2012 Oregon Beef Council Report
Wolf Cattle Interaction Study
26 October 2012

Introduction

The reintroduction of wolves into Central Idaho and the Yellowstone National Park and their subsequent dispersal throughout the northern Rocky Mountains has led to increased livestock depredation and conflict with livestock producers (USFW 2011). Stock growers report both direct losses as injured or killed cattle, sheep, horses, and dogs, as well as indirect livestock losses from increased stress resulting in lower conception rates, higher incidence of respiratory and other diseases, lower body condition scores, and changes in temperament resulting in more difficult trailing and handling (Kluever et al. 2008, Lima and Dill 1990, Howery and Deliberto 2004, Williams 2010). Herd management costs also increase with wolves because producers need to check on animals more frequently, spend more time doctoring injured stock, and find animals scattered during predation events so they can be removed to safe locations (Williams 2010). Removal of cattle generally results in disruption of annual grazing plans and higher forage costs.

It has been suggested that wolves may create a "landscape of fear" that alters landscape use and preferred habitats because of the threat of predation (Manning et al. 2009, Kauffman et al. 2010). If livestock alter their resource use or the extent of their dispersal across the landscape because of wolves, currently preferred sites may not be grazed and the carrying capacity of the land could be reduced. Ranchers also report that livestock group into larger herds when predation is frequent which concentrate cattle making grazing management more difficult.

Research that examines wolf effects on wildlife populations is fairly common (Laundre et al. 2001, Garrott et al. 2005, Gude et al 2006, Creel et al. 2005, Muhly et al. 2010, Hebblewhite et al. 2002, Vucetich et al. 2005) but studies focused on wolf impacts on domestic livestock resource selection, behavior and ranch-level economics are rare (Muhly et al. 2010, Laporte et al. 2010, Oakleaf 2003, Bradley and Pletscher 2005, Rambler 2011). Our study was designed to document the effect of wolf predation on cattle behavior, landscape use patterns, and resource selection by comparing areas with high wolf densities against those with low wolf densities. This study was also designed to generate baseline information on cattle spatial behavior before wolves become common on landscapes where they currently are rare.

Materials and Methods

Study Sites

The study areas used consist of 3 sites in Adams, Idaho, and Washington counties Idaho on the Payette National Forest (PNF) in a region that had established wolf populations as well as, documented wolf depredation before the beginning of the study in 2008. Idaho sites were paired with 3 sites in Baker, Union, and Wallowa counties, Oregon on the Wallowa Whitman National Forest (WWNF) without active wolf packs. The study covered both high wolf density areas in west central Idaho (PNF) and low wolf density areas in Northeast Oregon (WWNF).

The 3 active grazing allotments within the WWNF were paired with 3 active grazing allotments in the PNF according to land form and vegetation characteristics at the landscape scale (Sneft et al. 1987, Bailey et al., 1996). Oregon sites cover 43,972 ha (108,655 acres) while the Idaho sites cover approximately 54,388 ha (134,395acres). All sites span a distance of approximately 125 km (78 miles) East/West and 140 km (87 miles) North/South. Idaho sites are at the same latitude as Oregon sites. They border the Snake River and extend eastward approximately 35 miles (56 km). These six grazing allotments vary in elevation from 510 m (1680 ft.) to 2500 m (8,200 ft.) and are characterized by rugged mountains and uplands that are deeply dissected by canyons.

The study area in Oregon is entirely within the Wallowa Whitman National Forest and is comprised of three currently active grazing management areas. 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) just as it transitions from 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 17 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 remainder being forest lands (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 MLRA is represented by a small portion in the Wallowa Whitman and Umatilla National Forests and is 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 having 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.

Experimental Design

This research is being conducted under a Before-After/Control-Impact Paired (BACIP) experimental design (Stewart-Oaten et al., 1986; Skalski and Robson, 1992; Smith, 2006; Manly, 2009; also see appendices of this report). In this case, the experimental treatment or Impact is the change in wolf presence on Oregon study areas from a long-term, very low level to a sustained higher level. Note this excludes brief elevations in wolf presence on Oregon study areas as individual or pairs of wolves initially disperse from areas of high wolf presence (e.g., western Idaho) into and back out of Oregon. The Before period of the BACIP design is the period before the Oregon study areas acquire a substantial and sustained wolf presence while the After period is the period after that transition point when both the Idaho and Oregon study areas have substantial and sustained wolf presence. The Control sites, in this case, are the Idaho study areas which will have a substantial wolf presence during both the Before and After periods whereas, the Impacts sites are the Oregon study areas which start out with wolves being absence or at very low presence levels and eventually acquire substantial and sustained wolf presence. This is a paired BACI design (i.e., BACIP) because each of the Oregon study areas was selected to pair with an Idaho study area in terms of ecological and managerial setting. Each Oregon-Idaho pair has similar vegetation; soils, wild prey species, and livestock management (e.g., study area entry/exit dates, mean calf age at entry, etc.). Under this BACIP design, a typical statistical analysis would contrast the differences in a response (e.g., wolf depredation losses, mean daily travel distance by cattle, or riparian occupancy rates by cattle) between Oregon-Idaho study area pairs during the Before and After study periods. As there are 3 Oregon-Idaho pairs, this experimental design affords 3 replicates of this contrast.

Sampling Design – GPS Tracking of Livestock

Animal ethologists and ecologists have traditionally been limited to direct observation or radio telemetry tracking for quantifying animal activities and habitat use. Development and deployment of the NAVSTAR Global Positioning System (GPS) by the United States military has opened new methods for determining the movement and behavior of both domestic stock and wildlife. Autonomous GPS receivers record geographic position (e.g., lat/long), elevation, date/time, speed, and direction of movement, and estimates of positional accuracy. GPS hardware can also be modified to collect temperature, 3-axis acceleration, and other parameters deemed important. In this study, we employed Clark Animal Tracking System (ATS) collars because they offered both long deployment lives (e.g., up to 1 year) at intensive sampling rates (e.g., collection of GPS positions at 5 minute intervals) (Clark et al. 2006). A 5 minute GPS sampling rate permits evaluation of habitat use patterns, activity budgets, and movement path characteristics (Johnson and Ganskopp 2010).

Each spring between 2008 and 2011, 10 mature cows were randomly selected from commercial livestock herds grazing each study area. These herds have been grazing their respective study sites for years and cattle have experience with the landscape, environment, and managerial operations in place. GPS collars were attached to cows and animals were transported to study areas where they grazed with herd mates in accordance with ranch and US Forest Service grazing management plans. Some Forest Service allotments (study areas) have private land inclusions, adjacent private ground or other federal lease lands that are contiguous with allotments and are also grazed by these herds during the summer grazing season. Turn out dates of livestock vary between study areas from April to June. At the end of the grazing season in the autumn, cattle were gathered and returned to the home ranches or winter quarters where GPS collars were removed, returned to project scientists, and data downloaded.

During the grazing season, all animals in the herd were treated similarly, but producers and range riders were asked to note the date, time, and location of any collared cattle observed on the range. Herd size varies from site to site and somewhat from year to year. Oregon and Idaho Sites had similar stocking rates of approximately 450 head. We assume that the movement and resource preference of collared animals is representative of other cattle in the herd.

At a 5 minute logging interval, we could potentially collect 288 positions for each collared animal each day. However, Clark GPS collars are programmed to activate and begin to search for satellites at 5 minute intervals, thus the recorded interval is somewhat longer than 5 minutes. In addition, if the collar cannot obtain a fix in a set amount of time, the collar is programmed to shut down and wait for the next collection period. In a test of 1194 days of data collection during 2008 on Oregon Site 1, collars logged an average of 269 positions per day. The maximum number of positions recorded during a day in this test was 279 positions. For a 200 day grazing season with 10 collared cows, we therefore would collect approximately 500,000 cow positions.

Positional accuracy of GPS receivers may be compromised in complex landscapes with deep canyons or locations without a full 180° sky view. We tested the Clark ATS collar design under extreme conditions in 2 canyons of northeastern Oregon (Figure 1). This test evaluated 192 sample positional fixes with the Clark ATS which logged a mean absolute error of 21.5 m (Std. Dev. =23.7 m). The maximum error was 146 m. Surprisingly, largest errors were not in the deepest portions of the canyon which suggests that large errors were the result of multipath of the GPS satellite signals or incomplete trilateration.

Under optimal, open-sky conditions Clark ATS Collars had a 95% Circular Error Probability CEP of 6.3 m. CEP is the radius of a circle (horizontal) that is centered at the GPS antenna's true position and contains 95% of the GPS locations. If the position was Wide Area Augmentation System (WAAS)-corrected the mean 95% CEP was 2.7 m (Clark et al. 2006).

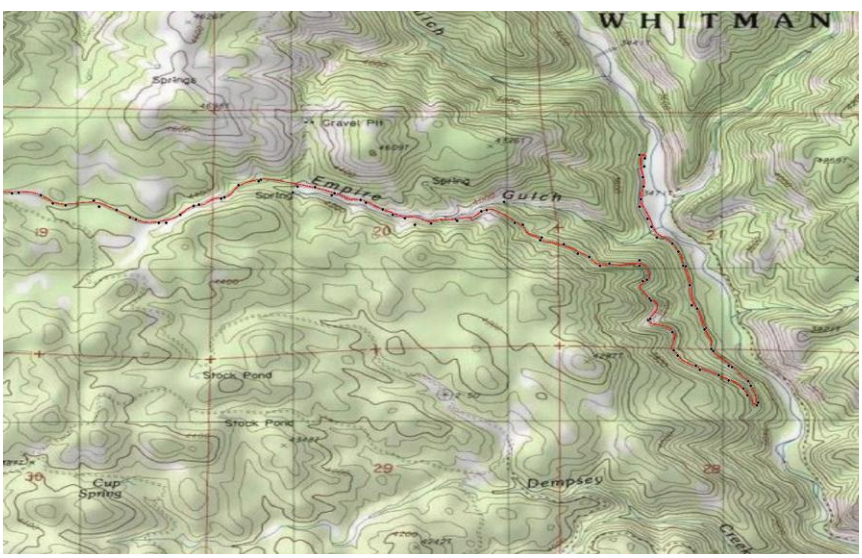

Figure 1. Location of one field test of Clark ATS in deep canyons. Note the closeness of the contour lines on the right side of this topographic map. The red line is the track followed and the black dots are the positions logged with the collar. This test included 2 deep canyons and evaluated 192 sample locations. The mean positional error was 21.5 m (Std. Dev. =23.7 m) with a maximum error of 146 m.

Collar speed was also calculated and recorded by the Clark ATS. We used the pattern of velocity measurements to indicate animal activity (Figure 2). Cow velocities rarely rise above 6.2 miles/hr. (10 km/hr.) under normal grazing conditions (Norman 2012). Grazing periods are represented by a string of speeds above the detection threshold, resting periods by strings of values below the detection limit of the instrument. Direction travel to or from water or herded movement between pastures is represented by normal walking speeds between 2 and 4 mph (0.89 and 1.79 m/s). Under field test conditions the Clark ATS units recorded somewhat higher speeds than continuously recording WAAS enabled GPS units but values were highly correlated (3.36 m/sec $Y=0.4855x + 0.2132$ $R^2 = 0.8715$).

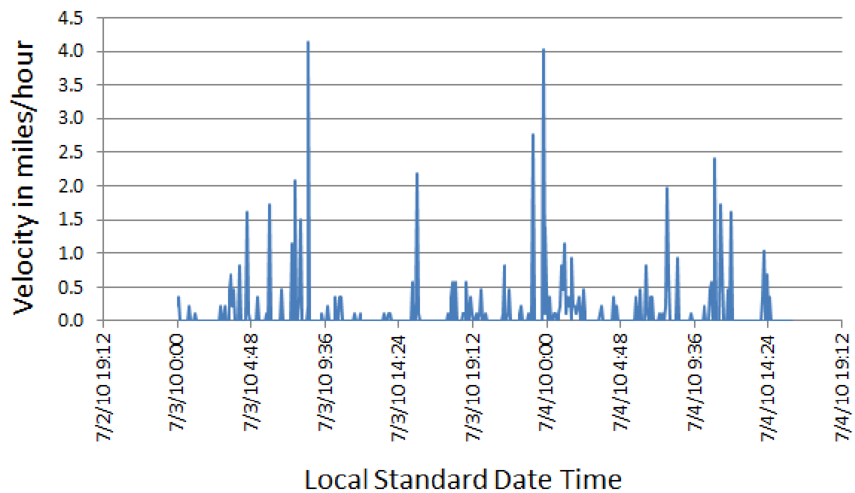

Figure 2. Typical velocity diagram of a cow grazing on a project study site. Actual cow velocities rarely rise above 6.2 miles/hr. (10 km/hr.) under normal grazing conditions.

Sampling Design – Assessing Wolf Presence

Wolves are elusive by nature, consequently, the level of their presence is difficult to assess and document. Accurate assessment of wolf presence requires multiple monitoring approaches, all of which and strengths and weakness (e.g., high temporal accuracy but limited spatial extent), thus no single approach is adequate for the task. In this study, we have used a combination of GPS tracking collars, scat and sign surveys, camera traps (i.e., trail cameras), augmented by radio-tracking, direct observation, and depredation data from wildlife agencies to assess wolf presence in time and space within our study areas. Wolf presence, based on all these data sources, will be classified into 3 presence levels: low, moderate, and high within a relevant sampling period (e.g., grazing season or month with a grazing season).

GPS Tracking of Wolves

GPS collars have been deployed on wolves within project study areas. The wolf GPS collars are of the same basic design as cattle collars except each collar also contain a radio beacon transmitter, like a traditional radio-tracking collar, which is used to locate and monitor the collared wolves so their collars could eventually be retrieved from the field for data download. Wolf collars were programmed to record GPS locations at a slower frequency, or coarser sampling interval (i.e., 15-min instead of 5-min) than cattle collars to increase battery life and extend deployment life expectancy. Three wolves were collared by the project. The first collar was deployed on a male wolf (B446) that was positioned every 15 minutes for 200 days beginning on 22 May 2009. This animal was shot by a rancher during a depredation attempt and the collar was returned to the project. A second collar was deployed in 2011 but its radio beacon has stopped transmitting and the collar has not yet been retrieved. The third collar was deployed in early October 2012 and this animal is being actively tracked.

Wolf Scat and Track Surveys

Survey routes consisting of forest roads and established trails were established in each study area. During each grazing season since 2009, these survey routes have been traversed using all-terrain or 4 wheel drive vehicles and any wolf sign observed recorded. Wolf scat and tracks were photographed and positioned with a handheld GPS. Observed scat and tracks were marked with wooden toothpicks to prevent erroneous recounts yet allow identification of over-marking (e.g., deposition of new scat over existing scat).

Camera Trapping of Wolves

Trail cameras or passive infrared (IR)-activated camera traps were established, as a test case, in one of the Idaho study areas during the 2011 field season. These tools were found to be quite effective in documenting wolf presence on the study area, particularly, when used in combination with other assessment techniques (e.g., wolf scat and track surveys). Camera traps were deployed in all the project study areas during the 2012 grazing season (Figure 3).

Figure 3. Photograph of three unmarked wolves acquired with a trail camera or passive infrared (IR)-activated camera trap located on an Idaho study area during the 2012 grazing season. Note the date and time of acquisition are automatically imprinted on the digital image.

Ancillary Wolf Presence Data

Wolf packs acknowledged by wildlife agencies (e.g., ODFW, IDFG, and Nez Perce Tribe) typically have at least one wolf per pack collared with a traditional radio-tracking transmitter. The locations of these radio-collared wolves are typically acquired by these agencies via aerial monitoring every two weeks. During aerial monitoring, direct observations (i.e., visual sightings) of these radio-collared wolves and their pack mates are typically recorded and the location of the observations determined using a GPS unit. Livestock depredation reports are compiled by USDA Wildlife Services (WS). The WS provides the project with a summary of recorded depredations within each project study area. Records of confirmed and probable wolf depredation incidents are then used as another wolf presence data source.

Identifying Factors and Covariates

Landscape Data

Landscape data, including GIS data layers and remote sensing imagery, for each study site was compiled from existing data sources and stored in Universal Transverse Mercator projection using a WGS 1984 Datum. U.S. Geologic Service 7.5 minute topographic maps were downloaded as Digital Raster Graphic (DRG) files so the locations of animals or events could be interpreted and ground based features mapped. Similarly, geo-rectified aerial images from the USDA National Imagery Program (NAIP) and were also compiled used for mapping and data interpretation. Concatenated 10 meter digital elevation models (DEM) were obtained from the USGS National Elevation Dataset (NED) and both slope, as percent, and aspect, as degrees, were derived using a “Queen’s Case” algorithm. In addition, a topographic surface shape classification based on the polynomial surface fitting of each 3 x 3 grid cell area (Pellegrini 1995) was applied which produced 11 possible topographic features: peak, ridge, saddle, flat, ravine, pit, convex hillside, saddle hillside, slope hillside, concave hillside, and inflection hillside.

Landsat ETM+ scenes from 28 July 2006 (path 42, row 29) and 13 August 2006 (path 42, row 28) were used to produce Normalized Difference Vegetation Indices (NDVI) (Rouse et al. 1973, Tucker, 1979). NDVI values vary from -1 to 1 and are directly related to the photosynthetic capacity of vegetative communities on the ground. NDVI values can infer attractiveness for grazing animals and have been used in predictive resource selection models for ungulates (Peterson et al. 2002).

We employed the National Land Cover Database 2006 for land cover classification (Fry et al. 2011). This data set was derived from multiple Landsat ETM+ scenes collected between 2001 and 2006 and has a ground resolution of 30 m. Principle classes on our research sites were: evergreen forest, shrub/scrub, grassland/herbaceous, pasture/hay land, deciduous forest, woody wetlands, barren rock/sand/clay, and open water.

Oregon Map Development of the 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 thalweg 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.

Analysis of Cattle Occupancy along Oregon Streams

Time spent within a defined distance of a perennial watercourse was 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. Because of the linear nature of the attribute a buffer zone out to 10m (32.8ft) was established on either side of the map line feature representing streams in order to mediate the estimated potential horizontal error of both GPS locations (Agouridis et al. 2004) and map data (NAIP, 2009 "metadata"). This area is considered as the potential interface area between cattle and aquatic habitats as defined by Ballard (1999). Beyond this area 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.

Cow Position Data

Each cow position falling within the study area was attributed by appending the values from the associated GIS data layers: 1) slope in percent, 2) aspect in degrees, 3) topographic shape class, 4) land cover class, and 5) NDVI value. Each study area was also categorized and the relative proportions of each class available in each study area were calculated. Thus, for each theme or data layer, we derived both the proportion of each class within the study site and the relative use or occupancy by livestock. This information was used to determine the relative preference of cattle for each class of landscape theme using the formula % occupied/% available. Values below 1 indicate avoidance, near 1 are neutral and those well above 1 are preferred. We have not broken data into shorter durations for intra-seasonal preference, normalized this data to account for varying logging completeness from month to month, or separated occupancy based on cattle activity (stationary vs. moving periods) during the day. Analysis continues. More sophisticated methods of analysis of distribution patterns and resource selection (resource use) than those reported in this paper exist and we are in the process of applying them to this data set but as of the writing of this report, they have not been completed.

We also created a 328 ft. by 328 ft. (100m by 100m) grid that covered each of the study areas. All cow positions were then located on the grid and each grid cell attributed with the number of positions falling in that cell. This produced a grid file that contained the relative occupancy, both resting and foraging, for each 2.47 acre (1 ha) location on the study site. This occupancy theme was also converted into occupancy contour lines which identified foci within the study areas with higher cattle occupancy rates, as well as those areas with low levels of use.

Development of Videos Showing Animal Movement

We were asked by our Project Advisory Board to produce time stamped videos of cattle and wolf movement on map backgrounds (Figure 4). The AVI generator in the data layer toolbox of the KRESS Modeler (Johnson et al. 2010) was used to produce these videos. Although this is a qualitative tool, it does provide insight as to the movement of cows in relation to one another and visible landscape features. Data was plotted at the logging rate of the wolf collar (≈15 minute interval) and with the temporally closest interpolated cow position. Videos also show wolf movement across the landscape, locations where the wolf stopped for a period of time. Focal points for this wolf on the landscape such as den location, rendezvous sites, kill sites, and ridges used as observation posts were identified. Videos produced were viewed at full or slow speed, stopped, backed up, and restarted as an observer documented activity of importance. These videos also allowed us to identify the time, and date wolf/cattle interactions (flight events, as well as, proximity with no unusual cattle movement), herd dispersion or bunching events.   The geo-database was then examined and movement patterns identified.

