Interspace/Under-canopy Foraging Patterns of Beef Cattle in Sagebrush Communities: Implications to Sage-grouse Nesting Habitat

by
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A THESIS

submitted to

Oregon State University

In partial fulfillment of
the requirements for the
degree of

Master of Science

Presented September 9, 2005
Commencement June 2006

AN ABSTRACT OF THE THESIS OF

Kevin A. France for the degree of Master of Science in Rangeland Resources presented on September 9, 2005.
Title: Interspace/Under-canopy Foraging Patterns of Beef Cattle in Sagebrush Communities: Implications to Sage-grouse Nesting Habitat.

Abstract approved:

Chad S. Boyd David C. Ganskopp

Livestock grazing has been indirectly related to sage-grouse (*Centrocercus urophasianus*) declines in the western United States and southern Canada; however, there is a lack of scientific research that directly relates the two. Our objective was to investigate the influence of livestock herbivory on sage-grouse nesting habitat by determining the spatial aspects of cattle forage selection patterns and possible changes in screening cover as forage utilization increases. An eighteen-day, replicated, small pasture trial was conducted in the summers of 2003 and 2004. This trial (trial 1) was developed to initially examine a null hypothesis that cattle foraged on interspace and under sagebrush canopy grasses with equivalent frequencies. If that hypothesis was deemed invalid, we hoped to determine the level of forage utilization at which cattle began to differentially access grasses adjacent to and under sagebrush canopies (*Artemisia* L. spp.). Understory grasses provide important cover for nesting sage-grouse. Four pastures (6.1 to 6.5 ha) were fenced in a

Wyoming big sagebrush (*Artemisia tridentata* ssp. *wyomingensis*) community and each stocked with 3 to 4 yearling heifers (mean 385 kg). Within each pasture we randomly selected 30 sagebrush plants, marked a perennial grass tussock under the canopy of each sagebrush, and a second grass tussock of the same species in the adjoining interspace. Grass plants were checked every second day after turnout and given a grazed or un-grazed score. Shrub measurements (height, area, volume, and angle of accessibility of the under-canopy plants) were taken for each sagebrush to evaluate the influence of shrub morphology on grazing occurrence of under-canopy grasses. Visual obstruction for potential nest sites was evaluated using a modified Robel pole viewed from 2m to document changes in obstruction with increasing herbaceous utilization. Changes in standing crop and utilization (by weight) were assessed weekly by clipping 20 random 1-m^2 plots in each pasture. Grazing of under-canopy plants was negligible at light to moderate levels of utilization (e.g. < 10% of under-canopy plants were grazed when 30% of the standing crop was utilized). At utilization levels >35%, under-canopy plants were used with increasing frequency ($P<0.0001$). Logistic regression indicated angle of accessibility ($P <0.0001$) was the only shrub morphology variable influencing grazing occurrence of under-canopy grasses. As angles increased grazing susceptibility increased. Visual obstruction decreased over time, but consistently across all strata. We erroneously anticipated a strata X utilization interaction as the herbaceous level was grazed and trampled by the cows ($p = 0.9995$). Possible explanations include 1.) ephemeral leaf fall from sagebrush and the grazing effects on the removal of the herbaceous component coincided, 2.) the physical and foraging activities of cattle affected all strata equally, or perhaps some combination of these. The fact that 75% removal of standing crop and affected only a 5% decrease in the ground level obstruction suggests that sagebrush constitutes the bulk of the obstructing cover.

A larger 800ha pasture was utilized in 2003 and 2004 to test the influence of plant position on probability of grazing at larger pasture scales and to examine the modifying influence of geophysical landscape characteristics (Trial 2). We randomly selected 30 sagebrush plants and under-canopy and interspace grasses as described for trial 1. Shrub morphology variables were quantified (as per trial 1) and we derived several geospatial characteristics for each location. Grass plants were checked every 4th day after turnout and given a grazed or un-grazed score. Standing crop and overall herbage utilization were assessed by clipping 30 randomly located 1m^2 plots at the beginning and end of the trial, and utilization was indexed at 4 day intervals by noting frequency of herbivory on 10 grass plants near each marked sagebrush. For trial 2, livestock did not display a conclusive preference for plant position as herbage utilization increased (2003: $P = 0.07$, 2004: $P = 0.47$, and Pooled: $P = 0.28$). Differences in stocking rates between the 2 years indicated that forage selection patterns and livestock distribution were most influenced ($P = 0.0002$) by slope ($P = 0.036$), distance from water ($P = 0.0061$), and stocking density ($P < 0.0001$). When plant locations relative to sagebrush canopies were analyzed separately, distance from water affected grazing of interspace plants ($P < 0.0001$), while stocking intensity influenced grazing of under-canopy plants ($P = 0.011$).

In summary, cattle use of under-story plants was minimal until herbage utilization exceeded about 35% utilization for trial 1. Livestock grazing at “moderate” levels would reduce impacts on screening cover for sage-grouse nesting habitat. At larger pasture scales there are management opportunities for modifying livestock distribution to reduce grazing impacts within critical sage-grouse nesting habitat.

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Master of Science thesis of Kevin A. France presented on September 9, 2005.

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Head of the Department of Rangeland Resources

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ACKNOWLEDGEMENTS

I would like to extend great appreciation to Chad Boyd and David Ganskopp and their families for all of their support and input into this project. Without your support this would have never been accomplished. A special thanks to Oregon Cattlemen's Association for their insight into the needed research. Thanks to the employee's of Oregon State University, Rangeland Resources department and ARS in Burns, Oregon for their support and use of facilities. Thank you all very much.

CONTRIBUTION OF AUTHORS

Drs. Chad Boyd and David Ganskopp assisted with experimental design, data collection, writing, and editing of all chapters.

Dustin Johnson assisted with data collection and editing. Joanna Hurlbert assisted with data collection.

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INTERSPACE/UNDER-CANOPY FORAGING PATTERNS OF BEEF CATTLE IN SAGEBRUSH COMMUNITIES: IMPLICATIONS TO SAGE-GROUSE NESTING HABITAT

CHAPTER 1:

GENERAL INTRODUCTION

While herbivory is not a new disturbance to sagebrush/steppe communities (*Artemisia* L. spp.) within the Great Basin (Burkhardt 1996), introduction of domestic livestock to the region in the late 1800's had a profound impact on the system's ecology (Miller et al. 1994). Historical grazing practices consisted of unregulated season-long use combined with excessive stocking rates (Young and Sparks 1985). These practices resulted in dramatic alterations in sagebrush communities including an increase in non-native plants (Young et al. 1976), decrease in forbs and perennial grasses (Young et al. 1976), altered fire regimes (Whisenant 1990), and an increase in sagebrush density (Miller et al. 1994). Grazing management practices have improved substantially over time (Laycock et al. 1996). Present day management challenges include overcoming problems resulting from historical grazing practices (e.g. non-native plants) as well as facing new management difficulties like developing grazing strategies complementary to the needs of wildlife.

Historically, sage-grouse (*Centrocercus urophasianus*) inhabited most of the sagebrush communities in the western US and western provinces of Canada (Klebenow 1985, Connelly and Braun 1997, Crawford et al. 2004). However, since European settlement 40% of these shrub-steppe communities have been extirpated

(Braun et al. 1977, and Wisdom et al. 2002). Coinciding with the loss of sagebrush communities, sage-grouse populations have declined to 50% of historic estimates over the past 50 years (Connelly and Braun 1997). Reductions in sage-grouse populations have been associated with historic and current habitat degradation (Miller and Eddleman 2001), and have prompted an increased interest in defining impacts of land management practices on habitat quality for this species. Habitat modification and degradation have been associated with changes in fire regimes, excessive livestock grazing, increases in non-native plants, conversion to cropland, seeded pastures, roads and energy development, and other land alterations (Klebenow 1970, Braun and Beck 1996, Beck and Mitchell 2000). Fire suppression in high elevation sagebrush communities has contributed to western juniper (*Juniperus occidentalis* Hook.) encroachment, and more frequent fire return intervals at lower elevations have fostered invasions by annual grasses (Miller et al. 1994, Miller and Eddleman 2001).

Some speculate that livestock grazing has negatively impacted sage-grouse populations by decreasing residual cover, reducing forage quality and quantity, and lowering nesting success for sage-grouse (Sveum 1998, Gregg 1992) and other ground nesting birds ((e.g. western meadow lark (*Sturnella neglecta*), common nighthawk (*Chordeiles minor*), common poorwill (*Phalaenoptilus nuttallii*), horned lark (*Eremophila alpestris*), hermit thrush (*Catharus guttartus*), vesper lark (*Poaecetes gramineus*), savannah sparrow (*Passerculus sandwichensis*), song sparrow (*Melospiza melodia*) and white crowned sparrows (*Zonotrichia *leucophyrs*)) (Guthery 1996). Sage-grouse typically nest beneath sagebrush that are 40-80cm tall (Gregg et al. 1994, Connelly et al. 2000, Crawford et al. 2004). Additional cover from adjacent herbaceous vegetation can increase nest concealment and decrease predation rates (Sveum et al. 1998, Watters et al. 2002). Bunnell et al. (2004) found that nest selection in Utah was correlated with higher amounts of canopy cover and taller vertical cover provided by grasses and forbs. Sage-grouse generally nest from March through April (Sveum et al. 1998), which is usually before current year herbage growth and livestock turnout. Consequently, current year's nesting cover typically consists of shrubs and residual vegetation from the previous growing season.

Sage-grouse inhabit a wide range of environments, both temporally (i.e. seasonally) and spatially. They utilize sagebrush habitat for nesting, brood rearing, and wintering (Sveum et al. 1998), and these same areas are grazed by livestock. While many speculate that recent sage-grouse declines are related to livestock grazing (Gregg et al. 1994, Delong et al. 1995, Connelly and Braun 1997), there is no direct experimental evidence relating the two. Previous research suggests near-nest herbage is important for sage-grouse nest concealment, and declines in abundance of this vegetation result in a higher frequency of nest predation (Gregg et al. 1994, Watters et al. 2002). In fact, sage-grouse tend to select nest sites with the highest amounts of sagebrush cover and tallest and densest herbaceous cover (Gregg 1992, Sveum et al. 1998). Gregg et al. (1994) reported that tall residual cover (mainly perennial grasses) was greater at successful nests than unsuccessful nests, and that cover of bunchgrasses within a 1-m radius of the nest site was positively related to nest success. The relationship between distance from the nest and concealing grass cover has not been investigated for successful vs. unsuccessful nests.

Indirect evidence suggests livestock grazing can have both positive and negative effects on nesting and brood rearing success for ground nesting birds (Guthery 1996). For example, grazing can attract sage-grouse to densely vegetated communities by opening habitat, stimulating forb growth (Severson and Urness 1994), and increasing the abundance of sagebrush leaves (Vale 1975). Sagebrush leaves are important because they constitute 90% of sage-grouse diets during winter months (Evans 1986). Excessive grazing, however, may predispose ground nesting bird clutches to predation (Errington 1993) and result in trampling of nests (Paine et al. 1996). Heavy grazing can reduce herbaceous cover needed for sage-grouse nesting success (Gregg 1992) and increase annual grass and weed invasions (Beck and Mitchell 2000).

In the Great Basin, sagebrush ecosystems are most frequently associated with bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), Thurber needlegrass (*Stipa thurberiana* Piper), squirreltail (*Sitantion hystix* (Nutt.) J.G. Sm.), and many other grasses and forbs (Barler and Mickell 1983, Shumer and Anderson 1986). Within these ecosystems, distribution of herbaceous under-story vegetation is generally sparse and heterogeneous. Livestock forage selection is usually dependent upon relative plant availability and bunchgrass structure (Ganskopp et al. 1992, Ganskopp and Rose 1992). Forage selection patterns of livestock in sagebrush-dominated communities have not been related to the spatial distribution of grass plants (e.g. interspace vs. under sagebrush canopy) or sagebrush morphology.

The utility of short-term and small-scale experiments is to provide insight into cause and effect relationships affecting large-scale systems (Gardner et al. 2001). However, research at small scales has been questioned for its applicability at larger management scales. Some view short-term studies as having limited application for predicting processes in large-scale systems; though, studies in smaller-scale systems usually uncover patterns sooner than in larger-scale systems (Gardner et al. 2001). The need for large-scale studies is related to current management practices involving livestock and wildlife management at landscape scales. Landscape scale environmental variables like slope, aspect, distance from water, and vegetation may influence the distribution and behavior of grazing animals (Bailey et al. 1996, Gillen et al. 1984, Kie and Boroski 1996, Owens et al. 1991, Pinchak et al. 1991, Senft et al. 1985). Small-scale studies may not exhibit the effects of landscape level variables on animal behavior because environmental variability is reduced.

