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Landscape Influences on Elk Vulnerability to Hunting

Abstract

*We evaluated landscape elements that we believed influenced elk (*Cervus elaphus*) vulnerability to hunting in western Montana from 1993 to1995. We used six Geographic Information System (GIS) coverages to describe 84 elk-kill locations, 267 live-elk locations, and 166 random locations at three scales (point, 200-m radius, and 700-m radius). We used discriminant function analysis (DFA) to differentiate among these locations using four road variables, three topographic variables, 24 vegetation classes, four vegetation-change classes, hydrography, and a fragmentation index. Road proximity or density discriminated among elk-kill, live-elk, and random locations at each scale. In addition, a vegetation-change variable and two vegetation classes (lodgepole pine [*Pinus contorta*] and open Douglas fir [*Pseudotsuga menziesii*] classes) improved differentiation of the locations ($\bar{x}$ = 50% correct classification). Elk selected locations away from open roads in areas with low road density and large patches of forest with substantial hiding cover. In contrast, elk were killed in areas with higher road density and less hiding cover.*

Key words: *Cervus elaphus*, elk, GIS, habitat, hunting, landscape, mortality, security, vulnerability.

Introduction

A current concern of wildlife managers involves several aspects of elk vulnerability to hunting and specifically a resulting decreased bull:cow ratio. Reduced bull:cow ratios may lead to an increased reliance on immature bulls for breeding and a prolonged calving season. This, in turn may result in increased predation losses and/or decreased survival of elk calves over winter. Although causes of low bull:cow ratios have been studied and discussed by numerous researchers, no individual factor has been consistently isolated. However, three factors have been routinely identified: 1) insufficient hiding cover, 2) increased or unimpeded access of hunters via roads, and 3) hunting seasons that are too long or regulations that are too liberal.

Management of elk hunting in Montana has focused on maintaining a five-week season for bulls without controlling the number of licensed resident hunters. As a result, the number of mature bulls has declined in some populations. In parts of Oregon some elk herds have a distorted population structure (Leckenby *et al.* 1991) that substantially deviates from public expectations and may be biologically unsound (Squibb *et al.* 1991, Prothero *et al.* 1979, Noyes *et al.* 1996).

Our objective was to examine sites where elk were killed by hunters and assess vulnerability and security (Lyon

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and Christensen 1992) of elk in relation to various landscape elements such as vegetation, topography, and proximity to roads and trailheads. Although other factors likely were involved, we presumed that animals killed were associated with inadequate security. Our null hypothesis was that habitat factors at elk-kill sites, live-elk locations, and random points were not statistically different.

Study Area

The 259-km^2 Chamberlain Creek study area lies approximately 56 km east of Missoula, Montana, in the Garnet Mountains. Sport hunting is the primary recreational use of the study area. As part of the Blackfoot Block Management Area, interior roads were closed to motorized traffic from 1 September through 1 December. Bicycles and horses were allowed, but commercial outfitting was prohibited. Hunters wishing to use the walk-in area entered at any of twelve parking and access sites, i.e., trailheads. Two elk herds were identified in the study area, each containing approximately 200-250 elk. During this study (1993-95) a 7-week archery season was followed by one week of no big game hunting, and a five-week general firearm season that ended on the last Sunday in November. During the general firearm season, all hunters possessing a valid license could harvest any antlered bull. The number of antlerless elk permits (n = 250, 250, and 200 in 1993, 1994, and 1995, respectively) issued by Montana Fish, Wildlife and Parks (MFWP) was relatively stable during this study.

Methods

We compared locations of elk kills with random locations and locations used by live radio-collared elk during the same time period using spatial variables at three landscape scales: point, near (200 m radius/17.6 ha), and far (700 m radius/ 125 ha). Both bull and cow elk were radio-collared, and both bull and cow elk were hunted during this study.

Aerial telemetry relocations were made for approximately 30 radio-collared elk (7 mature bulls [>2yrs], 3 immature bulls [≤ 2yrs], and 20 cows) twice/ week throughout the general firearm season. We located most radio-collared elk during each flight; these locations were defined as live-elk locations. Location accuracy was ±100 m (Weber 1996, Burcham *et al.* 1998).

