AN ABSTRACT OF THE THESIS OF

Michael D. Pope for the degree of Master of Science in Wildlife Science presented on October 27 1994. Title: Roosevelt Elk Habitat Use in the Oregon Coast Range.

Abstract approved: Redacted for Privacy
Robert G. Anthony

Few studies have evaluated non-migratory Roosevelt elk (*Cervus elaphus roosevelti*) interactions and habitat use on lands undergoing extensive timber removal. We captured and radio-tracked for 14 months representatives from 29 different bands of elk across a 37,000 ha area of Oregon's Coast Range. We identified 6 habitat variables within individual elk home ranges and across the study area. In general, elk use of these habitats within individual home ranges was not significantly ($P < 0.05$) different from availability. However, in pooling all elk locations and using the entire study area as the extent of habitat availability, a preference was shown for forb/grass habitats, areas within 300 m of the nearest water, and intermediate elevation areas. Elk avoided landtypes within 50 m of the nearest road. We evaluated levels of elk interaction and found remarkably low levels of interchange between adjacent bands of elk. Home range size ranged from 290 to 1896 ha. Because levels of interaction were low for elk in our study, we suggest that elk have strong site fidelity and band cohesion even in highly fragmented habitats. Areas nearest streams and with adequate amounts of forb/grass patches are preferred for home range location.

Roosevelt Elk Habitat Use in the Oregon Coast Range

by

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A THESIS

submitted to

Oregon State University

in partial fulfillment of
the requirements for the
degree of

Master of Science

Completed October 27, 1994
Commencement June 1995

Master of Science thesis of Michael D. Pope presented on October 27, 1994

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Michael D. Pope, Author

ACKNOWLEDGEMENTS

Without the strong support and encouragement of the cooperating agencies and organizations, this project would not have been possible. I would like to thank Bret Christiansen, Larry Mangan and Steve Langenstein from Coos Bay Bureau of Land Management for not only their wonderful support and assistance, but also for their patience and friendship. From the Oregon Department of Fish and Wildlife, I give my thanks to John Toman and Pete Perrain for going above and beyond the call of duty. The Rocky Mountain Elk foundation was instrumental in providing financial help when this project most needed it.

I would like to acknowledge Doug McAlister for his invaluable field work. For Karl Martin, John Loegering, Jerome Leonard, Eric Pelren, Bob Steidl, Dan Rosenberg, Carolyn Mairn and all my other fellow graduate students who answered endless questions and bore the brunt of my teasing, thanks for your help and support.

I would like to acknowledge my major advisor, Bob Anthony, who gave wisdom and encouragement when most needed. I thank Dan Edge for responding intelligently and patiently to thousands of questions.

I want to give my love and thanks to Nathaniel, my son, whose bright eyes and sweet smile made everyday wonderful. Finally, I want to thank my wife, Becca, who soothed my fears, encouraged my dreams, and gave love every step of the way. Thanks Becca!

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ROOSEVELT ELK HABITAT USE IN THE OREGON COAST RANGE

CHAPTER I

HOME RANGE, ELK ASSOCIATIONS AND SURVIVABILITY OF ROOSEVELT ELK IN THE OREGON COAST RANGE

INTRODUCTION

Home range has been defined as "that area traversed by the individual in its normal activities of food gathering, mating and caring for young" (Burt 1943:351). White and Garrott (1990:145) suggest that the key word in the above definition is "normal", which specifies the area that an animal normally uses in daily activities, not the entire range of its lifetime movements. Unbiased estimates of home range are useful in estimating population densities, distribution patterns, habitat use and intraspecific behaviors (Sanderson 1966, Michener 1979). In addition, core areas or areas of intensive use within home ranges have been described as areas that contain homesites, refuges and the most dependable food sources (Burt 1943, Kaufmann 1962). Underlying the concepts of home range and core areas is that in any given environment or landscape certain areas are preferred by a particular species. Identifying these areas is an important part of understanding patterns of habitat use; consequently one objective of our research was to estimate home range and core area sizes from locations of Roosevelt elk (Cervus elaphus roosevelti) in the southern Oregon Coast Range.

There are a number of factors that influence the distribution and abundance of elk across the landscape. The complex social organization of elk directly effects the geographic distribution and spacing of this species (Franklin et al. 1975). Additionally, elk learn easily from their experience and adjust their ecology and behavior accordingly (Geist 1982). Elk modify their social patterns in response to different or changing environmental conditions. Within this century, many forest habitats in the southern Oregon Coast Range have been extensively altered primarily from timber harvesting. Given this continually changing forest landscape, the second objective of our research was to evaluate the levels of group interchange among elk within our study area.

Information on survival rates is important for managing populations and establishing harvest levels. Determining cause-specific mortality for elk is integral to evaluating harvest strategies and habitat management goals. Our third objective was to estimate survival rates and determine the causes of mortality of elk in the southern Oregon Coast Range.

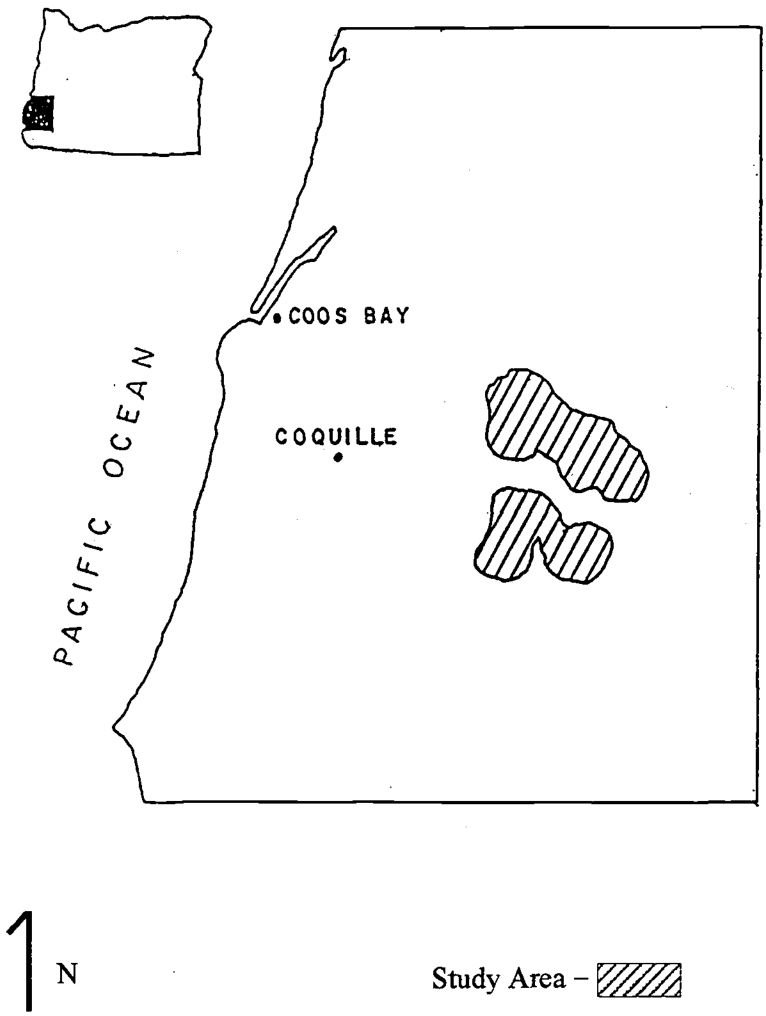
STUDY AREA

The study was located within Tioga and Myrtlewood Resource Districts of the Bureau of Land Management (Fig. 1). This area is approximately 24 km southeast of Coos Bay and covers nearly 38,000 ha. in the southern Oregon Coast Range. Forest cover was historically dominated by climax (>200-year-old) Douglas-fir (Pseudotsuga menziesii) and western hemlock (Tsuga heterophylla) (Franklin and Dryness 1973). Extensive timber harvesting in the previous two decades has removed most large blocks of late-successional forests. Riparian areas are dominated by dense stands of red alder (Alnus rubra), bigleaf maple (Acer macrophyllum), and myrtle (Umbellularia californica). Shrub understories are predominately huckleberry (Vaccinium ovatum and V. parvifolium), vine maple (Acer circinatum), salal (Gaultheria shallon), rhododendron (Rhododendron macrohpyllus) and oceanspray (Holodiscus discolor) (Franklin and Dryness 1973).

Elevation within the study area varies from 200 m in drainage bottoms to 900-1000 m on the main ridges. The area is extensively interlaced with stream systems. Franklin and Dryness (1973) describe this secton of the Oregon Coast Range as typographically mature with steep mountain slopes and extremely sharp ridges.

Landownership is a checkerboard array in nearly equal proportions of public and private ownerships. Most private lands are used for commercial timber production. Both private and

Figure 1. Study area for Roosevelt elk in southern Oregon Coast Range, 1991-92.



public lands have been intensively managed for timber harvest, resulting in a highly fragmented forested landscape. Logging, salvage operations, thinning, cedar bough collecting, and many other commercial activities have occurred throughout the area. Most active logging during this project was on private lands primarily in the south half of the study area.

Both deer and elk are hunted within the boundaries of our study area. Regulated rifle season for deer was from 28 September to 6 November 1991. Bull elk season for rifle hunters occurred on 9-13 November 1991 and 16-24 November 1991. An antlerless archery and muzzleloader season began on 30 November and ended 6 December. A limited permit-only rifle season for cow elk was open from 14-15 December 1991. In the West Tioga Subunit, where this research was conducted, 437 anterless elk and 549 bulls were harvested during the 1991 archery and rifle hunts.

The study area has an extensive network of logging roads with 863 km of roads (6.04 km/km^2). Paved roads crisscross most BLM lands with a complex system of rocked and unrocked secondary and spur roads branching off these paved roads. During this research, a fire season road "entry by permit" restriction limited public access to the study site from 4-23 October 1991. No the road foot traffic was allowed during this period, and only vehicles with authorized management activities were permitted on the roads. Outside of the fire season all roads except one permanently gated spur road and one temporarily-gated (October 1991-November 1991) secondary road were open to public access.

Annual rainfall within the study area varied from a maximum of 218 cm to a minimum of 97 cm over the last 24 years (Oregon Climatological Center 1993). Over this same period, temperature (Table 1) varied from a mean maximum high of 78.6 (K) in August to mean minimum low of 35 (K) in January (Oregon Climatological Center 1993). Snowfalls are rare at lower elevations. On higher ridges snow may block road access for 1-2 months. During this study, only one significant snowfall (12.7 cm) occurred above 500 m but this did not block road access.

Table 1. Monthly mean minimum and maximum temperatures (K) and precipitation (cm) from 1969-1992 for center[a] of study area in Oregon Coast Range (Oregon State Climatological Center).

Month	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Ann
T-min.	35.0	36.9	38.5	39.7	43.7	48.5	51.1	51.3	48.0	43.0	39.6	35.8	42.6
T-max.	53.9	56.9	59.4	62.5	67.6	72.8	77.6	78.7	76.9	69.7	58.0	52.4	65.5
Precip.	23.3	18.3	19.1	12.4	7.6	4.1	1.27	2.54	5.3	9.9	24.6	25.1	155.7

[a] Sitkum Station

METHODS

Elk Captures

Oregon Department of Fish and Wildlife captured 29 cow elk in March 1991 by aerial darting using carfentanil citrate as an immobilization agent. An effort was made to capture an equal number of elk in the north and south halves of the study area. Animals were selected from as many distinct bands and areas as possible. Each animal's estimated weight, sex, age, and general physical condition were recorded. Radio transmitter (Telonic's MOD-600) collars (164/165 MHZ) with an operational life of > 36 months were fitted to each elk. Each transmitter had a "motion sensor" that when activated increased the pulse rate from 50 to 100 pulses per minute. Additionally, all animals were fitted with a pair of numbered, color-coded ear tags (Nasco TUFF-FLEX, Modesto, Cal.).

Radio-Telemetry

Telonic's TR-2 receivers with two-element (RA-2AHS) yagi antennas were used to receive signals from radio-collared elk. Throughout the period of this study all animals were located from the ground using 3-5 intersecting compass bearings. The "loudest signal method" (Springer 1979) was used to estimate bearings on radio-collared elk, and attempts were made to minimize distance between receiver and source of signals. Time intervals between individual bearings were generally less than 20 minutes. Azimuths were plotted on United States Geologic Survey (USGS) topographic maps (7.5 minute, 1:24,000). Receiver locations were recorded using Universal Mercator grid (UTM) coordinates. Transmitter UTM coordinates for radio-collared animals were derived from azimuth intercepts using the telemetry data processing program XYLOG (Dodge and Steiner 1986). Additionally, XYLOG calculated a confidence ellipse (CE) for each location as described by Lenth (1981) and evaluated by White and Garrott (1984).

