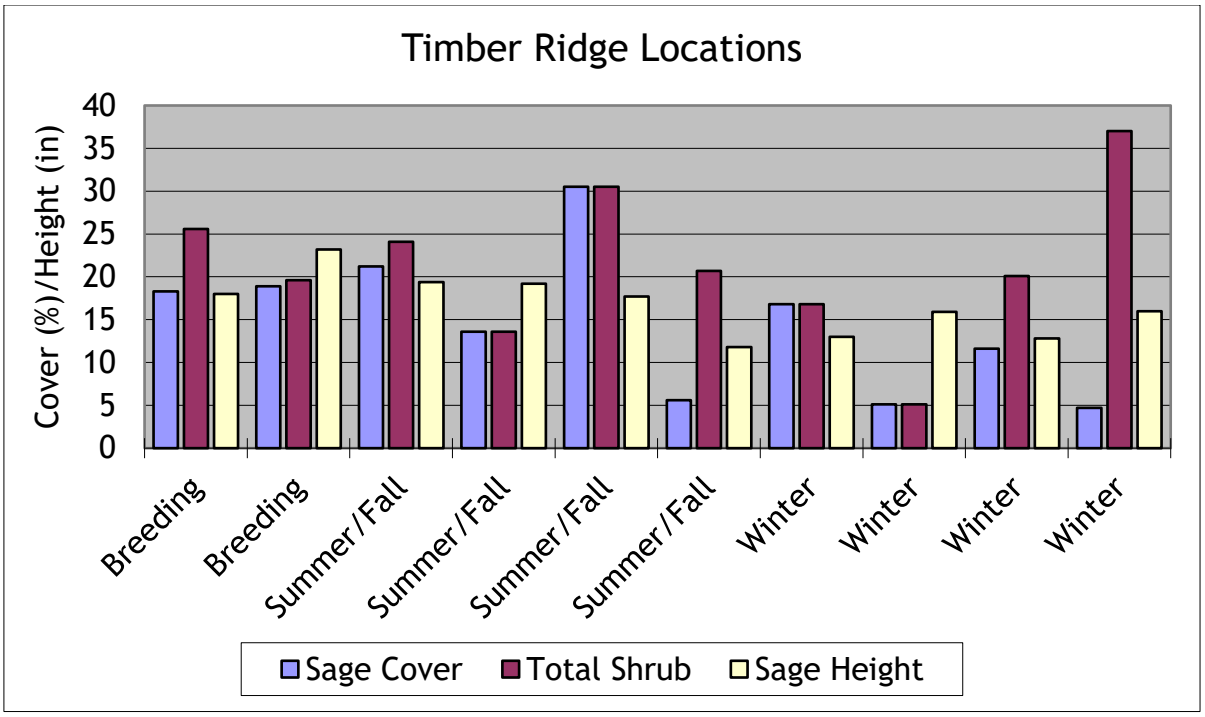
Figure 9. Average sagebrush cover (%) and height (inches) collected in 2012 at 9 locations for Gunnison sage-grouse located during winter, 2010–2012 on Piñon Mesa. Sage cover and height guidelines are provided from the GuSG RSC (2005) and Connelly et al. 2003 for reference with the later developed for Greater sage-grouse.

Because the Timber Ridge and Dominguez Canyon areas have not had the vegetation community measured previously we broke these two areas out for closer examination. Sage cover and height for 10 transects on Timber Ridge generally appears suitable during Breeding and Summer/Fall. Most transects for this area fell below those recommended when being compared to Winter GuSG RSC (2005) guidelines (Table 11, Figure 10). Bitterbrush was the dominant non-sagebrush cover on Timber Ridge with patches of Gambel oak also being common. While average grass cover was 12.88 percent on Timber Ridge, average forb cover amounted to only 2.22 percent (Table 11, Figure 10). Nine grass species were found in 100 Daubinmire frames on Timber Ridge (Table A3) with crested wheat (AGCR) the most dominant species followed by Western wheatgrass (PASM), and Junegrass (KOMA). Eleven forb species were identified in those same 100 microplots. Snakeweed (GUSA2), long-leaf phlox (PHLO2), showy golden aster (HEVI4), and rock goldenrod (PEPU9) were most common in that order though all averaged less than 1 percent cover.

Table 11. Vegetation characteristics for 10 transects conducted on Timber Ridge in 2012 based on locations of Gunnison sage-grouse collected during breeding (2), summer–fall (4), and winter (4) from 2010–2012. Guidelines from the Gunnison sage-grouse rangewide conservation plan (GuSG RSC 2005) for arid breeding, summer/fall, and winter habitat are provided for comparison. Average percent cover (%) for sagebrush, non-sagebrush, total shrubs, grasses, and forbs as well as heights (inches) of sagebrush, grass and forbs are presented.

	Breeding		Summer–Fall		Winter	
Vegetation Variable	**2012**	**Arid**	**2012**	**Arid**	**2012**	**Arid**
Sagebrush Cover (%)	18.6	15–25	17.7	5–15	9.6	30–40
Non-Sage Cover (%)	4.0	5–15	4.5	5–15	10.2	-
Total Shrub Cover (%)	22.6	20–40	22.2	10–30	19.8	-
Sagebrush Height (in)	20.6	10–20	17.0	8–16	14.4	16–22
Grass Cover (%)	10.8	10–30	11.3	10–25	-	-
Forb Cover (%)	0.8	5–15	2.7	5–15	-	-
Grass Height (in)	7.0	4–6	4.9	4–6	-	-
Forb Height (in)	0.6	2–4	1.4	1–4	-	-

A)



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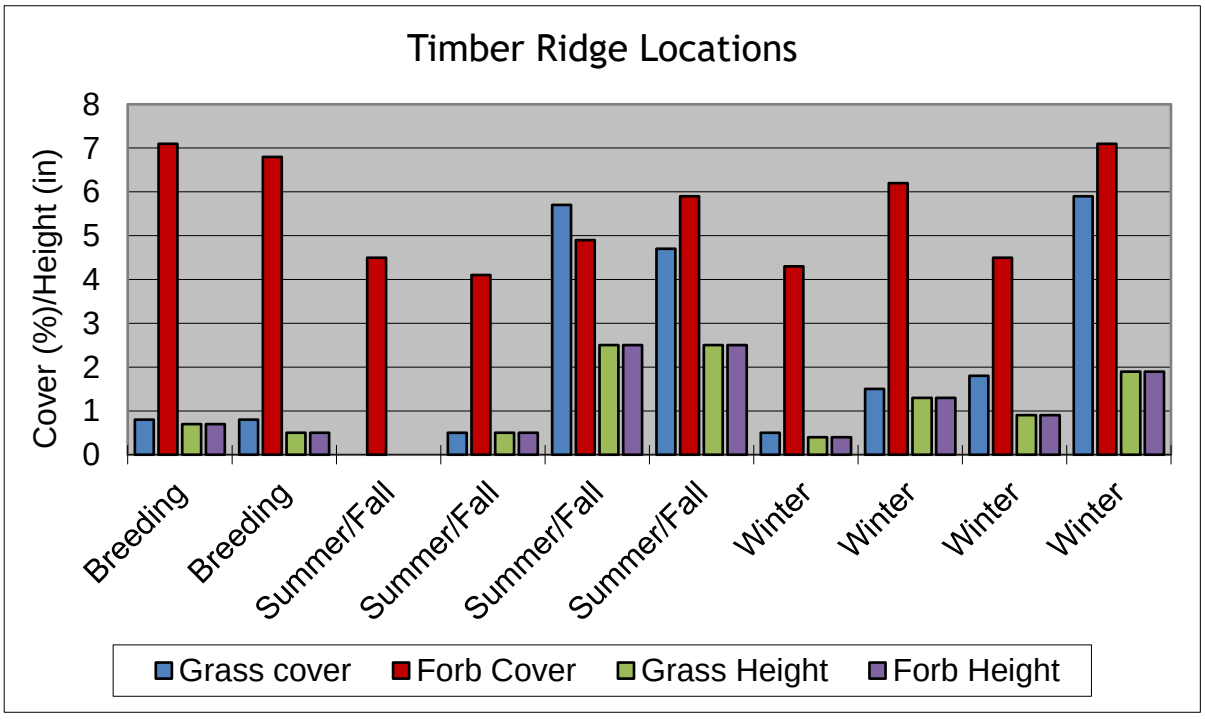


