THESIS

RESPONSE OF DEER AND ELK TO ROADS

Submitted by

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ABSTRACT OF THESIS

RESPONSE OF DEER AND ELK TO ROADS

Responses of deer and elk to roads were assessed by counting fecal pellet groups on plots spaced systematically along 1/4-mile (0.4 km) transects perpendicular to roads on winter ranges. Data were obtained in a broad-leaf shrub and in ponderosa pine vegetative zones adjacent to paved, gravel, and dirt roads in a mountainous area east of the continental divide in Colorado; and in a broad-leaf shrub and in juniper vegetative zones adjacent to three classes of roads in three areas west of the continental divide in Colorado. Information on slope, aspect, ground cover, tree canopy cover and road visibility was recorded at each plot on all areas.

Analysis of the data with a stepwise multiple regression model indicates that deer and elk avoid areas near roads, particularly areas within 10 chains (0.2 km) of the road. East of the continental divide, avoidance by deer was more pronounced adjacent to paved roads than adjacent to gravel or dirt roads, but the difference was not statistically significant. Deer avoided even dirt roads, some of which are used only by four-wheel drive vehicles, trailbikes and hikers. Avoidance was more pronounced in the shrub zone than in the ponderosa pine zone. West of the divide, deer avoided roads in the shrub zone more

than in the juniper zone, but this difference was not statistically significant.

East of the divide, elk avoided paved and gravel roads in the ponderosa zone, but seemed little affected by dirt roads which are usually snow-covered in winter. There was little use by elk of the shrub zone on the east side. West of the divide, elk pellet-group density decreased near roads in the juniper and in the shrub zones, but the trends were weak and not statistically significant.

Deer on the east-slope area showed greater and more consistent avoidance of roads than deer on west-slope areas, the difference being statistically significant. Similar, but weaker, trends were noted for elk, but the difference in avoidance between east- and west-slope areas was not statistically significant. Because of less snowfall and accumulation, winter habitat is more abundant and available to deer and elk east of the continental divide. More pronounced avoidance of roads on east-side winter ranges presumably results from the greater availability of suitable habitats away from roads.

An expanding road system and/or an increasing traffic volume on National Forest roads would affect the distribution of deer and elk, at least at times of the year, and might affect their welfare.

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INTRODUCTION

Increased use of forest land in the Rocky Mountain region for recreation, timber production, and other purposes has resulted in increased use and construction of forest roads and highways. Construction of a new two-lane highway, 40 feet (12.2 m) wide, results in the loss of 4.85 acres (1.96 hectares) of habitat per mile of pavement. However, there is little information on effects of road construction and use upon the behavior, distribution and abundance of big game in areas adjacent to roads.

A model of habitat use by deer and elk in relation to roads would be useful in assessing effects of roads upon big game abundance, productivity and visibility. Reactions of wild ungulates to roads and to disturbance associated with roads may be very complex. Factors likely to be involved are (1) species of ungulate, (2) age and type of road, (3) density of traffic, (4) construction associated with the road, (5) distance from the road, (6) vegetation type, (7) season, (8) whether or not the big game population is hunted, and (9) whether or not the road is located in an abundant or in a scarce habitat type. Evaluating these several factors and their interactions will require study of several ungulate populations in response to several kinds of roads in several kinds of environments. An inexpensive and broadly-applicable method of evaluating ungulate response to roads is needed for this purpose.

The objectives of this study were (1) to evaluate the measurement of pellet-group densities along transects perpendicular to roads as a method for assessing ungulate responses to roads; and (2) to assess responses of mule deer (Odocoileus hemionus) and elk (Cervus canadensis) to roads on winter ranges of these species in Colorado. Responses of deer and elk to roads were measured on winter ranges east of the continental divide (east-slope study area) and west of the divide (west-slope study areas). Both east- and west-slope areas were examined because snowfall and snow accumulation is greater on the west-slope areas than on the east-slope area, sometimes resulting in a more restricted available food resource on the west-slope areas.

Ream (1972), reviewing effects of logging upon big game populations, noted the potential impacts of road construction and use but concluded (p. 120), "we know little about elk behavior, particularly in relation to human activity." Similarly, Lyon (1971) concluded that there was virtually no information on responses of elk to human activities associated with forest roads. The Wyoming Forest Study Team (1971:48) stated, "The effects of roads on big game populations, specifically elk, are almost impossible to evaluate because there is no adequate information," and suggested a slowdown in construction of new permanent forest roads until such information becomes available. This suggestion met qualified acceptance by the Forest Service (U.S.F.S., 1972:12) which did agree to avoid construction of roads, particularly permanent roads, in known, vital elk habitats unless other considerations were overriding.

Behrend and Lubeck (1968) found that older male deer (having more than "spike" antlers) were more wary of vehicles on a hunted area than they were on an unhunted estate. In this area, most hunting was for male deer and few females were harvested. Huff and Savage (1972) concluded that deer avoided areas of much use by snowmobiles in Minnesota.

Ward et al. (1973) indicated that logging and recreation roads with moving traffic would have little effect on elk activity once the elk become accustomed to them. However, they apparently did not measure habitat variables that might attract elk to or away from roads and their sampling scheme apparently was not random.

In South Dakota, Berner (1955) noted that pellet-group densities were comparatively low in those portions of transects that tended to be near (within 300 feet of) roads. On the Cibola National Forest, New Mexico, deer pellet-group densities declined near roads, the effect being most pronounced within 5 chains of the roads (personal communication, Henry McCutchen, Cibola N. F., Albuquerque).

In this study, the initial null hypothesis was that no relationship exists between roads and the distribution of deer and elk fecal pellet groups. Upon rejection of this hypothesis, three additional hypotheses were considered: (1) the relationships between deer and elk pellet-group distributions and roads are the same in broad-leaved shrub vegetation zones as in conifer vegetation zones; (2) the relationships are the same for classes of roads carrying different volumes of traffic; and (3) the relationships are the same on east- and west-slope winter ranges.

METHODS

Study Areas

Location. The study area east of the continental divide (hereafter referred to as the east-slope study area) consisted of 32 sites adjacent to roads in the Roosevelt National Forest in north-central Colorado (Figs. 1, 2). Of these sites, 27 were in the Cache la Poudre River drainage, and 5 were along Buckhorn creek, approximately 12 miles south of the Cache la Poudre River. Sites were adjacent to state road 14, the Crown Point road, the Pingree Park road, and many unimproved dirt roads intersecting these roads. Elevation at these sites ranged from 5800 to 7800 feet (1770 to 2380 m) above mean sea level. This east-slope area was examined during September and October, 1973.

The study areas west of the continental divide (hereafter referred to as the west-slope study areas) consisted of 34 sites on private and public land in three areas near the White River National Forest in northwestern Colorado (Figs. 1, 3, 4, 5). Of these sites, 16 were adjacent to state road 132, which parallels the White River, or nearby along Rio Blance County roads; 11 sites were located near Eagle, adjacent to I-70 and US 6-24, the paved road paralleling the Colorado River north from Dotsero, and state road 131 north from Wolcott; and 7 sites were adjacent to state and county roads in the area between

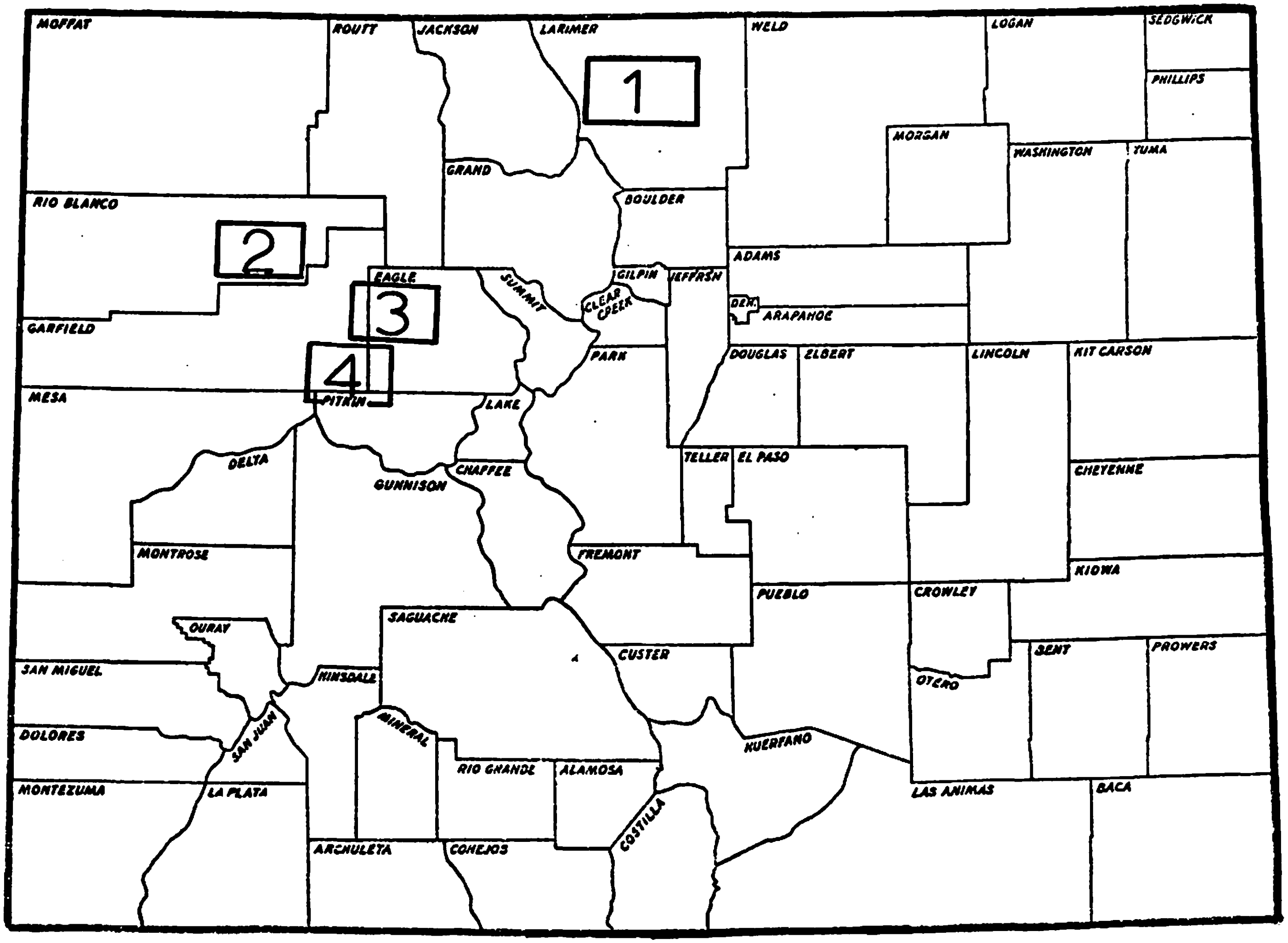

Fig. 1. Location of study areas in Colorado. Numbers refer to following enlargements.