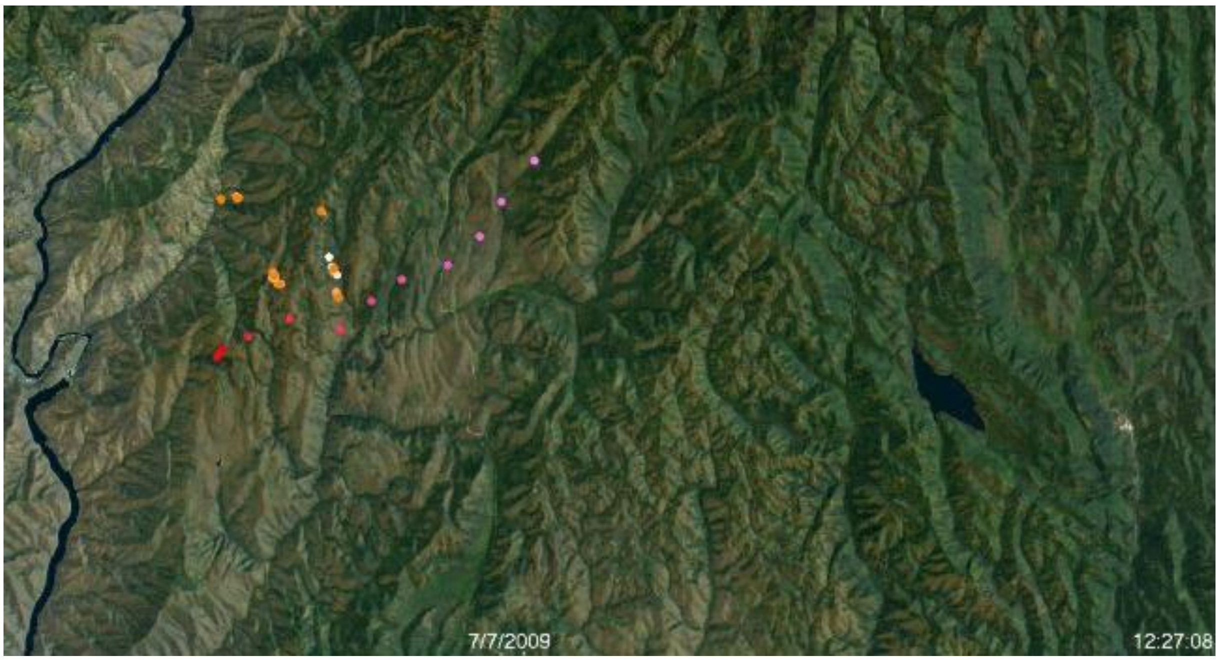

Figure 4. This is a screen capture from a video showing the positions of collared cows and a wolf on 7 July 2009. The Universal date and time are shown at the bottom of the screen. The wolf position is shown as a red dot that fades to pink then disappears. Twelve positions or approximately 3 hours of movement are visible. Cattle positions are shown as orange dots that fade to white then disappear.

Statistics Analysis

Percentages, means, and standard deviations were generated for each land cover classes and toposhape class or, in the case of continuous variables, for intervals of each of aspect, slope, elevation, or NDVI value from attributed animal position files for each grazing allotment. We employed a modification of Van Dyne and Heady's (1965) relative preference index (RPI = the percentage of site occupancy divided by that site's relative contribution to available site in the pasture) to rank the site preferences of cows (Krueger 1972). Because these animals are controlled, the relative use probably does not represent true "preference" but rather sites selected out of those available. Availability depends on pasture boundaries, fencing, steep slopes, dense forest with downed timber etc. Availability is variable depending on the juxtaposition and circumstance of land types. Some circumstances, such as weather and managerial herding are difficult to quantify. For example, on hot or cold days cattle may restrict their travel and thus have less area available or cattle may be deliberately herded by a range rider away from a sensitive location. Events such as these are not immediately obvious in our data. For convention sake, we will use the term “site preference” in this report.

Chi-square statistical tests were used to compare observed data with data we would expect to obtain assuming neutral preference (Snedecor and Cochran 1989). These tests determine the "goodness to fit" between observed and expected values and can indicate if departures from expected are significant. Work on our data sets continues and is not complete as of this writing. These data sets are very rich and can also be analyzed using other resource selection approaches thus our project is actively pursuing these avenues.

Results and Discussion

Cattle Distribution

When viewing the data sets in a geographical context it was immediately obvious that cattle position and movement was the result of managerial objectives, ranch/USFS grazing management plans, topography, phenology or seasonal development and maturation of vegetation, water distribution, and a host of other natural and anthropogenic factors (Figures 5, 6 and 7). Many authors have addressed factors controlling livestock distribution (Cook 1966, Ganskopp and Vavra 1987, Bryant 1982, Coughenour 1991, Bailey et al. 1996, Harris 2001, Wilson 2010). Fencing was obviously important and those allotments that have been subdivided to implement rotational grazing strategies were evident in the spatial-temporal pattern of cattle movement. Also important was the location where livestock enter allotments because it was used by managers in conjunction with topography, drift fencing, and water to alter grazing patterns from year-to-year.

Herding and movement of cattle by range riders also had a major influence on use pattern. This is not too surprising since these are managed landscapes and one primary objective of both producers and USFS personnel is to prevent over-use of the resource and ecosystem degradation. This was accomplished by dispersing and moving cattle throughout the grazing season. We were able to identify times when cattle were gathered and moved within allotments, sometimes passing off of USFS allotments on to private land then at a later time movement back onto the allotment. Grazing plans are also responsive to the relative availability of forage and water. As one rancher told us “Our grazing system is designed to follow the availability of forage, when the forage is palatable and nutritious and water is available the cattle are there, as forage matures, dries and decreases in quality, we move to higher elevation grazing areas or other sites where forage is better.” Thus, superimposed on this landscape is a targeted movement, generally up the elevation gradient.

A glance at Figure 5 also provides insight as to the extent of these grazing lands. The greater area used by the cattle on Idaho Site 3 was approximately 125 square miles (325 km^2). There are obvious areas within the land base that are excluded from grazing such as hay meadows, residences, roads, and some private land inholdings, as well as rocky ridges or dense forests. None the less, it must be remembered that the land available to grazing cattle on USFS allotments and ajacent private land was very extensive.

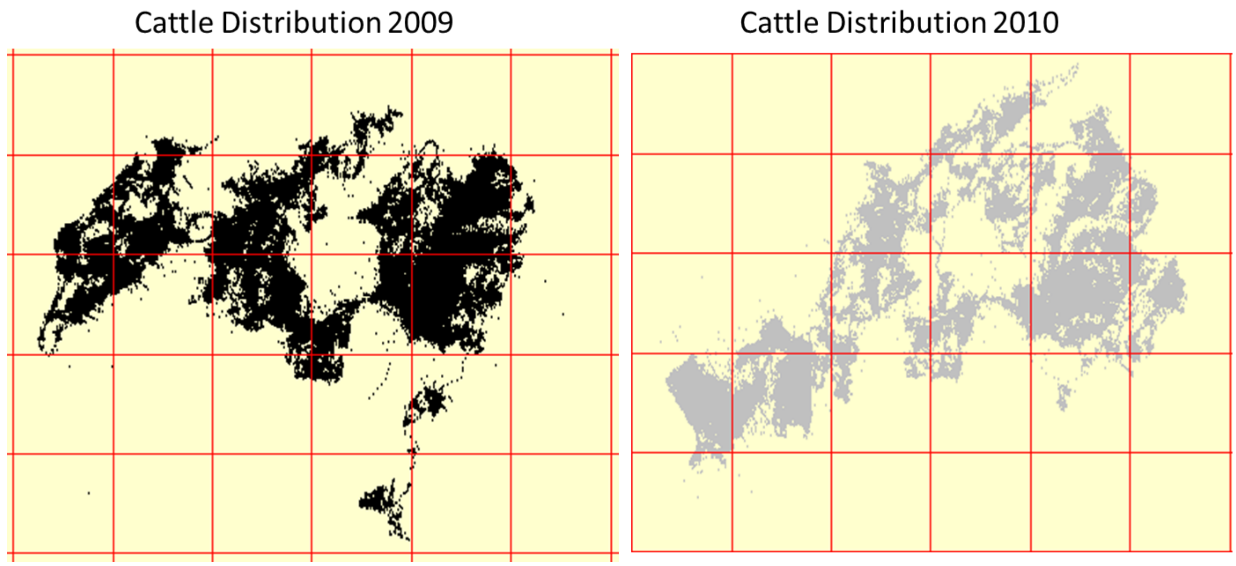

Figure 5. Cattle distribution on Idaho Site 3 in 2009 (black dots on image on the left) and 2010 (Gray dots on the right image) are shown superimposed on a 3.1 mile (5 km) grid. The upper left corners of the left and right images are the same geographic location. The ranch grazing plan calls for rotating animals on a 2 year cycle to maintain range health. This image includes both public and private lands.

Cattle Dispersal

When individual cow locations were examined within a year, it was also apparent that animals tend to disperse rather than graze as a single large unit (Harris 2001, Harris et al. 2007) (Figures 6 and 7). In the field, we observed that cows tend to break into groups of 5 to 15 cows that function as subgroups in loose association with the greater herd. It was not unusual for collared animals to be found several miles from herd mates but remain close to animals in their subgroup (Table 1). We hypothesize that subgroups function to reduce competition for preferred food between herd-mates, yet provide a sense of security for individuals in the subgroup. We do not know if these subgroups are stable throughout the season or between years, but if they are, it could have managerial implications. For example, it could be better to keep subgroups together throughout the entire year because the dominance hierarchy is established and individuals are spared the stress of reestablishing dominance hierarchies as cattle are mixed and remixed in ranch operations.

From a managerial perspective, subgroups or the presence of independent individuals, facilitate cattle dispersal. Rangeland managers typically want animals to disperse to reduce the incidence of local or spot over-utilization of vegetation (Stoddart and Smith 1943, Heady and Child 1999, Holechek et al. 2011). Figure 6 shows the relative dispersal of all 10 collared cows (black dots) logged on 26 September 2009 on a topographic map background. Collared cattle in this herd of approximately 400 head on this day were found in a rectangular area approximately 5.2 by 4.3 miles (8.4 km by 6.9 km) or approximately 20 mi^2 (52 km^2). Dispersal is also evident in Figure 7 which shows the position of 3 cows throughout the 2010 grazing season. Animals started the year in close proximity but ended in widely separated areas. Obviously, the pattern of dispersal is somewhat controlled by the rancher or range rider, but superimposed within this pattern is the animal's natural tendency to break into smaller groups and disperse. This brings up many interesting questions regarding breed/line differences in stock. Under many conditions, such as grazing on landscapes without large predators, the tendency to disperse is desirable and those animals with this trait would selected for. In other situations, such as close herding across common lands, animals that stay in close association are easier to move and manage.

Stock growers also have their own set of criteria that they apply when selecting replacement animals for their breeding herd and fitness for the local environment is generally high on the list.

We also hypothesize that dominant cows, that have experience and spatial knowledge of specific rangelands, can induce a more efficient landscape use/grazing pattern on naive or young members of the subgroup through a passive learning process. It seems reasonable to assume that more experienced members would lead others to preferred grazing locations and watering sites, if they have spatial memory of the landscape.   It has been observed in dairy cattle that younger subordinate heifers are usually found at the rear of the herd (Kilgour and Dalton 1984). Data collected by this project cannot address this question because we have not had sufficient numbers of cattle collared, but we believe that this could be a fruitful area of research.

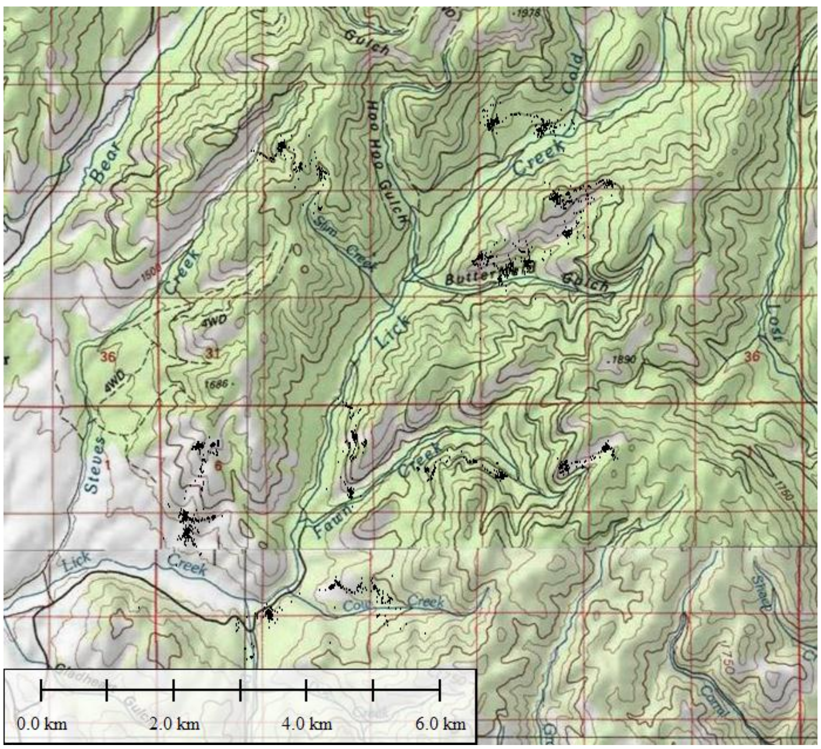

Figure 6. The positions of 10 cows (black dots) logged on 26 September 2009 are shown on a topographic map background. Square mile gridding (in red) can be seen in the topographic map background and a metric scale is provided. Collared cattle in this herd of approximately 450 head on this day are found in a rectangular area approximately 5.2 by 4.3 miles (8.4 by 6.9 km).

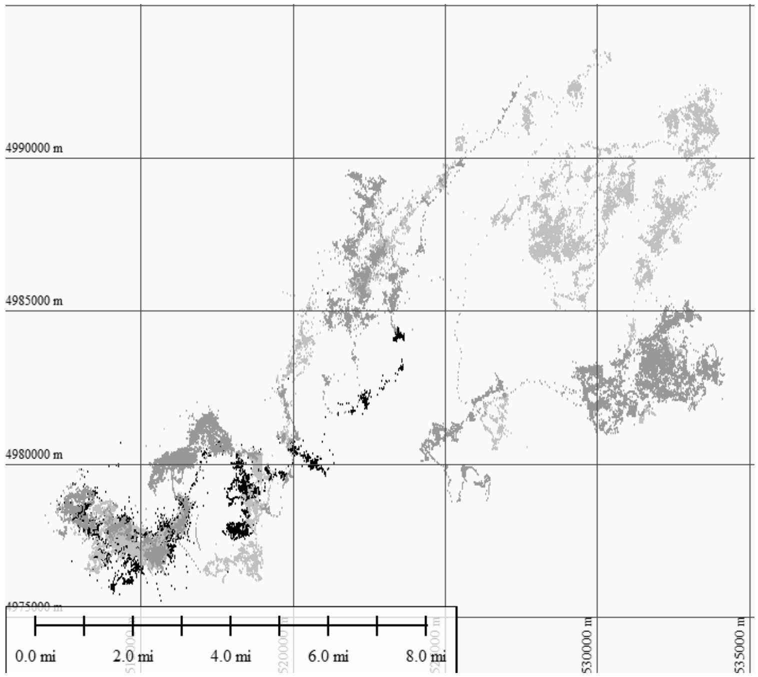

Figure 7. This was the season-long grazing pattern of 3 collared cows grazing Idaho Site 3 during 2010. Each cow is represented with different shade of gray dots, black, gray, and light gray, superimposed on a geo-referenced grid of the area. This area was grazed between April and October 2010. Although the grazing pattern covers the same general area, substantial differences in individual cow movement were apparent. Also apparent were movement corridors between grazing areas.

Table 1. Distance in meters from cow collar 10 to other collar carrying cattle grazing the same pasture on 15 July 2010. Three cows averaged less than 1 km distant from cow 10 while 4 averaged more than 2.5 km. One cow was omitted from the analysis because GPS positions did not cover the entire day.

July 15, 2010	C10 to C17	C10 to C33	C10 to C35	C10 to C45	C10 to C63	C10 to C70	C10 to C72
Daily Average	2842	787	950	3573	2606	451	3592
Std. Deviation	1785	675	674	1122	1211	316	3592
Max Distance	4539	1899	1611	4879	3914	1110	4877
Min Distance	19	3	5	1655	750	4	1955

Cows also showed individual differences in their spatial activity on a daily basis (Figure 7 and 8, Table 2) sometimes staying in the same area and at other times moving across the landscape. Harris (2001) noted that cows may come together periodically, yet still function independently, even in small pastures (Harris et al. 2007). As can be seen in Figure 8, the range of movement is variable with some animals remaining in an area of less than 0.2 mi^2 (0.5 km^2). While others moved directionally across the landscape for miles. We should note several GPS errors, which are represented by light blue lines stretching out and back from the occupied area, were obvious on the animal in the upper right portion of this image. These errors occur periodically, often when animals are lying close to trees or topographic obstructions which prevent the GPS collar from obtaining a good fix.

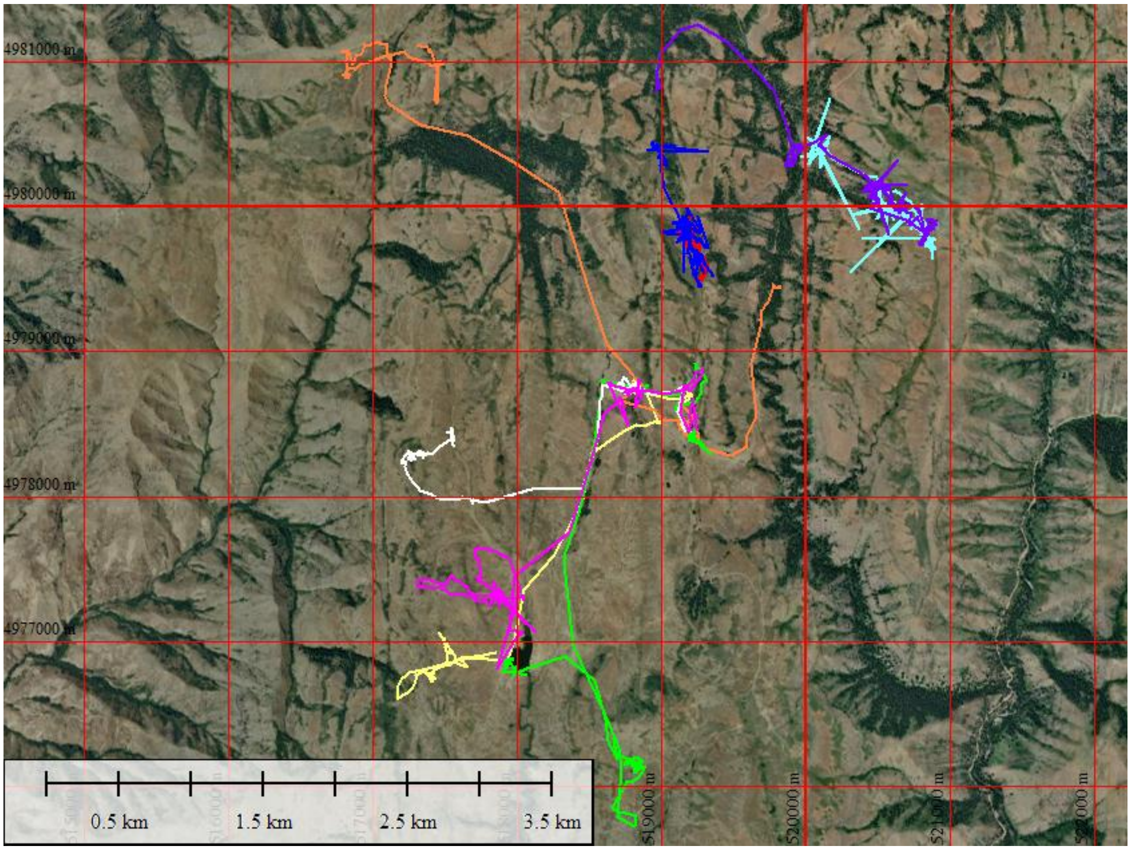

Figure 8. Grazing paths of cattle on 15 July 2010 at Idaho Site 3 superimposed on a NAIP image of the area. An overlain 0.62 mile grid (1 km) Universal Transverse Mercator grid provides scaling for animal routes and relative proximity of areas occupied to those used by other collared cows. Each collared cow is plotted in a different color. Some cows traveled farther than others on this day, contrast the cow plotted in orange vs. the animal in dark blue.

Travel Distance

Our data can be used to estimate travel of each collared animal each day and to estimate the relative time spent moving and stationary (Johnson et al. 2008, Johnson and Ganskopp 2008). There are 2 issues with estimating travel distance using periodic GPS positions. First, animals typically do not move in straight lines but weave across the landscape following either food patches or least-effort pathways between grazing areas (Ganskopp et al. 2000), thus connecting positions at 5 minute intervals underestimates distance traveled. Second, cattle typically rest/ruminate for 12 to 14 hours a day and GPS positions collected when an animal is stationary contain errors. GPS errors are added in distance calculations which artificially inflate the estimate of travel. We are currently examining travel distances in relation animal activity (moving vs. stationary). This should also allow us to identify more precisely areas that are being grazed vs. those locations where animals rest. By isolating and excluding GPS log points when animals are in fact stationary, we should be able to remove spurious GPS positions, reduce cumulative track log errors, and obtain better estimates of actual travel distances.

It is still possible to gain insight as to the travel distances of cattle with the raw (uncorrected) data sets. This data indicates that cows travel different distances depending on the season and the site. Travel distance also varied by year. Cattle grazing Idaho Site 3 traveled an average of 0.91 mi (1.47 km) further per day in 2009 than in 2008. Variability in daily travel distance was similarly low in both years. Wolf presence was low in 2008 on this site while high in 2009. Travel distance of collared cows which lost their calves in 2009 however varied relative to the herd average.