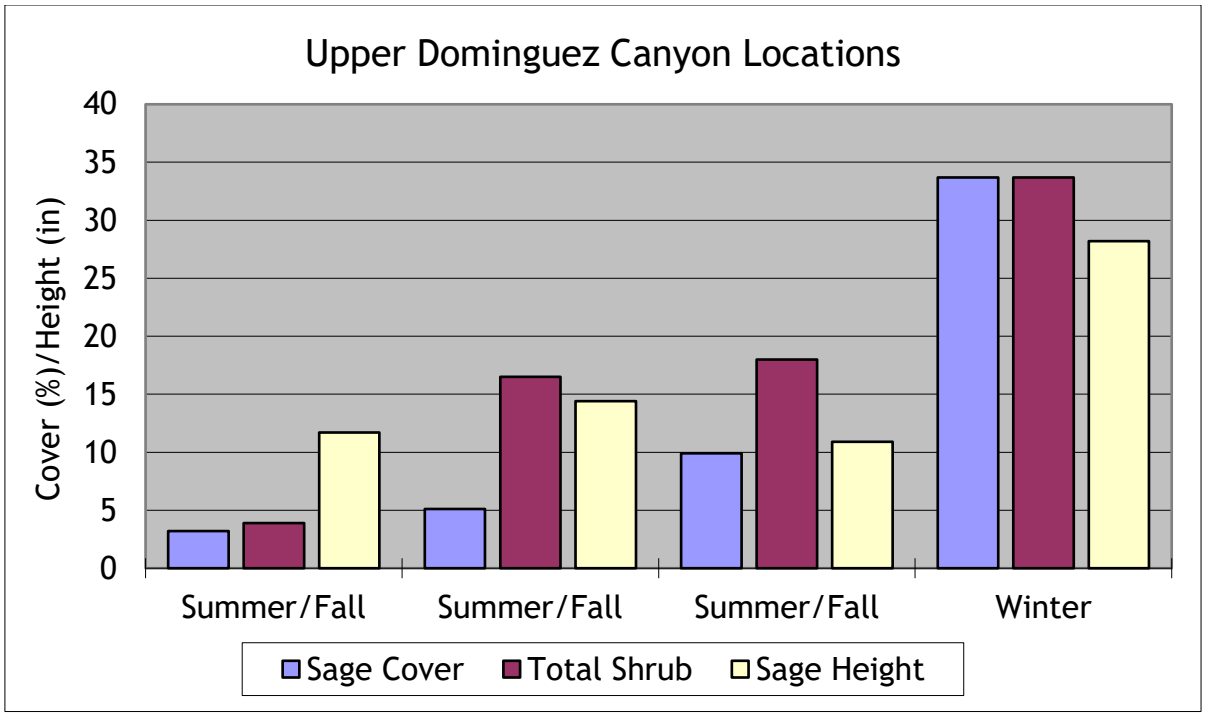
Figure 10. Average percent cover (%) and height (inches) for A) sagebrush and total shrub, and B) grasses and forbs collected in 2012 at 10 locations for Gunnison sage-grouse using breeding (2), summer–fall (4), and winter (4) habitat on Timber Ridge from 2010–2012.

Upper Dominguez Canyon vegetation transects collected for transplant bird locations were located on the edge of a burn, and are not representative of sage cover results in this area. Because these transects do not reflect the majority of the habitat surrounding these points, a random transect was sampled to capture sage cover and heights that are more typical of the area. Sage and total shrub cover for the three bird locations where transects were run were lower than RSC guidelines for Breeding and Summer/Fall habitat (Table 12, Figure 11). Measurements at the random transect were close to RSC guidelines (GuSG RSC 2005). Grass and forb cover, and heights across all sites generally met guidelines (Table 12, Figure 11). Seven grass species were found in 40 Daubinmire frames by upper Dominguez Canyon (Table A3). A Poa species (POA) was the most dominant grass followed by Western wheat (PASM) and Junegrass (KOMA) across all four transects. Twenty-three forb species were identified with ballhead sandwort (ARCO5) and milkvetch (ASTRA) occurring the most often across the three transects at locations for marked birds and lupine (LUPIN) at the random transect.

Table 12. Vegetation characteristics for 10 transects conducted on Upper Dominguez Canyon in 2012 based on locations of Gunnison sage-grouse collected during summer–fall (3), and winter (1) from 2010–2012. Guidelines from the Gunnison sage-grouse rangewide conservation plan (GuSG RSC 2005) for arid breeding, summer/fall, and winter habitat are provided for comparison. Average percent cover (%) for sagebrush, non-sagebrush, total shrubs, grasses, and forbs as well as heights (inches) of sagebrush, grass and forbs are presented for the summer–fall data. Data for 1 winter location was originally measured at a random location used by grouse in subsequent years.

	Summer–Fall		Winter	
Vegetation Variable	**2012**	**RSC**	**2012**	**RSC**
Sagebrush Cover (%)	6.1	5–15	33.7	30–40
Non-Sage Cover (%)	6.7	5–15		-
Total Shrub Cover (%)	12.8	10–30		-
Sagebrush Height (in)	12.3	8–16	28.2	16–22
Grass Cover (%)	8.9	10–25	-	-
Forb Cover (%)	16.5	5–15	-	-
Grass Height (in)	2.7	4–6	-	-
Forb Height (in)	2.1	1–4	-	-

A)



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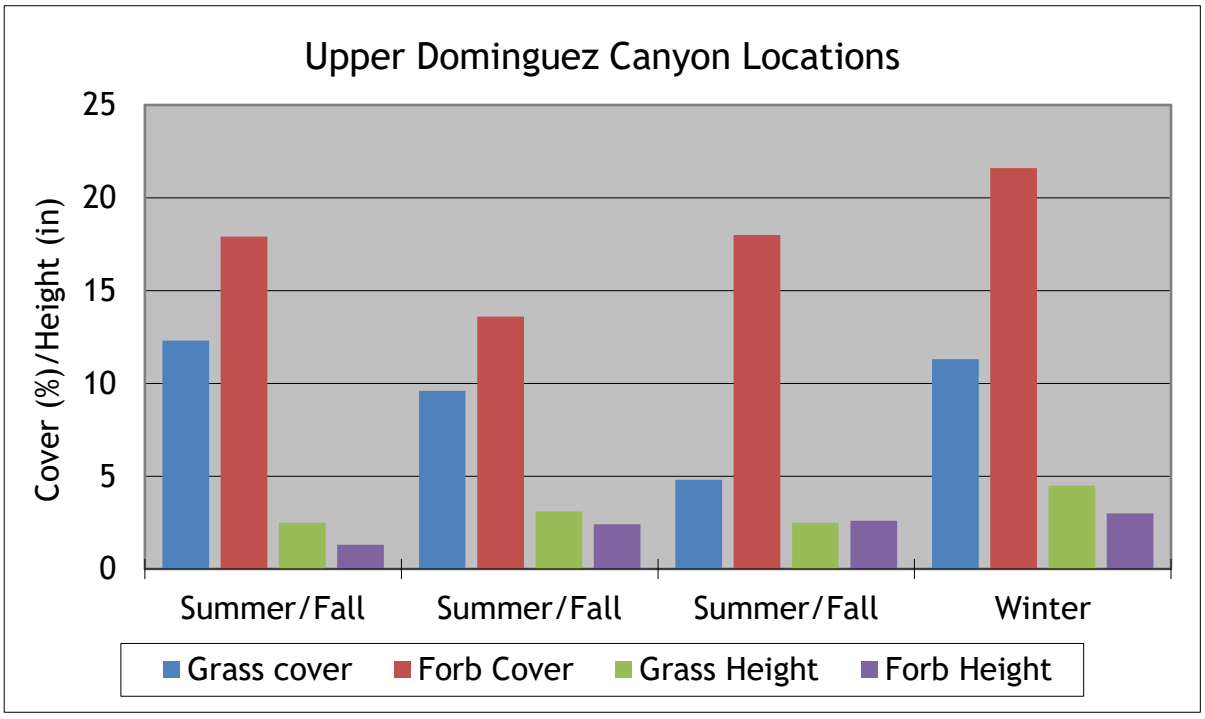

Figure 11. Average percent cover (%) and height (inches) for A) sagebrush and total shrub, and B) grasses and forbs collected in 2012 at 4 locations for Gunnison sage-grouse using summer–fall (3), and winter (1) habitat on Upper Dominguez Canyon from 2010–2012. Data for 1 winter location was originally measured at a random location used by grouse in subsequent years.