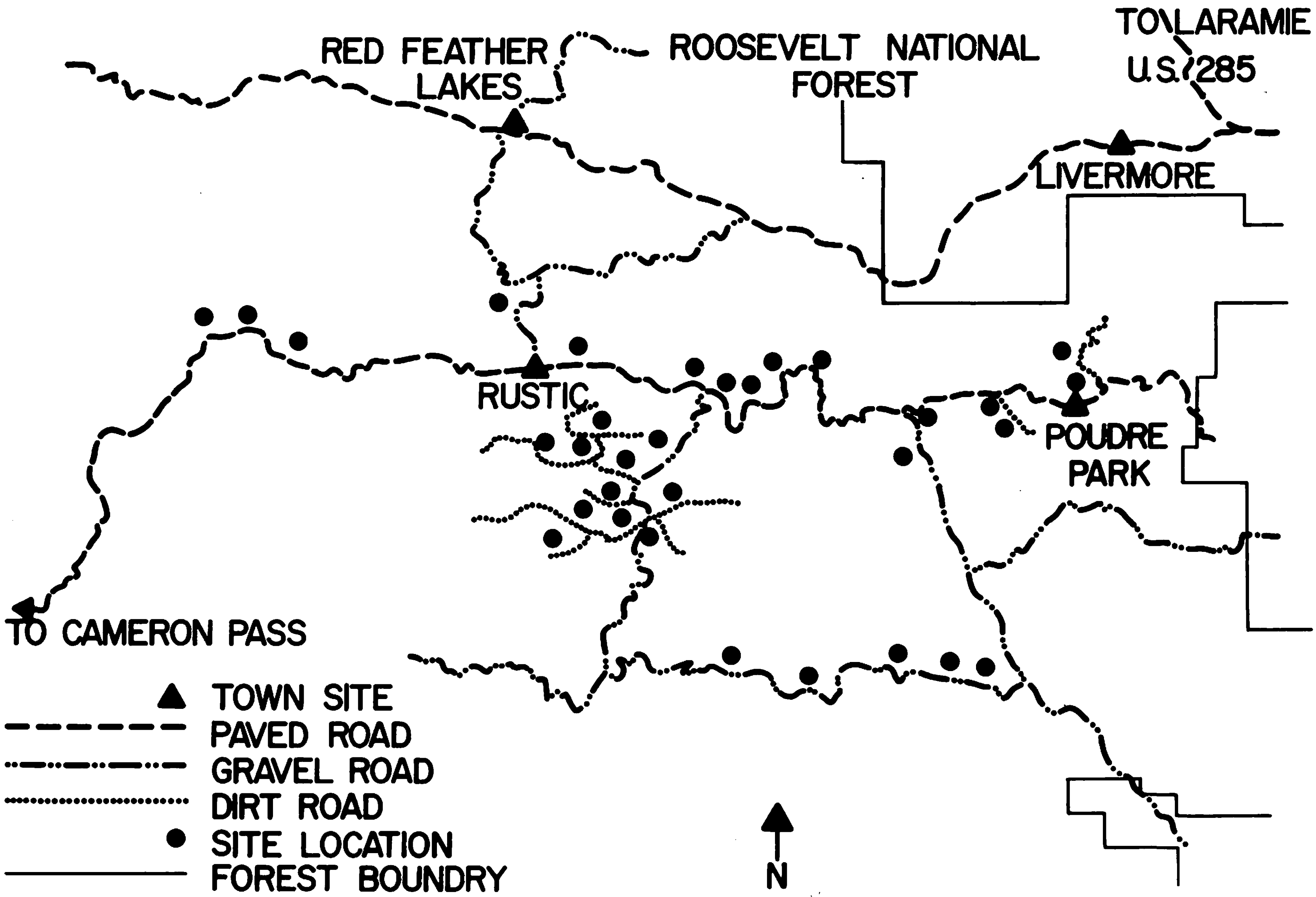

Fig. 2. East-slope study area, number 1.

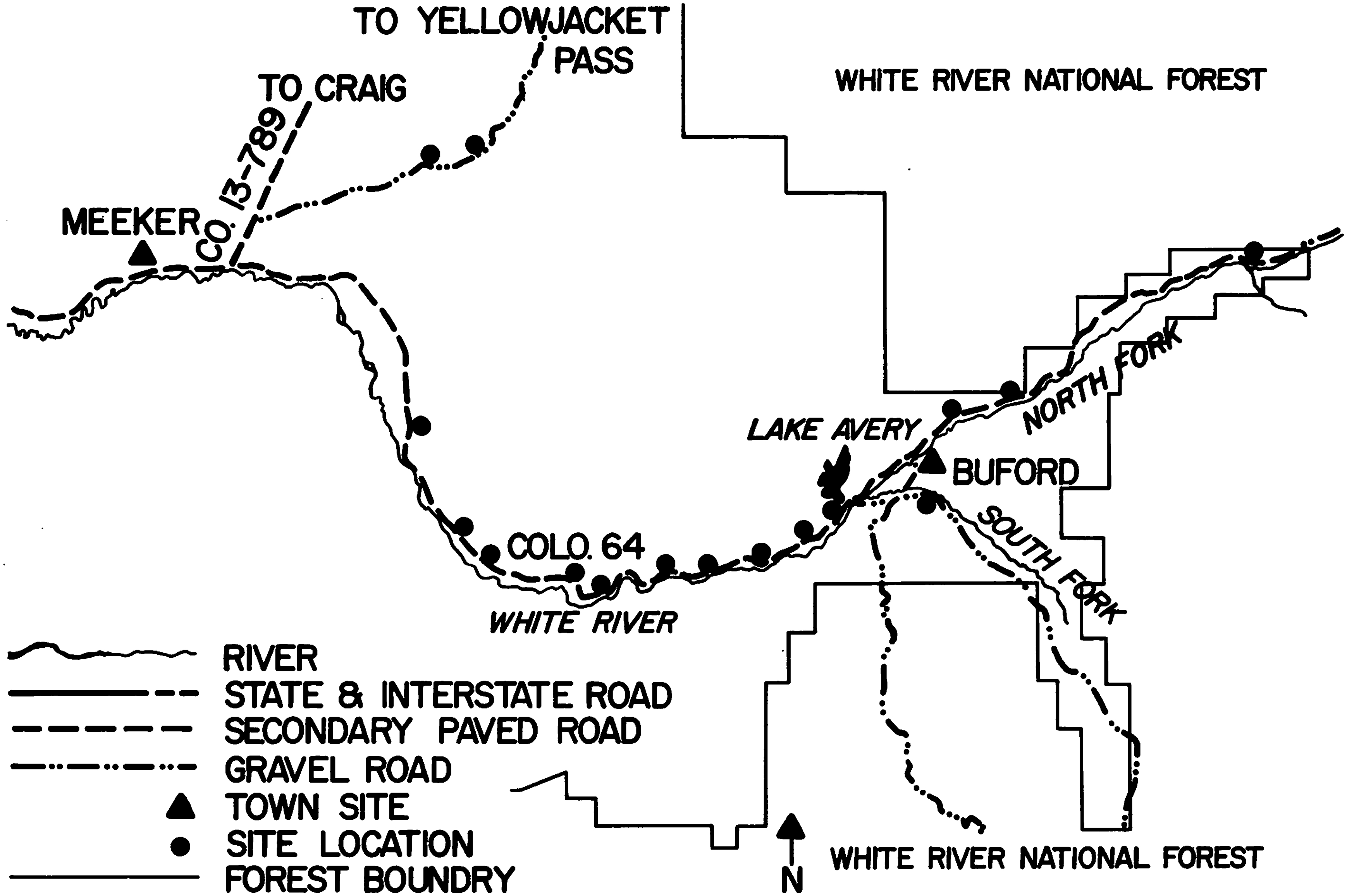

Fig. 3. A west-slope study area, number 2.