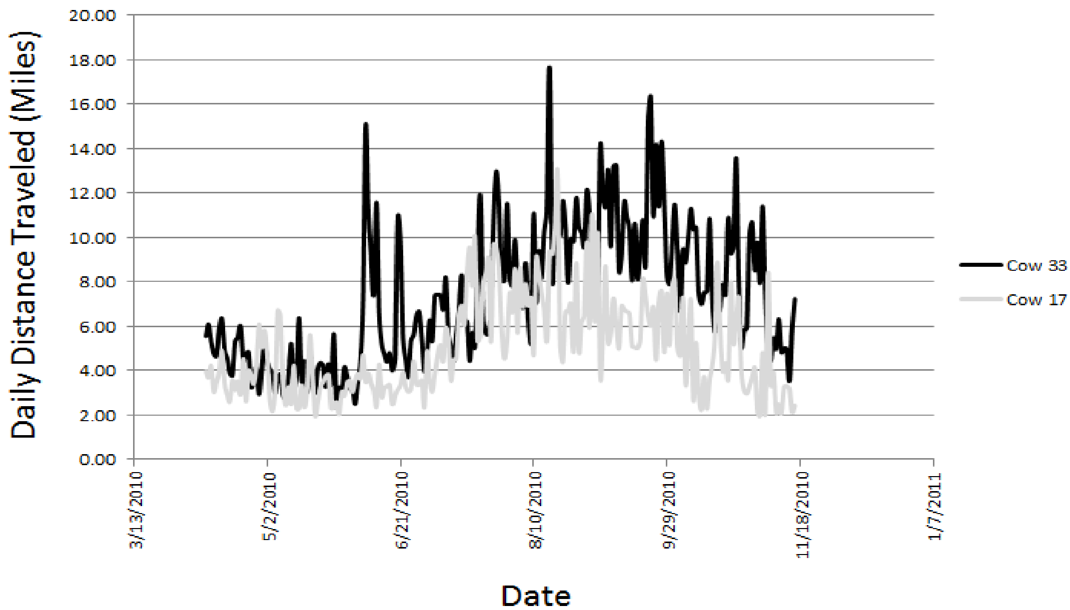

Figure 9. Individual animals varied considerable in their daily travel distances. This figure shows travel distances of 2 cows grazing Idaho Site 3 during 2010. Cow 33 traveled an average of 7.37 miles/day (std. dev. = 3.13 mi.) compared to 4.99 miles/day (std. dev. = 2.19 mi) for Cow 17 (P<0.0001). Maximum and minimum daily travel distance was 17.62 mi. and 2.39 mi. for Cow 33 while Cow 17 had 12.89 m. and 1.97mi for these parameters.

There are annual patterns in the distance traveled by cattle (Figure 9) that are probably the result of topographic factors as well as the pattern of preferred forage on the landscape, both from the perspective of quality and quantity. In Figure 9, low travel distances during the early spring could be caused by abundant forage and animals grazing steep hillsides. Abundant forage in spring may reduce the need to travel between foraging stations; reducing daily travel. Cows grazing hillsides typically move in across the thalweg on terracettes that have a relatively low gradient because the steepness of the terrain restricts movement to directions transverse to the maximum slope. We have observed on very steep hills cattle grazing on the "high side" of trails that crisscross these steep hillsides. On more level ground travel is easier and animals move farther. We have not examined travel distance in light of weather variables but it seems reasonable that cattle respond to periods with very high temperatures by traveling less. We do not know how they might respond to storms or cold temperatures in the autumn.

Some individual cows travel farther than others (Figure 9, Table 2). In the 2008 grazing season the cow wearing collar 2 on site 3 traveled 60% farther than the cow wearing collar 4 (Table 2). For data collected during 2010, cow collar 33 traveled an average of 7.37 miles/day (std. dev. = 3.13 mi) compared to 4.99 miles/day (std. dev. = 2.19 mi) for cow collar 17 (P<0.0001). Maximum and minimum daily travel distance was 17.62 mi and 2.39 mi for Cow 33 while Cow 17 had 12.89 mi and 1.97mi for these parameters. Thus, it appears that some cattle were more athletic than others, covering more ground during the day. We believe that we can identify animal factors such as age, breed, weight, temperament, etc. that correlate with travel distance using our data set. It would also be interesting to see if travel distance is related to measures such as calf weaning weight, cow average daily gain, cow body condition score, or other indices of performance.

Table 2. Mean daily travel distance and standard deviation for GPS collared cattle on Idaho Site 3 during the 2008 grazing season.

Animal	Mean Daily Travel Distance 2008	Std. Dev.
	Miles (km)	Miles (km)
Cow Collar 001	5.20 (8.37)	2.37 (3.82)
Cow Collar 002	8.19 (13.18)	3.06 (4.93)
Cow Collar 003	6.23 (10.02)	3.35 (5.39)
Cow Collar 004	5.06 (8.15)	1.80 (2.9)
Cow Collar 005	6.15 (9.9)	2.44 (3.93)
Cow Collar 006	5.37 (8.65)	1.94 (3.12)
Cow Collar 008	5.49 (8.83)	2.33 (3.75)
Herd Mean	5.96 (9.59)	2.47 (3.98)

Cattle Preference for Landscape Features

Distribution of cattle on our study sites was not uniform with some locations selected over other locations. The Oregon Site 1 Allotment was characterized by mountainous terrain with V-shaped valley form. The predominant stream types (Rosgen A and B stream types) in the allotment are characterized by steeper gradients, limited sinuosity and narrow floodplain width. In this allotment livestock spent 84% of their time above elevations of 1300m (Table 3). Their usage was proportional to the acreage available in each elevation range and was influenced by the annual rotation pattern which changed the entry points for the livestock ($p<0.05$) into the allotment. Livestock spent 33% of their time on preferred slopes of 0-12% and an additional 56% of their time on slopes 12-36% using those slopes proportional to their occurrence within the allotment. Livestock did not show a preference toward aspect or landscape cover classes. They spent 90% of their time in conifer forest type which dominates the allotment.

Table 3. Relative preference values by livestock grazing the Oregon Site 1 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
1100-1300	2.44	6.76	<0.1	0.36
1300-1500	24.83	30.77	NS	0.80
1500-1700	34.3	35.45	NS	0.96
1700-1900	24.93	21.01	NS	1.18
Slope %				
0-12	33.17	19.85	<0.01	1.67
12-24	35.41	32.01	NS	1.10
24-36	21.11	25.3	NS	0.83
36-60	10.09	21.59	<0.01	0.46
Aspect				
North	14.68	18.48	NS	0.79
East	19.5	18.49	NS	1.05
South	29.81	29.13	NS	1.02
West	36.05	33.48	NS	1.07
Cover Class				
Conifer Forest	89.68	92.32	NS	0.97
Shrub/Scrub	8.32	6.14	NS	1.35
Grassland	1.67	1.28	NS	1.30
NDVI				
-0.1 to 0.1	13.38	11.15	NS	1.20
0.1 to 0.3	54.85	41.74	<0.01	1.31
0.3 to 0.4	30.39	45.44	<0.01	0.66

The Oregon Site 2 Allotment is characterized by mountainous terrain containing significant areas of both steep and moderately sloped valleys. As a result the A and B stream channels formed in the steeper sloped valleys tend to have steeper gradients, narrow floodplains, and V-shaped valleys. Moderately sloped valleys tend toward moderate gradient B streams and support wider floodplain development. Livestock preferred elevations below 1600 m (Table 4). They spent 84% of their time between 1300 and 1600 m. which contains 38% of the allotment acreage. Overall 88% of allotment occupancy occurred on 41% of the allotment acreage. Livestock preferred slopes 0-12% and continued to access slopes up to 36% proportional to their availability. Livestock did not show a preference aspect or landscape cover class. They spent 85% of their time in the conifer forest which is the dominant landscape type (Table 4).

Table 4. Relative preference values by livestock grazing the Oregon Site 2 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
1100-1300	7.79	3.05	<0.01	2.55
1300-1600	80.92	38.17	<0.01	2.11
1600-1900	10.32	58.86	<0.01	0.17
Slope %				
0-12	44.64	26.12	<0.01	1.71
12-36	46.99	53.07	NS	0.88
36-60	7.48	19.14	<0.05	0.39
Aspect				
North	16.40	22.63	NS	0.72
East	31.98	29.34	NS	1.08
South	30.69	26.66	NS	1.15
West	21.44	21.44	NS	1.0
Cover Class				
Conifer Forest	85.17	85.5	NS	0.99
Shrub/Scrub	14.35	14.19	NS	1.01
Grassland	0.15	0.06	NS	2.5
NDVI				
-0.2 to 0.0	5.51	10.96	<0.1	0.50
0.0 to 0.3	83.81	72.06	<0.01	1.16
0.3 to 0.4	9.74	14.54	NS	0.67

The Oregon Site 3 allotment is characterized by steep canyons and plateaus. Livestock enter the allotment at low elevation, early in the grazing season, migrating up canyon drainage ways to higher elevation plateaus as grazing becomes available. Livestock spent 65% of their time at plateau landform elevations (Table 5). These lands contain 40% of the allotment acreage and livestock were consistent in their usage across years. Livestock did not indicate any preference toward the lower elevations where they enter the allotment. Livestock traverse the steep slopes of the canyon lands to reach the plateaus by following a limited number of drainage ways which require a climb in elevation of 400 m. Livestock do not show a preference toward the canyons (50% of allotment acreage), spending 22% of their time on those acreage. Livestock spent 65% of their occupancy time on slopes 0-24%. These slopes are predominantly located in the elevation range of the plateau and occur on all aspects of the plateau. Livestock did not show a preference toward aspect. Livestock did not show a preference toward any of the major cover class and occupied those communities in proportion to their available acreage. Livestock did show a preference toward abandoned grass hay fields that occur on benches within the canyons. These areas are used early in the grazing season by livestock as community resting areas for young calves while the cows graze the surrounding slopes.

Table 5. Relative preference values by livestock grazing the Oregon Site 3 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
900-1100	11.8	9.4	NS	1.25
1100-1500	22.6	49.9	<0.01	0.45
1500-1700	65.4	40.5	<0.01	1.61
Slope %				
0-24	65.19	29.0	<0.01	2.24
24-36	16.25	12.3	NS	1.32
36-60	17.14	42.49	<0.01	0.40
Aspect				
North	16.71	21.78	NS	0.76
East	18.55	23.97	NS	0.77
South	26.13	22.03	NS	1.18
West	38.6	32.22	NS	1.20
Cover Class				
Conifer Forest	49.09	56.25	NS	0.87
Shrub/Scrub	17.24	12.97	NS	1.32
Grassland	32.7	30.73	NS	1.06
Cultivated	0.95	0.03	<0.01	31.6
NDVI				
0.0 to 0.1	9.89	7.03	NS	1.4
0.1 to 0.2	25.47	26.6	NS	0.95
0.2 to 0.3	17.78	14.34	NS	1.23
0.3 to 0.4	19.50	15.67	NS	1.24
0.4 to 0.5	18.19	18.99	NS	0.95
0.5 to 0.6	8.92	16.58	<0.05	0.53

The Idaho Site 1 allotment is characterized by mountainous terrain with V-shaped valley form. The predominant stream types (Rosgen A and B stream types) in the allotment are characterized by steep gradients, limited sinuosity and floodplain width. Livestock preferred elevations 1400 to 1500 m. spending 54% of their time on 35% of the allotment and were neutral (8% occupancy) toward elevations 1300 to 1400m (Table 6).

Livestock preferred slopes 0-12% spending 65% of their time at those locations and preferred north and east aspects (58% occupancy). Livestock preferred grassland and cultivated landscape cover classes spending 24% of their time on 7% of the allotment. The majority of livestock time was spent in forest and shrub communities (73% occupancy). Livestock used shrub communities proportional to their acreage but tended to limit occupancy in forest vegetation (57% of allotment acreage).

Table 6. Relative preference values by livestock grazing the Idaho Site 1 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
1100-1300	1.21	8.32	<0.01	0.14
1300-1400	8.52	10.13	NS	0.81
1400-1500	54.07	35.47	<0.01	1.52
1500-1700	31.48	42.34	<0.05	0.74
Slope %				
0-12	64.62	27.91	<0.01	2.31
12-36	33.2	46.58	<0.05	0.71
36-60	2.09	18.3	<0.01	0.11
Aspect				
North	27.44	23.22	<0.01	1.18
East	30.71	21.54	<0.01	1.42
South	13.31	16.81	NS	0.79
West	31.86	38.47	NS	0.83
Cover Class				
Conifer Forest	38.41	57.01	<0.01	0.67
Shrub/Scrub	35.94	35.47	NS	1.01
Grassland	22.13	6.17	<0.01	3.58
Cultivated	2.37	0.59	<0.01	4.01
Wetland	1.15	0.34	<0.2	3.38
NDVI				
-0.2 to 0.0	42.16	34.69	NS	1.21
0.0 to 0.1	10.69	17.93	<0.1	0.59
0.1 to 0.3	36.07	32.16	NS	1.12
0.3 to 0.4	11.03	31.35	<0.01	0.35

The Idaho Site 2 Allotment is characterized by mountainous terrain with V-shaped valley form. The predominant stream types (Rosgen A and B stream types) in the allotment are characterized by steep gradients, limited sinuosity and floodplain width. Livestock prefer elevations 2100 to 2300 m spending 41% of their time on 23% of allotment acreage (Table 7). In addition Livestock demonstrated a neutral preference to the 1900 to 2100 and 2300 to 2500 m elevation zones adding 29% occupancy. Livestock prefer slopes 0-24% spending 74% of their time on 48% of the allotment. Livestock preferred east aspects (36% occupancy) and were neutral to north and south aspects (39% total occupancy). Livestock preferred shrub landscape cover classes spending 34% of time on 16% of allotment acreage. Livestock did spend 62% of their time in conifer forest which represents 75% of the allotment (Table 7).

Table 7. Relative preference values by livestock grazing the Idaho Site 2 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
1300-1500	8.29	5.1	NS	1.62
1500-1700	10.98	22.97	<0.01	0.47
1700-1900	9.53	16.21	<0.01	0.58
1900-2100	18.86	22.27	NS	0.84
2100-2300	40.66	23.23	<0.01	1.75
2300-2500	10.44	9.99	NS	1.04
Slope %				
0-24	73.93	47.8	<0.01	1.54
24-36	19.28	28.79	<0.05	0.67
36-60	6.07	22.03	<0.01	0.27
Aspect				
North	14.83	14.38	NS	1.03
East	36.22	24.94	<0.01	1.45
South	24.16	23.24	NS	1.04
West	24.77	37.75	<0.01	0.65
Cover Class				
Conifer Forest	62.46	75.27	<0.01	0.83
Shrub/Scrub	34.53	16.29	<0.01	2.11
Grassland	1.79	6.63	<0.05	0.29
NDVI				
-0.1 to 0.1	3.83	20.61	<0.01	0.18
0.1 to 0.3	42.45	57.98	<0.01	0.73
0.3 to 0.4	47.9	16.84	<0.01	2.84

The Idaho Site 3 Allotment is characterized by a wide elevation range that contains steep canyons with low elevation valley bottoms and higher elevation mountainous terrain between 1300 and 1700 m. Livestock spent 75% of their time at elevations above 1300 m (Table 8). All elevation categories were selected in proportional to their availability within the allotment. However the occupation pattern changed between years in the elevation range of 1300 to 1500 m. In that elevation range, livestock occupation was 22% below the average ($p<0.05$) in 2008 and was 53% above the average ($p<0.05$) in 2011 (Table 8). These differences correspond with periods of moderate and high wolf predation, respectively. This could also result from managerial or climatic differences. Livestock preferred slopes 0-24% spending 72% of their time on the portion of the allotment containing those slopes (51%). Livestock used slopes 24-36% proportional to their availability with the allotment. Livestock were neutral in preference toward differences in aspect and landscape cover classes. They spent 88% of their time in the forest and shrub communities that dominate the allotment vegetation (Table 8).

Table 8. Relative preference values by livestock grazing the Idaho Site 3 Allotment for selected landscape classes across all years. A departure from expected occupancy on a proportion of surface area basis was noted in the column labeled significance.

Attribute	% Occupancy	% Allotment	Significance	Preference
Elevation m				
900-1100	3.91	3.55	NS	1.1
1100-1300	5.95	8.69	NS	0.68
1300-1500	38.28	38.49	NS	0.99
1500-1700	37.62	34.05	NS	1.1
Slope %				
0-24	72.52	51.03	<0.01	1.42
24-36	16.98	19.72	NS	0.86
36-60	9.02	22.51	<0.01	0.40
Aspect				
North	17.96	18.03	NS	0.99
East	21.47	23.3	NS	0.92
South	26.31	21.74	NS	1.21
West	34.27	36.92	NS	0.93
Cover Class				
Conifer Forest	45.94	47.91	NS	0.96
Shrub/Scrub	42.06	42.64	NS	0.98
Grassland	11.51	9.07	NS	1.26
NDVI				
-0.3 to 0.0	43.36	50.94	NS	0.85
0.0 to 0.1	14.43	12.8	NS	1.12
0.1 to 0.3	41.36	34.87	NS	1.18

Cattle Occupancy along Perennial Stream Systems in Oregon

The use by cattle of free flowing perennial streams and the closely associated potential riparian landforms is a management concern. In this report, cattle occupancy in buffer zones around perennial streams was studied for the years 2008 and 2009. Analysis of the remaining data for the Oregon sites and the Idaho sites will be completed for future reports and documents. The perimeter of Oregon study site 1 encloses 47 kilometers (30 miles) of perennial stream while Oregon study site 2 has 24 kilometers (15 miles) of perennial flow within its boundary and Oregon 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.

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 9). 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 cattle moved upland, following snow melt, these same canyons limit their return to the streams for the remainder of the grazing period.

Cattle occupying site 2 are on a landscape where riparian areas 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 9). 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 reflects 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 sites it should be noted that occupation of this zone was always less than 1 percent. This Observation was supported by information reported by Ballard (1999) where intensive visual observations indicated a similar percentage of use. On a per day average the individual animals on site 1 spent 2.43 minutes per day in this zone with site 3 cows being similar at 2.58 minute per day. Site 2 cows spent 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 known what they were doing while in this zone.

Cumulative stream buffer zone occupancy was similar between site 1 and site 3 with both reaching percent occupancy of just over 1 percent for all area between 0 m and 60 m (Table 9). Site two was again different in this analysis as occupancy began in the 0-10 and 10-20m zone with a higher numeric values than the other two and was nearly 4 percent cumulative occupancy out to the 50-60 m zone.

Table 9. Occupancy of buffer zones along streams for the 3 Oregon study areas.

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

Duration of Cattle Occupancy

Sites in both Idaho and Oregon are large and not surprisingly, between 70% and 80% of the 2.47 acre (1 ha) gridded locations within allotments and private land inclusions received 12 or fewer cow positions (Table 10) throughout the grazing season. Twelve positions for a collared cow translate to slightly longer than one hour of occupancy (66 minutes on an average data set). Areas that tend to be lightly used are widespread which reflects managerial objectives and the natural tendency for these cattle to disperse. Other factors are more difficult to discern. On one of our Oregon sites we had an area of several square miles that showed low usage and we were unable to see an obvious reason for it. The area was relatively level and appeared to have adequate forage in aerial images. When we asked the local rancher about this area, we were told that that the location had had a recent fire and they were asked to keep the cows out of the burned area, which he did.

When plotted on a map (Figure 10), it is also possible to identify foci on the landscape where collared cattle have congregated or remained for longer periods (Appendix Tables 1 to 6). These sites are sometimes associated with corrals where animals are gathered and held, but generally represent sites that are attractive because they offer more forage, easy access to water, shallow terrain, or are on topographically constrained routes between portions of the grazing allotment. Factors that lead to the development of foci vary by site and situation and are best interpreted by the ranchers or range riders that have long experience with each landscape. Our cooperators can often explain why animals were found at a specific location. It is sometimes a salting site or it could be an area with deeper soils. One site was identified as a long abandoned hay field that was miles from the nearest existing farmstead.

We are in the process of categorizing and cataloging foci in each of the study areas for each year in cooperation with the ranchers and range riders. The information we have collected thus far leads to several apparent questions: 1) are foci stable between years or if a rotational grazing system is followed, when animal rotations are the same?, 2) are foci more prevalent in one portion of the grazing season as compared to another?, 3) are some cows more likely to use or remain at foci?. We would also like to determine if dominant animals or subgroups lead by dominant animals are more likely to use foci i.e. do groups lead by dominant animals choose the best areas first relegating other groups to less preferred sites?

For those sites that provide better forage, do animals have sufficient spatial knowledge that they move directly from one preferred area to another or do they learn as they progress through the landscape? We are currently building resource selection models that hopefully will identify preferred sites with a degree of precision.

Table 10. Percentage of 328 ft. by 328 ft. (100 m by 100 m) gridded cells on study sites in Oregon and Idaho (allotments and included private lands) that had 12 recorded cow positions or less throughout the grazing season. Gridded cells are positioned on gridlines of the UTM, Zone 11 coordinate system using the WGS84 datum. Since positions are generally logged at approximately 5 ½ minute intervals, 12 positions represent slightly longer than 1 hour of occupancy. This information includes the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Study Area	**Year**			
	2008	**2009**	**2010**	**2011**
Oregon 1	83.6%	79.3%	89.2%	81.6%
Oregon 2	73.9%	61.8%	61.6%	74.1%
Oregon 3	74.5%	74.5%	59.6%	38.4%
Idaho 1	66.1%	68.0%	60.4%	63.8%
Idaho 2	90.2%	82.6%	85.2%	78.9%
Idaho 3	87.9%	74.1%	85.7%	89.0%

Foci within the grazing areas (for collared cattle) change between years as a result of management plans and individual animal behavior (Figures 10 and 11). For example, the foci in the upper left portion of the Idaho Site 3 grazing allotment in 2009 were not grazed the following year (Figures 10 and 11) or in 2011 because of the grazing plan. Table 11 provides the count of foci with greater than 500 cow positions on each site during each year.