Seasonal Use Mapping

After three years of transplant efforts to Pinon Mesa had been completed (2010–2012), species distribution models created from MaxEnt outputs using transplant bird locations were run in simultaneous autoregression (SAR) models by Carlson (2013) as part of a graduate degree. Carlson's models identified elevation and distance from woodland as the most influential predictors regardless of season. Grouse distributions corresponded strongly with elevation and herbaceous cover during the breeding (Figure 12) and summer/autumn seasons. Winter habitat use models were influenced by terrain smoothness, mixed shrub cover, and lower perennial grass understory. Carlson (2013) notes that "There were critical differences between SAR models and non-spatial generalized linear models, suggesting that accounting for spatial structure in the population is important for accurate modeling of sage-grouse." While the Gunnison Basin is generally thought of as high elevation GuSG habitat (range 7500–9500 ft.), much of the occupied habitat on Piñon Mesa is situated at higher elevations situated at the upper end of the available elevation range there (range 5700–9800 ft.). Consequently, grouse may favor different sagebrush heights at different elevations due to increased snow depths. These preferences are not explicitly accounted for by these models or GuSG RSC (2005) winter guidelines as data for snow depth was not available for Pinon Mesa. A thorough description of Pinon Mesa seasonal mapping methods and results can be found in Carlson (2013).

Discussion and Recommendations

Radiotracking of birds transplanted into the Piñon Mesa population from 2010 – 2013 provided year round location data on seasonal habitat types used by grouse. Occupied breeding, summer/fall brood-rearing, and winter range have been expanded significantly from previously classified potential habitat based on telemetry results. Although marked grouse were transplanted from the Gunnison Basin to Piñon Mesa, our radiotracking work revealed that transplanted grouse were regularly accompanied by unmarked resident grouse. Observations of incidental unmarked grouse in the proximity of birds being radiotracked were made at a minimum of 17% of all locations collected (338 of 1993 locations). In addition, 175 observations of unmarked resident sage-grouse incidentally encountered were made independent of marked transplant birds being tracked while technicians were in the field. Home range analysis for locations of these birds was similar to that developed for transplant birds with the degree of overlap emphasizing how widespread transplant and resident birds were documented together (Figure 6). Home range estimates for transplants also largely overlap areas used by birds marked in 1995 and 2002 (Figure 5). Consequently, it is

our belief that the data we collected for the transplanted (marked) individuals are indicative of movements and habitat use by resident grouse on Piñon Mesa.

Radiotracking work on grouse that previously occurred on Piñon Mesa by Woods and Braun (1995) and Wenger (2002) focused on resident birds captured and marked in the area. Although direct comparisons between these studies and recent transplant efforts must be made with caution, in part due to the variation in capture site versus release site, some interesting similarities are worth noting. The highest elevations of Piñon Mesa continue to be used heavily by transplant and resident grouse across all of these studies. However, some changes have been noted. In 1995, birds were using the Fish Park area as well as Payne Mesa. Soon after the Woods and Braun study confirmed use by GuSG of the lower elevation Fish Park the area burned, effectively removing large amounts of the sagebrush habitat. A second burn moved through Fish Park in 2002 that continued to inhibit regrowth of sagebrush in the previously burned area while also removing addition acres of sagebrush. While it is not surprising that almost no transplant locations were found in the Fish Park, one marked transplant did briefly investigate the area. Birds in 2002 were also relying on Payne Mesa and one record of a hen originally marked there made a brief movement over to Timber Ridge in May of that year. Encroaching pinyon-juniper was roller chopped on Timber Ridge in August of 2002. Transplant birds were regularly noted there by 2012, often in the company of unmarked birds, suggesting that habitat suitability had improved in the short time span of only 10 years.

Survival of female transplant birds to 12 months (0.52 ± 0.08) in this study are remarkably similar to estimates collected by Apa (2004) from resident grouse pooled across several satellite populations (0.52 ± 0.08). This trend was similar for males as well (0.46 ± 0.12 vs. 0.51 ± 0.09). Survival estimates collected from the Gunnison Basin from larger samples showed more disparity between females and males with 0.71 ± 0.11 and 0.41 ± 0.12 respectively (Apa 2004). Survival pooled across all transplant birds at one year varied slightly by season with spring transplants having slightly higher survival than birds released in the fall (Table 5, Figure 4). These findings are counter intuitive as the breeding season is generally thought to expose birds more to possible mortality events such as predation. Interactions with sex, age, and year are likely to have an effect on survival but sample sizes were too small to perform statistical analysis to that extent in our study. Davis et al. (2015) examined survival rates for the Gunnison Basin and Miramonte satellite population from 2005–2010 and found them to be constant across populations, ages, and years (females: 0.61 ± 0.06, males: 0.39 ± 0.08). Sex and season were different in our study with lower survival in males, particularly during the lekking season. In general, survival estimates for birds transplanted to Piñon Mesa fell within the range of findings from other grouse studies in Colorado and elsewhere (Hausleitner 2003, Zablan et al. 2003,

Apa 2004, Davis et al. 2015) where female survival of resident birds was generally higher than males. Musil et al. (1993) found transplanted greater sage-grouse made the greatest movements within the first three to six weeks after release with the lowest survival in the first three weeks. Four transplant GuSG made long distance movements (range 31–50 km) south onto the Uncompahgre Plateau where two ended as mortalities and two returned to Piñon Mesa. Of these birds, one individual left less than six weeks after being transplanted while another made a long distance movement a year later. Transplant individuals that make these long movements, possibly in an effort to return to their original home ranges, do appear to be at high risk of predation.

Survival estimates by radio type for males fitted with necklace versus backpack mounted transmitters were hampered by small sample sizes as well. Estimates suggest that males fitted with necklace transmitters may have lower survival than rump mounted transmitters but confidence intervals largely overlapped (Table 5, Figure 4). However, anecdotal observations made during the breeding season when males were lekking suggest that necklace radios interfere with male reproductive behavior. Radio collars appear to interfere with strutting both behaviorally and physically based on these observations. Adult males with necklace transmitters were occasionally observed trying to strut but more often were seen on the periphery of the lek not strutting and often being chased by dominant males. While we cannot say if this demotion (at best) or complete inhibition (at worst) is the result of the bird being a new transplant, from being fitted with a necklace transmitter, or both, we do believe an effect is occurring. Rump mounted radios may also have an effect behaviorally or on survival as they could be interfering with the wing action used during strutting. In contrast, we have observed transplanted males on several occasions that have dropped their radios but are still marked with leg bands exhibiting dominant strutting behavior on the leks. While an improved status on the lek for birds who have shed their radios over birds still carrying them may be the result of a given individual simply becoming established in its new territory, the lack of a transmitter seems likely to influence the bird's status on the lek as well. Consequently, if male GuSG are to be transplanted with the goal of improving genetic diversity and boosting population numbers we suggest that they not be fitted with a transmitter (regardless of design) unless necessary for survival estimation so that attempts to reproduce are not inhibited. A possible alternative to transmitters that could be used to monitor grouse would be a radio frequency identification (RFID) device such as passive integrated transponders (PIT tags) affix to a leg band that are detected by antennas placed on and around a lek site. PIT tags are passive and consequently have the ability to last the lifetime of the bird and can be monitored for

continuously. Such a system would provide information not only about survival but also lek attendance.

Home range analysis suggests that transplanted GuSG tended to settle within a couple kilometers from where they were released. These findings have important implications in helping determine where future transplant birds should be released. Findings for resident birds tracked in 1995 (n = 5 males) and 2002 (n = 3 males, 6 females) with enough locations to develop home ranges polygons with 95% probability of use highly overlapped those of transplanted birds (Figure 5). These findings suggest that transplant birds generally adopted areas used by resident birds. Grouse tracked in 1995 with home ranges in the Fish Park area were not overlapped by those marked in later studies which are likely the result of that area burning twice (1999 Wrigley complex and 2006 Spring fire) after that initial tracking effort. More extensive use of low elevation habitat used by transplant birds, sometimes in the company of unmarked resident birds, was much more extensive. Many of these areas fell in what is currently mapped as potential or unknown habitat. Treatments such as pinyon-juniper removal conducted a decade or more ago now fall within suitable habitat guidelines as noted by monitoring (Neubaum 2010).

