

AN ABSTRACT OF THE THESIS OF

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Title: Greater Sage-grouse Movements and Habitat Use During Winter in Central Oregon

Abstract approved: \_\_\_\_\_  
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Greater sage-grouse (*Centrocercus urophasianus*), a sagebrush obligate species, has contracted in extent by nearly half its original distribution. This is primarily due to habitat loss and degradation over the past 150 years. During winter, sage-grouse depend completely on sagebrush habitat for food and cover, yet sage-grouse winter ecology has been poorly studied in the past. We studied greater sage-grouse winter habitat use and movement in central Oregon by tracking 22 radio-collared sage-grouse (7 female, 15 male) from January through mid March 2007 to record specific characteristics of sagebrush used and patterns of movement for each sex during winter. We quantified winter habitat characteristics such as canopy height and topography at each sage-grouse location, estimated winter distances moved using weekly to biweekly point locations, and compared this information between males and females. The sage-grouse we studied moved extensively across the landscape in central Oregon, using approximately 1,480 km<sup>2</sup> during winter. Sagebrush canopy height in

sites used by sage-grouse varied from 0.25 to 0.75 m, with females tending to use sites with taller sagebrush plants and less total foliar cover than sites used by males. The difference in foliar cover between sexes was related to a seasonal change in habitat use; four females found in low sagebrush in January and early February stopped using it after 15 Feb 2007. Also by this date, most male sage-grouse had stopped using big sagebrush as they migrated to lekking areas. During our study there was half as much snow cover on average, which may explain why sage-grouse mortality rates were low. Managers interested in preserving sage-grouse populations should provide large areas (thousands of square km) of habitat that contain heterogeneous sagebrush habitat, specifically with both low and big sagebrush so that food and cover are available for greater sage-grouse during winter.

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Greater Sage-grouse Movements and Habitat Use During Winter in Central Oregon

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Jennifer R. Bruce, Author



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## CONTRIBUTION OF AUTHORS

Drs. Douglas Robinson, Richard Miller, and Steven Petersen were involved in the study design, writing, and editing of this manuscript while Dr. Douglas Robinson also assisted in analysis.

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## **CHAPTER 1: GREATER SAGE-GROUSE MOVEMENTS AND HABITAT USE DURING WINTER IN CENTRAL OREGON**

### INTRODUCTION

Greater sage-grouse (*Centrocercus urophasianus*) populations have declined across western North America as sagebrush habitats have diminished (Connelly et al. 2004). The historic (pre-European) distribution of potential habitat is estimated to have been 1.2 million km<sup>2</sup>, however current sage-grouse range only occupies 56% of that area (Schroeder et al. 2004). The loss and fragmentation of sagebrush habitat has been attributed to land conversion (McDonald and Reese 1998, Vander Haegen et al. 2000), oil and natural gas exploration (Bay 1989, Lyon 2000), urbanization (Griffin 2002), grazing (Crawford et al. 2004), invasive annual grasses (Young and Allen 1997, Knick 1999, Gelbard and Belnap 2003), increased fire frequency (d'Antonio and Vitousek 1992, Miller and Wigand 1994, Brooks and Pyke 2001), and juniper and pinyon pine encroachment (Miller and Wigand 1994, Miller et al. 2000, Miller and Tausch 2001).

Concomitant with habitat loss has been a decline in the abundance of sage-grouse, with a 70% reduction from 1965 to 1985, and a current decline of 2.0% per year (Connelly et al. 2004). Population declines along with continuing habitat loss and degradation have been severe enough to warrant consideration of listing greater sage-grouse for protection under the federal Endangered Species Act (ESA). The U.S. Fish and Wildlife Service decided in 2005 that protection of greater sage-grouse was not warranted. However, in December of 2007 this finding was challenged in federal court

and the decision is being reconsidered.

More information on the factors that influence population dynamics of greater sage-grouse are needed to be included in the decision-making process. Most sage-grouse studies have focus on habitat use and reproduction during the breeding season (Barnett and Crawford 1994, Gregg et al. 1994, Sveum et al. 1998a, Sveum et al. 1998b, Schroeder et al. 1999). Winter, however, can be a season when mortality rates for yearlings and adults may be high due to prolonged cold weather and reduced access to food and refuge when snow covers sagebrush, their primary source of food and cover during winter months (Patterson 1952, Eng and Schladweiler 1972, Wallestead 1975, Remington and Braun 1985, Schroeder et al. 1999, Connelly et al 2000a, Crawford et al. 2004). Therefore, it is critical to better understand factors that influence sage-grouse survival during winter, such as percent cover and height of sagebrush used, as well as energy spent on movements in terms of distances moved and area used by sage-grouse during winter.

Very limited work has evaluated sage-grouse movements, habitat structure, and mortality during the winter. Past studies have determined that during winter sage-grouse are known to use sagebrush either 25 – 46 cm above the snow, or sagebrush having a total height of 41 – 56 cm (Connelly et al 2000), and prefer sagebrush canopy cover of at least 10 to 20% (Eng and Schladweiler 1972, Beck 1977). The species of sagebrush preferred by sage-grouse varies geographically and according to snow depth, but sage-grouse have been mostly found in either early sagebrush (*A. longiloba*), low sagebrush (*Artemisia arbuscula*), Mountain big (*A. tridentata* ssp



*tridenata*) and/or Wyoming big (*A. t. ssp wyomingensis*) sagebrush during winter (Patterson 1952, Wallested et al. 1975, Connelly 1982, Barrington and Back 1984, Klebenow 1985, Remington and Braun 1985, Welch et al. 1988, Hupp and Braun 1989, Welch et al. 1991, Hanf et al. 1994). The use of these species may be related to the palatability of each species to sage-grouse. According to Rosentreter (2005), there is a relative palatability gradient for sage-grouse where early sagebrush is found to be the most palatable, which is then followed by low sagebrush, mountain big sagebrush, and finally Wyoming big sagebrush. In terms of topography, past studies describe sage-grouse winter habitat as either shallow or having little slope with generally southern or western aspects (Beck 1977, Hupp and Braun 1989). The movements of greater sage-grouse from nesting sites to wintering areas have been reported as 16 to 180 km (Dalke et al. 1960, Wallestad 1975, Martin 1976, Beck 1977, Connelly et al. 1988), with observed minimum daily movements during winter of less than 1.21 km (Eng and Schladweiler 1972).

Few studies have recently been conducted to understand ecology of sage-grouse during winter, and complete information on movement distances between habitat patches, habitats selected for foraging, and over-winter survival are generally lacking. We studied greater sage-grouse in central Oregon to address these information gaps. Our objectives were to: 1) measure distances greater sage-grouse move during winter to describe sage-grouse distribution patterns across the landscape and be able to relate them to the sex of the sage-grouse, 2) characterize habitats occupied (for foraging and for cover) by sage-grouse during winter and determine if

there are habitat differences between the sexes, and 3) quantify mortality rates of sage-grouse during winter and associate occurrences of mortality with characteristics of individuals and habitats occupied.