Table 11. A number of the 328 ft. by 328 ft. (100 m by 100 m) gridded cells on study sites in Oregon and Idaho (allotments and included private lands) that had >500 recorded cow positions throughout the grazing season. Since positions are generally logged at approximately 5 ½ minute intervals, 500 positions represent approximately 46 hours of occupancy. This information includes the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Study Area	Number of Foci on the Landscape (1 ha cells with > 500 cattle locations)			
	2008	2009	2010	2011
Oregon Site 1	8	12	23	8
Oregon Site 2	19	11	9	21
Oregon Site 3	28	49	126	79
Idaho Site 1	47	125	152	154
Idaho Site 2	10	6	19	45
Idaho Site 3	57	79	14	4

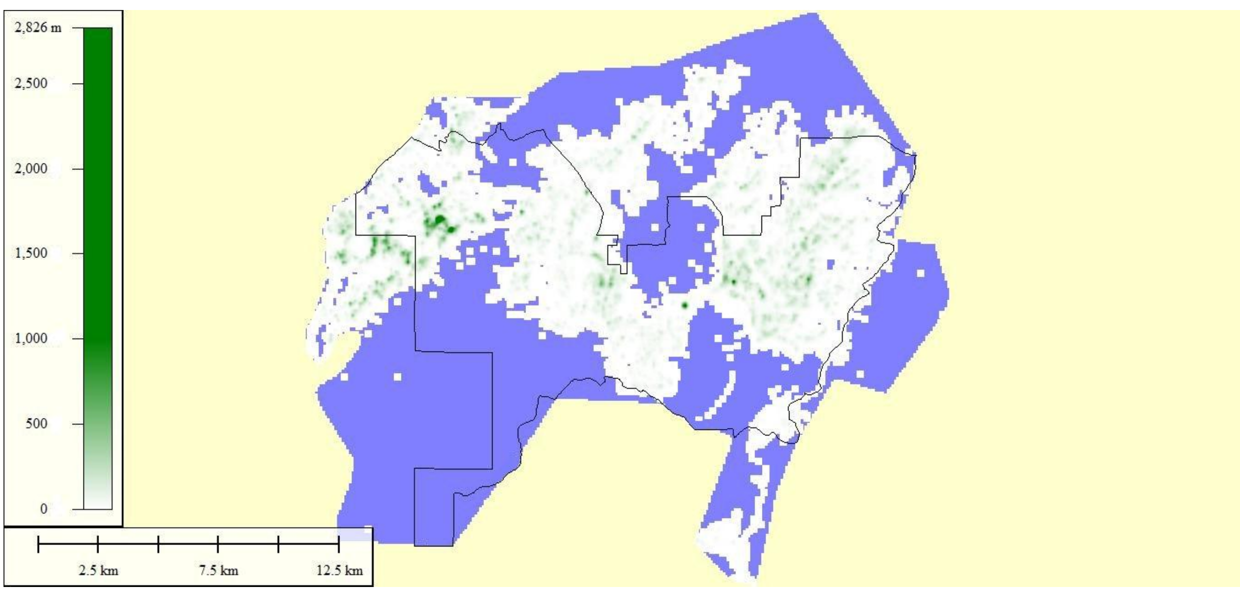

Figure 10. Site occupancy map of collared cattle grazing Idaho Site 3 and included and surrounding private lands during the 2009 grazing season. Sites where cattle spent more time are shown in darker shades of green while blue areas are those with no recorded positions. The scaling of the number of locations per cell is given on the left. The maximum number of positions in a cell during this year was 2,826. Each cell attributed on this map is a square area of 2.47 acre (1ha).

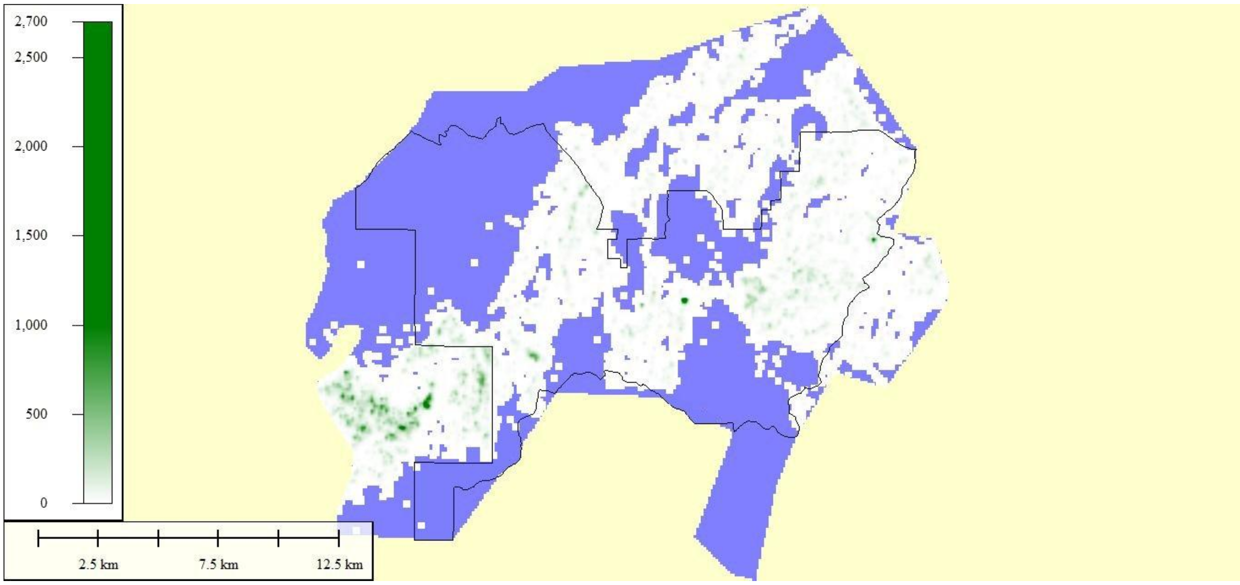

Figure 11. Site Occupancy map of collared cattle grazing Idaho Site 3 and included and surrounding private lands during the 2010 grazing season. Sites where cattle spent more time are shown in darker shades of green while blue areas are those with no recorded positions. The scaling of the number of locations per cell is given on the left. The maximum number of positions in a cell during this year was 3,398 which occurred in a corral on included private land. Each cell attributed on this map is a square area of 2.47 acre (1ha).

Wolf Movement

Wolf B446 was tracked at 15 minute intervals for 209 days in the summer and autumn of 2009 (Figure 12). The minimum convex polygon (MCP) area occupied by this wolf covered 214 mi^2 (553 km^2) as he ranged between the Snake River and through the mountains of west central Idaho. Average daily travel distance, based upon our 15 minute logging interval, was 11.3 mi (18.2 km), however daily travel distance varied substantially (Table 12). This animal appeared to have long distance travel days that alternate with shorter distance days throughout the season (Figure 13). There was no overall linear trend apparent in this data ($y = -0.0021x + 94.465$, $R^2 = 0.0007$) which suggests no seasonal change in mobility between May and December (Figure 13).

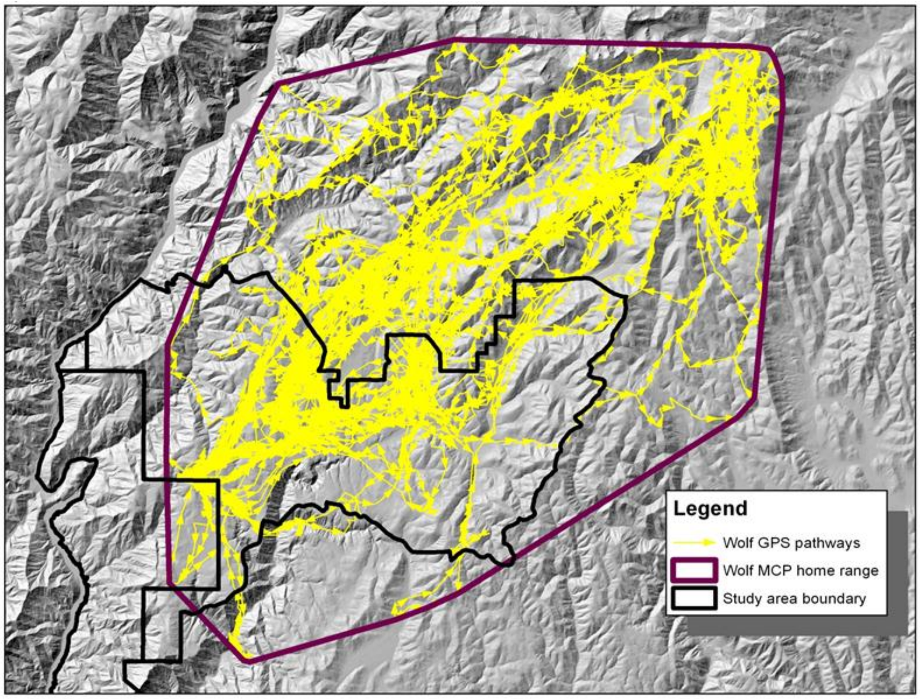

Figure 12. The pathways followed by Wolf B446 between 23 May to 18 December 2009 (209 days). 19,575 positions were logged at approximately 15 minute intervals with a GSP accuracy (horizontal error) of approximately 5 yards (<5 m). A minimum convex polygon was constructed around these wolf tracks (shown in purple) that covered 214 mi^2 (553 km^2).

Minimum daily travel distance for this animal was 2.56 mi (4.12 km) while the maximum daily travel distance was 24.94 mi (40.13 km) (Table 12). The maximum distance covered in 1 hour of continuous movement was 6.29 mi (10.13 km) and in a 2 hour continuous period was 8.39 mi (13.51 km).

Table 12. Travel distance of Wolf B446 between 24 May and 8 December 2009. All distances are based on GPS positions collected on a 15 minute logging interval.

	2D Distance Miles (km)	3D Distance Miles (km)
Total 198 Day Travel Distance	2259 (3636)	2490 (4008)
Mean Daily Travel Distance	11.28 (18.16)	12.43 (20.01)
Standard Deviation of DTD	4.68 (7.54)	4.77 (7.68)
Maximum Daily Travel Distance	24.94 (40.13)	26.15 (42.09)
Minimum Daily Travel Distance	2.56 (4.12)	3.01 (4.84)

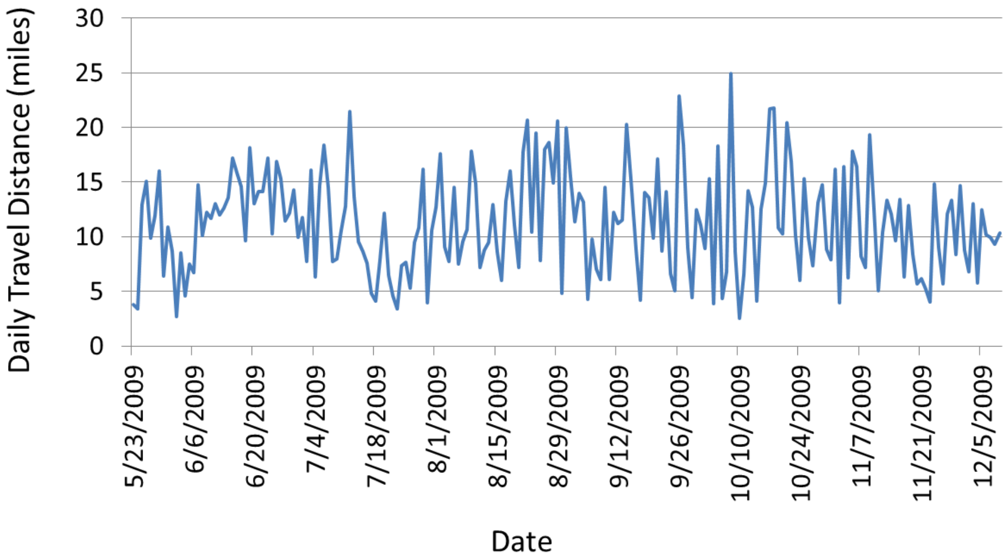

Figure 13. Daily travel distance of Wolf B446 between 24 May and 8 December2009. All distances are based on GPS positions collected on a 15 minute logging interval.

Wolf B446 traveled at all hours of the day but tended to move mostly at night i.e. from 8:00 PM to 8:00 AM Local Standard Time. Travel was greatest near midnight (Table 5). This wolf was also quite tolerant of human dwellings and roadways and frequently spent time near houses during the night but also sometimes in the day.

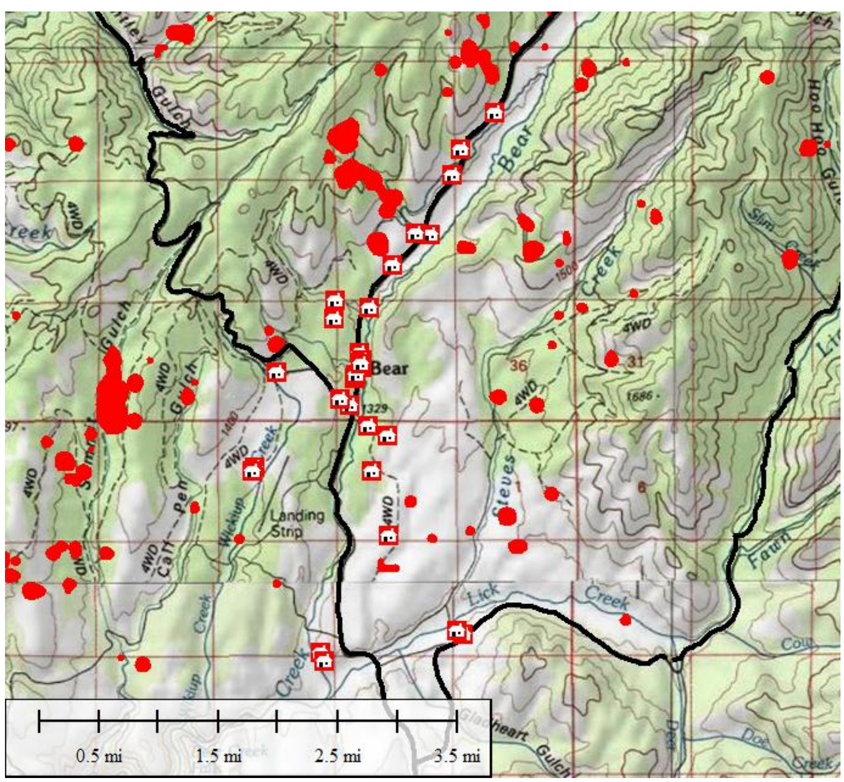

Figure 14. Positions of dwellings (house symbols) and positions where Wolf B446 had more than 2 ½ hours of occupancy (red-filled polygons). A rendezvous site is located in the center left of this map. Principle roadways are shown as black lines.

Figure 14 shows locations where this wolf was logged more than 10 times or approximately 2 ½ hours of occupancy. Several of these locations were close to dwellings (Figure 14). Wolf B446 was positioned 588 times within 547 yards (500 m) of houses between 24 May and 8 December2009. Figure 15 provides the timing and frequency of locations within 547 yards (500 m) throughout the period he was collared. 24 positions translate to approximately 6 hours of occupancy.

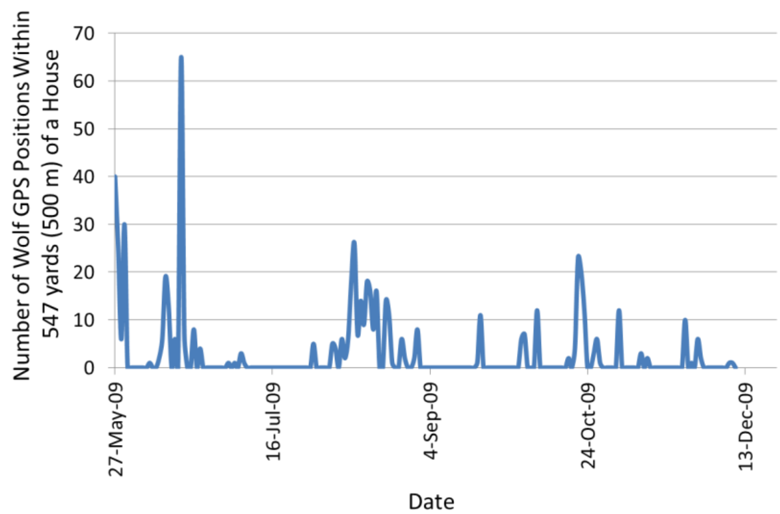

Figure 15. Timing and frequency of Wolf B446's proximity (<547 yards) to houses. Throughout the period that this wolf was collared he frequently was near houses, often for extended periods.

Table 13. Travel distance of Wolf B446 partitioned by the hour of the day. Data was collected between 23 May and 30 November 2009. All distances are based on GPS positions collected on a 15 minute logging interval.

Hour of the Day	Mean Travel (m/hr.)	Std. Dev. (m/hr.)
Midnight to 1 AM	1041	1273
1 to 2 AM	992	1252
2 to 3 AM	1044	1327
3 to 4 AM	1083	1422
4 to 5 AM	1028	1347
5 to 6 AM	989	1215
6 to 7 AM	972	1191
7 to 8 AM	971	1063
8 to 9 AM	779	894
9 to 10 AM	679	798
10 t0 11 AM	551	715
11 to 12 Noon	472	611
12 to 13 PM	451	690
13 to 14 PM	388	491
14 to 15 PM	366	486
15 to 16 PM	355	518
16 to 17 PM	390	544
17 to 18 PM	395	516
18 to 19 PM	451	604
19 to20 PM	641	900
20 to 21 PM	822	1117
21 to 22 PM	1070	1113
22 to 23 PM	1111	1293
23 to Midnight	1304	1436

Depredation

Depredation in the vicinity of the Idaho Study Sites were compiled from USDA APHIS Wildlife Services data and are provided in Appendix Table 13. There were 15 confirmed or probable depredations on Idaho Site 3 in 2009; most were near roads or habitations (Figure 16). Land in this area is quite rugged and dead cattle off of roadways or in forested or shrubby areas are unlikely to be found. The ranch reported 65 head missing, above normal death loss, at the end of the grazing season out of a total herd of 580 mother cows with calves.

Confirmed or probable depredation locations on Idaho Site 3 were also mapped and the relative position with landscape features such as dwellings and roadways determined (Figure 16). This was done because we had a collared wolf on this site and believed it could shed light on the methods employed by wolves in their pursuit and attack sequence. We also wanted to determine if human activity and the presence of dwellings constituted a deterrent to wolf activity. We should note that some depredation occurred before Wolf B446 was collared. Wolf B446 was trapped and collared in the calving pasture and represents 1 animal of a larger pack (13 individuals including young of the year).

After collaring, Wolf B446 moved 2.22 miles (3.6 km) northward and circled back to the den site, approximately 5.8 miles to the west southwest of the calving pasture (Figure 16). He was back on the den site by 24 May 2009 at 10:30 PM LSDT. By 25 May 2009 at 22:53, Wolf B446 was back in the calving pasture and was GPS logged within 500 yards (456 m) of a ranch house. This wolf covered a curved route to the calving pasture of 6.8 miles (10.9 km) from the den site to the calving pasture in 2 hours 33 minutes. He returned to the heifer calving pasture 14 of the next 28 days and to the den site 18 of the next 28 days. Thus, he seemed to be focused on two locations during this period, the den site and the calving pasture. We should note that calving pastures are close to the house because cattle are watched carefully and frequently during calving. Any difficulties the cow may have during birth must be addressed quickly or problems are likely to occur that could lead to the loss of a calf or cow. Ranchers like to check animals frequently to prevent losses during this critical point in the production sequence. Ranchers also like to keep cows as quiet as possible because birth problems increase as handling stress increases (Kilgour and Dalton 1984, Dufty, 1981).

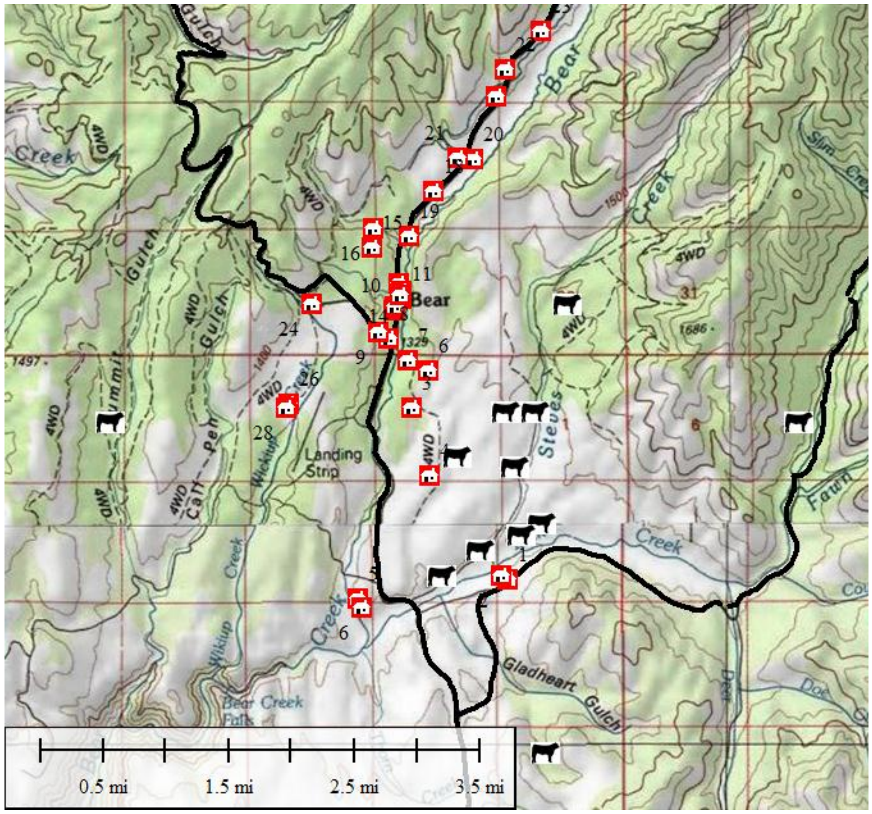

Figure 16. Cattle killed or wounded by wolves, marked by a calf symbol, in the vicinity of a calving pasture on Idaho Site 3. The Calving Pasture is on the open hillside in the center-right portion of this image where the bulk of the depredations are marked. Our major routes are shown in black and dwellings are marked in with house symbols. Many of the depredations occurred before Wolf B446 was collared. Cattle losses in the rougher forested portions of the landscape are much more difficult to detect because of topographic roughness and vegetation that obstructs the view.