A number of biotelemetry error sources have been identified (White and Garrott 1990, White and Garrott 1986, Garrott et al. 1986, Lee et al. 1985, Springer 1979). To minimize potential triangulation errors, azimuths were taken on transmitters at 40 different locations and at various times, distances and topographies in the study area. A mean variance of 5 derived from these azimuths was used as input into XYLOG for determination of maximum likelihood estimates (Lenth 1981) and confidence ellipses for each location.

Elk Monitoring

Elk were located at least once each week between sunrise and sunset for 15 months (June 1991 to August 1992). To minimize autocorrelation of successive locations, individual animals were located at least 18 hours apart. Successive locations that are separated by relatively short time intervals may result in autocorrelated telemetry data (Swihart and Slade 1985, Lair 1987, Worton 1987) and bias home range estimates (Ackerman et al. 1990). The necessity to obtain 50-70 locations per animal during the study period precluded complete randomization of radio-locations.

No systematic effort was made to visually locate animals because of dense vegetative cover, elk were easily disturbed if approached, which could bias habitat selection patterns of individual elk. If any three consecutive locations on a given elk were in the same site, an attempt was made to visually locate the animal. When radio-collared elk were observed, we recorded location, habitat type, number of elk, band composition, date, time and specific activities of elk.

Home Range and Core Activity Areas

Locations for 24 radio-collared elk were tested for bivariate and weighted bivariate normality using a Cramer-von Mises goodness-of-fit test (Ackerman et al. 1990). This test indicated that 8 of 24 elk data sets were not bivariate normal and 15 data sets did not have a weighted bivariate normal distribution. Given these results, we decided to use two home range estimators; the minimum convex polygon (Hayne 1949) and the non-parametric adaptive kernel (Worton 1989) estimators. Home range estimates for 24 elk at the 95%, 75%, and 50% contour levels were generated using the adaptive kernel and the minimum convex polygon methods with Program CALHOME (Baldwin and Kie 1992).

Core activity areas for the same elk were estimated using the harmonic mean method from program Home Range (Ackerman et al. 1990). Core areas were defined as the "maximum area within which the observed utilization distribution exceeds a uniform utilization distribution" (Ackerman et al. 1990). Program HOME RANGE uses a x^2 test "made on the ordered cumulative distribution of observed data, compared to the uniform model" to estimate if observed use was greater than a uniform distribution (Ackermann et al. 1990).

Elk Associations

Coefficients for associations between cow elk were determined using the formula:

$$CA=\frac{2AB}{A+B}$$

where AB= number of times elk A and elk B were observed together, A= number of times elk A was located B, and B= number times elk B was located (Cole 1949). If A and B were always located together, then the coefficient would equal 1. If there is no association, coefficient indexes would be 0. Not enough locations were taken to estimate daily cow associations or to determine social organization patterns in specific forests habitats.

Survival of Elk Cows

Survival rates for radio-collared elk in this study were estimated using Heisey and Fuller's (1985) extension of the Mayfield (1961, 1975) survival estimator for radio-tracking data and Pollack et al.'s (1989) adaptation of the Kaplan-Meier product estimator (Kaplan and Meier 1958) for staggered entry. Mayfield estimators were generated using program MICROMORT (ver 1.3: Heisey and Fuller 1985) while the Kaplan-Meier estimators were derived from a spread sheet program developed by Pollack et al. (1989).

Two separate intervals each 365 days long were selected for survival estimates. The first interval started with capture dates of the radio-collared elk in March 1991 and ended on the last day of Febuary 1992. The second interval started on 1 March 1992 and ended on the last day of Febuary 1993. No attempt was made to estimate seasonal survival rates because of the small sample (n=29) of animals in this study. All animals that disappeared were 'censored ' and their radio-telemetry days, until the time of disappearence, were included in survival estimates.

RESULTS

Elk Captures

Thirty-four animals were darted from 3 to 26 March 1991 using aerial (helicopter) darting; 5 eluded capture or expired (2 known mortalities). Twenty-nine adult females (Table 2) were successfully captured and fitted with transmitters for this study. Average handling time for tranquilized animals was 33 minutes with an estimated average recovery time of 60 seconds after injection of the antidote Naloxone (20 cc). Estimated weights for the 29 radio-collared cow elk ranged from 181 to 318 kg ($\bar{x}$= 278 kg). Ages for radio-collared cows ranged from 2 to 14 years ($\bar{x}$ = 6.4 yr). In the north half of the study area, 16 elk were captured and radio collared; 13 elk were captured and radio-instrumented in the south half.

Table 2. Radio frequencies, capture dates, estimated age (yrs), and weights (kg), drug dose (mg), and total number of locations of radio-collared elk in the southern Oregon Coast Range, 1991-92.

Elk #	Freq.	Date	Age	Weight	Drug Dose	#Locations
1	164.022	3/6/91	8	295	3	67
2	164.041	3/7/91	4	318	3	48
3	164.061	3/7/91	2	227	3	64
4	164.081	3/8/91	5	272	3	66
5	164.100	3/8/91	5	295	3	66
6	164.120	3/9/91	8	318	3	59
7	164.161	3/9/91	3	272	3	68
8	164.181	3/11/91	6	295	3	60
9	164.211	3/11/91	2	181	3	2
10	164.232	3/13/91	8	272	3	66
11	164.251	3/13/91	6	261	3	69
12	164.271	3/13/91	4	249	3	67
13	164.291	3/19/91	10	272	3	56
14	164.311	3/18/91	8	318	3	65
15	164.330	3/19/91	2	227	3	59
16	164.351	3/19/91	8	318	3	62
17	164.370	3/19/91	10	329	3	61
18	164.390	3/20/91	8	272	3	64
19	164.421	3/20/91	8	227	3	65
20	164.441	3/20/91	10	283	3	21
21	164.461	3/20/91	4	272	3	63
22	164.491	3/20/91	5	295	3	64
23	164.532	3/20/91	14	295	3	62
24	164.551	3/25/91	8	283	3	67
25	164.571	3/25/91	5	261	3	28
26	164.591	3/25/91	5	283	3	31
27	164.611	3/25/91	6	318	3	32
28	164.631	3/26/91	7	238	3	61
29	164.651	3/26/91	6	306	3	63

Home Range and Core Activity Areas

Home range size was estimated for 24 of 29 elk for which there were >45 locations (Table 3). The number of locations for the 24 animals ranged from 48 to 68 ($\bar{x}$= 61) In pooling all elk confidence ellipses (CE), mean CE size equaled 0.90 ha. Of the 24 elk, all but one survived until the end of the study. This animal disappeared (presumed poached) in May 1992 after 11 months of monitoring.

Home range size based on adaptive kernel (ADK) estimates using 95% contours was 765 ha (SD= 407) for the 24 elk. ADK estimates for individual home range sizes varied from 296 ha to 1,865 ha. Minimum convex polygon (MCP) methods using 95% contour levels produced smaller (then ADK) home range sizes with a mean of 514 ha (SD= 319) and range of 184 ha to 1,391 ha. Number of locations on any individual animal were not sufficient to estimate seasonal home ranges.

Core areas were defined as the maximum area beyond which observed utilization distributions exceeded a uniform utilization distribution (Ackermann et al. 1990). Average core area (Table 4) was 433 ha (SD= 200) with a range of 228 to 891 ha. Utilization volumes varied from a high of 67.6% to a low of 53% ($\bar{x}$= 63.6%). Core areas averaged 34% (SD= 4.5) of total home range for all elk.

Elk Associations

Eighteen of the 24 radio-collared elk had some level of association with other collared elk (Table 5). Combining all seasons (spring, calving, summer, rut, fall, and winter) the highest association was 0.50 (Elk # 4.271 and Elk # 4.232) (SD= 0.22) and the lowest association was .01 (Elk # 4.161 and Elk # 4.532) (SD= 0.03). Seasonal variations in association indices were highest for two cows (4.632/4.651) with 0.91 (SD= 0.34) association during spring and 0 association for rut.

Table 3. Adaptive kernel (ADK) and minimum convex polygon (MCP) home range estimates at 95%, 75%, and 50% contour levels for Roosevelt elk in the Oregon Coast Range, 1991-92.

Elk#	ADK 95	ADK 75	ADK 50	MCP 95	MCP 75	MCP 50
4.022	694	295	100	447	232	101
4.041	960	495	260	712	509	226
4.061	497	202	88	335	143	89
4.081	625	221	56	392	143	50
4.100	690	249	108	475	225	95
4.120	810	302	118	536	214	78
4.161	1865	952	545	1391	676	389
4.181	1071	360	154	513	246	102
4.232	364	176	93	264	159	95
4.251	314	100	53	184	119	46
4.271	296	156	58	249	145	105
4.291	956	605	264	680	410	243
4.311	910	546	190	712	442	232
4.330	1666	723	282	1287	525	280
4.351	1000	356	184	614	405	244
4.370	1156	565	180	937	481	261
4.390	476	248	92	297	150	72
4.421	528	237	88	342	176	70
4.461	354	179	68	227	128	72
4.491	406	203	93	274	190	93
4.532	790	241	100	381	171	87
4.551	1025	331	201	610	275	193
4.631	471	130	71	222	96	46
4.651	437	166	69	272	109	51
$\bar{x}$	765	334	334	514	265	138
SD	398	206	107	312	158	92

Table 4. Core area size (ha), percent of total home range, utilization volumes, and harmonic mean (HM) values of radio-collared elk in the Oregon Coast Range, 1991-92.

Elk#	Core Area	% Area	Utilization Volume	HM Value
4.022	287	37	61	887
4.041	389	35	53	1099
4.061	302	34	65	887
4.081	238	30	63	828
4.100	281	36	58	896
4.120	327	34	62	1021
4.161	891	41	62	1476
4.181	545	30	65	1190
4.232	375	30	68	973
4.251	228	30	67	770
4.271	239	41	68	763
4.291	778	37	66	1371
4.311	624	38	64	1233
4.330	804	40	66	1460
4.351	654	38	64	1244
4.370	689	40	64	1336
4.390	391	32	67	994
4.421	308	32	64	890
4.461	166	36	61	705
4.491	295	37	63	875
4.532	290	32	62	887
4.551	494	36	66	1120
4.631	382	25	66	1019
4.651	406	26	67	1055
$\bar{x}$	433	34	64	

Table 5. Seasonal association indexes for radio-collared elk in the southern Oregon Coast, 1991-92.

Elk #	Elk #	Spring	Calving	Summer	Rut	Fall	Winter	Mean	SD
4.022	4.100	0.17	0.00	0.00	0.00	0.00	0.00	0.03	0.07
4.041	4.441	0.00	0.00	0.16	0.33	0.35	0.00	0.14	0.17
4.081	4.232	0.16	0.08	0.00	0.00	0.00	0.00	0.04	0.07
4.081	4.271	0.00	0.00	0.00	0.00	0.13	0.00	0.02	0.05
4.120	4.291	0.11	0.55	0.06	0.00	0.00	0.38	0.18	0.23
4.120	4.330	0.31	0.10	0.14	0.00	0.00	0.12	0.11	0.11
4.120	4.532	0.09	0.00	0.09	0.00	0.00	0.00	0.03	0.05
4.161	4.551	0.41	0.00	0.00	0.00	0.10	0.31	0.14	0.18
4.161	4.532	0.00	0.00	0.07	0.00	0.00	0.00	0.01	0.03
4.181	4.351	0.00	0.09	0.00	0.00	0.00	0.00	0.02	0.04
4.232	4.271	0.66	0.54	0.24	0.23	0.75	0.63	0.50	0.22
4.330	4.532	0.00	0.00	0.00	0.00	0.00	0.20	0.03	0.08
4.351	4.371	0.55	0.54	0.22	0.00	0.00	0.50	0.30	0.26
4.390	4.421	0.18	0.09	0.04	0.14	0.31	0.00	0.13	0.11
4.461	4.491	0.18	0.37	0.33	0.36	0.57	0.20	0.34	0.14
4.631	4.651	0.91	0.66	0.42	0.00	0.11	0.40	0.27	0.34

In combining seasonal associations for the 18 elk, spring had the highest mean association index (0.21) (SD= 0.27) with rut having the lowest (0.07) (SD= 0.12) index.

Survival Rates

From March 1991 to March 1992, three elk with radio-collars died and three additional animals disappeared with their fates unknown (Table 6). The known mortalities were from poaching. From March 1992 to March 1993, two radio-collard elk died and one disappeared. Of the two known mortalities, one animal was shot during a three day cow hunt and one animal died from unknown causes.

