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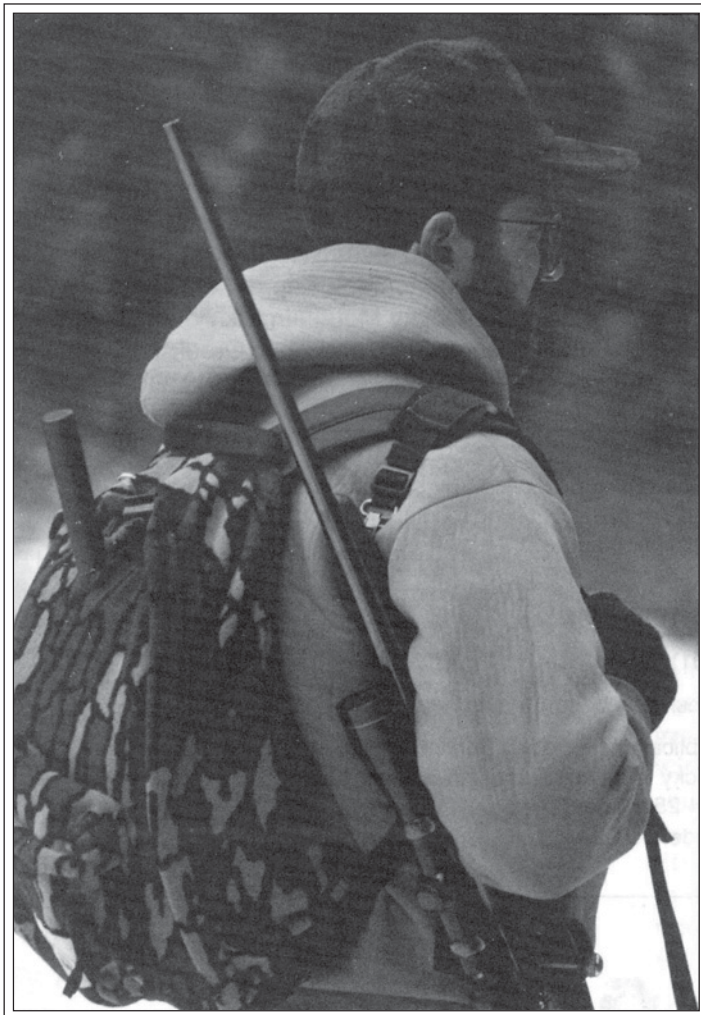
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Tracking Elk Hunters with the Global Positioning System

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Research Summary

We examined elk-hunter behavior and movement patterns within an area that has no motorized access. We used Global Positioning System (GPS) units to record hunter locations at 15 second intervals during 99 hunting expeditions in 1993, 1994, and 1995. Subsequent analysis within a Geographic Information System (GIS) enabled us to determine that hunters averaged 4.7 hours per hunt while moving at a speed of 40 m per minute for a distance of 10.7 km. Sixty percent of all hunting took

place on slopes less steep than the study area average, and westernly aspects were favored. Only one-half of all hunters traveled more than 2.5 km from their starting point, and only 12.5 percent traveled more than 4.5 km. The average distance from the nearest road while hunting was only 267 m, and hunters on foot spent 26 percent of their hunting time on roads. Hunters who spent the most time on roads also recorded the greatest distances from their starting point. Forests were selected over sagebrush by elk hunters, but hunters avoided lodgepole pine and chose more open forest types with mature trees.

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Introduction

In recent years, research on management and protection of North American elk has expanded beyond purely biological considerations. Resource managers have demonstrated they can produce elk in a variety of habitats. We are now entering an era in which we will have to consider some of the ethical and moral reasons for doing so. If elk hunting is to continue as legitimate recreation, consideration must be given to controlling harassment of wildlife and the behavior of the participants.

In 1991, the Elk Vulnerability Symposium (Christensen and others 1991) produced a state-of-knowledge compendium, including an evaluation of our understanding of elk mortality during the hunting season. Among the defining parameters of elk vulnerability to hunting, various authors identified road densities, hunter numbers, topography, cover quality, hunting regulations, and changing technology.

All of these parameters affect elk populations through direct or indirect modification of hunter behavior. However, the existing information describing hunter behavior is almost entirely confined to interview results. Smith and Yuan (1991) cite seven studies in which hunter behavior was determined by questionnaire. They cite no studies in which actual hunter behavior in the field was recorded and reported. Bryant and others (1991) tracked hunters with LORAN-C, but they reported only the interactions with elk. The most nearly comparable study of hunters, reported by Thomas and others (1976), asked hunters to draw their daily travel routes on maps. We believe GPS units carried by hunters provide better information because data are unaffected by hunter memory or the ability to interpret maps. We examined hunter behavior and movement patterns in an area with no motorized access.