The objective of this study was to relate grazing intensity/duration with grazing of under-canopy and interspace grasses. A second, landscape-scale study was used to relate grazing intensity/duration, geospatial, and site-specific variables with grazing of under-canopy and interspace grasses.

Objectives

1) Use small scale pastures (6 ha) to document the relative rates of utilization by cattle of interspace and under-canopy perennial bunchgrasses.

2) Determine the influence of sagebrush morphology on the occurrence of grazing by cattle on under-story perennial bunchgrasses.

3) Quantify possible changes in visual obstruction of potential sage-grouse nest sites with increasing herbaceous utilization in zones from ground level to a 1-m height.

4) Determine the influence of several geospatial characteristics and stocking pressure on the relationship between bunchgrass position (interspace vs. under-canopy) and grazing occurrence at larger pasture scales (up to 800+ha).

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CHAPTER 2:

Interspace/Under-CNOPY FORAGING PATTERNS OF BEEF CATTLE IN SAGEBRUSH COMMUNITIES: IMPLICATIONS TO SAGE-GROUSE NESTING HABITAT

ABSTRACT

Livestock grazing has been indirectly related to sage-grouse (*Centrocercus urophasianus*) declines in the western United States and southern Canada; however, there is a lack of scientific research that directly relates the two. Our objectives were to investigate the influence of livestock grazing on sage-grouse nesting habitat by determining forage selection patterns of cattle, the effects of shrub morphology on under-canopy grazing occurrence, and possible changes in screening cover as forage utilization increases. An eighteen-day, replicated, small pasture trial was conducted in the summers of 2003 and 2004 (trial 1). Grazing of under-canopy grass tussocks was negligible at light to moderate levels of utilization (e.g. $< 10\%$ of under-canopy plants were grazed when 30% of the standing crop was utilized). At utilization levels $>35\%$, under-canopy tussocks were used with increasing frequency ($P<0.0001$). Logistic regression indicated that angle of accessibility ($P <0.0001$) was the only shrub morphology variable influencing grazing occurrence of under-canopy grasses. As angles increased grazing susceptibility increased. Visual obstruction decreased over time, but the decline was consistent across all strata to a height of 1-m. We expected a strata X period interaction as the herbaceous vegetation level was grazed and trampled by cattle, but this interaction did not occur ($p = 0.9995$).

Removal of 75% of the standing crop affected only a 5% decrease in ground level obstruction suggesting that sagebrush constituted the bulk of screening cover.

A larger 800ha pasture was utilized in 2003 and 2004 to test the influence of plant position relative to sagebrush canopies on the probability of grazing at larger pasture scales and to examine the modifying influence of geophysical characteristics (Trial 2). Livestock did not display a conclusive preference based on plant position as pasture utilization increased (2003: $P = 0.07$, 2004: $P = 0.47$, Pooled: $P = 0.28$). Slope ($P = 0.036$), distance from water ($P = 0.0061$), and stocking density ($P < 0.0001$) affected the likelihood of forage selection across the pasture. In 2003, the mean herbage utilization as indexed by standing crop at the end of trial was 66% with a total 288 AUM's. In 2004, the mean herbage utilization by weight was 45% with a total of 144 AUM's.

In summary, cattle use of under-story plants was minimal until herbage utilization exceeded about 35% utilization for trial 1. That being the case, livestock grazing at "moderate" levels would have little effect on herbaceous screening cover. This work suggests management practices for modifying livestock distribution that could decrease forage utilization within critical sage-grouse nesting habitat.

INTRODUCTION

Because sage-grouse (*Centrocercus urophasianus*) depend upon sagebrush communities (*Artemisia* L. spp.) (Klebenow 1970, Braun et al. 1977, Connelly et al. 1991, Gregg 1992, Sveum et al. 1998), there is a need to determine the effects of livestock grazing on sagebrush and its associated herbaceous vegetation. Maintaining nesting success is critical to sustaining sage-grouse populations over time (Bunnell et al. 2004, Crawford et al. 2004). In spite of high reproductive potential, sage-grouse often exhibit low reproductive success due to nest failures (Crawford et al. 2004). Predation is a leading cause of low nest success, and habitat quality is inversely correlated with predation rates (Braun and Beck 1996, Sveum et al. 1998, Crawford et al. 2004). Sage-grouse generally nest under sagebrush plants (Sveum et al. 1998). Nest site selection is related to key structural features such as shrub canopy cover, shrub height, and residual bunchgrass screening cover, all of which have been correlated positively with nest success (Gregg 1992, Gregg et al. 1994). Research in eastern Oregon (Gregg et al. 1994) suggests successful nests are associated with increased canopy cover of medium height (40-80 cm) sagebrush, and bunchgrasses in the surrounding 3-m^2 area. Management guidelines for sage-grouse habitat recommended a 15-25% shrub canopy cover and >15% grass/forb cover at nest sites (Connelly et al. 2000, Connelly et al. 1991, Delong et al. 1995). Coyotes (*Canis latrans*), avian, and small mammal species are the main nest predators, however, adequate vegetation cover (sagebrush and bunchgrasses) provides visual, scent, and physical barriers that may decrease nest susceptibility to predation (Gregg 1992, Crawford et al. 2004). Livestock grazing has been indirectly implicated as one of the factors promoting sage-grouse declines in the western United States and southern Canada (Sveum et al. 1998, Gregg 1992). There is however, a lack of scientific evidence directly relating the two. At present, there is a need to describe forage extraction patterns of livestock grazing in the various sagebrush/steppe communities with respect to the needs of sage-grouse.

Historically, sage-grouse inhabited most of the sagebrush communities in the western U.S. and western provinces of Canada (Klebenow 1985, Connelly and Braun 1997, Crawford et al. 2004). Since European settlement, 40% of these shrub-steppe communities have been extirpated range-wide (Braun et al. 1977, Wisdom et al. 2002), and sage-grouse populations have dwindled to 50% of their historic estimate over the past 50 years (Connelly and Braun 1997). Reductions in sage-grouse populations have been associated with both historic and current habitat degradation (Miller and Eddleman 2001) including changes in fire regimes, excessive livestock grazing, increases in non-native plant species, conversions to cropland, seeded pastures, roads and energy development, and other land alterations (Klebenow 1970, Braun and Beck 1996, Beck and Mitchell 2000, Crawford et al. 2004).

Livestock grazing has occurred in sagebrush communities for over a century (Young et al. 1976, Laycock et al. 1996), but no study has directly assessed the effects of livestock grazing on sage-grouse habitat and/or population dynamics. Historic over-use of sagebrush communities by livestock brought about increases in sagebrush abundance, decreases in perennial grasses, and increases in non-native annual grasses (Young et al. 1972). In the past 50 years, grazing management and the condition of sagebrush communities have improved (Laycock et al. 1996), and research suggests that livestock grazing can be compatible with the maintenance of perennial grasses and forbs in sagebrush habitat (Miller et al. 1994, Bork et al. 1998). Excessive grazing however, can lead to decreases in perennial grasses and forbs, increases in non-native annual grasses, and increases in shrub density and abundance (Bork et al. 1998).

Tussock grasses are distributed throughout the interspaces and under canopies of sagebrush with no reported spatial trend or pattern. In these communities, forage selection by cattle is usually dependent upon relative plant availability and bunchgrass structure (Ganskopp et al. 1992, Ganskopp and Rose 1992). Specific foraging patterns by beef cattle in sagebrush communities, particularly interspace versus under-canopy grass plants, have not been investigated.

Small-scale studies have been criticized for their relevance at larger-scale management levels (Gardner et al. 2001). Large-scale studies are increasing as emerging technologies like GIS systems facilitate analyses. Fuhlendorf and Engle (2001) illustrated that traditional grazing management encourages uniform utilization of forages across the landscape. Such practices if carried to extremes could have detrimental effects on wildlife habitat. The use of heterogeneous grazing could increase biodiversity across the landscape. Tools to increase heterogeneity include: water placement, herding, drift fences, and strategic salt and mineral placement (Gillen et al. 1984, Bailey et al. 1996, Ganskopp 2001). Geospatial characteristics such as slope, aspect, topography, and distance from water have also been shown to effect livestock distribution and forage selection (Bailey et al. 1996, Gillen et al. 1984, Kie and Boroski 1996, Owens et al. 1991, Pinchak et al. 1991, Senft et al. 1985).

The objectives of this study were: 1) quantify cattle selection of interspace and under-canopy grasses at small pasture scales, 2) assess the influence of sagebrush morphology on the likelihood of under-canopy grazing by cattle, 3) quantify the affects of cattle grazing on nest site visibility, and 4) assess forage selection patterns of cattle at a landscape scale to evaluate the effects of geospatial variation, shrub morphology, and stocking rate on grazing behavior. We hypothesized 1) that forage selection would be affected by interspace/under-canopy location as forage utilization increased, 2) that shrub morphology would affect under-canopy plant grazing occurrence, 3) that visual obstruction would decrease in lower strata but not higher strata as forage utilization increased, and 4) that geospatial characteristics and stocking rates would influence foraging patterns at landscape scales.

MATERIALS AND METHODS

Study Sites

Two study sites were chosen for the trials. The first (trial 1) was used to investigate hypotheses 1 through 3. The second site (trial 2) was chosen to represent large-scale management scenarios and used to evaluate hypothesis 4. Both trials were conducted after the cessation of herbaceous growth within each season.

Trial 1

The small pasture study site was conducted on an intensively grazed setting 100km south of Burns, Oregon, near Foster Flat (42.98 N, 119.25 W). Elevation was approximately 1525m with a mean annual precipitation of 26.8cm (Anderson et al. 1998). Property is presently seasonal rangeland administered by the Bureau of Land Management and the site is sage-grouse nesting habitat (Willis 2004). Four pastures were established in a Wyoming big sagebrush (*Artemisia tridentata* Nutt. ssp. *wyomingensis* Beetle and Young)/bottlebrush squirreltail (*Sitantion hystix* (Nutt.) J.G. Sm.) community (Figure 1). Pastures ranged from 6.1 to 6.5 ha.

Standing crop and forage utilization were measured by clipping 20 randomly located 1-m^2 plots in each pasture at weekly intervals. The first clipping indexed initial standing crop, and subsequent data was used to measure herbage utilization as the study progressed. Stocking rate was based on the initial standing crop and the number of cattle needed to deplete the forage in a 16-18 day window. Four yearling heifers (325 kg) were stocked in each pasture for 18 days in 2003 from July 07 – July 25, and 3 yearling heifers were stocked in each pasture for 18 days in 2004 from July 20 – August 06.

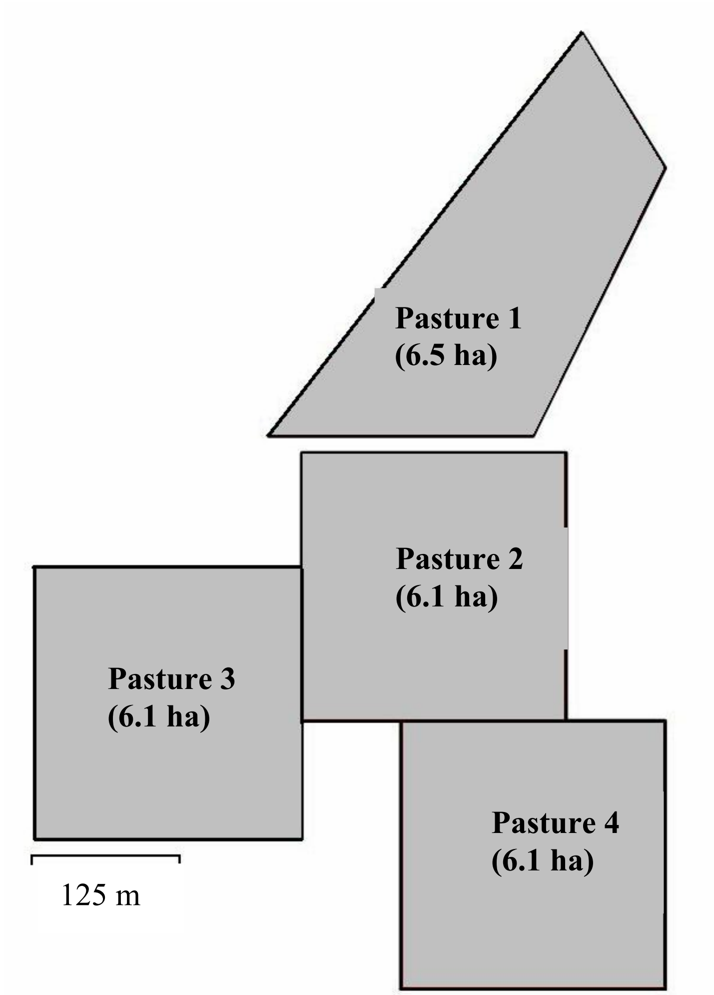

Figure 1: Four fenced pastures established for trial 1 at Foster Flat, Oregon, in which livestock grazed for 18 days for assessments of under-canopy and interspace utilization of grass tussocks in a Wyoming big sagebrush environment in 2003 and 2004.