Survival rates for 1 March 1991 to 28 February 1992 were 0.896 (SE= 0.032 and .012) for both the Mayfield and Kaplen-Meier methods (Table 7). Survival rates for 1 March 1992 to 28 February 1993 were 0.916 (SE= 0.037) for the Mayfield method and 0.913 (SE .011) for the Kaplen-Meier method.

Table 6. Frequency, fate and last date[a] of contact of radio-collared elk in the southern Oregon Coast Range, 1991-92.

Unknown	Disappeared	Poaching	Hunting
4.351 4/93	4.041 5/92	4.211 7/90	4.461 12/92
	4.441 12/91	4.611 2/92	
	4.491 12/92	4.591 2/92	
	4.571 1/92		

[a]Month and year.

Table 7. Annual survival rates and standard error (SE) for Roosevelt elk in the southern Oregon Coast Range (n = 29 and n = 24) during 2 one year intervals.

	Method	Survival (est)	SE
3/1/91 - 3/1/92	Kaplen-Meier	.896	.012
	Mayfield[a]	.896	.032
3/2/92 - 3/1/93	Kaplan-Meier	.913	.011
	Mayfield[a]	.916	.037

[a] Heisey-Fuller (1985) extension of Mayfield.

DISCUSSION

Home Range

Home ranges for the 24 elk in this study were initially estimated using 5 methods (bivariate normal (BN), minimum convex polygon (MCP), weighted bivariate normal (WBN), harmonic mean (HM) and the adaptive kernel (ADK)) at a 95% contour level (Table 8). The MCP provided the lowest estimates (514 ha), and the HM method gave the highest home range estimates ($\bar{x}$ = 1094). ADK estimates were selected in this study as the most reliable estimate of home range because of this estimator's flexibility and robustness. The MCP method has been widely used and reported during the previous 2 decades, but the usefulness of this estimator has been questioned (Schoener 1981, Anderson 1982, Worton 1987, Ackermann et al. 1990) because of the bias of the MCP associated with small sample sizes. Additionally, the MCP is strongly influenced by outliers (MacDonald et al. 1980). The BN estimator is limited to data that is bivariate normally distributed (Andersen 1982, Schoener 1981). The WBN method while more robust to deviations from bivariate normal distributions is still dependent on animal locations that are temporally independent and that fit into some bivariate normal pattern (Garrott and White 1990). Worton (1987) has criticized the non-parametric and HM estimators as too sensitive to cell size and density. The subjective placement of grid cells and selection of inadequate scaling parameters with the HM will influence and potentially bias home range estimates. Worton (1989) proposed using a non-parametric, kernel approach to home range estimation. This adaptive kernel method has the flexibility of many non-parametric approaches yet is more robust to variations of grid cell placement, size and density. This method uses a smoothing parameter which provides less biased estimates of home range sizes.

Table 8. Adaptive kernel (ADK), harmonic means (HM), weighted bivariate normal (WBN), minimum convex polygon (MCP), and bivariate normal (BN) home range estimates at 95% contour levels for Roosevelt elk ($\underline{n}$ = 24) in the southern Oregon Coast Range, 1991-92.

Elk #	ADK 95	HM 95	WBN 95	MCP 95	BN 95
4.022	694	716	829	447	801
4.041	960	992	1240	712	1432
4.061	497	819	540	335	691
4.081	625	728	395	392	550
4.100	690	650	693	475	850
4.120	810	892	800	536	1111
4.161	1865	1901	2098	1391	2453
4.181	1071	1494	732	513	996
4.232	364	1050	445	264	560
4.251	314	647	276	184	385
4.271	296	566	454	249	541
4.291	956	1785	1295	680	1653
4.311	910	1424	1260	712	1467
4.330	1666	1962	1656	1287	2132
4.351	1000	1495	1253	614	1417
4.370	1156	1556	1610	937	1902
4.390	476	1097	485	297	679
4.421	528	850	491	342	627
4.461	354	427	380	227	453
4.491	406	690	491	274	585
4.532	790	756	497	381	648
4.551	1025	1249	851	610	1126
4.631	471	1200	314	222	577
4.651	437	1308	341	272	591
$\bar{x}$	765	1094	809	514	1009
SD	398	432	488	312	561

The radio-collared elk in this study had a mean home range size of 765 ha which was significantly higher (>50%) than reported for Roosevelt elk in the same area (400 ha) by Witmer (1981). Smaller home ranges for non-migratory Roosevelt elk have been reported in California (Franklin et al. 1975: 300 ha), British Columbia (Janz 1980: 520 ha), and Washington (Schwartz 1943: 512 ha). In Olympic National Park, Washington, Jenkins (1980) estimated mean home ranges of 1000 ha for radio-instrumented non-migratory Roosevelt elk.

Home range sizes for elk varied dramatically among different areas of the Mount St. Helens blast zone in Washington (Merrill et al. 1987). Elk in the blast zone interior had home range sizes of 7,900 ha compared to 1874 ha for areas outside the blast zone. Witmer, Jenkins, Merrill, and Janz based their home range estimates on radio-telemetry locations, but Schwartz and Franklin used visual observations to estimate home range size. Janz used the minimum area method (Mohr 1947), Jenkins the bivariate ellipse (Koepple et al. 1975) and Witmer used both these methods. Merrill used the harmonic mean method after initially comparing it to three other home range methods (bivariate normal, minimum convex polygon, and weighted bivariate normal). Therefore, the differences reported above may be due to different fields methods or estimation techniques.

Core activity centers have been defined as areas that include 50% of all locations (Kaufmann 1962), 50% convex polygons (Michener 1979) or 50% harmonic mean contours (Dixon and Chapman 1980). Core areas in this study were identified as those maximum use areas where the observed utilization distribution exceeded a uniform utilization distribution (Ackermann et al. 1990). Samual et al. (1985) have defined these areas in simpler terms as those portions of an animal's home range that exceed equal-use. These areas are used more frequently than any other areas and probably contain the most valuable resources such as preferred food, mates, and refuges (Kaufmann 1962, Burt 1943). Samual et al. (1985) proposed the χ^2 to determine if observed use was significantly greater than expected. Program HOME RANGE uses a χ^2 test with the uniform distribution as the null model. This distribution is, supposedly, indicative of lack of preference for areas within the home range (Ackermann et al. 1990).

Few studies have described core area size for non-migratory Roosevelt elk. Franklin et al. (1975) reported a central core of activity of 32 ha for a Roosevelt elk herd in the Coastal Prairies of northern California. This area was 11% of the total home range where, on average, 31% of all herd locations were observed. A 68 ha central home range area was reported for this Coastal Prairie herd where over 50% of all observations occurred. Witmer and de Calesta (1985) found central core activity areas of 85 ha for several elk bands in the central Oregon Coast Range. These areas contained 53.6% of all elk observations. Core areas in this study (Table 4) were much larger ($\bar{x}$ = 433 ha or 5-6 times greater) than those reported by Franklin et al. (1975) or Witmer and deCalesta (1985). This difference may be due to different interpretations of core areas, and the different methods used to estimate home range size and core areas. However, core areas for our study animals were still much greater ($\bar{x}$ = 547 ha versus $\bar{x}$ = 334 ha) using a 50% HM or a 50% ADK as a core area estimate than those reported by Franklin et al. (1975) and Witmer (1981). Franklin's research was conducted in coastal redwood forests on an unhunted population of elk. Our research was in highly fragmented Douglas-fir forest on a hunted population of elk; consequently, these differences are not surprising. Witmer's research occurred on lands adjacent and similar to our study site; however, the much smaller core areas reported in his research relative to our results may be indicative of the small number ($\underline{n}$ = 6) of elk represented in his study.

Elk Associations

Franklin and Lieb (1979) reported high levels of group cohesiveness and stability in a population of Roosevelt elk in coastal redwood forests and prairies of California. Elk in this non-migratory herd banded into distinct, filial groups. Harper (1971) found considerable interchange between groups of elk on the Millicoma Tree Farm in the Oregon Coast Range, and herd stability appeared to be dependent on the character of the terrain. Elk herds in steep, rugged canyons had less interchange with adjacent elk bands than herds on ridge tops or in flood plains (Harper 1971).

Franklin et al. (1975) hypothesized that less interchange would occur among elk groups in areas where disturbance and habitat alterations are minimal. This hypothesis may explain the differences in group cohesiveness reported by Franklin and Lieb (1979) and Harper (1971). Jenkin's (1980) results support the assumption that habitat alterations and disturbance affect elk social stability. Roosevelt elk in his study had high levels of association and group stability within the Olympic National Park as compared to those groups in more cutover areas outside the park (Jenkins 1980). Witmer and deCalesta (1985) found strong site fidelity and herd stability among elk in a drainage adjacent to our study area.

Our results suggest there is limited interchange of cow elk among different bands or herds within the study boundaries. Animals in areas of active logging did not appear to associate more or less frequently with adjacent bands than those cows in areas without logging. All elk in our study were subject to hunting and a variety of other human activities. Given these levels of disturbance, the strong site fidelity of most radio-collared elk in this study suggest that area familiarity, strong filial bonds, or other factors may limit intermixing in highly disturbed habitats. Most associations with adjacent bands occurred at the periphery of home ranges. Among elk with high levels of association with other collared elk, intermixing among bands occurred throughout the home range area and these animals had home ranges that overlapped substantially.

Survival Rates

Few studies estimate survival rates for Roosevelt elk. Traditionally, annual survival rates for Roosevelt elk were estimated from harvest data and age structure of populations by life table analyses. There has been no research that estimates survival rates of Roosevelt elk in Oregon's Coast Range from radio-telemetry data. Previously, the prohibitive labor and material costs of intensive radio-telemetry studies and the lack of reliable survival estimators prohibited the acquisition of these estimates.

Pollock et al's. (1989) modification of the Kaplan-Meier (1958) estimator and Heisey and

Fuller's (1985) extension of the Mayfield (1961, 1975) survival estimator provide reliable estimates of survival rates from radio-telemetry data. Their methods of estimating survival are particularly useful for telemetry studies because not all animals have to be radio-marked at the same time. Additionally, the Pollock et al. (1989) estimator avoids the bias produced if daily survival rates between intervals are not constant. These methods do have inherent problems that should be recognized. Pollock et al. (1989) cautioned that precision may be poor if <20 animals were used to estimate survival. A strong assumption of the Heisey and Fuller (HF)(1985) estimator is that survival rates are constant over the interval of interest. This assumption may result in biased survival estimates if survival rates vary over time (White and Garrot 1990).

I used Pollock et al's. (1989) modication of the Kaplan-Meier (1958) survival estimator to estimate survival for radio-marked elk in our study. For comparison with the Kaplan-Meier estimator, I report the Heisey and Fuller (1985) estimator with the recognition that this estimator may be biased if survival rates were different for different seasons. Vangilder and Sheriff (1990) found in an evaluation of four methods of handling censored observations that bias was nearly zero, and mean square error was lowest throughout the entire range of censoring and survival rates when censored animals were included in the analysis. Additionally, a 95% confidence interval of the survival estimate included the true survival rate 95-100 times throughout the entire range of censoring and survival probabilities when censored animals were used in survival estimations (Vangilder and Sheriff 1990).

The HF (1985) and Pollock et al. (1989) estimates of survival for animals during the first interval of our study are identical (0.89) and nearly equal during the second interval (HF= 0.92 and Pollock et al.= 0.91). These estimates are similar to annual survival estimates (0.89) from radio-telemetry data on resident female Roosevelt elk in the Oregon Cascades reported by Stussey et al. (1993). Additionally, our estimates of annual survival are comparable to estimates on survival rates (0.89) of radio-collared female Rocky Mountain elk in Idaho (Leptich and Zager 1991, Unsworth et al. 1993).

Poaching accounted for 50% of known mortalities in the first interval. Given the high densities of accessible roads in the study area the number of mortalities attributed to poaching is not surprising. Stussey et al. (1993) reported a poaching rate of 44%, nearly three times the number of female elk legally harvested within their study area in the Oregon Cascades. This area also had an easily accessible road network and high human population densities. The large number of animals (50%) lost during the first interval of my study and reported by Stussey et al. (1993) (54% of lost animals) suggest that poaching levels may be higher than reported for western Oregon

ROOSEVELT ELK HABITAT USE IN THE OREGON COAST RANGE

CHAPTER II.