Hunters who killed an elk in the study area were interviewed at a game check station and asked to indicate on a map the exact site where the elk was initially shot and where the viscera were located. We also asked hunters if the elk had run after being shot. Using this information, we searched for viscera and recorded the location of kill using a global positioning system (GPS) receiver. All recorded kill sites represented the point where the animal was initially shot and not necessarily where viscera were found. If the hunter stated the elk had run after being shot we back-tracked using blood trails or other evidence, e.g., tracks, etc., to find the point where the elk was originally shot. Normally, the location of the viscera and the point where the elk was first shot were one-and-the-same. Ninety-five percent of hunters stated the elk did not run after being shot and our investigation found little evidence to suggest otherwise. We did not find all reported elk-kill locations. To determine if a bias existed between elk-kill locations found and sites we did not find, we tested located versus non-located (using the point supplied by the hunter) elk-kill sites for distance to any road, distance to an open road, and vegetation type present at that location.

All locations (elk-kill, live-elk, and random points) on properties closed to public hunting were removed from our analysis to eliminate a potential bias caused by varying hunter accessibility.

Although elk were killed on private land, the landowner frequently limited access to hunters that possessed cow permits. Further, road restrictions often did not exist and hunter numbers were controlled. For these reasons, elk-kill sites located on private land were very different from the elk kill sites found on land open to the general public. Some of the primary factors contributing to the mortality of elk on private land (access, land-owner/hunter relations, etc.) were not landscape related and therefore not of direct interest in this particular study.

We used 84 elk-kill locations, 267 live-elk locations, and 166 random locations in our analysis. The minimum and maximum X- and Y-coordinates describing the geographic extent of our study were used as upper and lower bounds for random coordinate generation using Quattro Pro spreadsheet software. We used six Geographic Information System (GIS) data sets to describe trailheads and roads (created by digitizing USGS 7.5' topographic series maps and aerial orthophotography at a scale of 1:24,000), hydrography (obtained from the MFWP at a scale of 1:24,000), vegetation-change between 1984 and 1992, hunter density, and current vegetation. The vegetation-change coverage used four change classes: no vegetation-change, intermediate vegetation loss, e.g., shelterwood and selection timber harvest treatments, high vegetation loss, e.g., clear-cut and seed-tree timber harvest treatments, and gained vegetation. This coverage was created using methods described by Winne (1996). We created polygon coverages of vegetation from 30-m resolution satellite imagery. The hunter density coverage (Weber 1996) was created using hunter-GPS routes (Lyon and Burcham 1998), a trailhead coverage, and trailhead-use data (684 trailhead-use samples from 11 trailheads during the 1993, 1994, and 1995 hunting seasons). We sampled most trailheads daily throughout three hunting seasons (1993-1995) and recorded the number of vehicles parked at each trailhead and the number of hunters/ vehicle when known. We used the mean (+1 SD) of the maximum distance traveled by a hunter from a trailhead (n = 93 hunter routes) to create a buffer polygon around each trailhead. We then used trailhead use data (n = 71 days) to assign hunter frequency and density values to each trailhead polygon.

We used unsupervised classification of Landsat thematic mapper imagery, remotely sensed in 1992, to distinguish different spectral groups in the study area. We generated polygons from these pixel aggregations (or groups) and ground-truthed them during summer 1994. Ground-truth sites could not be within 70 m of a polygon's edge and had to be representative of the entire polygon. Using data collected from 242 ground-truth samples, the University of Montana, Wildlife Spatial Analysis Laboratory produced a supervised classification with 24 vegetation classes utilizing methods similar to those described by Hart (1994).

To assess the impact of various landscape elements and to better understand the scale at which elk respond to their environment, we chose three landscape scales to analyze each elk-kill, live-elk, and random location. We assembled a point analysis database that contained ten variables describing each location: distance to any road, distance to an open road, distance to a mapped source of water, distance to the nearest trailhead, vegetation class, vegetation-change class, hunter density, elevation, slope, and aspect. We determined the latter three variables using mean elevation, mean slope, and majority aspect for the vegetation polygon where the point was located. The near analysis database contained a description of the landscape within a 200 m radius of each location. We selected this scale because it approximates the distance at which an elk and a hunter might first encounter one another. Further, it represented a reasonably long-range shot for most hunters. Variables in this database were the area of each vegetation class and vegetation-change class, the number of pixels of open and closed roads, the number of non-road pixels, and the number of different vegetation classes within the sampling perimeter (a fragmentation index). The far analysis database contained a description of the landscape within a 700-m radius of each location using the same variables as the near analysis database. We chose this scale to describe the landscape available to the elk within a short spatial-temporal period.