Vegetation

Vegetation at Foster Flat was dominated by shrubs, grasses, and perennial and annual forbs. In order of dominance, shrubs included Wyoming big sagebrush, low sagebrush (*Artemisia arbuscula* Nutt.), and green rabbit-brush (*Chrysothamnus viscidiflorus* Pallas ex Pursh). Grasses included the dominant bottlebrush squirreltail, and the subordinates Thurbers needlegrass (*Stipa thurberiana* Piper), bluebunch wheatgrass (*Pseudoroegneria spicata* (Pursh) A. Love), and Sandberg's bluegrass (*Poa secunda* J. Presl). Associated dominant perennial forbs included low pussytoes (*Antennaria diamorpha* (Nutt.) Torr. & Gray), largeflower hawksbeard (*Crepis occidentalis* Nutt.), velvet lupine (*Lupinus leucophyllus* Dougle. ex Lindl.), and longleaf phlox (*Phlox longifolia* Nutt.). The dominant annual forbs included maiden blue eyed Mary (*Collinsia parviflora* Lindl.), western tansymustard (*Descurainia pinnata* (Walt.) Britt.), and fireweed (*Epilobium* spp. L.).

One 80 X 50 m (0.4 ha) macro-plot was used to quantify community composition in each pasture. Five, 50-m transects spaced at 20-m intervals were used to measure shrub canopy cover by the line intercept method (Canfield 1941). Sagebrush density was measured by counting the number of plants rooted within a 2 x 50m belt transect centered over each of the 50-m transects. Five, 50-m transects (per pasture) spaced at 20-m intervals were used to quantify herbaceous cover. Herbaceous cover was measured using twenty-five Daubenmire frames (20cm x 50cm,) spaced every 1-m per transect.

Project Design

The study was replicated in 2003 and 2004 with grazing commencing on July 7th and 20th, respectively. Trials began at the end of the growing season for the herbaceous community. Project design was a randomized complete block (n = 4) with 2 treatments (interspace and under-canopy grasses) (Figure 1). Thirty randomly generated UTM coordinates were derived for each of the 4 pastures (n = 120) to select sagebrush plants. Coordinates were then located in the field with a GPS unit and the nearest suitable sagebrush chosen (>40-cm in height).

Plant Position

Paired grass tussocks were marked at each sagebrush plant. We randomly selected one perennial tussock fully contained under the dripline of the sagebrush (under-canopy), and then selected the closest plant of the same species in the adjacent interspace between shrubs. Both plants were marked with white landscape rock near the tussock base (Figure 2). After livestock turn out (July 7th or 20th), grass plants were checked every second day and given a grazed (1) or un-grazed (0) score.

Figure 2: Permanently marked paired under-canopy and interspace tussock which were checked every second day to monitor grazing occurrence and determine preference of location on Foster Flat, Oregon study area in 2003 and 2004.

Shrub Morphology

Based on nesting site criteria described by Connelly et al. (2000), selection of suitable shrubs was limited to those >40cm in height. To assess shrub morphology, measurements were taken on each selected sagebrush plant. These included, maximum height, maximum diameter, and a second maximum diameter perpendicular to the first to facilitate the derivation of elliptical canopy area and volume. A measurement to characterize the accessibility of the under-canopy grass plants was taken by describing an angle of accessibility for each of the chosen tussocks. The bottom of a meter stick was placed against the edge closest to the dripline of the tussock in question and the stick was raised until it made contact with sagebrush foliage or twigs (Y). We then measured, a.) the ground distance from the point of canopy interception to the base of the grass plant (X), and b.) the distance vertically from contact point to the ground (Z). These 2 lengths provided ground (X) and height (Z) measures and the $\tan^{-1}$ function was used to determine the angle of accessibility (α) (Figure 3).

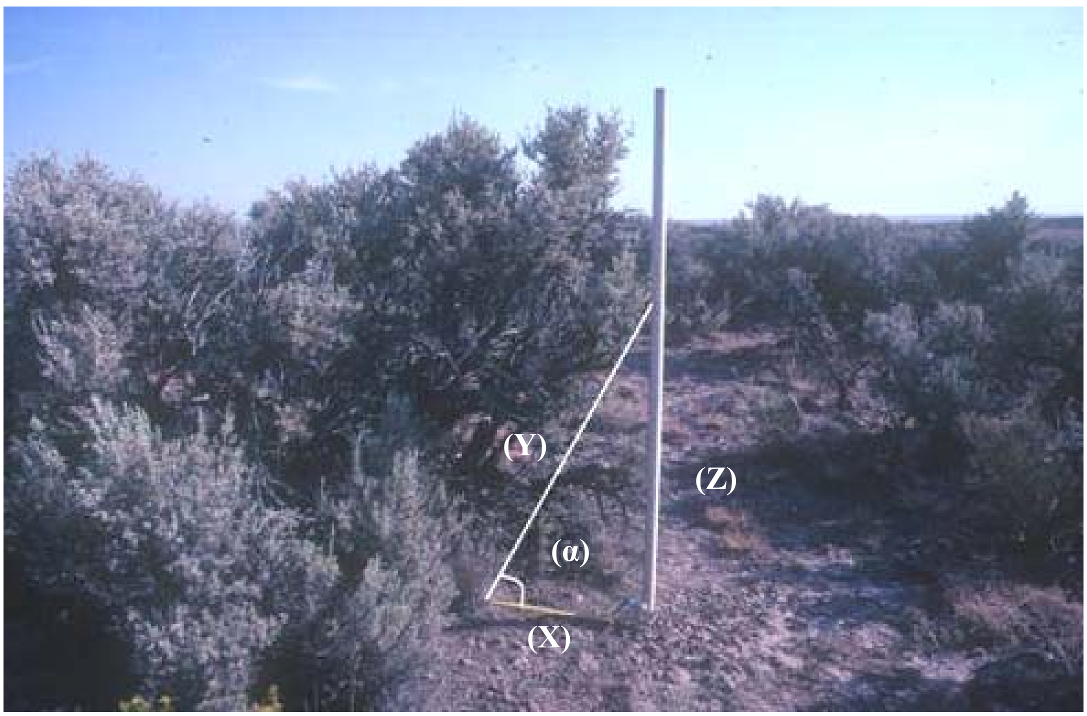

Figure 3: Angle of accessibility measurement to assess the vulnerability of under-canopy grasses to herbivory. Measurements were taken at the beginning of the trial for 2003 and 2004 at Foster Flat, Oregon.

Visual Obstruction

In 2004, we used a modified Robel pole (Robel et al. 1970) to estimate visual obstruction in the vicinity of each sagebrush plant (n = 120). The pole was 1-

m long and 2.5-cm in diameter. Dimensions for each band on the pole were 2.5-cm with a total of 39 bands (Figure 4). For purposes of data analysis, strata were developed by combining 3 bands (e.g. 1-3 bands = strata 1) with a total of 13 strata. Visual obstruction was evaluated by scoring the bands as visible (1) or not visible (0); percent obstruction for each stratum was then derived by averaging the band score for each stratum across all of the sampled sagebrush within a pasture and sampling date.

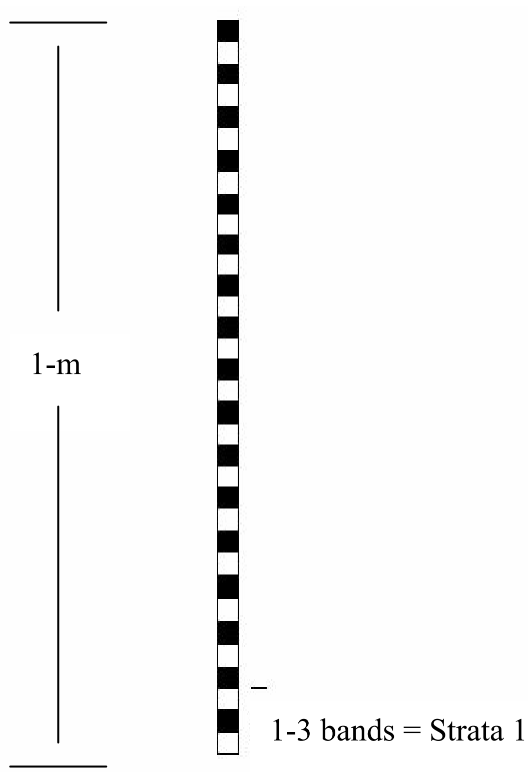

Figure 4: Modified robel pole 1 m used to measure visual obstruction of potential nesting sites at each sagebrush plot for 2004 at Foster Flat, Oregon.

The pole was located at a marked position at the base of each sagebrush, and 2 sighting positions were established in the interspace 2 m from the pole. The azimuth for the first position was randomly selected and the second position was in an interspace locale where the view was unobstructed by intervening sagebrush. The latter was an attempt to discount the influence of additional sagebrush and focus the measurement on just the herbaceous component of the community. Visual obstruction measurements were sighted from a height of 50cm, which approximates a coyote's eye level. All positions (viewing angles) were permanently marked with rebar and visual obstruction measurements were repeated at weekly intervals during the 2004 field season.

Trial 2

The study site for trail 2 was located 72km west of Burns, Oregon on the Northern Great Basin Experimental Range (NGBER) (119° 43'W, 43° 29' N). Elevation was approximately 1500m with a mean annual precipitation of 26.8cm (Anderson et al. 1998). The study site was located in a 800ha pasture (Figure 5). Relative to site 1, this area had a more variable physical environment with respect to slope, distance from water, aspect, topography, and plant communities. Stocking rates were different between years. In 2003, 180 cows grazed the 800 ha pasture for 48 days, and in 2004, 60 cows utilized the pasture for 72 days. These values translated to 288 animal unit months (AUM's) for 2003 and 144 AUM's for 2004.

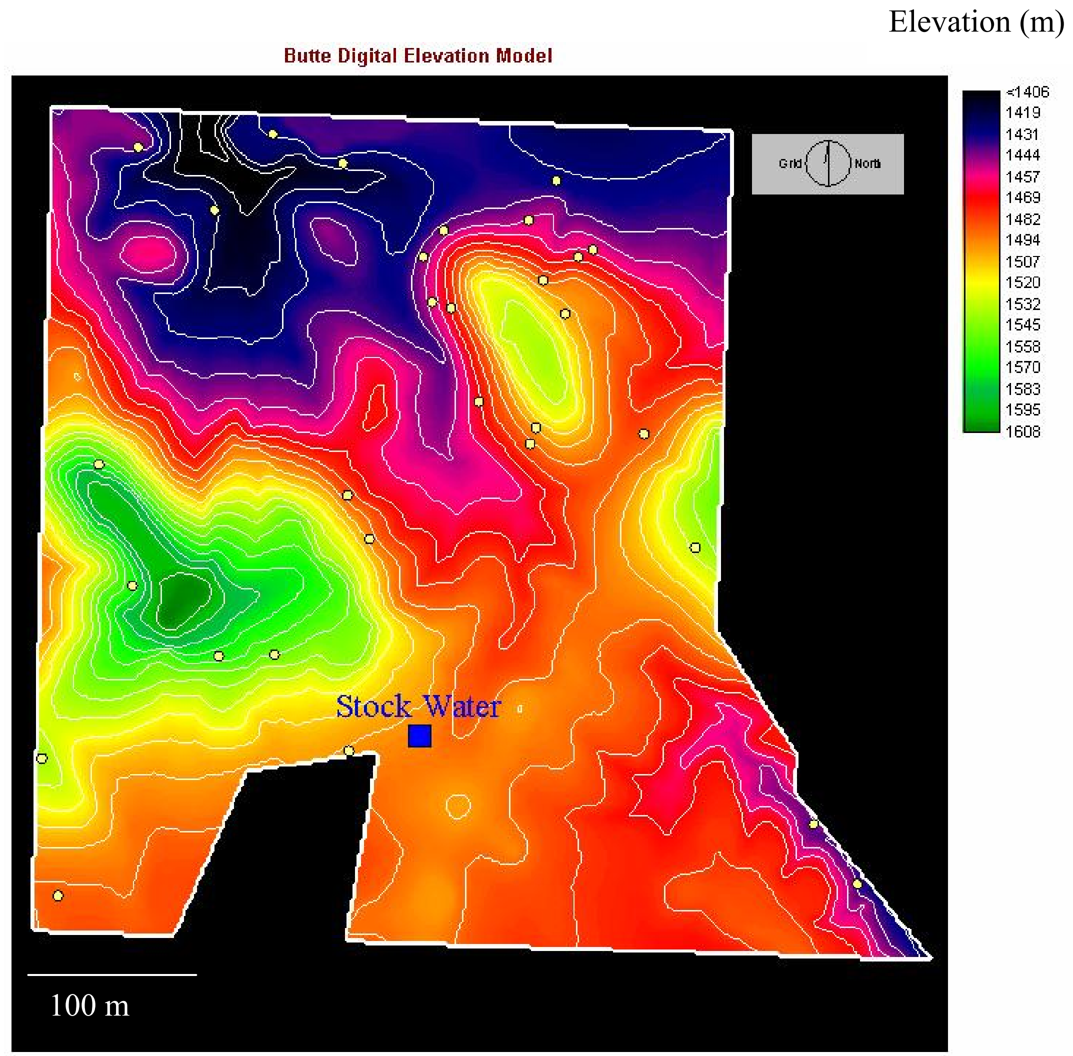

Figure 5: The 800ha fenced pasture with 30 randomly selected plots (white dots) which were used to locate the sagebrush and paired grass plants plot for trial 2 at the Northern Great Basin Experimental Range, Oregon in 2003 and 2004.

