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Identifying landscape elements in relation to elk kill sites in western Montana

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Identifying Landscape Elements in Relation to Elk Kill Sites in Western Montana

by

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ABSTRACT

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The landscape elements that influence elk (*Cervus elaphus*) vulnerability during hunting season were studied in the Chamberlain Creek area of western Montana from 1993-1995. Nine GIS coverages were used in PC Arc/Info and MAYA to describe 84 elk kill sites, 267 live elk locations, and 166 random points, at three scales (site specific, 200 m, and 700 m radii (15.2 ha and 155.2 ha respectively)). Discriminant function analysis (DFA) was used to differentiate among three point groups (elk kill sites, live elk locations, and random points) using 4 road variables, 1 hydrography variable, 24 vegetation classes, 4 vegetation-change classes, an index of fragmentation, and 3 topographic variables. At each scale examined, a variable was used which describes some aspect of road proximity or road density. In addition, a vegetation-change variable and two vegetation classes (lodgepole pine and open Douglas-fir vegetation classes) were used to achieve maximal differentiation of the groups ($\bar{x}$ = 50% correct classification) . These variables were examined in detail to understand their importance to elk ecology.

Elk kill sites could not be differentiated from random points, but locations of live elk were readily differentiated from elk kill sites and random points. Elk selected particular elements of the landscape which 1) were not in close proximity to open roads, 2) had low road densities, and 3) contained forested cover in large patches which had not sustained a timber harvest treatment within the past 10 years, and provided substantial hiding cover. This summary does not describe security areas that are independent of other influences, however. With sufficient hunting pressure any elk will be vulnerable in any type of cover. Further, elk security is dynamic and based ultimately on moment-to-moment decisions and reactions by the animal. Therefore, security areas must meet not only cover and topographic requirements, they must also be large enough to ameliorate the effect of concentrated hunting pressure.

Keywords: *Cervus elaphus*, elk, GIS, habitat, hunting, landscape, mortality, security, and vulnerability.

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CHAPTER I

INTRODUCTION

A current problem for elk biologists involves several aspects of elk vulnerability during the hunting season. Management of elk harvest in Montana has involved controlling the length of the season and allowing permit hunting of cows. A liberal bull harvest has been retained. One result has been a decline in the number of mature bulls remaining after the hunting season. Today, as is the case in Oregon, some elk herds have distorted population structures (Leckenby et al. 1991) that deviate substantially from public expectations and may be biologically unsound (Squibb et al. 1991, Prothero et al. 1979).

Lyon and Canfield (1991) studied habitat selection by elk before and during the rifle season in Montana. In that study, habitats were examined under a test hypothesis that survivors had made appropriate selection for survival. Other than the expected negative correlation with road density, nothing in habitat structure was detected as important to hunted elk at the site specific scale. However, landscape level selection for large patches was detected.

An elk vulnerability symposium, held in 1991 at Montana State University examined many facets of elk vulnerability and produced a state-of-the-knowledge compendium for the complex situations involving elk and their habitats during the hunting season (Christensen et al. 1991). Among many papers presented, Leptich and Zager (1991) demonstrated that elk mortality was higher where road densities were higher and that a bull elk in an area with high road density ($\geq$ 9.5 km of road/ km^2 ($\geq$ 5.9 miles of road/ mi^2)) has virtually no probability of surviving to age five. Vales et al. (1991) showed that hunter densities are an important component of vulnerability. Their data indicate that any situation where hunters outnumber legal bulls is certain to produce distorted post season bull:cow ratios. In the Clearwater drainage of Idaho, Unsworth and Kuck (1991) studied bull elk vulnerability and habitat use by comparing mortality in roaded and unroaded portions of their study area. Annual survival rates of bull elk in roaded areas were significantly lower than in unroaded areas.

Previous elk research in the Chamberlain Creek area includes a 9 year study completed by Marcum et al. (1984), a pellet transect study identifying elk habitat selection (Scott 1978), a radio telemetry study of elk habitat selection (Lehmkuhl 1981), an investigation of elk heart rate and activity patterns (Lieb 1981), short term changes in elk distribution (Edge 1982), and a habitat selection study using multivariate statistical techniques (Edge et al. 1987).

The goal of my research was to examine the sites where elk were harvested by hunters, and to assess the vulnerability and security of elk in relation to various landscape elements such as vegetation and topography.

Specific objectives of this study were to evaluate the interaction of landscape and habitat variables influencing elk vulnerability during the hunting season, provide information for wildlife and land managers to enable them to design landscapes to better manage elk vulnerability, and provide some basic insight into the variations in elk habitat selection corresponding to changes in landscape characteristics.

I examined habitat selection by elk that were killed, and the selections made by live, radio-collared elk. Although many other factors were involved, the test hypotheses presumed that any animal killed made an error in security selection. Locations of kill sites were compared with random samples and with security selections made by live elk during the same time period. This study tested the following specific hypotheses:

H_0 : Habitats at kill sites were not different than habitats used by live radio-collared elk during the hunting season.

H_A : Habitat use by live radio-collared elk during the hunting season differed from habitat use by elk that were killed.

H_0 : Habitats at kill sites were not different than randomly selected habitats.

H_A : Habitats at kill sites differed from randomly selected habitats.

H_0 : Habitats used by surviving elk were not different than randomly selected habitats.

H_A : Habitats used by surviving elk differed from randomly selected habitats.

Study Area Description

The Chamberlain Creek study area lies approximately 56 km (35 mi.) east of Missoula, Montana in the northern Garnet Mountains (Fig. 1). The study area is roughly circumscribed by the Blackfoot River to the north, Elevation Mountain to the south, Dunigan Mountain to the east, and Morrison Peak to the west. The home ranges of at least two non-migratory elk herds (Marcum et al. 1984) are contained in this area.

Public land in the study area is managed by the Bureau of Land Management, Montana Department of State Lands, and The University of Montana's Lubrecht State Experimental Forest. Plum Creek Timberlands LP owns most of the private forest land. A number of other areas are under private ownership.

Elevations within the 259 km^2 (100 mi^2) study area range from 1,140 m (3,740 ft.) to 2,156 m (7,073 ft.). Slopes vary from gentle, nearly level ($<$ 5%) along the valleys and ridgetops, to steep ($>$ 60%) on some of the hills and mountains. Precipitous slopes occur along the north face of Blacktail Mountain.

Hot, dry summers are typical, with the majority of precipitation falling as snow in winter. These conditions give rise to primarily xeric vegetation types. Open areas are dominated by grasses. Six major tree species occur in forested areas: ponderosa pine (*Pinus ponderosa*), Douglas-fir (*Pseudotsuga menziesii*), western larch (*Larix occidentalis*), lodgepole pine (*Pinus contorta*), Engelmann

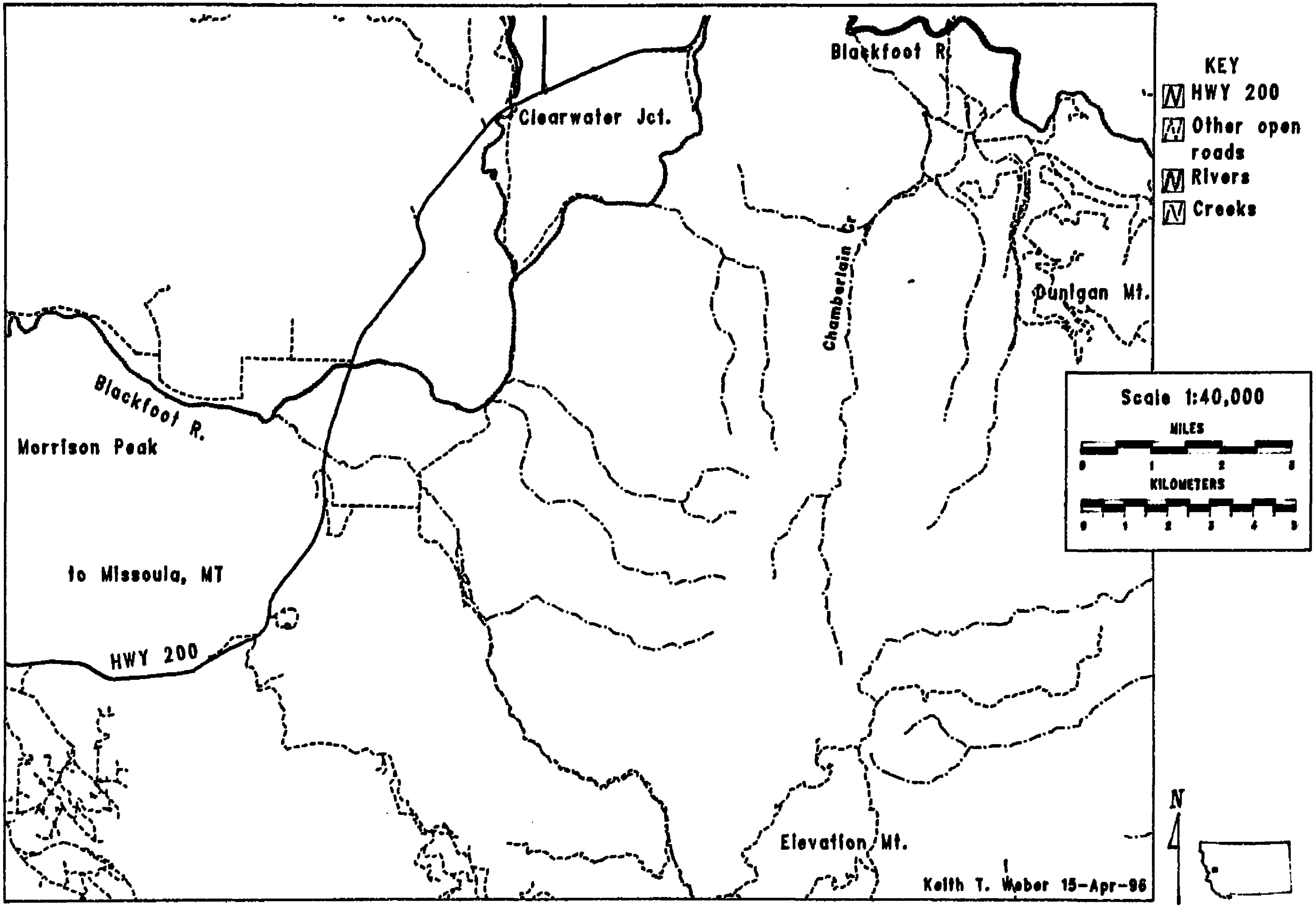

Figure 1. Map of the Chamberlain Creek study area

spruce (*Picea engelmannii*), and sub-alpine fir (*Abies lasiocarpa*). Lodgepole pine and sub-alpine fir are restricted to higher elevation sites, whereas ponderosa pine is found at lower elevations.

Much of the study area has been logged in the past 20 years, especially the lower elevation foothills. Cattle ranching and grazing were moderate. Agriculture was limited to production of alfalfa (*Medicago sativa*) at lower elevations.

The primary recreational use of the study area is sport hunting. However, horse-back riding occurs, and some sportfishing and canoeing access points exist. As part of the Blackfoot Special Management Area, many roads are closed to vehicular traffic between September 1 and December 1 by the use of gates.

Elk hunting season typically begins on the first Sunday in September and ends on the last Sunday in November. The general rifle season occurs during the last 5 weeks of hunting season, preceded by a bow-hunting-only season. During this study (1993-95) hunters possessing a valid license could harvest any antlered bull. The number of antlerless elk permits issued by Montana Department of Fish, Wildlife and Parks remained relatively stable during my study. In 1993 and 1994, 250 antlerless elk permits were issued while 200 antlerless elk permits were issued in 1995.

CHAPTER II

METHODS

GIS Coverages

Nine GIS coverages were used for my study. Four point coverages (elk kill sites, live elk locations, random points, and trailheads), two line coverages (roads and hydrography), and three polygon coverages (existing vegetation, vegetation-change, and hunter density). Topography was incorporated into the existing vegetation coverage by using majority aspect, mean slope, and mean elevation for each polygon.