## METHODS

### *Study area*

We studied greater sage-grouse habitat use and movement in central Oregon on publicly-owned land, managed by the Prineville and Burns Bureau of Land Management district offices, and state and private land in Crook, Deschutes, Harney and Lake counties (Figure 1). This region falls within the High Desert Ecological Province in eastern Oregon, along the western edge of the current geographic range of the greater sage-grouse (Anderson et al. 1998). It encompasses an area of approximately 14,800 km<sup>2</sup>, and elevation ranges from 1250 m to 1950 m. Annual precipitation in this area averages 30 cm (Oregon Climate Service) with 62% falling from November to May. Mean temperatures vary from an average minimum of -7.0° C in January to an average maximum of 27.7° C in July. During 2006, daily temperatures ranged from an average low of or a -7.4 °C in December to 30.4° C in July, while average monthly precipitation was 1.2 cm (Oregon Climate Service). During January and February, monthly temperatures in this area vary from a daily average of -6.1° C to 2.7° C, with a mean precipitation of 3.1 cm (Oregon Climate Service, Squaw Butte Experimental Station, OR). During our study, the mean daily

temperatures ranged from a low of -7.5 °C to a high of 3.9° C, with a mean precipitation of 1.5 cm (Oregon Climate Service, Squaw Butte Experimental Station, OR). In mid January, during the coldest period of the study, temperatures dropped to -20°C for multiple days. The winter of 2006-2007 also contrasts with the long-term average in that 48.4% less precipitation accumulated. Only three snow storms that resulted in accumulation of snow occurred during our study. The second storm in late February resulted in the deepest snow of 19 cm, which melted completely within 10 days.

Habitat in the study area was semi-arid sagebrush rangeland, with most canopy cover provided by early sagebrush, low sagebrush, mountain big sagebrush, Wyoming big sagebrush, and basin big sagebrush (*A. t. spp tridentata*). Some cover is also provided by encroaching western juniper (*Juniperus occidentalis*) in scattered locations. Basin big sagebrush and Wyoming big sagebrush occupy most of the area below 1,430 m, whereas mountain big sagebrush and low sagebrush occupy most of the elevations above 1,430 m. The abundance of early sagebrush is unknown for this site. Silver sagebrush (*A. cana*) and stiff sagebrush (*A. rigida*) were also present but less common throughout the study area. Other canopy vegetation consisted mainly of green rabbitbrush (*Chrysothamnus viscidiflorus*), gray rabbitbrush (*Chrysothamnus nauseosus*), and scattered antelope bitterbrush (*Prushia tridentata*). Common grasses in the area include bottlebrush squirreltail (*Elmus elymoides*), bluebunch wheatgrass (*Psuedoroegneria spicata*), Idaho fescue (*Festuca idahoensis*), Thurbers needlegrass (*Acnatherum thurberianum*) and western needlegrass (*Acnatherum occidentalis*).

Common forbs during spring and summer include buckwheat (*Erigonum* spp.), desert parsley and biscuit-root (*Lomatium* spp.), pussytoes (*Antennaria* spp.), lupine (*Lupinus* spp.), monkey flower (*Mimulus* spp.), Oregon sunshine (*Eriophyllum lanatum*), phlox (*Phlox* spp.) and small-flowered blue-eyed Mary (*Collinsia parviflora*). Forbs are a key source of nutrients for greater sage-grouse during the breeding season, especially for the diet of prelaying females (Barnett and Crawford 1994), and they are known to eat biscuit-root, pussytoes, monkey flower and phlox.

The study area has a history of human related disturbance. Between the late 1800s and early 1900s, cattle and sheep were grazed and dry-land farming practices were implemented (Allen 1987). By the 1920s farming was reduced in the area, but grazing continues today. Most of the study area also experiences hunting for game, including greater sage-grouse, each year.

#### *Sage-grouse capture and tracking*

We opportunistically captured 15 male and 7 female sage-grouse from 23 Mar to 13 Dec 2006 (Table 1). We captured over half these sage-grouse using five leks during the spring of 2006, where 5 males and 1 female were caught at Rickman lek, 2 males at Glass Butte lek, 2 males at Ibex lek, 1 male at Willow lek, and 1 female at Swamp Lake lek (a new lek discovered through our study). We conducted further trapping efforts during fall and winter by targeting roosting areas within the study site. We used a spotlighting technique to capture sage-grouse at night with long-handled nets (Giesen et al 1982). We attached Advanced Telemetry Systems Model A4060

radio transmitters weighing 22 grams each and banded sage-grouse with a numbered aluminum leg band. The age (subadult versus adult) and sex of each bird was identified from morphological attributes. We measured morphological traits including mass ( $\pm 5$  g), wing chord ( $\pm 1$  cm) and tarsus ( $\pm 1$  mm).

We tracked movements and monitored locations of sage-grouse mostly from the ground, but also used flights over the area. After each of the 3 flights (conducted on 1/04/07, 2/3/07, and 2/24/07), we located birds on the ground to obtain GPS coordinates ( $\pm 4$  m) of foraging or roosting sites. We used Advanced Telemetry Systems Model R2000 portable receivers with a frequency reception of 164 –165.999 MHz, and a three-element Yagi antenna. At each detection we recorded date, time, GPS coordinates (using a Garmin eTrex Legend), elevation, number of birds in group, and presumed activity at time of location. Locations of sage-grouse were determined by sight as well as sign (such as fresh feces, cecal droppings, or tracks in snow and mud) and foraging evidence. We tracked winter movements of each sage-grouse, locating them every  $10 \pm 3$  (mean  $\pm$  SD) days. We calculated the minimum distance moved between each location using the Distances Between Points analysis option in Hawth's Tools through ArcView 9.2. We estimated mean daily movement for each sage-grouse by dividing the minimum distance moved by the number of days between each date with location information. For simplicity of presentation, we refer throughout this manuscript to distances traveled as an abbreviated way of saying estimated minimum distances traveled.

### *Winter Habitat Sampling*

From 8 Jan - 9 Mar 2007 we measured habitat characteristics at locations used by all (7 female, 15 male) greater sage-grouse. We established a plot at every location a radio-collared sage-grouse was found. At each sage-grouse location, we quantified the plant community composition and structure following protocols similar to those described by Herrick et al. (2005), which included identifying sagebrush species and subspecies, measuring height of shrubs, estimating foliar cover, and noting presence or absence of other plant species. Plots contained five parallel transects 30 m long that were spaced 10 m apart (Appendix 1). We used the UTM coordinate of the sage-grouse location as the center of each plot. If the slope was less than 5%, transects were aligned parallel to magnetic north. If the slope was greater than 5%, transects were positioned in the direction of the aspect of the area. To quantify live and dead foliar shrub and tree cover by species or subspecies, we used a line-point intercept method (Herrick et al. 2005). Beginning at 0.0 m along the 30 m long transect, we dropped a pin every 0.5 meters along each transect for a total of 61 pin drops per transect, and 305 pin drops per plot. Once the entire pin (30.5 cm long) was flush with the ground, all sagebrush, rabbitbrush and/or juniper species touching any part of the pin, as well as its live or dead status, was recorded for that point. This method differs slightly from that used by previous researchers (Herrick et al. 2005). We later determined dominant sagebrush cover of each plot by recording the species that composed greater than 50% of total measured foliar cover in each plot. We estimated mean sagebrush height ( $\pm 20$  cm) by placing a meter stick at the center of each plot and using it to estimate the

