SHORT COMMUNICATION

USING PELLET GROUPS TO ASSESS RESPONSE OF ELK AND DEER TO ROADS AND ENERGY DEVELOPMENT

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Abstract
Human activity and development have directly and indirectly reduced available habitat to wildlife through changes in behavior and resource use. To assess how elk (Cervus elaphus) and deer (Odocoileus spp.) were spatially distributed relative to roads and coal-bed natural gas well pads, we collected pellet group data during 2 summers in south-central Colorado. We used generalized linear mixed models to assess the relative probability of use of elk and deer in relation to roads and well pads. We found relative probability of use was positively associated with distance from roads, indicating greater use of areas farther away from roads. Relative probability of use was greater nearer to well pads, potentially because of plant phenology and reseeding in areas around well pads. Other factors such as elevation, slope, and vegetative security cover also influenced elk and deer spatial distributions. Based on these data, it appears resource use may be driven seasonally by forage and security cover more than anthropogenic features. Pellet group surveys appear to be an appropriate technique for evaluating resource use of populations across large spatial extents when logistical and financial constraints limit the use of more advanced technology such as very high frequency and global positioning system collars.

Introduction

Human populations are rapidly expanding, requiring more resources in the form of energy (e.g., coal, gas and oil), food and products (e.g., wood and steel). Most energy consumption (95%) comes from petroleum (44%), natural gas (26%) and coal (25%) [1]. In the Rocky Mountain region (including Colorado, New Mexico and Wyoming), coal-bed natural gas (CBNG) production has been on the rise since 1989 due to more efficient and widespread technologies used to extract it [2]. Increased development for CBNG results in the concomitant increase in road networks to facilitate activities associated with CBNG extraction.

Many times, land development (e.g., roads, buildings, well pads) will alter the face
of the landscape, which can be a concern for wildlife conservation and for other land uses in these areas such as recreation. The direct loss of wildlife habitat from land development can be substantial, but associated indirect losses of habitat due to altered behavior associated with human activity can be even greater [3-6]. Exploration and development for energy reserves will likely continue into the near future, so science-based studies should be conducted to help minimize impacts to wildlife and their habitats.

Expansion of CBNG in the Rocky Mountain regions often occurs at the landscape-level; therefore, we needed a survey technique to sample elk (*Cervus elaphus*) and deer (*Odocoileus* spp.) distributions over large spatial extents. Pellet group surveys have been criticized for not being able to detect habitat use [7]. However, they have been useful for documenting trends and changes in spatial distributions of animals [8-11]. The benefits of using pellet groups are that they provide persistent evidence of where an animal has been, are relatively easy to collect over broad spatial scales, and can sample the entire population. Many of the logistical issues of collecting large samples over broad spatial scales for the entire population are difficult with more advanced technologies such as VHF and GPS collars due to expense and limited sample size of individuals.

We used pellet-group counts for elk and deer to evaluate changes in spatial distributions relative to roads and CBNG well pads (hereafter well pads). Collection of pellet-groups was part of a larger research project on female elk fitted with GPS collars. We felt the collection of both types of data could reveal changes in spatial distributions of elk and deer at multiple spatial scales and on different segments of the population (only female elk sampled using GPS collars versus all elk and deer sampled with pellet groups). Our objective was to document spatial distributions of elk and deer relative to two land development features (i.e., roads and well pads).

**Methods**

**Study area**

We conducted our study on 4 privately owned sites located in the Raton Basin of south-central Colorado, USA. The area comprised by each of the 4 study sites was 9.33, 2.57, 18.87 and 2.58 km². These study sites were part of a larger study area where 206 female elk were fitted with GPS and VHF collars over 4 years. Ranching, hunting, energy development, and residential home development were the predominant land use practices. The center of the study area encompassed historic and ongoing CBNG development, which contained 2,421 well pads (1.77 well pads/km²) and 2,933 wells (2.14 wells/km²) as of 2009. Well placement ultimately was driven by geology, but where possible, wells were often located at forest/grassland edges to minimize visual presence of infrastructure in open areas. Road density in the center of the study area where development for natural gas occurred was 2.4 km/km² and 1.1 km/km² in areas without gas development.