The den site was regularly visited by the collared B446: 31 days of the 45 days between 24 May 2009 and 7 July 2009 when he abandoned this location. He returned to the den site on November 4th and 5th 2009. The Calving Pasture ceased to become a focus after 3 July 2009 but was visited periodically (on 30 of the 159 days between 4 July 2009 and 9 December 2009).

Because Idaho Site 3 had a collared wolf, it was possible to examine wolf tracklogs in relation to known cattle depredation locations (Figure 17). In some depredation events Wolf B446 showed a circular track with a radius of several hundred yards (200 m) and in others a simple linear track across the site (Figure 17). In several cases, confirmed depredations occurred at locations where B446 was not present which suggests that other pack members were involved.

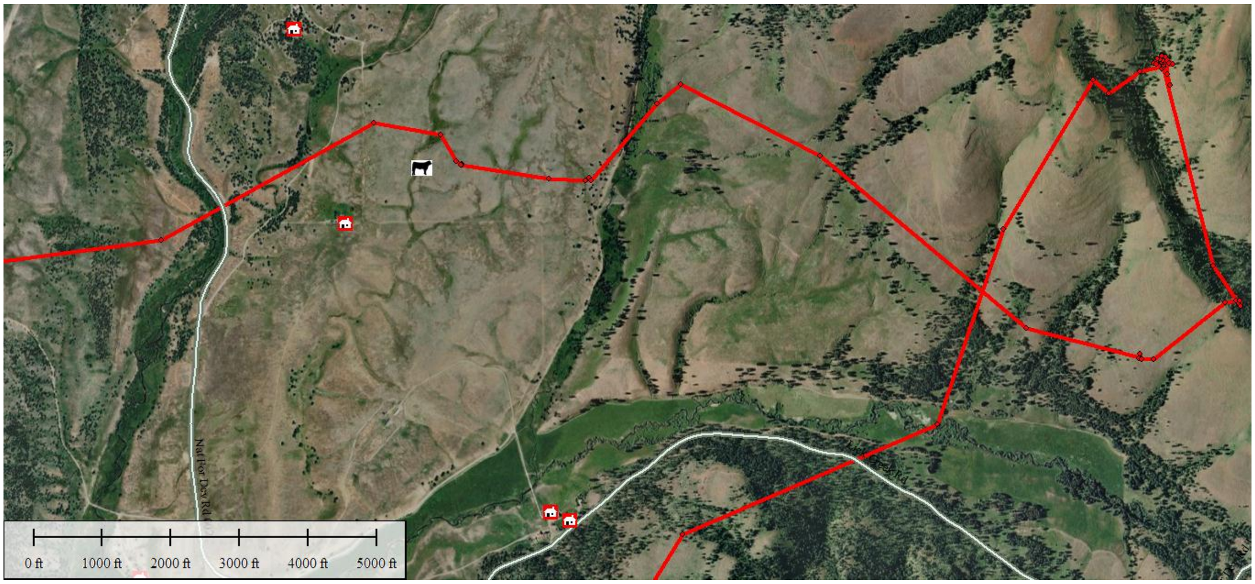

Figure 17. Wolf track log in proximity to a depredation event on 7 June 2009. The wolf track is shown in red, depredation location with a calf symbol on a white rectangle, and habitations with house symbols. The wolf entered from the center left and exited at the bottom of the image. The calf was a confirmed kill that lived for 19 days before death from bites to the neck.

When confirmed and probable depredation events and wolf GPS locations are plotted, a clearer picture of wolf activity emerges. It has been suggested that human presence and activity is a deterrent to wolves. In this case, we found that depredation sites were often near dwellings and roadways (Figures 16, 17, and 18).

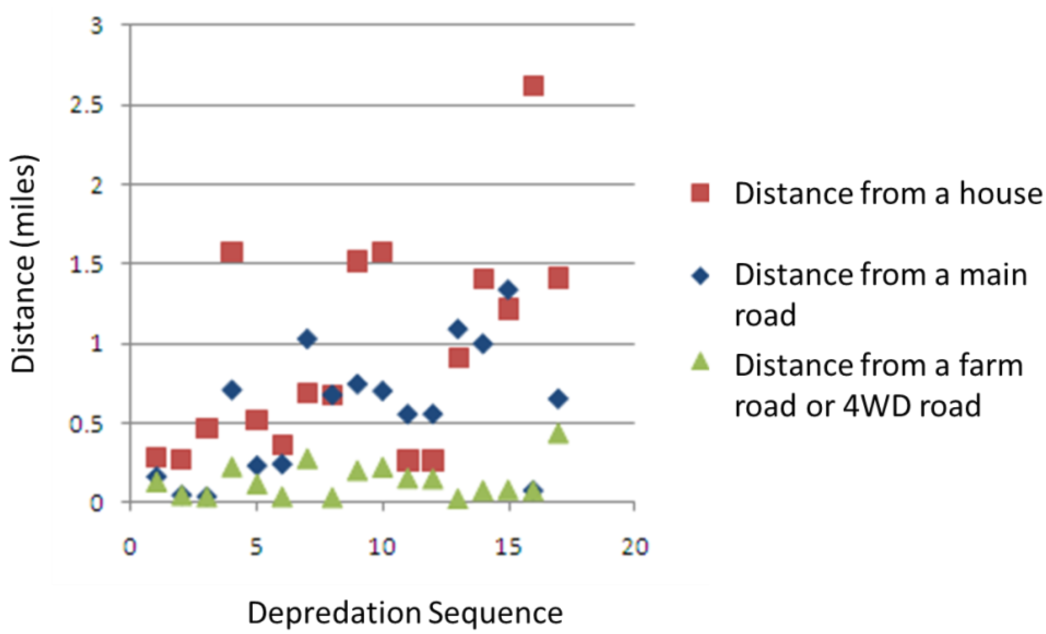

Figure 18. Distance of confirmed and probable depredation sites from houses, main roads, or unimproved roads at Idaho Site 3 during the 2009 grazing season.

Wolf/Cattle Interactions

Collared cattle on Idaho Site 3 first encountered the collared Wolf B446 at less than 547 yards (500 m) on 19 June 2009. This herd of 450 head had 10 collared cows. Collared cows periodically encountered the wolf until 3 November 2009 when cattle were removed from the range. We should remember that the collared wolf was part of a larger pack of as many as 12 individuals and other wolves may have also encountered these cattle prior to these dates or at closer distances that B446. Also, since B446 was logged at 15 minute intervals and cows at 5 minute intervals, encounters could be much closer and if the encounter was of relatively short duration, not be accurately documented.

Two of the cows wearing collars had lost their calves by the end of the grazing season. Both these calves were unaccounted for, never found, and were listed as missing. We were surprise by the frequency of interactions between cattle and this wolf and examined it further. Sometimes more than one GPS-collared cow was encountered simultaneously. The maximum number of simultaneous encounters was 6 cows which could indicate bunching of animals. When broken out as separate events, there were 448 of the 783 total encounters at <500m that were independent.

Most of the encounters at less than 109 yd. (100 m) occurred at night with all but 1 of the 53 encounters occurring between 8:00 pm and 7:00 am. The timing of nighttime encounters at < 100m was bimodal with 24 occurring between 10:00 pm and 1:00 am and 24 between 2:00 am and 6:00 am with peaks near 11:30 pm and 3:30 am.

Table 14. The number of times each of the collared cows on Idaho Site 3 encountered Wolf B446 at 547 yards (500 m), 273 yards (250 m), and 109 yards (100 m) during the 2009 grazing season. The period between first and last encounter was 137 days.

Animal	Cow/Wolf B446 Interactions (Count)		
	547 yd. (500 m)	**273 yd. (250 m)**	**109 yd. (100 m)**
Cow Collar 003	73	24	3
Cow Collar 005	121	43	5
Cow Collar 008*	41	14	3
Cow Collar 018	61	10	0
Cow Collar 019	99	36	7
Cow Collar 020	140	37	12
Cow Collar 021	93	20	5
Cow Collar 022*	23	4	1
Cow Collar 023	52	15	2
Cow Collar 024	80	41	15
Total	**783**	**244**	**53**

* Animals marked with a star lost calves during the summer grazing season.

We wondered if it were possible to see the effects of an encounter by analyzing the velocity of cattle immediately before and after an event. Figure 19 shows the straight-line distance between cow 8 and Wolf B446 as well as the velocity diagram of this cow between 1 July and 15 July 2009. Wolf was recorded 617 m from this cow on 7/5/2009 at 1:57:42 AM. It was 112 m from Cow 8 on 7/10/2009 06:29:23 and beginning on 7/10/2009 at 23:25:16 the wolf was with this cow for 1hr. The velocity diagram shows much more activity following these encounters than during the time just prior to the events. Cow 8 lost her calf during the grazing season.

Other encounters show no increase in cow activity and it does not necessarily follow that an encounter leads to increased activity. It appears that in some cases, Wolf B446 was within 500m of a cow and the cow was unaware of its presence. In other cases we see rapid movement away from the wolf.

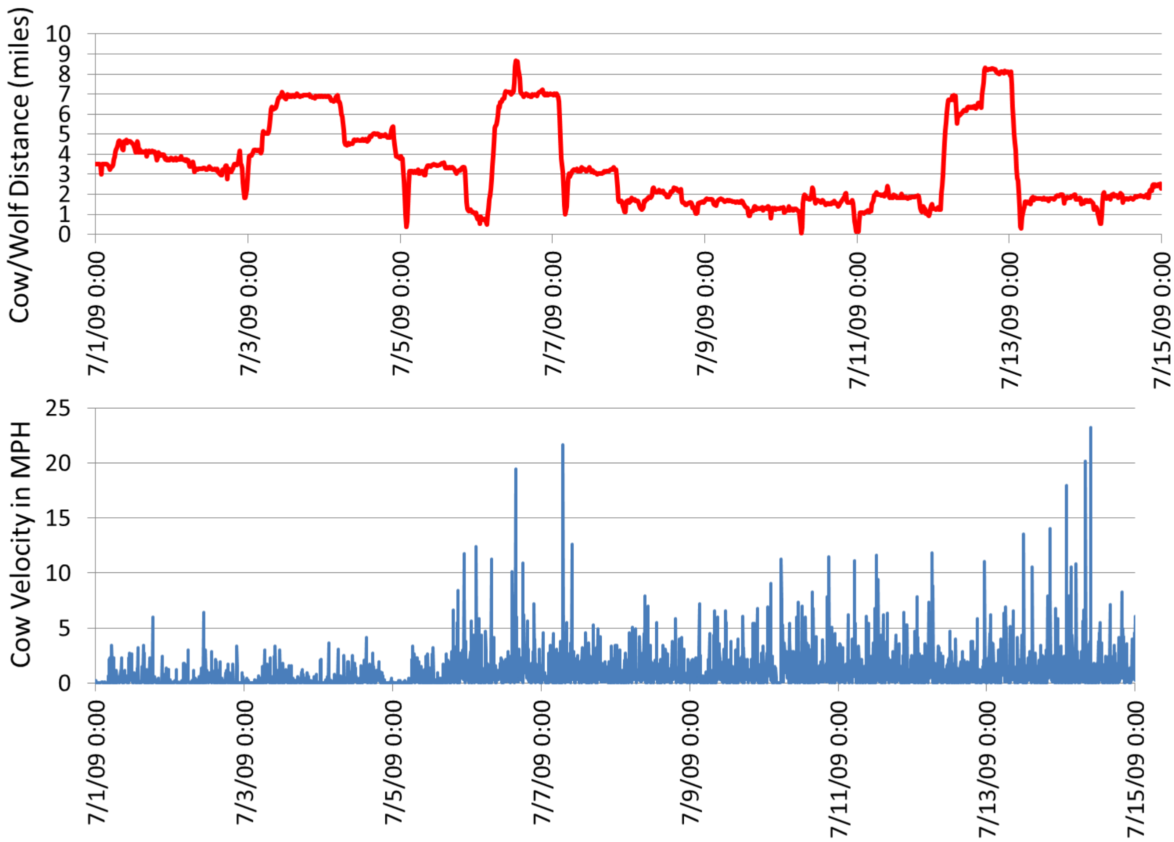

Figure 19. The upper graph shows the distance of a Cow 8 from Wolf B446 in July 2009 based on 15minute logging interval. Wolf was recorded 617 m from this cow on 7/5/2009 at 1:57:42 AM. It was 112 m from Cow 8 on 7/10/2009 06:29:23 and beginning on 7/10/2009 at 23:25:16 the wolf was with this cow for 1hr. Cow 8 lost her calf during the grazing season. It should be remembered that Wolf GPS locations were only taken at 15 minute intervals and cow GPS locations at 5 minute intervals and locations may be offset in time by as much as 3 minutes. Note the increased activity in Cow 8 after the encounters.

Cattle Grazing Response to Wolf Presence

Since we had a period of documented wolf presence and as well as the wolf's pattern of landscape use, we examined the spatial patterns of cows grazing during this year. We contrasted cow activity in July for 2008 through 2011 because cattle were in the same pastures in these years (Figure 20).

2008 was the first year that wolf depredations were recorded in this area. These depredations occurred on 11, and 22 July and on August 6, 2008. Prior to 1 August, there were 3 confirmed calf depredations and 2 probable depredations on calves on this area. July 2009 and 2011 were high wolf presence years with 9 confirmed and 1 probable depredation before 1 August 2009 and 16 confirmed and 3 probable depredations before 1 August 2011. 2010 was lower wolf presence years with 2 confirmed and 1 probable depredation before 1 August 2008 and 2 confirmed depredations before 1 August 2010. Thus we have 2 years of high wolf presence (2009 and 2011) and 2 years of moderate wolf presence (2008 and 2010).

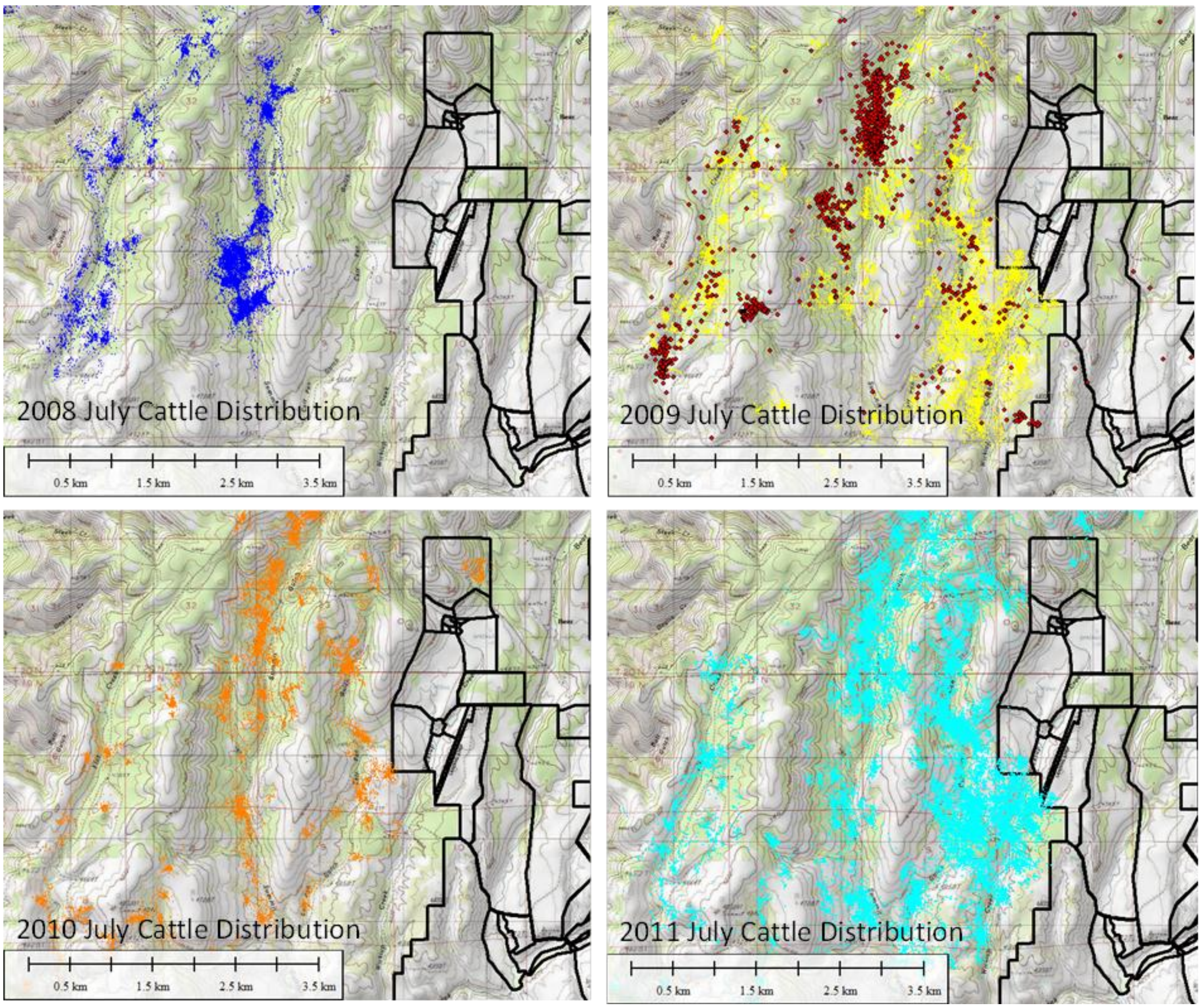

Figure 20. Cattle distribution on a portion of Idaho Site 3 during July of 2008, 2009, 2010 and 2011. July 2009 and 2011 were high wolf presence years with 9 confirmed and 1 probable depredation before 1 August 2009 and 16 confirmed and 3 probable depredations before 1 August 2011. 2008 and 2010 were lower wolf presence years with 2 confirmed and 1 probable depredation before 1 August 2008 and 2 confirmed depredation events before 1 August 2010. Black lines represent fences around and inside private land holdings. Blue, yellow, orange and light blue dots represent cattle locations for the various years, red dots are July wolf locations in 2009. 2008 and 2009 have approximately 32,000 positions, while 2010 and 2011 have approximately 72,000 positions logged in July.

Ranchers tell us that when cows are being harried by wolves that they often try to “come home” or are found near fence lines and gates. Our distribution data supports this observation. In Figure 20, fences are shown as black lines while cow positions are shown as colored dots. The positions of Wolf B446 in 2009 are plotted as red circles. In both 2009 and 2011 cattle concentrated in the indented area on the western boundary of the ranch's private land boundary. Ranchers also tell us that wolves will run animals along fences or use fence corners as traps for prey.

Wolf B446 used the Summit Gulch area which arcs toward the northeast more heavily because it contained a rendezvous site, which is visible in Figure 20 and afforded easy travel routes. If we assume that other wolves in the pack used the landscape in a similar fashion, cattle would be forced towards the ranch and away from Summit Gulch by wolf pressure. We should note that roads lead from the allotment to the ranch facilities in this area and cattle are often moved into the ranch proper via gates on the indented portion of the western ranch boundary, the same area where they concentrated in 2009 and 2011.

Cow Movies

Another way that spatial data can be viewed is with "cow movies" in which animals positions are sequentially plotted on a background map so points recorded in the same period are visible. These files typically show current positions as bright points that fade and disappear over an hour or so. The video files that we produced are stamped with Universal Date/Time so spatial relationships, activities, or specific events can be identified and, if needed, the original data sets reexamined. The videos created from each site and year can be viewed at any desired frame rate, stopped, and backed up as necessary to gain insight as to herding behavior and land use. Because file size can become very large with long duration data sets, we break our observation periods into units of 10 days or less. An example of this type of data can be viewed at http://oregonstate.edu/dept/range/node/49149 .

Dates when animals are gathered and moved from pasture to pasture are easily seen with these videos, as well as general dispersion of animals throughout the day. When coupled with wolf locations from tracking collars, movement relative to collared cattle and cattle spatial response can also be examined. Unfortunately only three wolf collars have been deployed in our study with only one collar retrieved to date (from Idaho Site 3). As was mentioned previously, sometimes the collared wolf passes by cows and we see little change in cow activity (Figure 21). In other cases, cattle have a flight response and in others cow activity patterns change dramatically (Figure 22).

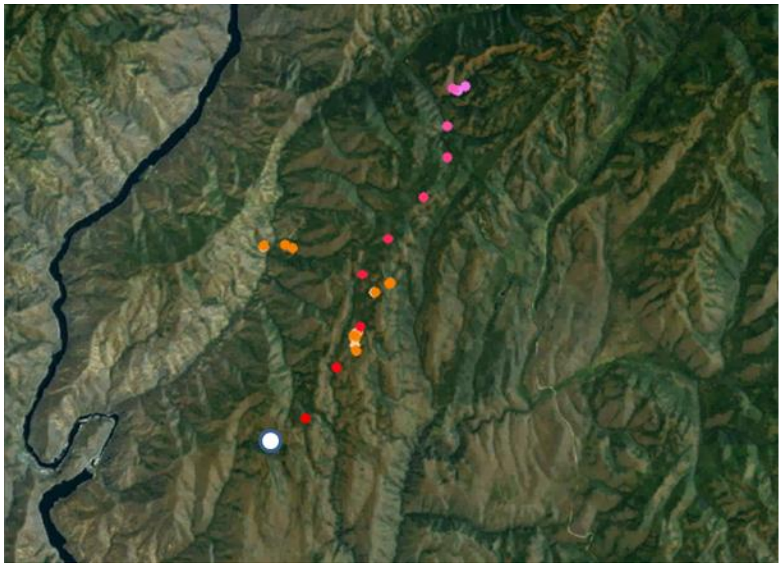

Figure 21. Movement of Wolf B446 through a group of collared cattle on 5 July 2009 at 1:46 a.m. LST. Collared cattle gave no apparent response to this encounter. The wolf was traveling south toward the den site shown as a large white dot.