In general, sage-grouse made small movements (<5 km) away from release sites and between lekking and nesting sites, remaining in the same area throughout the year. However, some individuals did make notable movements (e.g., Dominguez Canyon to Timber Ridge, 30.7 km). While a few transplant birds undertook long movements soon after transplant, possibly in an effort to return to their origins of capture, most stayed close to the area of release. In addition to home range results already noted, these findings also suggest that areas of release should be considered carefully by those transplanting grouse, with locations containing a mix of good habitat and resident birds that may help transplants transition. Transplant individuals in our study showed the ability to use several leks in a season. These findings suggest that if lek competition becomes too high at any given lek, based on ratios of strutting males to hens and physical space on the lek arena, transplants are willing to strut at other locations they have learned about. Hen movements, in relation to lekking and nesting, also tended to be oriented around areas where they were released but some individuals did relocate to habitat that is farther away for unknown reasons. A comprehensive evaluation of the habitat where grouse were captured in comparison to that where they were released may be beneficial. For example, a hen that used shorter sagebrush in the Gunnison Basin may look for a similar ‘search image’ when deciding where to nest in the new area she has been transplanted.

Transplanted male sage-grouse of all ages were noted strutting on leks which they were released by in a previous year. One bird released at a smaller lek on Timber

Ridge (< 5 birds) in the fall, when strutting would not have been occurring, made the longest movement to a different strutting ground. Conversely, birds released by the largest lek site on Piñon Mesa in the fall were found strutting there during subsequent years. These findings may suggest that if retention of transplant birds near release sites with smaller leks is desired, birds may need to be released in the spring when strutting activity is apparent as presence of other grouse alone may not hold them in that area during other times of the year. Transplant activities may have aided in the expansion of breeding range of the Piñon Mesa population onto Timber Ridge or, at the least, telemetry work confirmed the behavior occurring there. In addition, the dominant bird at the Timber Ridge lek was a transplant male identified by leg bands. Musil et al. (1993) documented transplanted greater sage-grouse establishing new leks which suggests that this may be the case in our study but unmarked hens were noted at the lek leading to uncertainty of such an assertion.

In small populations, the detectability of Greater sage-grouse males attending leks has been shown to be lower than for larger populations with males regularly moving between multiple leks (Shyvers et al. 2018; Brett Walker, Colorado Parks and Wildlife, pers. comm., October 2018). One male released near 2V Lek was later confirmed lekking on Payne Mesa and Luster Basin. A hen released near the corrals off of MS road on top of Piñon Mesa was later documented attending the lek on Timber Ridge. Numbers of birds strutting on several known leks after transplant birds were released were the highest noted since 2000. Strutting at historic and new lekking locations was also confirmed between 2010–2015 but it is unclear if this was the result of transplant birds as markings could not always be discerned or from increased efforts to count grouse. Similar increases in high male counts at leks have been noted for greater sage-grouse after translocations of birds were made in Utah (Baxter et al. 2008). In our study, five transplanted birds were noted attending more than one lek. While two males moved the short distance between Luster Basin and Tipping Ridge leks, other individuals used leks that are considerable distances from each other both within and between years (e.g. Timber Ridge to Luster Basin = 12 km).

The discovery of transplanted grouse using the sage flats south of upper Big Dominguez Canyon on the Uncompahgre Plateau is noteworthy. This area contained a historic lek with grouse last documented strutting there in 1960. That year, portions of the sagebrush in the area were treated with the herbicide 2,4-D. Pellet transects conducted as part of a graduate study pre- and post-treatment showed notable declines of sage-grouse (Anderson 1960). Subsequent efforts to count this lek site since that time have never observed strutting sage-grouse.

In addition to telemetry findings related to lekking, transplanted birds were confirmed breeding with resident GuSG on Piñon Mesa through genetic analysis.

Zimmerman et al. (2019) used feathers collected on leks to show individuals with distinct genetic markers attributable to both transplant and resident grouse. These findings confirm that transplanted grouse successfully bred with resident grouse resulting in viable offspring who attended leks themselves in subsequent years. This interbreeding suggests that transplanting grouse has the potential to address problems of genetic isolation and boost resident reproduction.

Nest sites used by transplanted GuSG hens were located an average of 5 km from release sites by leks. Apa (2004) found 85% of nests to be within 6.5 km of the leks when resident GuSG hens were captured. Slightly lower movement distances were used by hens tracked in the Gunnison Basin, which incidentally is the area that accounted for all of the hens transplanted to Piñon Mesa. Habitat and interactions with resident birds are more likely to dictate where transplant birds nest but considering information from the source population may also be beneficial. Interestingly, one nest site at lower elevation in 2014 and 2015 was found to be in the immediate vicinity of a new lek site discovered in 2016. Transplanted hens successfully hatched chicks throughout the 2010–2015 period. Although our study did not examine recruitment closely in an effort to reduce stress to transplanted birds, Davis et al. (2016) suggest that juvenile survival will be important to monitor given the declines noted in their study.

Vegetation measurements collected at nesting locations suggest that brood rearing habitat on Piñon Mesa generally meets RSC guidelines. Rangewide habitat guidelines present wide ranges in cover classes of sagebrush, grasses and forbs. Consequently, most transect data falls within the guidelines with some borderline measurements. Most noteworthy departures from the Rangewide Guidelines (GuSG RSC 2005) on Piñon Mesa were for winter use sites. However, sample sizes were relatively small within this season and transects were conducted only at lower elevation sites. These measures match guidelines proposed by Connelly et al. (2003) for Greater sage-grouse with their data collected from arid environments that may be more comparable to those from our lower elevation transects. Tracking work during the winter after 2012 revealed that grouse are spending much of the winter on top of Piñon Mesa and are pushed down to lower benches only in years when snowfall completely covers sagebrush. Additional transects in this high elevation mapped winter range above 2,682 m (8,800 ft) would better characterize the condition of this seasonal habitat used by grouse on Piñon Mesa. In addition, this data could be used to refine the GuSG RSC (2005) winter guidelines which are based on one study from the Gunnison Basin.

On Timber Ridge, both sagebrush cover and heights are below or at the bottom limit of RSC habitat guidelines (Table 11). Mechanical treatment (roller chopper) was used to remove pinyon-juniper here in 2002. However, some of the lowest

measurements (those falling outside of the guidelines) were at transects that birds used during winter, suggesting that the sagebrush height was suitable given the associated snow accumulations in this area. Timber Ridge is situated at a much lower elevation than Piñon Mesa proper which undoubtedly buffers the amount of snow fall. Less snow fall would allow GuSG to utilize shorter sagebrush during the winter season. Conducting additional vegetation transects in lower elevation areas used by sage-grouse in winter from this satellite population may also help better characterize the habitat conditions for this season (Appendix Table A1; GuSG RSC 2007). Data from Timber Ridge for average forb cover and height was very low suggesting that efforts to establish a healthier forb community could improve Summer/Fall use for hens and their broods. This low forb and grass cover may be the result of soil disturbance caused by the roller chopping treatment or simply reflecting drought conditions noted periodically over the last decade in this area.

Vegetation at Dominguez Canyon is notably variable depending on the area sampled. Sagebrush and total shrub cover in the area where transplant birds were located were lower than recommended for breeding and summer/fall habitat. Data was collected in a grazed area that had previously burned, and may also reflect drought conditions. Despite these conditions grass and forb cover and height tended to meet guidelines unlike measurements from Timber Ridge. A random site on Dominguez measured near locations of transplanted birds met winter guidelines for an arid environment. This area would more likely be classified as mesic but no winter guidelines for mesic habitats are available in which to make comparisons. The variability in shrub height is due in part to the presence of several sagebrush types, including silver, basin, and black sagebrush. Long-term changes from a herbicide treatment in 1959 is also likely to have resulted in the current multi-aged stands of sagebrush(Anderson 1960). Removing younger Gambel oak stands and pinyon-juniper that have encroached into this area may create larger, contiguous stands of sagebrush that are attractive to sage-grouse. However, these improvements may be short-lived as Gambel oak can have a vigorous growth response post-treatment (Kaufmann et al. 2016). Caution should be used when considering removal of older savannah Gambel oak as grouse on Piñon Mesa were noted using sagebrush intermixed with this age class.