Topography ranges from rolling ridges and valleys to steep alpine slopes and cliffs [12] with elevation ranging from 1,800-4,300 m. Mean annual precipitation ranges from 15 cm at lower elevations to 51 cm at higher elevations [12]. We obtained site-specific temperature data from 7 weather stations located across the study area at
elevations ranging from 1,983 to 2,841 m. At the highest elevation weather station, minimum and maximum January and July temperatures were -26.3, 12.4, 3.2 and 26.4°C, respectively. Minimum and maximum January and July temperatures were -25.2, 20.9, 7.1 and 33.8°C, respectively at the lowest elevation weather station.

**Pellet groups and transects**

Pellet group transects (i.e., strip or belt) were allocated throughout each of the 4 study sites and based on area (km²) of each study site; 1 km of transect was established for every 0.22 km². In total, we created 221 permanent transects totaling 154 km and ranging in length from 0.1-1.05 km. Length and orientation of transects varied because boundaries of study sites were irregular. Transects were spaced 134 m apart and oriented in either N-S or E-W directions to allow transects to run perpendicular to topography. Surveyors used handheld GPS units (Garmin® eTrex®, iQue M5™ and ArcPad 7.x) and compasses to aid in following transects as closely as possible. We counted pellet groups of both elk and deer. Differentiating pellets among deer species can be problematic; however, few problems have been encountered differentiating elk and deer pellets [9]. We differentiated pellets of elk and deer primarily by size but also by shape [10, 13]. Only fresh pellet groups from the current season (mid-April to July) and within 1 m of the path walked by the observer were counted. We considered pellets a group when there were ≥12 pellets within a group and in close proximity to one another. We only counted pellet groups that were coalescent or amorphous with high moisture contents and black in color because these features of pellets are unique after spring green-up [8, 13-15]. On our study area, spring green-up occurred around mid-April each year (J. Wondzell, personal observation). Therefore, we considered fresh pellet groups to have been deposited from a period approximately encompassing mid-April to July. Spatial data (X and Y coordinates) and attributes (i.e., date, study site, transect number and species) of each pellet group were stored in handheld GPS units. We conducted pellet group surveys each summer during 2006 (13 July – 22 July) and 2007 (13 July – 19 July). During 2006 and 2007, we counted 1,138 and 1,869 fresh elk pellet groups and 350 and 820 deer pellet groups, respectively.

**Covariates**

We examined elk and deer spatial distributions using pellet-groups relative to 2 land development features: roads and well pads. We determined temporal changes in the area of land surface development associated with roads and well pads from annual high-resolution (0.3 m) aerial photography. Disturbance features were interpreted, digitized, and attributed based on annual aerial photography (2006 and 2007). We used heads-up digitizing of roads and well pads within our study area and performed all spatial analyses using ArcGIS® 9.3 software (ESRI, Inc., Redlands, CA).

Although we were interested in determining spatial distributions of elk and deer relative to roads and well pads, we also considered that landscape characteristics influence ungulate spatial distributions. Therefore, we accounted for landscape effects by including 3 features into our models as covariates, which included elevation (m), slope (degrees) and vegetation cover type (i.e., riparian, dense forest, open forest, oak-shrubland and grassland). We used a 10 m digital elevation model (DEM) to
calculate elevation and slope. Slope was calculated from the DEM using Surface Tools within Spatial Analyst of ArcGIS® 9.3. Elevation at observed and random (see below) pellet group locations ranged from 2,158 – 2,762 m and slope ranged from 0.15 – 50.9 degrees.