Elk Kill Sites: Three methods were used to determine elk kill sites; contacting hunters at the Bonner game check station, interviews with hunters who had killed an elk, and evidence found in the field. Hunters who had killed an elk in hunting district 292 (or in that part of hunting district 283 south of the Blackfoot River (Fig. 2)) were interviewed and asked to indicate on a map the exact site where the elk was initially shot and where the viscera were located. Using this information, a search was conducted to locate the remaining viscera of the elk and record the location of the kill site using a global positioning system (GPS) receiver. The GPS units (Garmin GPS100 SRVY) were considered accurate to +/- 50 m (164 ft.) using a 2 minute running average (Garmin 1992). This technique continuously

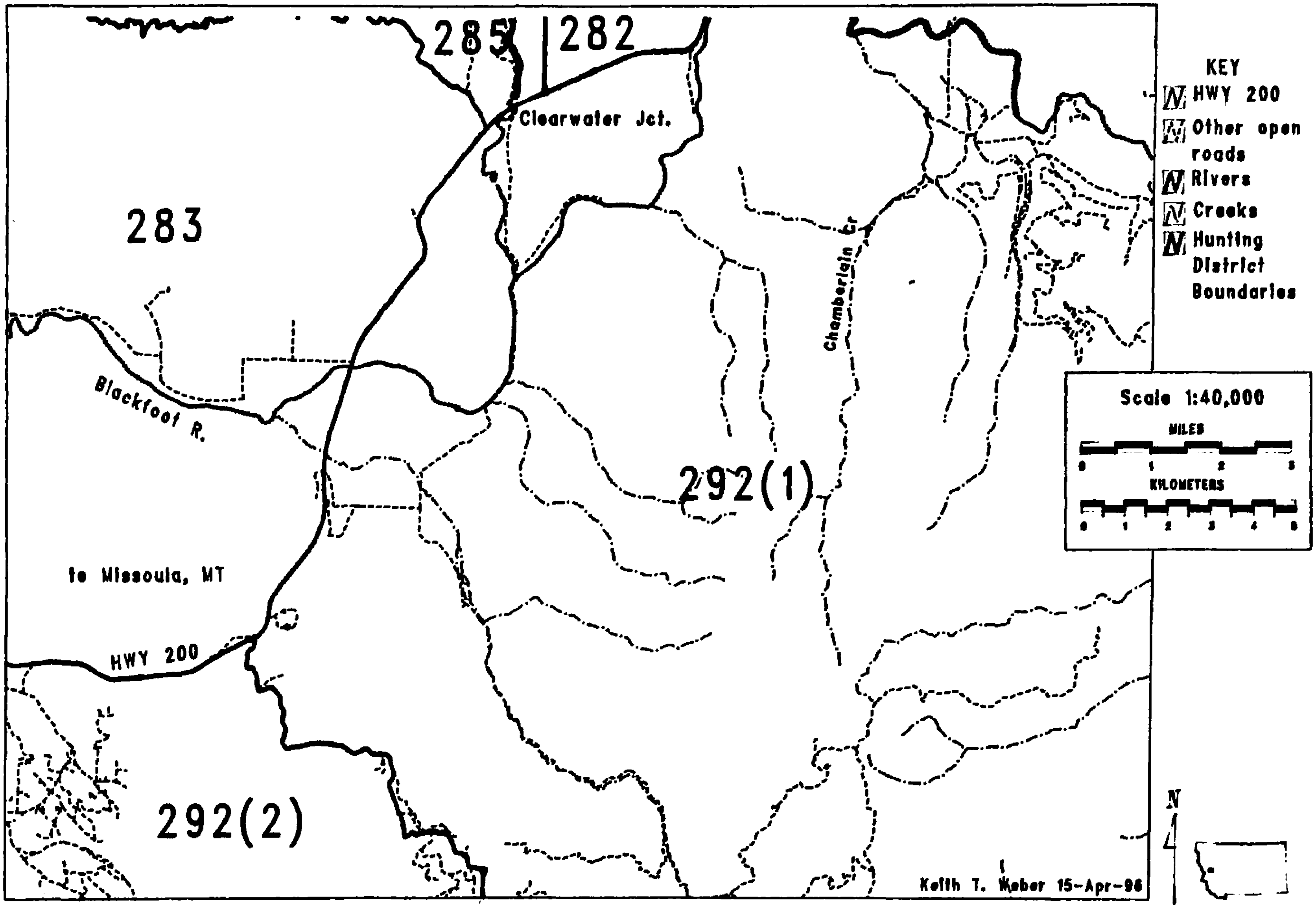

Figure 2. Map of hunting district boundaries.

updates the position until the averaging session is completed. These positions were not differentially corrected.

I estimated the age of all elk killed in the study area using tooth wear and replacement (Quimby and Gaab 1957). On several occasions elk were brought to the game check station in quarters, and the age of these animals was recorded as unknown. In other cases, some hunters who had harvested older bull elk (often considered trophy animals) requested that their elk not be aged as the aging technique involves cutting the hide from the cheek to expose the mandibular dentition, thereby destroying the appearance of the hide. In this situation, the age of the animal was estimated by the size and mass of the antlers.

Live Elk Locations: Aerial telemetry flights were performed once or twice per week throughout the hunting season to locate approximately 30 radio- collared elk. Sex and age of the animal, and Universal Transverse Mercator (UTM) coordinates identifying each point were recorded to the nearest 100 m (328 ft.).

Elk kill sites and live elk locations on land closed to public hunting were removed from the sample to eliminate the potential bias produced by these areas. These elk were not available to the average hunter and may not have responded to hunting pressures that influenced the habitat and security selections made by elk on forested lands that were open to the general public.

Random Points: To reliably approximate available habitat (cf. Thompson 1987), 1,200 random points were generated by computer. Statistical testing required that the sample of random points be comparable in number to the sample of elk kill sites and live elk locations (Norusis 1990), therefore a randomly selected subset of the original 1,200 points was used (n = 166). A use-availability approach was employed to test the efficacy of this random sampling scheme using Chi-square (Neu et. al 1974, Byers et al. 1984). I compared the relative percent each vegetation class was identified by a random point (use), with the relative percent of the area occupied by each vegetation class (availability), and found no difference between the frequencies of sampled vegetation and available vegetation ($P < 0.05$, Table 1). Further, the subset of 166 random points sampled the available vegetation as accurately as the 1,200 random points. UTM locations were used to create point coverages in PC ARC/INFO for all elk kill sites, live elk locations, and random points.

Trailheads: The study area, part of the Blackfoot Special Management Area, was designated a walk-in only hunting area. Although mountain bikes and horses were allowed, commercial outfitting was prohibited. Hunters wishing to use the study area entered any of 11 parking and access sites (i.e., trailheads), located at low elevation foothills (approx 1,140 m

Table 1. Chi-square test of random sampling efficiency

Vegetation class	Observed[a]	Expected[b]	Chi-value
Urban industrial	0.6	0.4	0.1
Cropland/ pasture	0.0	0.4	0.4
Irrigated crops	1.8	2.4	0.1
Rangelands	0.6	1.4	0.4
Foothills/ parklands	10.9	7.5	1.6
Disturbed grasslands	1.2	1.2	0.0
Other herbaceous	10.9	8.2	0.9
Mesic upland shrub	0.0	0.1	0.1
Xeric upland shrub	0.0	0.0	0.0
Sagebrush	3.0	2.8	0.0
Mixed grass/ shrub	0.0	1.0	1.0
Other shrub	0.0	0.2	0.2
Broadleaf forest	0.0	0.0	0.0
Spruce forest	0.0	0.0	0.0
Lodgepole pine	10.9	12.4	0.2
Ponderosa pine	4.2	4.5	0.0
Douglas fir	20.6	21.5	0.0
Western larch	2.4	1.1	1.5
Mixed coniferous	15.2	17.2	0.2
Open Douglas fir	15.8	15.5	0.0
Regenerating clearcut	1.8	1.9	0.0
Lakes/ water	0.0	0.6	0.6
Wet meadows	0.0	0.0	0.0
	Chi-square		7.4
	n =		23
	d.f.		22
	critical Chi-value (0.05)		35.17

[a] observed values are the relative percent of each vegetation class identified by the random point sub sample.

[b] expected values are the relative percent of each vegetation class found in the supervised vegetation coverage.

(3,740 ft.)). The trailhead coverage was created using PC ARC/INFO. The proximity of each point (elk kill site, live elk location, and random point) to the nearest trailhead was determined using PC ARC/INFO (NEAR).

Roads: This coverage was created using United States Geological Survey (USGS) 7.5′ topographic series maps (1:24,000 scale) and aerial orthophotography (1:24,000 scale). The coverage was edited annually to include new roads, correct errors, and update road status information. Road status for motorized traffic was coded as 1) open all year, 2) closed seasonally (September 1 - November 30), 3) closed all year, or 4) not traversable. The road coverage was used to determine the proximity of each point (elk kill site, live elk location, and random point) to any road, and to open roads only.

Hydrography: This coverage was obtained from the Montana Department of Fish, Wildlife and Parks (1:24,000 scale), and was used to determine the proximity of each point (elk kill site, live elk location, and random location) to streams or rivers. The hydrography coverage did not include wet micro-sites which could have been adequate to satisfy an elk's demand for water.

Existing Vegetation: Landsat Thematic Mapper (TM) digital coverages and maps were used to identify different vegetation classes within the study area. Polygons were created by unsupervised classification and sampled in the summer of 1994 by ground-truthing.

Thematic Mapper samples vegetation by recording the amount of light reflected from the earth's surface at a variety of wavelengths. Pixel size is 30 m (98 ft.) when using TM bands 1-5 and 7 (Barrett and Curtis 1992). These bands sample wavelengths from 0.45-2.35 μm (Table 2). The frequency of each spectral class assigned by the unsupervised classification was used to determine sampling frequency for ground truthing. Spectral classes representing < 1% of the study area were sampled once. All other spectral classes were sampled a minimum of five times. Each 7.5' topographic map contained no less than 30 vegetation samples. The criteria used to select sample sites were; 1) no sample point could be within 70 m (230 ft.) of a polygon's edge, and 2) the sample point appeared representative of the entire polygon.

Several independent variables were measured or described for each sample site. These variables are listed below with units of measure and precision where appropriate:

Geographic Location of the sample in latitude/ longitude, UTM, and Public Land Survey System (PLSS) validated by GPS.
Elevation, determined from 7.5' maps within the nearest 12.2 m (40 ft.) contour interval.
Slope, degrees using a clinometer.
Aspect, degrees using a compass.
Overstory Canopy Cover estimated to the nearest 5%
Canopy Closure attributable to each overstory species was estimated.

Table 2. Thematic Mapper Sampling Bands and their applications (Barrett and Curtis 1992)

Band	TM Wavelength	Application
1	0.45-0.52	Soil/ Vegetation differentiation
2	0.52-0.60	Green reflectance by healthy vegetation
3	0.63-0.69	Plant species differentiation
4	0.76-0.90	Biomass survey
5	1.55-1.75	Vegetation moisture
7	2.08-2.35	Vegetation moisture and geologic mapping

Stand Structure based on DBH size classes for trees < 25 mm (< 1 in.), 25-125 mm (1-5 in.), 125-225 mm (5-9 in.), 225-525 mm (9-21 in.), and > 525 mm (> 21 in.).

Vegetation Land Classification (Hart 1994)

Cover Type (Society of American Foresters (SAF))

Habitat Type according to Pfister et al. (1977).

Basal Area, measured using a 5 BAF prism.

Overstory Species present in descending order of prevalence (Hitchcock and Cronquist 1973, Patterson et al. 1985, Nelson 1992).

Mean DBH for each overstory species.

Basic Stand Structure as grass/forb, low shrub, saplings, poles, mature trees, old growth forest, and/or snags if the structure class can be considered a significant part of the site.

Dominant Tall Shrub Understory species > 1.2 m (> 4 ft.).

Percent Composition of the tall shrub understory, estimated as < 25%, 25-50%, or > 50%.

Understory species, the most abundant species and estimated percent cover.

Hiding cover, how well elk could be seen at a distance of 61 m (approximately 200 ft.), as either visible all the time, some of the time, or never visible (cf. Skovlin 1982).

Difficulty of travel, based on the amount of dead-fall and classified as either easy, pick your way, or struggle.