HABITAT ASSOCIATIONS OF ROOSEVELT ELK IN THE OREGON COAST RANGE

INTRODUCTION

Roosevelt elk (Cervus elaphus roosevelti) were historically distributed throughout western coniferous forest of the Pacific Northwest. With the settlement of Oregon, elk numbers declined from overharvesting and loss of suitable habitat (Mace 1956, Bryant and Maser 1982), and concerns about elk population declines led to restrictive hunting legislation at the turn of the century. From 1905 to 1938, no Roosevelt elk were legally hunted (Bryant and Maser 1982) in Oregon, and elk populations in western Oregon increased rapidly until the 1950s. A reported decline of Roosevelt elk herds in western Oregon in the 1960s and 1970s provided impetus for continuing translocation programs. From 1947-1991, 2,723 elk were transplanted to various counties in western Oregon (ODFW 1991), because Oregon Department of Fish and Wildlife (ODFW) actively managed elk as one of the state's premier wildlife species. Given this objective, ODFW's management goals for elk include the maintenance, restoration, and enhancement of elk habitat throughout Oregon (ODFW 1991).

Since the end of World War II, timber harvests on private and public lands in the Pacific Northwest have consistently exceeded 10 billion board feet annually (Brown and Curtis 1985). A consequence of this intensive harvest in western Oregon has been the fragmentation of large blocks of late-successional forests into small isolated patches. Timber harvest may influence elk vulnerability and habitat use through changing the structure, size, juxtaposition and accessibility of security areas (Hillis et al. 1991) Additionally, intensive forest use has resulted in the widespread expansion of logging roads throughout public and private timberlands. With this tremendous expansion in roads, the potential for human activities to disturb wildlife has increased. The effects of harassment on wildlife can produce elevated metabolic expenditures, inhibit reproduction, and result in a displacement of animals from preferred habitats (Ward 1977, Ward and Cupal 1979, MacArthur et al. 1982, Perry and Overly 1977, Lyon and Basile 1980, Roberts 1974).

From 1969 through 1976, Congress passed legislation (National Environmental Policy Act-1969, Endangered Species Act-1973, and National Forest Management Act-1976) that affected management of wildlife resources in the United States. In response to mandates contained within these laws, wildlife biologists and managers have attempted to predict the effects of timber harvest and other management activities on wildlife species and their habitats (Berry 1986). One technique used to predict change in habitat quality for selected species is the Habitat Suitability Index (HSI) model. A common measure of habitat quality is "habitat effectiveness". Habitat effectiveness is a measure of present habitat versus an optimum condition and is defined on a scale from 0 to 1. Habitat Effectiveness Indexes (HEI) for elk are HSI models that attempt to denote habitat effectiveness as the geometric mean of three or more habitat parameters. These parameters are supposed to reflect the key environmental variables eliciting the greatest species response.

Thomas et al. (1979) measured the effects of land use proposals on Rocky Mountain elk on summer ranges of the Blue Mountains of Oregon with the use of an HEI model. This model described a number of critical habitat variables for elk that have been used with slight modifications in subsequent models. Some of these critical variables are: (1) forage, water and cover are the primary habitat factors limiting elk populations, (2) the amount, type and interspersion of the above factors can be controlled to achieve predictable results in elk use, (3) habitat suitability can be judged by the ratio of cover to forage areas and their size and arrangement in time and space, and (4) roads that are open to vehiclar traffic will adversely effect the use of an area by elk (Thomas et al. 1979).

Wisdom et al. (1986) developed a model to evaluate the effectiveness of elk habitat in western Oregon based on four variables: (1) size and spacing of forage and cover, (2) road density, (3) cover quality, and (4) forage quality. Cover types for this model were adapted from Witmer et al. (1985) and Thomas et al. (1979). The three components of cover used by elk in western Oregon are optimal, thermal, and hiding cover. Thermal cover is used to moderate the effects of heat or cold and is defined as a forest stand at least 40 feet in height with at least 70% tree canopy cover. Hiding cover is classified as any vegetation capable of hiding 90% of a standing elk at 200 feet or less. Optimal cover is defined as a forest stand with four separate layers, an overstory canopy capable of intercepting snow, and with small (1/8 acre) openings dispersed throughout. This cover type is generally found only in late-successional forests. Typically, stands with optimal cover will have dominant trees >21 inches d.b.h. with a least 70% crown closure (Witmer et al. 1985).

The Bureau of Land Management (BLM) and the Forest Service (USFS) are currently using the Wisdom et al. (1986) HEI model to evaluate habitat for elk on their lands in western Oregon. The potential for inaccurate calculations of habitat effectiveness may be exacerbated if variables in HEI models do not adequately predict elk responses to habitat alterations or conditions. Assumptions of Roosevelt elk habitat use and relationships in the Wisdom model are derived from research conducted by Witmer (1981) and Harper (1971). Unfortunately, Witmer's data on habitat selection was from only two bands of elk with two closely associated radio-collared elk in one band and 4 in the other band. Harper's research reports are deficient in statistical analysis and descriptive methods, making comparisons with other studies difficult. Wisdom et al. (1986) recognized the necessity for additional research designed to carefully evaluate HEI variables. One critical assumption of the Wisdom model is that: the model could be field tested and modified through an assessment of the habitat variables. The last objective of our research was to clarify how elk select habitat on public and private lands and to assess the potential effect of road density, vehicular traffic, and elk habitat use.

METHODS

Traffic Counters

Thirty loop detector traffic counters (Safetran Model LDC355, Springfield, Colo.) were installed on secondary rocked, unrocked and spur roads throughout the study area. The first counter was installed on 2 September 1991, the last counter on 18 November 1991. Between 22 September and 24 October no counters were installed due to fire season restrictions on the operation of power equipment. Traffic counters were removed from the study area by 28 August 1992. No counters were installed on primary paved roads because of problems in cutting through asphalt surfaces and the potential for damaging these roads. Magnetic counting loops were installed in a 7 x 7 ft diamond configuration under road surfaces. Traffic counters were hidden off the road and not visible to approaching vehicles. Most traffic counters were read and tested at least once every two weeks.

Habitat Variables

Study area boundaries were delineated using a 100% adaptive kernel contour on all radio-telemetry locations of all radio-collared elk. Habitat variables within this area were slope, aspect, elevation, landtype, and distance from water and roads. Slope, aspect, and elevation layers were developed from 1:250,000 USGS Digital Elevation Model (DEM) data. The DEM data was transformed to a 25 m cell size and registered to UTM coordinate system. Landtypes were derived through an unsupervised classification of a rectified LANDSAT Thematic Mapper image (taken 9 Sept. 1991) resampled to a 25 m resolution using the Earth Resources Data Analysis System (ERDAS). An initial unsupervised classification was developed, dividing the image into 25 spectral classes. An additional reclassification was done with two aspect masks when it was determined that there was too much shadow and relief to facilitate an accurate land cover classification. Landtypes were divided into seven habitat classes: grass/forb, shrub, open sapling, pole/small sawtimber, large sawtimber/mature, old growth, and hardwoods. Once the image was classified into 7 habitats, photo interpretation for each of the clustered images with 1:12,000 true color photographs (taken 1 July 92) was conducted. The entire image was edited using aerial photos until an accurate and satisfactory land cover image was produced. Road and stream layers were obtained from the Bureau of Land Management, Coos County and Douglas County GIS (MOSS) systems and imported into ARC/INFO. These layers represented 1991 road and stream systems within the study area. Distance from radio-telemetry locations to nearest road and permanent water source was determined with ARC/INFO using a specific automated machine language (AML) program. To analyze the entire range of road distance values, all roads and streams (2-4 order) in the study area were divided into seven distance categories (m): < 51, 51-150, 151-300, 301-450, 451-600, 601-900, and > 900 m.

Availability and Observed Habitat Use Within Home Ranges

A 95% adaptive kernel home range for each of 24 radio-collared elk was estimated using the program CALHOME (see Chapter 1). Boundary files for these home ranges were imported into ERDAS to assess habitat use and availability for each elk. A 95% adaptive kernel estimate of home range is a more appropriate representation of areas of use and availability, because it excludes the extreme outlying observations that may overestimate areas actually in use.

Radio-telemetry locations for each elk were used in ERDAS to generate summary statistics for each of the habitat features. After reviewing the range of these data, I determined categories for slope, aspect, elevation, and habitat type. A preliminary analysis of these categories suggested that some classes should be combined for an adequate comparison of observed and expected values for individual elk. Aspect was divided into four categories: east/northeast, north/northwest, south/southwest, and south/southeast. Slope was divided into four categories: 0-15%, 16-30%, 31-45%, and >46%. Elevation categories were defined as: 61-250, 251-375, 376-500, 501-625, 626-750 and 751-914 m. Habitat categories were: grass/forb/shrub, open sapling, pole/small sawtimber, large sawtimber/mature, old growth, and hardwoods. Road and water distance classes were reduced from 7 to 5 categories with the last three (451-600, 601-900, and > 900 m) categories combined into one class (> 450 m).

Radio-telemetry locations for each of 24 elk were compared with known proportions of habitat within individual home ranges using a Pearson χ^2 statistic (Neu et al. 1974, Zar 1984) to determine if there was a significant difference ($\underline{P}$ <0.05) between expected and observed use of habitats. A Bonferroni $\underline{Z}$-statistic (Neu et al. 1974, Byers et al. 1984) was used to test whether the observed use of habitat categories was significantly ($\underline{P}$ <0.05) less than or greater than expected based on availability.

Availability and Observed Habitat Use of Pooled Elk

All radio-telemetry locations for 24 elk were pooled to estimate observed use for the sample population of elk found in the study area. Extent of availability of habitat variables for these animals was estimated with a 100% adaptive kernel estimate after combining observations from the 24 elk. A similar estimate was derived for animals located only in the north half (n = 13) and those only in the south half (n = 11) of the study area because these areas are geographically separated. Additionally, BLM land in the north half is in the Tioga resource area while BLM land in the south half is in the Myrtlewood resource area. The Tioga area has more more restrictions on timber harvests than Myrtlewood because of higher northern spotted owl (Strix occidentalis caurina) densities in the Tioga resource area, consequently management strategies for each resource area are different.

Habitat variables were slope, aspect, elevation, landtype, and distance to nearest road and water. All habitat variables except habitat type and distance categories for roads and water were divided into the same categories as used in home range areas. For habitat categories, the forb/grass/shrub class was separated into two groups: a forb/grass category, and a shrub category.

Distance of elk locations to roads and water were divided into categories (< 50, 51-150 , 151-300 , 301-450, 451-600, 601-900, and > 900 m).

A chi-square goodness-of-fit test was used to determine if observed use was significantly different ($P < 0.05$) from expected use for all 24 animals combined and for each group of elk in the different halves of the study area. A Bonferroni Z-statistic was used to test if observed use of habitat variables was more or less than expected.

Seasonal Habitat Use

To evaluate seasonal use of habitat variables, all elk locations were pooled and divided into six biologically significant intervals: spring (March-April), calving (May-June), summer (July-August), rut (September-October), fall (November-December, and winter (January-February). A chi-square goodness-of-fit test was used to determine if observed use of any habitat variables was significantly different ($P < 0.05$) from use during the six seasons. A Bonferroni Z-statistic was again used to test if observed use of habitat variables was more or less than expected.

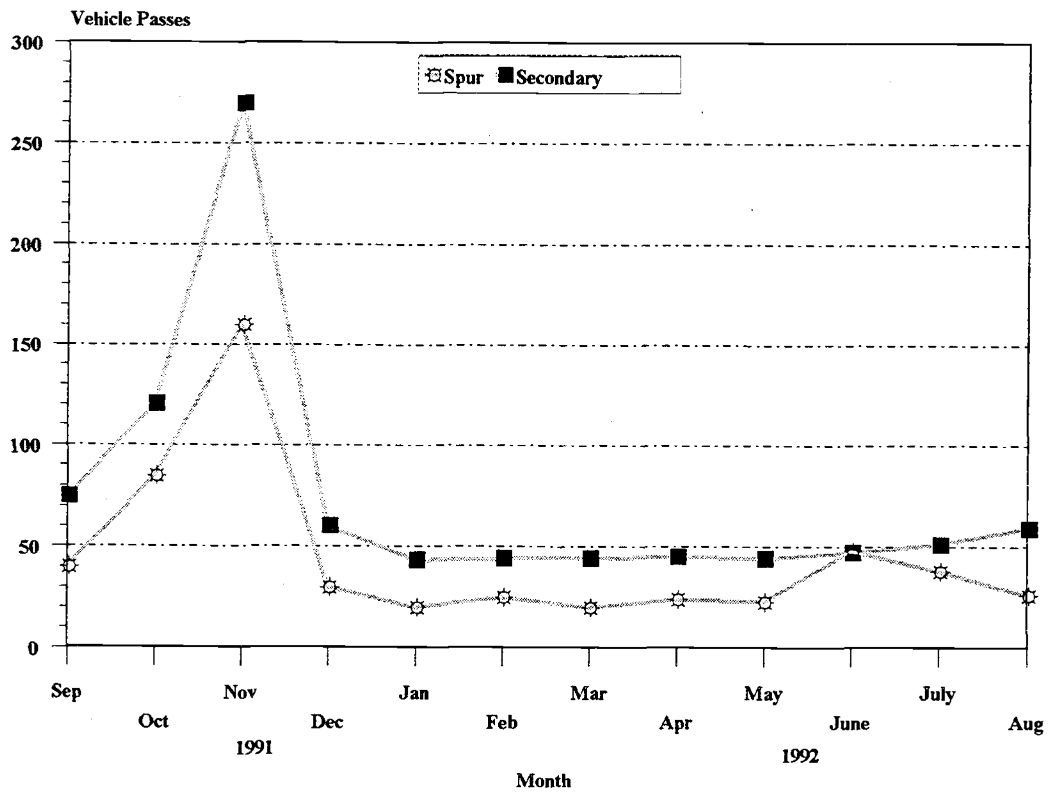
RESULTS

Traffic Counts

Only 14 of 30 counters were working at the conclusion of this study. Reasons for counter failures were primarily mechanical. Most counters had been used periodically for 20 years by the BLM; consequently, corrosion of internal parts was not uncommon. On six occasions road graders damaged the underground loops and these loops were reinstalled.