We developed a vegetation cover type map using high resolution (0.3 m) true-color and color-infrared (CIR) aerial photography and Feature Analyst® 4.2 (FA; Visual Learning Systems, Inc., Missoula, MT) for ArcGIS® 9.3 [16]. We conducted a supervised classification using delineated polygons of known vegetation type for use with object-based feature extraction algorithms. The true-color and CIR bands were combined using FA, which resulted in 4 spectral bands (i.e., red, green, blue and near-infrared). We also specified the green spectral band be used to develop a texture band. We used DEMs to develop an elevation band, which finally resulted in 6 bands (i.e., 4 spectral bands, 1 texture band and 1 elevation band). Last, we varied our resolution/pixel classifier pattern and size combinations based on vegetation type. Prior to running classifiers, we resampled vegetation cover types that occurred over extensive areas (e.g., forests, shrublands and grasslands) to 3 m resolution and vegetation cover types that were more restricted or linear (i.e., riparian) to 1.5 m resolution. We used the Manhattan classifier pattern and a width of 7 pixels to classify extensive vegetation types. For more restricted vegetation types, we used the Bull’s Eye 2 classifier and a width of 15 pixels.

We used the Extraction Tool within Spatial Analyst to extract elevation and slope values from the raster images to each individual pellet group location. We used the Spatial Join feature of ArcGIS® 9.3 to attribute values from our vector habitat type map to each pellet group location. In addition, we used the Spatial Join feature to calculate the minimum distance from each pellet group location to the nearest road and well pad.

**Relative probability of use**

In order to address use patterns of elk and deer in relation to roads and well pads, we generated an equal number of species and year-specific random locations to actual observed pellet group locations within each study site. We used Sampling Tools within Hawth’s Tools to generate random points. We took the same steps to attribute anthropogenic and landscape feature values to the random locations as we did for observed locations. We used generalized linear mixed models (GLMM) to determine the relative influence of roads and well pads on the probability of space use for elk and deer. Observed use of an area was analyzed as a binomial response variable (1 = observed; 0 = random). We included study site and year as random effects, which took into consideration unmeasured study site and environmental variations. We also included slope, elevation and habitat type into our model as covariates to account for factors in the environment that influence space use of ungulates. For our GLMM, we used a compound symmetry covariance structure, binary distribution, logit-link function and a degrees of freedom adjustment developed by Kenward and Roger [17]. The Kenward-Roger option accounts for unbalanced data, multiple random effects, and any model with correlated errors [18]. GLMM were conducted using SAS® 9.2 and PROC GLIMMIX (SAS Institute, Inc., Cary, NC).
Results

Roads and well pads

Modeling the relative probability of use in relation to roads revealed similar trends between elk and deer. The relative probability of use for both elk and deer increased with increasing distance from roads (Fig. 1). Roads had a stronger influence on elk use patterns ($\beta_{\text{road}} = 0.0005 \pm 0.0002$ SE, $F_{1,5957} = 6.23, P = 0.013$; Fig. 1a) than on deer use patterns ($\beta_{\text{road}} = 0.0004 \pm 0.0003$ SE, $F_{1,2308} = 1.49, P = 0.223$; Fig. 1b).

The relative probability of use by elk and deer decreased with increasing distance from well pads (i.e., elk and deer were distributed closer to well pads; Fig. 2). Well pads did not exert a strong influence on deer use patterns ($\beta_{\text{well}} = -0.0001 \pm 0.0001$ SE, $F_{1,1636} = 0.47, P = 0.492$; Fig. 2b) but did for elk ($\beta_{\text{well}} = -0.0005 \pm 0.0001$ SE, $F_{1,4440} = 67.33, P < 0.001$; Fig. 2a).

Environmental covariates

Because deer use patterns were not influenced by roads or well pads, it is conceivable that other environmental features influenced their use patterns. Cover type ($F_{4,2308} = 7.04, P < 0.001$) influenced deer selection whereas elevation ($F_{1,111} = 2.02, P = 0.183$) and slope did not ($F_{1,2308} = 0.19, P = 0.662$). Deer generally selected for dense forest and oak-shrubland cover types and less for riparian and open forest cover types (using grassland as a baseline reference).
Although elk use patterns were influenced by roads and well pads, other covariates also influenced their use patterns. Elevation ($F_{1, 41.4} = 24.62, P < 0.001$), slope ($F_{1, 5957} = 19.47, P < 0.001$) and cover type ($F_{4, 5957} = 28.96, P < 0.001$) all influenced elk use patterns. Elk used higher elevations and dense forests but avoided steep slopes, riparian, open forest and oak-shrubland vegetation cover types (using grassland as a baseline reference).