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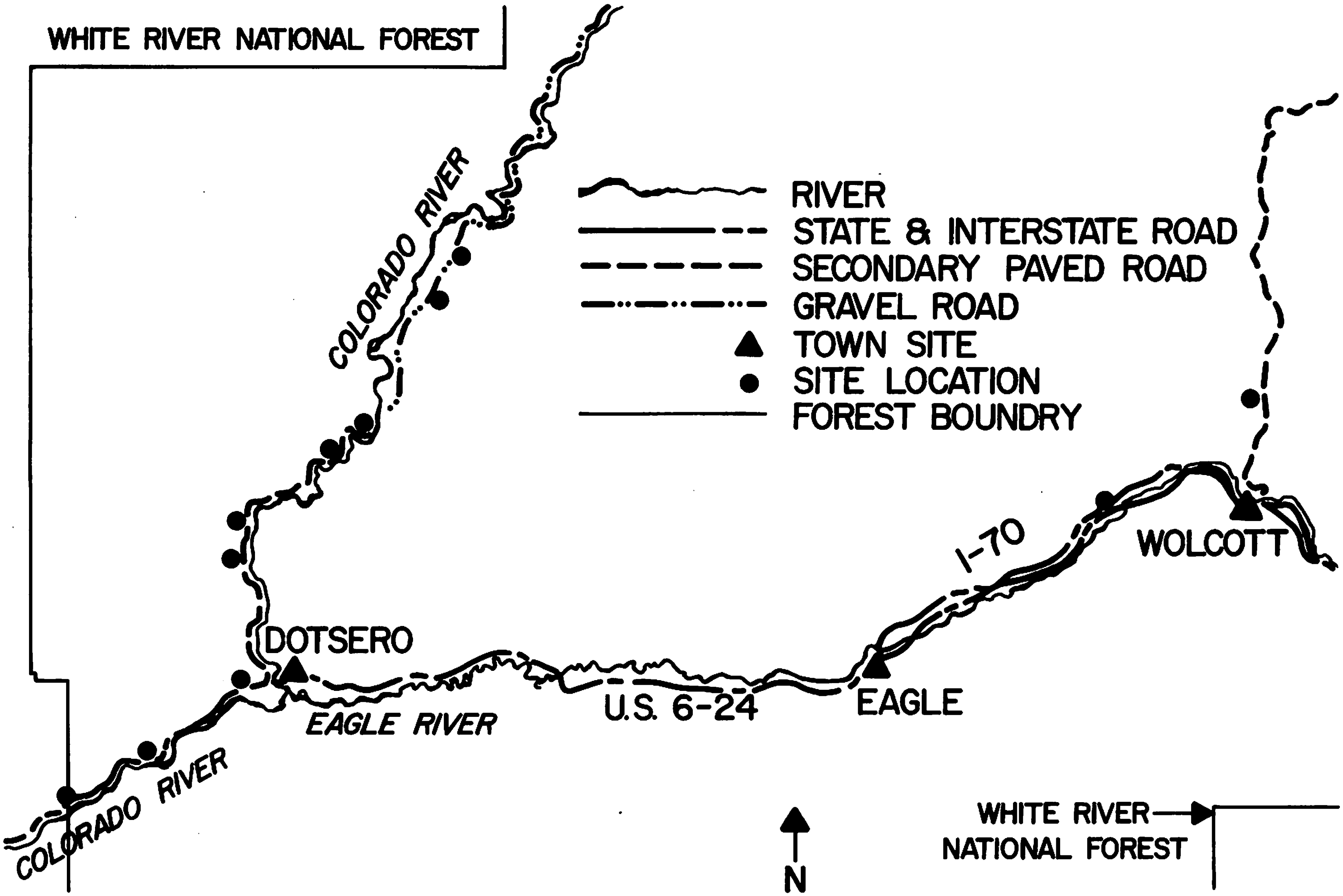

Fig. 4. A west-slope study area, number 3.

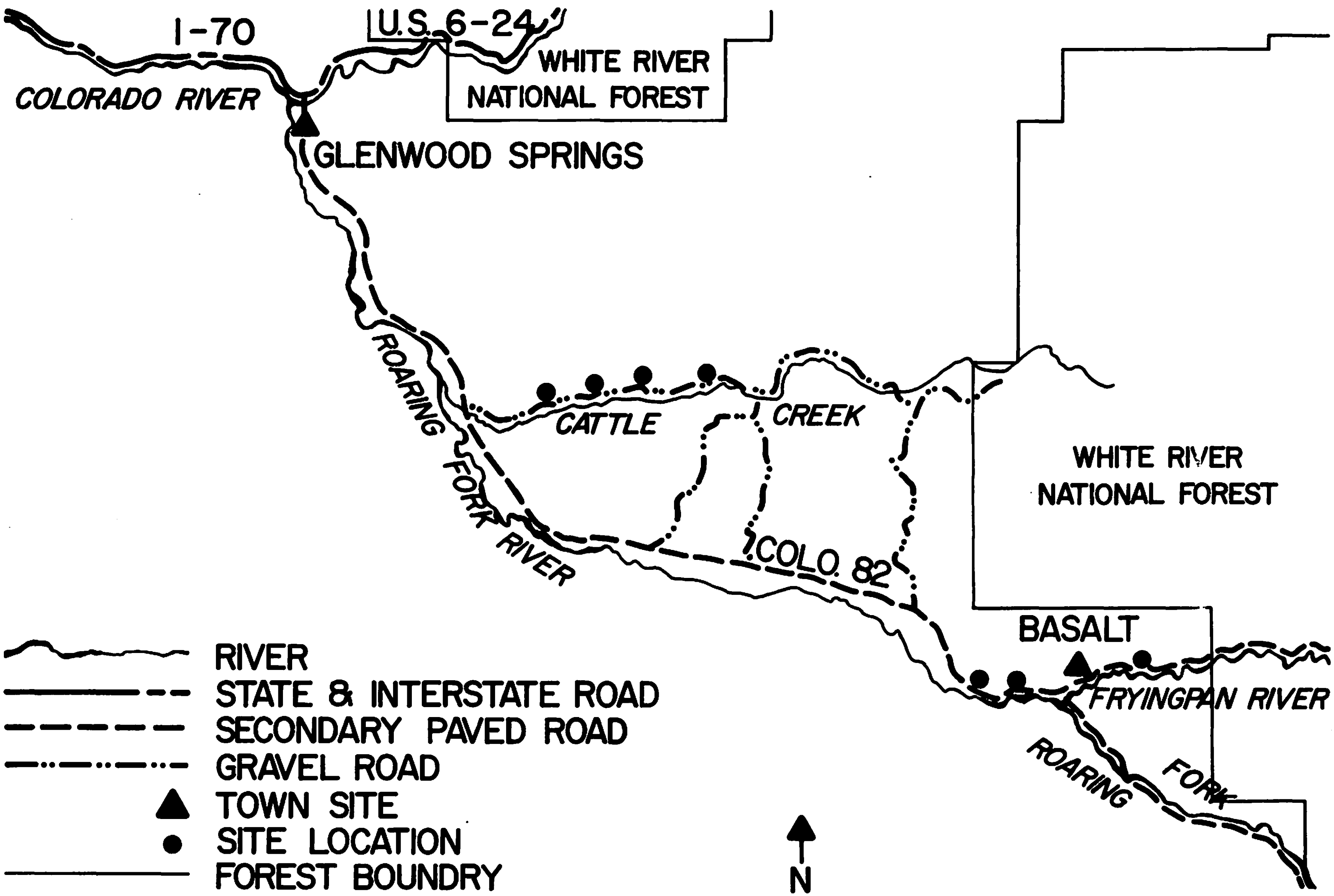

Fig. 5. A west-slope study area, number 4.

Glenwood Springs and Basalt. Elevation above mean sea level ranged from 6600 to 7700 feet (2010 to 2350 m) in the White River area; 6100 to 6500 feet (1860 to 1980 m) in the Eagle area; and 6200 to 6900 feet (1890 to 2100 m) in the Glenwood Springs area. These west-slope areas were examined during August and September, 1974.

Characteristics. Fecal pellet groups were counted in the primary winter habitats of deer and elk to maximize data collection in relation to field time, and to examine critical habitat. In the east-slope study area, these were a broad-leaf shrub type for deer and a ponderosa pine type for elk. The shrub type consisted of mixed stands including antelope bitterbrush (*Purshia tridentata*), big sage-brush (*Artemisia tridentata*), and true mountain mahogany (*Cercocarpus montanus*), with grass and forb understories, and occasional trees, including juniper (*Juniperus scopulorum*), ponder-osa pine (*Pinus ponderosa*), and aspen (*Populus tremuloides*). The ponderosa pine type varied from dense to sparse ponderosa pine overstory, sometimes with lodgepose pine (*Pinus contorta*) or Douglas fir (*Pseudotsuga menziesii*), with an understory of grasses, forbs and occasional shrubs.

On the west-slope study areas, deer winter habitat was a shrub type with oakbrush (*Quercus gambelii*), big sagebrush, rabbitbrush (*Chrysothamnus nauseosus*), and true mountain mahogany in varying mixtures. Some sites were predominantly one species, such as sagebrush, with only small amounts of other species. The lower limits of the elk habitat were similar to deer habitat, the two species often wintering near one another. The upper limits of the elk winter areas consisted of a juniper type (J. scopulorum) with browse, grass and forb understory.

Data on winter traffic volumes were not available for most roads in the study areas. Therefore, assumptions were made concerning the relative amounts of traffic on three classes of roads to examine responses of deer and elk to roads with different traffic levels. On the east-slope area, it was assumed winter traffic was heaviest on paved roads, intermediate on gravel roads, and lightest on dirt roads. On west-slope areas, the three road classes in order of assumed winter traffic volume were: Interstate 70 and US 6-24, highest; other paved roads, intermediate; and gravel roads, lowest.

Three road classes and the two vegetative zones provided six combinations on both east- and west-slope areas in which to observe pellet group distribution (Tables 1, 2).

Data Collection

Site Selection. Sites were located along relatively straight 1/8-mile (0.2 km) segments of road. They were selected in areas where no physical barriers (such as rivers or deer-proof fences) were present between the road and the adjacent slope, and where no

Table 1. Number of study sites in each road class - vegetative zone category on the east slope.

Vegetation Zone	Road Class		
	Paved	Gravel	Dirt
Ponderosa Pine	4	8	7
Mountain Shrub	4	4	5

Table 2. Number of study sites in each road class - vegetation zone category on the west slope.