Study Area

This research was conducted during the 1993, 1994, and 1995 elk hunting seasons in the Garnet Mountains, south of the Blackfoot River in western Montana. The primary study area included about 1000 square kilometers centered around Bata Mountain and the Blackfoot Block Management Area. There was a mixture of Bureau of Land Management, State

of Montana, and private (Plum Creek) timberland as well as old mining claims, commuter inholdings, and several cattle ranches. Some of the timberlands have been heavily harvested, but there were roadless areas remaining within a landscape that rises from the Blackfoot River floodplain at about 1100 m to the mountain peaks along the Garnet Divide at 1800 m. The average slope on the study area, measured at 30 m intervals on a digital elevation model, was 22 percent. About one-third of the area had slopes greater than 30 percent, but less than 1 percent of the slopes were over 70 percent. The Blackfoot Management Area is a road-closure management unit, open to the public, in which primary access points (trailheads) are located at gates, and most of the hunters can be readily counted and contacted. Elk hunting in this area begins early in September with the archery season; the rifle season starts the third week in October and continues for 35 days. A limited number of cow permits are issued in a random drawing, but antlered bulls are legal to anyone holding a Montana elk license. Thus, the primary hunting pressure falls on the bull elk segment of the population.

Study Methods

During three fall hunting seasons, Global Positioning System (GPS) recorders (GARMIN 100 SRVY) were carried by elk hunters while hunting. These battery operated units can continuously record geographic positions at intervals of 2 or more seconds with about 6 hours battery life and data storage capacity over 4,000 locations. We selected 15 seconds as an appropriate time period for maintaining satellite contact while providing adequate data replication to detect movement distances as little as 15 m. The manufacturer's specifications indicate 5 to 15 m accuracy for autonomous averaging with Selective Availability turned off and 40 m if Selective Availability is on. Since neither estimate would lead to greater loss of accuracy than already inherent in the 30 m pixels of our digital elevation model and Landsat coverages, we did not attempt differential correction. Our primary confirmation of accuracy was empirical comparison of hunter routes with road and topographic maps in the GIS.

Elk hunters were contacted in the field and asked to carry GPS units. Those who agreed were queried about previous elk-hunting experience. We then provided written instructions for starting the GPS unit, obtaining satellite coverage, and initiating the tracking mode. When possible, we arranged to be present to start the units. The GPS units were normally carried inside a backpack with the antenna protruding on a short cable.

At the end of each hunting day, data were downloaded from the GPS units to a computer and examined in a GPS graphics program. To reduce receiver-induced, atmospheric, and signal multipath location variance, all data were smoothed to a five-point running average. Global Positioning System locations were projected to Universal Transverse Mercator coordinates to create Arc/Info point coverages of hunter routes. Distances between points were used to determine average speed of movement and total distance moved. Point coverages in Arc/Info were overlaid on a vector map to determine distances to the nearest road. When the distance was less than 50 m, we assumed the hunter was on the road. We determined slopes and elevations for each point using digital elevation model point coverages in Arc/Info.

Vegetation

After analysis and reclassification of a Landsat Thematic Mapper coverage, a map was projected to an Arc/Info vector coverage of vegetation polygons with 23 verified classes. Point coverages of hunter routes were overlaid on the polygon coverage to determine the time spent by hunters in each vegetation class. We also created 80 random transects of points using the average speed and distance recorded on hunter routes. These transects provided an unbiased estimate of the time potentially available to hunters in each vegetation class.

Data Summary and Analysis

The information compiled for each GPS record provided data for one "hunter-day." In some records there were gaps because of poor satellite coverage, and in a few cases, battery life was exceeded by the length of the hunt. We were able to reconstruct short sections of missing data, but even when this was not possible, every record provided some information concerning the time spent hunting, distance traveled, speed of travel, maximum distance from starting point, and elevational change or as summaries of slopes and aspects hunted, use of both closed and open roads, and use of available vegetation types for hunting. We calculated the average distance from roads, time spent on roads, and maximum distance from any road. In developing a comprehensive examination of the way

roads are used, we separated hunts into four groups using maximum distance from the starting point. Among groups, we compared the percentage of time spent on roads, and within groups, we examined the constancy of road usage at increasing distances from the starting point.