Vegetation

Plant communities within the 800ha pasture were characterized by a scattered western juniper (*Juniperus occidentalis* Hook.) overstory across about 60% of the pasture. Shrub dominants included Wyoming, mountain (*Artemisia* *tridentata* Nutt. spp *vaseyana* (Rydb.) Beetle), basin (*Artemisia tridentata* Nutt. spp. *tridentata*) and low sagebrush. Dominant under-story grasses included bluebunch wheatgrass, Idaho fescue, and sandberg's bluegrass; dominant forbs included *Antennaria* spp., *Agoseris* spp., and *Crepis* spp.

Project Design

Selection criteria and measurements for sagebrush/grass plants were identical to trial 1. We located thirty sagebrush and paired grass plants within the pasture, which were utilized for both years (2003 and 2004). For each paired plot we determined site-specific characteristics including elevation, horizontal distance from stock water, slope, aspect, and elevation above or below stock water extracted from digital elevation models using GIS. Other independent quantitative measurements included: angle of accessibility for grasses beneath shrubs, shrub height, shrub canopy area and volume, herbage production, and days elapsed from the beginning of the trial until interspace and/or under-canopy grasses were defoliated. Qualitative variables included: the species of grass at each location, and grazed or un-grazed status of tussocks by sampling date. Additional parameters included: animal unit days elapsed (stocking density X days in pasture) until plants were grazed, frequency of utilization derived from a 10-plant pace transect at each sampling site, and an overall estimate of herbage utilization across the pasture.

Standing crop measurements for the pasture were acquired by clipping 1, 1-m^2 plot near each of the 30-paired plots. Standing crop data were collected 1 day prior to livestock turn out and immediately after the cattle exited the pasture. The difference between initial and final clipping was used to characterize the level of herbage utilization within year.

A second index of utilization was determined every 4^{th} day of the grazing periods. A random direction of travel was chosen from each designated shrub and a 10-pace transect was conducted. At each pace, we scored the nearest perennial grass as grazed or un-grazed. This data indexed the progression of herbage utilization across the study pasture over time (e.g. 8 plants grazed out of 10 = 80% grazed).

Data Analysis

Trial 1

Plant position effects on grazing

Analysis of variance (Montgomery 1991) was used to test the null hypothesis that foraging behavior was independent of plant location over time. Data were analyzed using a repeated measures analysis of variance with 4 blocks (pastures, n = 4, df = 3) and 2 treatments, or plant positions (under-canopy or interspace, n = 2, df = 1), and 9 sampling days (n = 9, df = 8) as a repeated factor. The response variable was the number of plants, by position, that were grazed within a block on each sampling day of the trial. Treatment effects were tested with the block X treatment error term (df = 5). Day effects and the day X treatment interaction were tested with the residual error term (df = 10). Model and treatment effects were considered significant at $P \leq 0.05$. If significant main or interaction effects were found, mean separations at the appropriate level were accomplished with the Least Significant Difference Means (LS Means) (SAS 1999) procedure at $\alpha = 0.10$. Analyses were conducted for the pooled data across the 2 sampling seasons and if year was significant separate analyses were conducted for each year.

The model used in analysis of variance for plant position effects on grazing occurrence was:

Formula 1:

$$\textbf{Grazed} = \beta_0 + \beta_1\textbf{Year} + \beta_2\textbf{Location} + \beta_3\textbf{Day} + \beta_4\textbf{Location x Day} + \beta_5\textbf{Year x Location} + \beta_6\textbf{Year x Day} + \beta_7\textbf{Year x Location x Day.}$$

Shrub morphology effects on under-canopy grazing

The relationship between shrub morphology and grazing of under-canopy grasses was examined using logistic and step-wise regression (SAS 1999) testing the null hypothesis that shrub morphology does not influence cattle use of under-canopy grasses. Individual shrubs and associated grass tussocks were considered experimental units. Logistic regression was used to model end-of-trial grazing scores (0 or 1) for under-story grasses based on shrub morphology variables (i.e. height, elliptical crown area, volume, and angle of accessibility). Significance was accepted at $P \leq 0.05$. Analyses were conducted for the pooled data across the 2 sampling seasons and if year was significant separate analyses were conducted for each year.

The model used in the logistic regression for shrub morphology effects on grazing occurrence of under-canopy plants was:

Formula 2:

Under-canopy grazed = β_0 + $\beta_1$year + $\beta_2$shrub height + $\beta_3$volume + $\beta_4$area + $\beta_5$angle of accessibility.

Visual Obstruction

Repeated measures analysis of variance (Montgomery 1991) was used to test the null hypothesis that visual obstruction was independent of changes in herbaceous utilization by cattle over time. Data were analyzed using 4 blocks (pastures, n = 4, df = 3) with 13 treatments or visual obstruction strata by viewing position (1 bottom – 13 top of Robel pole) (n = 13, df = 12), and 4 sampling days (n = 4, df = 3) as a repeated factor. The response variable was visual obstruction, which was percent obstruction for each stratum within sampling period. Treatment effects were tested with the block X treatment error term (df = 16). Day effects and the day X treatment interaction were tested with the residual error term (df = 16). Model and treatment effects were considered significant at $P \leq 0.05$. Analyses were conducted for the pooled data which included random views (potentially influenced by other shrubs) and unobstructed views (only affected by the sampled shrub and intervening herbaceous components) to separate the influence of shrub from herbaceous components on percent visual obstruction. If location was significant separate analyses were conducted for each view.

The model used in the analysis of variance for visual obstruction was:

Formula 3:

Visual Obstruction = β_0 + β_1Pasture + β_2Utilization + β_3Strata + β_4Unobstructed/Random Location + β_5Pasture x Utilization + β_6Pasture x Strata + β_7Utilization x Strata + β_8Fixed/Random x Pasture + β_9Fixed/Random x Utilization + β_{10}Fixed/Random X Strata + β_{11}Pasture x Utilization x Strata + β_{12}Fixed/Random x Pasture x Utilization x Strata.

Trial 2

Grazing preference for interspace/under-canopy tussocks was determined by visual inspection of life-test and survival regression analyses of under-canopy and interspace plants until the end of the trial (Cox and Oakes 1984). The life-test procedure allowed for a comparison of survival curves between stocking rates and tussock locations. Survival regression analysis provided a method to analyze plants that were not grazed by the end of the trial in which these subjects could be censored and analyzed with the grazed times (Cox and Oakes 1984). The Cox proportional hazards model (survival regression) was used to evaluate the effect of explanatory variables on survival times of plants and to test the null hypothesis that geo-physical/environmental variables and stocking rates do not influence grazing selection. Backward elimination was then used on the survival regression analysis to identify important prognostic factors from the large number of explanatory variables. Day grazed for both under-canopy and interspace plants functioned as the response variable and was analyzed using presence (1) or absence (0) of grazing as an indicator variable. Independent explanatory variables included: angle of accessibility, canopy area, canopy volume, shrub height, elevation, slope, aspect, horizontal proximity of stock water, elevation relative to water, standing crop measures, end-of-trial pasture utilization, mean rate of utilization for each site derived from changes of pace transect scores across time, and animal unit days elapsed until a plant was grazed. Data were pooled and analyzed across all years and locations to assess the predictive utility of the models among a variety of environments and stocking rates. If year or location were significant, separate analyses were conducted. Statistical significance was accepted at $P \leq 0.1$. Appendix 1 outlines the statistical design for trial 2.

The regression analysis of the survival data based on the Cox proportional hazards model was:

Formula 4:

$$\textbf{Day Grazed * Grazed (0)} = \beta_0 + \beta_1\textbf{Location} + \beta_2\textbf{Angle of accessibility} + \beta_3\textbf{Shrub height} + \beta_4\textbf{Shrub area} + \beta_5\textbf{Shrub volume} + \beta_6\textbf{Slope} + \beta_7\textbf{Aspect} + \beta_8\textbf{Elevation} + \beta_9\textbf{Water elevation} + \beta_{10}\textbf{Distance from water} + \beta_{11}\textbf{Production} + \beta_{12}\textbf{Pasture utilization} + \beta_{13}\textbf{Utilization index} + \beta_{14}\textbf{AUDays}$$

RESULTS AND DISCUSSION

Trial 1

In 2003, precipitation for the calendar year was 24.8 cm (93% of the 40 year average) (NOAA 2003) and initial above ground herbaceous production was 182 kg (dry matter)/ha ± 2.76. In 2004, precipitation for the calendar year was 17.2 cm (64% of the 40 year average) (NOAA 2004) and above ground herbaceous production was 103 kg (dry matter)/ha ± 1.77. Sagebrush canopy cover and density for the site was 17.1% ± 0.3 and 3209 ± 36.6 plants/hectare, respectively. Herbaceous cover for the site was 9.0% ± 0.01 (Appendix 3).

Utilization

Herbage utilization increased in a linear fashion over time and was similar across both pastures and years ($R^2 = 0.93$). Livestock were removed from the pastures at approximately the 75% ± 1.35 utilization level in both years (Figure 6).

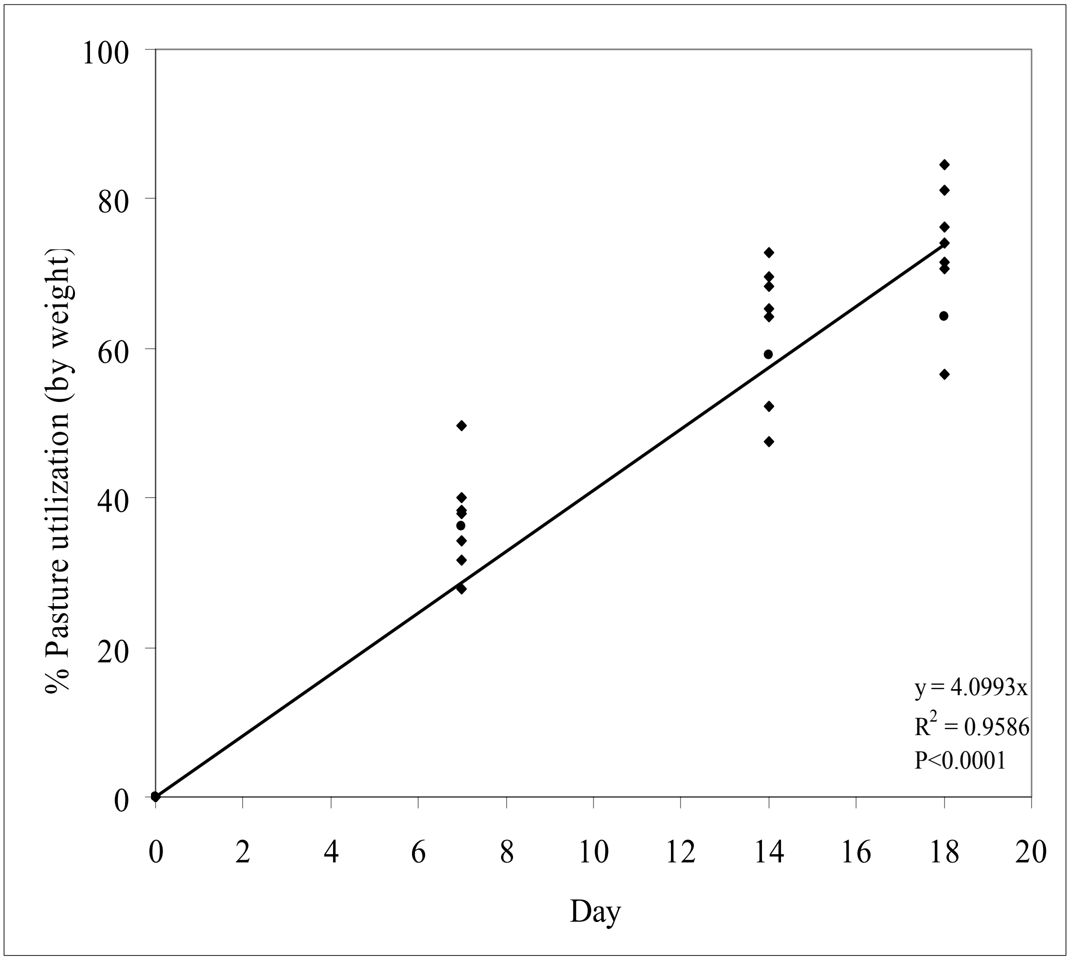

Figure 6: Percent utilization by weight and grazed days elapsed among the 4 pastures at Foster Flat, Oregon in 2003 and 2004 in trial 1 ($R^2 = 0.93$) ($P < 0.0001$).

