AN ABSTRACT OF THE THESIS OF

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Landscape use of free ranging cattle in Northeast Oregon.

Abstract approved:

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GPS and GIS technologies were employed to evaluate cattle occupancy rates pertinent to three landscape attributes on three different grazing allotments administered by the Wallowa Whitman National Forest in Northeast Oregon. Topographic characteristics of slope; 0-4%, 4-12%, 12-35% and >35% were evaluated as well as north and south aspects. Vegetation alliance categories of ponderosa/Douglas fir (pine/fir), mixed conifer and upland grass were also assessed. Occupancy of area around perennial streams was analyzed using buffer zones of 0-10m (aquatic habitat), 10-20m, 20-30m, 30-40m, 40-50m and 50-60 meters from both sides of the watercourse. As well an appraisal of total cattle landscape occupancy for each relevant allotment was performed by individual sample animals and by sample sets as an evaluation of the home range concept as applied to managed domestic cattle.

Cattle highly preferred slopes less than 12% did not avoid slopes between 12 and 35% but did avoid slopes greater than 35%. Cattle were indifferent to north and south aspects.

Vegetative alliance structures were variable as to preference by cattle. In study area 1 mixed conifer was avoided while the pine/fir and upland grass were both equally preferred. Cattle in study area 2 preferred only the mixed conifer while avoiding both the pine/fir and upland grass classifications. Study site 3 cattle also preferred mixed conifer but displayed a moderate indifference toward upland grass and pine/fir.

When evaluating buffer zones established on either side of the water course cattle in site 1 and 3 were indifferent to all zones demonstrating equal dispersion throughout the area as well the individual zones in these study areas were occupied less than 1%. In site 2 cattle preferred the first three zones out to 30m over the area between 30 and 60m. In all study sites cattle occupied the allotment area beyond 60m between 96 and 98 percent of the time while the aquatic habitat zone (0-10m) was occupied less than 1% in all study areas.

Landscape occupancy was shown to be variable between allotments. Individual animal average for site 1 was 40 to 50% less per year than the average in study area 2. Variation between animals was also less in area 1 as compared to area 2. Site 3 was evaluated for one year's data and with a time period over twice that of site 1 and 2 so comparisons between this site and the others are merely illustrative. The average of individual samples was larger than both area 1 and 2 but with less variation than all trials except site 1 2008.

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Landscape use of free ranging cattle in Northeast Oregon

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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.

Kerry D. Wilson, Author

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Landscape use of free ranging cattle in Northeast Oregon

Introduction

Decades of study on the distribution of cattle on rangelands has led to a large accumulation of knowledge connecting environmental factors to cattle behavior while grazing in rugged terrain typical of forested public lands. However much of our understanding of these relationships was acquired in the absence of the gray wolf (*Canis lupus*). It is anticipated that introduction of gray wolf predation will impact our understanding of the hierarchal choices foraging animals routinely make while grazing rangelands.

The successful establishment and subsequent growth of the gray wolf population within the Yellowstone and Central Idaho ecosystems has led to the migration of the species into adjoining areas where they interface with domestic livestock. Increased predation on domestic animals represents an obvious direct financial loss to the livestock industry and associated communities. As well, little is known of the potential change in spatial and temporal activities of livestock on rangeland that come in contact with the new apex predator. It has been speculated in a recent vegetation case study within the greater Yellowstone ecosystem that the inclusion of the wolf may encourage improvement in ecological condition of riparian ecosystems through reduction of use by large ungulates in these sensitive areas. Unfortunately, these speculations provide little insight into the cause and effect relationships the wolf pack may have on ecosystems that fall under actively managed public lands designated for multiple-use.

Establishment of the gray wolf into Northeastern Oregon is anticipated and provides a window of opportunity to contrast livestock activity in areas with high wolf incidence to areas with little to no wolf presence. A ten year study was initiated in 2008 with cooperation between Oregon State University (OSU), the Agriculture Research Service (ARS) and the University of Idaho (UI). Information contained in

this thesis relates to cattle behavior and landscape use on areas of no wolf/ low density wolf occurrence. It encompasses two grazing seasons and is limited to describing landscape use relative to topography, vegetation and perennial stream use as a water source for free ranging cattle in Northeast Oregon. Specifically, the objectives of this study are: 1. Develop landscape attributes maps appropriate for analysis of animal GPS locations. 2. Analyze GPS locations with specific questions relative to landscape attributes. 3. Evaluate and summarize results of GPS queries to suggest animal behavior interpretation. There are a number of factors associated with decision making by free ranging animals relative to biotic and abiotic conditions and changes in these over time including management scenarios (human control) imposed on the animals that are beyond the scope of this report. This case study should be considered not only as a continuation of decades of case studies in cattle distribution but as one of the increasing number of case studies using new technologies to study rangeland use by grazing animals over extensive spatial and extended temporal conditions. The approach is a matter of scale.

Literature review

Distribution of cattle across landscapes has been a subject of interest and concern for many years (Coughenour 1991, Bailey et al. 1996). The grazing animal uses a variety of ecological components found within a landscape to fulfill a set of hierarchal requirements it needs to function optimally. Three of these physiological needs were identified by Smith (1988) in order of consequence: 1. Water (or thirst), 2. Thermoregulation (energy conservation), 3. Food (hunger). These hierarchal requirements for life function are common among the animal kingdom differing only in the amounts by which they influence decisions made in daily activity. They also regulate the level and type of the activity needed to satisfy those requirements such as distance and direction traveled, time spent within a certain range site, as well as activity duration within a time period. The physical biotic and abiotic attributes of a landscape influence animal behavior and performance in all activities.

Topography

Slope on most forested grazing lands has been identified as one of the most limiting factors to cattle distribution. Cook (1966) indicated that slope was highest in importance of the 21 major factors used to explain cattle distribution. Ganskoop and Vavra (1987) found cattle prefer foraging on slopes in the 0-9% category, are indifferent to slopes between 10 and 19%, and avoid grades exceeding 20%. Slopes of less than 35 percent were preferred throughout the grazing season as reported in Bryant (1982). Mueggler (1965) reported that slope was a major factor influencing cattle distribution. He found 75 percent utilization 810 yards from the bottom of a 10 percent slope while the same level of utilization extended only 35 yards from the bottom of a 60 percent slope. Pinchak et al. (1991) found 79 percent of cattle use on slopes under 7 percent. Slope was cited as being an important physical limitation on cattle movement by Roath and Krueger (1982a) that constrained grazing distribution patterns. Gillen et al. (1984) reported that slope gradient was the only physical factor

related to cattle grazing in Northeast Oregon. Clary et al (1978) did not find any relationship of cattle use to slope, but noted that the topography on their study site was so gentle that slope was not an issue. Wade et al. (1998) used slope, along with distance from water, and vegetative type, to model grazing using a Geographic Information Systems (GIS) for the state of Oregon.

The importance of aspect as a factor in cattle distribution is determined by factors such as diurnal temperature swings, solar radiation amounts and seasonal vegetation condition. Wagon (1968) observed that cattle used south-facing range sites more in the late winter, spring, and early summer while north-facing sites were used more in late summer and fall. Harris (2001) observed that topographical range sites improved the resolution of vegetation classification and the use patterns exhibited by cattle.

Vegetation

Vegetation is one of the strongest attributes affecting cattle distribution on a landscape (Brock and Owensby 2000, Senft et al. 1987, Smith 1988, Wade et al 1998). The spatial arrangement of plant life is dependent on the spatial and temporal array of abiotic resources found on the landscape that plants need to complete their life cycle (Harper 1977). Soil is a dominant abiotic resource that influences available moisture and nutrients (Brady 1990). The topographic characteristics of aspect and exposure influence where plants find a suitable habitat (Hobbs 1997). A number of abiotic and biotic components influence the kind and vigor of the plant species that make up plant communities or associations but the one component that is required by all plants is heat and light. The ability of plant life to convert solar radiation into chemical energy (photosynthesis) and thus biomass is identified as primary production (Briske and Heitschmidt 1991). It is estimated that less than 1 percent of the sun’s radiation striking the earth’s surface is converted into chemical energy by terrestrial vegetation (Lewis 1969). Secondary production occurs when cattle consume plant biomass and convert plant energy into energy for physiological needs of the animal including growth. That conversion represents about 10 percent of the

available plant energy ingested (Briske and Heitschmidt 1991). The energy cycle, with its gains and losses, is integral to any discussion of grazing cattle distribution.

Cook et al. (1962) found that animal utilization and daily intake was less on range in poor condition compared to range in good condition. A review by Cordova et al. (1978) noted that with advanced plant maturity forage intake usually decreased. Ganskoop et al. (1993) observed that cattle were less likely to graze plants that contained residual or cured straw and that animals removed less material from plants when the density of cured stems increased. Hein (1935) found quantity and quality to be directly proportional to grazing time. Anderson and Kothmann (1980) found that distance traveled by cattle was positively correlated to forage attributes particularly when the forage was palatable forbs. Clary et al (1978) noted forage utilization was significantly linked to forage production which was related to tree density. On the other hand Havstad et al. (1983) found insignificant differences in forage intake with heifers grazing on a lessening supply of crested wheatgrass. Animal behavior showed little effect from varying forage conditions in central Australia but they did seem to graze more widely as forage became scarcer (Low et al. (1981c). Similarly, Herbel and Nelson (1966) found no apparent relationship between grazing time and quantity of forage per unit area while observing cattle in southern New Mexico.

Water

Most activities undertaken by cattle are associated with body water management and energy budget. Animals restrict movement and seek rest areas with a more comfortable environment to avoid high temperatures during hot days (Bennet et al. 1984, Bryant 1982, Reppert 1960, Roath and Krueger 1982a, and Senft et al. 1985b). Radiation (solar and atmospheric) striking the body of a cow is converted into and felt as heat (Harris, 2001). As well, heat is generated within the cow due to physiological functions necessary for life. Bryant (1982) noted that to regulate body temperature and deal with excessive heat cattle can do one or more of the following: Increase their respiration rate, consume more water, restrict or slow down movement, seek more comfortable environments and perspire through relatively

insufficient apocrine sweat glands. A strong correlation between respiration rate while in the sun and time spent in the shade was identified by Bennett et al. (1984).

Water availability and vegetation attributes are identified as important factors in livestock distribution patterns. Mueggler in 1965 stated that distance to water was a factor affecting cattle distribution. Miller and Krueger (1976) determined that distance to water, salt and canopy cover as well as soil depth were associated with utilization but that distance to water and salt were dominant, accounting for 71 percent of the variation in the amount of forage consumed by livestock. It was reported by Pinchak et al. (1991) that 77 percent of cattle use was within 366 m of water and only 12 percent of observed vegetation use was found beyond 723m where nearly 65 percent of the available land was located. Cook (1966) found distance to water to be an important dynamic in explaining cattle distribution but felt that none of the environmental factors single-handedly explained cattle utilization patterns adequately. Senft et al. (1985a) found seasonal–grazing distribution to be linked to proximity of water and forage quality indicators. They also found a combined relative measure of forage quality and quantity to be a good predictor of use. Delcurto et al. (2000) using cattle locations obtained with a LORAN-C automated telemetry system (ATS) and GIS software observed that season of use relative to water location had a strong influence on animal distribution choices. Senft et al. (1985b) found water availability to be strongly associated with daytime rest areas. Roath and Krueger (1982b) stated that water and vegetation type were the most important factors in determining the spatial and temporal level of utilization on forested range. They found the vertical distance above a water source to be an important factor in determining vegetation utilization when moderately steep slopes were encountered. Owens et al (1991) determined that water availability was an important factor in regression models, developed to explain forage utilization in Texas pastures. The decline of forage utilization on a 207-ha pasture but not on 24-ha pastures as distance to water increased was discovered by Hart et al. (1993). They speculated that pasture sizes and/or distance to water needed to be optimal for

intensive grazing systems to benefit animal performance. Smith et al. (1992) observed avoidance of upland areas by cattle in a large allotment of 49,900 ha due to greater distances to drinking water and speculated that preference of grazing sites was in part based on the availability of succulent forage. One of the few studies that did not find a correlation between utilization and distance to water was conducted by Clary et al (1978) in an Arizona Ponderosa Pine forest.