Seasonal maps indicate that a number of areas on Piñon Mesa proper could benefit from protection of private lands to limit future development and fragmentation regardless of the season under consideration (Figures 12–15). Protection of habitat used by grouse on Piñon Mesa, beyond what has already been conserved, could come in several forms including the establishment of additional conservation easements (e.g., Colorado West Land Trust), safe harbor agreements (U.S. Fish and Wildlife Service), or conservation practice agreements (Natural Resource Conservation

Service, Working Lands for Wildlife program). The latter two agreements provide private landowners with Endangered Species Act predictability or protection from incidental take without encumbering the property in perpetuity as with easements. Such options may be attractive to private landowners that do not wish to pursue permanent conservation easements. Areas on the seasonal maps that appear warm in color (red) should be given the greatest attention as the protection of those lands has the greatest potential for having suitable grouse habitat (Figures 13–15). Unprotected habitat on Piñon Mesa proper continues to show some of the highest probabilities of use by grouse across all seasons for this satellite population. These unprotected areas accounted for nearly one-third of all telemetry locations collected during the study across all seasons. Additional areas with high probabilities of use include south of Payne Mesa and west of the U.S. National Forest parcel; and the mesa north of the Unaweep to the east of North Fork Creek. Habitat both northeast and south of BS road, in the large sagebrush surrounding Battleship and Bottle Rock, indicates high probabilities of use may occur as well.

Treatments conducted in areas originally mapped as potential habitat have yielded use by grouse in recent years (e.g., Timber Ridge). These areas now indicate high probability of use by the seasonal modeling (Figures 13–15). Areas adjacent to those with slightly cooler probabilities of use (e.g., yellows) may lend themselves to future treatments as a method of improving habitat for grouse if site examination verifies models. Although many of the areas affected by piñon-juniper succession have been addressed, habitat remains that could benefit from mechanical treatments. Further investigation of areas considered to be connective corridors may benefit grouse habitat the most from these types of treatments. In many cases, follow-up treatments at sites where pinyon-juniper was removed will be necessary to see if reestablishment of saplings is occurring. Consequently, long-term monitoring of previous treatment sites should be conducted. Alternative treatment methods such wet meadow restoration (Zeedyke and Clothier 2009, Zeedyke and Vrooman 2017, Maestas et al. 2018) should also be considered to improve brood rearing habitat. Reviewing breeding and summer/fall maps (Figures 13–14) may assist in targeting spots for these types of actions.

One rock dam used for wet meadow restoration.

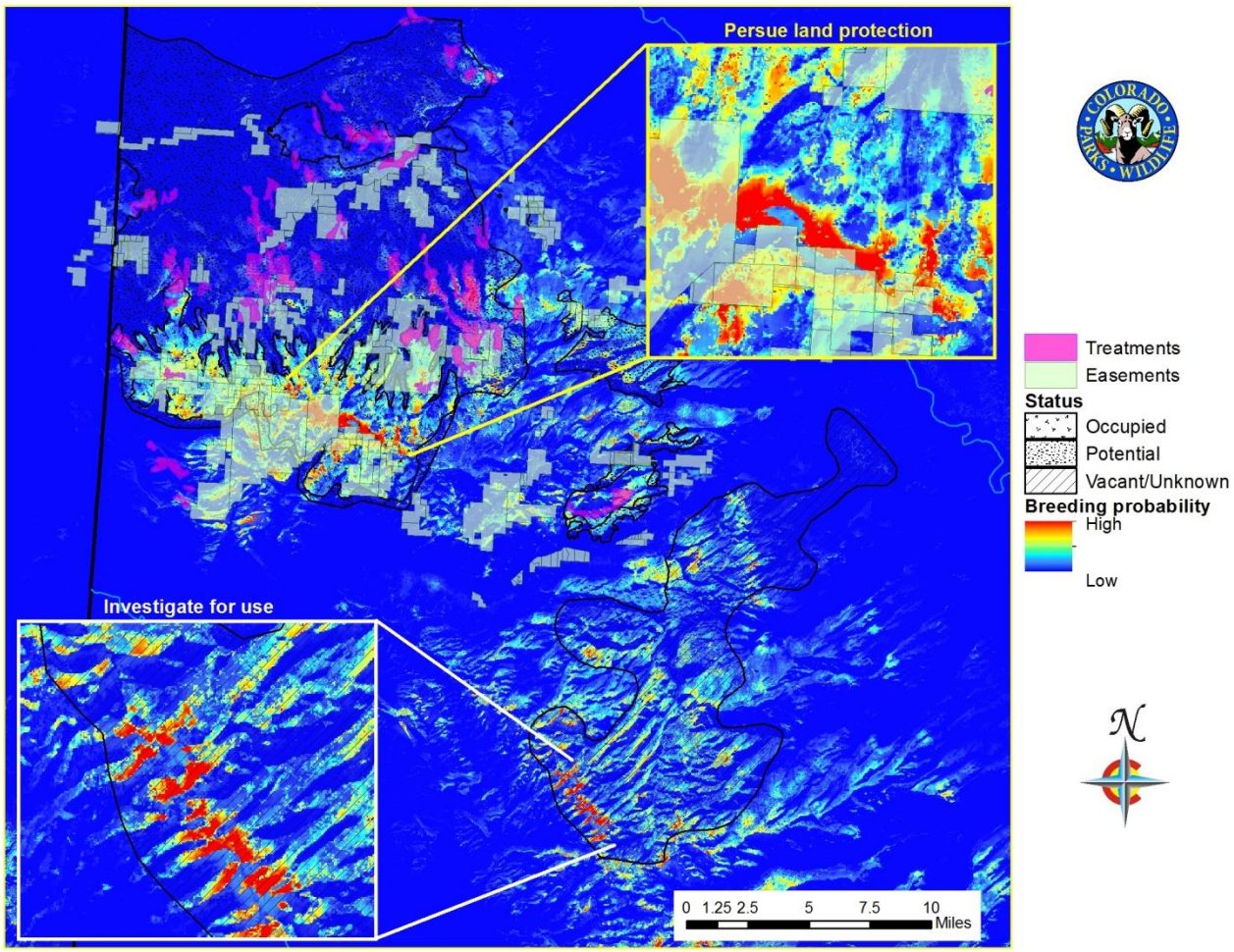

Figure 12. Probability of habitat being used by Gunnison sage-grouse on Piñon Mesa, Colorado for breeding activities as mapped in 2010. Warmer areas reflect higher probabilities of use. Treatments and easements conducted or in place as of 2015 shown to depict conservation efforts.