Using these data from 242 vegetation ground-truth samples, the University of Montana, Wildlife Spatial Analysis Laboratory produced a supervised classification of the study area using methods similar to those described by Hart (1994). Relative frequencies for the 24 vegetation classes are given in Fig. 3. Canopy and hiding cover estimates associated with the

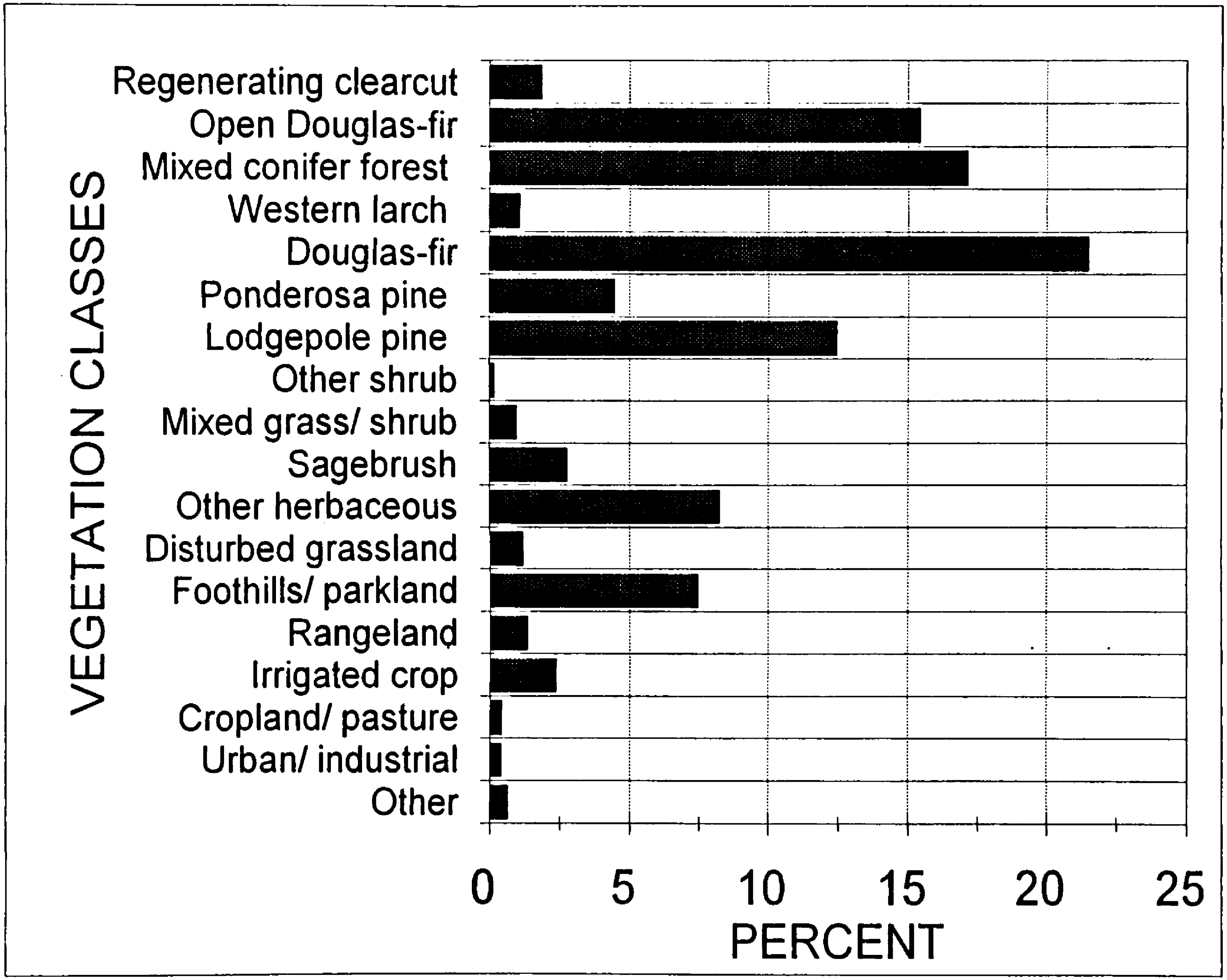

Figure 3. Distribution of vegetation classes in the study area

vegetation classes were summarized using ground-truth data (Table 3 (cf. Appendix A)).

Vegetation-Change: The vegetation-change coverage was created by comparing waveband 7 (cf. Table 2) on a TM image recorded in 1992 with one recorded in 1984. Increasing soil reflectance values (detected by waveband 7) indicates a loss of vegetation, while decreasing soil reflectance values indicates a gain or regrowth of vegetation. This coverage was used in my analysis because sites where vegetation was lost presumably increased the elk sightability distance and the area of a hunter's viewshed. This could have a direct influence on elk mortality and habitat selection. The four vegetation-change classes created were adjusted to match areas of known vegetation-change. They were:

1- No vegetation-change: This class represents those polygons with no tangible changes in the landscape.

2- Intermediate Vegetation Loss: This class represents shelterwood and selection harvest treatments that occurred between 1984 and 1992.

3- High Vegetation Loss: This class represents clear cut, and seed tree harvest treatments that occurred between 1984 and 1992.

4- Gained Vegetation: Polygons with > 10% of their area having increased vegetative cover.

Table 3. Measured parameters associated with some vegetation classes

CODE NO.	CLASS	CANOPY[a]		HIDING COVER[b]	SAMPLES (n =)
		MIN	MAX		
2101	Cropland/ pasture	0	2	1.0	5
3101	Foothills/ parklands	1	19	1.3	14
3102	Disturbed grasslands	5	18	1.1	10
3103	Other herbaceous	1	16	1.5	40
4202	Lodgepole pine	39	85	2.7	24
4205	Ponderosa pine	19	43	1.8	4
4211	Douglas fir	48	78	2.5	48
4214	Western Larch	17	67	2.0	6
4217	Mixed conifer	38	76	2.4	67
4250	Open Douglas fir	23	31	1.8	8

Notes: This table was created using field measured data obtained during ground-truthing.

[a] % Canopy minimum and maximum values are based on the mean +/-1 standard deviation (66%confidence level).

[b] Hiding cover estimates are subjective approximations of the likelihood that elk could be seen by an observer (located at the center of a vegetation plot) from a distance of 200 feet. The discrete values ranged from 1 (elk could be seen all the time), 2 (elk could be seen part of the time), to 3 (elk could never be seen). The values given in this table are the mean of these approximations.

Hunter Density: A hunter density map was created for the Blackfoot Special Management Area (a walk-in area). This was accomplished using the trailhead coverage, data from trailhead use sampling, and hunter-GPS routes (Lyon and Burcham 1995). Most trailheads were sampled daily throughout three hunting seasons (1993-95). The number of vehicles parked at each trailhead was recorded, as was the number of hunters per vehicle when known. Eleven trailheads were sampled yielding 684 trailhead use observations.

The mean plus one standard deviation (66% confidence interval) of the maximum distance travelled by a hunter from a trailhead (n = 93 routes) was used to create a buffer polygon around each trailhead point using PC ARC/INFO (BUFFER). The extent of each trailhead-polygon was cropped to eliminate those areas where hunters were unlikely to enter (e.g., land closed to public hunting and safety zones). This resulted in each trailhead-polygon having a unique size. Trailhead use data (n = 71 days) allowed me to assign hunter frequency values to each trailhead-polygon. This was estimated by multiplying the mean number of vehicles at each trailhead with the mean number of hunters per vehicle ($\bar{x}$ = 1.8; n = 154 vehicles). After appending all trailhead-polygons into a single coverage, numerous polygons were found to overlap adjacent polygons creating new polygons that could theoretically contain hunters from more than one trailhead. Hunter use of the area encompassed by a given polygon was assumed to be evenly distributed across the available landscape. The number of hunters within a polygon was found by (cf. Fig 4):

$$NH_i = \Sigma\ [(H_n(\text{total}) / TA_n(\text{total})) * PA_i]$$

Where;

NH = the total hunters included in the polygon.
H_n(total) = the number of hunters entering the polygon from a given trailhead.
TA_n(total) = the area of the complete trailhead-polygon in km^2
PA_i = the area of an individual polygon in km^2.
n = identifies a specific trailhead.
i = identifies a specific polygon.

note: The contribution of each trailhead (n) to the specific polygon (i) is summed to give the total number of hunters included in the polygon (NH) (Table 4).

Hunter density (HD) for a given polygon was found by:

$$HD_i = NH_i / PA_i$$

The hunter density at each point (elk kill site, live elk location, and random point) was found using PC ARC/INFO (IDENTITY).

Database Production and Statistical Procedures

Three databases were assembled for statistical testing (site specific, near, and far analysis). Each database contained three types of point locations (elk kill sites, live elk locations, and random points).

The site specific analysis database contained the following 10 variables: proximity to any road, proximity to an open road, proximity to water, proximity to the nearest trailhead, vegetation class, vegetation-change class, hunter density, elevation, slope, and aspect.

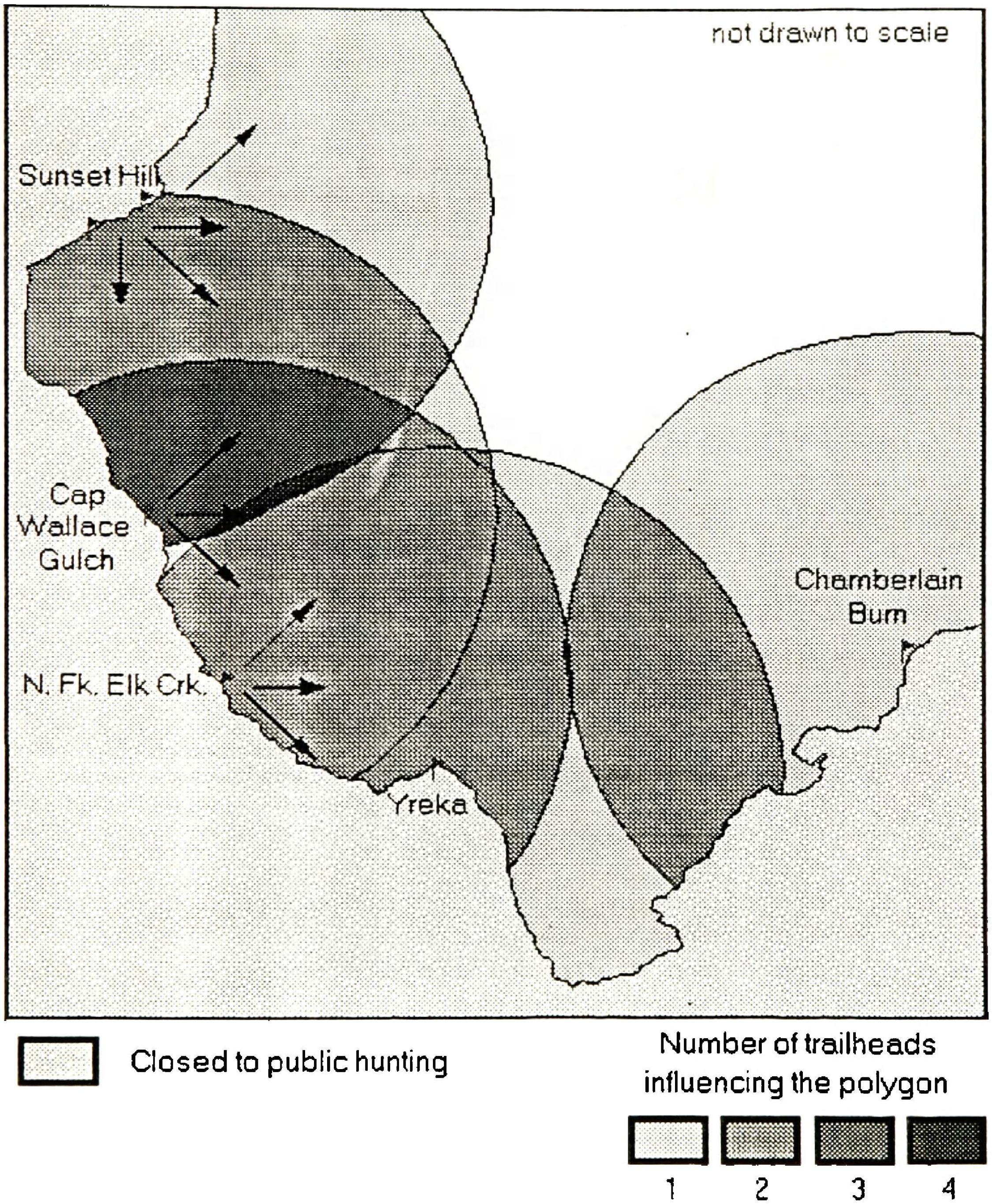

Figure 4. Illustration of hunter density modelling.

Table 4. Hunter use and densities in the study area

Trailhead no.	Trailhead Name	Mean no. hunters[a]	Hunter density per km^2
1	Cap Wallace	13.6	0.44
2	N. Fk. Elk Creek	2.6	0.10
3	Yreka	3.2	0.09
4	Chamberlain Burn	1.2	0.03
5	Wales Creek	1.2	0.02
6	Sunset Hill	18.5	0.58
7	Blackfoot River	5.9	0.25
8	Chamberlain	34.1	0.63
9	E. Fork Chamberlain	8.3	0.23
10	Pearson	6.7	0.20
11	Granite Mt.	5.5	0.27

[a] - mean number of hunters per day was based on weekend use of the study area.