Impact to streams and associated vegetation

An issue facing users of public grazing areas is that of riparian and stream health. Several federal agencies, including the U.S. Forest Service, the Bureau of Land Management, and the Environmental Protection Agency have stated that livestock grazing has adversely impacted a majority of the stream systems in the western United States (Armour et al. 1994, U.S. GAO 1988). Minimizing undesired impacts on sensitive areas by controlling cattle distribution is a major concern of land managers (Coughenour 1991, Bailey et al. 1996). It has generally been stated that free ranging cattle use riparian areas more than they use the surrounding upland areas (Bryant 1982, Gillen et al. 1984, Roath and Krueger 1982a, Kauffman et al. 1983a, Wagnon 1968). Ames (1977) observed that riparian zones often receive more use than upland areas because they provide water, shade, thermal cover and are a productive source of high quality forage. Working on the San Joaquin Experimental Range in California, Bentley and Talbot (1951) found that even though they comprised only a small part of the landscape cattle preferred to graze in swale sites.

Livestock grazing can affect four general components of an aquatic system: Streamside vegetation, stream channel morphology, shape and quality of the water column and the structure of the soil portion of the stream bank (Kauffman and Krueger 1984). Kauffman et al. (1983b) observed that cattle grazing riparian areas caused significant differences in 4 out of 10 vegetative communities sampled. They also found heavy browsing of willows on gravel bars and speculated that this retarded succession. McLean et al. (1963) observed an increase in plant biomass the following year with a reduction in grazing intensity. On the other hand, Roath and

Krueger (1982a) found that grazing was unlikely to have long term effects on either the grass or shrub communities present in a mountain riparian system. Again, Kauffman et al. (1983a) speculated that cattle grazing on Catherine Creek in Eastern Oregon caused greater than normal erosion and more loss of stream bank. However, Laliberte et al. (2001), using precise ground measurements and remote sensing on the same stretch of Catherine Creek determined that over a twenty-year period that topography and stream dynamics had a greater influence on stream morphology than grazing. In addition, with intense observation of cattle movement in the same Catherine Creek pasture Ballard (1999) observed cattle using terrestrial habitats 94 percent and stream habitats 6 percent while actual direct stream contact was less than 1 percent. Buckhouse et al. (1981) found no significant effect of cattle grazing on Meadow Creek morphology and attributed morphological change to damage from high runoff and ice flows.

Damage to riparian vegetation and stream banks is not the only concern. Clean water standards emphasize the importance of controlling microbial populations in watersheds used by livestock. Buckhouse and Gifford (1976) observed that indicator bacteria from cattle fecal deposits were transported under artificial rainfall. Tate et al. (2000) determined that *Cryptosporidium parvum* oocysts were transported from cattle fecal deposits for a distance of at least 1 meter by rainstorms. As well, changes in soil character are an additional concern. Orr (1960) identified a trend in the top 4 inches of soil where bulk density increased and large macropore space decreased in grazed sites compared to sites where grazing was excluded. They noted that values obtained within exclosures that had not been used for five years were on par with older exclosures and suggested that recovery was relatively rapid upon removal of grazing pressure. Rauzi and Hanson (1966) reported surface runoff increased with grazing intensity along with a near linear decrease in infiltration. Watershed condition can be improved and erosion reduced by distributing livestock across watersheds more evenly (Kauffman and Krueger 1984). Therefore understanding how spatial and temporal factors influence cattle

distribution is critical for effective management of livestock on these landscapes (Senft et al. 1987). As a test of scientific accountability a total of 428 articles relating to grazing impacts on riparian communities and fish habitat were examined by Larsen et al. (1998). They found that only 89 were experimental, replicated, and statistically valid. Harris (2001) noted that scientific conclusions relative to the complex ecology of cattle and aquatic systems have resulted in contradictory conclusions.

General cattle activity

Moorefield and Hopkins (1951) noted three distinct daylight-grazing bouts with resting times in-between: early morning, mid-day and evening, but did not observe animals before 8 a.m. or after 8 p.m. and therefore did not generate information about grazing after dark. Johnstone-Wallace (1938) reported that cattle in New York graze as much at night as in the daylight. During late summer and fall, groups of cows in Montana were observed for 24-hour periods by Peterson and Woolfolk (1955). They noted that over one-third of all grazing occurred at night in August but decreased later in October when daytime grazing increased. Wagnon (1963) observed as much as 25% of grazing time occurred at night and suggested vegetation condition may determine potential night grazing with longer periods being associated with new forage. Low et al. (1981b) found cows grazed less at night in the spring and summer than during the other two seasons. While Reppert (1960) observed that little grazing occurred in complete darkness but noted that a full moon significantly prolonged the duration of evening grazing. Sneva (1970) noted much the same pattern in eastern Oregon. Both studies chose to follow animals only until they bedded down at night due to very little night time grazing activity.

Pratt et al. (1986), working in southern England, identified potential changes in habitat use relative to changes in the animals requirements for food and shelter throughout the year. They reported that through the spring and summer daytime distribution seemed primarily determined by foraging activity while the animals withdrew to cover for the night during this time period. Then through the winter

months the animals restricted their foraging to communities providing cover, as shelter assumed a greater priority at all times during the day. Seasonal trends in cattle use of riparian and upland sites were also reported by Marlow and Poganik (1986) where upland areas were used for grazing and resting appreciably more during early part of the season (late June and July) while more time was spent grazing riparian vegetation sites in August and September during which there was no distinction in the time spent resting in either the riparian or uplands sites. Cool-season and warm-season models were developed by Senft et al. (1985b) to account for the differences they observed in similar trends of night resting areas. This may be important as Low et al. (1981a) reported that 72 percent of cattle observed at dawn spent the next 24 hours grazing in that plant community leading them to believe the location of the night time resting period was an important indicator of where the animals would spend the next day grazing. Similarly, Bailey et al. (1990) observed that cattle looked as if they grazed nearby areas on the following morning but rarely foraged in the same area for more than two consecutive mornings

Observing behavior

Although it is assumed that observation and management has been practiced since the domestication of ungulates it wasn't until the last century that scientific evaluation of grazing behavior was conducted. "The Trail of the Shortgrass Steer" by J.H. Sheppard published in 1921 is the first observational behavior study of record (Sneva, 1970). Activities of grazing animals were studied in detail by Cory (1927). Harris (2001) offers that researchers have been studying grazing cattle for decades with the hope that years of observations will gain useful insight into the decision making processes cattle employ in their activity patterns and spatial distribution.

It is important to understand where and how long cattle utilize various elements of a landscape (Ungar et al. 2005). Identification of activity while use is in progress would be constructive to understanding potential impact. Early studies estimated animal travel by following the animal on foot (Cory, 1927). Significant behavioral differences between individual cows were noted by Hull et al. (1960) who

concluded at least 4 animals needed to be observed during each observation period in order to approximate behavior. In a clear tradeoff between one continuous observation and many interval observations Wagon (1963) observed the grazing habits of one animal continuously. Herbel and Nelson (1966) also observed a single animal for extended periods of time but chose a different animal each observation period. Different individual animals observed over a twenty four hour period at two week intervals over a 6 month grazing season was used by Ehrenreich and Bjugstad (1966). A herd observation method was employed by Reppert (1960) which included 20 freely grazing heifers with one animal observed at a time as they came into view over a 48 hour period every month. More recently Ballard (1999) employed a method described by Martin and Bateson (1986) where an individual animal was observed in each of two out of three randomly selected four hour periods on days where cattle activities were monitored in a riparian pasture. Pinchak et al. (1991) also restricted observation to daylight hours with the day divided into three equal periods of (0600 – 1100), (1101 – 1600), and (1601 – 2030).

Consideration has also been given to the interval of visual observation. Hull et al. (1960) concluded an interval of 30 minutes was enough to capture major behavior patterns. Nelson and Furr (1966) generally agreed with the 30 minute interval but noted that it failed to give reliable estimates of fine scale activities such as walking, nursing calves, defecation, urination, and drinking. Agouridis et al. (2004) states the primary difficulties of tracking animal location via visual observation are that the method is labor intensive and it is prone to error since the observer can alter cattle behavior, observation periods are generally too short to obtain confidence in daily behavior patterns, and observer fatigue can be problematic.

Tracking animals using the global positioning system (GPS) represents a major advance in spatiotemporal data acquisition (Ungar et al. 2005). Using GPS to locate livestock on a continual basis (24/7) eliminates the need for constant human interaction with the animals but the technology comes with its own set of issues.

Observational interval (GPS integration) can still be problematic depending on the research question asked. It was recognized by Ganskoop (2001) that frequency of integration set at 20 min was not adequate to separate fine scale activities, he offered that greater resolution may be warranted. Ganskoop and Bohnert (2006) used GPS collars at 10 minute intervals to compare travel distance, velocities and treatment occupation when giving cattle a choice between senescent or conditioned areas in four pastures. Bailey et al. 2001 used GPS collars set to log cattle locations every 10 minutes to evaluate the effectiveness of using dehydrated molasses supplement to modify grazing distribution in Northern Montana. Turner et al. (2000) suggest any interval greater than 5 min may overlook data apart from pasture utilization, such as discrete watering events or interpreting animal activity. Brosh et al. (2006) were able to define four activities: lying down, standing, walking without grazing, and grazing, using GPS collars set to catalog locations every 5 minutes when motion sensor data was also collected. Ganskoop and Johnson (2007) used collars programmed to take a GPS location at 5 min intervals and each animal was observed a minimum of eight daylight hours over a 15 day duration to give an indication of the interval settings ability to determine activity. They successfully classified 81-92 % of resting events. They also noted distance traveled as measured by unfiltered GPS locations were overestimated by about 15.2% or 1.15 km daily due to GPS error. In a simple field test using Trimble™ GPS units set at 2 second intervals, DeCesare et al. (2005) found GPS error increased track lengths by 27.5% under high canopy (> 40%) while open canopy (< 10%) tracks were increased by 8.5%. However actual point displacement did not deviate more than 7.98 m and 2.53 m respectively. They offer that this bias should be considered before interpreting GPS based animal movement data. Ganskoop and Johnson (2007) suggest the relative importance of deleting GPS error accruals from estimates of travel by an animal could be potentially quite small if they were equally or partially offset by the animals' undetected meanderings. On the other hand assessments of travel are of little value when the question a researcher

asks relates to frequency of animals in treatments or management units (Ganskoop and Johnson, 2007).