To perform these analyses, we used 30x30-m pixels to rasterize vector coverages of vegetation, vegetation-change, and roads. As a result of the rasterization process, the actual area sampled was different than predicted when computing the area of a circle, e.g., area = πr^2, 3.14 x 200^2 = 12.6 ha compared with 17.6 ha actually sampled, and 3.14 x 700^2 = 154 ha compared with 124 ha actually sampled. MAYA software (Glassy and Lyon 1989) determined the number of pixels of each vegetation class, vegetation-change class, and road type for both near and far analyses.

We used discriminant function analysis (DFA) to differentiate among elk-kill, live-elk, and random locations at each scale. A step-wise procedure that maximized Wilks-lambda was used, i.e., the variable that provided the best discriminating ability was selected first. The three groups (elk-kill, live-elk, and random) were tested simultaneously and in pairs. To compensate for the bias induced by disproportionate sample sizes (Norusis 1990) we corrected classification rates using the Kappa statistic (Titus *et al.* 1984). This technique provides a statistic that indicates how much better (or worse) the classification performed relative to what would have occurred by chance alone.

To examine the importance of the vegetation classes detected by DFA, we made a use-availability comparison using Chi-square analysis (Neu *et al.* 1974, Byers *et al.* 1984). We calculated use as the percent of each vegetation class identified by a live-elk location (site specific) and calculated availability as the percent of each vegetation class contained within the 95 percent isopleth of the home range of each elk herd. We determined herd home ranges with the adaptive kernel method (Worton 1989) using independent cow elk locations (n =112).

Results

During three hunting seasons (1993-95) 257 elk kills were reported, but only 125 of these were located. Of those located, 41 (32.8%) were found on land closed to the general public. Eighty-four elk-kill sites were used in the DFA. The 132 kill sites never located in the field were lost due to weather conditions, and/or errors in map interpretation. We were concerned that elk-kill sites most likely to be found were not randomly distributed, but rather those that were easiest to locate, i.e., close to roads open to vehicular traffic, trailheads, or areas with little or no forested vegetation. We made a concerted effort to locate each elk-kill site, including those in areas difficult to access, but the probability of finding these points, using only verbal instructions from excited hunters, seemingly diminished as the complexity of instructions increased. However, few kills were reported in areas far from open roads and trailheads or in dense forests or in areas that were atypical of the other kill sites. Mean distance to an open road ($\bar{x}$ = 1.54 km vs. 1.28 km) or to any road ($\bar{x}$ = 0.19 km vs. 0.25 km) varied little between found and lost elk-kill sites. Further, maximum distance from an open road is nearly identical for all elk locations (found elk-kill sites =

5.65 km, lost elk-kill sites = 5.50 km, and live-elk locations = 5.77 km). This suggested that in this heavily-roaded study area, elk cannot find areas >6 km from an open road. In addition, we determined the vegetation type found at each lost elk-kill site. Over 20 percent of these sites were located in the Douglas fir vegetation class, which corresponded well with found elk-kill sites where the same Douglas fir vegetation class also was found for 20 percent of the sites. The second most common vegetation class found at lost elk-kill sites was termed foothills and parklands, a non-forested bunchgrass type (19%) while the second most common vegetation class at found elk-kill sites, nearly 19 percent, was open Douglas fir (typified by having <30% canopy closure). Open Douglas fir was the third most common vegetation class found at lost-elk kill sites (16.7%). It is interesting to note that 19 percent of lost elk-kill sites were reported in foothills and parklands. This vegetation class contains no forested vegetation and only the most minimal hiding cover. It also is noteworthy that vegetation classes in which found elk-kill sites and lost elk-kill sites were located approximated their occurrence and order of importance. Thus, we believe that the actual error caused by any bias of lost elk-kill sites was minimal.