Point coverages were overlaid on the existing vegetation and vegetation-change coverages using PC ARC/INFO (IDENTITY) to determine the vegetation class, elevation, slope, aspect, and vegetation-change class at that point. Hunter density at each point was also determined using PC ARC/INFO (IDENTITY). Point proximities to an open road, to any road, to the nearest trailhead, and to water were determined using PC ARC/INFO (NEAR).

Near Analysis Database: The near analysis database contained a description of the landscape within a 200 m (656 ft.) radius of the point. Variables included in this database were the area of each vegetation class, and vegetation-change class, number of pixels of open and closed roads, and the number of non-road pixels (the rasterized road coverage contained 3 types of pixels; open road, closed road, and non-road), and the total number of different vegetation classes encountered within the sampling perimeter (a measure of fragmentation). The area contained within the analysis perimeter was 15.2 ha (31.1 acres).

Far Analysis Database: The far analysis database contained a description of the landscape within a 700 m (2,297 ft.) radius of each point (selected to approximate short-term habitat availability). The same variables are included in this database as in the near analysis database. The area contained within the analysis perimeter was 125 ha (307.7 acres). To perform this analysis, vector coverages of vegetation, vegetation-change, and roads were rasterized using 30 m pixels. As a result, the actual area sampled was smaller than predicted when computing the area of a circle (e.g., area $= \pi * r^2$, $3.14 * 700^2 = 154$ ha (380 acres)). MAYA software (Glassy and Lyon 1989) was used to determine the number of pixels of each vegetation class, vegetation-change class, and road type within 200 and 700 m (656 ft. and 2,297 ft.) radii of each point.

Discriminant function analysis (DFA) was used to address the test hypotheses. Each DFA attempted to discriminate among three groups (elk kill sites, live elk locations, and random points). A step-wise procedure that maximized Wilks-lambda was used (i.e., the variable that provides the best discriminating ability is used by the DFA first). A second iteration was performed using a direct procedure with only the first two variables that were selected by the step-wise procedure. The resulting mean correct classification was 50%. A third iteration was performed with the direct procedure using variables that were not selected by the step-wise procedure but seemed biologically important. The resulting correct classification rate of the latter functions was very poor ($\bar{x} = 35\%$). The three groups (elk kill sites, live elk locations, and random points) were tested together and in pairs. Each test was run several times, first using the full database, and then using 1 of the following 3 subset databases.

1) Because cow elk were harvested only by permit, data pertaining to cow elk were removed from kill sites and live elk locations. A hunter may

have encountered a cow elk that could have been harvested, but because of hunting restrictions, and not security areas, the animal was not killed. Spike bulls (1.5 years-old) were also excluded because they tended to remain with cow herds and did not use the higher elevation, more heavily forested areas favored by older bulls. If cows and spike bulls responded to hunting pressure differently than adult bulls, this exclusion should have produced different classification results.

2) Radio-collared elk that did not survive the hunting season were excluded from live elk locations. If a given home range contained little or no security cover, elk living in this area may have had an increased probability of harvest, and the live locations obtained from such animals would have been indistinguishable from a kill site.

3) Both exclusion criteria described above were applied to create a third subset to analyze surviving adult bull elk only.

Each exclusion could improve the classification rate in several ways. First, the effect of the exclusion may reveal differences between certain biological classes of elk and hence, add to our knowledge of elk ecology. Second, improved classification may reflect reduced within-group variance due to smaller sample size. The statistical significance and validity of each exclusion was tested by comparing the exclusion groups with the remaining groups using an F-test.

Any DFA that tests groups with disproportionate sample sizes will contain a classification bias for the group with the largest sample size (Norusis 1990). In essence, the disproportionate groups are subject to chance classification. To compensate for this, the resulting classification rates were corrected for the effect of chance using the Kappa statistic (Titus et al. 1984). Kappa values were reported as a proportion, indicating how each classification performed relative to chance alone (e.g., a Kappa value of 0.40 indicates that a classification performed 40% better than could be expected by chance). The Z-statistic was computed to determine the significance of the classification. Interpretation of the results was made by examining the classification rates, eigenvalue, F-test, Kappa, and Z-statistic.

CHAPTER III

RESULTS

Description and Summary of Points Used in the Study

During the 3 hunting seasons (1993-95), 257 elk kills were reported, and 125 of these were located in the field. Of those located, 41 were found on land closed to the general public (Table 5). A marked increase in live elk locations on land closed to the general public was observed in 1995 (Table 5). This was primarily a result of several ranches that allowed some hunting on their property during 1993 and 1994, but closed their ranches to hunting in 1995.

The mean age of elk killed (and aged) in the study area was approximately 2 years for bulls, and approximately 3 years for cows (Table 6). Forty-nine percent of the bulls killed in the study area were 1.5 years-old. The number of bulls killed during the first week of the hunting season was approximately equal to the total number of bulls killed during the remaining four weeks (Fig. 5). In comparison, the age of cows killed in the study area was relatively uniform.

A summary of the points used in the DFA was prepared to describe each elk kill site, live elk location, and random point (Table 7). Comparing

Table 5. Status of reported elk kill sites and recorded live elk locations

	1993	1994	1995	Total
Elk kill sites				
Included in the DFA	20	38	26	84
Not found	52	52	28	132
Closed to general public	5	20	16	41
Total	77	110	70	257
Live Elk locations				
Included in DFA	92	95	93	267
Closed to general public	25	21	73	119
Total	117	116	166	399

Table 6. Summary of elk harvested in the study area 1993-95[a]

Age Class	Cows (%)	Bulls (%)
0.5	23	7
1.5	17	49
2.5	8	25 [b]
3.5	19	9
4.5	18	7 [b]
5.5	8	2
6.5	3	0
7.5	1	0
8.5	3	1 [b]
9.5	1	0
$\bar{x}$ =	3.06	2.20
Minimum	0.50	0.5
Maximum	9.50	5.5
n =	78	121

[a] includes all elk killed and aged, not just those used in the DFA.

[b] includes some elk that were aged based on antler characteristics.

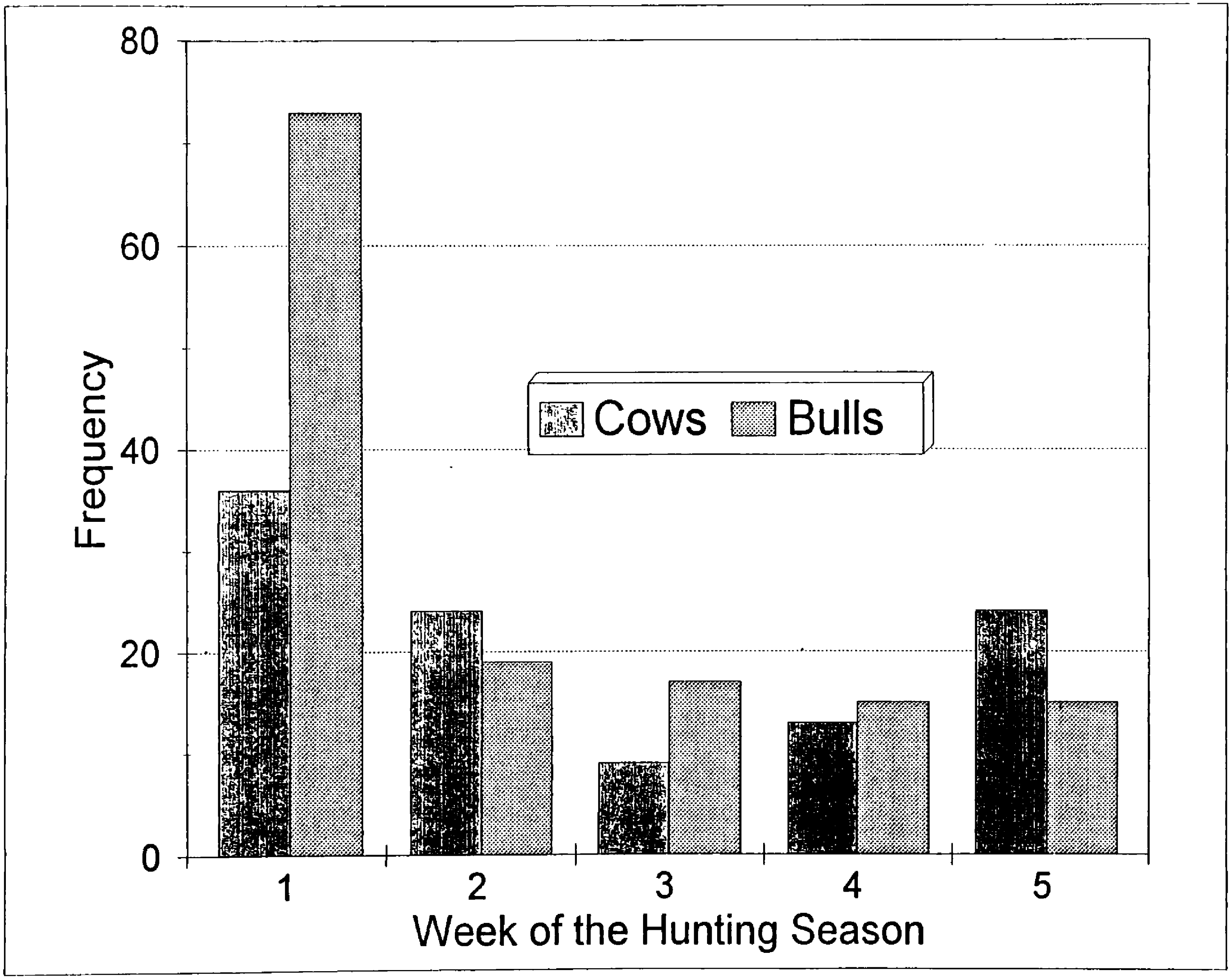

Figure 5. Weekly summary of elk harvest

Table 7. Summary of sites used in the discriminant function analysis

	Proximity to any road	Proximity to an open road	Proximity to water	Vegetation class
Elk Kill Sites (*n* = 84)				
Mean	192	1,540	356	
Median	142	1,085	315	Douglas fir
Standard deviation	194	1,486	234	
Standard error	21	162	26	
Minimum	0	9	1	
Maximum	939	5,646	911	
Live Elk locations (*n* = 267)				
Mean	315	2,545	465	
Median	231	2,527	450	lodgepole pine
Standard deviation	273	1,405	287	
Standard error	17	86	18	
Minimum	2	3	14	
Maximum	1,741	5,770	1,384	
Random points (*n* = 166)				
Mean	223	1,301	307	
Median	152	882	268	Douglas fir
Standard deviation	221	1,286	223	
Standard error	17	100	17	
Minimum	3	5	1	
Maximum	1,297	6,171	860	

Note: all distances are given in meters

proximity to open road measurements revealed that live elk locations were found, on average, 1,000 m (3,281 ft.) farther from open roads than either elk kill sites or random points. However, due to relatively large standard deviations, when a 66% confidence interval was applied, each measurement was found to exhibit a great deal of overlap between groups. The vegetation class where most elk kill sites and random points were found was the *Douglas-fir vegetation class* (20% of both elk kill sites and random points), which was the most common vegetation class. Live elk locations were typically associated with the *lodgepole pine vegetation class* (52%).

Biological and Statistical Results

The site specific database contained 10 variables and provided an overall correct classification of 53% using *proximity to open road* and *vegetation-change* variables (Table 8). As previously mentioned, the mean distance of live elk locations from an open road was found to be approximately 1,000 m farther than either elk kill sites or random points (Table 7). The *vegetation-change* variable identified those polygons that had sustained losses in vegetative cover since 1984 using four discrete classes (polygons with a vegetation-change classification of 1 were those areas that had sustained no vegetation-change, a classification of 2 designated a polygon with intermediate vegetation loss, a classification of 3 designated a polygon with high vegetation loss, and 4 designated those polygons that had

Table 8. Variables used in discriminant function analyses

Points analyzed	Landscape Scales		
	Site specific	**Near analysis**	**Far analysis**
All points (elk kill sites, live elk locations, AND random points)	Proximity to open road Vegetation-change	Lodgepole pine Non-road pixels	Open Douglas-fir Open road pixels
Paired groups (elk kill sites and live elk locations, live elk locations and random points)	Proximity to open road Vegetation-change	Open Douglas-fir	Open Douglas-fir Open road pixels

exhibited gained vegetation). All points used in this study were ordinarily associated with areas of no vegetation-change (class 1). However, closer examination revealed that while 95% of all live elk locations were found in areas of no vegetation-change, only 60% of elk kill sites were found in these areas. Further, 35% of elk kill sites were found in areas of intermediate vegetation loss (e.g., shelterwood and selection harvest treatments). Vegetation-change did not enter into either the near or far analysis DFA. This could be due to the slightly different method of measurement used in these databases. Site specific analysis identified the vegetation-change class found at each elk kill site, live elk location, and random point, while the *vegetation-change* variable used in the near and far analysis databases was a measure of the area occupied by each of the four vegetation-change classes within the sampling perimeter.