height of shrubs within plots. We measured snow depth ( $\pm 1$  cm) by averaging 5 measurements at randomly selected points along each transect (N=25 measurements per plot). We measured topographic information from the center of each plot. A GPS unit was used to record elevation, a compass was used to determine aspect in the direction of negative slope, and slope in percent was later determined using spatial analyst tools in ArcView 9.2. Therefore, the habitat variables we measured were 1) aspect (degrees); 2) elevation (meters); 3) slope (percent); 4) dead shrub foliar cover (percent); 5) live shrub foliar cover (percent); 6) shrub canopy height (centimeters); and 7) total shrub foliar cover (percent). Shrub foliar cover included the following additional variables of species: 8) *Artemisia tridentata* (percent); 9) *A. arbuscula* (percent); 10) *A. cana* (percent); 11) *Chrysothamnus viscidiflorus* (percent); and 12) other shrub species (percent). Snow depth was not included in the description of winter habitat or in analysis due to the low amount of snowfall during the study period.

To characterize habitats used by birds, we summarized the average elevation, slope, aspect, percent foliar cover, and shrub height for all plot locations, quantified and compared species of shrubs (and subspecies of *Artemisia*) for each plot, and estimated the percent of shrubs found to be browsed in each plot. Our objective was to describe characteristics of habitats used by sage-grouse during winter, so we did not sample randomly chosen sites with the assumption they are not used by sage-grouse. Data to evaluate habitat selection require knowledge of the landscape-level distribution of habitats, which were unavailable to us, but are part of another study (M.

Freese, unpublished data).

We characterized habitat in plots associated with points where sage-grouse were detected. Though we could not be certain about the potential reasons sage-grouse were in a given location when they were detected, we nonetheless collected information on evidence of use in each plot if it was present. To help determine if sage-grouse were roosting in plots, we looked for fresh, large fecal piles as well as cecal droppings within plots. Multiple fresh fecal droppings per pile suggests that the sage-grouse may have recently been sitting in the same place for an extended amount of time, and hence provide evidence of roosting during the previous night. Also, since cecal droppings are usually only dropped once per day and usually in the morning (Schroeder et al. 1999), fresh cecal droppings may also be further evidence of recent or nearby sage-grouse roosting sites. To ascertain if sage-grouse were foraging in plots, we examined sagebrush along each transect for signs of browsing. Sage-grouse have a species specific foraging method that involves cutting rather than picking leaves from sagebrush plants, and so identification of browsed plants can be reliably determined by the light green inner portion of the freshly eaten leaf that strongly stands out against the rest of the uneaten leaf (Remington and Braun 1985). At a random sample of 25 points distributed across each of the 5 line transects per plot, we inspected sagebrush within a 0.5 m radius for signs of browsing. We noted presence or absence of browsing. We then determined the frequency of plots with foraging evidence by calculating the percentage of plots at which browsing was detected. We also determined the relative frequency of browsing within each plot by calculating the



percentage of points at which browsing was detected out of the number of possible foraging points.

### *Data Analysis*

We evaluated the relationship between distances moved by individual sage-grouse throughout the winter by sex. We analyzed movement data using a nonparametric Mann-Whitney U test to determine if there was a significant difference among males and females in 1) the minimum distance moved during the study period and 2) average daily movements. Since two sage-grouse were only found once, movement comparisons were made for 20 of the birds. Also, unless otherwise noted, we considered alpha less than or equal to 0.05 to be statistically significant.

We compared with a Mann-Whitney U test the characteristics of habitats used during winter by males versus females. Comparisons were made for 22 birds. When more than one plot had been measured per bird, we used the mean values from all plots measured per bird in our comparisons among birds. We used indicator variables for aspect, where flat ground = 0° and cardinal and sub cardinal directions included the following degree ranges: N = 336.6–22.5°; NE = 292.6–337.5°; E = 247.6–292.5°; SE = 202.6–247.5°; S = 157.6–202.5°; SW = 112.6–157.5°; W = 67.6–112.5°; and NW = 22.6–67.5°.

A cost of averaging habitat plot data is that seasonal changes in characteristics of habitats used by individual birds are lost. Therefore, we examined winter habitat use by sex of sage-grouse as a function of date using logistic regression with repeated

measures, where the binary response variable was sex. We used Akaike's Information Criterion with the additional bias correction term (AIC<sub>c</sub>) for small sample sizes (Burnham and Anderson, 2002) to select the top models associating sex with habitat characteristics over time.

We developed models from 12 explanatory variables measuring winter habitat vegetation and topography. Prior to developing the candidate model set, we examined multicollinearity using Pearson correlation coefficients for the averaged explanatory variables using the PROC CORR procedure in SAS v. 9.1.3. We decided *a priori* that a Pearson correlation p-value of less than 0.05 would merit exclusion from possible regression models. Seventeen out of 132 possible pairs of variables were correlated in this manner (Table 2). Using this information as well as data from past studies on both Greater and Gunnison sage-grouse (Eng and Schladweiler 1972, Hupp and Braun 1989), we decided the variable percent live cover would best represent most of the other vegetative variables we measured, while elevation would probably best represent most topographical variables. We generated a candidate set of 63 *a priori* models using percent live cover (L), elevation (E), date (D), and the interactions of each. The full model is explained by the equation:

$$\text{Log}_{(p/1-p)} = \beta_0 + \beta_1 D + \beta_2 L + \beta_3 E + \beta_4 D * L + \beta_5 D * E + \beta_6 L * E$$

where  $p/1-p$  is the odds that a female greater sage-grouse is present given a particular value of the explanatory variable(s);  $\beta_1 D = \beta_1$  is the linear coefficient for the explanatory variable D, which is date measured in Julian date format;  $\beta_2 L = \beta_2$  is the

linear coefficient for the explanatory variable L, which is live shrub canopy cover measured in percent;  $\beta_3 E = \beta_3$  is the linear coefficient for the explanatory variable E, which is elevation measured in meters;  $\beta_4 D * L = \beta_4$  is the interaction of the explanatory variables date and live cover;  $\beta_5 D * E = \beta_5$  is the interaction of the explanatory variables date and elevation; and  $\beta_6 L * E = \beta_6$  is the interaction of the explanatory variables live cover and elevation. The response data have a Bernoulli distribution, so  $Y = \{1 \text{ female occupied, } 0 \text{ male occupied } Y \sim \text{Bernoulli}(p)\}$ . Residual and residual versus predicted value plots were not used to address the distributional assumptions or model fit since the binary response fits only a Bernoulli distribution.

We quantified mortality during the study period. Estimated dates of death were determined by using the midpoint between the date each sage-grouse was last detected alive and the date mortality signals from transmitters were first detected. We report mortality as a simple percent dying during the study period as well as a daily mortality rate, which is calculated by dividing the number of mortality events observed into the total number of days radio-tagged sage-grouse were known to be alive during the study.