Distance to open road and vegetation-change variables provided an overall correct classification of 53 percent using the point analysis database. Elk-kill, live-elk, and random locations were ordinarily associated with areas of no vegetation change. However, 35 percent of kill locations were found in areas of intermediate vegetation loss, e.g., shelterwood and selection timber harvest. Live elk were found 1 km farther, on average, from open roads than elk-kill or random locations. The Douglas fir vegetation class had the highest frequency of kill and random locations (20%) and also was one of the most common vegetation classes (20%, Table 1). Live-elk were most often associated with the lodgepole pine vegetation class (52%). Elk use of lodgepole pine exceeded availability ($\chi^2 = 64.3$, d.f. 11 (critical value [0.05] = 19.7)), whereas elk use of the open Douglas fir vegetation class (≤30% canopy closure) was not different than availability ($\chi^2 = 3.1$, d.f. 11 (critical value [0.05] = 19.7)(Table 1).

The area of lodgepole pine and the

Table 1. *Availability and use of vegetation classes by radio-collared elk during the hunting season, and vegetation class availability.*

Vegetation class	% live-elk use	% Availability	Significance[a]
Cropland/ pasture	0.5	0.5	
Foothills/ parklands	1.6	6.9	
Disturbed grasslands	0.5	0.7	
Other herbaceous	0.5	3.5	
Sagebrush	1.1	5.4	
Mixed grass/ shrub	0.5	0.7	
Lodgepole pine	51.9	17.9	+
Ponderosa pine	7.0	5.3	
Douglas-fir	20.0	20.0	
Mixed coniferous	9.7	20.2	
Open Douglas-fir	4.3	9.9	
Regenerating clearcut	1.6	2.1	

a. + Indicates elk use exceeded availability, - indicates elk use was less than availability.

number of non-road pixels found within the sampling perimeter of each location achieved the best overall classification (50%) in near analyses. Similarly, the area of open Douglas fir and the number of pixels of open road were used to achieve the best overall classification (49%) for far analyses.

The highest correct classifications were achieved using the point analysis database. At this scale, 80 percent of live-elk locations were correctly classified (Table 2).

Discussion

Although elk distributions relative to open roads were generally uniform (Fig. 1), nearly 50 percent of all elk-kills occurred ≤ 1 km of an open road, which suggested elk vulnerability increased close to open roads. The importance of roads as a discriminant factor at each landscape scale illustrated not only the impact of open roads on elk security, but also a discernible benefit of walk-in areas for elk security during the hunting season. Our results concur with findings

Table 2. *Results of discriminant function analysis (DFA) and chance-correction classification (Kappa statistic)*

Database type	% Correctly classified: Elk kill locations	Live elk locations	Random locations	Kappa
Point analysis	41	80	39	0.32
Near analysis	31	66	52	0.30
Far analysis	38	63	46	0.26