The near analysis database (containing a description of the landscape within a 200 m (656 ft.) radius of each elk kill site, live elk location, and random point) used 32 variables and provided an overall correct classification of 50%. The variable included during the first step was the number of pixels of the *lodgepole pine vegetation class* followed by the number of *non-road pixels*.

The far analysis database (containing a description of the landscape within a 700 m (2,297 ft.) radius of each elk kill site, live elk location, and random point) incorporated the same 32 variables used in the near analysis and provided an overall correct classification of 49%. The variable included in the far analysis DFA at step one was the number of pixels of the *open Douglas-fir vegetation class* followed by the number of pixels of *open road.*

To further investigate the importance of the specific vegetation classes used by the DFA, a use-availability comparison was made using a Chi-square test (Neu et al. 1974, Byers et al. 1984). Use was calculated as the relative percent of each vegetation class identified by a live elk location (site specific). Home range polygons were determined for both elk herds in the study area with the adaptive kernel method (Worton 1989) using 112 independent live elk locations. Availability was calculated as the relative percent of each vegetation class contained within the home range of each elk herd. The results from each home range were first examined individually, and then combined and reported in Table 9. Elk use of the *Douglas-fir vegetation class* did not exceed the availability of the vegetation class, however, 20% of live elk locations used in the study were found in the *Douglas-fir vegetation class,* demonstrating the importance of these forests. Elk use of the *lodgepole pine vegetation class* significantly exceeded availability, while use of the *open Douglas-fir vegetation class* was not significantly different than its availability.

Habitat use described by live elk locations was found to be different than the habitat use described by elk kill sites (Table 10). Habitat use described by live elk locations were also different than random points;

Table 9. Chi-square test of elk use during the hunting season and vegetation class availability

Vegetation class	Observed (use) Relative %	Expected (availability) Relative %	Chi-value
Cropland/ pasture	0.5	0.5	0.0
Foothills/ parklands	1.6	6.9	4.0
Disturbed grasslands	0.5	0.7	0.1
Other herbaceous	0.5	3.5	2.6
Sagebrush	1.1	5.4	3.5
Mixed grass/ shrub	0.5	0.7	0.1
Lodgepole pine	51.9	17.9	64.3
Ponderosa pine	7.0	5.3	0.5
Douglas fir	20.0	20.0	0.0
Mixed coniferous	9.7	20.2	5.5
Open Douglas-fir	4.3	9.9	3.1
Regenerating clearcut	1.6	2.1	0.1
		Chi-square	83.8
		Critical Chi-value (0.05)	19.7
		d.f.	11

Note: These results are the mean values for both elk herds.

Table 10. Summary of probability values from F-test of groups used in the discriminant function analysis

	Elk kill sites	Live elk locations
Live elk locations	0.00	n/a
Random points	0.32	0.00

however, no difference existed between elk kill sites and random points. A close examination of the variables used in the DFA was performed to help explain this finding. While live elk locations were found approximately 1 km (0.6 mile) farther from open roads than either elk kill sites or random points, the minimum and maximum distances from an open road are nearly identical. Further, all points used in this study (elk kill sites, live elk locations, and random points) were typically associated with areas that had sustained no vegetation-change within the past 10 years. The importance of these variables suggest a biological effect. Specifically, these results reveal a relatively uniform distribution of elk from open roads with increasing vulnerability close to open roads, and demonstrate selection by elk for sites without disturbance (Fig. 6).

A comparison of the mean patch size of *lodgepole pine vegetation class* polygons selected by elk ($\bar{x}$ = 77.65 km^2, n = 120), with the mean patch size of all *lodgepole pine vegetation class* polygons ($\bar{x}$ = 0.34 km^2, n = 415), and with the mean patch size of all vegetation polygons ($\bar{x}$ = 0.16 km^2, n = 7,168), was made using a Z-test. In all cases a significant difference was found ($P < 0.05$).

Subsets of the original databases where cow elk and 1.5 year-old bull elk, and/ or killed radio-collared elk were removed from the sample were analyzed using an F-test. For any of the exclusion subsets to have been considered valid a difference should have been seen between groups 1 and

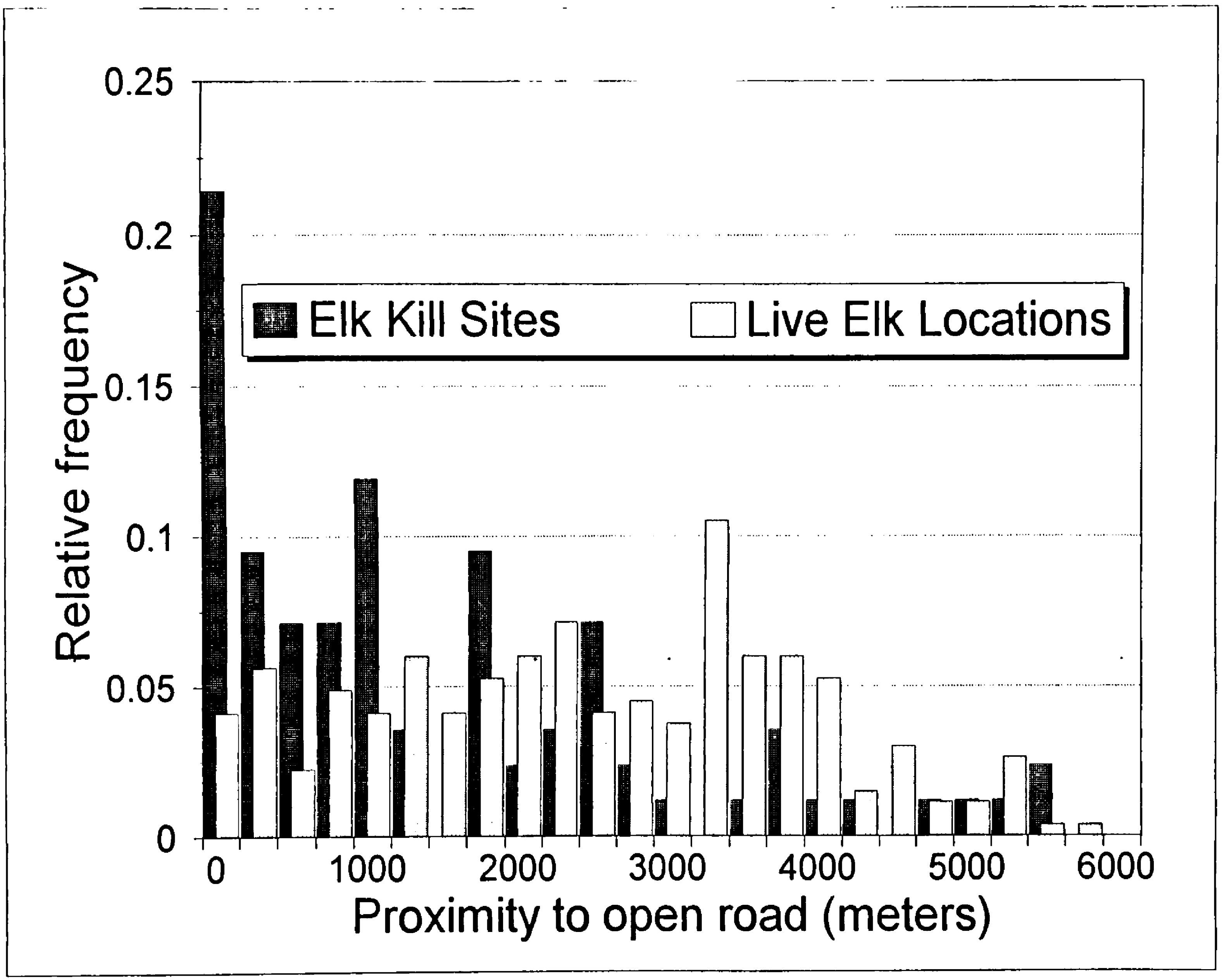

Figure 6. Proximity to open road distribution of elk kill sites and live elk locations

2, or between groups 3 and 4, or between group 6 and groups 3 or 4. No significant difference between these subset groups was revealed (Table 11).

The best correct classification was achieved using the site specific database. At this scale, live elk locations were correctly classified 80% of the time (Table 12). The resulting eigenvalues reveal a relatively low ratio of between-groups to within-groups sums of squares. This indicates that the within-groups variance is nearly as large as the between-groups variance, and that a fair amount of overlap exists when comparing the descriptions of each group. This helps explain why overall classification rates were not very high (Norusis 1990). Kappa values (Titus et al. 1984) indicate that the DFA performed approximately 29% better than would be expected by chance alone (Table 12). Further, all three classifications were found to be statistically significant using a Z test ($P < 0.05$). Paired group tests produced similar results, but typically yielded higher correct classification rates (Table 13).

Table 11. Summary of probability values from F-test of exclusion database subsets

	Group 1	Group 2	Group 3	Group 4	Group 5
Group 2	0.34				
Group 3	0.00	0.00			
Group 4	0.00	0.00	0.24		
Group 5	0.31	0.46	0.00	0.00	
Group 6	0.00	0.00	0.38	0.38	0.00

Note: Group 1 (cow and spike bull elk kill sites) n = 67
Group 2 (adult bull elk kill sites). n = 17
Group 3 (cow and spike bull elk live locations) n = 192
Group 4 (adult bull elk live locations) n = 75
Group 5 (random points) n = 166
Group 6 (killed radio-collared elk locations) n = 83

Table 12. Results of discriminant function analysis

Database type	% Correctly classified: Elk kill sites	Live elk locations	Random points	Kappa	Z
Site specific	41	80	39	0.32	8.7
Near analysis	31	66	52	0.30	8.9
Far analysis	38	63	46	0.26	7.7
	n = 84	*n* = 267	*n* = 166		

Table 13. Results of paired discriminant function analysis

Database type	% Correctly classified: Elk kill sites	Live elk locations	Random points
Site specific analysis			
Elk kill sites and live elk locations	57	90	
Live elk locations and random points		82	55
Near analysis			
Elk kill sites and live elk locations	51	78	
Live elk locations and random points		78	54
Far analysis			
Elk kill sites and live elk locations	67	68	
Live elk locations and random points		65	75

CHAPTER IV

DISCUSSION

Points Used in the Study

Forty-nine percent of the bulls killed in the study area were 1.5 years-old. At this age bull elk have grown their first set of antlers (normally spikes), and are usually associated with cow groups (Geist 1982). Cow groups typically contain more animals than do the bachelor bull groups and may be easier for hunters to locate as they inevitably leave more tracks. For this reason, spike bulls may be more vulnerable to hunting. Another potential reason why spike bulls may seem more vulnerable to hunting is that this cohort contains the largest number of individuals and correspondingly, accounts for the largest proportion of kill sites. In comparison, the age of cows killed in the study area was relatively uniform. The mean age of elk killed (and aged) in the study area was approximately 2 years for bulls, and approximately 3 years for cows. This deviation may reflect a real difference in the age structure of the elk population or disproportionate vulnerability between 1.5 year-old bulls and mature bulls. Another factor affecting the reported age distribution of killed elk was the number of cows that were brought to the game check station in quarters (n = 31 (28%)). In speculation, it seems likely that at least some of these cows were older, larger animals, and because of their size, were more manageable by the hunter in quarters than in 1 piece. Similarly, smaller, younger animals were more likely to be brought to the game check station in 1 piece. As a result, younger cows may have had a greater probability of being aged than older cows. Based on the relatively small proportion of unaged cows it seems unlikely that the mean age of killed cow elk would change much even if all the unaged cows were older animals (> 4.5 yrs).

As noted earlier, the number of bull elk killed during the first week of the hunting seasons was approximately equal to the total number of bulls killed during the remaining four weeks. Decreased hunting pressure after the first week of the season may offer a partial explanation for this observation, however another important factor was that fewer bulls were left alive after the first week of the hunting season.