## RESULTS

### *Movements*

We located seven females and 13 males two to 7 times during the study (Table 3). Two males were located only once and were not included in calculations of

distances moved. It is not clear whether those two males moved out of the study area or the transmitters failed. The mean distance traveled during the study was nearly the same (4 km) by females as it was by males (U-test,  $p > 0.95$ ). Mean daily movements were also nearly identical at  $427 (\pm 276)$  m by females and  $426 (\pm 284)$  m by males (U-test,  $p > 0.95$ ; Table 3).

Distances moved were consistent throughout most of the study period, however, we observed two exceptions related to migration toward leks. First, four males began moving to leks in mid-February and their average daily movements increased from 1.5 to 2 km during that time (Figure 2). Second, four females and the remaining males moved longer distances toward leks in early March. Most females appeared to winter closer to the leks than did some males because the longest migration distance to a lek by females was 10 km. Four of the seven females moved approximately 10 km in a south-westerly direction toward leks at the end of February. The longest daily average distance moved toward a lek was by a male who moved 4,184 m per day for three days at the beginning of March. The longest distance moved by a male sage-grouse was 38 km from one lek to another in early March. By the end of the study period, all males had migrated to leks, whereas only 66% of females were detected at leks. In summary, male and female sage-grouse moved an average of 425 m per day during late winter; males tended to move further to leks in early spring than did females.

### *Habitat Characteristics*

We measured 81 plots used by the 22 sage-grouse. The number of plots per bird ranged from 1 to 7. Thirty-three plots were measured from locations of the 7 females, and 48 from 15 males. Of all plots measured, 94% had evidence of plot use in addition to observation of the birds at each location. Of those plots with evidence, 75% had been foraged and 25% contained other signs including tracks, roosting, fecal, and/or cecal droppings. Evidence of foraging was present in at least one plot from each of the 22 sage-grouse we tracked. The frequency of plants browsed per plot by females was 14.3% ( $\pm 10.3\%$ ) with a range from 0 – 65.0%, where the frequency browsed by males was 19.7% ( $\pm 11.4\%$ ) with a range from 0 – 60.9%.

The only habitat variable that differed strongly in plots used by males versus females was percent live cover (Figure 3). Females used sites with less live cover, on average, than males, but values in plots used by males were quite variable so ranges overlapped. Females also tended to use sites with taller cover; average canopy height in plots used by females was 0.54 ( $\pm 0.17$ ) m with a range of 0.28 – 0.75 m compared with a mean of 0.37 ( $\pm 0.10$ ) m and a range of 0.25 – 0.63 m in plots used by males. However, statistical comparisons between canopy height and sex were not significantly different (Figure 3).

Most birds chose sites with  $< 2\%$  slope. Seventy-five percent of female locations and 60% of male locations were found on approximately flat ground. Of the locations found on a slope, the mean slope for male locations was 4.8% ( $\pm 3.9$ ) while the mean for females was 4.2% ( $\pm 3.8$ ). When sage-grouse were not on flat ground, the

greatest fraction of all sage-grouse were found on a northeast-facing aspect (37.5% of the females and 32% of males were found on aspects facing this direction compared to the other 7 cardinal and subcardinal directions).

We encountered the following plant species when measuring winter habitat plots: low sagebrush, silver sagebrush, stiff sagebrush, basing big sagebrush, mountain big sagebrush, Wyoming big sagebrush, gray and green rabbitbrush, bitterbrush, a woody *Eriogonum* spp., and western Juniper. The most frequent cover types were low sagebrush, and both mountain and Wyoming subspecies of big sagebrush. Four plots were located in silver sagebrush, but only females were associated with this sagebrush species. The only common non-sagebrush shrub often found within winter plots was both subspecies of rabbitbrush. Males and females used plots with different dominant shrubs providing cover (Table 4). Females used plots with more cover from big sagebrush and silver sagebrush, whereas males used plots with more cover provided by low sagebrush and rabbitbrush. Of all sage-grouse found in big sagebrush, 80% of the plots were Wyoming big sagebrush whereas 20% were mountain big sagebrush.

We calculated  $AIC_c$  and  $\Delta AIC_c$  for each model (Table 5). The model with the smallest  $AIC_c$  value was the global model including all variables and interactions. The second best model ranked 0.914  $AIC_c$  units away from the first, and excluded the interaction of elevation and live cover. Due to the fact that interactions are in all the top models, it was not possible to calculate the odds that a female greater sage-grouse was present given a particular value of the explanatory variables compared to males.

To better understand how characteristics of habitats used changed with date, we examined how percent live cover and height changed through the study period using simple linear regression with repeated measures for each sex. There was a significant positive linear relationship for females between percent live canopy cover and date (estimate:  $0.2421 \pm 0.1155$ ;  $Z \text{ Pr} > |Z|$ : 0.0360) but that there was not a significant linear relationship for males between percent live cover and date ( $Z \text{ Pr} > |Z|$ : 0.8386). We found no significant linear relationships between canopy height and date for females ( $Z \text{ Pr} > |Z|$ : 0.2655) or males ( $Z \text{ Pr} > |Z|$ : 0.8099).

The remaining six females alive late in the study period stopped using low sagebrush after 15 Feb 2007, switching to communities dominated by big sagebrush habitat types during this period (Figure 4). Two females moved into an area where low sagerush was present in small, isolated pockets within a Wyoming big sagebrush dominated landscape. This information indicates that the difference in live canopy cover chosen between sexes may be due to the change in habitat types that the females were located in during mid February.

### *Survival rates*

We calculated percent survival to be 95.5% out of 22 grouse total. Only one female sage-grouse perished around the estimated date of death 24 Feb 2007. The mean number of exposure days since the beginning of the winter study period was 59 for females and 60 for males, with corresponding daily mortality rates of 1.7% and 0%.

## DISCUSSION

We described structural characteristics of habitat used by sage-grouse in central Oregon in January and February of 2006. Compared to the averages for this area during the same time period, there was half as much precipitation (and subsequently little to no snow collected on the ground) but temperatures were similar. We documented sagebrush heights in sites used by sage-grouse that varied from 0.25 to 0.75 m, where females tended to use sites with a smaller percentage, as well as taller, cover than those used by males. We found this difference to be related to the change in habitat use as late winter moved into early spring because female sage-grouse completely stopped using low sagebrush after 15 Feb 2007.

Past studies have characterized preferred winter habitat of greater sage-grouse to include preferred sagebrush with specific heights (Connelly et al. 2000), and choice of winter habitats may be influenced by topographic factors such as slope and aspect (Beck 1977, Hupp and Braun 1989). These studies were conducted on Greater and Gunnison sage-grouse winter habitat studies have occurred in Colorado and Montana, where depth of snow (15- 25 cm) may have had a large effect on structural and topographic factors influencing choice of winter habitat. Conditions during our study strongly contrast with these studies in that the limited number of winter snow storms we encountered generally resulted in a shallow depth of snow that melted off within 10 days. Differences in snow depth may explain why the northeast aspect that greater sage-grouse were found on during our study differed considerably from those selected



by sage-grouse in Colorado (Beck 1977, Hupp and Braun 1989 ). Those studies typically found flocks located on south- to west-facing slopes, but use of these exposures was assumed to be related to depth of snow on northeast exposures where wind created snow drifts that covered most sagebrush. However, our study is similar to Beck's in that 60-70% of sage-grouse were located in areas with less than 5% slope. Eng and Schladweiler (1972) also found that most sage-grouse locations were in areas with little slope.