Traffic counts on spur and secondary roads were parallel for the entire year with counts being lowest from December through September and increasing substantially during hunting season from October to November. Mean traffic counts for secondary roads were highest in November 1991 with a monthly average of 262 vehicular passes (Fig. 2). Lowest mean counts on

Figure 2. Mean monthly number of vehicle passes on spur and secondary roads in the southern Oregon Coast Range, 1991-92.



secondary roads were in January, April and May 1992 with average monthly counts of 42 passes. On spur roads, the maximum mean monthly count was in November of 1991 with an average of 171 vehicle passes. The minimum mean count on spur roads was in January 1992 with an average of 14 passes.

Habitat Use

For the combined area (Table 9), the dominant habitat was pole/small sawtimber with 42% (15,745 ha) of the study area. Open sapling cover and hardwoods were the least prevalent habitats (3.5 % and 4.1 % respectively). Large sawtimber/mature and old growth combined accounted for 29% of the landbase. Shrub cover types were 14% of the total area. The north and south halves were similar, but the south had slightly more large sawtimber (19 % vs 14 %) and shrub areas (17% vs 13%), while the north had more old growth (15 % vs 10.8%) and hardwoods (4.9 % vs 2.9%).

For all elk ($\underline{n}$ = 24) combined (Table 9), forb/grass were used more than expected, and only pole areas were used less than expected. The remaining habitats were not used significantly different from expected. For all elk ($\underline{n}$ = 13) in the north (Table 10), elk used only forb/grass habitats significantly ($\underline{P}$ < 0.5) more than expected while pole and hardwood stands were used significantly ($\underline{P}$ < 0.5) less than expected. The remaining habitat types were used in proportion to availability. For all elk ($\underline{n}$ = 11) in the south half (Table 11), open sapling and hardwood stands were used more than expected. All elk in the south used the other 5 habitats in proportion expected.

Three elk (Table 12) used shrub/forb/grass areas more than expected and one elk used hardwoods less than expected in use versus availability analyses for the north half of the study area. For the remaining habitats use for all elk in the north area was not significantly different from expected. Similarly in the south half, most elk used all habitats in proportion to their

Table 9. Habitat availability and Roosevelt elk ($\underline{n}$ = 24)[a] use of habitats in combined north and south halves of study area in the southern Oregon Coast Range, 1991-92.

Habitats	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
Forb/Grass	5.8	87.4	134	24.9	6.9 - 11	More
Shrub	14.8	222.3	236	.9	13.1 - 18.2	Equal
Open Sapling	3.5	52.5	72	7.3	3.2 - 6.2	Equal
Pole	42.1	632.9	545	12.2	32.9 - 39.6	Less
Mature	16.3	245.8	247	.01	13.8 - 19	Equal
Old Growth	13.4	202.1	208	.2	11.4 - 16.3	Equal
Hardwoods	4.1	61.1	62	.01	2.7 - 5.5	Equal

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using the pooled observations.

Table 10. Habitat availability and Roosevelt elk ($\underline{n}$ = 13)[a] use of habitats in north half of study area in the southern Oregon Coast Range, 1991-92.

Habitats	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
Forb/Grass	4.5	37	86	64.7	7.6 - 13.5	More
Shrub	13.1	107.1	122	2	11.5 - 18.3	Equal
Open	3.4	27.3	25	.2	1.4 - 4.7	Equal
Pole	44.4	363.6	302	10	32 - 42	Less
Mature	14.4	117.3	114	.10	10.7 - 17.3	Equal
Old Growth	15.3	125	143	2.6	13.9 - 21	Equal
Hardwoods	4.9	39.7	24	6.2	1.3 - 4.5	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using the pooled observations.

Table 11. Habitat availability and Roosevelt elk ($\underline{n}$ = 11)[a] use of habitats in south half of study area in the southern Oregon Coast Range, 1991-92.

Habitats	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
Forb/Grass	7.6	52	48	.3	4.3 - 9.6	Equal
Shrub	17.1	117	114	.1	12.7 - 20.4	Equal
Open Sapling	3.7	25	47	18.4	4.2 - 9.4	More
Pole	38.8	267	243	2.2	30.4 - 40.3	Equal
Mature	19.1	131.2	133	.03	15.2 - 23.4	Equal
Old Growth	10.1	74	65	1.2	6.4 - 12.4	Equal
Hardwoods	2.9	20	38	15.8	3.2 - 7.9	More

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 12. Comparison of use to expected for habitats of 13 radio-collared elk in the north half and 11 of radio-collared elk in the south half of study area in the southern Oregon Coast Range, 1991-92.

Habitats	Use Compared With Expected[a] In North			Use Compared With Expected[a] In South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
Shrub/Forb/Grass		10	3	1	10	
Open Sapling		13		2	7	2
Pole/Small Sawtimber		13		1	10	
Large Sawtimber/Mature		13		1	10	
Old Growth		13		2	9	
Hardwoods	1	12			9	2

[a] Expected values were calculated using proportions of landtypes within a 95% adaptive kernel home range for each elk.

availability. Two elk used open sapling areas more and two used these habitats less than expected. Two elk used old growth less than available while two elk used hardwoods more than expected.

Aspect

Nearly 52% of the study area (Table 13) was in north/northwest or west/southwest aspects while 31.7% was south/southeast. Only 16% of the area had east/northeast aspects.

For all elk (n = 24) combined (Table 13) north/northwest and south/southwest aspects were used more than expected while north/northeast and south/southeast aspects were used less. For all elk in the north (Table 14), south/southeast aspects were used less than expected while south/southeast aspects were used more than expected. North/northeast and north/northwest areas were used equal to expected. North/northwest areas were used equal to expected. For combined observations in the south (Table 15), north/northeast aspects were used less and north/northwest aspects were used more than availability.

In the north (Table 16), the majority of elk used all aspects equal to their availability within their home ranges. One elk used north/northwest aspects less and one used south/southeast aspects less than available. One elk used south/southwest aspects more than expected. For the south, most elk used the four aspects equal to expected. However, one elk used north/northeast aspects less and 1 elk used south/southeast aspects less than expectd while 1 elk used north/northwest aspects more than expected.

Slope

The study area was almost equally divided in per cent of landbase among the four slope categories (table 17). However, in the south half only 17% of the area had slopes >46%.

Table 13. Availability and use of aspects by Roosevelt elk (n = 24)[a] in combined north and south halves of study area in the southern Oregon Coast Range, 1991-92.

Aspect	Available (%)	Values		X2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
North/Northeast	16.2	242.5	174	19.3	9.5 - 13.7	Less
North/Northwest	28.9	431.3	493	8.8	29.9 - 36	More
South/Southwest	23.1	345.4	437	24.3	26 - 32	More
South/Southeast	31.9	476.6	392	15	23.3 - 29.1	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 14. Availability and use of aspects by Roosevelt elk (n = 13)[a] in north half of study area in the southern Oregon Coast Range, 1991-92.

Aspect	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
North/Northeast	15.9	131.6	112	2.9	10.5 - 16.5	Equal
North/Northwest	30.4	252.7	274	1.8	28.9 - 37.1	Equal
South/Southwest	23.7	196.7	260	20.4	27.3 - 35.4	More
South/Southeast	30	249	184	16.9	18.5 - 25.8	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 15. Availability and use of aspects by Roosevelt elk ($\underline{n}$ = 11)[a] in south half of study area in the southern Oregon Coast Range, 1991-92.

Aspect	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
North/Northeast	17.1	113.7	62	23.5	6.5 - 12.1	Less
North/Northwest	26.3	174.8	219	11.2	28.3 - 37.5	More
South/Southwest	22.3	148.6	177	5.4	22.3 - 30.9	Equal
South/Southeast	34.4	228.7	208	1.9	26.7 - 35.8	Equal

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 16. Comparison of use to availability of aspects for 13 radio-collared elk in north half and 11 radio-collared elk in the south half of study area in the southern Oregon Coast Range, 1991-92.

Aspect	Use Compared With Expected[a] For North			Use Compared With Expected[a] For South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
North/Northeast		13		1	10	
North/Northwest	1	12			10	1
South/Southwest		12	1		11	
South/Southeast	1	12		1	9	

[a] Expected values were calculated using proportions of aspect categories within a 95% adaptive kernel home range for each elk.

Table 17. Availability and use by Roosevelt elk ($\underline{n}$ = 24)[a] of slopes in combined north and south halves of study area in the southern Oregon Coast Range, 1991-92.

Slope (%)	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
0 - 15	24.8	371.7	358	.5	21.1 - 27	Equal
16 - 30	27.9	418.7	463	4.7	27.9 - 34	Equal
31 - 45	25.4	379.8	404	1.5	24.1 - 30	Equal
>46	21.8	326.8	272	9.2	15.7 - 20.1	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

For all elk ($\underline{n}$ = 24) combined (Table 17), only the >46% slope areas were used less while the remaining three categories (0-15%, 16-30%, 31-45%) were used in proportion to availability. For all elk in the north (Table 18), all slope classes were used in proportion to availability while for all elk in the south (Table 19), the second category (16-30%) was selected more and the fourth category (>46%) was used less than expected. The other two categories were used equal to availability. In the north half (Table 20), most elk in their home ranges used slopes in proportion to their availability. One elk used 0-15% slope areas less, 1 elk used 16-30% slopes less, and 1 elk used 31-45% slopes less than available. Two elk used >46% slopes less than expected while 2 elk used 31-45% slopes more than available. For the south, all slope areas were used equal to availability.

Elevation

Almost 65% of the study area was in elevations from 376-750 m (Table 21). Only 9.3% of the area had elevations 61-250 m while 10.1% of the area was greater than 750 m in elevation.

For all elk locations combined (Table 21) the lowest (61-250) and the two highest elevations 626-750 and 751-914 m were used less than expected. Elevations 251-375, 376-500, and 501-625 m were used more than expected. For all elk in the north half (Table 22), elevations 61-250, 376-500, and 501-625 m were used more than expected. Elevations 626-750 and 751-914 m were used less than available. For all elk locations in the south (Table 23), elevations 251-375 and 376-500 m were used more while elevations 61-250, 626-750, and 751-914 m were used less than expected. Nearly all elk in the north and south portions of the study area (Table 24) used elevations equal to expected within their home ranges. Two elk used 626-750 m elevations less than expected in the north and south while two used 376-500 m elevations more than expected in both areas. One elk used 251-375 m elevations less while one used 501-625 m elevations more than expected in the north.

Table 18. Availability and use of slopes by Roosevelt elk (n = 13)[a] in north half of study area in the southern Oregon Coast Range, 1991-92.

Slope (%)	Available (%)	Values: Expected	Values: Observed	X^2	Bonferroni 95% Confidence Interval	Use
0 - 15	24.2	198.5	192	.2	19.7 - 27.2	Equal
16 - 30	25.1	205.7	212	.2	22 - 29.7	Equal
31 - 45	25.6	209.8	236	3.3	24.8 - 33	Equal
>46	25.1	206	180	3.3	18.3 - 26	Equal

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 19. Availability and use of slopes by Roosevelt elk (n = 11)[a] in south half of study area in the southern Oregon Coast Range, 1991-2.