Because the primary purpose of this study was to provide a descriptive baseline of hunter behavior, statistical tests are not particularly informative. Where possible, however, we compared hunters on foot with those on horseback and evaluated differences among three hunter-experience groups. In most comparisons, we used a t-test of the difference between group means. Vegetation selections were examined in an analysis of variance, comparing average time spent by hunters against average time on random transects in each vegetation class.

Results and Discussion

During the 1993, 1994, and 1995 hunting seasons, we obtained GPS records for 99 elk hunts involving 50 different hunters. Fifteen individuals carried GPS units for more than one hunt, five recorded more than two hunts, and seven participated in the study for at least 2 of the 3 years. The average recording contained 898 locations, and although about one-fifth of all recordings were incomplete, every recording containing more than 200 locations provided some useful information.

We obtained records for five archery hunts and 94 rifle hunts. Most elk hunting is done on foot, but we recorded 15 hunts using horses, and three were conducted entirely from a moving vehicle on roads surrounding the study area. On four hunts, a bicycle was used to get from the trailhead to a hunting site, and on two hunts, a snowmobile was used to reach the hunting site. Nineteen of our hunters started from overnight camps while 75 initiated hunts from trailheads.

Hunters in our sample averaged 41 years of age (range 14 to 71), and 96 percent were men. This compares to averages of 37 years and 95 percent men reported for Montana elk hunters by Allen (1988). Hunting experience in our sample included 10 hunters who had never killed an elk, 30 who had killed at least one elk, and 16 hunters who had killed more than five elk. The least experienced hunters averaged 36 years of age, while the more experienced averaged 42 years, and the most experienced averaged 44 years. Three hunters killed an elk while carrying GPS units.

In the following data summaries, we provide means and indicate sample sizes, but we mention significant differences only when the statistical probability was 0.05 or less. None of the averages we present are based on the full 99 records. Our largest samples include the 70 to 80 hunts in which walking was the primary mode

of travel. The behavior and actions of elk hunters seem consistent in these data, but we recognize some apparent inconsistencies in smaller samples.

Time Spent Hunting

For the 77 hunts on which we have complete information, the average time spent per hunt was 4.7 hours. Walking hunters averaged less time per hunt (4.5 h, $n = 65$) than those using horses (5.5 h, $n = 12$), but the most experienced walkers spent significantly more time (5.6 h, $n = 11$) hunting than the least experienced (4.4 h, $n = 8$). Montana hunters told Allen (1988) that they averaged 8 hours hunting each day, but that estimate was probably not limited to actual "weapon-in-hand" minutes.

Yuan, Smith, and Zager (1991) reported that hunters interviewed in Idaho spent 10 percent of hunting time sitting or standing still. In our data, we classified moving at a pace slower than 10 m per minute as equivalent to sitting or standing. Hunters in this study invested 9 percent of their time in this technique, and nearly one-fourth of them spent over 10 percent. Archery hunters ($n = 5$) were not significantly different in this respect, or in any other characteristic of hunters on foot, and for most of our analysis they are included in the averages without differentiation.

Distance Traveled

Distances traveled in 78 complete hunting expeditions averaged 10.7 km. The greatest recorded distance for a single hunt was a horseback trip of 31.7 km. Hunting with a horse significantly increased the average travel distance (16.8 km, $n = 11$) over the average distance by hunters on foot (9.5 km, $n = 63$). Bicycle hunters also covered great distances (average 18.0 km, $n = 1$), but our sample was too small to be considered characteristic. Among hunters on foot, the average distances traveled are comparable to the median distance of 6 miles (9.7 km) reported by Allen (1988) for Montana hunters. In our sample, hunters with the most experience walked significantly greater distances (12.6 km, $n = 10$) than those with moderate experience (8.7 km, $n = 45$); the least experienced hunters averaged an intermediate distance (10.0 km, $n = 8$).

The total distance traveled provides only a partial description of any elk hunt. In terms of elk vulnerability, it may be more important to determine the maximum distance away from the trailhead or starting point. For the 93 hunts in which maximum distance from starting point could be determined, the average was 2.6 km. Less than one-half of the hunters went farther than that, and only 12.5 percent reached a point further than 4.5 km from their starting points. This maximum distance group consisted of five walkers, five on horseback, and one using a bicycle.

Speed of Travel

Hunters in our sample used several different methods to get from one place to another. We report the average speed of each method for comparison purposes. We only considered individuals to be hunting when walking or on horseback. In getting to or from a hunting site, however, bicycles rolled along at 109 m per minute, snowmobiles at 224 m per minute, and pickup trucks at 208 m per minute (a little less than 8 mph). The average speed of movement for sportsmen actually hunting was 40 m per minute ($n = 93$). Hunters on foot averaged 37 m per minute ($n = 78$), which was significantly slower than the horseback pace of 51 m per minute ($n = 15$).