Activity and location may be asked as two separate questions depending on study objectives. Horizontal error inherent in GPS technology at the level used today should be considered. Since the inception of use by behavior ecologists of GPS technology questions of error specific to particular activities has been foremost in inquiry. There is a tendency to desire more of the data then it is able to give at a given resolution. GPS technology shines when frequency of occupation questions are asked as long as it is understood what the potential spatial error can be. In a study to determine suitability of GPS technology for grazing studies Agouridis et al. (2004) tested potential error under static conditions (not moving) while in an open field, along fence lines and under deciduous tree canopy. They noted average probable horizontal error with 95% of coordinates included to be: 3.93±0.86 meters under open conditions, 6.21±1.66 meters along a fence line and under deciduous tree canopy to be 12.31±2.15 meters. When testing in open field conditions while moving (dynamic) they obtained an average of 4.48±0.83 meters at 95%. They concluded when analyzing GPS data obtained from animal collars a 4 to 5 meter buffer zone around the boundaries of a creek should capture animal presence in these areas. At times the researcher will observe horizontal error that is just not possible. Moen et al. (1997) evaluated canopy effects on GPS collar performance and proposed that spurious records linked to inactive animals be withdrawn from datasets.

Because of the significant behavioral differences between individual cows as noted by Hull et al. (1960) error not associated with collar performance (sample adequacy) may enter into the picture when few animals are used as observations within the herd dynamic. Anderson and Urquhart (1986), while using digital pedometers to monitor travel of cows grazing arid rangeland, noted that because of cow individuality a large number of animals would need to be fitted with pedometers to capture the information desired. Turner et al. (2000) suggests, since animals express individuality and as fewer cows in a herd are collared the range of error

increases then it must be determined beforehand how much of this error is acceptable. They suggest studies in extensive grazing systems may require collaring dominant or social animals which may represent herd locations adequately. In addition Hebblewhite and Haydon 2010 noted that sample size requirements may be able to be achieved by redeploying GPS units on new individuals each year when studying resource selection or movement. Bailey et al. (2001) considered each collared cow as an observation and the data for that cow were averaged during the period.

Despite concerns over GPS location error, crude and inaccurate attribute maps (Frair et al. 2010) and inadequate sample size; many positives have been noted by researchers with the use of remote sensing technology. Gaillard et al. 2010 suggest when studying the dynamics of space use and animal movements, GPS technology can be very useful. When it comes to resource selection by animals, GPS data may require biologists to become more sophisticated and, perhaps more honest in the kinds of ecological questions they ask about animal use of a resource (Hebblewhite and Haydon, 2010). As well, Kie et al. (2010) suggest that previous sampling limitations in observer-based studies such as inclement weather and darkness are overcome by GPS observation which may ensure a more representative sample of an animal's space use. Kochanny et al. (2009) offer that GPS technologies makes possible more frequent sampling of animal locations which may be more apt to capture corridors and connecting paths and to capture occasional use of areas or resources that are important to an animal. Owen-Smith et al. (2010) propose that changing predation pressure and food availability may be able to be evaluated with GPS technology as well as changes in animal optimal behavior routines during good and bad years. DeCesare et al. 2005 suggest the advancing role of Global Positioning System (GPS) technology in ecology has made studies of animal movement possible for larger and more vagile species. With the ongoing discussion of accuracy issues and rapid development of new technologies in the remote sensing field the study of animal ecology, using GPS/GIS technology has a bright future as long as scientists

use it as tool to augment, not replace, the on-the-ground observation and understanding of the species they are studying. Hebblewhite and Haydon 2010 argue that technology should not replace field biology, but be combined with animal observation in the field in efforts to interpret behavior and ecology from GPS technology. Knowledge from past observation is important to not only understand and remember what we have already learned but to steer us in the proper direction in the field of animal behavior study.

Methods and Tools

Study Area

The ten year parent study "Wolf impacts on cattle productivity and behavior" is looking at both high wolf density areas in west central Idaho (Payette National Forest) and low wolf density areas in Northeast Oregon (Wallowa Whitman National Forest). Three active grazing allotments within the Wallowa Whitman National Forest (WWNF) were identified and paired with three active grazing allotments in the Payette National Forest (PNF) according to land form and vegetation characteristics at landscape scale (Sneft et al. 1987, Bailey et al., 1996) and grazing practices in order to fulfill the two general objectives of the parent study. Data reported in this thesis were derived from the WWNF data set.

The study area in Oregon is entirely within the Wallowa Whitman National Forest and is comprised of three currently active grazing management areas which together equal 43,972 hectares (108,655 acres). Two of the management areas (Site 1, Site 2) lay on the Southwest flank of the Wallowa Mountains and fall almost completely within the Blue and Seven Devils Mountains Major Land Resource Area (MLRA) where it transitions to the Central Rocky and Blue Mountain Foothills (MLRA). The third grazing management area (Site 3) is located at the northern extent of the Wallowa Mountains and is mostly (two thirds) characterized by the Blue and Seven Devils Mountains MLRA with the southerly third entering into the Palouse and Nez Perce Prairies MLRA. All are found within the Blue Mountain Ecological Province.

Elevation in the Blue Mountain Province ranges from 305 m (1000 ft) at the Snake River in the extreme northeast corner of Oregon to over 2,987 m (9,800 ft) in the Eagle Caps of the Wallowa Mountain Range (Anderson et al. 1998). Precipitation averages about 56.85 cm (22.4 inches) with over half coming during the winter months between November and March. Precipitation follows the elevation gradient with the most arid being in the lower reaches of the Inmaha and Snake

Rivers and the greatest values of 292 cm (115 inches) found in the Eagle Mountains south of Enterprise Oregon (Anderson et al. 1998). In the Blue Mountain Province elevation in combination with aspect, precipitation, and temperature gradients determine potential vegetation which has been described as a continuum by Hall (1973). The natural vegetation produced under these diverse combinations can be described as a third being grasslands with the remaining being forest (Anderson et al., 1998).

The Blue and Seven Devils Mountains MLRA geology is characterized by sedimentary, metasedimentary, and volcanic rocks which have been uplifted and faulted. The Wallowa Mountains consist of mostly greenstone (metamorphic lava) with some peaks and ridges being limestone with a core of granite. Mollisols and Andisols are the dominant soil orders in this area. Soil temperature regimes vary from mesic at lower elevations grading into frigid or cryic with increased elevation. Soil moisture regimes are generally either xeric or udic. Land use in this MLRA is a mix of timber production, livestock grazing, wildlife habitat, recreation and watershed. Population density is minimal with no large cities or towns. The United States Forest Service is the primary managing entity (USDA, 2006).

The Palouse and Nez Perce Prairies represented small portions of the Wallowa Whitman and Umatilla National Forests and are characteristic of the lower dryer portions of the Blue Mountain Province as described by Anderson et al. (1998). Annual precipitation averages 33 – 71 cm, (13 – 28 inches) but can be as high as 23 cm (43 inches) when adjoining MLRAs have much higher elevation. Summers are relatively dry with precipitation evenly spread over the other seasons. Thick layers of loess and volcanic ash overlay the undulating Miocene basalt flows that comprise most of the foundation rock. Elevation generally ranges from 660 – 1,220 m (2,000 – 4,000 ft) with steep-walled canyons cut by major streams. The dominant soil order is Mollisol with a mesic or frigid temperature regime and a xeric moisture regime. Soils are deep to very deep and moderately to very well drained. Small areas of forest are typical on north-facing slopes. Idaho fescue and bluebunch wheatgrass are

dominant grass species. Rangeland is the major use on the breaks, scablands and buttes. Dryland wheat is the principal crop areas of urban development occurring in Southeast Washington.

Technology

The relatively recent (mid 1990s) use by animal behavioralists of Global Positioning System (GPS) technology to track animal movement has led to improved information gathering of animal spatial and temporal movements relative to their surrounding ecological conditions. Until very recently temporal limitations were imposed by power requirements and data storage capacity of GPS collar technology. Investigators were required to make a choice between duration of collar life versus frequency of GPS locations cataloged. The development of the "Clark Animal Tracking System" (Clark ATS) with high capacity on board data storage has enabled researchers to collect relatively frequent (five minute interval) GPS locations for extended periods of time (Clark et.al. 2006). This GPS cataloging frequency allows for greater understanding of landscape use and movement characteristics of free ranging animals (Johnson and Ganskopp, 2008). GPS data collected in this manner may be managed and prepared either through non commercial developed software (Johnson et.al., 2005) or by hand in excel format for analysis in a variety of Global Information System (GIS) programs. ESRI® ArcMap™ 9.3 was used for the most part to develop landscape maps and perform data analysis queries. Global Mapper v9.03© 2002-2008 was used for some map development exercises. As well an extension for ArcMap 9.3, Hawths Analysis Tools™ v.3.27, was acquired to perform functions not available in ArcMap 9.3.

Samples

In 2008 and 2009 ten mature beef cows with calf (*Bos tuarus*) were randomly selected from each allotment herd and were collared with GPS collars (Clark ATS) prior to the herd moving into the grazing unit. The collars were collected and returned to the lab when livestock were gathered in the fall. The cattle were

otherwise left alone by researchers during the season long trials to interact with their environment in the way ranch and agency personnel routinely manage the spatial and temporal aspects of grazing use within the respective study areas. This gave the two year study a potential of 60 data sets, 20 from each study site. Each collar seasonal data set is considered as a single observation (Bailey et al. 2001) as the GPS locations themselves are auto correlated being logged at five minute intervals.

Map Development

Stream layer

Stream layer data were obtained and refined from several different sources; United States Geological Survey (USGS), United States Forest Service (USFS) and Streamnet.org (2010). Spatial errors among these data sources were significant enough to require correction for the purposes of this study. Paper maps were developed and supplied to permittee cooperators showing line files representing the water courses for identification of perennial flow. The identified streams were digitized using Digital Raster Graphic (DRG) maps acquired from the USGS. The digitization was compared with the United States Department of Agriculture's "National Agriculture Imagery Program" (NAIP) GIS layers for further correction. Water courses identified in the 2009 NAIPs imagery were corrected to be as close to the thalwag as possible. Where visual identification was not possible the DRG stream location was used as it generally closely matched that of the 2009 NAIPs imagery which has an accuracy level of ± 5 meters.

Some of the streams in two of the study areas are classified by the streamnet.org GIS layers as having listed fish as a management concern. Not all watercourses considered in this analysis contain listed fish but all listed fish designated streams are included when they are found within the study area boundary. The analysis results are not separated as to whether the interaction of cattle with the aquatic system was involved with a listed fish stream.

Topographic layers

Slope, Aspect and Elevation range sites were developed, using ArcMap 9.3 software, from 10 meter Digital Elevation Model (DEM) data acquired from the USGS database. Slope delineations of 0-4%,4-12%, 12-35% and >35% and aspect (North, South, None) were used when classifying maps to identify the character of the topography in each study site. A ten foot contour layer was developed to determine elevation characteristics of the landscapes. Each study area was evaluated for percentage of defined topographical differentiation contained within the allotment relative to the total area of the study site.