Vegetation Zone	Road Class[1]		
	I	II	III
Juniper	2	10	2
Shrub	2	13	5

[1] I = I-70 and US 6-24; II = Other state, county, and local paved roads; III = Gravel roads.

other roads came within 1/4-mile (0.4 km) of any peripheral plot on the site (Fig. 6). Most sites were located on southeastern to southwestern aspects to minimize variation in deer and elk use due to aspect.

Transects. Each site consisted of 10 parallel 1/4-mile transects about 66 feet (20 m) apart and perpendicular to the road. Along each transect, 4-foot (1.2 m) radius sampling plots were examined every 33 feet (10 m), with the first plot 33 feet from the edge of the road bed or road cut. In cases where traditional stock fences were situated parallel to roads and within 33 feet of the road, the first plot was located 33 feet from the fence. Forty plots were examined along each transect, 400 on each site. Transects and plots were located by compass and pacing.

Variables. At each plot, all identifiable deer and elk pellet groups, regardless of age, were recorded. It was assumed that habitat utilization by deer and elk in relation to roads did not change appreciably among winters for the several years that pellet groups remained identifiable. Thus, number of months' accumulation was assumed equal at all distances (within 1/4-mile) from each road. Deer pellets were distinguished from elk pellets by their smaller size. Pellets were separated into groups by the common size, shape, color, and state of decomposition of the pellets. A group was counted when at least half the pellets were inside the plot.

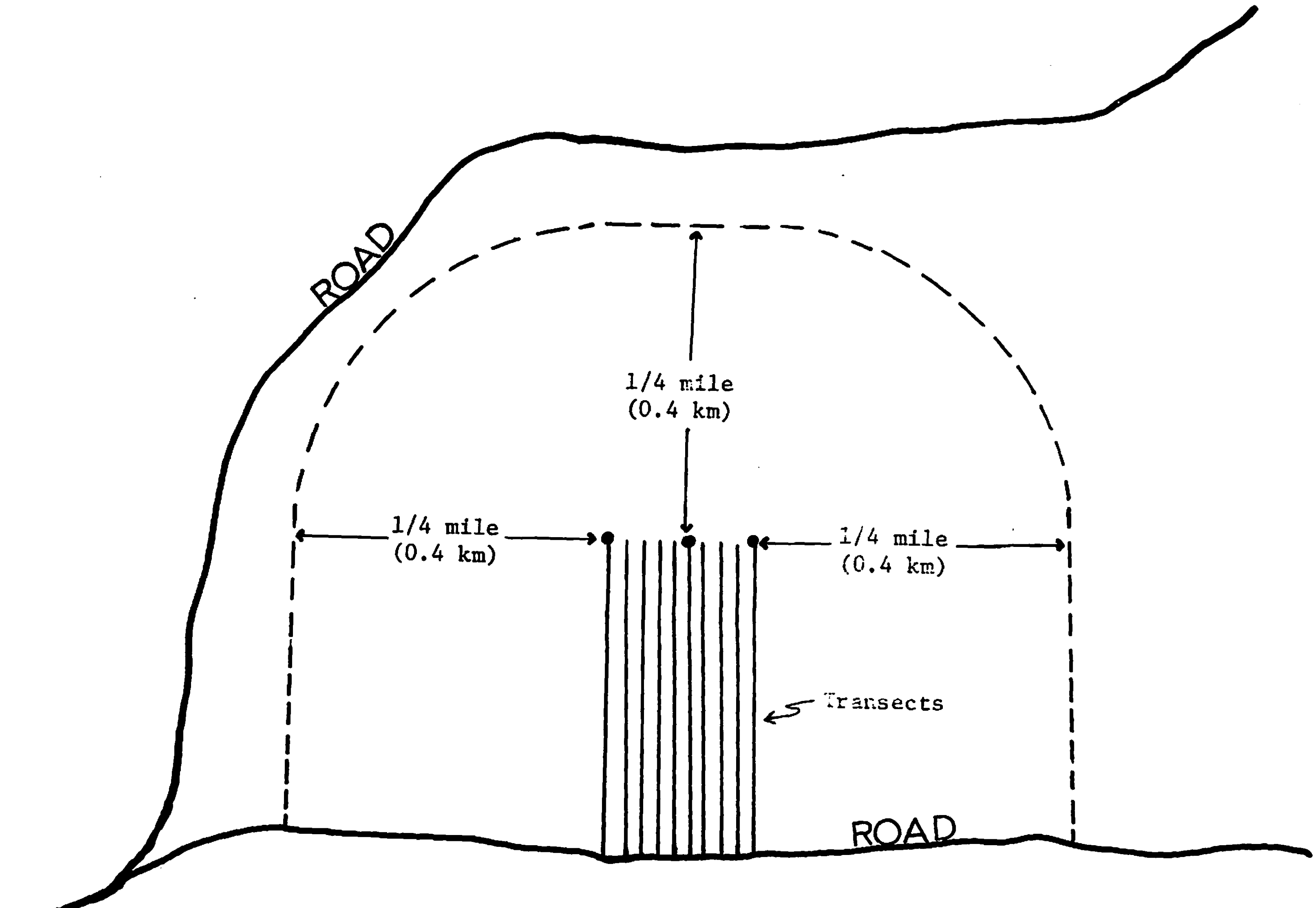

Fig. 6. Site layout.

The slope, aspect, abundance of grass and grass-like plants, of forbs, shrubs (woody plants less than 10 feet tall), and trees, and the visibility of the road were recorded at each plot. Oakbrush was not present on the east-slope study area. However, its abundance was recorded separately on the west-slope study areas because of its major importance in the vegetation and its failure to fit into either the shrub or tree category.

Percent slope, aspect, and abundance of grass, forbs, shrubs, and oakbrush were estimated for the area within 10 feet (3 m) of the plot center; canopy coverage by trees was estimated for the area within 20 feet (6 m) of the plot center. Aspect was recorded in five classes as deviations from south: (1) south; (2) southeast or southwest; (3) east or west; (4) northeast or northwest; (5) north. The percent slope was recorded in five classes: (0) level ground; (1) 1 - 25; (2) 26 - 50; (3) 51 - 75; (4) above 75 percent. Percent ground cover by grass, forbs, shrubs, tree canopy, and oakbrush was recorded as (0) not present; (1) 1 - 25; (2) 26 - 50; (3) 51 - 75; (4) above 75 percent. At each plot the road was recorded as (1) visible or (2) not visible.

Field Crews. Selected undergraduate field personnel assisted in data collection. Field crews practiced pacing, and were instructed in the field by the principle investigator to reduce among-observer variation in subjective estimates of the independent variables.

Whenever possible (all but 9 sites), one investigator observed all plots on any one site to eliminate among-observer variation within the data for each site.

Analysis of Data

Data for elk and for deer were analyzed separately for each site that had at least 50 elk or deer pellet groups, respectively. Data were analyzed using a stepwise multiple regression model (STAT38R, CSU Statlab series) to determine the amount of variation in pellet-group densities due to the independent variables, including distance from the road. To approximate a normal distribution, pellet-group data were transformed to $\log_{10}(y + 1)$, where y equals the number of deer or elk pellet groups on a plot.

Untransformed data were analyzed using a multiple regression model (STAT03R, CSU Statlab series), or the above stepwise multiple regression model with a low level of significance designated, to obtain a partial regression coefficient for pellet-group density vs. distance from the road for each site. These partial regression coefficients (the slopes of the regression lines) were analyzed with an analysis of variance model (STAT31V, CSU Statlab series, 1973 data), or Student's *t* tests (1974 data) to determine if statistically significant differences existed among road classes or between vegetative zones. Four mean partial regression coefficients (for deer and for elk on the east-slope study area and on the west-slope study areas) were tested with Student's $\underline{t}$ to determine if they differed statistically from zero.

The importance of the association between pellet-group density and distance from a road was evaluated by observing (1) the frequency among sites of positive partial regression coefficients for these variables - from the multiple regression model or the stepwise multiple regression model with a low α level designated; (2) the frequency among sites of significant positive partial regression coefficients for thse variables - from the stepwise multiple regression model with an α level of 0.05 designated; and (3) the values of the regression coefficients for these variables - from the multiple regression model or the stepwise multiple regression model with a low α level designated.

For the second observation above, both the proportion of significant positive partial regression coefficients, and the probability of observing that proportion by chance were examined.

The proportion of sites with statistically significant ($P < 0.05$) positive partial regression coefficients ($\underline{b}_{Y \cdot X_1 / X_2, X_3, \ldots X_n}$; hereafter termed $\underline{b}$) for pellet-group density vs. distance from the road was calculated for each road class - vegetation zone cateogy, for each road class, and for each vegetation zone. The probabilities of obtaining these proportions by chance (Tables 4, 6, 8, 10) are based on the null hypothesis that no relationship exists between pellet-group distribution and distance from the road ($\beta = 0$). Under this hypothesis, and by definition of $\alpha = 0.05$, one would expect 5 percent of the sites to show statistically significant *b*'s for pellet-group density vs. distance from the road due to random chance. Assuming a significant *b* has equal chance of being positive or negative (i.e., pellet groups increase or decrease with distance from roads), the probability of a site having a significant positive *b* for distance from the road vs. pellet-group density by chance alone is 0.025 (probability of being significant X probability of being positive = probability of being significant and positive). Knowing the probability of obtaining a significant positive *b* for distance from the road vs. pellet-group density, one can calculate the probability of obtaining an observed number of such relationships in a given number of trials. The probability, P, of obtaining X significant positive *b*'s in N sets of data, with a probability, p, of obtaining one such relationship in one trial is:

$$P = \frac{N!}{X!\,(N - X)!} \quad p^{X}\,(1 - p)^{(N-X)}.$$

Thus, the probability of observing 4 significant positive *b*'s for distance from the road with pellet-group density out of 8 sites would be 0.000025. Observing 4 significant positive *b*'s in 8 sites with such a low probability of occurrence would lead to rejection of the null hypothesis, and conclusion that a relationship does exist between pellet-group distribution and distance from the road.