Winter habitat used by sage-grouse has, in other states, been reported to be influenced by the amount of big sagebrush exposed above the snow (Beck 1977), and these past studies had snow when they measured sagebrush as being either 0.25 – 0.46 m above the snow, or having a total sagebrush height of 0.41 – 0.56 m (Connelly et al. 2000). These contrast strongly with our reported average canopy height range of 0.25 to 0.75 m. We suggest that this larger range may be that our study lacked enough snow to cover sagebrush, and the period we measured sagebrush height in plots used by sage-grouse extended into late winter/early spring when females tended to begin using taller sagebrush.

We found that, overall, sage-grouse were most often observed using low sagebrush compared to big sagebrush, which agrees with studies conducted in Idaho and Nevada (Connelly 1982, Klebenow 1985). This maybe due to the fact that low sagebrush is more palatable to sage-grouse than all subspecies of big sagebrush (Rosentreter 2005). However, even though snow depth was presumed to be a factor driving sage-grouse to taller sagebrush in the study by Barrington and Back (1984),

Wyoming big sagebrush was still used during our study even with little snow as well as presence of low sagebrush within the study site. Our findings contrast with some findings from a (1992-93) study conducted 65 km east of our study site during a winter with more snow (Hanf et al 1994). In that study, 20 out of 44 sage-grouse were observed in low sagebrush while the others were observed in mountain big sagebrush (Hanf et al. 1994). In contrast, we consistently found 16 out of 22 sage-grouse in low sagebrush. However, of sage-grouse found in big sagebrush, 80% were Wyoming big sagebrush whereas 20% was mountain big sagebrush. It is possible that this difference is due to the habitat types available as well as topographical variation present between the two study sites, along with the fact that the winter conditions differed. Yet this finding is consistent with big sagebrush presence in past studies that have reported sage-grouse preference for either mountain big sagebrush (Welch et al. 1998, 1991) or Wyoming big sagebrush (Remington and Braun 1985, Myers 1992).

Sage-grouse are known to move rather long distances within and, especially, between seasons (Berry and Eng 1985). We found that movements of sage-grouse to and from wintering areas were well within the extremes found by past studies. The sage-grouse we studied did not travel more than 40 km to wintering areas, compared to studies conducted in Colorado, Idaho, Montana, and Wyoming that reported movements between 16 and 180 km (Dalke et al. 1960, Wallestad 1975, Martin 1976, Beck 1977, Connelly et al. 1988). The average daily movements moved during winter were 425 m for the sage-grouse we studied, which is 35 % less than the observed minimum daily movements of 1.21 km from the majority of the sage-grouse studied in

central Montana by Eng and Schladweiler (1972). One of the major differences between our study and that by Eng and Schladweiler is that they found bird locations daily, while we estimated minimum daily distances moved from data gathered on locations every 7 to 13 days, which underestimates daily movements. Another factor that contributes to our underestimation of actual distances that sage-grouse probably moved during winter is that the straight line distance calculation doesn't take into account distances sage-grouse move altitudinally from one area to the next.

Sage-grouse migration patterns vary mostly according to seasonal habitat quality and weather, and populations can have individuals that are seasonal migrants as well as residents (Eng and Schladweiler 1972, Wallestad 1975a). We determined that this sage-grouse population is a resident population, as opposed to a migrant one, according to criteria explained by Eng and Schladweiler (1972) and Wallestad (1975a). However, it is possible that this population of sage-grouse could be described as migrant if more severe winter weather caused grouse to move longer distances in order to find appropriate food and cover.

Distances moved can influence mortality risk (Yoder et al. 2004), so it's possible that the high survival rate of 95.5% during our study suggests that the relatively smaller daily movements were not associated with increased mortality. The survival rate we determined is slightly higher than a study done by Aldridge et al. (2004) in Alberta, Canada who found that adult female sage-grouse survival during winter was 88% for 2002/03 and 73% 2003/04. These slightly lower survival rates may be due to the fact that snow is generally deeper, leaving less food available to

sage-grouse in Alberta compared to Oregon. Also, confounding habitat and topographic elements related to sage-grouse survival that differ between these areas may exist. Additionally, male survival rates were not determined by Aldridge and there may be survival rate differences between sexes. A factor that may explain high winter survival rates for sage-grouse is that they have been found to gain weight during late winter (January through March); those weight gains may be more important for meeting the increased energy demands of breeding instead of overwinter survival (Beck and Braun 1978).

January through March includes a transition period between late winter and spring for greater sage-grouse. From mid February through March males and females generally begin preparing for the breeding season. In the year of our study, groups of males were first seen strutting at leks on the 10<sup>th</sup> of February, although many males did not arrive at leks until about 2 weeks later. Also, late March is the average copulation date for sage-grouse in Oregon (Batterson and Morse 1948), and females begin to seek out nesting habitats that provide a specific type of cover for nesting, typically 1 – 2 weeks before copulation (Bradbury et al. 1989a). This nesting area usually includes an average sagebrush height of 36 – 79 cm with 15 – 38% sagebrush cover and 3 – 30% residual grass cover (Schroeder et al. 1999). Therefore, our study period may encompass not only the habitat preference of sage-grouse during winter but also that of early spring, especially by pre-nesting females. This information helps to explain why we found an interaction between date, live canopy cover and canopy height that differed among sexes. We conclude that the significant difference in choice

between male and female greater sage-grouse for live canopy cover was probably due to the change in habitats used by females as the study period progressed.

## MANAGEMENT IMPLICATIONS

Based on a year of limited snow cover, we recommend management strategies for winter habitats that restore or enhance a mosaic of low, mountain, and Wyoming big sagebrush with sagebrush heights ranging from 0.25 m to 0.75 m tall in areas that have a large percentage of flat ground and/or areas having no greater than 10% slope and provide northeast aspects. However, these inferences are limited by a single winter field season that identified habitat characteristics chosen by 22 sage-grouse during a mild winter, so this information may only be beneficial for this population of sage-grouse during similar winters. Compared with long-term mean weather characteristics for January through February for this area, the range of temperatures was wider and precipitation was much less. The weather during our study was 1.4 ° C cooler than the mean minimum temperature for this period, and 1.2 ° C warmer than the maximum temperature. The mean precipitation during our study was 1.6 cm below, or 48.4% of, the long term mean precipitation for the area. Therefore, the time period of our study had a larger range of temperatures, and was much drier than average overall. Also, though this study found that most sage-grouse were located in low sagebrush, various types of sagebrush habitat are necessary to provide differing sagebrush heights and cover during winter as snow depth may be a limiting factor to sage-grouse survival during winters with more precipitation. Furthermore, since we

measured use and not selection of habitat, additional data is needed to determine what habitats are available on the landscape if sage-grouse choice is to be evaluated for certain winter habitat characteristics over other habitat types.