Vegetation layer

GIS vegetation maps were obtained from the Wallowa Whitman national forest GIS database and used to classify over-story. Spot checks were conducted to confirm the predicted overstory and identify associated understory. The maps generated were a bit broad but this was the only option at the time for the extensive scale of the project. Analysis was initially performed at this level.

Late in the study period the Natural Resource Conservation Service (NRCS) published online soil survey maps with related range vegetation compositions based primarily on plant associations described by Johnson and Clausnitzer (1992). The GIS soils maps, with associated data base information, was attained from the NRCS Soil Data Mart web site and clipped to the related study areas. After manipulation within GIS software the soil classifications using the vegetation composition information were cross referenced using Hall (1973). With information from the spot checks previously completed and by examining the 2009 NIAPs imagery overlain with the new vegetation layer, confirmation of the resulting new vegetation GIS layer was accomplished. This classification system reduced the number of vegetation categories to a manageable level. Site 1 contained 17 distinct communities, site two had 12 and site three had 8 vegetation communities as classified by Fred hall.

Analysis was again performed using the new vegetation classification maps. The resulting use percentages were determined to be generally too small for many of

the plant communities as indicated by the lack of preference values attained in communities of small area relative to the study area. Using the values gained in the analysis the communities were pooled into the over-story classifications used by Hall (1973) and calculated again. This resulted in a better fit for the spatial scale of the project. For reporting purposes the values were again pooled into no more than 3 growth form types. All upland shrub and grass communities were classified as "upland grass". Upland forests were classified as to whether they were on the dry side or the more mesic type of moisture regime with the classifications designated ponderosa pine/Douglas fir (pine/fir) or mixed conifer.

Data Management

Collar data was downloaded and processed through a software program developed for the specific format of the data set. The resulting Microsoft Office Excel™ comma separated values (CSV) contained columns with GPS point location information in latitude/longitude in decimal degrees and UTM east/north. Each data point row contained information relative to Greenwich Mean Time, metric elevation, speed in knots, dilution of precision (position, vertical, and horizontal), bearing, accelerometer values, and battery condition.

Each CSV file was processed by hand in Microsoft Office Excel 2007™ by inserting columns and converting information into applicable formats. Collar Greenwich Mean Time was transformed to reflect local time relative to standard time and daylight savings time. Speed was converted to kilometers per hour and miles per hour and the metric elevation was transformed to English values (feet). All original information was retained as provided. Each file was tagged with pertinent identifying information and then formatted to be functional in ArcCatalog™ enabling the CSV file to be transformed into an ArcMap shapefile for analysis. Each step was archived from raw collar data to finished shapefile to prevent potential loss of information and to retain the opportunity for analysis in the future.

Collar unit shapefiles were clipped to their representative study site boundaries' and analyzed for day and time entrance into and exit from the relevant

study site. This allowed for all GPS locations taken outside the grazing season date and time parameters to be filtered from analysis. From these data set shape files data was clipped and/or selected within the ArcMap software for various types of analysis. Neither dilution of precision values nor the distance between points was used as a filter. Obvious location errors were either clipped from the file or moved with the editor tool in ArcMap depending on analysis performed. The published static test (not moving) horizontal accuracy of the Clark ATS collars yielded a mean 95% CEP of 2.7m (Clark et al. 2006).

Data selection for analysis

Not all GPS data points determined to be relevant to the grazing season were used in analysis. The data established the time frame for analysis. Study areas 1 and 2 GPS data were selected by analysis of data constraints to include the 12 week period from June 21 to September 12 (84 days) for both 2008 and 2009. This was done to realize the greatest number of data sets out of each of the two herds for each year that would cover an equal period of time. Preliminary analysis using full sets of unequal time frame gave unsatisfactory results as compared between years, particularly in study area 3. The 2008 data set was not used for analysis of site 3 due to only for units having enough GPS data extending far enough into the April to October grazing period to be considered for inclusion in general analysis. None of these data sets made it to the end of the grazing season therefore it was decided to excluded them from analysis for this particular report. Seven of the collar units in 2009 cataloged GPS locations from April 27, the first full day after initial study area occupation, to October 22, the last full day before exit. These were used in this report even though the time frame of these data sets is over twice that of the other study areas.

To achieve the indices of preference for the attributes slope, aspect and vegetation the data sets analyzed had to be enclosed by the area extent of the study site therefore any points occurring outside the boundary were clipped from the data set for analysis. For the analysis of perennial stream systems the data sets were not

clipped to area boundaries as a relative preference was not calculated.

Reported for site 1 and site 2 are the results of 14 individual mature grazing cows' w/calf (*Bos tuarus*), 7 sets from each year's trial (2008, 2009) as combined. Site 3 with one year's worth of complete data and having a different grazing system and land form was analyzed using 7 data sets that contained GPS locations beginning on April 27 and continuing thru October 22 (179 days). All sets contain complete 24 hour days beginning at 12:00 AM Pacific standard time (PST).

Evaluation

Slope, aspect, vegetation Analysis

Data was analyzed, using ArcMap 9.3 programming, to determine the total time spent by cattle associated with each landscape attribute (slope range, aspect and vegetation type). Comparison of the percentage of time spent in relation to percentage of spatial area was used to derive indices of preference.

Slope values of (0-4%, 4-12%, 12-35%, > 35%) and aspect values of (North, South, None) were appended to the shapefile attribute table within the ArcMap software. The selection of attributes feature in the ArcMap software was used to count GPS locations occurring in each attribute. Percentage of occupancy was calculated as well as relative preference (RP) for that attribute. Aspect "None" was shown to be insignificant in all analysis, less than 1 percent, therefore it was dropped from reporting for all study areas.

Stream systems analysis

The question asked is how often cattle occupy the area around perennial water flows relative to time spent within the study area while under the present management scenarios imposed by public land and ranch management personnel. Times spent within a defined distance of a perennial watercourse were evaluated. Percent time within each category was found as well as cumulative occupancy within the defined distances. In this analysis it was not needed to restrict the data sets to an area extent as preference indices were not produced due to the linear nature of the

attribute in question. All cataloged GPS locations were evaluated as long as they were within the time frame established for analysis. This was in order to capture all available occupancy potential allowed by the data sets themselves.

Initially the inquiry was performed using a simple “within distance of” query in the ArcMap selection tool. However because of the linear nature of the of the attribute queried a buffer zone out to 10m (32.8ft) was established on either side of the line feature representing the streams in order to mediate the estimated potential horizontal error of both GPS locations (Agouridis et al. 2004) and map data (USDA, 2009). This area is considered as the potential interface area between cattle and aquatic habitats as defined by Ballard (1999). Beyond this area of ambiguity five other buffer zone classifications were established on both sides of the stream of 10-20m (65.8ft), 20-30m (98.4ft), 30-40m (131.2ft), 40-50m (164ft) and 50-60m (196.8ft). These zones may or may not represent potential riparian land forms relative to each study area depending on the valleys topographical character and stream channel shape and structure. Although riparian zones are not explicitly defined the distance values do give an indication of time spent within the immediate area of the perennial water courses that are found within the respective study areas.

Landscape occupancy

As a supplement to the general analysis the kernel density tool found in the ArcMap 9.3 “toolbox” was used on the selected data sets for each site. When the data information, in the form of point shapefiles, is entered into the tool it analyzes the spatial relationship of the GPS locations and offers a mathematical suggestion for search radius and raster output cell size. These suggestions were accepted. Because the suggested search radius and raster cell size are affected by the spatial relationship of the data set GPS locations, which at times contain a few obvious spurious locations, the data set was clipped to the area boundary of the study site in question. This not only solved the problem of outlier locations but restricted the resulting density raster to the area boundary of the study site allowing for percentage calculations. The density raster was then processed in the “Hawths Analysis Tool”

percent by volume contour function. The isopleths values were set at 10%, 20%, 30%, 50%, 70% and 95%. The area of the 95% isopleths was compared with the area of the site in question (Fig.1). This analysis allows a type of home range comparison between individual animals within a site and between sites. Percentages of total area relative to study site area are reported by individual sample animal on a season basis as well as animal sample sets by study area and yearly trial.

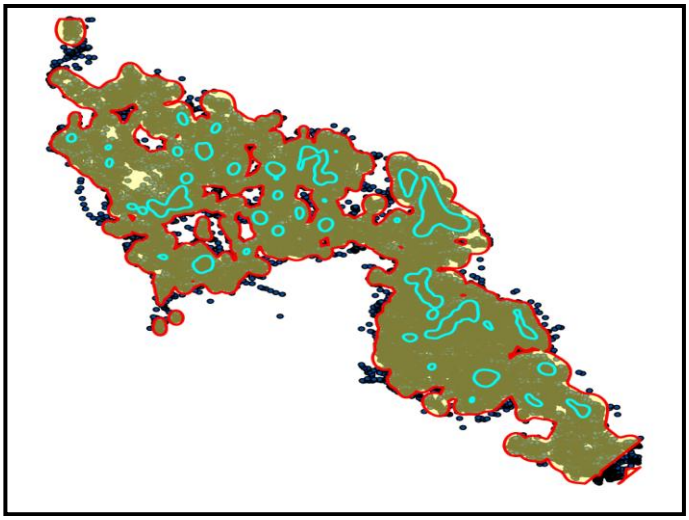

Figure 1. Polygon representing 95% by volume contour with 20% by volume highlighted.

Statistical analysis

The descriptive statistics of average, percentage and standard deviation are reported for analysis where they are relatable to the question posed for the analysis of the attribute. As well relative preference indices (RPI) are generated when area occupancy relative to the study site area is found; these are calculated using the GPS point frequency percentages found within an attribute divided by the percent of attribute area found within the relevant study area. The strength of these observed RPIs was refined using a battery of Chi-square assessments (Snedecor and Cochran, 1973) to determine significance ($p < 0.05$).

Note to reader

Percentage values reported for all attribute analyses are relative to occupancy for all activities within a particular attribute. Some confusion may be unintentionally induced with the word “use”. For the most part where the word “use” would seem to be the norm the word occupancy, or a variation of, was substituted so as to imply the correct meaning to the phrase. Percentage of time spent, within the attribute in question, relative to the time frame of the data set used for all activities. No distinct activity classifications are implied in this report.

Results and discussion

GPS collar performance

Over the two year period of the study 60 collars were deployed and 60 collars were retrieved. Of the sixty collars only one came back with no data at all, yielding a 98% success rate when considering collar integration potential. Of the thirty collars deployed in 2008 ten collars failed to gain enough data to be meaningful for grazing season analysis. Six of these unsuccessful collars were deployed in April on site 3. The defective collars had an external design flaw that was identified and corrected before the deployment of site 1 and 2 collars in June. The other 4 collars that were discarded from general analysis (two each from site 1 and 2) also ceased to function too early. In 2009 one collar unit retrieved from site 2 failed early in the grazing season. Overall, the 60 deployed collars yielded 1,719,181 GPS locations that met the study criteria and were used in the subsequent analyses (Table 1).

Table 1. Point tallies by unit and by year; dark highlighted units used in analysis.