However, the proportion of significant negative *b*'s must also be considered. Improbable proportions of both significant negative and significant positive coefficients led to rejection of the null hypothesis, and to the conclusion that non-random distribution of pellet groups in relation to roads was related to independent variables not measured in this study. This situation occurred only twice in the study.

RESULTS

Deer

East Slope. When data from 32 sites on the east-slope area were combined by road class and vegetation zone, densities of deer fecal pellet groups increased with distance from the road in all categories (Figs. 7, 8). This trend was most pronounced within 10-15 chains from the road in the shrub zone. However, pellet-group densities were still increasing at 20 chains from the road in the ponderosa pine zone.

Results of analysis with the stepwise multiple regression model reveal that increasing deer pellet-group density is significantly ($P < 0.05$) correlated with increasing distance from the road, increasing grass cover, increasing shrub cover, and decreasing tree canopy cover (Table 3). The latter relationship is possibly due to leaves and needles covering pellet groups. Other independent variables were not frequently correlated with pellet-group density or were not consistently positive or consistely negative in their association with pellet-group density.

Partial regression coefficients for pellet-group density vs. distance from the road were positive, indicating increasing pellet-group density away from roads, at 29 (91 percent) of the 32 sites. Assuming positive and negative relationships had equal chances of

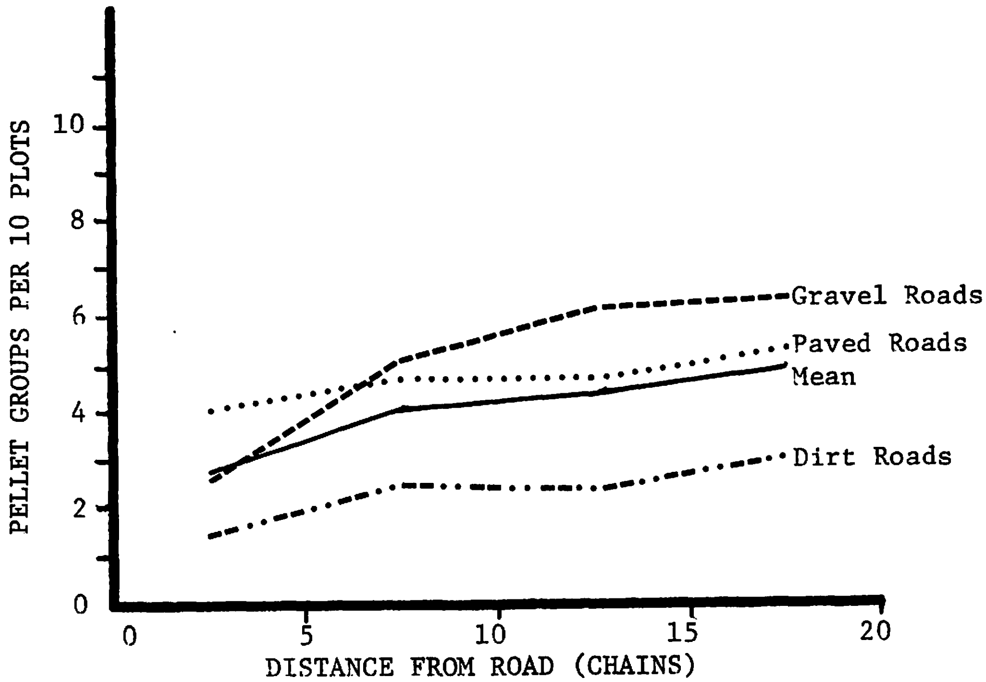

Fig. 7. Distribution of deer fecal pellet groups in relation to roads at 19 sites in the ponderosa pine zone, east slope. (Effects of seven independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5 chain (10 plot) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

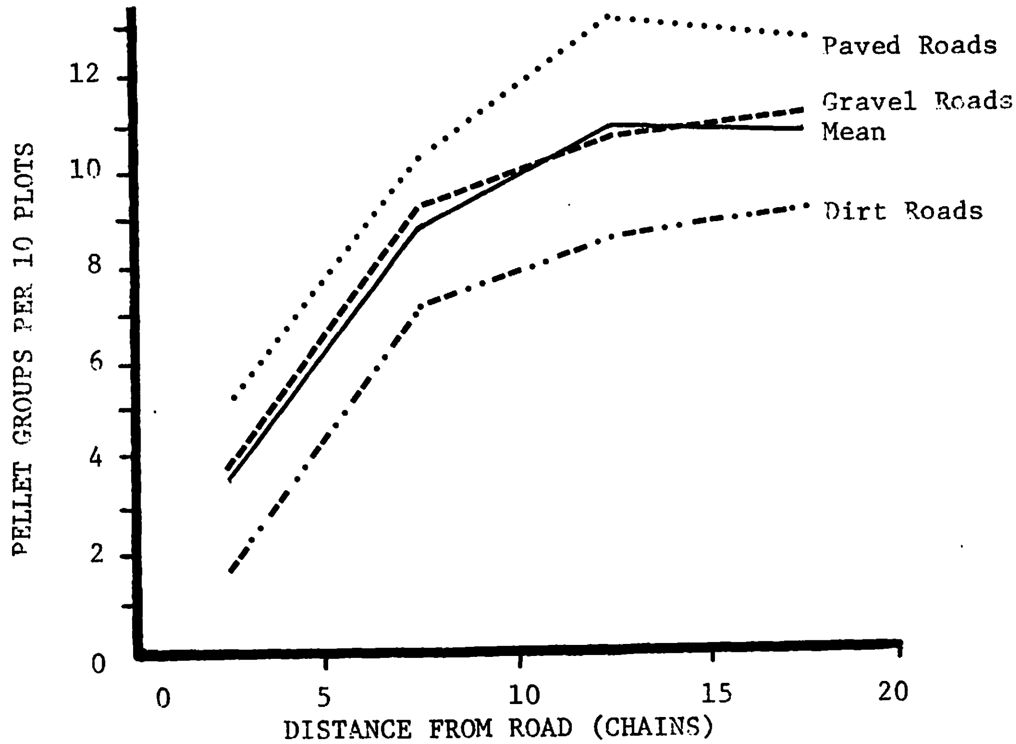

Fig. 8. Distribution of deer fecal pellet groups in relation to roads at 13 sites in the mountain shrub zone, east slope. (Effects of seven independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5-chain (10 plot) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

Table 3. Significance of eight variables related to deer fecal pellet-group density on the east-slope study area[1].

Variable	Sites with significant partial regression	Percent of sites
Distance to road	22* (+)	69
Slope	8	25
Aspect	8	25
Grass	13* (+)	41
Forbs	6	19
Shrubs	15* (+)	47
Trees	14* (-)	44
Road Visibility	4	13

[1] Number of sites, among 32 observed, at which each variable had a significant ($P < 0.05$) independent correlation with pellet-group density.

* +, - Variables considered important in this study, with signs of partial regression coefficients.

occurring in the data, this proportion of positive relationships is unlikely ($P < 0.001$).

Partial regression coefficients for pellet-group density vs. distance from the road were significant and positive at all sites in the shrub zone and at 9 (47 percent) of 19 sites in the ponderosa pine zone (Table 4). In the ponderosa pine zone, the proportion of significant positive b's was higher for sites adjacent to paved roads (0.75) than for sites adjacent to gravel (0.5) or dirt (0.29) roads. All associated probabilities are so small as to support rejection of the null hypothesis.

The mean regression coefficient for deer pellet-group density vs. distance from the road was 0.025 pellet groups/plot/chain (Table 4) on the east-slope area, indicating that there were 0.48 more pellet groups per plot 1/4 mile away from the road than 33 feet from the road edge. The average regression coefficient for the shrub zone (0.045) was significantly ($p < 0.02$) larger than that for the ponderosa pine zone (0.013). Though differences were not statistically significant, there was a trend for the average regression coefficient to be larger adjacent to paved roads (0.043) than adjacent to gravel (0.020) or dirt (0.019) roads.

West Slope. When 31 sites were combined by road class and vegetation zone for the west-slope areas, deer pellet-group density increased with distance from roads in the shrub zone (Fig. 9). This increase was evident for the first 10 chains from all road classes.

Table 4. Distribution of deer fecal-pellet groups in relation to roads on the east-slope study area.

Vegetation Zone	Road Class: Paved	Gravel	Dirt	Vegetation Zone Mean
Ponderosa				
No. Sites	4	8	7	19
Proportion[1]	0.75	0.50	0.29	0.47
Probability[2]	<0.001	<0.001	=0.012	< 0.001
Mean b[3]	0.033	0.005	0.010	0.013
Shrub				
No. Sites	4	4	5	13
Proportion[1]	1.00	1.00	1.00	1.00
Probability[2]	<0.001	<0.001	<0.001	<0.001
Mean b[3]	0.052	0.051	0.032	0.045
Road Class Mean				
No. Sites	8	12	12	32
Proportion[1]	0.89	0.67	0.58	0.69
Probability[2]	<0.001	<0.001	<0.001	< 0.001
Mean b[3]	0.043	0.020	0.019	0.025

[1] The proportion of sites with statistically significant ($P < 0.05$) positive partial regression coefficients for pellet-group density vs. distance from the road.

[2] The probability of obtaining each proportion of significant coefficients if the null hypothesis, $\beta = 0$, is true. Many of these are much less than 0.001, as small as 10^{-28}.

[3] Average partial regression coefficient for pellet-group density vs. distance from the road (pellet groups per plot/chain from the road).