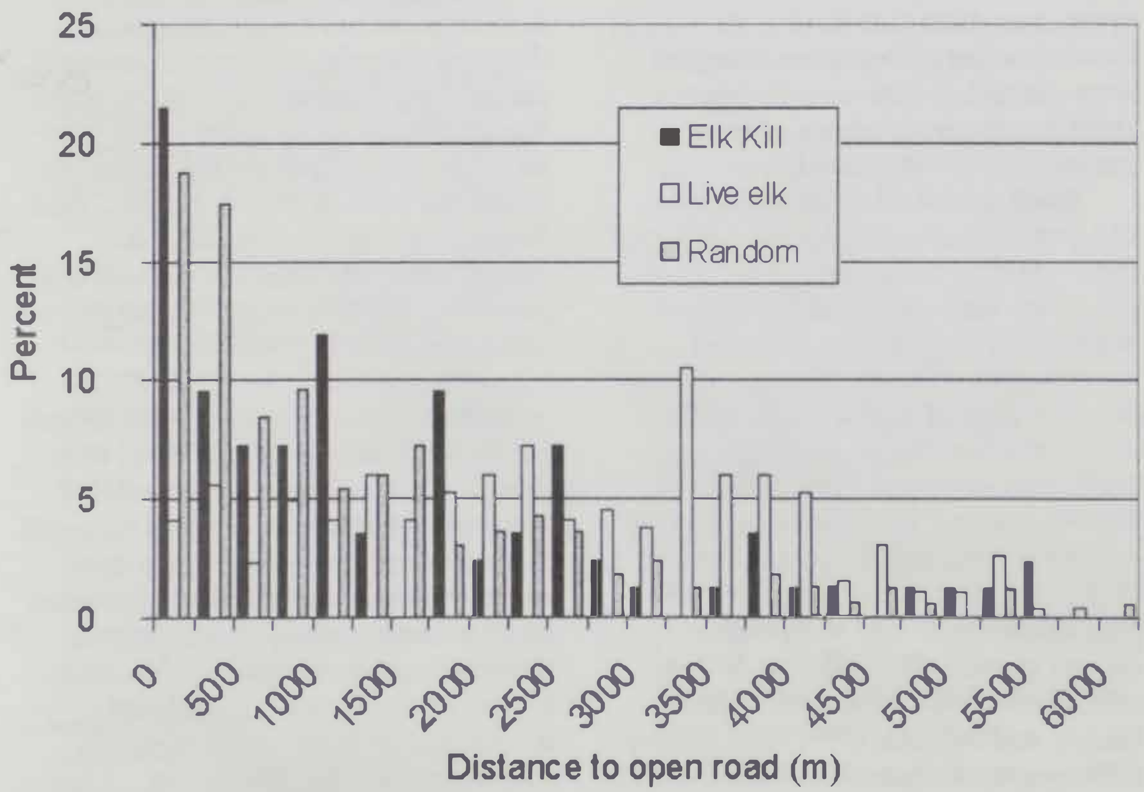

Figure 1. *Frequency distribution of elk-kill, live-elk, and random locations relative to the nearest open road.*

reported by Basile and Lonner (1979), Lyon and Canfield (1991), Unsworth and Kuck (1991), and Unsworth *et al.* (1993).

Although elk-kills were associated most with areas of no vegetation change, 35 percent of kills were found in areas of intermediate vegetation loss, e.g., shelterwood and selection timber harvest, compared to only 4 percent of live-elk locations. This suggested elk vulnerability increased greatly where timber harvests had occurred. However, vegetation change may not be the sole contributing factor to this increase in vulnerability. Although closed to vehicular traffic, roads that lead to these areas provide hunters easier access and greater sight distance.

Only 5 percent of live-elk locations were found in the open Douglas fir vegetation class, compared to nearly 17 percent of elk-kill locations. This agreed with the results of other researchers (Irwin and Peek 1983, Wright 1983, Canfield 1988, Hurley and Sargeant 1991, Vales 1996), who found elk use of open areas decreased during the hunting season. Elk that ventured, or were pushed, into areas with poor security appeared to have a higher probability of being killed.

Based on field data describing the 242 ground-truth samples used to create the vegetation coverage, the lodgepole pine vegetation class had the highest hiding cover estimate and densest canopy cover, which probably explains why elk selected this vegetation class during the hunting season. Marcum (1975) and Edge *et al.* (1987) reported that elk selected sites with high canopy closure and/or dense cover. Irwin and Peek (1983) found that elk preferred pole-timber sites with >75 percent canopy closure with little use of clear-cuts, grass-shrub, or brushfield sites. Hurley and Sargeant (1991) and Hurley (1994) reported that elk in roaded or partially-roaded areas increased their use of dense coniferous cover and subsequently decreased their use of more open sites during the hunting season. Of the 415 individual polygons assigned the lodgepole pine vegetation class, elk in the study area routinely selected ten large polygons with 85 percent of those locations occurring in the largest polygon. These results, when coupled with data we presented regarding use-availability and the results of DFA, indicated selection for large cover patches (Lyon and Canfield 1991, Hillis *et al.* 1991). Elk seem to have selected these sites for the security provided by these forests rather than for lodgepole pine as a species. In other regions sub-alpine fir (*Abies lasiocarpa*) or Douglas fir may provide security. Thus, the vegetation classification becomes less important than the characteristics, i.e., size and structure of the stand, used to describe it.

Management Implications

Implementation of the following suggestions in timber harvest planning, road construction, and property development has the potential to decrease elk vulnerability to hunting: (1) design road closures, i.e., walk-in areas, that provide security cover >1km from an open road, (2) reduce road densities inside the walk-in area by limiting road development and instituting road obliteration projects, and (3) retain large patches of forest with high canopy cover values and hiding cover. These considerations must be applied collectively to be effective because forest patches with dense canopy cover only marginally diminish elk vulnerability when unrestricted use of roads is maintained (Lyon 1979). It does not seem feasible to assign threshold values to act as maximum road density or minimum patch-size guidelines. However, our data suggested that minimum patch size required by elk may be greater than the 100 ha previously recommended by Hillis *et al.* (1991). Because of numerous interacting variables, land managers must assess each landscape individually, considering hunter density and hunter use patterns in conjunction with road and forest variables.

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