	Site 1				Site 2				Site 3			
Year	**Unit**	**Points**	**In**	**Out**	**Unit**	**Points**	**In**	**Out**	**Unit**	**Points**	**In**	**Out**
2008	38	25023	6/16	9/15	27	36220	6/3	10/18	15	8522	4/18	5/24
2008	39	31371	6/16	10/11	33	34356	6/3	10/6	16	7256	4/18	5/15
2008	40	33987	6/16	10/18	45	38208	6/3	10/20	17	42954	4/18	9/29
2008	41	34393	6/16	10/19	46	19572	6/3	8/13	18	10593	4/18	5/29
2008	42	17841	6/16	8/29	50	38760	6/3	10/22	19	35775	4/18	9/10
2008	43	2246	6/16	6/24	53	38218	6/3	10/20	20	0		
2008	44	34302	6/16	10/19	54	38164	6/3	10/20	21	15910	4/18	6/17
2008	47	30167	6/16	10/8	55	38136	6/3	10/20	22	0		
2008	48	24320	6/16	9/13	57	8445	6/3	7/4	23	31689	4/18	8/16
2008	49	0			59	38768	6/3	10/22	24	40322	4/18	9/20
2009	81	30293	6/17	10/12	33	39772	6/2	10/25	10	49721	4/26	10/24
2009	53	32979	6/16	10/14	41	35498	6/2	10/13	7	48883	4/26	10/24
2009	8	27431	6/16	10/1	54	40415	6/2	10/29	17	2141	4/26	5/4
2009	9	29977	6/16	10/8	69	35956	6/2	10/11	15	47975	4/26	10/24
2009	42	32438	6/19	10/15	12	40895	6/2	10/29	35	49760	4/26	10/24
2009	6	32133	6/13	10/8	11	38993	6/2	10/26	16	0		
2009	14	31998	6/17	10/17	65	39922	6/2	10/28	27	49314	4/26	10/24
2009	4	32791	6/16	10/21	68	37379	6/2	10/27	32	48731	4/26	10/24
2009	59	29308	6/16	10/1	NK	0			45	53019	4/26	11/5
2009	36	29702	6/16	10/5	50	30172	6/2	9/20	34	40752	4/26	9/26

Note: In = Into the study area, Out = Out of the study area for the season or the collar stopped.

Topographic Analysis

Topographic features can be highly variable in rugged mountainous terrains and can strongly influence cattle activity. Cook (1966) identified slope as one of the most influential factors controlling animal utilization on a landscape. Locally, elevation and aspect can influence air temperatures and precipitation patterns which in turn can influence soil character and vegetation quality/quantity.

Topographic character of study areas

Study Site 1 has an elevation gradient of 1,100m (3,608ft) to 2,526m (8,285ft), with a very small percent of land area being in the 0-4% (Fig. 2). The 4-12% slope area was next smallest followed by slopes greater than 35%. By far the 12-35% category was the largest percentage of landscape in site1.The study site 1 aspects of north and south is 44 and 56 percent of area respectively. Site 2 ranges in elevation from 949m (3,113ft) to 1724m (5,655ft). With the proportion of slope trending toward the gentler categories as exhibited by the increase in area percentage of the 0-4% and 4-12% categories over that of site 1. The category 12-35% was calculated at just half the study area decreasing inversely with the increase in the 4-12% classification. The classification > 35% decreased slightly comparative to the increase in the 0-4% range. The percent area of north and south aspect in site 2 was found to be 45 and 55 percent, respectively. Study area 3 is quite different from sites 1 and 2, with the greatest portion of land area classified with the > 35% slope designation. The 0-4% area percentage is very similar to site 2 while the 4-12% and 12-35% categories are reduced by about a third. The proportion of northern versus southern aspect is 52 and 48 percent respectively. The elevation values in study area 3 begin in at 736m (2414ft) and increase to 1599m (5245ft).

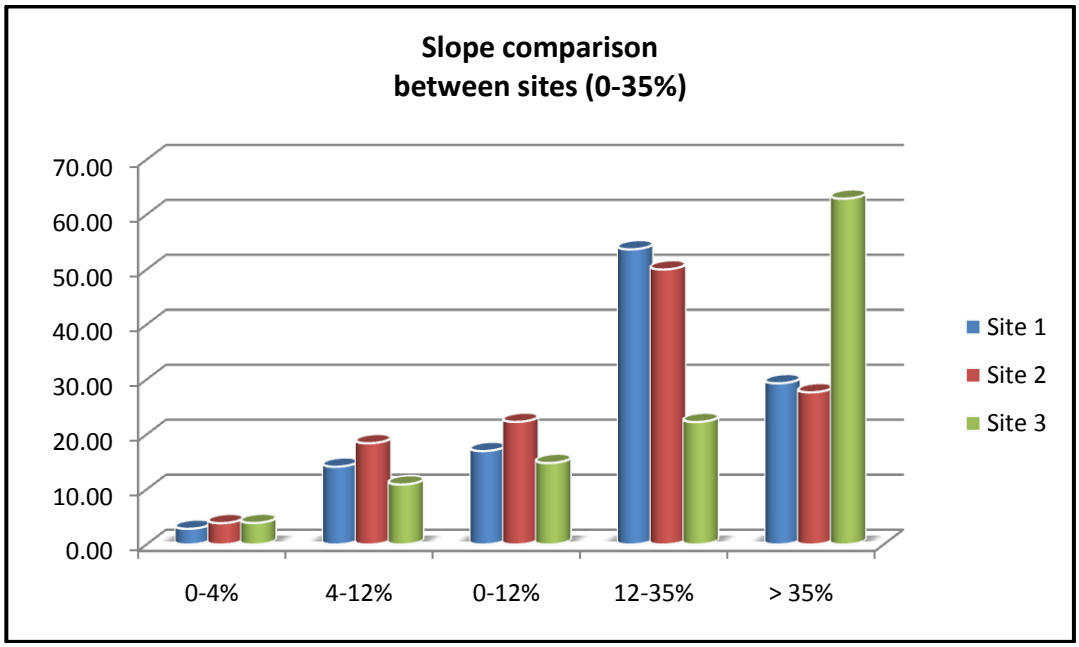

Figure 2. Visual representation of differences of slope between study areas.

Analysis of animal GPS locations relative to slope/aspect

Analysis of site 1 data indicates that cattle spent the greatest amount of time on slopes of 12-35% followed by 4-12%, > 35% and finally 0-4% (Table 2). Weighting the occupancy time with the proportion of the study area described in each slope or aspect category yielded an index of preference (RPI). These results indicate that cattle avoid the steepest slopes (> 35%; $p < 0.05$) were indifferent towards slopes of 12-35%, (ns) preferred slopes < 12% ($p < 0.05$) and only slightly preferred (ns) southern exposures over northern. In other words, cattle in site 1 utilized the landscapes they were placed on. They did not avoid any slopes < 35% but when given a choice between slopes greater or less than 12% they selected the flatter terrain. They were indifferent to slopes 12-35% using them proportional to the area of the slope available on the landscape.

The site 2 topographic analysis yielded similar results to site 1 with the greatest percentage of use for all purposes found in the 12-35% category followed by the 4-12% classification (Table 2). The >35% category was occupied much less ($p < 0.05$) than both the 4-12% and 12-35% categories but more than the 0-4% slope area.

By using the preference indices as comparison it is noted that similar to cattle on site 1 the site 2 cattle effectively occupied slopes < 35% but preferred ($p < 0.05$) slopes < 12%. Aspect preference was not significant but south aspects were numerically favored over north aspects.

In analyzing site 3 for topographic use the 12-35% slope range was again numerically occupied more than 4-12% but did not dominate as observed in analysis of sites 1 and 2 (Table 2). Another difference in this study area is slopes of > 35% were more strongly avoided ($p < 0.01$). This difference likely reflects the fact that slopes > 35% are proportionally twice as large when compared to the other two study areas. Logically this decreases area percentage of the less steep slope classifications increasing the portion of time concentrated on the moderate slopes thus increasing the preference relative to sites 1 and 2. Cattle continued, as in site 1 and 2, to prefer slopes less than 35%; ($p < 0.05$) and show the greatest preference to slopes less than 12%. Aspect preference was not significant but the northern aspects of site 3 were numerically favored over southern aspects (Table 2).

Table 2. Study area topographic and occupancy values.

Site 1 (08/09)						
Attribute	0 - 4%	4 - 12%	12 - 35%	> 35%	North	South
% Occupied	6.51	27.13	54.25	12.11	38.70	61.19
Area %	2.85	14.14	53.69	29.32	43.61	56.27
RPI	2.28	1.92	1.01	0.41	0.89	1.09
Site 2 (08/09)						
Attribute	0 - 4%	4 - 12%	12 - 35%	> 35%	North	South
% Occupied	7.40	30.52	49.72	12.36	40.38	59.53
Area %	3.88	18.42	50.03	27.68	45.31	54.62
RPI	1.91	1.66	0.99	0.45	0.89	1.09
Site 3 (09)						
Attribute	0 - 4%	4 - 12%	12 - 35%	> 35%	North	South
% Occupied	13.83	34.73	39.30	12.14	52.37	47.49
Area %	3.91	10.91	22.27	62.91	52.21	47.70
RPI	3.54	3.18	1.76	0.19	1.00	1.00

Vegetation

Herbaceous vegetation is considered one of the most influential factors affecting decisions grazing cattle make when grazing optimally (Brock and Owensby 2000, Senft et al. 1987, Smith 1988, Wade et al 1998).

Vegetation analysis

The majority of study area 1 consists of upland forests with the mixed conifer community occupying twice the area of "ponderosa pine/Douglas fir" (pine/fir) (Table 3). While a small percentage of the study site area is represented by the upland grass community.

Cattle in site 1 occupied the mixed conifer community for over half the time they were in the study area followed by the pine/fir community and the upland grass community which was a distant third in occupancy rate (Table 3). The RPI values indicate the pine/fir community was preferred, ($p < 0.05$) while cattle proportionally avoided ($p < 0.05$) the mixed conifer even though it was used more. The small area classified as upland grass was preferred ($p < 0.05$) at about the same preference level as the pine/fir community. With relative preference values based on occupancy rate and area percentages the only community avoided was the mixed conifer community which is by far the largest component community of the study area.

Upland forest also dominates the landscape of study area 2 but mixed conifer and pine/fir are similar in area of incidence. The upland grass community occupies a larger area percentage of the study area than in study site 1 but is still less than $1/5^{th}$ the study area.

In the site 2 landscape setting mixed conifer was occupied the most and was preferred ($p < 0.05$) over other communities (Table 3).. The next highest occupancy occurred in the pine/fir community but its relative preference indicates it was avoided ($p < 0.05$) by cattle as was the upland grass classification which was occupied very little in relation to the area percentage of the community.

The vegetation area percentages in site 3 is very different compared to sites 1 and 2 (Table 3). Upland grass occurs in nearly half the study area and is located at the higher elevations. In combination the pine/fir and mixed conifer communities cover more area of the study site but individually they are only about 2/3^{rds} that of the upland grass classification.

Even with larger areas of upland grass and pine/fir the mixed conifer community was occupied the greatest amount of time followed closely by the upland grass then the pine/fir communities As in study area 2 cattle preferred ($p < 0.05$) the mixed conifer community but displayed moderate indifference ($p < 0.05$) toward both pine/fir and upland grass communities.

Table 3. Study area vegetation community and occupancy values.