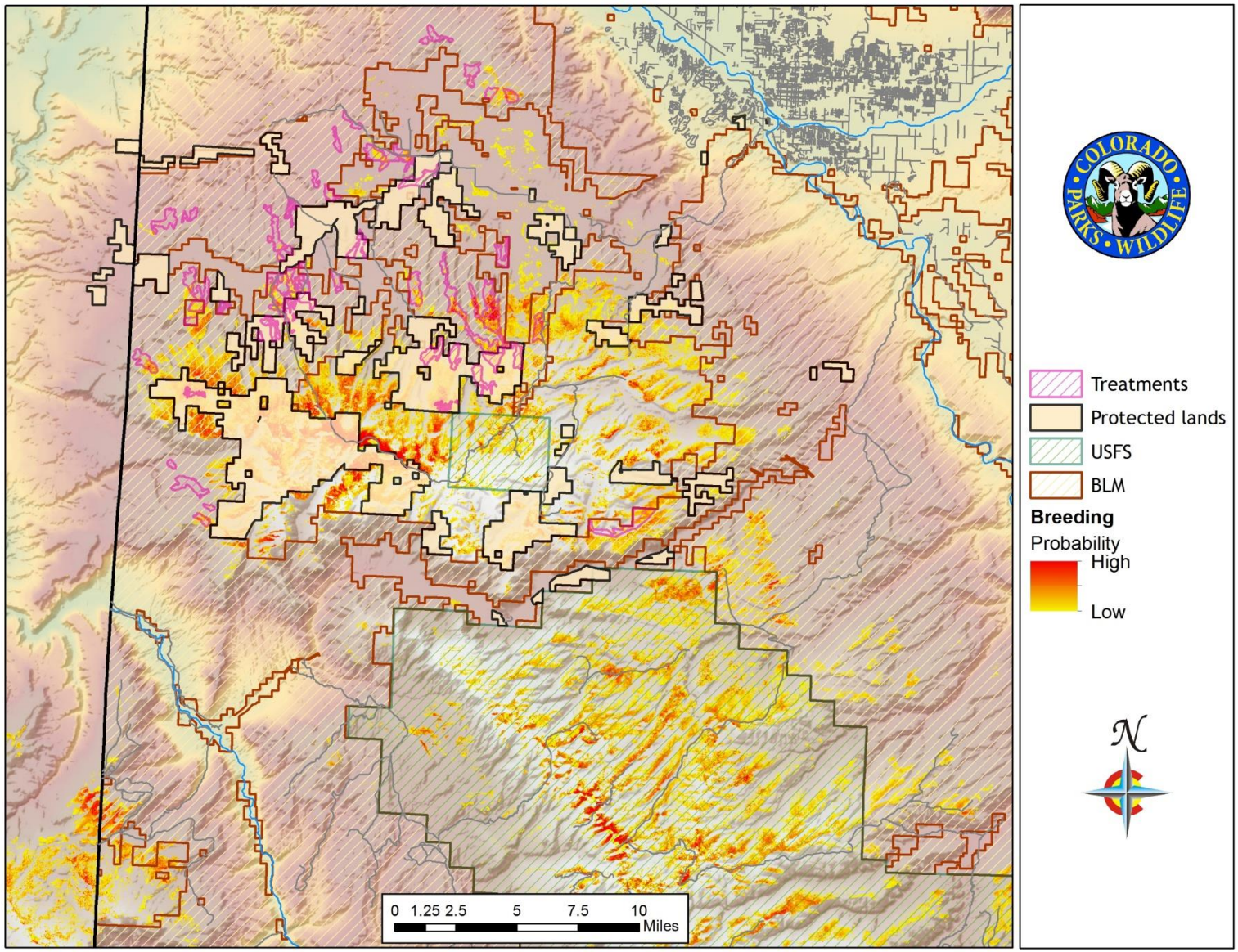

Figure 13. Treatments and protected lands (e.g., easements, conservation agreement with assurances) up to 2015 overlaying the probability of use model for Gunnison sage-grouse breeding habitat on Piñon Mesa, Colorado. Warmer areas reflect higher probabilities of use.

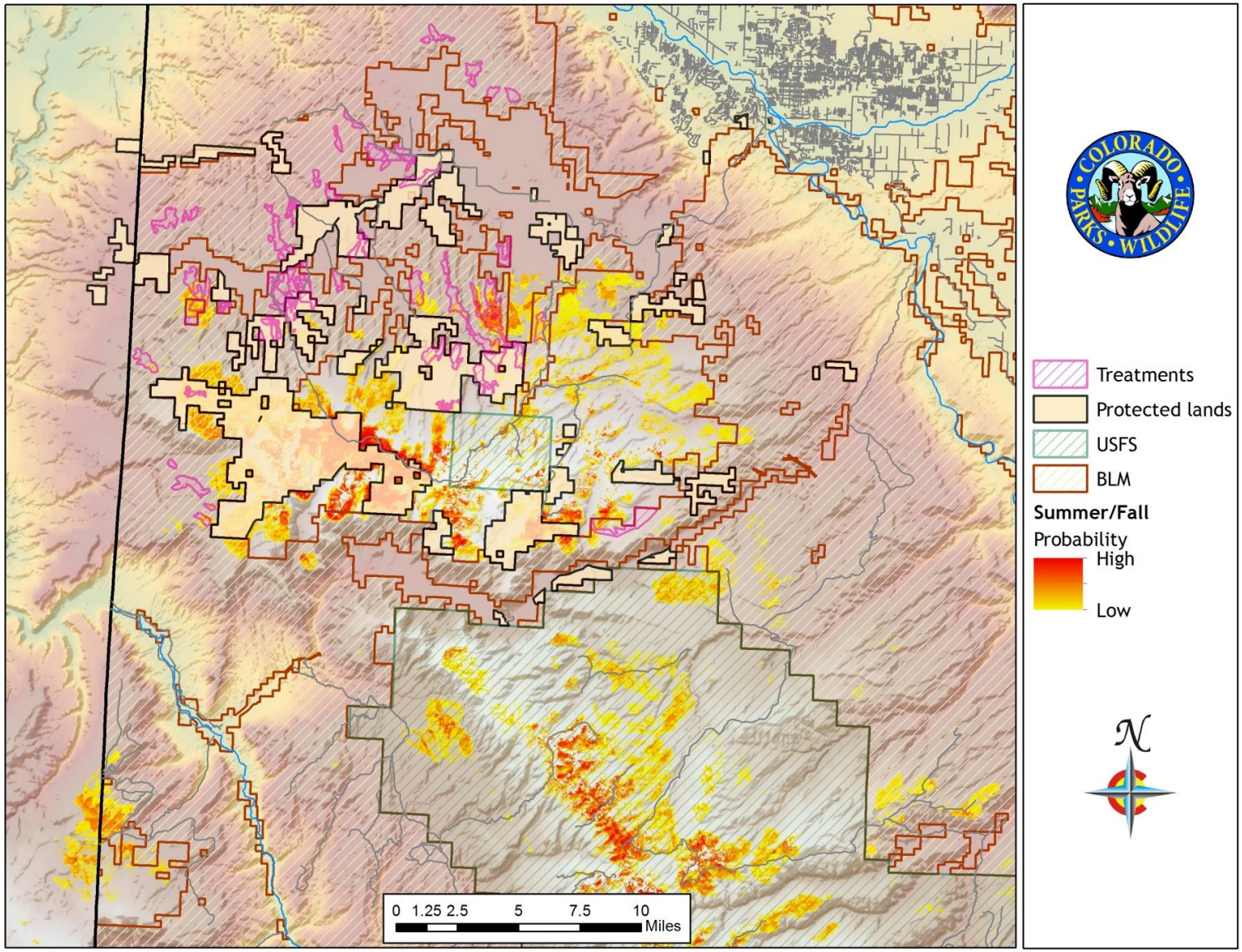

Figure 14. Treatments and protected lands (e.g., easements, conservation agreement with assurances) up to 2015 overlaying the probability of use model for Gunnison sage-grouse summer/fall habitat on Piñon Mesa, Colorado. Warmer areas reflect higher probabilities of use.

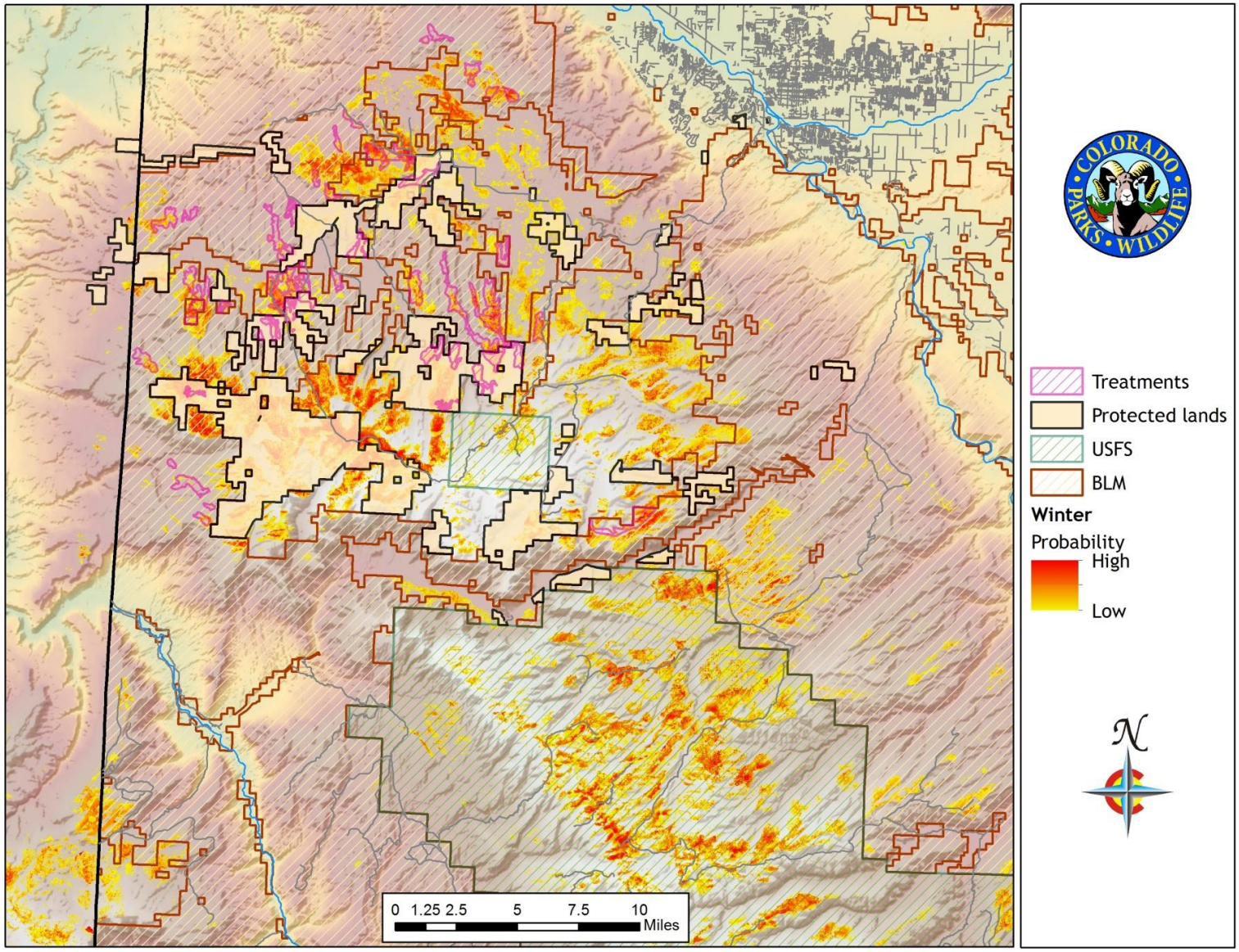

Figure 15. Treatments and protected lands (e.g., easements, conservation agreement with assurances) up to 2015 overlaying the probability of use model for Gunnison sage-grouse winter habitat on Piñon Mesa, Colorado. Warmer areas reflect higher probabilities of use.