Plant position effects on grazing

When data were pooled across years, percent of plants grazed was influenced by location (P<0.0001), day (utilization) (P<0.0001), year (P = 0.0324), and the location X day interaction (P<0.0001) (Figure 7).

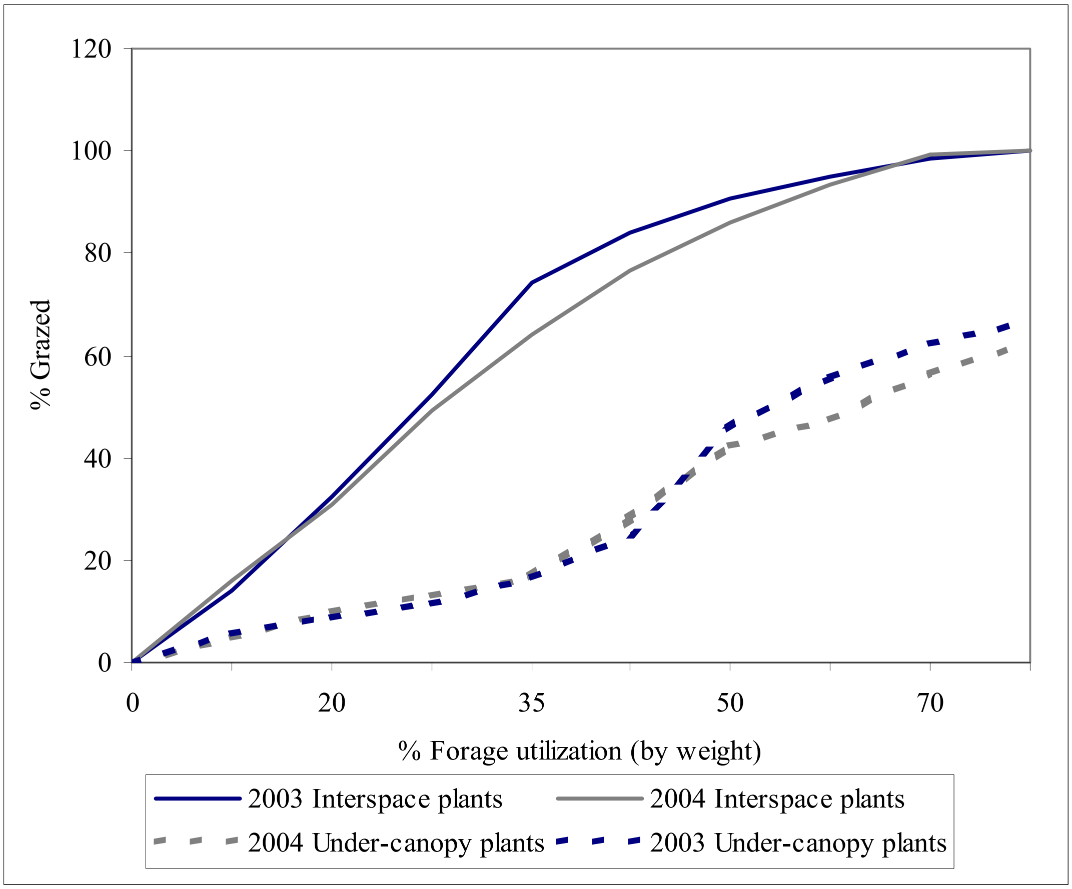

Figure 7: Percent of interspace and under-canopy plants grazed across pasture utilization for 2003 and 2004 at Foster Flat, Oregon for trial 1.

Since year had an effect on observed forage selection patterns ($P = 0.0324$) years were analyzed separately. Livestock demonstrated a preference for plant location (2003: $P<0.0001$, 2004: $P<0.0001$) and preference for foraging location changed as pasture utilization increased (2003: $P<0.0001$, 2004: $P<0.0001$). In 2003, 100% ($n = 120$) of the interspace plants were grazed and 70% ± 1.2 ($n = 80$) of the under-canopy plants were grazed when the trial ended. Mean forage utilization was 77% ± 1.8 at the end of the trial (Figure 8). In 2004, 100% ($n = 120$)

of the interspace plants were grazed and 62.5% ± 0.2 (n = 75) of the under-canopy plants were grazed when the trial ended. Mean herbage utilization was 71% ± 1.1 at the end of the trial (Figure 7).

Year effects may be partially explained by the fact that herbage production was different between the 2 years (182 kg/ha vs. 103 kg/ha). This disparity may have affected forage selection patterns between years to some degree. Additionally, in 2003, livestock were taken from a habitat similar to Foster Flat, while in 2004 livestock were moved from a more productive meadow hay pasture. Forage selection patterns may have also been influenced by previous grazing experiences potentially contributing to a year effect. We believe that statistical differences in foraging patterns between years had minimal biological significance given that inflection points of the response curves were similar between years (Figures 7).

The data suggest a threshold beyond which cattle shift forage selection from more accessible interspace plants to under-canopy plants. For both years this threshold occurred at approximately 35% herbage utilization (Figure 7). At this inflection point the slope of the relationship between grazing frequency and pasture utilization increased for under-canopy and decreased for interspace plants. At the 35% herbage utilization level, available forage in the interspaces was probably becoming limited because 70-90% of those plants were grazed. Our interpretation of the location by day interaction ($P < 0.0001$) is that animals began to show preference for under-canopy plants by about day 6 of the trials. These data suggest that at moderate levels of utilization (<35%) grazing would have negligible impacts on under-canopy grasses, and by extension would have minimal effects on under canopy cover because foraging was largely limited to interspace plants.

Shrub morphology effects on under-canopy grazing

For pooled analyses (2003 and 2004), the likelihood of grazing under-canopy plants was associated positively with angle of accessibility ($P<0.0001$, $\beta = 0.046$) and results were similar between years ($P = 0.3122$). No other shrub morphology variables contributed to the likelihood of under-canopy grazing ($P > 0.05$). The mean angle of accessibility for shrubs within the Foster Flat environment was 68.5° ± 0.3. Classification table output indicated that the logistic regression equation correctly classified plants as grazed or not grazed 65% of the time (i.e. of 47 plants not grazed our model successfully assigned 30 plants to the correct category and 17 were incorrectly assigned a grazed score. Similarly, of 193 plants that were grazed, the model was correct for 125 shrubs and erroneous in 68 instances) (Table 1).

Table 1: Classification table for a logistic regression model using angle of accessibility to predict grazed (1) and un-grazed (0) occurrences for grasses under sagebrush canopies in 2003 and 2004 in cattle grazed pastures near Foster Flat, Oregon (trial 1).

	Observed frequency	Predicted frequency	Misclassified frequency
Un-grazed	47	30	17
Grazed	193	125	68
Total	240	155	85

Large angles of accessibility increased the likelihood of grazing for under-canopy tussocks. Other shrub characteristics like shrub height, area, and volume had no effect on the likelihood of tussocks being grazed. Shrub morphology also affects sage-grouse nest selection (Gregg 1992, Gregg et al. 1994), but shrub morphology has not previously been related to grazing occurrence of under-canopy vegetation. Our data illustrate that if a sagebrush plant has a high canopy (large angle of accessibility); the likelihood of grazing for under-canopy tussocks increased. From a management perspective, these data suggest that variables other than simple measures of herbage utilization also affect the probability of under-canopy grazing selection. In summary, potential screening cover for sage-grouse nesting sites could be at greater risk as shrubs grow taller and angles of accessibility increase. If herbage utilization levels were kept below 35%, shrub morphology may be less of an issue because grazing is concentrated on interspace plants to that point.

Visual Obstruction

Analysis of the pooled data (both unobstructed and random locations kept in the model) indicated that visual obstruction varied by location ($P<0.0001$). Accordingly, data were analyzed separately. Results of the location analyses suggest visual obstruction was affected by pasture ($P<0.0001$ unobstructed, $P<0.0001$ random), strata ($P<0.0001$ unobstructed, $P<0.0001$ random), and herbage utilization ($P<0.0001$ unobstructed, $P<0.0001$ random) main effects, with a pasture X strata ($P<0.0001$ unobstructed, $P<0.0001$ random,) interaction. As utilization increased there was no interaction with strata ($P = 0.9995$ unobstructed, $P = 0.9995$ random) suggesting that all strata were affected equally over time when viewed from either position (Figure 8 and 9).

The lowermost 4 strata (totaling 30cm) included herbaceous inputs from grasses, forbs, standing litter, and shrubs, and visual obstruction ranged from 30-50% for both locations. We expected a decrease in obstruction measures in the lower strata as herbage utilization increased, however, the magnitude of change was similar across all strata, however, as our trial advanced. Sagebrush obviously contributed the majority of screening for the upper strata, which ranged from 10-20% visual obstruction. Appendix 2 outlines changes in percent visual obstruction across the 4 sampling dates and as herbage utilization levels increased across time, the changes in visual obstruction decreased consistently across all strata from both viewing positions. Observed differences between viewing locations could be related to the influence of additional shrub contributions. The unobstructed view eliminated the effects of additional shrubs on visual obstruction; as a result, percent visual obstruction was lower in the middle strata compared to the random view (Figures 8 and 9).

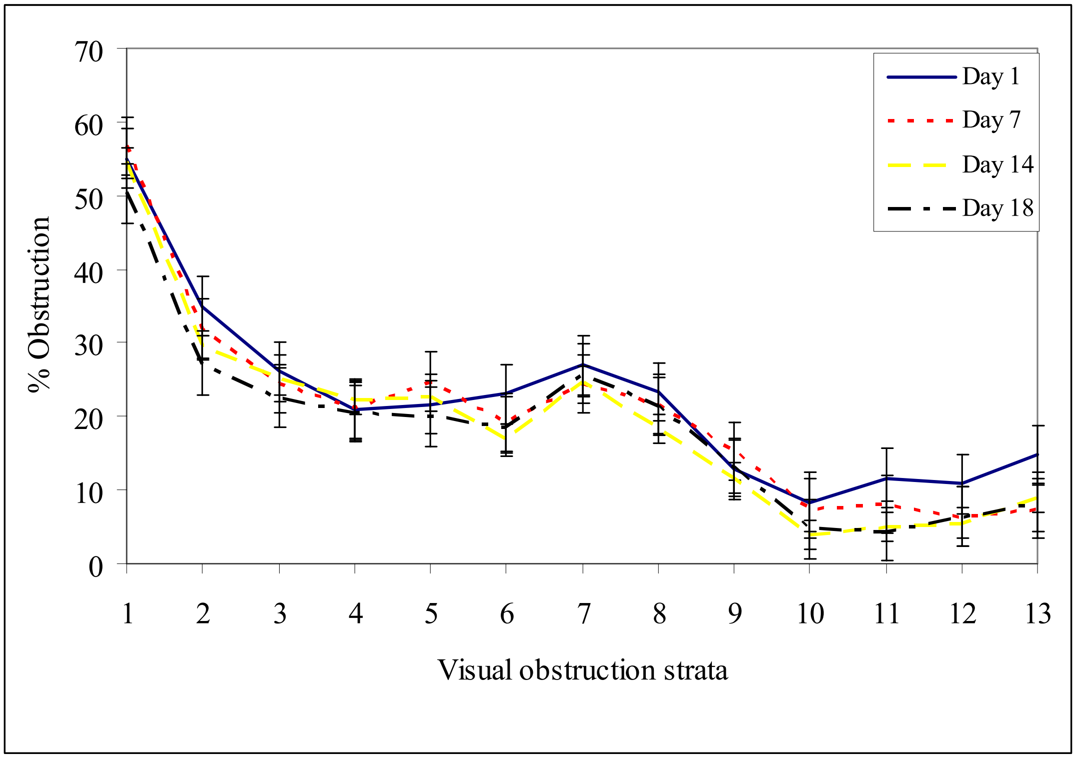

Figure 8: Percent visual obstruction for the unobstructed view for the 4 sampling times across the 13 strata (1 being the bottom and 13 being the top) of the Robel pole at Foster Flat, Oregon in 2004.