Slope (%)	Available (%)	Values: Expected	Values: Observed	X^2	Bonferroni 95% Confidence Interval	Use
0 - 15	25.7	173.9	166	.4	20.3 - 29	Equal
16 - 30	32	216.6	251	5.5	32.4 - 42	More
31 - 45	25.1	169.9	168	.02	20.6 - 29	Equal
>46	17.2	116.7	92	5.2	10.3 - 16.9	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 20. Comparison of availability to use of slopes by 13 radio-collared elk in north half and 11 radio-collared elk in south half of study area in the southern Oregon Coast Range, 1991-92.

Slope	Use Compared With Expected[a] For North			Use Compared With Expected[a] For South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
0-15%	1	12			11	
16-30%	1	12			11	
31-45%	1	10	2		11	
>46%	2	11			11	

[a] Expected values were calculated using proportions of slope categories within a 95% adaptive kernel home range for each elk.

Table 21. Availability and use of elevations by Roosevelt elk (n = 24)[a] in combined north and south halves of study area in southern Oregon Coast Range, 1991-92.

Elevation (m)	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
61-250	9.3	137.7	110	5.6	5.6 - 9.2	Less
251-375	16.8	249.6	294	7.9	17 - 22.6	More
376-500	20.3	300.9	410	39.6	24.5 - 30.7	More
501-625	22.9	340.7	405	12.2	24.2 - 30.4	More
626-750	20.6	306.1	201	36.1	11.2 - 15.9	Less
751-914	10.1	149.9	65	48.2	2.9 - 5.8	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 22. Availability and use of elevations by Roosevelt elk (n = 24) [a]categories in north half of study area in the southern Oregon Coast Range, 1991-92.

Elevation (m)	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
61-250	7.1	58.5	100	29.4	9.1 - 15.2	More
251-375	15.6	128.2	122	.3	11.6 - 18.2	Equal
376-500	19	156.2	192	8.2	19.5 - 27.3	More
501-625	25.5	208.9	270	17.8	28.5 - 37.3	More
626-750	23.7	194.6	121	27.8	11.4 - 18	Less
751-914	9.1	74.6	16	45.9	.6 - 3.2	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 23. Availability and use of elevations by Roosevelt elk ($\underline{n}$ = 24) [a]categories in south half of study area in the southern Oregon Coast Range, 1991-92.

Elevation (m)	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
61-250	12.3	81.4	10	62.6	.2 - 2.7	Less
251-375	18.5	122.6	172	19.9	21.4 - 30.4	More
376-500	22	146.1	218	35.4	27.9 - 37.7	More
501-625	19.4	129.1	135	.3	16.1 - 24.5	Equal
626-750	16.3	108.2	80	7.4	8.7 - 15.4	Less
751-914	11.5	76.6	49	9.9	4.7 - 10.1	Less

[a] Pooling all elk observations and defining area of availability with a 95% adaptive kernel using these pooled observations.

Table 24. Comparison of availability to use of elevations by 13 radio-collared elk in north and 11 radio-collared elk in the south half of study area in the southern Oregon Coast Range, 1991-92.

Elevation (m)	Use Compared With Expected[b] For North			Use Compared With Expected[b] For South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
61-250		4			4	
251-375	1	7		1	7	
376-500		10	2		10	2
501-625	1	10	1	1	10	1
626-750	2	7		2	7	
751-914		4			4	

[a] Numbers of elk do not equal 13 because some elk did not have all elevation categories within their home range.

[b] Expected values were calculated using proportions of elevation categories within a 95% ADK home range for each elk.

Influence of Roads

When the landbase within the study area was divided into seven road distance categories, 64.6% of the landbase within the study is within 300 m of the nearest road (Table 25). Only 8% (3,015 ha) of the area was greater than 900 m from a road while 14.3% (5350 ha) was < 50 m of the nearest road. For all elk ($\underline{n}$ = 24) combined (Table 25) observed use of areas < 50 m and > 900 m from roads was less than expected. Areas that were 301-450 m of the nearest road were selected significantly ($\underline{P}$ < 0.05) more while the remaining distance categories were used equal to availability. Elk in the north and south were not pooled separately because road densities in both areas were similar (Appendix B. Table 30). In comparing observed use of distance categories with availability ($\underline{P}$ < 0.05) within individual home ranges, the last three categories (451-600, 601-900 and >900 m) were combined into one category (> 450). Most elk in the north and south selected the seven distance categories in proportion to availability (Table 26). Six elk in the north used the first category (< 51 m) less while three elk use the last category (> 450 m) more than expected. In the south, 4 elk used the last category (> 450 m) less while 3 used the fourth category (300-450 m) less than expected. Two elk in the south used the last category (> 450) more than expected.

Proximity to Permanent Streams

When the study area was divided into 7 stream distance categories 57.5% of area was within 450 m from water (Table 27). Almost 12% (4405 ha) of the study area was > 900 m from any water while 6.8% (2535 ha) was < 51 m from water.

For all elk combined ($\underline{n}$ = 24), those areas (Table 27) within 300 m of water were used significantly ($\underline{P}$ < 0.05) more than expected and distances >300 m from streams were used significantly less. In comparing observed use with availability ($\underline{P}$ < 0.05) within elk home ranges, several categories had few observations, consequently the seven water distance categories were combined into five with the last three categories (451-600, 601-900, and >900 m) assigned to

Table 25. Availability and Roosevelt elk (n = 24)[a] use of road distance categories in combined north and south halves of study area in the southern Oregon Coast Range, 1991-92.

Distance	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
< 51	14.4	215	180	5.7	.97 - 14	Less
51 - 150	24.1	362	330	2.8	19 - 25	Equal
151 - 300	26.2	394	397	.02	23 - 30	Equal
301 - 450	10.2	154	270	88.3	15 - 21	More
451 - 600	9.0	139	138	.07	7 - 11	Equal
601 - 900	7.6	114	134	3.6	7 - 11	Equal
> 900	8.1	121	49	43	2 - 4.5	Less

[a] Pooling all elk observations and defining area of availability with a 100% adaptive kernel using these pooled observations.

Table 26. Comparison of availability to use of road distance categories of 13 radio-collared elk in north and 11 radio-collared elk in south half of study area in the southern Oregon Coast Range, 1991-92.

Road Category (m)	Use Compared With Expected[a] For North			Use Compared With Expected[a] For South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
< 51	6	7		1	9	1
51-150		13		1	10	
151-300		13			10	1
300-450		12	1	3	8	
> 450	1	9	3	4	5	2

[a] Expected values were calculated using proportions of road distance categories within a 95% adaptive kernel home range for each elk.

Table 27. Availability and use by Roosevelt elk (n = 24)[a] of water distance categories in combined north and south halves of study area in the southern Oregon Coast Range, 1991-92.

Distance (m)	Available (%)	Values		X^2	Bonferroni	Use
		Expected	Observed		95% Confidence Interval	
< 51	6.8	102	191	78	10 - 15	More
51 - 150	13.4	201	352	114.3	20 - 26.4	More
151 - 300	19.5	292	337	6.9	19.8 - 25	More
301 - 450	17.9	267.6	229	5.6	12.8 - 17.8	Less
451 - 600	14.9	224	148	25.9	7.8 - 11.9	Less
601 - 900	15.7	234.7	198	5.7	10.8 - 15.6	Less
> 900	11.8	177	43	101.5	1.7 - 4	Less

[a] Pooling all elk observations and defining area of availability with a 100% adaptive kernel using these pooled observations.

one distance category (> 450). Most elk used the distance categories in proportion to availability (Table 28). However, four elk in the north used the first category (< 51 m) more than expected while four used the fifth (> 450 m) and three used the fourth (300-450 m) categories less. Four elk in the south used the second (51-150 m) category more while four used the fifth (> 450 m) category less than expected.

Seasonal Use of Habitats and Landscapes

Elk used forb/grass areas more than expected during calving and summer (Table 29). The 16-30% slope category was used more during winter. South-SW aspects were used more during calving, S-SW and N-NW were selected in summer while N-NW aspects were used more during rut. The lowest (61-250 m) and intermediate elevations were used more during most seasons.

Pole/small sawtimber areas were used less during spring and summer (Table 30). Steep slope areas (> 46%) were used less during fall and winter. E-NE and S-SE aspects were used less in summer and rut while E-NE aspects were used less than expected during spring, fall and winter. Higher elevations (626-750 and 751-914 m) were used less during most seasons.

Seasonal Influence of Roads and Permanent Water

Areas 151-300 m from the nearest road were used more during spring (Table 31). In the winter, distances of 51-150 m from roads were selected more while the 301-450 m category was used more than expected during calving and rut. Areas > 900 m from roads were used less during all seasons. During fall and winter distances < 51 m were used less than available.

For water distance categories, areas 51-150 m from water were used more than available during spring, calving, summer, and rut (Table 32). Areas closest to water (< 51 m) were used more during summer, rut, winter and spring. Areas furthest from water (> 900 m) were used less

Table 28. Comparison of availability to use of water distance categories of 13 radio-collared elk in north and 11 radio-collared elk in south half of study area in the southern Oregon Coast Range, 1991-92.

Water Category (m)	Use Compared With Expected[a] For North			Use Compared With Expected[a] For South		
	Less Than	Equal To	More Than	Less Than	Equal To	More Than
< 51		9	4		11	
51-150		12	1		7	4
151-300		12	1		11	
300-450	3	10		2	8	1
> 450	4	9		4	7	

[a] Expected values were calculated using proportions of water distance categories within a 95% ADK home range for each elk.

Table 29. Habitat variables used more than expected by Roosevelt elk for six different seasons in the southern Oregon Coast Range, 1991-92.

Variable	Spring	Calving	Summer	Rut	Fall	Winter
Habitat		Forb/Gras	Forb/Grass			
Slope						16-30%
Aspect		S-SW	S-SW & N	N-NW		
Elevation	61-250 m	61-250 m	61-250 m	61-250 m	61-250 m	61-250 m
	376-500 m	376-500 m			501-625 m	376-500 m

Table 30. Habitat variables used less than expected by Roosevelt elk for six different seasons in the southern Oregon Coast Range, 1991-92.

Variable	Spring	Calving	Summer	Rut	Fall	Winter
Habitat	Pole/S.timber		Pole/S.timber			
Slope					> 46%	> 46%
Aspect	E-NE	S-SE	E-NE & S	E-NE &	E-NE	E-NE
Elevation	626-750 m	626-750 m	626-750 m	626-750 m	751-914	626-750 m
	751-914 m	751-914 m	751-914 m	751-914 m		751-914 m

Table 31 . Roosevelt elk use[a] of road distance categories during six seasons in the southern Oregon Coast Range, 1991-92.

Distance (m)	Spring	Calving	Summer	Rut	Fall	Winter
< 51	Equal	Equal	Equal	Equal	Less	Less
51 - 150	Equal	Equal	Equal	Equal	Equal	More
151 - 300	More	Equal	Less	Equal	Equal	Equal
301 - 450	Equal	More	Equal	More	Equal	Equal
451 - 600	Equal	Equal	Equal	Equal	Less	Equal
601 - 900	Equal	Equal	More	Equal	Equal	Equal
> 900	Less	Less	Less	Less	Less	Less

[a] Observed use compared with expected ($P < 0.05$).

Table 32. Roosevelt elk use[a] of water distance categories during six seasons in the southern Oregon Coast Range, 1991-92.

Distance (m)	Spring	Calving	Summer	Rut	Fall	Winter
< 51	More	Equal	More	More	Equal	More
51 - 150	More	More	More	More	Equal	Equal
151 - 300	Equal	Equal	Less	Equal	Equal	Equal
301 - 450	Equal	Equal	Equal	Equal	Equal	Equal
451 - 600	Equal	Equal	Less	Equal	Less	Less
601 - 900	Equal	Equal	Equal	Less	Equal	Equal
> 900	Less	Less	Less	Less	Less	Less

[a] Observed use compared with expected ($P < 0.05$).

than available during all seasons, and the remaining distances from water were used generally in proportion to their availability.

DISCUSSION

Intensive forest management in the Oregon Coast range has resulted in a continually changing forest matrix and wildlife managers have the difficult task of integrating wildlife management goals with intensive forest practices. HEI models have been used as a tool to evaluate the impacts of future forest management on elk habitat. However, many of the parameters in these models have not been adequately tested. The Wisdom model (Wisdom et al. 1986) is currently being used to evaluate elk habitat effectiveness in Western Oregon, yet the habitat relationships of Roosevelt elk assumed in this model have not been rigorously examined.

Most of the data available on habitat use by Roosevelt elk in Western Oregon is found in Witmer (1981) or Harper (1971), and both of these studies were conducted in areas adjacent or very near our research site. Unfortunately, Witmer's (1981) study on habitat selection was from only two bands of elk with two closely associated radio-collared elk in one band and 4 in the other band. Harper's (1971) study has limited descriptive methodologies and no statistical analyses making comparisons with other studies difficult.