We also recommend that efforts to preserve sagebrush habitats at the landscape level continue to be made. The 22 sage-grouse we studied moved up to 38 km across the landscape during our study, and represented an area of at least 1,480 km<sup>2</sup>. As sage-grouse seek different levels of cover or different compositions of sagebrush communities for food and shelter, they will require a landscape large enough to provide such habitats. Effective sage-grouse management efforts to create or maintain habitat diversity on extensive tracts large enough to encompass a mosaic of habitat types for different seasons is essential for the long-term conservation of sage-grouse populations.

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Table 1: Distribution of months in which birds radio-tracked in our study were first captured in central Oregon.

Year	Month	Males	Females
2006	Mar	2	2
	Apr	5	0
	May	3	0
	Oct	1	3
	Dec	4	2

Table 2: Correlation matrix of all winter vegetation variables. Seventeen out of 132 possible pairs of variables had a Pearson correlation p-value of < 0.05. Sagebrush codes: ARAR= Low, ARTR= Big, ARCA= Silver, and CHVI= Rabbitbrush.

	Deadcov	Livecov	Totcov	Elev	Height	Slope	Aspect	ARAR	ARCA	ARTR	CHVI	Other
Deadcov	1.000	0.356	0.508	0.105	0.142	-0.002	0.021	0.425	-0.179	0.349	0.029	0.135
Livecov	-	1.000	0.986	-0.236	-0.408	-0.376	-0.175	0.816	-0.199	-0.158	0.713	0.578
Totcov	-	-	1.000	-0.198	-0.351	-0.347	-0.165	0.829	-0.216	-0.083	0.662	0.557
Elev	-	-	-	1.000	-0.179	0.642	-0.223	0.159	-0.329	-0.102	-0.563	-0.277
Height	-	-	-	-	1.000	-0.047	0.112	-0.662	0.474	0.876	-0.385	-0.132
Slope	-	-	-	-	-	1.000	0.106	-0.108	-0.335	-0.054	-0.343	-0.222
Aspect	-	-	-	-	-	-	1.000	-0.123	-0.304	-0.041	0.124	-0.145
ARAR	-	-	-	-	-	-	-	1.000	-0.534	-0.454	0.420	0.351
ARCA	-	-	-	-	-	-	-	-	1.000	0.378	-0.242	-0.297
ARTR	-	-	-	-	-	-	-	-	-	1.000	-0.260	-0.048
CHVI	-	-	-	-	-	-	-	-	-	-	1.000	0.590
Other	-	-	-	-	-	-	-	-	-	-	-	1.000

Table 3: Male and female greater sage-grouse were found at similar time intervals and moved similar distances from 8 Jan - 9 Mar 2007, in central Oregon. Minimum distances are defined as the straight line distances calculated between two locations.

Movement Variable	N	Mean ( $\pm$ SD)	Range	N	Mean ( $\pm$ SD)	Range
Minimum Distance (m)	7	4005 ( $\pm$ 2948)	833 - 8849	13	4031 ( $\pm$ 3227)	891 - 12807
Days Between Locations	7	9 ( $\pm$ 2)	7 - 11	13	10 ( $\pm$ 3)	6 - 14
Daily Average Distance (m)	7	427 ( $\pm$ 276)	107 - 845	13	426 ( $\pm$ 284)	85 - 1045

Table 4: Percent composition of shrub species cover present in habitat plots differed among male and female greater sage-grouse in central Oregon during winter, 2006-7.

Plant Species	N	Female			Male		
		Mean ( $\pm$ SD)	Range	N	Mean ( $\pm$ SD)	Range	
<i>A. arbuscula</i> <sup>a</sup>	7	11.2 ( $\pm$ 11.5)	0–28.2	15	23.6 ( $\pm$ 9.3)	2.8–37.0	
<i>A. tridentata</i> <sup>a</sup>	7	6.7 ( $\pm$ 3.7)	0–11.7	15	2.3 ( $\pm$ 3.3)	0–12.3	
<i>A. cana</i> <sup>a</sup>	7	3.3 ( $\pm$ 5.8)	0–15.2	15	0.0 ( $\pm$ 0.0)	0	
<i>C. viscidiflorus</i> <sup>a</sup>	7	1.1 ( $\pm$ 0.9)	0–2.7	15	5.9 ( $\pm$ 4.6)	0.5–17.7	
Other <sup>a</sup>	7	0.9 ( $\pm$ 2.0)	0–5.3	15	1.8 ( $\pm$ 1.4)	0.1–5.0	

<sup>a</sup> Significant difference between sexes, Mann-Whitney U test,  $p < 0.05$ .

Table 5: The top 20 models according to  $AIC_c$  of habitat characteristics in plots used by male and female greater sage-grouse throughout the study period in central Oregon. Models with  $\Delta AIC_c$  less than 2 are bold-faced.

Models	$AIC_c$	$\Delta AIC_c$
<b>date elev livecov elev*livecov livecov*date elev*date</b>	<b>99.562</b>	<b>0</b>
<b>date elev livecov livecov*date elev*date</b>	<b>100.476</b>	<b>0.9141</b>
date elev elev*livecov livecov*date elev*date	102.124	2.5618
date elev*livecov livecov*date elev*date livecov	103.271	3.7093
date elev livecov elev*date	105.124	5.5618
date elev elev*livecov elev*date	105.285	5.7229
livecov elev*livecov livecov*date elev*date	105.397	5.8356
livecov livecov*date	105.459	5.8975
livecov elev*livecov livecov*date	105.634	6.0718
livecov	105.852	6.2904
livecov elev livecov*date elev*date	106.004	6.4423
livecov date elev*livecov livecov*date	106.348	6.786
livecov elev livecov*date	106.387	6.8247
elev*livecov	106.402	6.8403
livecov date livecov*date	106.488	6.9262
livecov livecov*date elev*date	106.514	6.952
elev*livecov livecov*date	106.545	6.9827
elev elev*livecov livecov*date	106.754	7.1923
date elev livecov elev*livecov elev*date	107.06	7.4982



Figure 1: Greater sage-grouse winter study area in central Oregon ( $43^{\circ} 39' 35.12''\text{N}$   $120^{\circ} 04' 59.85''\text{W}$ ), 2007.