Biological Interpretations

Elk kill sites could not be differentiated from random points with the variables used in this study. This does not imply that elk or hunters use the landscape randomly, rather it reflects the random occurrence of a specific sequence of events, such as a hunter and an elk in close proximity of each other, and the hunter detecting and shooting the elk without the elk first detecting the hunter and escaping.

Live elk locations were found approximately 1,000 m (3,281 ft.) further from open roads than random points or elk kill sites. Other road variables were included in both the near and far analysis (e.g., the number of *non-road*, and *open road* pixels, respectively). This illustrates a discernible benefit of walk-in areas and the increased vulnerability of elk in areas where roads remain open during the hunting season. Numerous other studies have reported similar results concerning the influence of roads on elk habitat effectiveness (Lyon and Christensen 1992) and use (Marcum 1975, Perry and Overly 1976, Rost and Bailey 1979, Lyon and Ward 1982, Skovlin 1982, Irwin and Peek 1983, Daneke 1980, Edge 1985, Lyon et al. 1985), and elk vulnerability (Lyon and Canfield 1991). The influence of roads and tree canopy on habitat effectiveness was studied by Lyon (1979 and 1983), who found that as road density increased, habitat effectiveness for elk decreased, and that this effect can be offset to some degree by maintaining forested cover adjacent to the road. Basile and Lonner (1979) reported that while unrestricted road travel was detrimental to elk security, vehicle restrictions on existing roads seemed to increase hunter effort. Hunters using walk-in areas will undoubtedly exert more effort, but they will not cover as much area, and may not be able to access sites farthest from the trailhead. In the Clearwater Drainage of Idaho, Unsworth and Kuck (1991) and Unsworth et al. (1993) studied bull elk vulnerability and habitat use by comparing mortality in roaded and unroaded portions of their study area.

Annual survival rates of bull elk in roaded areas were significantly lower than in unroaded areas.

Live elk locations used in this study were associated with areas having no vegetation-change in the past 10 years. Although, elk kill sites were also associated with areas of no vegetation-change, 35% of elk kill sites were found in areas of intermediate vegetation loss (e.g., shelterwood and selection harvest treatments). Live elk appeared to spend relatively little time (4%) in areas with intermediate vegetation loss. This suggests that elk vulnerability increased where a timber harvest treatment had occurred.

The *open Douglas-fir vegetation class* was not selected by elk in the study area during hunting season. Only 5% of live elk locations were found in the *open Douglas-fir vegetation class* compared to nearly 17% of elk kill sites. This indicates that elk vulnerability increased in the *open Douglas-fir vegetation class* which is characterized by minimal canopy cover (< 31%) and a lack of hiding cover. This agrees with the results of other researchers (Irwin and Peek 1983, Wright 1983, Canfield 1988, and Hurley and Sargeant 1991), who found that elk use of open areas decreased during the hunting season. Elk that ventured into poor security areas, such as the *open Douglas-fir vegetation class* and timber harvest areas, had an increased probability of being killed. Further, Vales (1996) reported that elk vulnerability increases as security cover decreases.

Elk use of the *lodgepole pine vegetation class* significantly exceeded availability. All other vegetation classes showed use to be approximately equal to availability. A characteristic of the study area is that the most popular trailheads are located at low elevations (approximately 1,128 m (3,700 ft.)). From these points, elevation increases as one enters the walk-in area. *Lodgepole pine vegetation class* polygons are found at relatively high elevations (approximately 1,524 m (5,000 ft.) or more) and consequently, are not in close proximity to many trailheads. A potential explanation for elk selection of the *lodgepole pine vegetation class* may be that this variable is correlated with the *proximity to open road* variable used in site specific analysis, and that elk are simply selecting sites that are farthest from human activity (Marcum 1975, Lyon and Ward 1982, Skovlin 1982, and Edge 1985). A correlation test was performed using *proximity to open road* measurements on the X-axis, and the number of pixels of the *lodgepole pine vegetation class* occurring within a 200 m (656 ft.) radius of each elk kill site and live elk location, on the Y-axis. The results of this test indicated that only 15% of the variation in the *lodgepole pine vegetation class* variable was explained by the *proximity to open road* variable ($r = 0.39$, $n = 243$). Therefore, elk use of the *lodgepole pine vegetation class* was not an expression of *proximity to open road.*

Several studies have indicated that patch size may be important to elk security (Lyon and Canfield 1991, Hillis et al. 1991). The mean patch size of the *lodgepole pine vegetation class* polygons selected by elk is much larger than the mean patch size of the available polygons. This is because the majority of live elk locations were found in the largest available polygon on the landscape, indicating selection for large patch sizes during the hunting season. Selection for large patch size has been previously reported by Lyon and Canfield (1991). They found the smallest patch associated with an elk location increased from 0.38 km^2 (0.14 mi^2) before hunting season, to 0.63 km^2 (0.24 mi^2) after the onset of the hunting season.

Hiding cover was determined for each ground-truth sample by estimating how often an elk could be seen at a distance of 61 m (200 ft.). Three discrete classes were used; a value of 1 indicated that elk would be seen all the time, 2 indicated that an elk would be seen part of the time, and 3 indicated that an elk would never be seen (cf. Skovlin 1982). The *lodgepole pine vegetation class* had the highest hiding cover estimate and potentially the highest canopy cover. The *open Douglas-fir vegetation class* had a comparatively low hiding cover estimate and a canopy cover of $<$ 31%. This may be one of the simplest and most plausible reasons that elk selected the *lodgepole pine vegetation class*. Other studies have arrived at similar conclusions and found that elk select sites with high canopy closure and/ or dense cover (Marcum 1975, Edge et al. 1988, Hillis et al. 1991). Irwin and Peek (1983) found that elk preferred pole-timber sites with $>$ 75% canopy closure and that there was little use of clearcuts, grass-shrub, or brushfield sites. Hurley (1994), and Hurley and Sargeant (1991) 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.

Lyon (pers. comm.) noted that use of both the *lodgepole pine* and *open Douglas-fir vegetation classes* by hunters in Chamberlain Creek was equal to availability. A direct relationship between elk use and hunter density was not evident, however many of my data, results, and observations indicate that elk were indirectly responding to hunting pressure by selecting sites that reduced their vulnerability (e.g., sites farther from open roads with densely forested cover in large patches).

Elk selection for the *lodgepole pine vegetation class* could have been forage based. I collected no data concerning forage availability or use within the vegetation classes, however, Edge et al. (1988) reported that late summer elk habitat use in Chamberlain Creek shifted to more closed canopy sites, probably in response to decreased palatability of forage on more open sites. Vegetation growing in shaded areas remains in a more nutritious state than that grown in open areas (Hanley et al. 1989). After freezing temperatures have killed the succulent vegetation (usually by mid to late September (Marcum, pers. comm.)) elk satisfy their energy requirements by relying on the cured forage found in open areas (Marcum 1975).

The *lodgepole pine vegetation class* may provide a security area for elk. This alternative seems more feasible than selection for forage because there is relatively little forage in lodgepole pine forests. However, Marcum (1975) found bear grass (*Xerophyllum tenax*) constituted 24% of the rumen volume of hunter killed elk in the Sapphire Mountains of western Montana. Bear grass was commonly found in the understory of the *lodgepole pine vegetation class* in the study area. Still, elk used the largest polygon on the landscape and selected sites with the highest available hiding cover and canopy cover. These characteristics describe the *lodgepole pine vegetation class*.

Several studies have identified clearcuts as having a detrimental impact on elk use of the landscape. In Chamberlain Creek, elk use of clearcuts during hunting season was minimal. In my study, only 1 live elk location was found in a clearcut polygon during three hunting seasons. Similarly, only 5 elk kill sites were found in clearcut polygons. These observations tend to support the research of Marcum (1976), Lyon (1976), Lyon and Jensen (1980), and Edge and Marcum (1985). In each of these studies, elk activity was directed away from the disturbance of logging. Other studies have demonstrated that elk use of clearcuts was less than expected (Marcum 1975, and Marcum et. al 1984). The degree to which elk avoided or otherwise failed to use clearcuts was influenced by cover considerations, and proximity to open roads.

Selection by elk for north aspects was reported by Irwin and Peek (1983). Another study that found aspect to be important in elk use of the landscape was Marcum et al. (1984). My study failed to identify aspect as an important variable. However, the goal of this study was to identify landscape elements that influence elk security and not necessarily those that best describe elk use of the landscape. This fundamental difference in study objective may explain why aspect was not detected by DFA. Another potential explanation concerns the method used to determine aspect. In my study, modal aspect for each vegetation polygon was used to describe the aspect at each point (elk kill site, live elk location, and random point). The fact that this variable represents a generalization for all the 30 m (98.4 ft.) pixels in an entire polygon may help explain why aspect was not detected by DFA.

The effect of snow depth was not included in my analysis of elk mortality because the objective of my study was to identify landscape characteristics that land managers can control, alter, or manipulate to improve elk security. However, the effect of snow depth on elk movement and its potential influence on elk vulnerability is not challenged by the results of this study (cf. Youmans 1991). To address the effect of snow on elk vulnerability, I recorded the estimated snow depth at each elk kill site, and examined the distribution of elk kill sites relative to snow depth. I found an inverse relationship between the frequency of elk kills and snow depth.

However, a direct inference is not appropriate in this case. The majority of elk kills occurred during the first week of hunting season which coincides with the period of least snow depth. Further, snow cover during 1993, 1994, and 1995 hunting seasons was relatively uniform among these years, and so the influence of snow cover on elk vulnerability could be not determined.

I believe that elk selected the *lodgepole pine vegetation class* to increase their security. The *lodgepole pine vegetation class* achieved increased security not by being composed primarily of lodgepole pine, but by having substantial hiding cover, canopy cover, and large patch size. Of interest, is that of the 415 individual polygons assigned the *lodgepole pine vegetation classification*, elk in the study area routinely selected the same 10 polygons, with 85% of those locations occurring in the same polygon. This polygon, as alluded to earlier, was the largest available polygon on the landscape. In light of this, two points must be kept in mind. First, if the locations were randomly distributed, large polygons should contain more point locations than smaller polygons. Therefore, this alone would not indicate selection for large patches. However, when coupled with the data that I have presented regarding patch size comparisons, use-availability tests, and the results of DFA, selection for large patches becomes more credible. Second, elk probably cannot detect polygon boundaries between most forested vegetation classes. Thus, the vegetation classification becomes less important than the characteristics used to describe them. The results of this study demonstrate that elk selected particular elements of the landscape during the hunting season. These sites or areas:

1) were not in close proximity to open roads,
2) had a low road density , and
3) contained forested cover in large patches, which:
    a) had no significant change in vegetation within the past 10 years, and
    b) provided substantial hiding cover.

Based on the results of this study and associated field observations, elk responded to hunting season pressure in one of two ways. The first was to seek large areas of forested cover with dense canopy closure and substantial hiding cover which are far from open roads. While these elk selected particular elements of a landscape that subsequently reduced their vulnerability to hunting, no site existed which could eliminate vulnerability. The second response was to seek property closed to hunting by the general public (Wright 1983, Hurley and Sargeant 1991). My study focused on detecting and explaining the variables important to elk security on land open to the general public. However, elk use of private ranches that are closed to the general public cannot be ignored. In 1993 and 1994 several large ranches in the study area were open to limited hunting for elk on their property. As a result, only 21% of live elk locations were found on these ranches in 1993, and only 18% in 1994. In 1995, hunting was not allowed on numerous ranches in the study area. The elk responded to this refuge effect, and as a result, 44% of live elk locations were found on these properties. Apparently, elk responded to the escapement provided by these ranches even though large forested security areas were not located on the ranch lands. These elk survived in areas that were near open roads, contained minimal hiding cover, but offered high quality forage (e.g., alfalfa) and security. A problem associated with this scenario is that elk are much more vulnerable to hunting while on the ranch because no large areas of forested cover exist, and elk may have become habituated to ranch activities and the presence of people. When disturbed, elk left the private ranches and sought security areas in high elevation forests. In the process of travelling from low elevation private ranches to high elevation forests, elk passed through sparsely forested foothills where hunter density and elk vulnerability was highest.

Assessment of Error and Bias

Hunters who killed an elk may have been reluctant to participate in the study and disclose the actual location of the kill site. While hunters were not obligated to participate in the study, the overwhelming majority were very cooperative (99%). Even with their cooperation however, less than half of all reported elk kill sites were located in the field. This was primarily due to weather conditions, and/ or errors in map interpretation.