Habitat Selection

Witmer (1981) found that female elk preferred old-growth and hardwood stands while mixed forest and sapling pole were used less ($\underline{P} < 0.05$) than expected. In the Olympic National Park, elk preferred hardwoods and mixed-conifer stands during all seasons (Jenkins 1984). In the Queets River valley on the Olympic Peninsula, Roosevelt elk selected mature hardwoods during spring, summer and autumn, and old-age Sitka spruce forests during winter (Schroer et al. 1993). Roosevelt elk in the Bald Hills of Redwood National Park did not use old-growth more than expected perhaps due to the abundant availability of prairies with rich forage (Grenier 1991). In our study, most elk in the northern group showed little preference within their home ranges for specific habitats. Some exceptions were: three out of thirteen elk used shrub/forb/grass habitats more than available while one of thirteen elk used hardwoods less than expected. Similarly, for the south half, most elk appeared to use habitats in proportion to their availablility. Results for elk selection in the south half were more mixed perhaps indicating that elk with larger home ranges have more access to a mixture of habitat types. In combining all locations in our study area, elk showed strong preference for forb/grass areas and avoided pole stands. The preference of forb/grass areas in these areas is not surprising given the high forage availability. Additionally, avoidance of pole habitats may be the result of the limited forage for elk in this seral stage. Old growth was available in nearly all the home ranges yet this habitat was not used more than expected by any of the elk.

Witmer (1981) found that elk preferred old-growth forests during most seasons while hardwood stands were selected more than expected during summer and fall. Jenkins (1980) reported that hardwood (alder) flats were important habitats for cow elk in the Hoh River valley, during late winter while old growth adjacent to clear cuts were preferred areas during winter. A young second growth stand appeared to be favored by these valley elk during summer. Merrill et al. (1987) found that elk selected mature/large sawtimber habitats around Mount St. Helens more during spring. Schroer et al. (1993) reported that elk selected mature deciduous (hardwoods) forests during spring, summer, and winter on the Olympic Peninsula while old-growth stands were used more than expected during fall and winter. Elk in Schroer et al's (1993) study avoided young clearcuts and even-aged regenerating stands (16-150 years old). Other studies have shown that Roosevelt elk seasonally prefer hardwood and/or riparian areas (Brunt et al. 1989, Cooper 1988 and Schroer 1987). Elk in our study used forb/grass areas more than expected during calving and summer. Given the availability of high quality forage in forb/grass areas during these seasons, selection for this habitat type is not surprising. New growth of forbs and grasses during spring and summer greenup is highly digestible (Van Soest 1982) with a gradual decline in digestibility starting in August (Merrill et al. 1987). Forbs comprised nearly 60% of the diet for Roosevelt elk near Mount St. Helens (Merrill et al. 1987) from June until August. During calving season, lactating females need additional energy which is more readily available in easily metabolized and handled forbs (Merrill et al. 1987). Elk in our study used pole/small sawtimber areas less during spring and summer. These areas are characterized by low understory production with limited forage and cover available for elk.

Aspect

Witmer (1981) suggested that the radio-marked elk in his study preferred south aspects throughout the year. In our results, most elk in our study used all aspects in proportion to their availability. However, in the north half of our study area elk preferred south/southwest aspects, and while in the south half elk selected north/northwest aspects. Given the disparities between these results and the lack of selection by most elk, I suggest that aspect is not a critical factor in habitat use of elk in the southern Oregon Coast Range. There was strong correlation between elk locations in our study and riparian areas. During hot summer days, the dense overstory found in riparian areas offer elk refuge from the heat regardless of aspect and is an alternative to the selection of cooler, north aspects. The moderate winter temperatures in the Coast Range may make the selection of warmer south aspects unnecessary.

Roosevelt elk have been reported to seasonally select different aspects (Harper 1971, Merrill et al. 1987, Grenier 1991). Witmer found that elk used more northerly aspects during the warmer seasons. Merrill et al. (1987) reported increased use of west/northwest aspects during the spring. Elk in our study used south/southwest aspects more during calving and summer and north/northwest aspects during rut. East/northeast aspects were avoided during spring, rut, fall, and winter. Preference for south/southwest aspects during calving and summer may be related to forage availability. These areas have a greater abundance and earlier appearance of new growth (forbs/grass/shrubs) than more northerly aspects. Additionally, the westerly off-shore winds and dense overstory may ameliorate the higher temperatures on these slopes during late summer.

Elevation

Elk have been reported to use higher elevations along windy ridge tops to avoid insects and escape from warmer valley bottoms (Skovlin 1982, Beall 1976). Other studies suggest elk prefer lower elevations during winter when ridge tops are covered with deep snow (Beall 1974, Jenkins 1980). Most individual elk in our study used elevations in proportion to their availability. In pooling all locations, elk avoided the highest (751-914 m) and lowest (61-250 m) elevation areas within the study area. The avoidance of these areas may be related to the high density of roads in valley bottoms and on ridge-tops.

During winter and fall, elk preferred low elevations in the Mount St. Helens area (Merrill et al. 1987). Witmer (1981) found that elk from his study used various elevations throughout the year, but with a trend towards using higher elevations as the year progressed from calving season. Elk in our study used lower elevation areas more than expected during all seasons and mid-elevation areas more during spring, calving, fall, and winter. Higher elevations were avoided during all seasons. Because elk in our area appear to have a strong association with stream drainages, the selection of lower elevations was likely related to the location of most of these riparian areas. Additionally, many ridgetops are dominated by roads which may discourage elk use of these areas.

Slope

Our results showed that individual elk used nearly all slope categories equal to availability. In pooling all elk locations, those areas with slope > 46% were used less than available. These results are similar to Merrill et al. (1987) who found that elk preferred slopes < 50% in the

Mount St. Helens area. However, Harper (1971) suggested that elk use all areas regardless of slope conditions unless slope was > 80%. Elk in the Bald Hills of Redwood National Park used areas with slope between 15 and 60% (Grenier 1991). Given the ability of elk to move efficiently up steep slopes (Cohen et al. 1978) and the abundance of high quality forage on many steep clear-cuts, I believe degree of slope is not a critical factor in elk habitat selection.

A number of researchers (Harper 1971, Witmer 1981, Schroer 1987, Grenier 1991) report elk using more gentle slopes during calving. Our results suggest that elk do not select for any particular slope category during most seasons. However, elk did use 16-30% slopes more in winter and areas with >46% slope less in fall and winter. Mid-slope areas are known to be warmer than valley bottoms or ridgetops during winter. This thermal difference may account for the greater use of mid-slope areas by elk in our study during winter, but the moderate winter weather in the Coast Range makes selection of these areas based on thermal conditions questionable. Thermal stress in summer may have a greater effect on elk fitness then previously reported (Leckenby 1977) while critically low temperatures for elk survival during winter may never be encountered in as mild a climate as found in the Northwest (Nyberg 1985).

Influence of Roads

The density of roads within an area is one of the variables used to evaluate elk habitat in the Wisdom HEI model. A number of studies (Perry and Overly 1977, Irwin and Peek 1979, Lyon 1979, and Hershey and Leege 1982) have reported that Rocky Mountain elk (Cervus elaphus nelsonii) avoid human disturbance or roads. Additionally, Witmer and deCalesta (1985) found that female Roosevelt elk avoided habitats associated with paved roads. Density of roads in the north and south portions of our study area was not significantly different within elk home ranges, and most elk in these home ranges did not select those areas that were furthest from roads. However, in pooling all elk locations, we found areas < 50 m and > 900 m from roads to be avoided. Those areas > 900 m from roads were only 8% of the landscape, perhaps indicating that these areas were not a significant component within elk home ranges. Even though elk used areas < 50 m from roads less than expected, areas 51-300 m from roads composed over 50% of the landscape and were used equal to expected. These results suggest roads may not significantly alter elk habitat use unless habitats are immediately adjacent (< 50 m) to roads. The excellent hiding cover provided by the thick Coast range understory vegetation and dense conifers may provide elk with adequate security even in areas of high road densities.

Elk used areas < 50 m from the nearest road less than expected during fall and winter. During calving and rut, elk used areas 301-450 m from the nearest road more than expected while areas 151-300 m wereused more more than expected during the spring. Traffic rates increased dramatically beginning in September and peaked in November. These elevated traffic rates during fall may account for the avoidance of < 50 m distance areas. Elk used areas > 900 m from the nearest roads less than expected during all seasons. This distance category, as mentioned previously, is only 8% of the study area; consequently, the rarity of this category within individual home ranges may account for its low use. There is little data from other research that demonstrates a relationship between elk use of areas near roads and measured traffic rates. The Wisdom model (Wisdom et al. 1986) assumes that any traffic regardless of the level may adversely influence elk use of habitats adjacent to roads. Our results suggest that elk may be responding to increased traffic rates in the fall by avoiding areas adjacent (< 50 m) to roads. However, the avoidance of these areas during winter when traffic volume were considerably lower suggests elk may need several months without high levels of traffic to begin using areas closer to roads.

Association with Streams

Studies from semi-arid regions demonstrate a high proportion of elk habitat use within riparian or open water areas (Marcum 1975, Lyon 1973, Pedersen and Adams 1976). Grenier (1991) found that Roosevelt elk in the Bald Hills area were usually within 500 m of water sources. For western Oregon, there are few reports of elk use of riparian areas. The easy accessibility to water in this region may have led previous researchers to assume that elk would not concentrate in riparian areas. However, elk in our study demonstrated a high use of areas near water. For all locations, elk used those areas < 301 m from water more than expected. Riparian areas can act as natural travel corridors, have greater plant diversity or forage variety, and possess different microclimates from surrounding areas due to increased humidity, consequently providing relief from temperature extremes (Oakley et al. 1985, Thomas et al. 1979). Additionally, riparian areas in the Coast range have extremely dense vegetation which provides excellent hiding and thermal cover. Most elk within their home range used all distance to water categories equal to expected, but this may be a result of low number of locations.

Elk selected areas < 51 m from water more than expected during spring, summer, rut, and winter. Those areas > 900 m were used less during all seasons. Grenier (1991) reported that elk in the Bald Hills used areas furthest from water during calving, while other studies found that elk prefer areas near water for calving (Marcum 1975, Witmer 1981). Elk in our study used areas adjacent to water (< 51 m) equal to availability during calving. However in the calving season, those areas 51-150 m from water were used more than expected. Skolvin (1982) suggested that lactating females require more water; consequently the high use of habitats near water during calving and summer is not surprising. Additionally, elk may select areas nearest water during summer and spring because these areas have preferable forage, cover, and microclimates. These areas are natural corridors that interface with a broad range of other habitats (Thomas et al. 1979).

MANAGEMENT IMPLICATIONS

Oregon Department of Fish and Wildlife's Elk Management Plan (1991) has an explicit goal to "protect, maintain, restore, and enhance elk habitat throughout Oregon." As an integral part of this goal, ODFW intends to solicit the cooperation of the US Forest Service and BLM in road management for elk. Additionally, evaluations of management plans for effective (westside) elk habitats will be determined through the use of the Wisdom (1986) model.

Schamberger and O'Neil (1986) cautioned against using HEI models unless the model parameters have been adequately tested. Guidelines for testing should include long-term, multi-year data collections, large sample sizes, and testing across a wide range of habitat qualities. Our study was designed to test the elk habitat use assumptions in the Wisdom model. The study area was selected to reflect a broad range of habitat qualities, land ownerships and management strategies. We attempted to collect data over multiple seasons in an area typifying the high levels of human disturbance occurring throughout the Oregon Coast Range. Within the study area, a variety of habitat conditions were available to elk, however no consistent pattern of habitat selection was apparent. While other studies (Jenkins 1980, Witmer 1981, Schroer 1987) have demonstrated that elk preferred old-growth, results from our research show no strong selection for this habitat. Old-growth in the Wisdom model is considered optimal habitat and given an effectiveness value of 1.0. The value of old-growth to Roosevelt elk within this model may be overrated based on our data. Elk within our area selected, seasonally, areas near streams. However, the Wisdom model does not evaluate elk access to riparian areas. Additionally, variables in this model are too narrow in defining elk habitat selection. I suggest that riparian zones or streamsides without roads be given strong consideration in any elk management plan. These areas provide elk with travel corridors, dense cover and diverse forage.
The Wisdom model does not evaluate elk access to riparian areas. Additionally, variables in this model are too narrow in defining elk habitat selection.