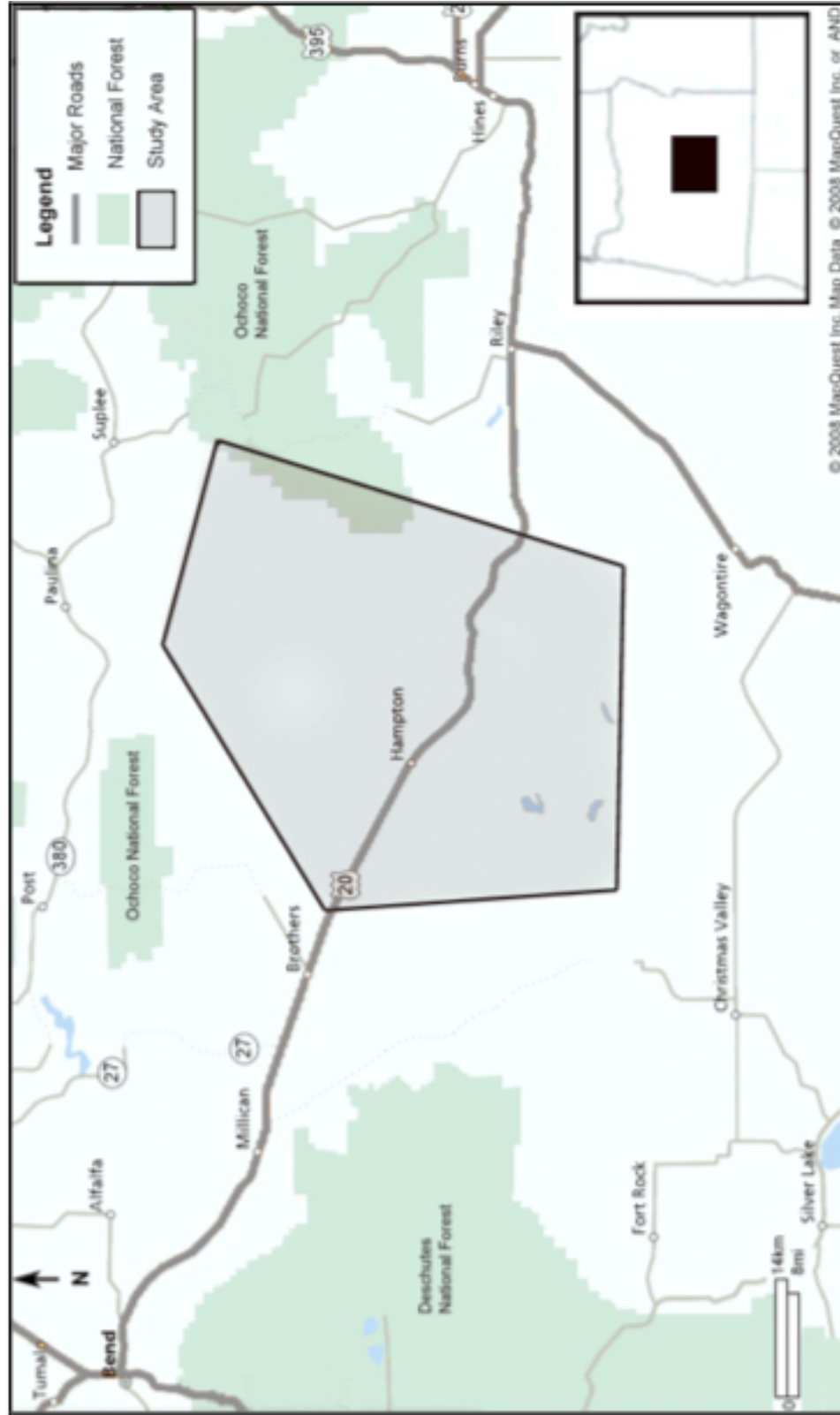
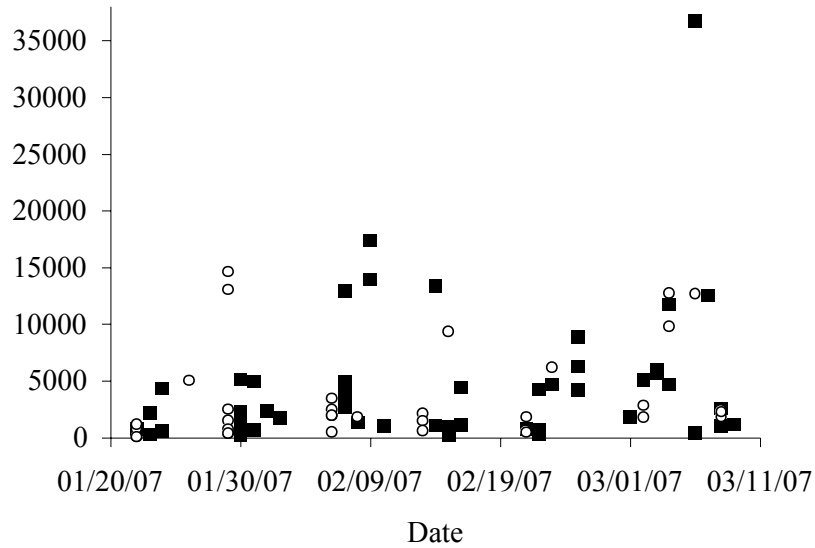


Figure 2: Minimum (A) and average daily (B) distances moved between locations by males (solid squares) and females (open circles).

**A**



**B**

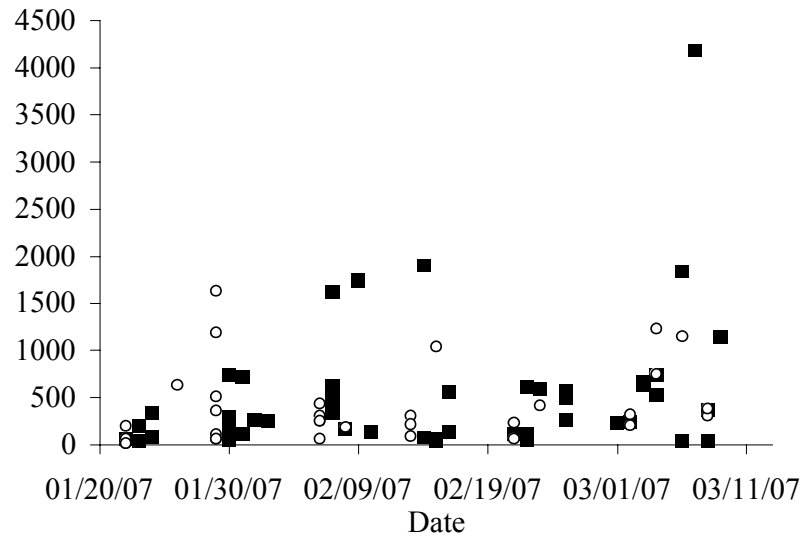


Figure 3: Winter habitat characteristics of plots used by male and female greater sage-grouse in central Oregon. Figures illustrate means  $\pm$  1 SD and ranges; outliers are depicted by circles. Mann-Whitney U-test statistics and p-values for each group are as follows: A=82.0; 0.9438, B=50; 0.0345, C= 55; 0.0780, D= 87; 0.6721, E=107; 0.0668, F= 74.5; 0.6982.