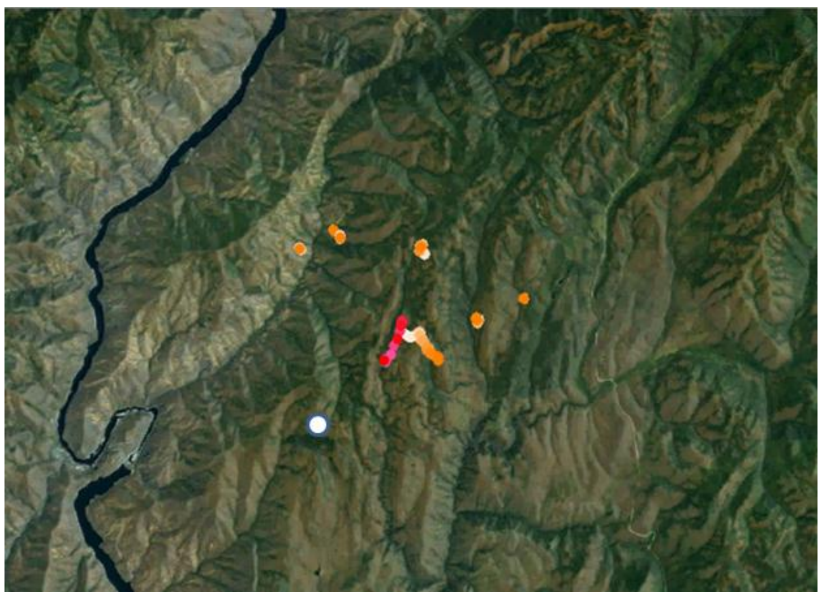

Figure 22. Flight event of a collared cow from Wolf B446 that began on 8 July 2009 at 3:45 a.m. LST and lasted until 5:30 a.m. LST. The cow is shown as an orange dot that has moved to the southeast away from the wolf position. This screen capture is from 4:00 a.m. LST. The wolf had recently left the den site, which is shown as a large white dot, and was moving northward when it encountered this collared cow.

Conclusions

After 4 years of data collection it is apparent that livestock movement on our 6 study areas is highly dependent on grazing management plans developed by individual ranches and the US Forest Service. These plans set the managerial objectives, stocking rate, entry and exit dates from allotments, which pastures within the allotments are to be grazed, and the sequence in which they will be grazed. Within this overarching framework of control, cattle distributions were controlled at the subunit level by fencing or drift fencing, range riders, topography, available forage, slope, elevation, and other factors. It must be stressed that cattle are not free to position themselves on the landscape according to natural tendencies except within the limits of the sub-allotment pasture boundary or, in some cases, what range riders permit. As with fenced pastures, if it is observed that cattle are spending too much time in an area the range riders will move them to another area.

In large measure it is the human manager that decides which area is to be grazed by cattle. With this scenario, one would expect that site occupancy of cattle would vary from allotment to allotment because management patterns also vary from site to site. Thus it is not surprising that factors that are found to be significant in defining landscape "preference" on one site are not always significant on other sites.

Across the land available to them, cattle in this study tend to naturally disperse and spread. Theoretically this reduces competition for high value feeding stations, those with more forage provided by preferred species (Senft et al. 1987, Senft 1989, Heitschmidt and Stuth 1991). Analysis of the occupancy of topographic landscapes substantiated a number of past evaluations of how landscape features influence decisions made by cattle under present conditions. Cattle tended to use plant communities within individual allotments based on the availability of forage. Once the foraging area was selected, cattle consistently favored slopes of less than 12% and in some cases extended the preference to include slopes up to 24%. Cattle occupied steeper landscapes up to 35% in proportion to their area. The consistency of slope use across allotments testifies to the influence of this factor on cattle distribution.

Analysis of the riparian buffer zones around perennial streams in Oregon (2008 & 2009) determined that in site 1 and 3, where streams are topographically confined and express minimal (area) riparian wetland development; cattle did not have a preference for any of the distance categories established. In other words, the defined zones had near equivalent dispersion over the area evaluated. In site 2, where streams were less confined and the area of flood plain/wetland development was greater, cattle exhibited preference toward the first 99 ft (30 m) adjacent to the stream over the area between 99 and 197 ft (30 and 60 m). However, regardless of these differences cattle did not use areas around perennial water more than upland areas. Cattle occupied areas beyond 197 ft (60 m) of the stream 96 to almost 99 percent of the time.

We are in the process of evaluating the degree of cattle dispersal during periods of known wolf presence. We were able to determine areas on the landscape where collared cattle were infrequent (on average 75% of the surface area studied was occupied by a collared cow for less than 1 hour), as well as where animals spent more time (foci). Foci were counted then sorted by year to identify overlap.

Rotational grazing systems would be expected to change foci from year-to-year and that is what we observed in this data. When collared cattle graze the same areas in different years some foci are the same but change is common. Foci typically are not on live streams.

Daily travel distance of collared cattle differs between animals and, at least on some sites, changes with season and the topography being grazed. We have concern about accumulation of GPS errors when the receiver is not actually moving and have worked on algorithms to increase accuracy. We believe that closer examination of temporal velocity charts and the patterns they contain should allow us to not only get better estimates of actual travel distance but also more accurately predict grazing vs. resting activities.

Although we only have analyzed 1 wolf (a total of 3 wolves have been collared but only 1 collar retrieved to date). This wolf had a sizable range and traveled prodigious distances. Most of his travel occurred at night as did most of the interactions he had with collared cattle. Close encounters between B446 and collared cattle were frequent and the rancher reported that cattle changed their behavior after wolves moved into the area by being more difficult to herd and handle and acting aggressively toward dogs. Wolf B446 was commonly within 547 yd. (500 m) of occupied houses (588 times or 3.1% of all wolf positions logged) during the 198 days he was tracked. Many confirmed depredations on this site were also close to houses, which implies that proximity to human habitation does not automatically confer protection from wolves. Wolf B446's daily travel distances varied substantially from day to day yet showed no seasonal trend between 24 May and 15 December 2009. This animal, like cattle, had foci on the landscape that he frequented. The den site, rendezvous site, heifer calving pastures, and several locations in the northern portion of his range were identified.

Cattle response to wolves is sometimes apparent in velocity charts as rapid velocities during and immediately after the encounter. This sometimes persists with movement at all hours of the day and night for days. However, considerable variation exists with some cow's velocities remaining similar before and after encounters. In spite of this disparity, we believe that there is a potential for monitoring cow velocity with electronic accelerometers that could then signal the herdsman that a problem exists.

Herd behavior is still being analyzed but on the site where collared wolf B446 was tracked, we saw cattle moved towards the fence lines adjacent to the private ranch lands and buildings. Whether this is a pattern that results from cognitive volition on the part of the herd to move toward safety or is simple non-directed flight, we don't know. We do not see large scale change in the types of land being occupied by cattle, perhaps because they are not free to move out of the area. We continue to monitor both cattle and wolf spatial behavior and as more information is gathered, the picture should become clearer.

Technologies, software, and methods developed by project scientists have opened new opportunities to examine not only the interaction between cattle and wolves but also the pattern of livestock use of rangelands and the response of livestock to distribution tools such as water and salt placement. Participating ranches can use the information on cattle distribution to structure their monitoring plans to improve their ability to detect and correct grazing issues as they develop. Areas that are underutilized can also be identified and grazing management tools employed to alter landscape use.

These technologies allow ranches to quantitatively evaluate the efficacy of managerial actions and gain insight as to which actions could be used to improve economically-sound sustainable management.

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Appendix Table 1. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Oregon Site 1. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Oregon Site 1 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	21269	0.98	21122	0.973	21293	0.981	21186	0.976
100	<200	323	0.015	424	0.02	281	0.013	403	0.019
200	<300	80	0.004	101	0.005	66	0.003	84	0.004
300	<400	20	0.001	37	0.002	29	0.001	21	0.001
400	<500	11	0.001	15	0.001	19	0.001	9	<0.001
500	<600	4	<0.001	5	<0.001	8	<0.001	4	<0.001
600	<700	3	<0.001	2	<0.001	2	<0.001	2	<0.001
700	<800	1	<0.001	2	<0.001	2	<0.001	2	<0.001
800	<900	0	0	0	0	3	<0.001	0	0
900	<1000	0	0	1	<0.001	2	<0.001	0	0
1000	<1100	0	0	0	0	3	<0.001	0	0
1100	<1200	0	0	0	0	1	<0.001	0	0
1200	<1300	0	0	1	<0.001	0	0	0	0
1300	<1400	0	0	1	<0.001	1	<0.001	0	0
1400	<1500	0	0	0	0	0	0	0	0
1500	<1600	0	0	0	0	0	0	0	0
1600	<1700	0	0	0	0	1	<0.001	0	0
Total Number of Cells in Allotment		**21711**		**21711**		**21711**		**21711**	

Appendix Table 2. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Oregon Site 2. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Oregon Site 2 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	11409	0.953	11116	0.929	11267	0.941	11457	0.957
100	<200	402	0.034	626	0.052	514	0.043	365	0.03
200	<300	90	0.008	150	0.013	120	0.01	79	0.007
300	<400	34	0.003	46	0.004	41	0.003	31	0.003
400	<500	14	0.001	19	0.002	17	0.001	15	0.001
500	<600	6	0.001	7	0.001	8	0.001	6	0.001
600	<700	7	0.001	2	<0.001	1	<0.001	5	<0.001
700	<800	3	0.0003	0	0	0	0	2	<0.001
800	<900	2	0.0002	1	<0.001	0	0	4	<0.001
900	<1000	0	0	0	0	0	0	1	<0.001
1000	<1100	0	0	1	<0.001	0	0	1	<0.001
1100	<1200	0	0	0	0	0	0	1	<0.001
1200	<1300	0	0	0	0	0	0	0	0
1300	<1400	1	<0.001	0	0	0	0	1	<0.001
1400	1500	0	0	0	0	0	0	0	0
1500	1600	0	0	0	0	0	0	0	0
1600	1700	0	0	0	0	1	<0.001	0	0
Total Number of Cells in Allotment		**11968**		**11968**		**11968**		**11968**	

Appendix Table 3. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Oregon Site 3. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Oregon Site 3 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	9852	0.963	9528	0.931	8797	0.86	9258	0.905
100	<200	245	0.024	435	0.043	803	0.078	550	0.054
200	<300	73	0.007	122	0.012	298	0.029	218	0.021
300	<400	15	0.001	67	0.007	136	0.013	79	0.008
400	<500	17	0.002	29	0.003	70	0.007	46	0.004
500	<600	9	0.001	23	0.002	47	0.005	23	0.002
600	<700	1	<0.001	14	0.001	17	0.002	15	0.001
700	<800	6	0.001	6	0.001	16	0.002	7	0.001
800	<900	6	0.001	0	0	10	0.001	11	0.001
900	<1000	2	<0.001	3	<0.001	8	0.001	5	<0.001
1000	<1100	0	0	3	<0.001	7	0.001	4	<0.001
1100	<1200	0	0	0	0	6	0.001	1	<0.001
1200	<1300	1	<0.001	0	0	4	<0.001	3	<0.001
1300	<1400	1	<0.001	0	0	1	<0.001	1	<0.001
1400	<1500	0	0	0	0	1	<0.001	2	<0.001
1500	<1600	0	0	0	0	3	<0.001	1	<0.001
1600	<1700	0	0	0	0	0	0	0	0
1700	<1800	0	0	0	0	0	0	1	<0.001
1800	<1900	1	<0.001	0	0	0	0	1	<0.001
1900	<2000	0	0	0	0	1	<0.001	0	0
2000	<2100	0	0	0	0	0	0	0	0
2100	<2200	0	0	0	0	1	<0.001	0	0
2200	<2300	0	0	0	0	1	<0.001	0	0
2300	<2400	0	0	0	0	0	0	0	0
2400	<2500	1	<0.001	0	0	0	0	2	<0.001
2500	<2600	0	0	0	0	0	0	1	<0.001
2600	<2700	0	0	0	0	0	0	0	0
2700	<2800	0	0	0	0	0	0	0	0
2800	<2900	0	0	0	0	0	0	1	<0.001
2900	<3000	0	0	0	0	0	0	0	0
3000	<3100	0	0	0	0	0	0	0	0
3100	<3200	0	0	0	0	0	0	0	0
3200	<3300	0	0	0	0	0	0	0	0

3300	<3400	0	0	0	0	0	0	0	0
3400	<3500	0	0	0	0	0	0	0	0
3500	<3600	0	0	0	0	2	<0.001	0	0
3600	<3700	0	0	0	0	0	0	0	0
3700	<3800	0	0	0	0	1	<0.001	0	0
Total Number of Cells in Allotment		**10230**		**10230**		**10230**		**10230**	

Appendix Table 4. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Idaho Site 1. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Idaho Site 1 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	5580	0.901	5504	0.889	5339	0.862	5374	0.868
100	<200	363	0.059	328	0.053	388	0.063	360	0.058
200	<300	131	0.021	138	0.022	180	0.029	169	0.027
300	<400	46	0.007	58	0.009	83	0.013	73	0.012
400	<500	26	0.004	40	0.006	51	0.008	63	0.01
500	<600	11	0.002	24	0.004	39	0.006	38	0.006
600	<700	15	0.002	19	0.003	21	0.003	29	0.005
700	<800	6	0.001	18	0.003	15	0.002	18	0.003
800	<900	3	<0.001	12	0.002	14	0.002	11	0.002
900	<1000	2	<0.001	10	0.002	15	0.002	15	0.002
1000	<1100	3	<0.001	9	0.001	7	0.001	12	0.002
1100	<1200	0	0	8	0.001	7	0.001	3	<0.001
1200	<1300	2	<0.001	3	<0.001	4	0.001	5	0.001
1300	<1400	0	0	5	0.001	2	<0.001	4	0.001
1400	<1500	2	<0.001	3	<0.001	2	<0.001	4	0.001
1500	<1600	1	<0.001	6	0.001	3	<0.001	2	<0.001
1600	<1700	0	0	3	<0.001	6	0.001	2	<0.001
1700	<1800	0	0	0	0	1	<0.001	0	0
1800	<1900	0	0	0	0	4	0.001	2	<0.001
1900	<2000	0	0	1	<0.001	2	<0.001	2	<0.001
2000	<2100	1	<0.001	1	<0.001	5	0.001	0	0
2100	<2200	0	0	1	<0.001	2	<0.001	0	0
2200	<2300	0	0	0	0	1	<0.001	1	<0.001
2300	<2400	0	0	0	0	1	<0.001	0	0
2400	<2500	0	0	0	0	0	0	1	<0.001
2500	<2600	0	0	0	0	1	<0.001	0	0
2600	<2700	0	0	0	0	0	0	0	0
2700	<2800	0	0	0	0	0	0	1	<0.001
2800	<2900	0	0	1	<0.001	0	0	0	0
2900	<3000	0	0	1	<0.001	0	0	2	<0.001
3000	<3100	0	0	0	0	0	0	0	0
3100	<3200	1	<0.001	0	0	0	0	0	0
3200	<3300	0	0	0	0	0	0	0	0

3300	<3400	0	0	0	0	0	0	0	0
3400	<3500	0	0	0	0	0	0	0	0
3500	<3600	0	0	0	0	2	<0.001	0	0
3600	<3700	0	0	0	0	0	0	1	<0.001
>3700		0	0	0	0	1	<0.001	1	<0.001
Total Number of Cells in Allotment		6193		6193		6193		6193	

Appendix Table 5. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Idaho Site 2. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Idaho Site 2 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	11905	0.983	11711	0.967	11711	0.967	11525	0.952
100	<200	126	0.01	277	0.023	242	0.02	342	0.028
200	<300	40	0.003	74	0.006	93	0.008	110	0.009
300	<400	16	0.001	26	0.002	23	0.002	62	0.005
400	<500	9	0.001	12	0.001	18	0.001	22	0.002
500	<600	5	<0.001	4	<0.001	8	0.001	15	0.001
600	<700	2	<0.001	1	<0.001	3	<0.001	13	0.001
700	<800	1	<0.001	0	0	2	<0.001	9	0.001
800	<900	0	0	0	0	2	<0.001	3	<0.001
900	<1000	0	0	1	<0.001	3	<0.001	4	<0.001
1000	<1100	1	<0.001	0	0	0	0	0	0
1100	<1200	0	0	0	0	0	0	0	0
1200	<1300	0	0	0	0	0	0	0	0
1300	<1400	1	<0.001	0	0	1	<0.001	1	<0.001
Total Number of Cells in Allotment		12106		12106		12106		12106	

Appendix Table 6. Frequency of collared cattle positions in 328ft. by 328 ft. (100m by 100m) gridded cells on the landscape occupied by Idaho Site 3. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period. The bulk of this allotment area had less than 100 positions counted per cell.

Idaho Site 3 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)									
Number of Positions		2008		2009		2010		2011	
Lower Limit	Upper Limit	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	<100	18285	0.972	17589	0.935	18407	0.978	18565	0.987
100	<200	320	0.017	782	0.042	284	0.015	192	0.01
200	<300	85	0.005	233	0.012	63	0.003	36	0.002
300	<400	41	0.002	97	0.005	31	0.002	15	0.001
400	<500	26	0.001	34	0.002	11	0.001	2	<0.001
500	<600	13	0.001	23	0.001	7	<0.001	0	0
600	<700	8	<0.001	16	0.001	4	<0.001	1	<0.001
700	<800	8	<0.001	8	<0.001	2	<0.001	1	<0.001
800	<900	5	<0.001	6	<0.001	0	0	0	0
900	<1000	6	<0.001	6	<0.001	0	0	0	0
1000	<1100	3	<0.001	2	<0.001	2	<0.001	0	0
1100	<1200	2	<0.001	4	<0.001	0	0	0	0
1200	<1300	2	<0.001	3	<0.001	0	0	0	0
1300	<1400	1	<0.001	3	<0.001	0	0	0	0
1400	<1500	1	<0.001	2	<0.001	0	0	0	0
1500	<1600	1	<0.001	1	<0.001	0	0	0	0
1600	<1700	2	<0.001	0	0	0	0	0	0
1700	<1800	0	0	0	0	0	0	0	0
1800	<1900	1	<0.001	0	0	0	0	0	0
1900	<2000	1	<0.001	1	<0.001	0	0	0	0
2000	<2100	0	0	1	0	1	<0.001	0	0
2100	<2200	0	0	0	0	0	0	0	0
2200	<2300	0	0	0	0	0	0	0	0
2300	<2400	0	0	0	0	0	0	0	0
2400	<2500	0	0	0	0	0	0	0	0
2500	<2600	0	0	0	0	0	0	0	0
2600	<2700	0	0	1	<0.001	0	0	0	0
2700	<2800	0	0	0	0	0	0	0	0
2800	<2900	0	0	0	0	1	0	0	0
2900	<3000	0	0	1	<0.001	0	0	0	0
3000	<3100	1	<0.001	0	0	0	0	0	0
3100	<3200	2	<0.001	0	0	0	0	0	0
3200	<3300	0	0	0	0	0	0	0	0

3300	<3400	0	0	0	0	0	0	0	0
3400	<3500	0	0	1	<0.001	0	0	0	0
3500	<3600	0	0	0	0	0	0	0	0
>3600		0	0	0	0	1	<0.001	2	<0.001
Total Number of Cells in Allotment		18814		18814		18814		18814	

Appendix Table 7. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Oregon Site 1. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Oregon Site 1 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	13118	0.604	10917	0.503	16994	0.783	13496	0.622
1	1269	0.058	1758	0.081	568	0.026	936	0.043
2	772	0.036	975	0.045	348	0.016	647	0.03
3	536	0.025	701	0.032	231	0.011	443	0.02
4	437	0.02	528	0.024	221	0.01	391	0.018
5	397	0.018	493	0.023	165	0.008	322	0.015
6	329	0.015	343	0.016	165	0.008	287	0.013
7	313	0.014	316	0.015	138	0.006	259	0.012
8	229	0.011	272	0.013	116	0.005	211	0.01
9	213	0.01	237	0.011	99	0.005	208	0.01
10	201	0.009	242	0.011	92	0.004	191	0.009
11	185	0.009	226	0.01	98	0.005	158	0.007
12	143	0.007	193	0.009	98	0.005	143	0.007
Sum 0 to 12 Positions	18142	0.836	17201	0.793	19333	0.892	17692	0.816
Total Number of Cells in Allotment	**21711**		**21711**		**21711**		**21711**	