Elevational Change

In addition to horizontal distances, we examined the vertical elevations covered by 93 elk hunters. The difference between the highest and lowest points reached on various hunts ranged from 33 to 807 m. The average was 306 m, and there were no significant differences associated with walking, with horses, or with bicycles.

Slope Selection

The average slope on hunter routes was 21 percent. Overall summaries show that hunters spent 60 percent of their time hunting areas less steep than the average for the study area (22 percent). The only slope-associated change in behavior was that walking speed on slopes under 10 percent was nearly 2 m per minute faster than on slopes over 30 percent (37.6 versus 35.7 m per minute). This difference was significant because we had over 10,000 observations for each mean, but we suspect that the statistic, in this case, is not particularly important.

Aspect Selection

Our evaluation of hunter response to aspect compares the amount of time spent by elk hunters on each aspect with the area of that aspect available. Availability is based on the summary of nearly 500,000 30 m pixels in the digital elevation model coverage. Data were summarized by percentage distribution (table 1) within an octant (45 degree arc). While there is an indication in these data that hunters selected westerly aspects, we hesitate to suggest any conclusion about hunter behavior until this study is replicated in some other geographic area.

Use of Roads

In the average 4.5 hours (271 minutes) spent hunting by elk hunters on foot, 70 minutes were spent

Table 1—Percentage distribution by octant of aspects available to hunters, and aspects selected by hunters in 96 elk hunts.

Category	Octant							
	NNE	ENE	ESE	SSE	SSW	WSW	WNW	NNW
	-----Percent-----							
Used by hunters	15	13	10	7	10	15	16	15
Available	16	14	11	10	9	12	14	13

walking on roads. Hunters with the least experience spent 40 percent of their hunting time on roads; those with the most experience spent 27 percent. The majority of roads in the Blackfoot Management Area were closed to motor vehicles, but the summary statistics indicate that elk hunters on foot spent an average 13 to 14 minutes per hunt walking on roads actually accessible to motor vehicles peripheral to the walk-in area. Hunters on horseback spent only 47 percent of their time on roads. However, this average was likely biased by a single individual riding the off-road ridgelines.

Because roads are such a significant part of the environment for elk in this area, we attempted several different approaches in examining the influence of roads on hunter behavior. Our conclusions are clearly subjective because the tests were intended to identify the role of roads in influencing hunter behavior and, ultimately, elk vulnerability.

The average walking speed for hunters on roads, 42 m per minute ($n = 75$), was significantly faster than the off-road walking speed of 36 m per minute ($n = 78$). Walking speeds on roads increased to 44 m per minute when adjacent slopes were over 30 percent, but walking speeds off roads declined to 33 m per minute on slopes over 30 percent. None of these movement speeds approach a normal walking pace, and observed differences might simply be attributed to the relative ease of walking on a nearly flat surface. However, if reduced movement speed is interpreted as representing greater concentration on hunting, these data imply that roads are more important for getting from one place to another than for actual hunting.

Possibly the most informative observations in regard to road use can be developed by examining the percentage of time spent on roads by hunters reaching different maximum distances from their starting point. During hunts in which the maximum distance from start was greater than 2.5 km ($n = 44$), hunters spent 38 percent of their time on roads. This was significantly more time than the 20 percent on roads by hunters who did not reach 2.5 km ($n = 49$). In a further examination of these data, we split the distance categories at 1.5 and 3.5 km and calculated the percentage of time spent on roads in 500 m increments from the starting points (table 2).

In confirmation of expectations, hunters going to greater maximum distances spent a higher proportion of time on roads than hunters who invested their hunting effort near the trailhead. It was, nevertheless, unexpected that these hunters did not eventually leave the roads. On the contrary, the evidence in table 2 shows that beyond 1500 m, one-third to one-half of all hunting takes place on roads if roads are present.

Distance from Roads

Any apparent preference for hunting on or near roads may simply indicate the heavily roaded character of the study area. After eliminating those observations in which a hunter was on or within 50 m of a road, the average distance to any road for all hunters while hunting was only 267 m ($n = 96$). Only three hunters managed to get farther than 1.0 km from a road, and the average maximum distance from a road

Table 2—Percentage of time spent on roads by elk hunters in 500 m distance bands within four categories of maximum distance from trailhead.