Site 1 (08/09)			
Attribute	Upland Grass	P. Pine/D. Fir	Mixed Con
% Occupied	8.80	37.64	53.56
Area %	6.48	26.95	66.57
RPI	1.36	1.40	0.80
Site 2 (08/09)			
Attribute	Upland Grass	P. Pine/D. Fir	Mixed Con
% Occupied	5.66	24.46	69.88
Area %	14.38	40.92	44.69
RPI	0.39	0.60	1.56
Site 3 (09)			
Attribute	Upland Grass	P. Pine/D. Fir	Mixed Con
% Occupied	35.59	24.30	40.11
Area %	43.95	28.77	27.27
RPI	0.81	0.84	1.47

Although the relative preference value describes one facet of landscape selection by cattle the percentage of occupancy offers an equally important illustration of actual time spent within different vegetative communities (Table 3). In all three study areas the most time spent for all purposes was in mixed conifer. Considering pine/fir, site 1 and site 2 were occupied at the next highest level in line with attribute area percentages. This relationship changed in study area 3 where upland grass was occupied more than the pine/fir but also had the most area by far compared to the other vegetation types.

Perennial stream systems

The use of free flowing perennial streams and the closely associated potential riparian landforms by cattle is a management concern that has been the subject of many scientific inquiries since the 1960s. In this report permanent flow was the main criteria by which streams were chosen for analysis. The perimeter of study site 1 encloses 47 kilometers (30 miles) of perennial stream while study site 2 has 24 kilometers (15 miles) of perennial flow within its boundary and study area 3 contains 36 kilometers (22 miles) of perennial stream. Evaluation of stream interaction as reported represents the zone on both sides of the stream effectively doubling the potential linear stream contact.

Perennial stream analysis

Cattle occupancy of the buffer zones of study area 1 and 3 did not show a pattern of occupancy preference (ns). Zones closest to the water were not occupied more than zones further from the water source (Table 4). In site 1 this is likely attributable to the V shaped valleys with “A” channels that pre-dominate the area and limit the development of riparian meadow vegetation. In study area 3 the elevation gradient of the landscape places the cattle in steep canyons containing perennial streams early in the grazing period. As the cattle are moved upland, following snow melt, these same canyons limit their access to the streams for the remainder of the grazing period.

In contrast the cattle occupying site 2 are on a landscape where riparian areas may form on more moderating slopes. This allows the formation of broader geomorphic surfaces that support riparian vegetation. Thus it is not surprising to find differing cattle preferences ($p < 0.05$) associated with the different riparian zones along the water course (Table 4). In this study area cattle favored ($p < 0.05$) the zones out to 30m (98.4ft) with the greatest preference ($p < 0.05$) occurring equally within the 0-10m (32.8ft) and the 10-20m (65.6ft) classifications. This preference may reflect the occupancy of stringer meadows that form on developed geomorphic surfaces along stream courses with this type of topographic character.

Although preference of the zone 0-10m (aquatic habitat) is variable between study areas it should be noted that occupation of this zone was always less than 1 percent. This seems to be supported by Ballard (1999) where intensive visual observations indicated a similar percentage of use. On a per day average the individual animals in site 1 spent 2.43 minutes per day in this zone with site 3 cows being similar at 2.58 minute per day and then by site 2 cows spending 11.78 minutes per day in the 0-10m zone. Partitioning of activities of cattle during these time frames was not attempted. It is not know what they were doing while in this zone.

Table 4. Stream area use by individual zone occupancy and cumulative occupancy.

Stream Area Occupancy	Percent occupied in buffer zone			Cumulative percent occupied 0-60m		
	Site 1 (08/09)	Site 2 (08/09)	Site 3 (09)	Site 1 (08/09)	Site 2 (08/09)	Site 3 (09)
Buffer Zones	%	%	%	%	%	%
0m-10m (Aquatic Habitat)	0.18	0.86	0.19	0.18	0.86	0.19
10m-20m	0.20	0.88	0.20	0.39	1.74	0.39
20m-30m	0.21	0.68	0.21	0.59	2.43	0.60
30m-40m	0.18	0.53	0.19	0.78	2.96	0.79
40m-50m	0.17	0.43	0.19	0.95	3.39	0.98
50m-60m	0.17	0.34	0.19	1.11	3.73	1.17

Cumulative buffer zone occupancy was numerically similar between site 1 and site 3 with both reaching occupancy rates of just over 1 percent for all area between 0m and 60m (Table 4). Site two was again different in this analysis as occupancy began in the 0-10m zone with a higher numeric value than the other two and was just shy of 4 percent cumulative occupancy out to the 50-60m zone.

Landscape occupancy

Landscape occupancy (LO) can be thought of as a type of home range analysis which is a concept that is discussed largely by wildlife researchers (Burt 1943, Powel 1987, Plowman et al. 2006, Kie et al. 2010) where animal movement is not directly managed in the sense that domestic livestock movement can be. The concept for domestic cattle can still be important in understanding how animals distribute themselves within the area allowed to them for use and may allow some insight into dispersion characteristics of individual animals sampled as well as for a study area sample set.

Landscape occupancy analysis

The LO analysis for individual animals in study area 1 exhibited less variability in 2008 between individual animals than in 2009. The average occupancy for individual animals in this study area was also less in 2008 than 2009 (Table 5). Similarly, when the polygons representing the individual samples were merged, effectively removing the overlap in area use by individuals, the sample set LO was less in 2008 than in 2009. Merging the 2008 and 2009 sample set polygons representing the respective LOs the coverage of use for all purposes was just under 50 percent of the area of study.

The standard deviation for individual sample animals was greater in study area 2 than in site 1 for both the 2008 and 2009 season trials with the 2008 trial showing more variation than the 2009 trial (Table 5). As well the average area occupied by the individual LOs increased in site 2 over that of study area 1 by a substantial factor in both 2008 and 2009. The sample set area values were also greater for both years than in site 1 with the 2008 and 2009 sample set polygon rates being just under 50 and over 50 percent respectively Then with both years pooled and the year by year overlap removed the area of occupancy for two years data demonstrated that well over half the study area was accessed by the 14 sample cows evaluated.

Table 5. Percent area values of polygons of 95% isopleths representing sample animal occupancy.

Utilization distribution Analysis	Percent occupancy at 95% of GPS locations					
	Site 1		Site 2		Site 3	
	2008	2009	2008	2009	2009	2010
Sample	%	%	%	%	%	%
1	4.66	2.50	6.15	10.06	19.64	NA
2	5.59	7.27	9.66	12.60	21.09	NA
3	6.51	7.63	11.28	13.42	21.32	NA
4	6.65	7.73	11.42	14.77	22.36	NA
5	6.94	8.02	11.81	15.35	23.63	NA
6	7.73	8.17	14.91	15.49	23.73	NA
7	9.89	10.51	16.00	18.07	24.75	NA
Total	47.96	51.84	81.23	99.75	156.51	NA
Rng	5.23	8.01	9.85	8.01	5.11	NA
Avrg	6.85	7.41	11.60	14.25	22.36	NA
Stdev	1.66	2.41	3.27	2.54	1.79	NA
Sample polys merged	29.12	33.91	47.33	52.75	47.35	NA
Two years merge		49.44		65.35		NA

The third study area was only evaluated for the 2009 grazing season but with a much longer time frame, over twice that of the other two sites. Variation between individual animals was less than that of all but one of the yearly trials for the other areas. While the cattle in this study area demonstrated an average individual LO well over that of both site 1 and site 2 but when the area occupancy percentage was calculated for the merged LOs the value was less than during 2009 in site 2 about the same for 2008 in site2 and exceeded that of both years in site 1 (Table 5).

Individually cattle may occupy a small portion of a study area but in combination, even with a small sample set from each study area, it appears they access a large percentage of extensive grazing areas, perhaps by exhibiting some independence. With added seasonal trials it may be possible to establish a norm specific to each study area enabling researchers to perchance detect change in the spatial arrangement cattle display (Figures 3, 4, 5) as new ecological or environmental factors become apparent. As well evaluations of spatial occupancy of a particular landscape attribute in addition to the GPS point frequency tallies may increase understanding of the occasions of attribute occupancy.

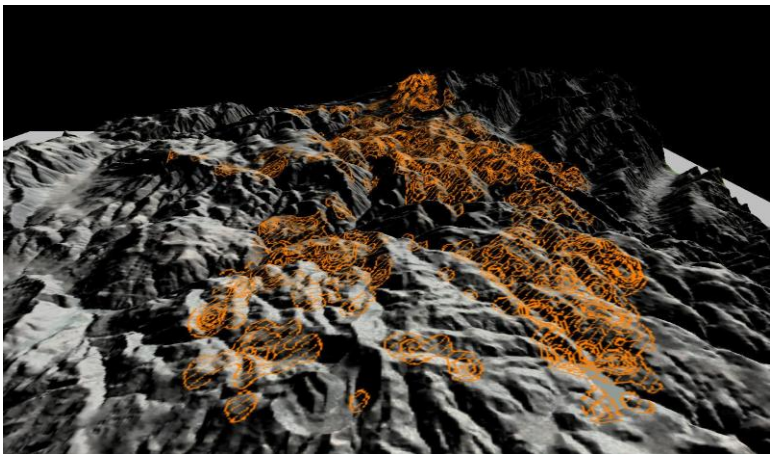

Figure 3. Site 1 terrain with 2009 sample set overlay.

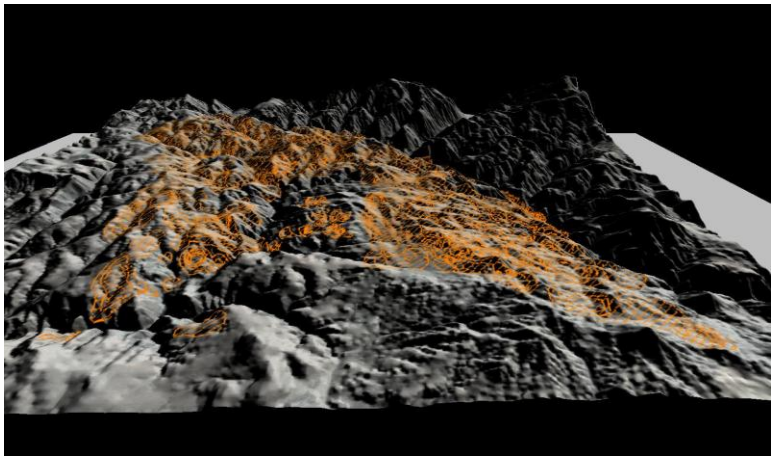

Figure 4. Site 2 terrain with 2009 sample set overlay.

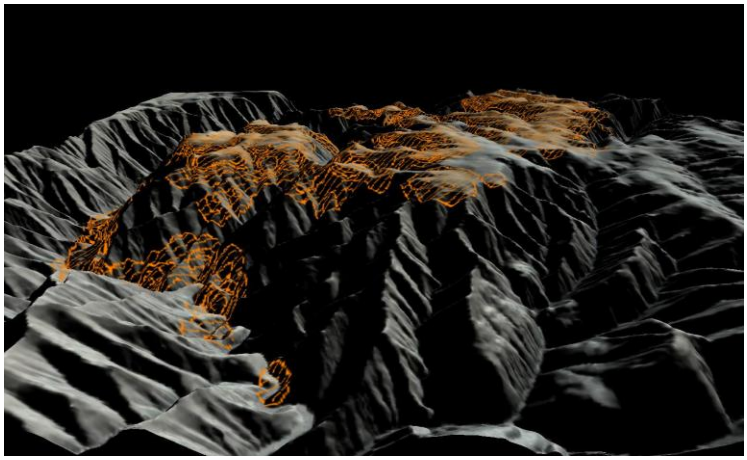

Figure 5. Site 3 terrain with 2009 sample set overlay.