Appendix Table 8. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Oregon Site 2. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Oregon Site 2 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	5189	0.434	3275	0.274	3444	0.288	5583	0.466
1	966	0.081	1003	0.084	860	0.072	888	0.074
2	541	0.045	596	0.05	548	0.046	506	0.042
3	405	0.034	437	0.037	407	0.034	345	0.029
4	331	0.028	377	0.032	364	0.03	303	0.025
5	262	0.022	294	0.025	321	0.027	223	0.019
6	224	0.019	275	0.023	274	0.023	191	0.016
7	221	0.018	231	0.019	254	0.021	168	0.014
8	180	0.015	190	0.016	215	0.018	136	0.011
9	158	0.013	205	0.017	192	0.016	149	0.012
10	140	0.012	184	0.015	178	0.015	149	0.012
11	117	0.01	153	0.013	161	0.013	132	0.011
12	113	0.009	157	0.013	156	0.013	118	0.01
Sum 0 to 12 Positions	8847	0.739	7377	0.618	7374	0.616	8891	0.741
Total Number of Cells in Allotment	**11968**		**11968**		**11968**		**11968**	

Appendix Table 9. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Oregon Site 3. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Oregon Site 3 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	5488	0.536	5488	0.536	3759	0.367	3931	0.384
1	672	0.066	672	0.066	605	0.059	819	0.08
2	361	0.035	361	0.035	353	0.035	423	0.041
3	218	0.021	218	0.021	210	0.021	280	0.027
4	159	0.016	159	0.016	208	0.02	272	0.027
5	139	0.014	139	0.014	160	0.016	171	0.017
6	114	0.011	114	0.011	146	0.014	169	0.017
7	109	0.011	109	0.011	128	0.013	135	0.013
8	84	0.008	84	0.008	133	0.013	139	0.014
9	84	0.008	84	0.008	106	0.01	109	0.011
10	85	0.008	85	0.008	105	0.01	121	0.012
11	65	0.006	65	0.006	84	0.008	78	0.008
12	47	0.005	47	0.005	99	0.01	100	0.01
Sum 0 to 12 Positions	7625	0.745	7625	0.745	6096	0.596	3931	0.384
Total Number of Cells in Allotment	**10230**		**10230**		**10230**		**10230**	

Appendix Table 10. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Idaho Site 1. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Idaho Site 1 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	2693	0.435	2870	0.463	2317	0.374	2437	0.394
1	342	0.055	348	0.056	302	0.049	401	0.065
2	220	0.036	194	0.031	179	0.029	197	0.032
3	159	0.026	142	0.023	168	0.027	153	0.025
4	121	0.02	99	0.016	114	0.018	120	0.019
5	85	0.014	92	0.015	119	0.019	110	0.018
6	101	0.016	90	0.015	98	0.016	91	0.015
7	95	0.015	74	0.012	80	0.013	87	0.014
8	76	0.012	67	0.011	79	0.013	94	0.015
9	71	0.011	59	0.01	79	0.013	66	0.011
10	44	0.007	60	0.01	69	0.011	60	0.01
11	48	0.008	47	0.008	64	0.01	68	0.011
12	38	0.006	62	0.01	73	0.012	58	0.009
Sum 0 to 12 Positions	4093	0.661	4204	0.68	3741	0.604	3942	0.638
Total Number of Cells in Allotment	**6193**		**6193**		**6193**		**6193**	

Appendix Table 11. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Idaho Site 2. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Idaho Site 2 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	9412	0.777	7694	0.636	8342	0.689	6589	0.544
1	435	0.036	640	0.053	560	0.046	967	0.08
2	247	0.02	343	0.028	302	0.025	518	0.043
3	177	0.015	252	0.021	203	0.017	308	0.025
4	113	0.009	179	0.015	173	0.014	208	0.017
5	124	0.01	160	0.013	150	0.012	181	0.015
6	81	0.007	146	0.012	134	0.011	152	0.013
7	77	0.006	127	0.01	108	0.009	119	0.01
8	66	0.005	112	0.009	81	0.007	107	0.009
9	70	0.006	97	0.008	83	0.007	104	0.009
10	47	0.004	85	0.007	66	0.005	98	0.008
11	42	0.003	94	0.008	66	0.005	114	0.009
12	48	0.004	71	0.006	59	0.005	79	0.007
Sum 0 to 12 Positions	10939	0.902	10000	0.826	10327	0.852	9544	0.789
Total Number of Cells in Allotment	**12106**		**12106**		**12106**		**12106**	

Appendix Table 12. Frequency of cells on the allotment and included lands with less than 12 cattle positions (approximately 1 hour of occupancy or less by collared cows). Cells were 328ft. by 328 ft. (100m by 100m) and contiguously gridded on the landscape occupied by Idaho Site 3. Cells are positioned on 100m gridlines on the UTM, Zone 11 coordinate system using the WGS84 datum. This information covers the entire grazing season and has not been normalized or weighted by adjusting for the number of functioning collars in each time period.

Idaho Site 3 - Frequency of Cow Locations in 100m by 100m cells (USFS Allotment & Inholdings Only)								
Number of Cells (0 to 12 GPS Positions Only) Throughout the Grazing Season	2008		2009		2010		2011	
	Freq.	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**	**Freq.**	**Prop.**
0	13671	0.727	9991	0.531	12319	0.655	13351	0.71
1	861	0.046	1006	0.053	1010	0.054	953	0.051
2	449	0.024	574	0.031	589	0.031	504	0.027
3	292	0.016	457	0.024	397	0.021	363	0.019
4	244	0.013	341	0.018	302	0.016	275	0.015
5	201	0.011	292	0.016	264	0.014	228	0.012
6	165	0.009	261	0.014	246	0.013	211	0.011
7	139	0.007	206	0.011	198	0.011	201	0.011
8	127	0.007	194	0.01	167	0.009	149	0.008
9	92	0.005	187	0.01	166	0.009	133	0.007
10	96	0.005	173	0.009	189	0.01	123	0.007
11	99	0.005	153	0.008	143	0.008	116	0.006
12	79	0.004	117	0.006	116	0.006	112	0.006
Sum 0 to 12 Positions	16515	0.879	13952	0.741	16106	0.857	16719	0.89
Total Number of Cells in Allotment	**18814**		**18814**		**18814**		**18814**	

Appendix Table 13. Confirmed and Probable Wolf Kills in Council, Idaho Area provided by USDA Wildlife Services Doug Hansen and Justin Mann (Personal Communication 2012)

2006

1. 8/28/2006 Lost Creek — Confirmed: 18 Ewes, 25 Lambs; Probable: 124 Missing Sheep

2007

2. 6/13/2007 Lost Creek — Confirmed: 1 Ewe; Probable: 1 Lamb
3. 11/30/2007 Middle Fork Weiser River, N 44.64438° W 116.23441° — Confirmed: 3 Hounds; Probable: 1 Hound

2008

4. 3/27/2008 Upper Weiser River, N 44.78714° W 116.43272° — Confirmed: 1 Calf
5. 7/22/2008 Lick Creek — Confirmed: 2 Calves; Probable: 1 Calf
6. 8/6/2008 Lick Creek — Probable: 1 Calf
7. 7/11/2008 Lick Creek, N 45.00558° W 116.65780° — Confirmed: 1 Calf
8. 8/16/2008 Lick Creek, N 45.10987° W 116.52100° — Probable: 1 Lamb
9. 8/17/2008 Boulder Creek, N 45.12914° W 116.39583° — Confirmed: 1 Ewe, 2 Lambs
10. 4/20/2008 Upper Weiser River, N 44.75869° W 116.44851° — Confirmed: 1 Calf

2009

11. 10/11/2009 Council Mountain — Confirmed: 1 Calf
12. 10/09/2009 Lick Creek — Confirmed: 1 Calf
13. 10/02/2009 Lick Creek — Confirmed: 1 Calf
14. 3/25/2009 North Hornet Creek — Confirmed: 1 Calf
15. 4/27/2009 Cuddy Mountain — Confirmed: 1 Calf
16. 5/12/2009 Lick Creek — Confirmed: 1 Heifer
17. 5/15/2009 Lick Creek — Confirmed: 2 Calves
18. 6/1/2009 Lick Creek — Probable: 1 Calf
19. 6/8/2009 Lick Creek — Confirmed: 3 Calves
20. 6/15/2009 Lick Creek — Probable: 1 Calf
21. 6/22/2009 Lick Creek — Confirmed: 1 Calf
22. 8/26/2009 Council Mountain — Confirmed: 1 Cow
23. 9/11/2009 Boulder Creek — Confirmed: 2 Guard Dogs
24. 7/28/2009 Boulder Creek — Confirmed: 3 Ewes, 5 Lambs
25. 8/25/2009 Lick Creek — Confirmed: 1 Calf
26. 8/14/2009 Lick Creek — Confirmed: 1 Calf

27. 7/23/2009 Lick Creek — Confirmed: 2 Calves

2010

28. 8/13/2010 Council Mountain — Confirmed: 1 Bull
29. 8/20/2010 Council Mountain — Probable: 1 Cow
30. 8/23/2010 Lick Creek — Confirmed: 1 Calf; Probable: 1 Calf
31. 8/16/2010 Lick Creek — Confirmed: 2 Calves
32. 7/13/2010 Lick Creek — Confirmed: 1 Calf
33. 7/10/2010 Lick Creek — Confirmed: 1 Calf

2011

34. 5/28/2011 Lick Creek — Confirmed: 1 Calf
35. 6/1/2011 Lick Creek — Probable: 2 Calves
36. 6/14/2011 Lick Creek — Confirmed: 1 Calf; Probable: 1 Calf
37. 7/13/2011 Lick Creek — Confirmed: 4 Calves
38. 7/28/2011 Lick Creek — Confirmed: 4 Calves
39. 8/9/2011 Wickiup Creek — Confirmed: 3 Calves
40. 9/6/2011 Wickiup Creek — Confirmed: 2 Heifers
41. 4/21/2011 Brownlee Creek/ Cuddy Mt. — Probable: 1 Calf
42. 8/17/2011 Dukes Creek/ Cuddy Mt. — Confirmed: 1 Calf
43. 8/13/2011 Pine Creek/ Cuddy Mt. — Probable: 1 Cow
44. 8/24/2011 Beaver Creek/ Cuddy Mt. — Probable: 1 Cow
45. 11/29/2011 North Hornet Creek — Probable: 1 Calf

2012

46. 6/27/2012 Bear Creek — Probable: 1 Cow
47. 6/11/2012 Lick Creek — Confirmed: 2 Calves
48. 5/30/2012 North Hornet Creek — Confirmed: 1 Calf; Probable: 5 Calves
49. 1/17/2012 Lick Creek — Confirmed: 2 Geldings
50. 8/6/2012 Wickiup Creek — Confirmed: 1 Calf
51. 8/16/2012 Indian Creek — Confirmed: 8 Calves; Probable: 16 Calves, 1 Cow
52. 8/20/2012 Indian Creek — Confirmed: 1 Calf

Confirmed and reported damage to cattle in the vicinity of Idaho Site 2, Adams County, Idaho.

2006

1. 10/04/2006 1 cow probable kill
2. 10/04/2006 1 calf probable kill

2007

3. 11/23/2007 1 calf confirmed killed
4. 11/23/2007 7 calves reported missing

2008 --No damage

2009

5. 4/29/2009 1 calf missing

2010

6. 8/03/2010 1 calf confirmed killed

2011

7. 10/05/2011 1 bull confirmed injured

2012

No damage as of 10/10.

Justin Mann, Wildlife Specialist, U.S.D.A., Wildlife Services

Appendix A

Report on the Evaluation of Existing Design Strategies, Design Recommendations and Analysis Recommendations for the project *Evaluating Wolf-Livestock Relations in the Northern Rockies and Pacific Northwest*

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Contents

1. Introduction

This report concerns the proposed study design for a project on evaluating wolf-livestock relations in the northern Rockies and Pacific Northwest. The background information for this project is that in 1995 and 1996, gray wolves (*Canis lupus*) were reintroduced to Yellowstone National Park and central Idaho by the U.S. Fish and Wildlife Service. Wolves had been absent from these areas since the 1930's and their reintroduction has had effects on both the natural ecosystems and livestock production systems of the Pacific Northwest and Northern Rocky Mountains. The wolf numbers and range have increased steadily since their reintroduction, and as wolves have expanded their range reports of livestock predation have also increased in the in the Pacific Northwest and Northern Rocky Mountains regions.

Counts of confirmed wolf depredations provide an estimate of the direct effects of wolf-livestock interactions. However, indirect effects of the wolf presence on livestock such as changes in habitat use remain largely unknown. One of the projects objectives is therefore to determine beef cattle resource selection patterns, activity budgets, and the occurrence of stress events relative to the level of wolf presence.

It is the study design relative to this objective that the present report specifically considers, in terms of:

- the evaluation of the existing study design,
- recommendations to improve or replace the existing study design, and
- recommendations for the analysis of the data that will be obtained from the project.

The following three sections of this report consider these aspects of the project in order, while the final section summarizes the recommendations made.

2. Evaluation of Existing Design Strategies

Scope of Work

The scope of work for the Evaluation of Existing Design Strategies was defined as follows:

> *A set of experimental design strategies exist which encompasses both the shorter-term, spatial-based contrast between cattle resource-selection patterns, activity budgets, and frequency of stress-inducing events in northeastern Oregon (low wolf presence) study areas with those in the western Idaho (high wolf presence) study areas; and the long-term, temporal-based contrast in cattle*

responses between periods of high and low wolf presence. West, Inc. will utilize source materials (described below) provided by Clark et al. to evaluate the statistical efficiency and appropriateness of the existing experimental design strategies and associated layouts and sampling designs.

To aid in the evaluation, three research proposals (Johnson, 2007; Clark, 2008; Johnson and Clark, 2009), representative data sets of GPS wolf and cattle locations, and a description of the current experimental design (Clark, 2010) were provided.

Current Study Design

At present the study involves six study sites, three with an initial high wolf presence and three with an initial low wolf presence. In addition, each high wolf site is paired with a low wolf site based on vegetation and range management strategies, as shown in Table 2.1. A fourth pair of study sites will be added in 2011, but for the present report only the sites shown in Table 2.1 will be considered.

Table 2.1 The six paired study sites in Idaho and Oregon, with the size of each study site shown.

Pair	High Wolf Presence (Idaho)	Low Wolf Presence (Oregon)
1	Idaho pair 1	Oregon pair 1
2	Idaho pair 2	Oregon pair 2
3	Idaho pair 3	Oregon pair 3

At each study site ten mature beef cows are selected each year to be GPS collared, with the collars being on from four to seven months, depending on the study site, and with relocation of the cows every five minutes. This will be repeated for up to five years for a short term study, and then possibly for up to ten or more years for a long term study.

For the short term study it is assumed that the wolf presence may remain low in Oregon relative to Idaho, which will be confirmed by VHF telemetry, scat surveys, GPS collars on some wolves, incidental direct observations and kill site examinations.

For the long term study it is assumed that the wolf presence level may increase in Oregon, at least at some sites. Therefore, the classification of each site in each year as having low or high wolf presence (or possibly medium wolf presence) will be based on the measures of the amount of wolf presence.

For the evaluation of resource selection functions that give the relative probabilities of use for different types of habitat it is necessary to define the habitat units that are used. These habitat units are non-overlapping plots of land that cover the whole study area. For the whole set of habitat units within the study area, or possibly a large random sample of them, covariates will be available on terrain feature (elevation, slope, aspect, convexity), vegetation types (percentage cover of different types), and distance variables (to streams, upland water resources, roads/trails, least-cost pathways, mineral/supplement sources). Values of these covariates will also be available for each habitat unit that cows are recorded as using, based on their GPS locations. This information on covariate values for available and used habitat units provides the data that is necessary for the estimation of resource selection functions. These data plus information on the presence or absence of wolves can also in principle be used to assess how the use of habitat by cows depends on their activity (bedding/standing, foraging, or traveling), and how this changes when wolves are present.

At the level of the study sites and years the proposed project design can be thought of as a modified version of the BACIP (before-after-control-impact-pairs) design that is popular for impact assessment studies (Manly, 2009, Chapter 6). With the BACIP design there are several control sites that are observed for a period of time (e.g., for several years) with no changes with regard to some factor that may effect a variable of interest measured at the sites. Each control site is paired with an impact site that is initially as similar as possible, and where the impact sites are observed for the same period of time as the control sites but all receive a change part way through the observation period that should effect the measured variable. With this design the essential idea is that a pair of control and impact sites will have similar values for the variable of interest before the time of the change, but are expected to have different values after that time because the change only occurred at the impact site.

The situation is modified for the proposed project design because at the three Idaho sites the impact (high wolf presence) has already occurred when the study begins, and is therefore always present, while for their paired Oregon sites (initially low wolf presence) the impact occurs later. Therefore with this design it is expected that there will be a difference between a pair of sites for the variable of interest when the study begins, but that difference will reduce with time as more wolves become present in Oregon. Although this is not a standard BACIP design the basic idea is similar and methods proposed for the analysis data from a BACIP design can be used with the proposed project design (e.g., see Smith, 2002).

3. Design Recommendations

The proposed project design is similar to the standard BACIP environmental impact design in terms of how the impact of wolf presence is quantified by differences between paired study sites before and after the impact. From this point of view the design is perfectly reasonable for quantifying wolf-livestock interactions. However, the limitations of the design also need to be noted. The study sites were presumably not randomly selected from populations of possible sites, and the paired sites may differ considerably in terms other than vegetation and ranch management strategies. Therefore, in the end the extent to which the results of the study can be generalized to other locations will be a matter of judgement, and there may well be large differences between the paired study sites for some variables of interest that are unrelated to the levels of wolf presence. These are, however, common problems with environmental impact assessment.

It is desirable with any study plan to have some idea of the accuracy of the results that will be obtained. It seems that past data are available on GPS collared cattle in Idaho and Oregon and, if so, there would be value in using these data to assess the likely results from the proposed study. For example, resource selection functions can be estimated for each area for which data are available using methods discussed below. The standard errors of estimated coefficients will then indicate how well these functions are estimated, while differences between the estimated resource functions in different sites will indicate the variation that can be expected with and without differences between the level of wolf presence. There is also the possibility of using bootstrap methods (resampling the available data to produce possible future data) to generate the type of results that might occur with the proposed study plan (Manly, 1992).

4. Analysis Recommendations

One outcome of the proposed study will be estimated resource selection functions for each of the monitored cows at a study site. In addition, there will be a number of variables calculated for each study site to summarize aspects of the activity and movement of the cattle in the area, such as the average number of recorded stress events per cow during a sampled season, or the average proportion of time spent foraging. These analysis of these two types data are considered in turn below.

Estimation of Resource Selection Functions

There are two types of approach that might be used to estimate a resource selection function in each study area where, as noted above, this is a function that gives the relative probability of use for different habitat units. One involves taking the GPS relocations of each cow to represent their habitat use over a season or part of a season, and to compare this with the available habitat that they could have used. The resulting data can then be used to estimate a resource selection function which quantifies the overall use of habitat by the cow for the time period considered, while the results for all cows can be combined to estimate a population level resource selection function. This type of analysis may then indicate differences in the overall use of habitat between sample sites and years that are apparently due to different levels of wolf presence.

Alternatively, the analysis for one cow can be based on the successive relocations of the animal with the idea that when it is located within a specific habitat unit there will be a set of habitat units where it could be at the time of the next relocation, including the habitat unit that it is currently in. The time considered between relocations and the definition of the habitat units used would then be chosen so that usually the cow would move to a new habitat unit between relocations, and the probability of the next relocation being in a particular habitat unit would be assumed to depend on how far it is from the current unit, the habitat in the habitat unit, and, possibly, the location of wolves in the study area.

If the first approach is used to estimate a resource selection function then a resource selection function for each animal can be estimated by logistic regression (Manly *et al.*, 2002, Section 5.3). Population level resource selection can then be estimated by averaging the results for different monitored cows at a site. This approach can even be used if the relocations of animals are not far enough apart in time to ensure their independence, as discussed by Fieberg *et al.* (2010, Section 4). There are several alternatives to logistic regression for estimation of the resource selection functions in this case and there has been some controversy about the validity of using simple logistic regression with samples of used and available habitat units, although in practice the simple logistic regression approach works well unless the proportion of used units is large (Nielson et al., 2004; Johnson et al., 2006).

One method for estimating a resource selection function based on this first approach that seems particularly suitable for the data on cow relocations is the one used by Sawyer *et al.* (2006, 2007, 2009). This estimates a generalized linear model for each animal with a negative binomial error distribution and averages the results to estimate a population level resource selection function. It should be noted, however, that new methods for analyzing data of this form are continually being proposed (e.g., Duchesne et al., 2010) so that possible alternative analyzes should be investigated when the data are available if samples of used and available habitat units are to be analyzed.

The second approach for analyzing the data on GPS relocations of cows should be better able to detect short term effects of the presence of wolves for the proposed study (e.g., a tendency to move away from wolves when they are close to a cow). In this case there are again many alternative methods of analysis that have been suggested for use, as described by Fieberg *et al.* (2010, Section 5), and new methods are still being proposed. Therefore, it would be appropriate to review the currently available methods when data become available. One approach that has been developed by Western EcoSystems Technology staff uses discrete choice modeling, whereby the probability of a habitat unit being used for the next relocation of an animal is proportional to an exponential function of the values of habitat variables for that unit, its distance from the current location, and the location of wolves (if any are close), and where the set of available units may change for each relocation (McDonald et al., 2006). This approach also makes it possible to allow for the probability of a relocation being recorded to be a function of the habitat at the relocation, and hence to allow for missing relocations should that be necessary (Nielson *et al.*, 2009).

Analysis of Other Variables

Resource selection functions as discussed above will be estimated for each of the radio-collared cows at a study site, and these can be averaged to represent the habitat selection for all cows at the site. In addition, the GPS data may be used to estimate other study site level variables like the number of stress events per cow and the fraction of time spent foraging by the cows.