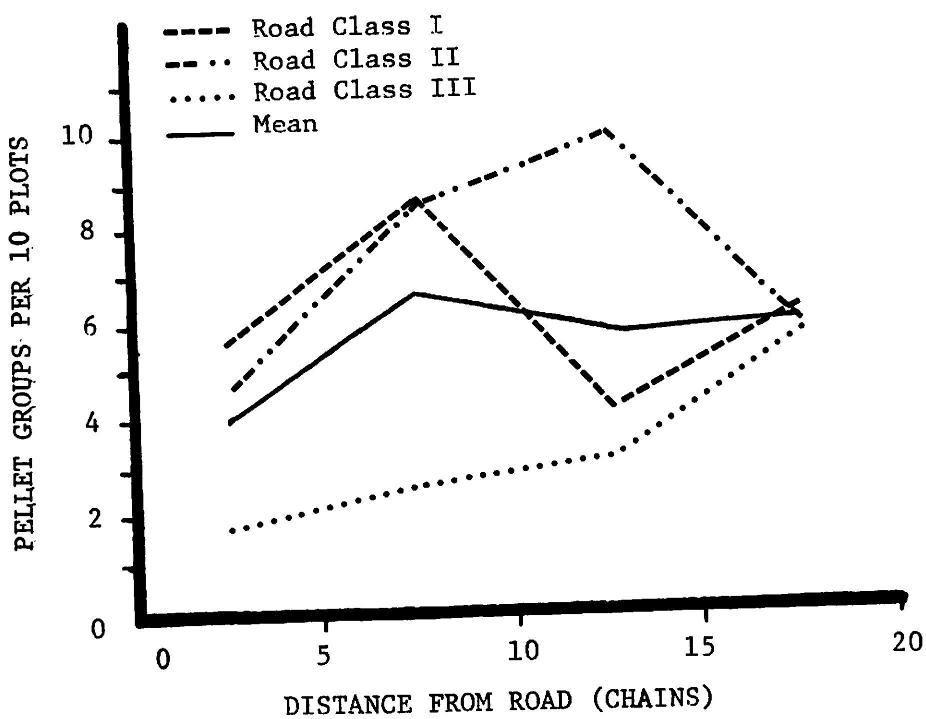

Fig. 9. Distribution of deer fecal pellet groups in relation to roads at 19 sites in the shrub zone, west slope. (Effects of eight independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5-chain (10 plot) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

Beyond 10 chains the trend was uncertain. The average of all road types in the shrub zone tended to increase and then level off. In the juniper zone, there was some increase in deer pellet-group density with distance from Class II roads (Fig. 10), evident for the first 10 chains from the road. The average of the three road types in the juniper zone showed no trend in numbers of pellet groups with distance from roads.

Analysis of the data with the stepwise multiple regression model showed increasing deer pellet-group density to be correlated with less slope, more abundant grass and shrub cover, and increasing distance from roads (Table 5).

Partial regression coefficients for deer pellet-group density vs. distance from the road were positive, indicating increasing pellet-group density away from roads, at 20 (64 percent) of the 31 sites. This proportion is unlikely ($P < 0.04$) is positive and negative relationships had equal chances of occurrence.

Partial regression coefficients for deer pellet-group density vs. distance from the road were statistically significant and positive at 11 (35 percent) of the 31 sites observed (Table 6), this proportion being highly unlikely ($P = 1.2 \cdot 10^{-10}$) due to random variation. Proportions of significant positive partial regression coefficients for 4 sites adjacent to Class I roads and for 6 sites adjacent to Class III roads are unlikely to have resulted from chance variation ($P < 0.01$). Although the proportion of significant positive partial regression

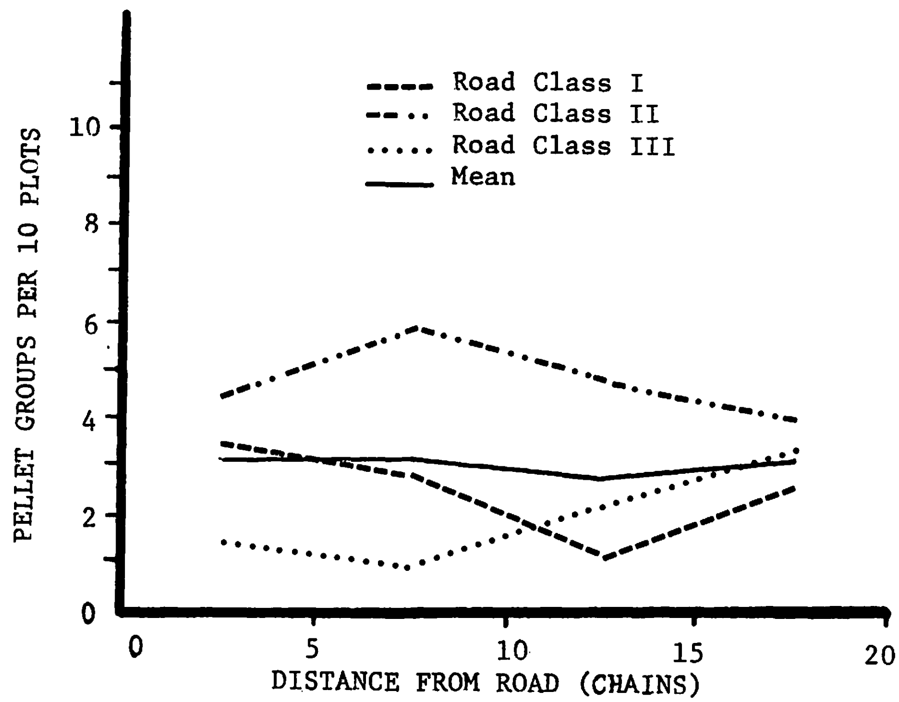

Fig. 10. Distribution of deer fecal pellet groups in relation to roads at 12 sites in the juniper zone, west slope. (Effects of eight independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5-chain (10 plot) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

Table 5. Significance of nine variables related to deer fecal pellet-group density on west-slope study areas[1].

Variable	Sites with significant partial regression	Percent of sites
Distance to road	14* (11, 3)	45
Slope	19* (2, 17)	61
Aspect	6	19
Grass	11* (9, 2)	35
Forbs	6	19
Shrubs	12* (12, 0)	39
Trees	7	22
Road Visibility	6	19
Oak Brush	6	19

[1] Number of sites, among 31 observed, at which each variable had a significant ($P < 0.05$) independent correlation with pellet-group density.
* (+, -) Variables considered important in this area, with numbers of positive and negative correlations in parentheses.

Table 6. Distribution of deer fecal-pellet groups in relation to roads on west-slope study areas.

Vegetation Zone	Road Class			Vegetation Zone Mean
	Paved	Gravel	Dirt	
Juniper				
No. Sites	2	8	2	12
Proportion[1]	0.00	0.125	0.50	0.17
Probability[2]	=0.95	=0.17	=0.050	= 0.032
Mean $\underline{b}$[3]	-0.002	0.001	0.008	0.002
Shrub				
No. Sites	2	13	4	19
Proportion[1]	1.00	0.31	0.75	0.47
Probability[2]	<0.001	<0.001	<0.001	< 0.001
Mean $\underline{b}$[3]	0.021	0.006	0.023	0.011
Road Class Mean				
No. Sites	4	21	6	31
Proportion[1]	0.50	0.24	0.67	0.35
Probability[2]	<0.01	<0.001	<0.001	< 0.001
Mean $\underline{b}$[3]	0.010	0.004	0.018	0.007

[1] The proportion of sites with statistically significant ($P < 0.05$) positive partial regression coefficients for pellet-group density vs. distance from the road.

[2] The probability of obtaining each proportion of significant coefficients if the null hypothesis, $\beta = 0$, is true. Many of these are much less than 0.001, as small as 10^{-10}.

[3] Average partial regression coefficients for pellet-group density vs. distance from the road (pellet groups per plot/chain from the road).

coefficients for 21 sites adjacent to Class II roads is unlikely ($P < 0.001$), there were also 3 sites with significant negative partial regression coefficients in sites adjacent to Class II roads.

The average partial regression coefficient for 31 sites is 0.007 pellet groups/plot/chain (Table 6), and is significantly different from zero ($P < 0.05$). This coefficient indicates 0.14 more pellet groups per plot 1/4-mile from the road than 33 feet from the road edge. The mean regression coefficient is larger in the shrub zone (0.011) than the juniper zone (0.002), and larger adjacent to Class III roads (0.018) than adjacent to Class I (0.10) or Class II (0.004) roads. None of these differences was statistically significant, however.