Elk populations in western Oregon are increasing despite the high levels of timber harvest, road building, and other human activities that are occurring throughout the Coast Range. The results from this study and much of the other research on Roosevelt elk suggest that this species is opportunistic, wide-ranging and capable of using a broad range of habitat conditions. However, for elk in the Coast Range, there are still a number of potential problems that should be addressed. Although elk did not demonstrate strong avoidance of roads, the extensive road systems in the Coast range may encourage high levels of poaching. Stussey et al. (1993) concluded that within their study area poaching rates may be considerably higher than the reported 31% for female Roosevelt elk and poaching was the major cause of female mortality. In our area poaching was also the leading cause of death for cow elk and, if the censored animals were included, would approach the levels reported by Stussey et al. (1993). Closing roads and limiting access would reduce poaching. Another potential problem is the high proportion of pole/small sawtimber habitat within our study area. Elk used these areas less than available probably because pole/small sawtimber habitats had poor forage and limited understory cover. Thinning of these habitats may be necessary to provide better forage for elk in the future.

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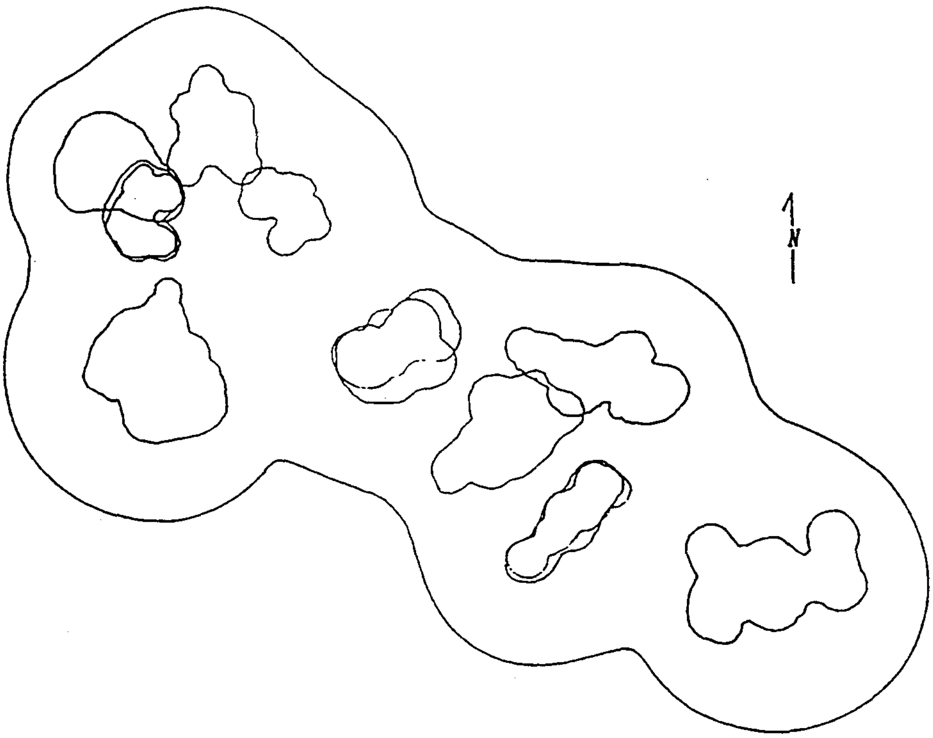
APPENDICES

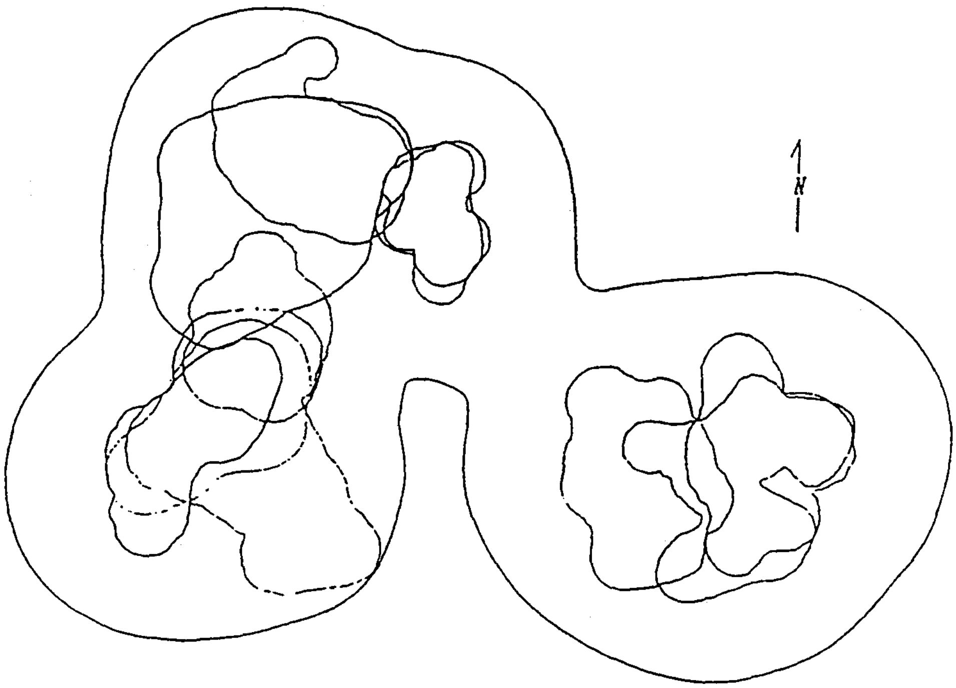
APPENDIX 1

Figure 3. Home ranges for 13 radio-collared elk in the north half of the study area in the southern Oregon Coast Range, 1991-92.



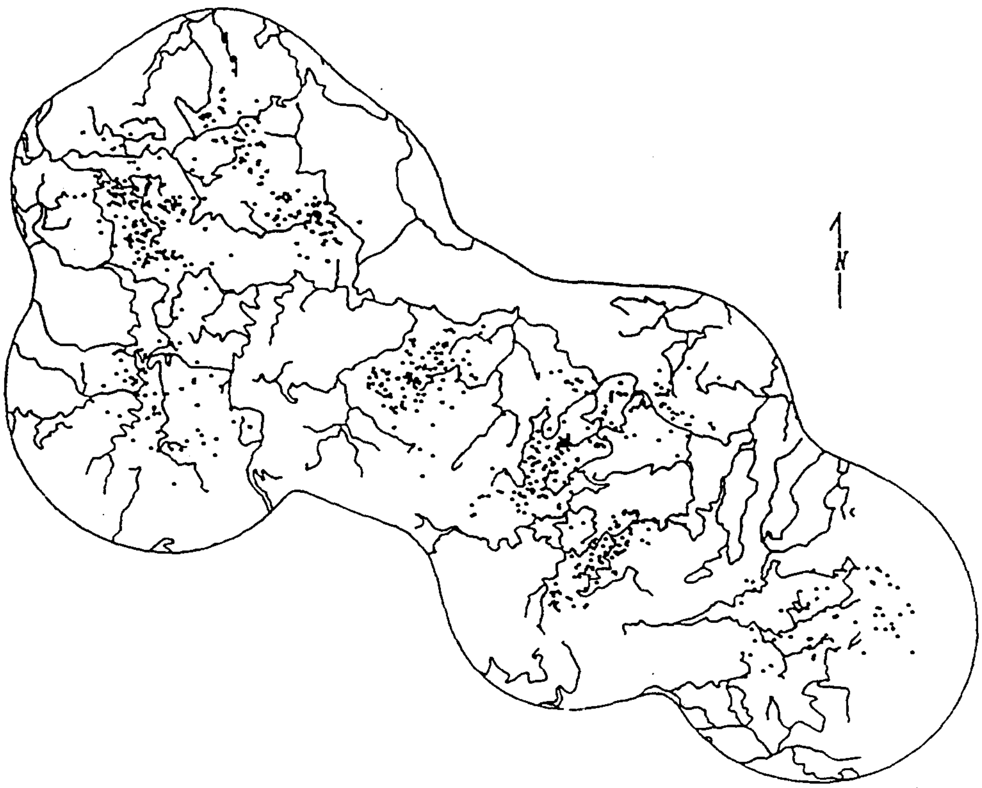
APPENDIX 2

Figure 4. Home ranges for 11 radio-collared elk in the south half of the study area in the southern Oregon Coast Range, 1991-92.



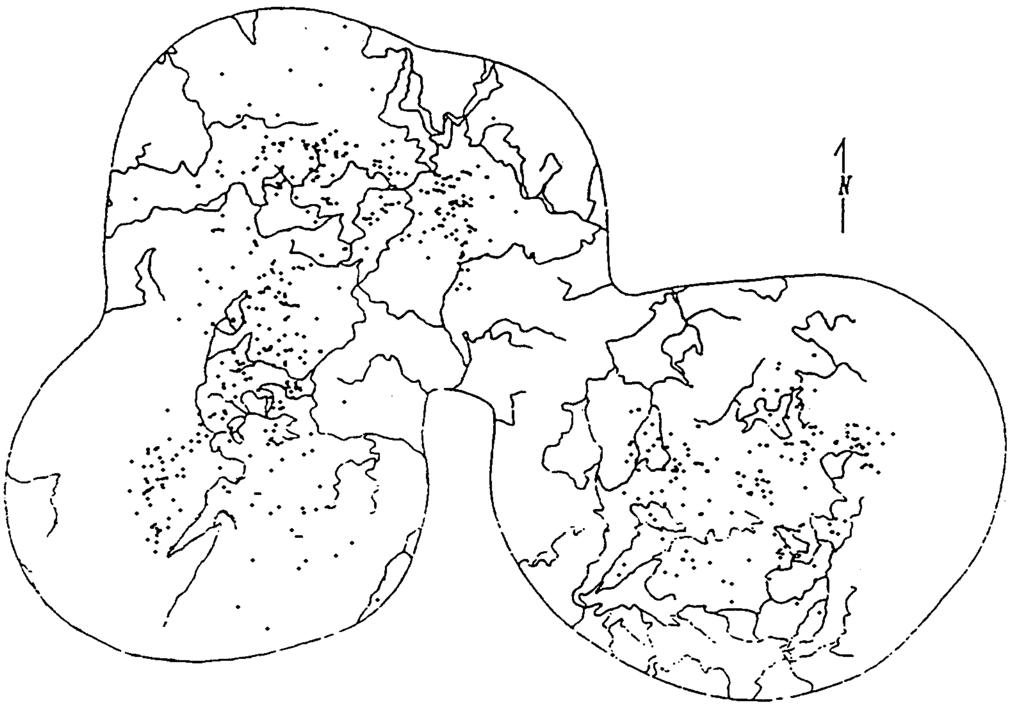
APPENDIX 3

Figure 5. Locations of 13 radio-collared elk in relation to road system in north half of study area in the southern Oregon Coast Range, 1991-92.



APPENDIX 4

Figure 6. Locations of 11 radio-collared elk in relation to road system in south half of study area in the southern Oregon Coast Range, 1991-92.



APPENDIX 5

Road and stream densities in study area in the southern Oregon Coast Range, 1991-92.

For the 37,000 hectare study area, there were 863 km of road or 6.04 km of road for each square mile of area. The north had 525 km of road with a road density of 6.50 km/km^2 while the south had 337 km of road or a road density of 5.48 km/km^2 of area.

Mean road density (table 30) for home ranges in the north was 5.94 km/km^2 while in the south mean road density within home ranges was slightly higher ($\bar{x}$ 6.50 km/km^2).

There were 398 km of streams within the study area with 160 km of streams in the south and 238 km of streams in the north. The north had higher densities ($\bar{x}$ = 4.0 vs $\bar{x}$ = 2.59 km/km^2) of streams than the south. Mean stream density (table 30) for home ranges in the north is 3.40 km/km^2 while for the south home ranges mean stream density was 2.81 km/km^2.

APPENDIX 6

Figure 7. Road and water density (km/km^2) within elk home ranges for both halves of study area in southern Oregon Coast Range, 1991-92.

North Area Elk			South Area Elk		
Elk	Road Density	Water Density	Elk	Road Density	Water Density
4.02	7.79	4.04	4.12	6.50	2.71
4.04	7.79	6.45	4.16	7.21	3.60
4.06	4.04	2.36	4.18	6.37	4.01
4.08	3.5	3.02	4.29	7.69	2.29
4.10	3.98	2.48	4.33	5.79	2.38
4.23	8.10	2.64	4.35	7.18	6.90
4.25	4.16	2.43	4.37	6.19	2.74
4.27	5.81	2.20	4.53	8.53	2.18
4.31	2.79	2.26	4.55	7.23	2.29
4.39	8.38	4.41	4.63	4.44	3.27
4.42	5.74	2.81	4.65	4.42	3.15
4.46	6.24	4.90	$\bar{x}$	6.50	2.82
4.49	8.81	4.14			
$\bar{x}$	5.94	3.40			