Conclusions

The objective of this research was to evaluate with GPS and GIS technologies the distribution disposition of cattle in commercial grazing operations under the conditions of low to no wolf impact. Evaluating cattle distribution with present conditions may make it possible to detect anti predator responses exhibited by cattle in the future if predation becomes excessive. It is not known what anti predator responses may be displayed by domestic cattle in the various ecosystems found in forested lands. For the short term the information reported here may have some implications for allotment administration as the study is directed toward a smaller scale more in line with management needs.

The analysis of the occupancy of topographic landscapes substantiated past evaluations of these features as principle factors in influencing decisions made by cattle under present conditions. The data demonstrated that cattle largely favored slopes of less than 12% regardless of the landform relative to topography and also were indifferent to steeper landscapes up to 35% using them in proportion to the area. This lack of overall variation in slope use despite changing landforms testifies to the influence of this factor in controlling distribution.

The vegetative analysis was not quite as straight forward as the topographic. The mixed conifer attribute was preferred in two study areas over that of the pine/fir and upland grass while in the last study area the upland grass and pine/fir were both preferred over mixed conifer. It is not know why this occurred but the elevation and slope occurrence of these communities on different landscapes likely influenced the greenness of forage at different times of the grazing season. In addition the large percentage areas of mixed confer in site 1 may have influenced preference levels exhibited by cattle.

The analysis of occupancy of perennial streams was the most illuminating of all the attribute analyses. It was found that in two of the study areas cattle did not have a preference between any of the distance categories established; in other words

when evaluating just this area in these two sites there was almost ideal dispersion. In the last study area the cattle exhibited preference toward the first 30m over the area between 30 and 60 meters. It is also interesting to note that cattle do not use the area around perennial water more than upland areas. Based on this data cattle occupancy rates of areas beyond 60m (196.8ft both sides) of the stream are 96 to almost 99 percent of the time spent by cattle in the study areas.

Results from the landscape occupancy analysis suggest that comparisons between site 1 and site 2 may be more valid than comparing site 3 to the other two as the time period evaluated for site 3 was more than twice that of the other two which were the same.

It appears that restrictive topographic character may reduce variation between individuals and increase the degree of individual overlap. This was displayed by site 1 which trends toward steeper slopes as compared to site 2 which has flatter terrain. As well when overlap was removed by merging the polygons for each site, over the two year study, site 2 covered over 30% more area by percentage than site 1.

Site three demonstrated less variability in 2009 than all other trials except site 1 in 2008. The terrain in this study area concentrates animal occupancy on areas of lower slope which are surrounded by slopes greater than 35%. This lowers individual deviation and may indicate more overlap but at least one more year of equivalent data is needed to assess landscape occupancy in this study area. It is interesting to note the average area occupancy of individuals was considerably greater than averages observed on the other two sites. This may be due to the extended time period animals spent on site 3 or it may be due to the flatter terrain. This analysis technique generates more questions than answers but may indicate the first noticeable behavior characteristic to changes due to increased predation pressure.

As well because isopleths can be established at any density value less than 100%. Analysis of landscape occupancy may be important to land and ranch managers for identifying concentrated occupancy of cattle in extensive environments. It was found in the analysis of perennial streams that most occupancy

was in the uplands. If areas of little to no use could be identified a targeted evaluation of those areas may increase the efficiency of determining where and what range improvement projects may be justified for improving cattle distribution.

The use of these technologies shows a great deal of promise in answering ecological as well as management questions. The most obvious caveat to that statement is the potential biases associated with map error (primary) and GPS error (secondary). Technology will eventually reconcile most potential GPS error as the industry is advancing rapidly as evidenced by the rapid change in consumer products almost on a daily basis. For the short term the huge volume of location data provided by these GPS collars appears to diminish the effect of intrinsic error expected with any GPS apparatus. Map error, however is most likely to be chronic and highly variable. The technology and time involved in addressing map bias is expensive but worth the effort for the advance in knowledge this type of data has the potential to provide. Understanding error potential should be one of the first steps in designing a study using these technologies. The scale at which evaluation is conducted can be the determining factor between whether good or uncertain information is gained.

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Appendix

Complete collar performance table for study site 1

Site 1

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2008	38	25023	6/16/2008	9:22:36 AM	9/15/2008	4:15:18 PM
2008	39	31371	6/16/2008	9:22:17 AM	10/11/2008	6:41:01 PM
2008	40	33987	6/16/2008	9:21:33 AM	10/18/2008	2:54:40 PM
2008	41	34393	6/16/2008	9:22:02 AM	10/19/2008	2:01:06 PM
2008	42	17841	6/16/2008	9:19:04 AM	8/29/2008	2/35/28 PM
2008	43	2246	6/16/2008	9:23:12 AM	6/24/2008	12:43:11 PM
2008	44	34302	6/16/2008	9:23:21 AM	10/19/2008	2:32:39 AM
2008	47	30167	6/16/2008	9:20:45 AM	10/8/2008	9:20:46 AM
2008	48	24320	6/16/2008	9:23:15 AM	9/13/2008	2:11:13 AM
2008	49	Did not make it to the study site				
		231404				

Site 1

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2009	81	30293	6/17/2009	9:07:29 AM	10/12/2009	10:17:37 AM
2009	53	32979	6/16/2009	3:49:17 PM	10/14/2009	9:36:53 AM
2009	8	27431	6/16/2009	1:16:41 PM	10/1/2009	9:37:51 AM
2009	9	29977	6/16/2009	3:03:42 PM	10/8/2009	8:46:25 AM
2009	42	32438	6/19/2009	7:02:46 AM	10/15/2009	9:41:54 AM
2009	6	32133	6/13/2009	5:26:55 AM	10/8/2009	3:41:56 PM
2009	14	31998	6/17/2009	4:01:24 AM	10/17/2009	4:18:03 AM
2009	4	32791	6/16/2009	3:59:16 PM	10/21/2009	12:59:21 AM
2009	59	29308	6/16/2009	3:36:54 PM	10/1/2009	11:23:54 AM
2009	36	29702	6/16/2009	3:15:44 PM	10/5/2009	7:27:43 AM
		309050				

Total values reflect only those GPS locations determined to be relevant to the period of time from when the cattle entered the study site to when the cattle exited the site for the season or in many cases when the collar stopped cataloging GPS locations.

Color legend

	Collar units not included in study total.
	Collar units included in study total but not reported on.
	Collar units use for analysis.

Complete collar performance table for study site 2

Site 2

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2008	27	36220	6/3/2008	1:32:58 PM	10/18/2008	9:38:59 AM
2008	33	34356	6/3/2008	1:32:36 PM	10/6/2008	3:01:07 PM
2008	45	38208	6/3/2008	1:35:45 PM	10/20/2008	12:12:03 PM
2008	46	19572	6/3/2008	1:33:55 PM	8/13/2008	4:09:03 PM
2008	50	38760	6/3/2008	1:45:37 PM	10/22/2008	12:43:59 PM
2008	53	38218	6/3/2008	1:34:20 PM	10/20/2008	12:14:13 PM
2008	54	38164	6/3/2008	1:35:16 PM	10/20/2008	12:11:46 PM
2008	55	38136	6/3/2008	1:34:39 PM	10/20/2008	12:17:01 PM
2008	57	8445	6/3/2008	2:16:12 PM	7/4/2008	4:18:05 PM
2008	59	38768	6/3/2008	1/42/59 PM	10/22/2008	12:51:40 PM
		300830				

Site 2

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2009	33	39772	6/2/2009	12:18:04 PM	10/25/2009	9:24:23 AM
2009	41	35498	6/2/2009	12:14:51 PM	10/13/2009	8:03:09 AM
2009	54	40415	6/2/2009	12:15:36 PM	10/29/2009	2:26:14 PM
2009	69	35956	6/2/2009	12:19:36 PM	10/11/2009	12:53:01 PM
2009	12	40895	6/2/2009	12:14:06 PM	10/29/2009	10:18:47 AM
2009	11	38993	6/2/2009	12:19:24 PM	10/26/2009	12:09:41 PM
2009	65	39922	6/2/2009	12:18:54 PM	10/28/2009	9:05:03 AM
2009	68	37379	6/2/2009	12:14:06 PM	10/27/2009	11:38:00 AM
2009		No Data				
2009	50	30172	6/2/2009	12:12:54 PM	9/20/2009	7:46:45 AM
		339002				

Total values reflect only those GPS locations determined to be relevant to the period of time from when the cattle entered the study site to when the cattle exited the site for the season or in many cases when the collar stopped cataloging GPS locations.

Color legend

	Collar units not included in study total.
	Collar units included in study total but not reported on.
	Collar units use for analysis.

Complete collar performance table for study site 3

Site 3

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2008	15	8522	4/18/2008	10:29:11 AM	5/24/2008	9:39:07 PM
2008	16	7256	4/18/2009	10:29:43 AM	5/15/2008	7:45:41 PM
2008	17	42954	4/18/2008	10:30:35 AM	9/29/2008	3:13:08 AM
2008	18	10593	4/18/2008	10:33:15 AM	5/29/2008	1:01:14 AM
2008	19	35775	4/18/2008	10:30:37 AM	9/10/2008	7:06:13 PM
2008	20	Did not make it to the study site				
2008	21	15910	4/18/2008	10:30:24 AM	6/17/2008	10:37:19 AM
2008	22	Did not make it to the study site				
2008	23	31689	4/18/2008	10:33:48 AM	8/16/2008	8:46:44:PM
2008	24	40322	4/18/2008	10:31:59 AM	9/20/2008	7:35:28 PM
		193021				

Site 3

Year	Unit	Points Taken	Date In	Time In	Date Out	Time Out
2009	10	49721	4/26/2009	2:15:25 PM	10/24/2009	2:17:46 PM
2009	7	48883	4/26/2009	2:18:33 PM	10/24/2009	10:01:55 AM
2009	17	2141	4/26/2009	2:19:26 PM	5/4/2009	9:16:02 PM
2009	15	47975	4/26/2009	2:17:36 PM	10/24/2009	10:02:23 AM
2009	35	49760	4/26/2009	2:16:38 PM	10/24/2009	10:59:52 AM
2009	16	Did not make it to the study site				
2009	27	49314	4/26/2009	2:17:38 PM	10/24/2009	10:01:48 AM
2009	32	48731	4/26/2009	2:17:02 PM	10/24/2009	10:49:47 AM
2009	45	53019	4/26/2009	2:18:24 PM	11/5/2009	12:34:33 PM
2009	34	40752	4/26/2009	2:17:42 PM	9/26/2009	5:54:31 PM
		388155				

Total values reflect only those GPS locations determined to be relevant to the period of time from when the cattle entered the study site to when the cattle exited the site for the season or in many cases when the collar stopped cataloging GPS locations.