Elk

East Slope. When data from 8 sites in the ponderosa pine zone were combined for gravel roads and for dirt roads, elk fecal pellet-group densities increased with distance from gravel roads, but changed little or none with increased distance from dirt roads (Fig. 11). Sites in the shrub zone were not illustrated because of the small sample size. When variation due to all independent variables was accounted for with the stepwise multiple regression model, increasing pellet-group density was most consistently correlated with increasing distance from the road, with increasing grass cover, and with decreasing tree canopy cover (Table 7). The latter correlation may be due to leaves and needles covering pellet groups. Other independent

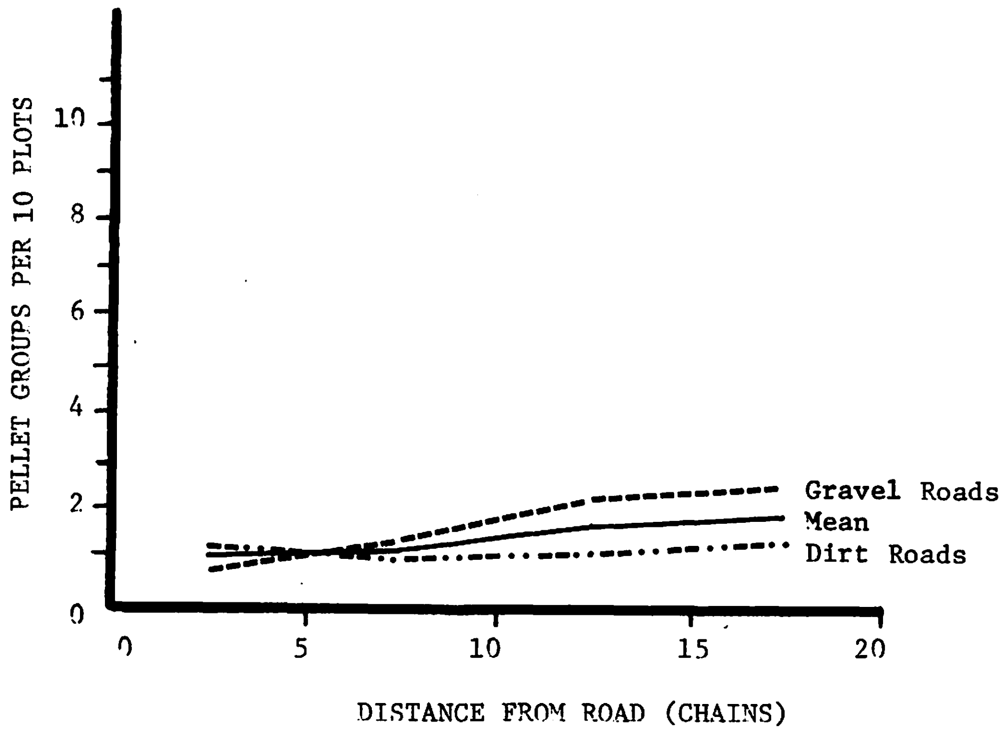

Fig. 11. Distribution of elk fecal pellet groups in relation to roads at 8 sites in the ponderosa pine zone on the east slope. (Effects of seven independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5-chain (10 plots) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

Table 7. Significance of eight variables related to elk fecal pellet-group density on the east-slope study area[1].

Variable	Sites with significant partial regression	Percent of sites
Distance to road	5* (+)	50
Slope	3	30
Aspect	2	20
Grass	4* (+)	40
Forbs	0	0
Shrubs	1	10
Trees	3* (-)	30
Road Visibility	0	0

[1] Number of sites, among 10 observed, at which each variable had a significant ($P < 0.05$) independent correlation with pellet-group density.

* +, - Variables considered important in this study with signs of partial regression coefficients.

variables were not frequently correlated with pellet-group density or were not consistently positive or consistently negative in their association with pellet-group density.

At 9 of 10 sites, partial regression coefficients for elk pellet-group density vs. distance from the road were positive, indicating increasing pellet-group density away from roads. This proportion of positive coefficients is unlikely ($P < 0.01$) due to random variation if positive and negative coefficients had equal chances of occurring.

Five of the 10 sites had significant positive partial regression coefficients for pellet-group density vs. distance from the road (Table 8). This proportion of significant positive partial regression coefficients is unlikely ($P = 2 \cdot 10^{-6}$) due to chance.

The mean partial regression coefficient for elk pellet-group density vs. distance from the road was 0.013 pellet groups/plot/chain (Table 8), indicating 0.25 more pellet groups per plot 1/4-mile from the road than 33 feet from the road edge. The mean regression coefficient is larger for paved (0.012) and gravel (0.017) roads than for dirt (0.004) roads, but this difference is not statistically significant.

West Slope. Combination of elk pellet-group data for 10 west-slope sites by road class and vegetation zone showed that elk pellet-group density increased in both juniper and shrub zones adjacent to Class II roads for the first 5 chains from the roads (Fig. 12). After

Table 8. Distribution of elk fecal-pellet groups in relation to roads on the east-slope study area.

Vegetation Zone	Road Class: Paved	Road Class: Gravel	Road Class: Dirt	Vegetation Zone Mean
Ponderosa				
No. Sites		5	3	8
Proportion[1]		0.60	0.33	0.50
Probability[2]		<0.001	=0.071	< 0.001
Mean $\underline{b}$[3]		0.017	0.004	0.012
Shrub				
No. Sites	1	1		2
Proportion[1]	0.00	1.00		0.50
Probability[2]	=0.97	=0.025		= 0.049
Mean $\underline{b}$[3]	0.012	0.019		0.016
Road Class Mean				
No. Sites	1	6	3	10
Proportion[1]	0.00	0.67	0.33	0.50
Probability[2]	=0.97	<0.001	=0.071	< 0.001
Mean $\underline{b}$[3]	0.012	0.017	0.004	0.013

[1] The proportion of sites with statistically significant ($P < 0.05$) positive partial regression coefficients for pellet-group density vs. distance from the road.

[2] The probability of obtaining each proportion of significant coefficients if the null hypothesis, $\beta = 0$, is true. Some of these are much less than 0.001, as small as 10^{-6}.

[3] Average partial regression coefficient for pellet-group density vs. distance from the road (pellet groups per plot/chain from the road).

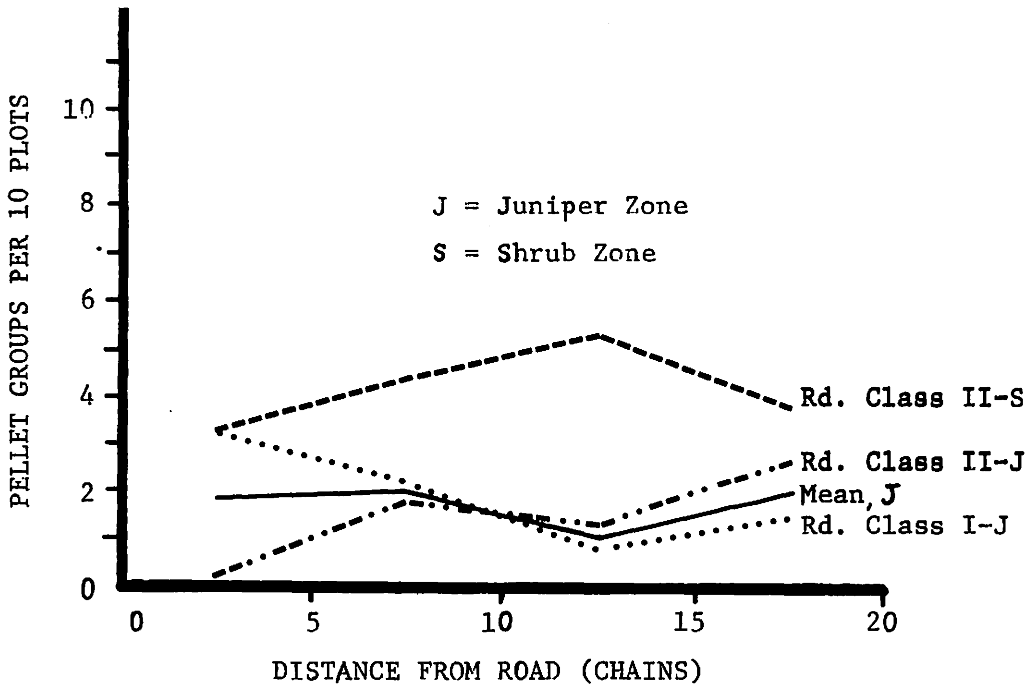

Fig. 12. Distribution of elk fecal pellet groups in relation to roads at 10 sites in the juniper and shrub zones, west slope. (Effects of eight independent variables, in addition to distance from roads, have not been accounted for in these data.)[1]

[1] Points plotted are the total number of pellet groups in each 5-chain (10 plot) segment, averaged for all sites in each road-class : vegetation zone category, and plotted at the mid-point of the 5-chain segment.

the first 5 chains, trends were uncertain. The average for the two road types in the juniper zone showed no trend.

In the stepwise multiple regression analysis, distance from the road was significantly ($P < 0.05$) correlated with pellet-group density at 4 sites (Table 9). In addition, increasing numbers of elk pellet groups were correlated with more southerly slopes and with an abundance of grass.

Partial regression coefficients were positive, indicating increasing elk pellet groups away from the road, at 6 of the 10 sites. Under the assumption that positive and negative relationships had equal chances of occurring, this proportion has a fair probability ($P = 0.2$) of being due to chance.

Only two sites had significant positive partial regressions for elk pellet-group density vs. distance from the road (Table 10). While the probability of this proportion occurring due to chance is 0.023, there were also two sites with significant negative coefficients.

The mean partial regression coefficient for elk pellet-group density vs. distance from the road on the west-slope areas was not significantly different ($P = 0.2$) from zero (Table 10). Thus, the null hypothesis that the distribution of elk pellet groups is unrelated to roads could not be rejected.

Table 9. Significance of nine variables related to elk fecal pellet-group density on west-slope study areas[1].

Variable	Sites with significant partial regression	Percent of sites
Distance to road	4* (2, 2)	40
Slope	2	20
Aspect	5* (1, 4)	50
Grass	4* (4, 0)	40
Forbs	2	20
Shrubs	1	10
Trees	1	10
Road Visibility	3	30
Oak Brush	0	0

[1] Number of sites, among 10 observed, at which each variable had a significant ($P < 0.05$) independent correlation with pellet-group density.

* (+, -) Variables considered important in this area, with number of positive and negative correlations in parentheses.

Table 10. Distribution of elk fecal-pellet groups in relation to roads on west-slope study areas.