**Discussion**

Elk and deer showed a tendency to use areas with increasing probability as distance to the nearest road increased (Fig. 1). However, elk were more sensitive to roads than deer; elk avoided roads whereas deer did not show a strong avoidance. We recognize most cervid species tend to avoid roads or are behaviorally affected by them [10, 19-23], as they were in our study. Similarly, additional studies have identified a number of ungulate species avoid well pads [5-6, 24]. However, in the present study, elk use of areas increased with proximity to well pads; deer distribution appeared to be less affected. The finding that elk and deer were distributed closer to well pads seems counterintuitive at first. However, other studies have documented similar responses; elk did not alter movements or ranges in response to oil and gas development [25-26]. Considering our temporal window from mid-April through July, and the results from previous studies, we hypothesize that foraging resources may be a driving force of resource use at finer spatial scales [27-28]. April through July on our study area is the primary growing season. In addition, areas associated with well pads were reseeded with annual mixes to limit erosion of bare soils. These areas also had disturbed topsoil, which promoted regrowth of highly nutritious herbaceous vegetation. Many times, disturbances such as fire, grazing, herbicides, or mechanical treatments result in the promotion, availability and palatability of preferred forages [29]. For these reasons, vegetation on and around well pads is usually the first to develop during the growing season (J. Wondzell, personal observation); thus making these areas temporarily more attractive.

The pattern of decreasing use of areas farther away from well pads during late spring and summer (i.e., the growing season) may indicate use of areas around well pads at an even finer temporal scale than season. Elk and deer may have exhibited diel (i.e., day versus night) use patterns of these areas depending on the level of human activity. Research of female elk within the same study area fitted with GPS collars revealed that females during reproduction (May to July) would shift use of resources between day and night, which was attributed to human activity near roads and well pads during daylight hours [30]. Therefore, it is conceivable that elk and deer only used areas nearer to well pads at night when human activity was minimal or non-existent. Our prediction is consistent with the finding that human disturbance can cause animals to become more nocturnal [31-33] or behaviorally adjust to disturbance [30].

Last, we acknowledge that other factors may influence use of areas around well pads. For example, a study conducted by Sawyer et al. [5] found that mule deer (*O. hemionus*) avoided well pads out to 3.7 km. Mule deer may have avoided well pads to a greater extent in their study because visibility of the well pads was greater.
because the area was dominated by sagebrush species (*Artemisia* spp.) and well pad development was just beginning. On our study area, well pads were less visible due to the amount of mature forest. Edge and Marcum [34] identified a similar phenomenon related to topography; use of areas near roads and other land development features was ameliorated by topography, which reduced visibility of the land modifications. Additionally, the CBNG field in our study area was well established since the mid-1980’s, so both cervid species may have learned to adapt temporally to human activity near well pads.

In conclusion, elk avoided roads whereas roads had little influence on deer distribution. Both elk and deer used areas of available security cover; thus, the use of security cover, or proximity to security cover, may mitigate some of the impacts well pads have on animals. Elk and deer may be able to exploit resources around areas of human disturbance if security cover is available or in close proximity. Therefore, areas with dense security cover should be retained as refuges where elk and deer can go to avoid human activity. Although reseeding of well pads to create available forage appears to be a promising reclamation effort because elk and deer were distributed closer to well pads (potentially as the result of reseeding and available forage; see above), population demographics may suffer in these areas based on recent evidence. Within the basin, elk that used areas near industrial development had a greater risk of mortality because of the associated human activity (i.e., hunting) in these areas [35-36]. Management decisions based on animal occurrence alone is cautioned without knowledge of how occurrence influences fitness [35]. It also will be important to design studies to elucidate whether road type or traffic volume, and well pad infrastructure or human activity are the driving forces behind space use patterns and behavioral modifications.

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**References**

*Five “key references”, selected by the authors, are marked below (Three recommended (●) and two highly recommended (●●) papers).*

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