Color legend

- Collar units not included in study total.
- Collar units included in study total but not reported on.
- Collar units use for analysis.

Table showing cross-referencing from plant associations (Johnson) to plant communities (Hall). Pg 1

FID	MUSYM	MUKEY	CJ_Codes or ECO site	Description	FH_Code	FH_Prod
0	0023AW	2436963	R009XY004OR, R010XY005OR	bunchgrass on deep soil, gentle slopes	GB-49-12	679
1	3514DS	2437143	R009XY036OR, CDS711	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
2	4909BO	2437228	GB5915, GB4113	bunchgrass on deep soil, gentle slopes	GB-49-12	679
3	5709AO	2437245	CWF311	white fir-twinflower-forb	CW-F3-11	208
4	5720DA	2437256	GB4113	bunchgrass on deep soil, gentle slopes	GB-49-12	679
5	5722AO	2437257	R009XY003OR, R009XY050OR	bunchgrass on deep soil, gentle slopes	GB-49-12	679
6	5751AR	2437286	GB4113	bunchgrass on deep soil, gentle slopes	GB-49-12	679
7	5759BO	2437289	CWF311	White-fir-twinflower-forb	CW-F3-11	208
8	5760AO	2437290	GB59, GB41	bunchgrass on deep soil, gentle slopes	GB-49-12	679
9	5771CO	2437297	CWF311	white fir-twinflower-forb	CW-F3-11	208
10	5775AO	2437298	CWS211, CWF421, CWF311	white fir-twinflower-forb	CW-F3-11	208
11	5775BO	2437299	CWS211	white fir-big huckleberry	CW-S2-11	301
12	5776AO	2437301	CWS211, CWF421, CWF311	white fir-twinflower-forb	CW-F3-11	208
13	5776BN	2437302	CWF311	white fir-twinflower-forb	CW-F3-11	208
14	5776CN	2437303	CWF311	white fir-twinflower-forb	CW-F3-11	208
15	5780AO	2437309	CWF311	white fir-twinflower-forb	CW-F3-11	208
16	5781CO	2437310	CDS622, CDS722	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
17	5788AO	2437317	CWG112	white fir-big huckleberry	CW-S2-11	301
18	5791BO	2437320	CWF311	white fir-twinflower-forb	CW-F3-11	208
19	5794RW	2437322	CWS211, CWF421, CWF311	white fir-twinflower-forb	CW-F3-11	208
20	5796DN	2437323	CWS211	white fir-big huckleberry	CW-S2-11	301
21	5809AO	2437333	GB41, GB4911, CPS522	bunchgrass on deep soil, gentle slopes	GB-49-12	679
22	5809BO	2437334	GB4113, GB5915, SD2915, GB4113	bunchgrass on deep soil, gentle slopes	GB-49-12	679
23	5809CO	2437335	GB41, GB4911, CPS522	bunchgrass on shallow soil, steep slopes	GB-49-13	300
24	5810DR	2437336	GB5915	bunchgrass on shallow soil, steep slopes	GB-49-13	300
25	5814AO	2437338	GB59, GB4911	bunchgrass on deep soil, gentle slopes	GB-49-12	679
26	5829CW	2437342	CDS722	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
27	5830BO	2437344	CPS222, CPS524, CPG222	ponderosa pine-Douglas fir-elk sedge	CD-G1-11	341
28	5830CO	2437345	CDS622, CDS634	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
29	5830DO	2437346	CDS622, CWG112	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
30	5834DA	2437351	GB4113, GB5915	bunchgrass on shallow soil, steep slopes	GB-49-13	300

Table showing cross-referencing from plant associations (Johnson) to plant communities (Hall). Pg. 2

FID	MUSYM	MUKEY	CJ_Codes or ECO site	Description	FH_Code	FH_Prod
31	5836AO	2437352	GB4113, GB5919	bunchgrass on deep soil, gentle slopes	GB-49-12	679
32	5836BO	2437353	GB4113, GB5915	bunchgrass on deep soil, gentle slopes	GB-49-12	679
33	5836DO	2437355	SD3111	bitterbrush-bunchgrass	SD-39	375
34	5838BO	2437356	GB4113, GB4911	bunchgrass on deep soil, gentle slopes	GB-49-12	679
35	5839CS	2437357	GB4113, GB5915	bunchgrass on shallow soil, steep slopes	GB-49-13	300
36	5841DS	2437361	GB4113, GB5915	bitterbrush-bunchgrass	SD-39	375
37	5844DN	2437363	GB5912, GB5911	bunchgrass on deep soil, steep slopes	GB-49-14	434
38	5845AO	2437364	GB41, SD9221, CDG111, CS525	mixed conifer-pinegrass, residual soil	CW-G1-11	309
39	5846CN	2437365	GB5913	bunchgrass on deep soil, steep slopes	GB-49-14	434
40	5846DN	2437366	GB5913	bunchgrass on deep soil, steep slopes	GB-49-14	434
41	5849DR	2437368	GB5915, GB5913	bunchgrass on deep soil, steep slopes	GB-49-14	434
42	5860CO	2437376	CDG121, CDS634, GB4113,	mixed conifer-pinegrass, residual soil	CW-G1-11	309
43	5861DO	2437377	CDS722, CWS412	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
44	5862AO	2437378	CDG121, CDS634, CDS623	mixed conifer-pinegrass, residual soil	CW-G1-11	309
45	5862BO	2437379	CDS622, CDG121, CDS634 CPG132, GB4113, GB5915	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
46	5862CO	2437380	CDG121, CDS634, CDS623	mixed conifer-pinegrass, residual soil	CW-G1-11	309
47	5867BO	2437382	GB41, SM31, SM1111	bunchgrass on shallow soil, gentle slopes	GB-49-11	363
48	5867CO	2437383	GB41, SM31, SM1111	bunchgrass on shallow soil, steep slopes	GB-49-13	300
49	5867DO	2437384	GB41, SM31, SM1111	bunchgrass on shallow soil, steep slopes	GB-49-13	300
50	5871CO	2437387	CDS711	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
51	5874CO	2437392	CDS622, CDS722	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
52	5874DO	2437393	CDS622, CDS722	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
53	5876CO	2437398	CDS722	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
54	5886AO	2437405	CDS622	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
55	5897DW	2437408	CDS722, CWS412	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
56	5949RW	2437424	CWF311	white fir-twinflower-forb	CW-F3-11	208
57	6060CS	2437447	GB4113, GB59, GB4112	bunchgrass on shallow soil, steep slopes	GB-49-13	300
58	6060DS	2437448	GB4113, GB59, GB4112	bunchgrass on shallow soil, steep slopes	GB-49-13	300
59	6067CN	2437451	CDS711, GB49	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296
60	6067DN	2437452	CDS711, GB49	ponderosa pine-Douglas fir-ninebark	CD-S7-11	296

Reclassification of plant communities into alliance structure

Fred Hall Code	Fred Hall Plant Community	Production	Reclass
GS-12-11	Alpine fescue	254 lb	Upland Grass
GB-49-11	Bunchgrass on shallow soil, gentle slopes	363 lb	Upland Grass
GB-49-12	Bunchgrass on deep soil, gentle slopes	679 lb	Upland Grass
GB-49-13	Bunchgrass on shallow soil, steep slopes	300 lb	Upland Grass
GB-49-14	Bunchgrass on deep soil, steep slopes	434 lb	Upland Grass
SD-29-11	Big sagebrush - bunchgrass	412 lb	Upland Grass
SD-39	Bitterbrush - bunchgrass	375 lb	Upland Grass
CD-S6-11	Ponderosa pine - Douglas fir - snowberry - oceanspray	384 lb	P. Pine/D. Fir
CD-S7-11	Ponderosa pine - Douglas fir - ninebark	296 lb	P. Pine/D. Fir
CP-G1-12	Ponderosa pine - fescue	359 lb	P. Pine/D. Fir
CE-S3-11	Sub-alpine fir - big huckleberry	292 lb	Mixed Conifer
CE-S4-11	Sub-alpine fir - grouse huckleberry	181 lb	Mixed Conifer
CL-S4-11	Lodgepole - grouse huckleberry	116 lb	Mixed Conifer
CW-F3-11	White fir - twinflower	208 lb	Mixed Conifer
CW-G1-11	Mixed conifer - pinegrass, residual soil	309 lb	Mixed Conifer
CW-G1-12	Mixed conifer - pinegrass, ash soil	330 lb	Mixed Conifer
CW-S2-11	White fir - big huckleberry	301 lb	Mixed Conifer
Lake	Water	0 lb	Mixed Conifer
R6-2210-C7	Moist meadow	1400 lb	Mixed Conifer
SM-29	Thinleaf alder snowslides	100 lb	Mixed Conifer

Reclass	Prod Avg.
Upland Grass	402 lb
P. Pine/D. Fir	346 lb
Mixed Conifer	248 lb

Plant communities Lake, Moist meadow, Thinleaf alder were found within the mixed conifer sites as very small inclusions only in site 1. For the scale of this study these small areas were included in the mixed conifer total area.

Table comparing values obtained using points selected for 12 week period versus all GPS locations.

Site 1	Even data sets (08/09)			Points used (317,756)		
14units 08/09 Combined	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	582	643	654	584	543	534
% Occupancy	0.18	0.20	0.21	0.18	0.17	0.17
Cumulative	582	1225	1879	2463	3006	3540
% Cumulative	0.18	0.39	0.59	0.78	0.95	1.11
Site 1	All locations (08/09)			Points used (520,050)		
17units 08/09 Combined	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	913	994	976	925	802	871
% Occupancy	0.18	0.19	0.19	0.18	0.15	0.17
Cumulative	913	1907	2883	3808	4610	5481
% Cumulative	0.18	0.37	0.55	0.73	0.89	1.05
Site 2	Even data sets (08/09)			Points used (322,107)		
14units 08/09 Combined	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	2785	2828	2202	1711	1382	1097
% Occupancy	0.86	0.88	0.68	0.53	0.43	0.34
Cumulative	2785	5613	7815	9526	10908	12005
% Cumulative	0.86	1.74	2.43	2.96	3.39	3.73
Site 2	All locations (08/09)			Points used (665,427)		
19units 08/09 Combined	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	4873	5045	4157	3374	2671	2081
% Occupancy	0.73	0.76	0.62	0.51	0.40	0.31
Cumulative	4873	9918	14075	17449	20120	22201
% Cumulative	0.73	1.49	2.12	2.62	3.02	3.34
Site 3	All locations (2008)			Points used (191,780)		
2008 8units	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	291	340	385	378	492	532
% Occupancy	0.15	0.18	0.20	0.20	0.26	0.28
Cumulative	291	631	1016	1394	1886	2418
% Cumulative	0.15	0.33	0.53	0.73	0.98	1.26
Site 3	All locations (2009)			Points used (383,691)		
2009 8units	0m-10m (32.8 ft)	10m-20m (65.6 ft)	20m-30m (98.4 ft)	30m-40m (131.2 ft)	40m-50m (164 ft)	50m-60m (196.8 ft)
GPS points	660	702	735	706	682	673
% Occupancy	0.17	0.18	0.19	0.18	0.18	0.18
Cumulative	660	1362	2097	2803	3485	4158
% Cumulative	0.17	0.35	0.55	0.73	0.91	1.08