Vegetation Zone	Road Class I	Road Class II	Road Class III	Vegetation Zone Mean
Juniper				
No. Sites	1	2		3
Proportion[1]	0.00	0.50		0.33
Probability[2]	=0.97	=0.049		= 0.071
Mean $\underline{b}$[3]	-0.011	0.018		0.008
Shrub				
No. Sites		7		7
Proportion[1]		0.14		0.14
Probability[2]		=0.15		= 0.15
Mean $\underline{b}$[3]		0.007		0.007
Road Class Mean				
No. Sites	1	9		10
Proportion[1]	0.00	0.22		0.20
Probability[2]	=0.97	=0.019		= 0.023
Mean $\underline{b}$[3]	-0.011	0.010		0.008

[1] The proportion of sites with statistically significant ($P < 0.05$) positive partial regression coefficients for pellet-group density vs. distance from the road.

[2] The probability of obtaining each proportion of significant coefficients if the null hypothesis, $\beta = 0$, is true.

[3] Average partial regression coefficient for pellet-group density vs. distance from the road (pellet groups per plot/chain from the road).

East-Slope Vs. West-Slope

Deer showed greater and more consistent avoidance of roads on the east-slope area than on the west-slope areas. The proportion (0.69) of sites with significant positive $\underline{b}$'s on the east-slope area exceeded, significantly (Chi square = 6.98, $P < 0.01$), the proportion (0.35) for the west-slope areas. Likewise, the mean partial regression coefficient for the east-slope area (0.043) exceeded ($P < 0.01$) that for the west-slope areas (0.007).

Similar, but weaker, trends were found for elk. The proportion (0.5) of sites with significant positive $\underline{b}$'s on the east-slope area was not significantly different (Chi square = 1.98, $P = 0.18$) from the proportion (0.2) for the west-slope area. Differences in the mean partial regression coefficients (east-slope area, 0.013; west-slope areas, 0.008) also were not statistically significant ($P > 0.20$).

DISCUSSION

Evaluation of Method

The method, as described, is useful for collecting the type of data needed in this study. It yields relatively large amounts of pellet-group data for the field time expended, a necessity in working with fecal pellet-group indices.

The broad classes used for independent variables other than distance from the road provided sufficient information to account for their influences on pellet-group densities so that the effect of distance from the road could be evaluated independently. The small number of integral classes are not suitable for predicting relationships between these variables and pellet-group densities; however, prediction was not our intention. Some sites were relatively homogeneous with respect to some variables to the extent that all observations for that variable were recorded in one or two classes. In such cases, lack of correlation between that variable and pellet-group density may indicate that the variable was not measured over a wide enough range to determine if it affected pellet-group density, not necessarily that the variable does not affect pellet-group density. Although some variables were not considered an important influence on pellet-group density in this study, they should be retained in future studies because different variables may be important in different areas.

There is a possibility that some unmeasured factor, strongly correlated with distance from the road, affected variation in pellet-group densities. A possibility is position on a slope. Perhaps deer and elk avoid valley bottoms because escape from predators may be easier or winter air temperatures may be more suitable at some distance up-slope. However, three east-slope sites and two west-slope sites located adjacent to roads on sidehills or on level ground showed similar trends for pellet-group density to increase with increasing distance from the road.

Although deer and elk pellet-group density on most west-slope sites, and on some east-slope sites, had leveled off between 15 and 20 chains from the road, pellet-group density on some sites was still increasing at 1/4-mile from the road. In future studies, transects should be at least 1/4-mile long to determine the full range of effects of the road.

Because of the broad applicability of this method, it lends itself to a variety of studies dealing with the relationship between roads and pellet-group densities. It could be used to compare hunted and non-hunted populations, different species of ungulates, different habitat types, different areas and varying traffic levels. Such information would further the understanding of this complex problem.

Validity of Method

Little information exists concerning the relationship between pellet group distributions and utilization of habitat by ungulates. However, the existing information suggests a positive correlation. Bennett et al. (1940:401), referring to white-tailed deer, stated that "pellet group counts reveal deer movements and utilization by deer of the different forest types and subtypes" and that "deer deposit a great proportion of their pellet groups near where they feed." McCain (1948) reported that pellet groups show where deer spend most of their time, and Neff (1968), in his review, assumed this to be true. Anderson et al. (1972) noted a positive correlation between pellet groups and percent utilization of true mountain mahogany and antelope bitterbrush, even though these correlations were not statistically significant. The following discussion assumes that pellet-group densities are valid measures of habitat utilization by deer and elk.

Deer: All Areas

Deer on the east-slope study area avoid roads in the shrub zone, their primary winter habitat, where pellet-group densities tend to be an average of 4 times greater at 15 - 20 chains from roads than in areas within 5 chains of roads (Fig. 8). Deer also avoid roads in the ponderosa pine zone (Fig. 7), but avoidance is not as great as in the mountain shrub zone. Perhaps screening provided by trees moderates the effect of roads on deer in the ponderosa pine zone. However, since road visibility was not often correlated with pellet-group density, the effect of screening by trees upon deer response is not clear. Although differences among road classes were not statistically significant, trends in the data support the alternate hypothesis that deer avoid more heavily traveled roads more than less heavily traveled ones. However, deer avoid even dirt roads, some of which are used only by four-wheel drive vehicles, trailbikes and hikers.

In contrast, deer on the west-slope study areas avoid roads, but not as strongly as on the east-slope study area. On west-slope study areas, deer avoided roads in the shrub zone, their primary winter habitat, but pellet-group densities averaged only 50 percent higher 15 - 20 chains from the road than in areas within 5 chains of the road (Fig. 9). Deer in the juniper zone do not appear to consistently avoid roads, the average pellet-group densities being about equal at all distances from roads (Fig. 10). Differences among road classes were not statistically significant, but there was a trend in the data for Class III roads to be avoided more than Class I or Class II roads. At first, this seems to be opposite the situation on the east-slope area. However, upon closer inspection, I think it is similar. Four of the six sites adjacent to Class III roads were located along Cattle Creek, southeast of Glenwood Springs. Though this road probably receives no more traffic than some of the secondary paved roads or I-70 in the winter, it may receive as much. In addition, most of the many homes along the road are year-round residences. Thus, disturbances other than traffic associated with this road appear greater than with any other road on the west-slope study areas.

The similarity in trends in the shrub zone between east- and west-slope data indicates that, in their primary winter habitat, deer avoid roads. The weaker tendency to avoid roads on the west-slope areas could be due to several factors.

Because of less snowfall and snow accumulation, available winter habitat is relatively more abundant on the east-slope study area than on the west-slope study areas. Deer on the east-slope study area can afford to avoid roads, presumably without risk to their nutritional well being. On the west-slope areas, however, because snow lingers and accumulates during the winter, deer have to utilize areas near roads to avoid malnutrition. In this case, I would expect deer use of areas near roads to be greater during severe winters than during mild winters (with less snow accumulation), during more severe periods within winters, and later during each wintering period after forage away from roads has been utilized.

Conceivably, deer could utilize the area near roads and still avoid most disturbances associated with roads. Areas near roads might be utilized at night, avoiding most traffic, and avoided during the day. If this were true, pellet-group distributions would show no trends, even though deer were avoiding the disturbance.

Elk: All Areas

On the east-slope study area elk avoid gravel roads in the ponderosa pine zone, their primary winter range (Fig. 11). In contrast to deer, elk do not seem affected by dirt roads. However, the majority of elk use of the ponderosa pine zone is in midwinter when dirt roads are snow-covered and used mostly to an unknown extent by snowmobiles.

In the west-slope areas, elk appear to avoid secondary paved roads (Class II) in both the juniper zone, their primary winter habitat, and in the shrub zone (Fig. 12). However, it is probable that the observed proportion of significant positive partial regressions in the shrub zone for Class II roads (Table 10) was due to chance variation, since the proportion could occur by chance in nearly one of every 5 trials. Conclusions about the other road classes would be inappropriate because of the lack of samples.

Although the probability for the observed proportion of significant positive partial regression coefficients (0.023, Table 10) is relatively small, an equal number of significant negative partial regressions was observed for pellet-group density vs. distance from the road, indicating that the observed non-random distribution of elk pellet groups in relation to roads is the result of the influence of some variable not measured in this study.

Elk may not have shown avoidance of roads on the west-slope areas to the degree exhibited on the east-slope area for the same reasons that deer avoidance of roads was less consistent on the west-slope areas than on the east-slope area.

Management Implications

It is not known whether deer and elk avoid roads to an extent that is detrimental to their welfare. Deer on west-slope study areas avoided roads at least part of the time, even though snow accumulation restricts the amount of available habitat. Therefore, the effect of roads on the welfare of individuals, and on the productivity of the herd is not clear. Batchelor (1968) described declines in productivity of populations of red deer (*Cervus elaphus*) and chamois (*Rupicapra rupicapra*) that had responded to intensive hunting by restricting themselves to the cover of substandard habitat. Similar declines in productivity of deer and elk populations would occur if avoidance of an expanding road system resulted in poorer nutrition for the animals.

However, the west-slope data in particular suggest that the animals may utilize areas near roads when hunger is sufficient to overcome fear. Such a response to roads might even be beneficial, in that a food supply near roads would be little used in moderate weather and reserved for critical periods. While such a response might help keep deer and elk alive, the productivity of the herd might still be affected.

The role of hunting in developing a road-avoidance response in big game is not clear. Geist (1970) maintained that ungulates learn to avoid unpleasant objects and can generalize to all similar objects and localities and avoid them also. He emphasized the role of hunting in educating large mammals to avoid humans. The report of Behrend and Lubeck (1968) supports the idea that deer learn to avoid roads because of hunting.

Results of this study indicate that range improvement projects designed to benefit deer or elk should be located away from roads. Although there is evidence from the east-slope data that an abundance of grass and shrubs near roads may help counter effects of the road, the data also indicate that habitat improvement projects would receive more use if they were carried out away from existing roads.

In summary, these data indicate that an expanding road system and/or an increasing traffic volume on National Forest roads would affect the distribution of deer and elk, at least at times of the year, and may affect their welfare. This response may be primarily a characteristic of hunted populations.

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