As noted before, variables that are recorded at the level of the study site can be analyzed in a similar way to variables from a BACIP design. For example, a simple analysis would take the differences between the paired sites in Oregon (initially with low wolf presence) and Idaho (always high wolf presence) to provide three differences each year, and see whether these differences tend to reduce as the wolf presence in Oregon increases. For example, after five years the data would be as shown in Table 4.1. A two factor analysis of variance can then be used to test for a difference between the yearly means, allowing for possible differences between the means for the three pairs. This assumes that the usual conditions for an analysis of variance (normality and a constant residual variance) apply. If not a non-parametric test or a randomization test could be used instead. If there is a significant difference between years then a regression model could be used to test whether there is a trend, with the yearly mean differences tending to become less with time.

Table 4.1 The difference data (Idaho - Oregon) after five years of the planned study.

Year	Pair 1 Difference	Pair 2 Difference	Pair 3 Difference	Mean Difference
1	d11	d12	d13	R1
2	d21	d22	d23	R2
3	d31	d32	d33	R3
4	d41	d42	d43	R4
5	d51	d52	d53	R5
Mean	C1	C2	C3	M

In some cases it may be desirable to analyze the values of the original variables, rather than the differences between the paired sites as in the above table. For example, if the original data is the number of wolf depredations in a season for each study site then this can be analyzed using a model for count data, such as a log-linear model (Manly, 2009, Section 3.6). The data might then take the form indicated in Table 4.2.

Table 4.2 Data on wolf depredations per month in Idaho (initially high wolf presence) and Oregon (initially low wolf presence).

	Pair 1		Pair 2		Pair 3	
Year	Idaho	Oregon	Idaho	Oregon	Idaho	Oregon
1	p111	p112	p121	p122	p131	p132
2	p211	p212	p221	p222	p231	p232
3	p311	p312	p321	p322	p331	p332
4	p411	p412	p421	p422	p431	p432
5	p511	p512	p521	p522	p531	p532

Suppose that this is the situation and that for each study site there is an observed number of depredations in a certain number of months. A reasonable model for the expected number of depredations in year i within pair j in site k might then be

$$E(D_{ijk}) = M_{ijk}\ Exp(Y_i + P_j + YP_{ij} + S_{ik}) \quad (4.1)$$

where (other things being equal) the expected number is assumed to be proportional to the months of observation M_{ijk}, there is a possible year effect Y_i affecting all study sites in year i, a possible pair effect P_j for pair j in all years, an interaction term YP_{ij} that is specific to pair j in year i, and a possible year i effect for all sites 2 (in Oregon) due to increasing numbers of wolves affecting these sites in a similar way. One interpretation of this model is that $Exp(Y_i + P_j + YP_{ij})$ gives the expected number or depredations per month for both sites in pair i and year j in the absence of any effect of wolves, and the term $Exp(S_{ik})$ represents the change from that expected value due to low wolf effects in Oregon.

Example: Paired Difference Analysis

As an example of the paired and study site analyses just described, consider the artificial data shown in Table 4.3. In year 1 the expected number of wolf kills per month was higher in Idaho than in Oregon, but the difference was reduced in subsequent years until the expected number of kills per month was nearly as high in Oregon as in Idaho for each of the paired sites.

Figure 4.1 shows the results of a two factor analysis of variance on the paired difference data shown in the last column of Table 4.3, carried out using the generalized linear model option in GenStat 13 (VSN International, 2010). In terms of monthly wolf depredation rates the estimated mean difference between the Idaho and Oregon sites in years 2 to 5 compared to year 1 are respectively an increase of 0.133, followed by decreases of 0.038, 0.301, and 1.206. This is then what is expected if the wolf presence was increasing in Oregon, but only year 5 has a significant difference from year 1.

Table 4.3 Artificial data to illustrate analyses. For the Idaho and Oregon sites the observed months and the recorded cattle depredations are shown. For example, for pair 1 in year 1 the wolf kills were recorded for four months at the Idaho site and five months at the Oregon site, with two recorded kills at each site. The final column shows the Idaho - Oregon difference in the mean kills per observed month.

		Idaho Sites		Oregon Sites		Paired
Year	Pair	Months	Kills	Months	Kills	Diff
1	1	4	2	5	2	0.10
1	2	5	5	5	0	1.00
1	3	6	11	7	1	1.69
2	1	4	5	5	2	0.85
2	2	5	4	5	1	0.60
2	3	6	13	7	3	1.74
3	1	4	2	5	2	0.10
3	2	5	13	5	5	1.60
3	3	6	11	7	6	0.98
4	1	4	3	5	4	-0.05
4	2	5	6	5	5	0.20
4	3	6	19	7	10	1.74
5	1	4	2	5	8	-1.10
5	2	5	9	5	8	0.20
5	3	6	15	7	17	0.07

Year	Pair	Diff	Fit
1	1	0.10	0.26
1	2	1.00	1.00
1	3	1.69	1.53
2	1	0.85	0.40
2	2	0.60	1.14
2	3	1.74	1.66
3	1	0.10	0.22
3	2	1.60	0.96
3	3	0.98	1.49
4	1	-0.05	-0.04
4	2	0.20	0.70
4	3	1.74	1.22
5	1	-1.10	-0.94
5	2	0.20	-0.20
5	3	0.07	0.32

	Est	SE	t	Sig
Constant	0.263	0.341		
Year 2	0.133	0.408	0.32	0.754
Year 3	-0.038	0.408	0.09	0.928
Year 4	-0.301	0.408	0.74	0.482
Year 5	-1.206	0.408	2.96	0.018
Pair 2	0.740	0.316	2.34	0.047
Pair 3	1.263	0.316	4.00	0.004

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	6	7.523	1.2539	5.02	0.020
Residual	8	1.998	0.2498		
Total	14	9.522	0.6801		

Percentage variance accounted for 63.3

Standard error of observations is estimated to be 0.500.

Figure 4.1 The data and results from a two factor analysis of variance on the paired site data in Table 4.3. To estimate parameters the effects for year 1 and pair 1 are set equal to zero, so that the effects for the other years and pairs are estimated as differences between the standard conditions for year 1 and pair 1. On this basis there is a significant difference between the dependent variable in year 1 and year 5, with the year 5 difference being significantly lower than the year 1 difference (t = 2.96, p = 0.018). Overall the model fits a significant amount of the variation in the data (63.3%, F = 5.02, p = 0.020). There are also significant differences between pair 1 and pair 2, and between pair 1 and pair 3.

Example: Analysis of Counts

Figure 4.2 shows the results of a log-linear model analysis based on equation (4.1) and carried out using GenStat 13, with an estimated variance inflation factor for the assumed Poisson error distribution. Based on this analysis it can be seen that a large and significant estimated difference between the monthly wolf depredation rates in Idaho and Oregon in year 1 (difference = -1.924, t = 3.26, p = 0.009) reduced to a difference close to zero and not at all significant in year 5 (difference = 0.117, t = 0.47, p = 0.646). This is then the expected result if the wolf presence level increased in Oregon from year 1 to year 5.

Year	Pair	Site	Month	Offset	Kills	Fit
1	1	Idaho	4	1.386	2	3.4
1	1	Oregon	5	1.609	2	0.6
1	2	Idaho	5	1.609	5	4.4
1	2	Oregon	5	1.609	0	0.6
1	3	Idaho	6	1.792	11	10.3
1	3	Oregon	7	1.946	1	1.7
2	1	Idaho	4	1.386	5	5.4
2	1	Oregon	5	1.609	2	1.6
2	2	Idaho	5	1.609	4	4.0
2	2	Oregon	5	1.609	1	1.0
2	3	Idaho	6	1.792	13	12.5
2	3	Oregon	7	1.946	3	3.5
3	1	Idaho	4	1.386	2	2.5
3	1	Oregon	5	1.609	2	1.5
3	2	Idaho	5	1.609	13	12.4
3	2	Oregon	5	1.609	5	5.6
3	3	Idaho	6	1.792	11	11.1
3	3	Oregon	7	1.946	6	5.9
4	1	Idaho	4	1.386	3	4.0
4	1	Oregon	5	1.609	4	3.0
4	2	Idaho	5	1.609	6	6.9
4	2	Oregon	5	1.609	5	4.1
4	3	Idaho	6	1.792	19	17.1
4	3	Oregon	7	1.946	10	11.9
5	1	Idaho	4	1.386	2	4.2
5	1	Oregon	5	1.609	8	6.8
5	2	Idaho	5	1.609	9	8.0
5	2	Oregon	5	1.609	8	9.0
5	3	Idaho	6	1.792	15	13.8
5	3	Oregon	7	1.946	17	18.2

	Est	SE	t	
Constant	-0.168	0.481		
Pair 2	0.031	0.634	0.05	0.962
Pair 3	0.703	0.546	1.29	0.226
Year 2	0.469	0.608	0.77	0.458
Year 3	-0.284	0.685	0.41	0.687
Year 4	0.170	0.611	0.28	0.787
Year 5	0.206	0.585	0.35	0.732
Pair 2 .Year 2	-0.544	0.842	0.65	0.533
Pair 2 .Year 3	1.325	0.822	1.61	0.138
Pair 2 .Year 4	0.287	0.782	0.37	0.721
Pair 2 .Year 5	0.400	0.736	0.54	0.599
Pair 3 .Year 2	-0.267	0.694	0.38	0.708
Pair 3 .Year 3	0.362	0.756	0.48	0.643
Pair 3 .Year 4	0.341	0.676	0.51	0.624
Pair 3 .Year 5	0.094	0.644	0.15	0.887
Year 1 .Site Oregon	-1.924	0.590	3.26	0.009
Year 2 .Site Oregon	-1.445	0.436	3.32	0.008
Year 3 .Site Oregon	-0.784	0.321	2.44	0.035
Year 4 .Site Oregon	-0.517	0.281	1.84	0.096
Year 5 .Site Oregon	0.117	0.248	0.47	0.646

			mean	deviance	approx
Source	d.f.	deviance	deviance	ratio	F pr.
Regression	19	87.892	4.6259	5.17	0.006
Residual	10	8.940	0.8940		
Total	29	96.833	3.3391		
Change	-8	-35.092	7.0184	7.85	0.003

Dispersion parameter is estimated to be 0.894 from the residual deviance.

Figure 4.2 The results of fitting equation (4.1) as a generalized linear model in GenStat 13. The dependent variables was the number of recorded wolf depredations, with the assumption that the expected number is proportional to the number of months considered allowed for by using Ln(Months) as an offset in the linear model. To identify parameters the Pair 1, Year 1 and Pair1.Year 1 effects are set equal to zero and the effects for other pairs and years are estimated relative to this. Also, the effect for the Idaho site in each paired site is set to zero so the terms of the form Year1.Site Oregon are estimates of the mean difference in the depredation rates of Oregon compared to Idaho for the stated year. These mean differences are estimated as -1.924 in year 1, reducing to -0.517 in year 4, with a slight positive value of 0.117 in year 5. These differences are significant at the 5% level for years 1, 2 and 3, but not for years 4 and 5. Therefore, according to the fitted model the difference between the Idaho and Oregon paired sites was initially large in year 1 but was close to zero by year 5.

The significance of the results is clearer with the second analysis that uses the data from each sampled site rather than the difference between monthly means for paired sites, presumably because more of the data are used for this analysis and also because the analysis recognizes that the data from the sites are counts. If the data from the sites are not counts then the second analysis would not be appropriate. The advantage of using the generalized linear model approach for analyzing the data is that the model used can be chosen based on the nature of the data. For count data the approach used here is appropriate, but for proportion data (e.g., the proportion of days when there was evidence of wolf presence near a site) a logistic regression model would be better choice, and for data that might be approximately normally distributed (e.g., the hours per day that cows spend foraging) an ordinary linear regression model would be more reasonable.

Example: Analysis of Counts Using Measures of Wolf Presence

As a third example consider the data in Table 4.4 that might arise from a ten year study with the level of wolf presence classified as low, medium or high based on various indications of the abundance of wolves at a site during a year. For this artificial example it is assumed that the wolf presence is always high at the Idaho sites and changes during the ten years from low to medium to high at the Oregon sites. A good deal of random variation was used when generating these data so that the average number of cow depredations per month varies from 0.00 to 0.25 when the wolf presence is low, from 0.00 to 0.60 when the wolf presence is medium, and from 0.25 to 2.00 when the wolf presence is high.

Table 4.4 Artificial data on the average number of cow depredations per month at six sites from a ten year study where the level of wolf presence at each site is classified as low, medium or high, with the level always high at the Idaho sites and changing from low to high at the Oregon sites.

		Idaho		Oregon			Idaho		Oregon			Idaho		Oregon	
Year	Pair	Wolf Level	Kills Per Month	Wolf Level	Kills Per Month	Pair	Wolf Level	Kills Per Month	Wolf Level	Kills Per Month	Pair	Wolf Level	Kills Per Month	Wolf Level	Kills Per Month
1	1	High	0.75	Low	0.20	2	High	1.20	Low	0.00	3	High	1.67	Low	0.00
2	1	High	0.75	Low	0.00	2	High	1.00	Low	0.20	3	High	1.50	Low	0.14
3	1	High	1.00	Low	0.00	2	High	1.80	Low	0.20	3	High	1.17	Low	0.29
4	1	High	1.50	Low	0.00	2	High	1.20	Low	0.00	3	High	1.00	Med	0.57
5	1	High	0.25	Low	0.00	2	High	2.00	Med	0.40	3	High	0.83	Med	0.43
6	1	High	1.00	Med	0.60	2	High	0.20	Med	0.00	3	High	1.00	Med	0.43
7	1	High	0.50	Med	0.20	2	High	1.20	Med	0.20	3	High	1.00	Med	0.00
8	1	High	0.25	High	0.40	2	High	1.00	Med	0.00	3	High	1.00	Med	0.00
9	1	High	0.75	High	0.60	2	High	1.00	High	0.20	3	High	1.67	Med	0.43
10	1	High	0.50	High	0.80	2	High	0.60	High	0.60	3	High	1.00	High	0.43

Figure 4.3 shows the results from a generalized linear model analysis of the data in Table 4.4 assuming a log-linear model where the expected number of wolf depredations at site k in pair i in year j is given by

$$E(D_{ijk}) = Exp(Pair_i + Year_j + Level_{ijk}), \quad (4.2)$$

where $Pair_i$ is an effect due to the pair being considered, $Year_j$ is an effect for the year being considered, and $Level_{ijk}$ is an effect for the wolf presence level, which is low, medium or high at site k in the pair and year being considered. A pair by year interaction was also considered for inclusion in the model but is not included because this was far from being significant at the 5% level.

As explained in the caption to Figure 4.3 it is estimated that the number of wolf depredations of cows with low wolf presence is estimated to be 0.08 times the number with high wolf presence, while the number of depredations with medium wolf presence is estimated to be 0.29 times the number with high wolf presence, with both of these effects being extremely significant ($t = 5.84$ and $t = 4.64$ with 46 df, respectively, with $p < 0.001$ in both cases).

Year	Pair	Site	Wolf Level	Months	Offset	Kills	Fit
1	1	Idaho	High	4	1.386	3	3.78
1	1	Oregon	Low	5	1.609	1	0.36
1	2	Idaho	High	5	1.609	6	6.15
1	2	Oregon	Low	5	1.609	0	0.46
1	3	Idaho	High	6	1.792	10	8.50
1	3	Oregon	Low	7	1.946	0	0.75
2	1	Idaho	High	4	1.386	3	3.59
2	1	Oregon	Low	5	1.609	0	0.34
2	2	Idaho	High	5	1.609	5	5.84
2	2	Oregon	Low	5	1.609	1	0.44
2	3	Idaho	High	6	1.792	9	8.07
2	3	Oregon	Low	7	1.946	1	0.71
3	1	Idaho	High	4	1.386	4	4.35
3	1	Oregon	Low	5	1.609	0	0.41
3	2	Idaho	High	5	1.609	9	7.07
3	2	Oregon	Low	5	1.609	1	0.53
3	3	Idaho	High	6	1.792	7	9.77
3	3	Oregon	Low	7	1.946	2	0.86
4	1	Idaho	High	4	1.386	6	3.75
4	1	Oregon	Low	5	1.609	0	0.35
4	2	Idaho	High	5	1.609	6	6.10
4	2	Oregon	Low	5	1.609	0	0.46
4	3	Idaho	High	6	1.792	6	8.43
4	3	Oregon	Med	7	1.946	4	2.90
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10	1	Idaho	High	4	1.386	2	2.02
10	1	Oregon	High	5	1.609	4	2.53
10	2	Idaho	High	5	1.609	3	3.29
10	2	Oregon	High	5	1.609	3	3.29
10	3	Idaho	High	6	1.792	6	4.55
10	3	Oregon	High	7	1.946	3	5.31

Source	d.f.	deviance	mean deviance	deviance ratio	approx F pr.
Regression	13	109.89	8.453	7.74	<.001
Residual	46	50.25	1.092		
Total	59	160.15	2.714		

Dispersion parameter is estimated to be 1.09 from the residual deviance.

	Est	SE	t	Sig	Effects
Constant	-0.056	0.278			
Pair 2	0.263	0.206	1.28	0.208	1.30
Pair 3	0.405	0.197	2.06	0.045	1.50
Year 2	-0.051	0.335	0.15	0.879	0.95
Year 3	0.140	0.320	0.44	0.664	1.15
Year 4	-0.008	0.325	0.02	0.981	0.99
Year 5	-0.113	0.332	0.34	0.734	0.89
Year 6	-0.368	0.353	1.04	0.302	0.69
Year 7	-0.428	0.358	1.20	0.238	0.65
Year 8	-0.689	0.369	1.87	0.068	0.50
Year 9	-0.254	0.317	0.80	0.427	0.78
Year 10	-0.625	0.328	1.90	0.063	0.54
Level Low	-2.584	0.443	5.84	0.000	0.08
Level Med	-1.222	0.263	4.64	0.000	0.29

Figure 4.3 The results of fitting equation (4.2) as a generalized linear model using GenStat 13. The dependent variable was the recorded number of wolf depredations of cows at sites, with the assumption that the expected number is proportional to the number of months considered, which is allowed for by using Ln(Months) as an offset in the model. To identify parameters the effects are set to zero for Pair 1 and Year 1, with the effects for other pairs and years then being estimated relative to this pair and this year. The effect for the High level of wolf presence is also set at zero in equation (4.2), so that the Low and Medium level effects are estimated relative to the High level. The effects column shown gives the estimated pair effects relative to Pair 1, the estimated year effects relative to Year 1, and the estimated wolf presence effects relative to High presence. For example, it is estimated that with Low wolf presence the expected number of wolf depredations per month is $\text{Exp}(-2.584) = 0.08$ times the number that there would be with High wolf presence, while it is estimated that with Medium wolf presence the expected number of wolf depredations is $\text{Exp}(-1.222) = 0.29$ times the number that there would be with High wolf presence.

5. Discussion

The current design strategy for the project *Evaluating Wolf-Livestock Relations in the Northern Rockies and Pacific Northwest* is a modified version of the BACIP (before-after-control-impact-pairs) design that is popular for environmental impact studies. The design is therefore reasonable for the project, although it suffers from the usual problem with this type of study design that the extent to which the study results can be generalized for impacts at other study sites is a matter of judgement.

It is suggested that the main outputs from the project will be (a) estimated resource selection functions for individual cows, and for all cows at a study site, where these functions should make it possible to quantify the effects of wolf presences on how the cows use the available habitat at the study sites; and (b) study site level variables such as the number of observed stress events per month for monitored cows.

There are many available methods for estimating resource selection functions for GPS collared animals, and new methods are still being published. It is therefore recommended that the final methods used for analyzing the project data should depend on a review of the available methods when it is time to start the analyses. However, discrete choice methods based on successive relocations of collared animals as described by McDonald *et al.* (2006) and Nielson *et al.* (2009) are appropriate for detecting the effects of wolf presence over short periods of time, while the methods used by Sawyer *et al.* (2006, 2007, 2009) can detect longer term changes in the use of habitat by cows as the level of wolf presence changes.

If GPS location data are available for cattle and wolves at a study site then short term wolf-cattle interactions should be obvious and easily quantified using discrete choice modeling. However, if the wolves at a site are not fitted with GPS collars then it will not be possible to include the position of a wolf in the cattle movement model. Without wolf location data it may be possible to tentatively identify interactions from cattle movement patterns alone, but clearly this will be much less satisfactory than an analysis that takes into account the relative positions of the wolves and cattle based on their GPS locations.

Variables measured at the level of the study site can be analyzed in term of differences between the paired sites in Idaho and Oregon, which can be done using a simple two factor model for years and pairs, as indicated in Figure 4.1. Alternatively, the data values at each study site can be analyzed using a generalized linear model, as indicated in Figure 4.2. The effects of different levels of wolf presence from high to low on variables measured at the level of sites and years can also be analyzed using a generalized linear model, as indicated in Figure 4.3 for data on the number of cow depredations by wolves at the different sites. These example analyzes do not allow for serial correlation in time for the observations at a study site, which seems unlikely to be an issue with a dependent variable like the number of cow depredations by wolves. However, for the analysis of some site level variables this may need to be taken into account. The appropriate way to do that will depend on the variable being considered.

It is possible that there will be more variability in the level of wolf presence at the Idaho sites that was originally expected for the study design, so that in some years the amount of wolf presence may be low for both the Oregon sites and some or all of the Idaho sites. The "impact" in the modified BACIP study design will then not always be present at the Oregon sites. If this is the case then an analysis along the lines illustrated by Table 4.4 and Figure 4.3 will still be appropriate providing that a measure of the level of wolf presence is available for each site in each year. It would just mean that the Idaho sites would not necessarily have a high wolf level in every year. This type of analysis can also be applied with less than ten years of data.

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