Elk kill sites that were most likely to be found and included in the DFA were those that were relatively easy to locate (i.e., close to roads, trailheads, and in open areas). This bias may have affected my study by decreasing the mean proximity to open roads for elk kill sites. However, the maximum distance from an open road was nearly identical for both elk kill sites (5.6 km (3.5 miles)) and live elk locations (5.7 km (3.6 miles)). This suggests that because of the heavily-roaded condition of the study area, elk cannot find areas that are more than 6 km (3.7 miles) from an open road. Based on this potential, the actual error caused by this bias may have been minimal. Further, I examined all elk kill site reports that were not located in the field, and plotted each using the point identified by the hunter (n = 69). Using PC ARC/INFO (NEAR) I determined the proximity of each point to an open road ($\bar{x}$ = 1,280 m (4,200 ft.)), and to any road ($\bar{x}$ = 250 m (820 ft.)). Using PC ARC/INFO (IDENTITY) I determined the Douglas-fir vegetation class was most often found at these points. These results are nearly identical to those reported for the elk kill sites used in my analysis (Fig. 7).

Hunters seeking trophy animals may pass-up an elk that could have been killed, resulting in elk kill sites that reflect selection by hunters instead of poor security decisions by elk. To address this possible bias, 55 hunters who had killed an elk in 1995 were asked whether they had passed-up any elk that could have been legally harvested. Ninety-three percent indicated

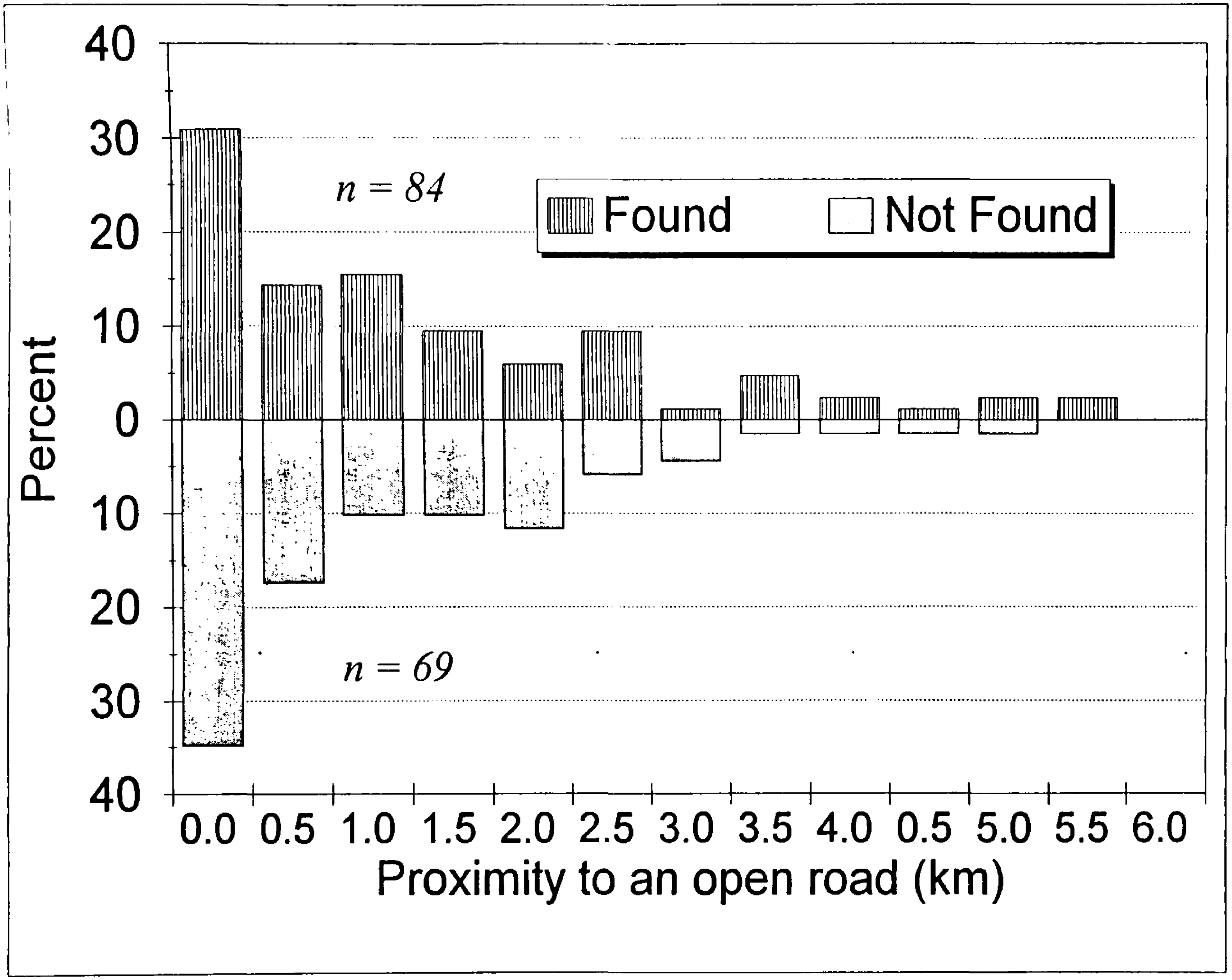

Figure 7. Proximity to open road distribution of elk kill sites that were found versus those that were not found.

they shot the first legal elk they saw. Based on this finding, I assumed that this potential bias was negligible.

Several new roads were constructed during the study that were not included on the GIS coverage, resulting in measures of proximity that exceed the real distance. This error affects proximity measurements for <u>all</u> point locations (elk kill sites, live elk locations, and random points) and is therefore relatively inconsequential because no bias was established.

The vegetation classes used in this study were the result of a supervised classification based on a set of 242 ground-truth data. While many polygons were correctly classified, some were incorrectly classified, and others were correct only as a gross generalization (e.g., a polygon labelled lodgepole pine might consist primarily of lodgepole pine but may also contain a considerable percentage of Douglas-fir). In addition, structural heterogeneity existed within the vegetation classes. However, because this error affects all groups (elk kill sites, live elk locations, and random points) equally, no bias was established.

No significant covariates or correlates were found in the databases. Data used in the DFA were not normally distributed even after a log transformation was performed. However, violation of this assumption is typical of wildlife studies (Green 1974, and Edge et al. 1987) and, due to the robustness of DFA (Klecka 1975), these results should be viewed as confirmatory and not exploratory or descriptive in nature (Morrison et al. 1992).

Management Implications

Implementing the following conditions in timber harvest planning, road construction, and property development (etc.) has the potential to dramatically decrease the vulnerability of elk in a given area; 1) properly designed road closures (i.e., walk-in areas) that provide elk with areas that are at least 1 km (0.62 mile) from an open road, 2) zero open road density and a relatively low closed road density, and 3) large forested patches with high canopy closure, and hiding cover estimates that provide elk with complete or nearly complete concealment at a distance of 61 m (200 ft.). These considerations must be applied collectively to be effective as elk vulnerability is only marginally decreased by forested cover with high canopy closure while maintaining an unrestricted use of roads (cf. Lyon 1979). It does not seem feasible to assign threshhold values to act as maximum road density or minimum patch size guidelines. However, my data suggests that the minimum patch size required by elk is larger than previously recommended (100 ha (250 acres), 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 forested cover variables.

Elk in the study area presumably used the landscape in ways similar to elk in other regions, states, or provinces. The results of this study agree with numerous other research projects regarding elk security and vulnerability. I found that open roads were detrimental to elk security, which confirms previous research by Unsworth and Kuck (1991). Further, elk security increased in large forested patches that contained substantial hiding cover, and had dense canopy closure. These same results were reported by Hurley and Sargeant (1991). Accordingly, the conclusions arrived at by this study should be applicable to other elk herds.

CHAPTER V

SUMMARY OF RESULTS

Elk kill sites could not be reliably differentiated from random points. Live elk locations were correctly differentiated from elk kill sites and random points using two variables in each of three analyses (site specific, near, and far). Landscape elements selected by elk:

1) were not in close proximity to open roads,
2) had a low road density , and
3) contained forested cover in large patches, which:
   a) had no significant change in vegetative cover within the past 10 years, and
   b) provided substantial hiding cover.

Live elk locations were found an average of 1,000 m (3,281 ft.) farther from open roads than elk kill sites. Only 17% of live elk locations and 45% of elk kill sites were found within 1,000 m (3,281 ft.) of an open road. Elk may have been using these areas for forage (especially when snow had covered the vegetation at higher elevations), or may have been travelling from lower elevation private ranches to higher elevation security areas due to some disturbance encountered on the private ranch.

Elk locations were found in areas with no vegetation-change. However, 4% of live elk locations and 35% of elk kill sites were found in areas where shelterwood or selection harvest treatments had occurred. Elk vulnerability increased in areas that had sustained vegetation losses by any of the various timber harvest methods (e.g., shelterwood, selection, seed tree, or clearcut treatments).

While only 5% of live elk locations were found in the *open Douglas-fir vegetation class* (which is characterized by < 31% canopy cover, and a lack of hiding cover), 17% of elk kill sites occurred there. In contrast, 52% of live elk locations occurred in the *lodgepole pine vegetation class* (characterized by dense canopy closure and substantial hiding cover) and only 8% of elk kill sites. Elk use of the *open Douglas-fir vegetation class* was equal to availability, however elk vulnerability increased in and near these areas.

The summary of landscape elements selected by live elk does not describe security areas that are independent of other influences. With sufficient hunting pressure any elk is vulnerable in any type of cover (Lyon and Canfield 1991). Further, elk security is dynamic and based ultimately on moment-to-moment decisions and reactions by the animal. Security areas must meet not only cover and topographic requirements, they must also be large enough to ameliorate the effect of concentrated hunting pressure.

Hunter density was not detected by DFA but will become more important in the future as hunter numbers increase (Flather and Cordell 1995) and/ or elk security areas are further depleted. Additional research needs to be conducted to better understand the role of increasing hunter densities on elk security (Vaske et al. 1995, Knight and Cole 1995).

LITERATURE CITED

Basile, J. V., and T. N. Lonner. 1979. Vehicle restrictions influence elk and hunter distributions in Montana. J. Forestry 77:155-159.

Barrett, E. C., and L. F. Curtis. 1992. Introduction to environmental remote sensing. 3rd ed. Chapman & Hall, London. 426 pp.

Byers, C. R., R. K. Steinhorst, and P. R. Krausman. 1984. Clarification of a technique for analysis of utilization-availability data. J. Wildl. Manage. 48:1050-1053.

Canfield, J. E. 1988. Impact mitigation and monitoring of the BPA 500-KV Garrison-Taft transmission line- effects on elk security and hunter opportunity. Final report, MT Dept. Fish, Wildlife, and Parks. 162 pp.

Christensen, A. G., L. J. Lyon and T. N. Lonner, comps. 1991. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman, Mont. 330 pp.

Daneke, D. E. 1980. Forage selection and population structure of the middle fork elk herd. M.S. Thesis, The Univ. of Montana, Missoula. 74 pp.

Edge, W. D. 1982. Distribution, habitat use and movements of elk in relation to roads and human disturbance in western Montana. M.S. Thesis, The Univ. of Montana, Missoula. 98 pp.

Edge, W. D. 1985. Habitat use and food habits of elk in western Montana. PhD. Thesis, The Univ. of Montana, Missoula. 76 pp.

Edge, W. D., and C. L. Marcum. 1985. Movements of elk in relation to logging disturbance. J. Wildl. Manage. 49:926-930.

Edge, W. D., C. L. Marcum, S. L. Olson-Edge. 1987. Summer habitat selection by elk in western Montana: A Multivariate Approach. J. Wildl. Manage. 51:844-81.

Edge, W. D., C. L. Marcum, S. L. Olson-Edge. 1988. Summer forage and feeding site selection by elk. J. Wildl. Manage. 52:573-77.

Flather, C. H., and H. K. Cordell. 1995. Outdoor recreation: historic and anticipated trends. Pages 3-16. in R. L. Knight, and K. J. Gutzwiller, eds. Wildlife and recreationists: coexistence through management and research, Island Press, Washington D.C.

Garmin. 1992. Owner's manual. PN 1023-S Rev. 1. Garmin communication and navigation. Lenexa, KS.

Geist, V. 1982. Adaptive behavioral strategies. p. 219-278. in J. W. Thomas, and D.E. Toweill. Elk of north america: Ecology and management. Wildlife management institute. Harrisburg, Pa.