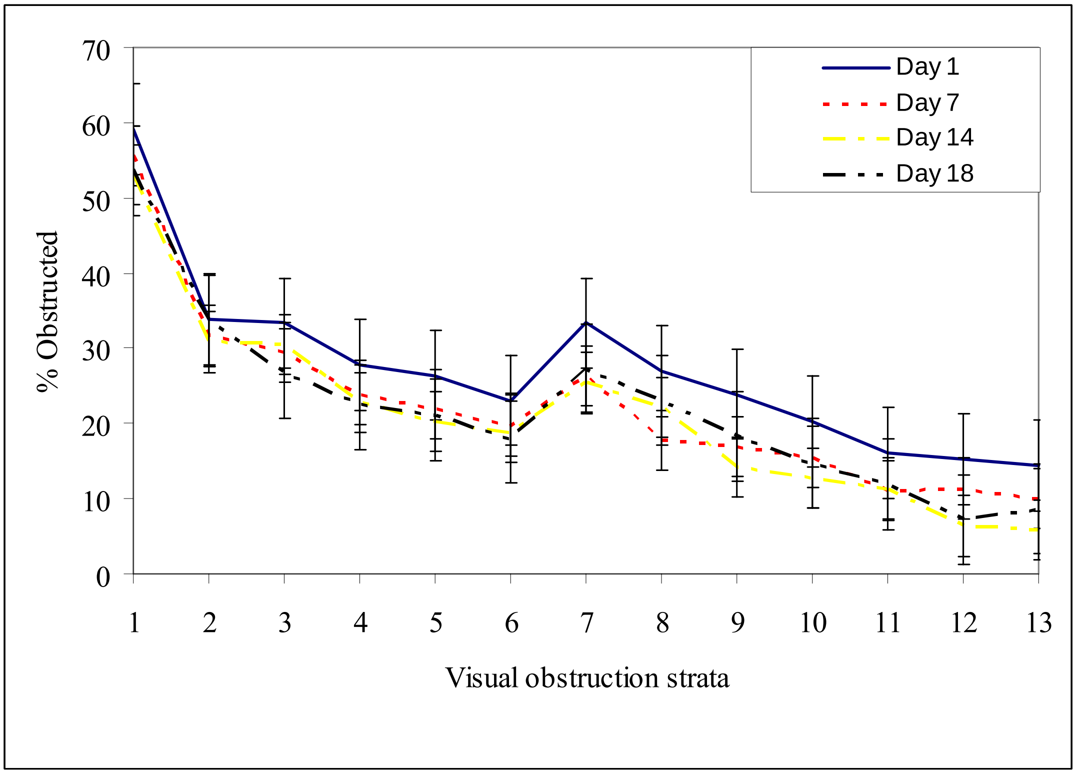

Figure 9: Percent visual obstruction for the random view for the 4 sampling times across the 13 strata (1 being the bottom and 13 being the top) of the Robel pole at Foster Flat, Oregon in 2004.

Our hypothesis was that we would experience a strata X sampling time interaction as the herbaceous level was grazed and trampled by the cows proved to be incorrect. This interaction did not occur for either location ($P = 0.9995$ unobstructed, $P = 0.9995$ random). Possible explanations include 1.) ephemeral leaf fall from sagebrush and the grazing removal of the herbaceous component coincided, 2.) the physical and foraging activities of cattle affected all strata equally, or perhaps some combination of these factors. Additionally, the fact that we removed 75% of standing crop and affected only a 5% decrease in lower level obstruction suggests that sagebrush constituted the bulk of the obstructing cover in the Foster Flat environment.

In some environments intervening herbaceous vegetation may be critical for providing nesting cover; however, the influences of herbaceous vegetation at the Foster Flat environment did not appear to be as valuable to screening cover as sagebrush. The relative importance of sagebrush and associated herbage may differ on more productive sites if herbaceous vegetation provides a higher proportion of screening cover (relative to the contribution of sagebrush).

Trial 2

In 2003, precipitation for the calendar year was 18.0cm (67% of the 40-year average) and standing crop averaged 383.8 kg (dry matter)/ha ± 1.1. In 2004, precipitation for the calendar year was 22.5cm (84% of the 40-year average) and standing crop averaged 401.3 kg (dry matter)/ha ± 0.9. In 2003, the mean herbage utilization as indexed by standing crop at the end of trial was 66% with a total 288 AUM's. In 2004, the mean herbage utilization by weight was 45% with a total of 144 AUM's. In 2003, a total of 22 under-canopy plants and 29 interspace plants were grazed compared to 13 under-canopy plants and 23 interspace plants grazed in 2004.

Life-test analyses indicated forage selection patterns varied between years, perhaps due to between-year disparity in stocking density (Wilcoxon chi-squared P value = 0.0002) (Figure 10). These between year differences suggest that stocking rate influenced animal distribution. In 2004 animal unit days was 40% of 2003. The increase in stocking density dispersed cattle across more of the pasture and increased overall grazing occurrence in 2003. With the low stocking density of 2004, cattle were less inclined to graze the entire pasture; and plants in less accessible locations were not as susceptible to grazing.

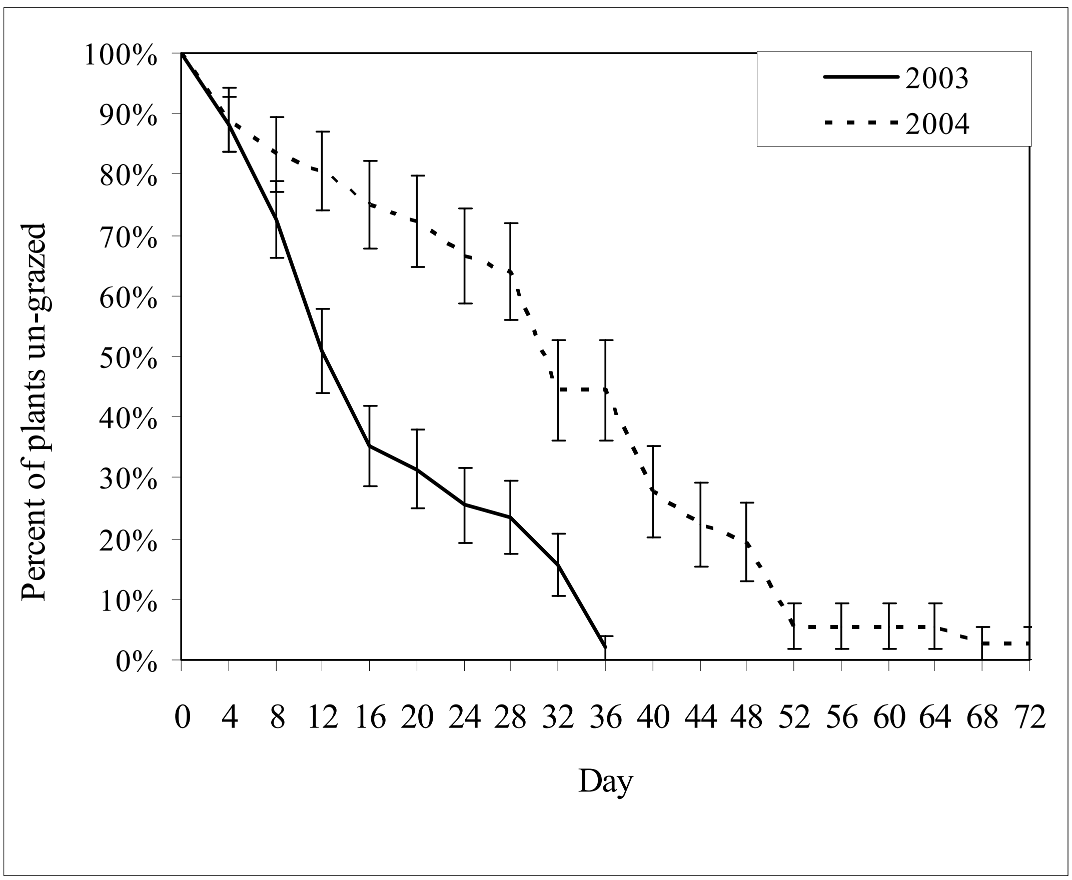

Figure 10: Life-test analysis of grass plants for trial 2 with different stocking rates (2003 180-cows, 2004 60-cows) at the Northern Great Basin Experimental Range, Oregon for 2003 and 2004.

Life-test analyses indicated plant location relative to sagebrush canopies influenced forage selection in 2003 (2003-Wilcoxon chi-squared P = 0.0767) but not in 2004 when fewer cattle were present (2004-Wilcoxon chi-squared P = 0.4672) (Figure 11 and Figure 12) or when years were pooled (Wilcoxon chi-squared P value = 0.2856) (Figure 13).

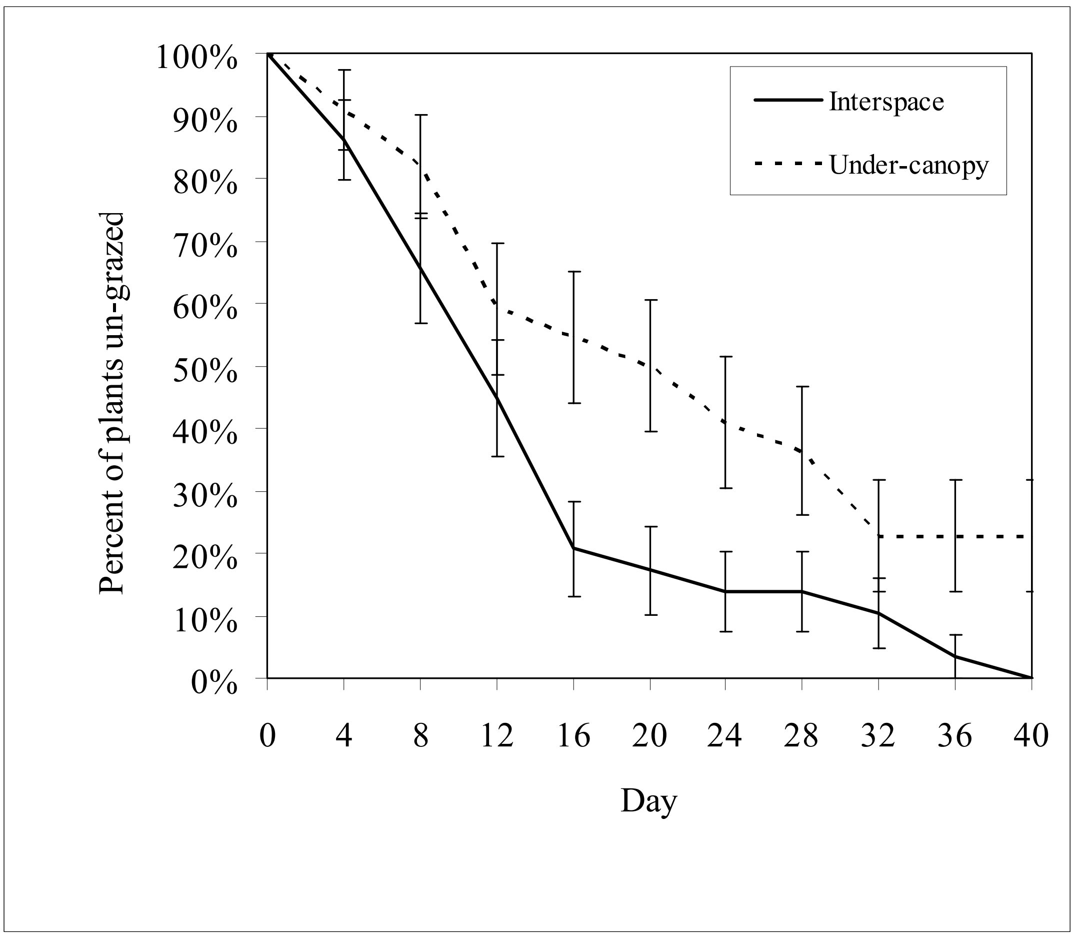

Figure 11: Life-test analysis evaluating cattle preference for interspace or under-canopy grass tussocks in an 800ha pasture on the Northern Great Basin Experimental Range, near Burns, Oregon in 2003.