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Appendices

Table A1. Gunnison Sage-grouse rangewide conservation plan habitat guidelines (GuSG RSC 2007). Habitat guidelines were developed from multiple data sources collected for Gunnison sage-grouse in the Gunnison Basin and satellite populations as described in Appendix H of the Gunnison sage-grouse rangewide conservation plan (2005).

	Breeding		Summer–Fall		Winter	
Vegetation Variable	**Arid**	**Mesic**	**Arid**	**Mesic**	**Arid**	**Mesic**
Sagebrush Cover (%)	15-25	10-20	5-15	5-20	30–40	-
Non-Sage Cover (%)	5-15	5-15	5-15	5-15	-	-
Total Shrub Cover (%)	20-40	15-35	10-30	10-35	-	-
Sagebrush Height (in)	10-20	12-20	8-16	10-20	16–22	-
Grass Cover (%)	10-30	20-40	10-25	10-35	-	-
Forb Cover (%)	5-15	20-40	5-15	15-35	-	-
Grass Height (in)	4-6	4-6	4-6	4-6	-	-
Forb Height (in)	2-4	2-6	1-4	2-6	-	-

Table A2. Scientific and common names of plants identified along vegetation transects in Gunnison sage-grouse habitat on Piñon Mesa, Colorado (2010–2015) with abbreviation codes.

Scientific name	Common name	Abbreviation
Shrubs		
Artemisia cana Pursh	silver sagebrush	ARCA13
Artemisia nova A. Nels.	black sagebrush	ARNO4
Artemisia tridentata Nutt. ssp. tridentata	basin big sagebrush	ARTRT
Artemisia tridentata Nutt. ssp. vaseyana (Rydb.) Beetle	mountain big sagebrush	ARTRV
Artemisia tridentata Nutt. ssp. wyomingensis Beetle & Young	Wyoming big sagebrush	ARTRW8
Chrysothamnus viscidiflorus (Hook.) Nutt.	yellow rabbitbrush	CHVI8
Dasiphora fruticosa (L.) Rydb. ssp. floribunda (Pursh) Kartesz	shrubby cinquefoil	DAFRF
Peraphyllum ramosissimum Nutt.	squaw apple	PERA4
Purshia tridentata (Pursh) DC.	antelope bitterbrush	PUTR2
Quercus gambelii Nutt.	Gambel oak	QUGA
Symphoricarpos rotundifolius Gray	roundleaf snowberry	SYRO
Tetradymia canescens DC.	spineless horsebrush	TECA2
Forbs		
Achillea millefolium L.	common yarrow	ACMI2
Antennaria rosea Greene	rosy pussytoes	ANRO2
Arenaria congesta Nutt.	ballhead sandwort	ARCO5
Arenaria fendleri Gray var. fendleri	Fendler's sandwort	ARFEF3
Artemisia ludoviciana Nutt.	white sagebrush	
Astragalus coltonii M.E. Jones	Colton's milkvetch	ASCO8
Astragalus mollissimus Torr.	woolly locoweed	ASMO7
Astragalus L.	milkvetch	ASTRA
Castilleja angustifolia (Nutt.) G. Don var. dubia A. Nels.	desert Indian paintbrush	CAAND
Castilleja linariifolia Benth.	Wyoming Indian paintbrush	CALI4
Cerastium arvense L. ssp. strictum (L.) Ugborogho	field chickweed	CEARS2
Cirsium P. Mill.	thistle	CIRSI
Collinsia parviflora Lindl.	maiden blue eyed Mary	COPA3
Comandra umbellata (L.) Nutt.	bastard toadflax	COUM
Crepis occidentalis Nutt. ssp. occidentalis	largeflower hawksbeard	CROCO2
Cymopterus bulbosus A. Nels.	bulbous springparsley	CYBU
Delphinium nuttallianum Pritz. ex Walp.	twolobe larkspur	DENU2
Erigeron flagellaris Gray	trailing fleabane	ERFL
Erigeron L.	fleabane	ERIGE2
Eriogonum flavum Nutt.	Alpine golden buckwheat	ERFL4
Eriogonum racemosum Nutt.	redroot buckwheat	ERRA3
Erigeron speciosus (Lindl.) DC.	aspen fleabane	ERSP4
Eriogonum umbellatum Torr.	sulphur-flower buckwheat	ERUM
Galium boreale L.	northern bedstraw	GABO2
Geranium richardsonii Fisch. & Trautv.	Richardson's geranium	GERI
Gutierrezia sarothrae (Pursh) Britt. & Rusby	broom snakeweed	GUSA2
Lathyrus lanszwertii Kellogg var. leucanthus (Rydb.) Dorn	Nevada pea	LALAL3
Linum lewisii Pursh var. lewisii	prairie flax	LILEL2
Lupinus argenteus Pursh	silvery lupine	LUAR3
Lupinus L.	lupine	LUPIN
Machaeranthera canescens (Pursh) Gray	hoary tansyaster	MACA2
Mahonia repens (Lindl.) G. Don	creeping barberry	MARE11
Polygonum L.	knotweed	POLYG4
Opuntia polyacantha Haw.	plains pricklypear	OPPO
Orthocarpus luteus Nutt.	yellow owl's-clover	ORLU2
Oreochrysum parryi (Gray) Rydb.	Parry's goldenrod	ORPA3
Oxytropis campestris (L.) DC.	field locoweed	OXCA4

Table A2. Continued.

Scientific name	Common name	Abbreviation
Forbs - continued		
Penstemon caespitosus Nutt. ex Gray	mat penstemon	PECA4
Petradoria pumila (Nutt.) Greene	grassy rockgoldenrod	PEPU7
Penstemon rydbergii A. Nels.	Rydberg's penstemon	PERY
Phacelia hastata Dougl. ex Lehm.	silverleaf phacelia	PHHA
Phlox longifolia Nutt.	longleaf phlox	PHLO2
Plantago lanceolata L.	narrowleaf plantain	PLLA
Potentilla hippiana Lehm.	woolly cinquefoil	POHI6
Potentilla pulcherrima Lehm.	beautiful cinquefoil	POPU9
Pseudostellaria jamesiana (Torr.) W.A. Weber & R.L. Hartman	tuber starwort	PSJA2
Senecio integerrimus Nutt.	lambstongue ragwort	SEIN2
Sedum lanceolatum Torr.	spearleaf stonecrop	SELA
Senecio L.	ragwort	SENEC
Solidago L.	goldenrod	SOLID
Sphaeralcea coccinea (Nutt.) Rydb.	scarlet globemallow	SPCO
Taraxacum officinale G.H. Weber ex Wiggers	common dandelion	TAOF
Thalictrum fendleri Engelm. ex Gray	Fendler's meadow-rue	THFE
Trifolium repens L.	white clover	TRRE3
Valeriana acutiloba Rydb. var. acutiloba	sharpleaf valerian	VAACA
Veronica anagallis-aquatica L.	water speedwell	VEAN2
Vicia americana Muhl. ex Willd.	American vetch	VIAM
Viola L.	violet	VIOLA
Wyethia arizonica Gray	Arizona mule-ears	WYAR
Grasses		
Achnatherum lettermanii (Vasey) Barkworth	Letterman's needlegrass	ACLE9
Agropyron cristatum (L.) Gaertn.	crested wheatgrass	AGCR
Bromus inermis Leyss. ssp. inermis var. inermis	smooth brome	BRINI2
Bromus marginatus Nees ex Steud.	mountain brome	BRMA4
Bromus tectorum L.	cheatgrass	BRTE
Carex geyeri Boott	Geyer's sedge	CAGE2
Carex L.	sedge	CAREX
Elymus elymoides (Raf.) Swezey	squirreltail	ELEL5
Elymus trachycaulus (Link) Gould ex Shinners	slender wheatgrass	ELTR7
Festuca idahoensis Elmer ssp. idahoensis	Idaho fescue	FEIDI2
Festuca thurberi Vasey	Thurber's fescue	FETH
Juncus arcticus Willd. ssp. littoralis (Engelm.) Hultén	Baltic rush	JUARL
Koeleria macrantha (Ledeb.) J.A. Schultes	prairie Junegrass	KOMA
Melica spectabilis Scribn.	purple oniongrass	MESP
Nassella viridula (Trin.) Barkworth	green needlegrass	NAVI4
Pascopyrum smithii (Rydb.) A. Löve	western wheatgrass	PASM
Phleum pratense L.	timothy	PHPR3
Poa L.	bluegrass	POA
Poa bulbosa L.	bulbous bluegrass	POBU
Poa fendleriana (Steud.) Vasey	muttongrass	POFE
Poa pratensis L.	Kentucky bluegrass	POPR
Poa secunda J. Presl	Sandberg bluegrass	POSE
Thinopyrum intermedium (Host) Barkworth & D.R. Dewey	intermediate wheatgrass	THIN6