Glassy, J. M., and L. J. Lyon. 1989. MAYA- A PC based environment for analyzing wildlife habitat. Application of geographic information systems to forestry, fisheries, and wildlife (Center for streamside studies, Univ. of Wash., Wenatchee. May 18-21, 1989). 16 pp.

Green, R. H. 1974. Multivariate niche analysis with temporally varying environmental factors. Ecology 55:73-83.

Hanley, T. A., C. T. Robbins, and D. E. Spalinger. 1989. Forest habitats and the nutritional ecology of Sitka-blacktail deer: A research synthesis with implications of forest management. USFS Gen. Tech. Rep. PNW-GTR-230. 52 pp.

Hart, M. M. 1994. Past and present vegetative and wildlife diversity in relation to an existing reserve network: A GIS evaluation of the Seeley-Swan landscape, northwestern Montana. M.S. Thesis, The Univ. of Montana, Missoula. 288 pp.

Hillis, J. M., M. J. Thompson, J. E. Canfield, L. J. Lyon, C. L. Marcum, P. M. Dolan, D. W. McCleerey. 1991. Defining elk security: the Hillis paradigm. Pages 38-54. in A. G. Christensen, L. J. Lyon and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Hitchcock, C. L., and A. Cronquist. 1973. Flora of the pacific northwest. Univ. of Washington press, Seattle. 730 pp.

Hurley, M. A. 1994. Summer-fall ecology of the Blackfoot-Clearwater elk herd in western Montana. M.S. Thesis, University of Idaho, Moscow, Id. 138 pp.

Hurley, M. A., and G. A. Sargeant. 1991. Effects of hunting and land management on elk habitat use, movement patterns, and mortality in western Montana. Pages 94-98. in A. G. Christensen, L. J. Lyon and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Irwin, L. L., and J. M. Peek. 1983. Elk habitat use relative to forest succession in Idaho. J. Wildl. Manage. 47:664-672.

Klecka, W. R. 1975. Discriminant analysis. Pages 434-467. in SPSS: Statistical package for the social sciences. McGraw-Hill, New York, N.Y.

Knight, R. L., and D. N. Cole. 1995. Factors that influence wildlife responses to recreationists. Pages 71-79. in R.L. Knight, and K.J. Gutzwiller, eds. Wildlife and recreationists: coexistence through management and research, Island Press, Washington D.C.

Leckenby, D., C. Wheaton, and L. Bright. 1991. Elk vulnerability- the Oregon situation. Pages 89-93 in A. G. Christensen, L. J. Lyon and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Lehmkuhl, J. F. 1981. Distribution and habitat selection of elk in the north Garnet Mountains of western Montana. M.S. Thesis. The Univ. of Montana, Missoula. 130 pp.

Leptich, D. J., and P. Zager. 1991. Road access management effects on elk mortality and population dynamics. Pages 126-131 in A. G. Christensen, L. J. Lyon and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Lieb, J. W. 1981. Activity, heartrate, and associated energy expenditure of elk in western Montana. PhD. Thesis. The Univ. of Montana, Missoula. 200 pp.

Lyon, L. J. 1976. Elk use as related to characteristics of clearcuts in western Montana. Pages 69-72 in J. M. Peek, and S. R. Hieb, eds. Elk-logging-roads symposium proceedings. Univ. of Idaho, Moscow, Id.

Lyon, L. J. 1983. Road density models describing habitat effectiveness for elk. J. Forestry 81:592-595.

Lyon, L. J. 1979. Habitat effectiveness for elk as influenced by roads and cover. J. Forestry 77:658-660.

Lyon, L. J., and A. G. Christensen. 1992. A partial glossary of elk management terms. USFS Gen. Tech. Rep. INT-288. 6 pp.

Lyon, L. J., and A. L. Ward. 1982. Elk and land management. Pages 443-447 in J. W. Thomas, and D.E. Toweill. Elk of north america: Ecology and management. Wildlife management institute. Harrisburg, Pa.

Lyon, L. J., and C. E. Jensen. 1980. Management implications of elk and deer use of clear-cuts in Montana. J. Wildl. Manage. 44:352-62.

Lyon, L. J., and J. E. Canfield. 1991. Habitat selections by Rocky Mountain elk under hunting season stress. Pages 99-105. in A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Lyon, L. J., and M. G. Burcham. 1995. Tracking elk hunters with global positioning systems. Paper presented at the Western States and Provinces 1995 Joint Deer and Elk Workshop, May 23-25, 1995, Sun Valley, Id.

Lyon, L. J., T. N. Lonner, J. P. Weigand, C. L. Marcum, W. D. Edge, J. D. Jones, D. W. McCleerey, and L. L. Hicks. 1985. Coordinating elk and timber management: Final report of the Montana cooperative elk-logging study 1970-1985. MT Dept. of Fish, Wildlife, and Parks. Bozeman. 53 pp.

Marcum, C. L. 1975. Summer-fall habitat selection and use by a western Montana elk herd. PhD. Thesis, The Univ. of Montana, Missoula. 188 pp.

Marcum, C. L. 1976. Habitat selection and use during summer and fall months by a western Montana elk herd. Pages 91-96 in J. M. Peek, and S. R. Hieb, eds. Elk-logging-roads symposium proceedings. Univ. of Idaho, Moscow, Id.

Marcum, C. L., W. D. Edge, M. D. Scott, J. F. Lehmkuhl, and S. L. Olson. 1984. Final report of the Chamberlain Creek elk study 1975-1984. School of Forestry, The Univ. of Montana, Missoula. 257 pp.

Morrison, M. L., B. G. Marcot, and R. W. Mannan. 1992. Wildlife-habitat relationships: concepts and applications. The University of Wisconsin Press, Madison. 343 pp.

Nelson, R. A. 1992. Handbook of Rocky Mountain plants. 4th Ed. Niwot, Colo. 444 pp.

Neu, C. W., C. R. Byers, and J. M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildl. Manage. 38:541-545.

Norusis, M. J. 1990. SPSS PC+: Advanced Statistics 4.0 for the IBM PC/XT/AT and PS/2. SPSS inc., Chicago, Ill.

Patterson, P. A., K. E. Neiman, and J. R. Tonn. 1985. Field guide to forest plants of northern Idaho. USDA Forest Service Gen. Tech. Rep. INT-180. Intermountain Research Station. Ogden, Ut. 246 pp.

Perry, C., and R. Overly. 1976. Impacts of roads on big game distributions in portions of the Blue Mountains of Washington. Pages 62-68 in J. M. Peek, and S. R. Hieb, eds. Elk-logging-roads symposium proceedings. Univ. of Idaho, Moscow, Id.

Pfister, R. D., B. L. Kovalchik, S. F. Arno, R. C. Presby. 1977. Forest habitat types of Montana. USDA Forest Service Gen. Tech. Rep. INT-34. 174 pp.

Prothero, W. L., J. J. Spillett, and D. F. Balph. 1979. Rutting behavior of yearling and mature bull elk: some implications for open bull hunting. Pages 160-165 in M. S. Boyce and L. D. Hayden-Wing, eds. North American elk: ecology, behavior, and management. Univ. Wyoming, Laramie.

Quimby, D. C., and J. E. Gaab. 1957. Mandibular dentition as an age indicator in Rocky Mountain elk. J. Wildl. Manage. 21:435-451.

Rost, G. R., and J. A. Bailey. 1979. Distribution of mule deer and elk in relation to roads. J. Wildl. Manage. 43:634-641.

Scott, M. D. 1978. Elk habitat selection and use on an undisturbed summer range in western Montana. M.S. Thesis, The Univ. of Montana, Missoula. 98 pp.

Skovlin, J. M. 1982. Habitat requirements and evaluations. Pages 369-414 in J. W. Thomas, and D. E. Toweill. Elk of North America: ecology and management. Wildlife Management Institute, Harrisburg, Pa.

Squibb, R. C., R. E. Danvir, J. F. Kimball, Jr., S. T. Davis, T. D. Bunch. 1991. Ecology of conception in a Northern Utah elk herd. Pages 110-118 in A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Thompson, S. K. 1987. Sample size for estimating multinomial proportions. Am. Statistician 41:42-46.

Titus, K., J. A. Mosher, and B. K. Williams. 1984. Chance-corrected classification for use in discriminant analysis: ecological applications. Am. Midl. Nat. 111:1-7.

Unsworth, J. W., and L. Kuck. 1991. Bull elk vulnerability in the Clearwater drainage of northcentral Idaho. Pages 85-88 in A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Unsworth, J. W., L. Kuck, M. D. Scott. 1993. Elk mortality in the Clearwater drainage of northcentral Idaho. J. Wildl. Manage. 57:495-502.

Vales, D. J., V. L. Coggins, P. Matthews, and R. A. Riggs. 1991. Analyzing options for improving bull:cow ratios of Rocky Mountain elk populations in northeast Oregon. Pages 181-94 in A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

Vales, D. J. 1996. Elkvuln: user's manual for elkvuln, an elk vulnerability, hunter, and population projection program, version 1.00. Univ. of Idaho, Moscow, Id. 24 pp.

Vaske, J. J., D. J. Decker, and M. J. Manfredo. 1995. Human dimensions of wildlife management: an integrated framework for coexistence. Pages 33-50. in R. L. Knight, and K. J. Gutzwiller, eds. Wildlife and recreationists: coexistence through management and research, Island Press, Washington D.C.

Worton, B. J. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164-68.

Wright, K. L. 1983. Elk movements, habitat use, and the effects of hunting activity on elk behavior near Gunnison, Colorado. M.S. Thesis, Colorado State Univ., Fort Collins, Colo. 206 pp.

Youmans, C. C. 1991. Analysis of long-term trends in elk vulnerability on th Bitterroot National Forest in relation to selected predictor variables. Pages 159-67 in A. G. Christensen, L. J. Lyon, and T. N. Lonner, comps. Proc. Elk Vulnerability Symposium, Montana State University, Bozeman.

APPENDIX A

VEGETATION CLASSIFICATION SYSTEM

The following classification system was used to identify the vegetation present in each polygon of the existing vegetation coverage. All cover percentages refer to canopy coverage.

COVER CODE	CLASS	DESCRIPTION
	Urban or Developed Land	
1500	Urban/ Industrial	
	Agriculture	
2101	Cropland/ Pasture	Small grains
		Fallow lands
		Shelter belts
2102	Irrigated Crops	Row crops
		Alfalfa
		Hay
2103	Rangelands	Crested wheatgrass
		Russian wildrye
		other dry-land pastures

COVER CODE	CLASS	DESCRIPTION
	Non-Forested Land	<15% forested
	Grasslands	<15% shrubs
3101	Foothills/ Parklands	Bluebunch wheatgrass
		Blue grama
		Idaho Fescue
		Lupine
		Shrubby cinquefoil
3102	Disturbed grasslands	Cheatgrass
		Japanese Brome
		Knapweed
3103	Other herbaceous	Clearcut with beargrass
		Fireweed
	Shrublands	≥30% shrubs
3201	Mesic upland shrub	Rocky Mountain Maple
		Serviceberry
		Western snowberry
		Ninebark
		Chokecherry
		Ceanothus
		Huckleberry

COVER CODE	CLASS	DESCRIPTION
3202	Xeric upland shrub	Raspberry
		Rose
		Mountain Mahogany
3206	Sagebrush	Mountain big sagebrush
		Bluebunch wheatgrass
	Mixed Grass & Shrubland	≥15% and <30% shrub
3301	Mixed Grass/ Shrub	Bitterbrush-grassland
		Sagebrush-grassland
3302	Other shrub	
	Forest Land	
4101	Broadleaf forest	>30% broadleaf and
		<30% conifers.
		Non-riparian areas.
	Coniferous forests	<30% broadleaf and
		>30% conifers.
4201	Spruce forest	Picea englemannii
4202	Lodgepole Pine forest	Pinus contorta

COVER CODE	CLASS	DESCRIPTION
4205	Ponderosa Pine forest	Pinus ponderosa
4211	Douglas fir forest	Pseudotsuga menzesii
4214	Western Larch forest	Larix occidentalis
4217	Mixed Coniferous forest	>2 spp., each with 15-30% total cover.
4250	Open Douglas fir	Douglas fir with a low canopy cover. Open park.
4260	Regenerating clearcut	A clearcut with a high percentage of tall (>8 ft.) regenerating trees.
	Water	
5200	Lakes	
	Riparian & Wetland Areas	Adjacent to surface water.
6201	Wet Meadows	Wet-moist meadow