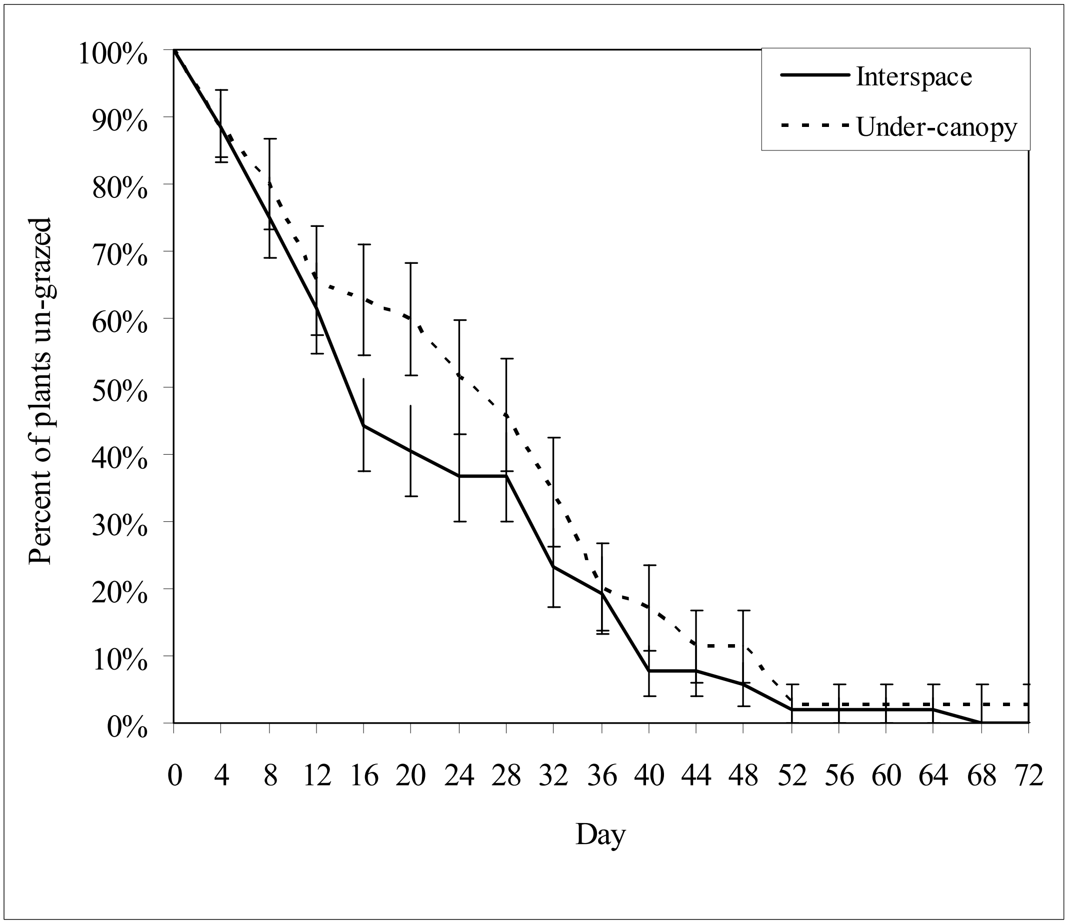

Figure 12: Life-test analysis evaluating cattle preference for interspace or under-canopy grass tussocks in an 800ha pasture at the Northern Great Basin Experimental Range, near Burns, Oregon in 2004.

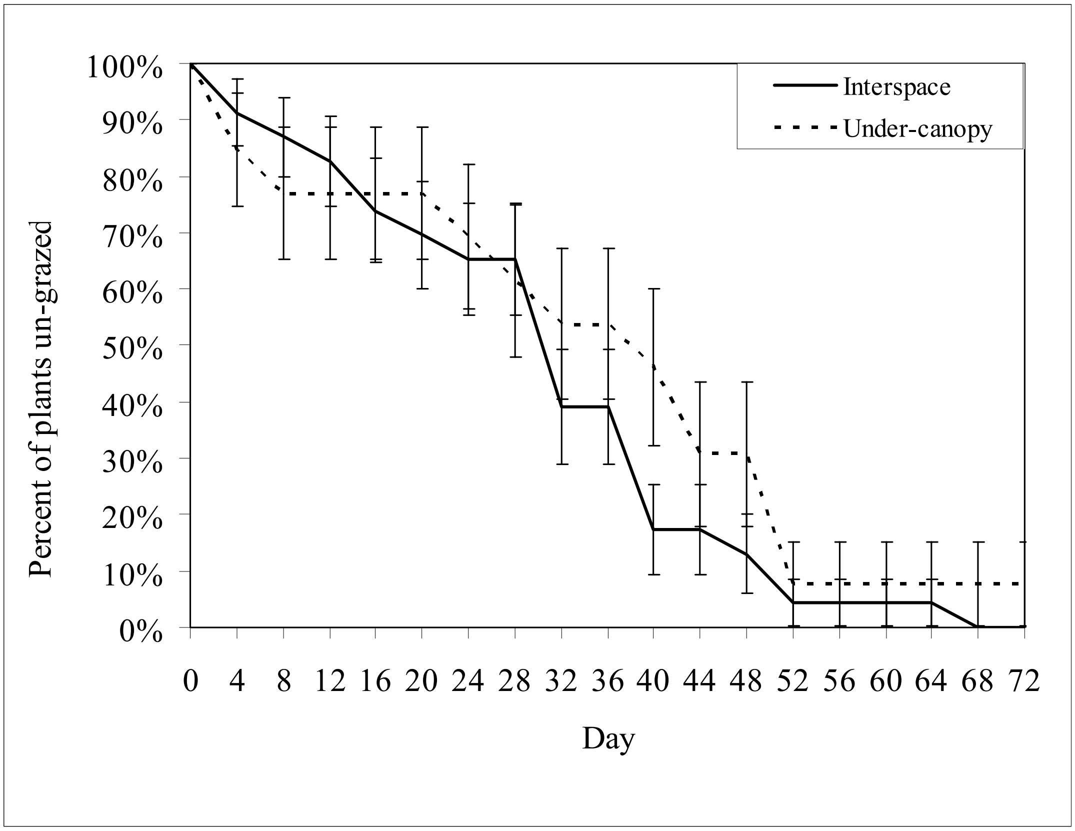

Figure 13: Life-test analysis evaluating cattle preference for interspace or under-canopy grass tussocks in an 800ha pasture on the Northern Great Basin Experimental Range, near Burns, Oregon with pooled data from 2003 and 2004.

Forage patterns were probably more influenced by geospatial and environmental variables in 2004 with fewer cattle present than in 2003. Interspace/under-canopy patterns observed during trial 1 were not as evident in trial 2. Environmental influences may have a greater influence on stock distribution and foraging patterns at landscape scales than under-canopy/interspace positions of grass tussocks in more intensively grazed environments. Results may have differed if our sample size was larger and observations taken more frequently. Our small sample size of 30 locations within a 800 hectare area may not have had sufficient resolution to consistently detect disparities in forage selection patterns.

When data were pooled across years, survival regression analysis indicated slope ($P = 0.04$, $\beta = -0.03$), distance from water ($P = 0.07$, $\beta = -0.0006$), and stocking density ($P = 0.0009$, $\beta = -0.0003$) affected whether a grass would be grazed whereas year had no effect ($P = 0.37$). As slope and distance from water increased the likelihood of being grazed decreased. As animal unit days (stocking density) increased the likelihood of being grazed increased.

Though tussock location was not significant in the regression analysis ($P = 0.29$), further investigation was warranted to determine if geophysical, shrub morphology, or stocking density influenced forage selection at larger scales. Separate analysis on interspaces and under-canopy tussocks indicated stocking density (animal unit days) was correlated positively with the likelihood that under-canopy tussocks would be grazed ($P=0.01$, $\beta = 0.0003$) in both years. Distance from water was correlated negatively with grazing occurrence of interspace plants ($P<0.0001$, $\beta = -0.001$) in both years. These findings suggest that as herbage availability decreases in the interspaces under-canopy plants become more likely to be grazed.

Herbage utilization by cattle in large pastures containing sage-grouse nesting habitat is probably affected by both stocking density and distance from water. When years were analyzed separately, no explanatory variables were significant for either under-canopy or interspace tussocks. With pooled data, however, degrees of freedom were doubled and the range of stocking rate indices was expanded. Both effects strengthened analyses and our explanatory powers.

Because pastures were not replicated within years, the application of those findings to other environments is somewhat limited. Results do illustrate, however, that several factors influence the spatial grazing patterns of cattle at landscape scales. The contributing variables in this study included: slope, distance from water, and stocking density, all of which have been previously related to cattle distribution, (Gillen et al. 1984, Ganskopp 2001).

The difference in forage selection patterns between our smaller pastures and the large-pasture study illustrates that several variables must be acknowledged when evaluating cattle grazing impacts on potential sage-grouse nesting habitat. Because cattle are not encouraged to travel extreme distances to forage when stocking rates were moderate, distant vegetation may be essentially immune to grazing. With increased stocking rates or duration of grazing, however, the likelihood of herbage removal envelops more of the pasture. Water placement may also be used to alter grazing impacts across larger pastures (Ganskopp 2001) and shift cattle use to less critical portions of the landscape.

CONCLUSIONS

There is a lack of information directly relating livestock grazing with sage-grouse declines and/or habitat deterioration. Previous to this study, livestock forage selection patterns had not been evaluated within sagebrush communities. It is known that herbaceous cover can positively affect sage-grouse nesting success by providing visual, scent, and physical barriers to nest predation (Gregg 1992, Gregg et al. 1994). Removal of herbage has been assumed to decrease screening cover and increase nest vulnerability to predation. Our results suggest that cattle-use of under-canopy tussocks was minimal until standing crop utilization exceeded about 35%. We saw a cattle preference for interspace plants until a large proportion of those plants were grazed and cattle began to seek vegetation beneath sagebrush canopies. That being the case, management that restricts herbage utilization to less than 35%, could be used to help sustain nest-screening cover beneath sagebrush for our site. The mechanism responsible for the change in forage selection from interspace to under-canopy bunchgrasses was related to the limited availability of forage in the interspaces. Once these plants become limited cattle are forced to seek out vegetation under the canopies of sagebrush. This utilization threshold will vary and is most likely dependent upon sagebrush density, sagebrush arrangement, bunchgrass structure, and forage production.

Sagebrush morphology, primarily through its affect on angle of accessibility, contributed to whether a grass tussock would be grazed or un-grazed. As angles increased the vulnerability of under-canopy grasses increased. Because angle of accessibility is related to sagebrush structure, managers should perhaps encourage development of sagebrush with spreading umbrella like canopies. If indeed sage-grouse select nest sites with low angles of accessibility grazing would be less likely to affect under-canopy vegetation. Research is needed to relate nest site selection to indices of sagebrush morphology, plus methods to increase the development of sagebrush with umbrella like canopies.

In our study, the bulk of visual obstruction was provided by sagebrush. Changes in visual obstruction occurred in all strata as herbage utilization progressed. This suggests that sagebrush was the most important screening vegetation for potential nest sites within our environment. Our data imply that forage utilization levels approaching 70% had minimal effects on screening cover at our site. Past efforts suggested the herbaceous component was an important source of screening cover and its presence enhanced nesting success (Gregg et al. 1994). We suggest, however, that in arid locations sagebrush constitutes the bulk of the screening vegetation.