Table A3. Species composition and average cover of grasses and forbs collected at vegetation transects on Piñon Mesa in 2012. Measurements reflect the average across transect areas (Luster = 14, Tipping Ridge = 6, 2V = 6, and Timber Ridge = 11, Payne Mesa = 2, Reservation = 3, and Upper Dominguez Canyon = 4). Scientific and common names, and abbreviations of all plant species are provided in Appendix A2.

Code	Common Name	Luster	Tipping	2V	Timber	Payne	Reservation	Dominguez
Grasses								
ACLE9*	Letterman's needlegrass	5.50	1.41	9.75	-	3.10	-	1.78
AGCR	crested wheatgrass	-	-	-	4.68	1.90	4.23	-
BRMA4	mountain brome	0.02	-	-	-	-	-	-
BRIN12*	smooth brome	1.65	3.58	0.34	0.81	-	-	-
BRTE	cheat grass	-	-	-	0.16	-	-	-
CAREX	Sedge species	0.24	0.08	-	-	-	-	0.08
ELEL5	squirreltail	0.18	-	0.30	0.69	-	-	1.15
ELTR7	slender wheatgrass	0.43	0.98	0.13	0.35	-	-	-
FEID12*	Idaho fescue	0.43	8.27	1.55	1.65	-	-	-
FETH*	Thurber's fescue	0.35	1.13	2.33	-	-	-	-
KOMA	prairie Junegrass	0.50	-	0.86	1.93	2.70	-	0.60
MESP	purple oniongrass	-	0.13	-	-	-	-	-
NAVI4*	green needlegrass	0.15	1.31	0.63	-	-	-	-
PASM	western wheat	-	-	-	1.95	0.40	-	0.45
per. grass	(unknown)	0.92	0.08	0.98	-	4.10	0.77	0.15
POA sp.*	bluegrass species	9.89	9.37	5.28	-	-	-	5.35
POBU	bulbous bluegrass	-	-	-	-	-	0.10	-
POFE	Mutton bluegrass	-	-	-	0.07	0.55	-	0.08
POPR	Kentucky bluegrass	-	-	-	-	2.45	-	-
POSE	Sandberg bluegrass	-	-	-	0.63	-	1.37	-
THIN6	intermediate wheatgrass	0.02	-	-	0.22	-	-	-
	Average total grass cover	*19.88*	*26.33*	*22.15*	*14.29*	*15.20*	*6.47*	*9.63*
Forbs								
ACMI2*	common yarrow	2.65	3.55	3.56	0.50	0.55	-	0.13
AGOSERIS	mt dandelion	-	-	-	-	-	-	-
ARCO5*	ballhead sandwort	0.93	-	0.47	-	-	-	3.95
ARLU	white sagebrush	-	-	-	-	-	-	0.53
ASMO7	woolly locoweed	-	-	-	-	-	0.10	
ASTRAG	milkvetch species	-	-	-	0.03	-	-	0.98
CAAND	desert Indian paintbrush	-	-	-	0.03	-	-	0.13
CEARS	Chickweed species	0.09	-	-	-	-	-	-
CEARS2	field chickweed	0.02	-	0.13	-	-	-	-
CROCO2	largeflower hawksbeard				0.03			
DENU2	twolobe larkspur	-	-	-	-	-	-	0.08
ERFL	trailing fleabane	0.07	-	-	-	-	-	0.65
ERFL4	Alpine golden buckwheat	-	-	-	-	-	-	0.08
ERIGE2	fleabane species	0.66	-	0.08	-	0.15	0.20	0.90
ERRA3	redroot buckwheat	-	-	0.04	0.03	0.40	-	1.10
ERSP4*	aspen fleabane	2.72	2.27	1.85	0.55	-	-	-
ERUM	sulphur-flower buckwheat	0.08	-	-	-	-	-	0.28
Forb	(unknown)	0.25	0.55	0.47	0.07	0.55	-	0.08

Table A3. Continued.

Code	Common Name	Luster	Tipping	2V	Timber	Payne Reservation	Dominguez
Forbs - continued							
GABO2	northern bedstraw	0.28	0.26	0.65	0.15	-	-	0.28
GERI*	Richardson's geranium	0.07	2.48	-	0.12	-	-	-
GUSA2	snakeweed	-	-	-	0.70	-	0.10	-
HEMU3*	showy goldeneye	-	1.31	-	-	-	-	0.08
HEVI4*	hairy false goldenaster	3.47	0.18	1.23	0.27	-	-	-
HYHO	Sneezeweed	-	5.06	-	0.49	-	-	-
IRMI*	Rocky Mountain iris	-	4.80	-	-	-	-	-
LALAL3*	Nevada pea	0.74	2.61	0.39	-	-	-	
LUPINUS*	Lupine species	3.98	2.21	1.76	0.15	2.25	-	3.60
MACA2	hoary tansyaster	-	-	-	-	-	-	-
MARE11	creeping barberry	-	-	-	-	-	-	0.40
OPPO	plains pricklypear				0.03			
ORLU2	yellow owl's-clover	-	-	-	-	-	-	-
ORPA3	Parry's goldenrod	-	-	-	-	-	-	-
OXCA4*	field locoweed	3.06	0.18	5.77	-	-	-	-
PECA4	mat penstemon	-	-	-	-	-	-	0.13
PEPU7	grassy rockgoldenrod	-	-	0.68	0.19	-	-	-
PERY*	Rydberg's penstemon	1.95	7.66	6.01	1.24	-	-	-
PHHA	silverleaf phacelia	0.38	-	-	-		-	0.58
PHLO2*	longleaf phlox	1.38	-	0.93	0.47	1.65	-	0.70
POHI6	woolly cinquefoil	0.51	-	-	-	-	-	-
POLYG4	knotweed	-	-	-	-	1.05	-	-
POPU9	beautiful cinquefoil	0.65	0.38	-	0.09	-	-	-
POTEN	cinquefoil species	-	-	-	-	-	-	0.08
PSJA2	tuber starwort	-	0.26	-	-	-	-	-
SEIN2	lambstongue ragwort	0.16	-	-	-	-	-	-
SELA	spearleaf stonecrop	-	-	-	-	-	-	0.20
SOLID*	goldenrod species	0.29	0.30	1.43	0.63	-	-	1.48
SPCO	scarlet globemallow	-	-	-	0.02	-	0.83	-
TAOF*	common dandelion	0.41	0.38	0.04	0.14	0.25	-	-
THFE	Fendler's meadow-rue	-	0.68	0.04	-	-	-	-
VAACA*	sharpleaf valerian	-	0.43	-	0.35	-	-	-
VIAM	American vetch	0.07	-	0.38	0.16	-	-	-
VIOLA	violet species	-	-	-	-	-	-	-
WYAR	Arizona mule's ear	-	-	0.22	-	-	-	-
	Average total forb cover	*24.87*	*34.23*	*26.12*	*6.85*	*6.85*	*1.23*	*16.35*

* Species with highest average cover.