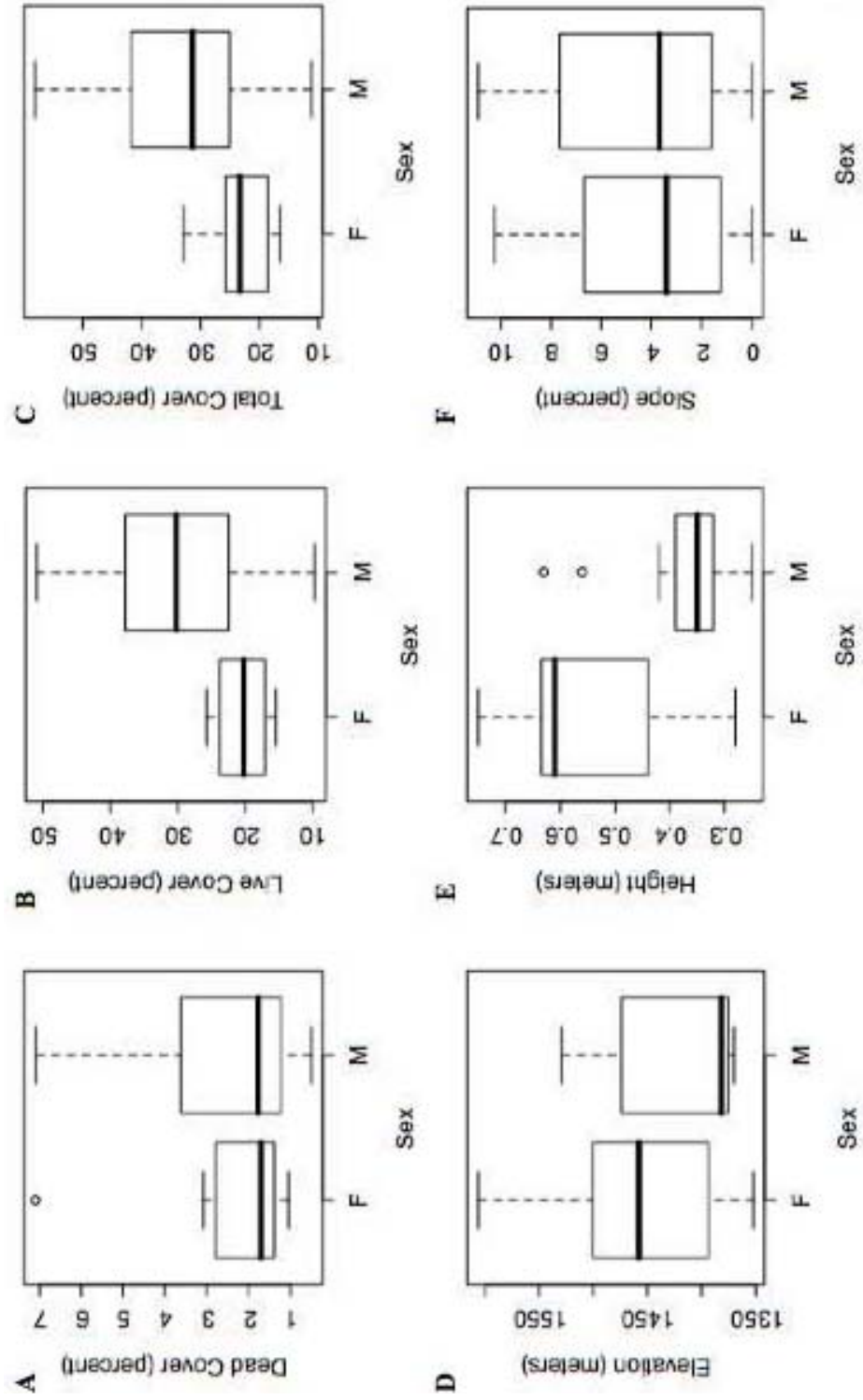
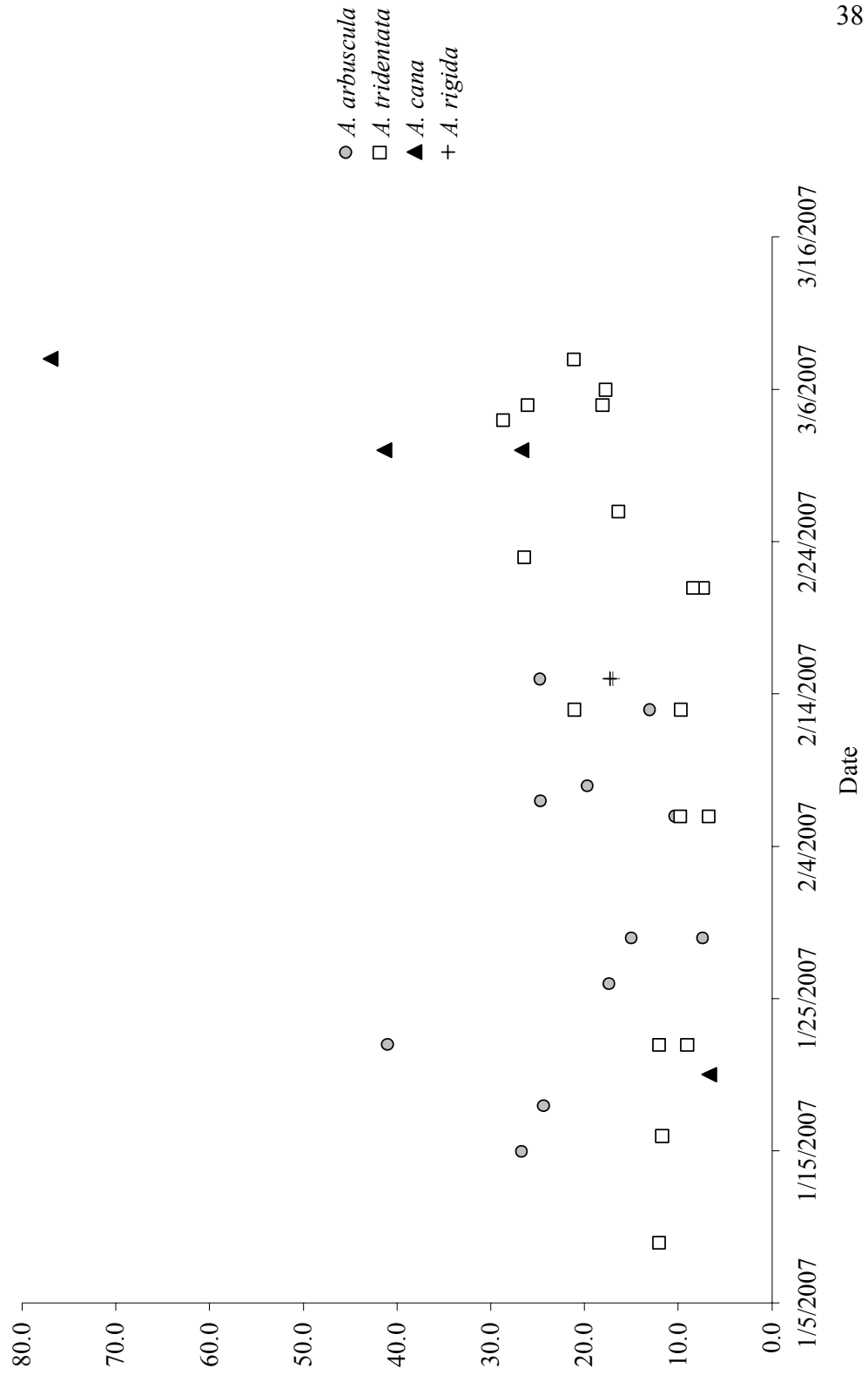


Figure 4: Dominant sagebrush type plotted against live percent cover for each female plot as the season progressed. Two females used isolated pockets of *A. arbuscula* within an *A. tridentata* dominated landscape later in the study period.



## Appendix 1: Winter habitat plot layout