Distance category ^a	n	Mean	Maximum distance from starting point									
			1000	1500	2000	2500	3000	3500	4000	4500	5000	5000+
			-----Percent-----									
km												
<1.5	27	16	19	8								
1.5 to 2.5	22	24	26	26	21	38						
2.5 to 3.5	23	34	41	34	46	31	31	32				
>3.5	21	42	55	44	38	29	35	46	46	54	47	43

^aMann-Whitney U for adjacent distance categories confirms significantly more time spent on roads with each increase in distance from trailhead (P : 0.07, 0.06, 0.05).

for all hunts was only 565 m. Hunters on foot maximized the distance from roads better than hunters with horses (591 m versus 420 m), and the most experienced hunters traveled further from roads than hunters with the least experience (702 m versus 444 m), but none of these differences were significant.

Vegetation Selections

A summary of polygon areas, taken from the Arc/Info coverage, shows the study area is 78 percent forested and 22 percent nonforested (table 3). In estimating the amount of time spent by hunters in each vegetation class, we eliminated all sample points in which a vehicle, snowmobile, or bicycle was used. Our summary included only vegetation classes in which at least 1 percent of the hunting effort was recorded, plus two classes that were specifically avoided by hunters.

Some hunting time was recorded in 20 of the 23 vegetation classes available to hunters, but over 98 percent of all hunting occurred in only nine classes, and over 80 percent occurred in the six forest types containing mature trees. Our random sample transects indicated lodgepole pine forests should have been hunted for 59 minutes in an average hunt, but the elk hunters spent significantly less time—only 31 minutes ($n = 1,174$). The open Douglas-fir, however, was relatively attractive to hunters and received 40 minutes of use as compared to the 23 minutes predicted on random transects ($n = 1,174$). The attraction of mature trees in open stands is further indicated by selection of both ponderosa pine and western larch vegetation classes, even though these forest types are a limited component of the vegetation. Sagebrush and

rangelands were both avoided by significant margins, but this is hardly a surprise because neither offers any kind of security cover for elk.

Management Implications

Most of the information summarized in this study will allow us to assign numbers to information already recognized but not numerically defined. On average, a day spent hunting elk involves walking slowly for 4 to 6 hours and traveling 10 to 12 km. Elk hunters are selective in choosing forested areas with mature trees, but they seem to prefer hunting in areas where the hiding cover is low and visibility is high. This selection is extremely important in evaluating elk vulnerability. Weber (1996), in a study of landscape effects on elk vulnerability, found that while only 4 percent of live elk locations during the hunting season were in open Douglas-fir, 17 percent of the kills occurred there.

Less than half of all hunters will travel farther than 2.6 km from their starting point, and only 12.5 percent will travel as far as 4.5 km. Hunters who go the greatest distance from trailheads spend a great deal of time on closed roads. Where such roads are present, horses, bicycles, and walking are all highly effective transportation modes. Our most important observation is that closed roads have a significant impact on hunter behavior. We hypothesize that closed roads facilitate access to areas most distant from open roads and trailheads. This information and the associated time and distance data provide a solid foundation on which a hunter density and elk vulnerability model can be developed.

Table 3—Vegetation classes used by elk hunters, predicted^a and actual time spent hunting in each class, percentage area^b, and physical characteristics^c of each class.

Vegetation class	Minutes hunting		Percent of area	Basal area	Canopy cover
	Predicted	Actual			
Douglas-fir	60	61	23	25.0	64
Lodgepole pine	59	31 ^d	21	37.0	62
Mixed conifers	36	45	18	17.0	57
Open Douglas-fir	23	40 ^d	11	8.6	28
Foothills parkland	12	14	7	4.1	10
Clearcuts	11	15	5	3.2	9
Regenerated clearcuts	5	4	2	2.3	40
Sagebrush	4	1 ^d	4	0.1	5
Rangeland	3	1 ^d	2	<1.8	<15
Ponderosa pine	3	4	2	18.9	31
Western larch	2	7 ^d	1	7.9	42

^aPredicted times from random transects of points generated at the average movement speed of elk hunters on GPS transects.

^bArea percentages taken from Arc/Info coverage.

^cBA is m²/km² and canopy is percentage crown closure.

^dIndicates a significant difference ($P < 0.05$).

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Global Positioning System (GPS) units were used to record hunter locations at 15 second intervals during elk hunting expeditions. This information allowed us to examine the influence of roads on hunter behavior, and along with associated time and distance data, provide a solid foundation on which a hunter density and elk vulnerability model can be developed.

Keywords: behavior, *Cervus elaphus*, GPS, Montana, vulnerability



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