Forage selection patterns in our large pasture trial did not precisely mimic those seen with our smaller scale grazing trial. However, the large pasture trial supports past research on various facets of livestock distribution and variables affecting forage selection. Slope, distance from water, and animal unit days (stocking density) most affected forage selection at the landscape scales in our study. Distance from water influenced the likelihood of interspace forage selection as plants were less likely to be grazed if they were at greater distances from water. Increased stocking intensity elevated the likelihood of under-canopy forage selection. These data suggest that by understanding the influences of environmental variability and management factors, the effects of livestock herbivory can potentially be reduced. Water location is critical with cattle remaining within about a 1.6-km radius of water. By manipulating access to water locations, managers can to some degree control use of herbaceous vegetation in expansive pastures.

An understanding of various aspects of livestock grazing behavior as they respond to forage and landscape characteristics should allow us to minimize grazing affects on known sage-grouse nesting habitat. Moderate levels of utilization combined with effective distribution tools will help reduce grazing impacts.

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CHAPTER 3:

GENERAL CONCLUSION

The objective of this research was to provide needed information about livestock grazing effects on sage-grouse nesting habitat. There is little information detailing effects of livestock grazing on sage-grouse population dynamics and their associated habitat. Because nesting success is a key component for recruitment of sage-grouse (Braun and Beck 1996), and nest success has been positively linked with herbaceous cover (Gregg et al. 1994), a study documenting forage extraction patterns of cattle in sagebrush communities was needed. Our findings suggested that cattle would have little effect on under-canopy nesting cover in arid sites if conservative cattle management is employed. Suggested practices include grazing to moderate levels of utilization and using cattle distribution tools such as manipulating watering locations to retard removal of screening herbaceous cover in critical sage-grouse nesting habitat.

Our results suggest that cattle use of under-story plants was minimal until pasture herbage utilization exceeded about 35% utilization (by weight). Cattle exhibited an initial preference for interspace plants until forage availability decreased in those areas. Subsequently cattle began to seek herbage directly under sagebrush canopies. Unmanaged grazing could therefore decrease screening cover at potential nest sites. If herbage utilization does not exceed 35%, under-canopy vegetation should largely be maintained. These results can help land managers develop grazing plans that minimize cattle impacts on herbaceous cover critical to nesting sage-grouse and other ground nesting birds.

We found shrub morphology, specifically angle of accessibility, affected forage selection of under-canopy grass tussocks. As angles increased the vulnerability of under-canopy grass plants increased. Sites beneath sagebrush that have large angles of accessibility may be more vulnerable to cattle grazing. Although angle of accessibility is related to sagebrush structure, range and wildlife managers have not developed any techniques for shaping shrubs. Our findings on the screening capacity of herbaceous components did not conform with expectations, as grazing effects were not limited to the lower strata containing the grasses and forbs. On our sites, the bulk of visual obstruction was provided by sagebrush, and significant changes in visual obstruction were detected at all height strata when herbage utilization levels approached 75%, implying that sagebrush constituted the bulk of screening cover. In arid sites, like our study area, nest success may be more affected by sagebrush cover than the herbaceous component.

In our smaller pasture study there was a distinct preference by cattle for interspace tussocks at low to moderate utilization levels. Patterns of herbage utilization in our large pasture study differed somewhat from this finding. This lack of parity between trials may have been related to our small sample size of 30 locations within an 800 hectare pasture, diminishing our capacity to detect forage selection patterns. A more frequent sampling schedule of perhaps every second day might have helped by increasing degrees of freedom.

Even though livestock did not display a consistent preference for tussock location relative to sagebrush canopies in the 800ha pasture, forage selection was influenced by several landscape variables. These findings agreed with other efforts describing livestock distribution and landscape characteristics affecting habitat use and foraging behavior. Slope, distance from water, and animal unit days (stocking intensity) all affected distribution and grazing behavior at landscape scales. Distance from water was linked with the likelihood of foraging on interspace tussocks. Grazing was obviously less likely when tussocks were further from water. Stocking density and duration were positively correlated with the use of under-canopy tussocks.

Of these landscape characteristics, water availability or access to stock water and stocking intensity fall under the potential control of managers. By controlling access to water, one could assert a high degree of control over potential cattle grazing in extensive landscapes. As pasture utilization increases, however, cattle are forced to seek vegetation further from water. Pairing moderate stocking intensities with restricted water availability may decrease the distribution of cattle and could potentially limit utilization in nesting habitat. Significant under-canopy/interspace foraging patterns were probably not consistently detected in our larger scale study because of the overriding influence of landscape variables.

Our findings are perhaps most relevant to the arid extremes of sage-grouse habitat, and results of similar studies might vary substantially in more mesic or moist environments. While interspace/under-canopy forage selection patterns were clearly evident, there is a need to replicate this study across all of the sagebrush alliances. Our intensive effort occurred in a Wyoming big sagebrush site, and while sage-grouse nest within this habitat, mountain big sagebrush sites may be more preferred by sage-grouse. Shrubs in most instances will most likely provide significant amounts of screening cover. Sites with higher annual forage production may be more dependent upon herbaceous screening cover and herbivory may have a more significant effect.

In closing, there is a need for additional short and long-term studies to elucidate the effects of herbivory on sage-grouse nest site selection and success. Future studies should examine effects of livestock presence and their accompanying herbage utilization patterns on nest site selection and recruitment.

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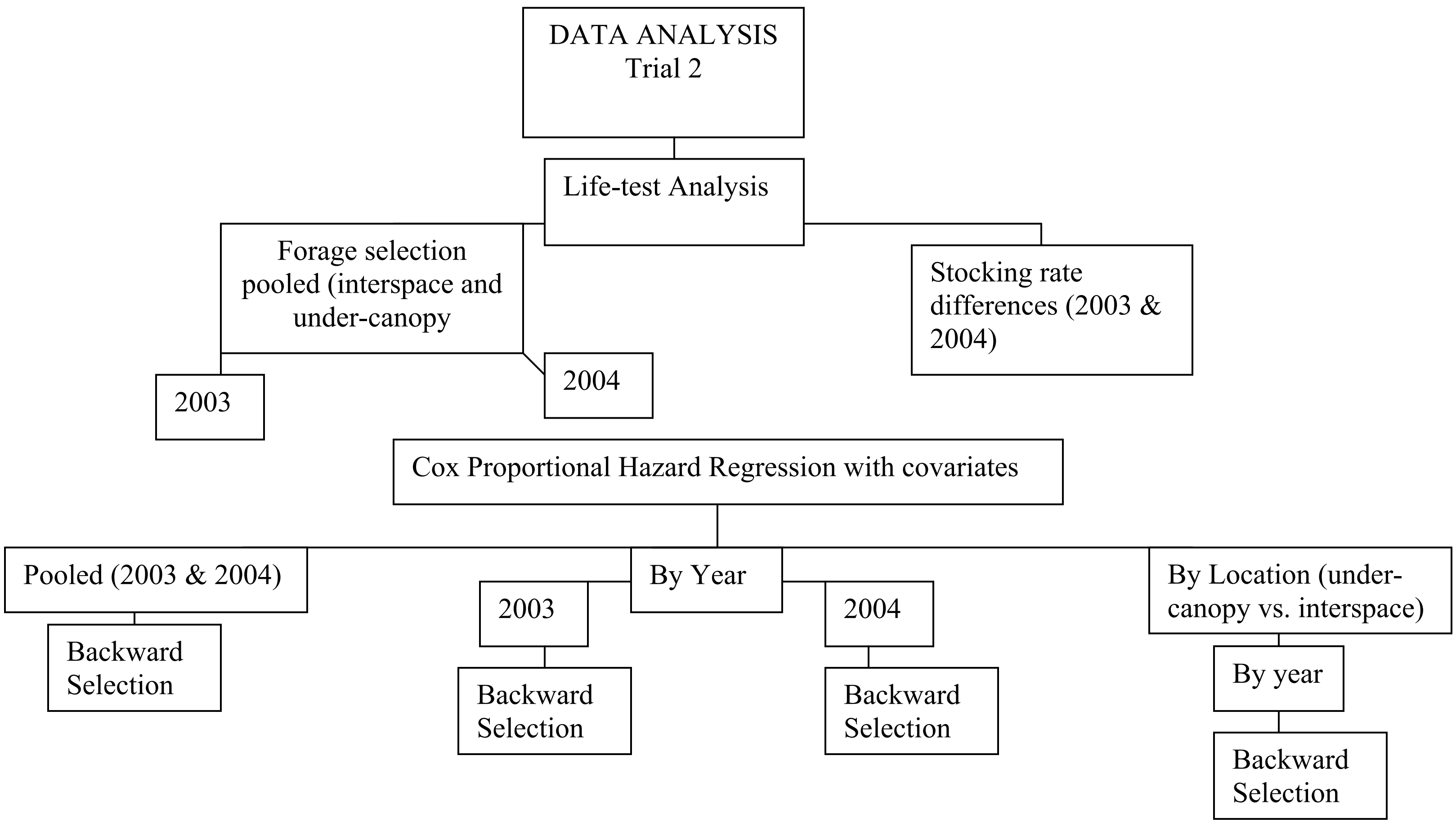
APPENDICIES

Appendix 1: Flow chart for analysis of trial 2 data, life-test analysis and survival regression analysis utilized to determine the effects of plant location, stocking density, and geo-physical variables at the Northern Great Basin Experimental Range, Oregon in 2003 and 2004.



Appendix 2: Percent visual obstruction for strata 1-13 with the 4 sampling days at Foster Flat, Oregon in 2004. Significant changes were observed with changes in visual obstruction across all strata with increasing pasture utilization (P = 0.0001).

		Strata												
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
Sample periods	**1**	59.4 +/- 4.1%	34.2 +/- 2.9%	31.9 +/- 5.9%	27.2 +/- 2.1%	25.8 +/- 3.3%	22.5 +/- 8.1%	30.8 +/- 12.7%	22.2 +/- 7.0%	16.9 +/- 6.9%	15.0 +/- 6.4%	14.7 +/- 2.3%	11.7 +/- 5.6%	12.2 +/- 4.7%
	2	55.6 +/- 5.9%	31.9 +/- 4.0%	29.2 +/- 6.0%	23.9 +/- 3.8%	21.9 +/- 8.0%	18.9 +/- 9.8%	26.9 +/- 9.2%	18.3 +/- 9.8%	16.9 +/- 7.4%	15.5 +/- 6.2%	11.1 +/- 3.5%	11.4 +/- 1.9%	10.0 +/- 3.6%
	3	53.1 +/- 3.3%	30.8 +/- 5.1%	30.6 +/- 5.3%	22.8 +/- 6.4%	20.3 +/- 4.8%	18.9 +/- 10.8%	25.6 +/- 8.6%	22.2 +/- 8.7%	14.2 +/- 5.7%	12.8 +/- 2.9%	11.4 +/- 5.4%	6.4 +/- 1.7%	5.8 +/- 2.1%
	4	53.6 +/- 3.3%	33.6 +/- 4.3%	26.7 +/- 3.8%	22.5 +/- 2.9%	21.1 +/- 6.1%	18.1 +/- 10.2%	27.2 +/- 11.1%	23.1 +/- 11.3%	18.3 +/- 9.0%	14.7 +/- 5.2%	11.9 +/- 4.3%	7.2 +/- 4.8%	8.6 +/- 3.1%

Appendix 3: Vegetation characteristics for Foster Flat, Oregon in 2004. Sagebrush canopy cover and density was 17.1% ± 0.3 and 3209 ± 36.6 plants/hectare, respectively. Herbaceous cover for the site was 9.0% ± 0.01.

	Pasture 1	Pasture 2	Pasture 3	Pasture 4
Canopy cover	19.3%	17.1%	16.7%	15.3%
Shrub density (stems/ha)	4180	2520	3160	2980

	% Cover
Bare ground	62.7
Rock	6.2
Litter	16.3
Moss	5.2
Crust	0.03

Annual Forbs	% Cover	Perennial Forbs	% Cover	Annual Grasses	% Cover	Perennial Grasses	% Cover
Collinsia parviflora	0.04	*Agosteris glauca*	0.1	*Bromus tectorum*	0.06	*Agropyron spicatum*	1.4
Microsteris gracilis	0.19	*Crepis occidentalis*	0.001			*Elymus trachycaulus*	0.2
Epilobium palustre	0.001	*Eriogonum ovalifolium*	0.4			*Sitantion hystrix*	2.03
Descuriania pinnata	0.001	*Lupinus leucophyllus*	0.8			*Stipa thurbiana*	1.87
Cryptantha circumscissa	0.01	*Phlox longifolia*	1.1				
Trifolium spp	0.06	*Senecio integerrimus*	0.4				
		Trifolium andersonii	0.03				
		Astragalus spp	0.05				
		Lomatium nevadense	0.2				
		Arabis sparsiflora	0.01				
		Antennaria dimorpha	0.05				