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Daily and seasonal habitat use by Roosevelt elk was investigated in the Oregon Coast Range on managed, public forestland. Over 3,700 locations of 6 radio-collared cow elk were recorded during 12 consecutive months. Two elk formed part of a north band and 4 elk were part of a south band. Home ranges for elk bands were mutually exclusive and enclosed areas of 400 ha or less each season. Heavily used central cores of activity comprised a small portion of the total home range. Seasonal home ranges of a given band overlapped substantially and were largest in calving and summer seasons. Cow elk of a given band were most often associated with one another during spring, rut and winter seasons and were otherwise more dispersed. Elk exhibited preferences for old-growth forest and hardwood stands over mixed forest and dense, young conifer stands. Brushy clearcuts were utilized more than new clearcuts for foraging. Use of new clearcuts increased in winter. Elk preferred southerly aspects throughout the year, avoided roads (especially paved roads), and did not venture far from forest/clearcut edges. During calving season, cow elk spent more time in cover and utilized areas that were characteristically of lower elevation, gentler slope, greater seclusion and were closer to water than the rest of the year. Elk appeared unaffected by weather during the mild winter of the study and sought out cover during warmer periods of the day during all seasons. A consistent daily pattern of habitat use was for elk to forage on brushy clearcuts during early and late daylight hours and to retreat to an old-growth stand to bed and/or loaf through the midday period. The pattern of several hours of activity followed by several of inactivity appeared to extend through the night, although elk were less active at night. Cover use, especially of dense, young, second-growth stands, increased and movement decreased during the hunting season. Despite variability in seasonal and individual elk habitat use, discriminant analyses suggested that cover types, adjacent cover types and aspects were the most promising of the parameters measured for the prediction of habitat use patterns of Roosevelt elk. Recommendations are proposed for the effective integration of management for elk and other forest resources.

ROOSEVELT ELK HABITAT USE IN THE OREGON COAST RANGE

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ROOSEVELT ELK HABITAT USE IN THE OREGON COAST RANGE

Roosevelt elk (*Cervus elaphus roosevelti*) occupy the coniferous forestlands of the coastal Pacific Northwest. As pioneers settled this area, elk numbers and suitable range declined dramatically (Rasmussen 1949). State game management agencies initiated steps to reverse this trend: Roosevelt elk hunting was prohibited for many years in Oregon (1909-1937), Washington (1905-1936), British Columbia (1910-1954) and California (1873-1963). Wolf (*Canis lupus*) and cougar (*Felis concolor*) numbers were reduced partly to help revive some elk populations (Brent 1967, Blood and Smith 1973). More recently, state game management agencies reintroduced elk to unoccupied parts of original ranges (Brent 1967, Mace 1971). Initial agency efforts were directed towards managing elk numbers, primarily by reducing elk mortality to predatory species, including man.

Concurrent with those efforts, elk habitat was improved by clearcut logging and by the increased number of fires that accompanied settlement and logging. In combination, these factors led to increased elk numbers (Mace 1971).

Whereas the federal government and private timber companies managed much forestland in the Pacific Northwest, and hence much elk habitat, the state wildlife agencies were entrusted to manage elk for hunters and non-consumptive users and keep elk damage within tolerable limits. Close cooperation was required to integrate the goals of state, federal and private agencies as they related to or impacted elk management (Thomas 1979:11).

As the demand for forest resources grew, the occasion for conflict became more frequent (Bunnell 1976). Intensified forestry practices caused significant changes in forest structure, composition (Edmonds 1979), micro-climate (Edgerton and McConnell 1976) and accessibility to forestland (Silovsky and Pinto 1974). Without careful planning those practices could adversely impact elk populations (Thomas 1979:104).

Federal land managing agencies are required by the National Environmental Policy Act and the Resource Planning Act to assess the impact of their forestry practices on other forest resources such as elk. To minimize potential adverse impacts, federal agencies are required to provide specific information on how their management activities affect animal populations (USDA 1979:29). For elk, this information must include a description of habitat use as well as consideration of the effects on elk of silvicultural treatments, the arrangements of stands in time and space, the stand condition, the size of treatment area and the landtype (Thomas 1979: 123, 129). For most regions, the information necessary for optimizing elk numbers on managed forestland is not available (Lyon 1975).

Detailed information on the use of cover by Roosevelt elk on managed forestlands is not available (Packee 1975). Some investigators (Janz 1980, Hines and Lemos 1974) suggested that mature forestland is important to elk, while others (Stevens 1965, Mandel and Kitchen 1979) concluded that it receives only light use. Harper (1971) reported that the degree of use of clearcut units for foraging is dependent upon the age and size of the units as well as the amount and proximity of cover to stands. Because old-growth forest stands are being liquidated rapidly in the Pacific Northwest and commercial forestland management is being intensified, it is desirable to acquire baseline information on elk use of these and other forest cover types before the number of management options is reduced (Overton and Hunt 1974, Schoen et al. 1981).

The goal of this study was to generate specific information useful to land and wildlife managing agencies for optimizing the integration of elk and forest management. To accomplish this, the objective was to quantify the daily and seasonal patterns of activity and habitat use by Roosevelt elk on managed forestland of the Oregon Coast Range.

STUDY AREA AND METHODS

The study was conducted in the Alder Creek basin of the Coos Bay District of the Bureau of Land Management. The 13 km^2 basin is located at T26S, R10W, 24 km southeast of Coos Bay (Figure 1). The basin varies in elevation from 119 m to 671 m above sea level. Paved roads form western and southern boundaries and the interior of the basin is bisected by many dirt and gravel-surfaced spur roads.

The basin, bowl-shaped with several spur ridges, has all possible slope and aspect combinations, and is formed primarily of micaeous sandstones of the Tyee formation which date to the Eocene era (Franklin and Dyrness 1973: 11-12). Predominant soils are haplumbrepts, western brown forest soils.

The predominant forest cover is 200-year-old conifers of the Western Hemlock Zone Forest as described by Franklin and Dyrness (1973). Salvage logging has occurred in most of the mature stands and 40% of the basin has been clearcut. Coniferous trees are Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*) and western redcedar (Thuja plicata). Riparian areas, portions of cutover land, and road easements are usually dominated by deciduous trees: red alder (Alnus rubra), bigleaf maple (Acer macrophyllum), and myrtle (Umbellularia californica). Predominant shrubs are myrtle, huckleberry (Vaccinium ovatum and V. parvifolium), vine maple (Acer circinatum) and, on the higher areas, rhododendron (Rhododendron macrophyllus) and oceanspray (Holodiscus discolor).

The area receives about 115 cm of precipitation a year, primarily as rain in winter. Average minimum temperature is 0° C in January; average maximum temperature is 27° C in July.

Active logging did not occur in the basin during the study. There was heavy log and gravel truck traffic on paved roads on weekdays. Outdoor recreationists utilized the basin primarily on weekends. The basin is a popular big game hunting area, although a 3-point-or-better bull elk hunting regulation substantially reduced the number of hunters in the November 1978 hunting season from what it had been in previous seasons. Also, there was a 2-day cow elk season on the first weekend of December 1978 with 125 permits issued for the Tioga Unit (about 5,200 km^2) which includes the basin. The basin supports about 40 non-migratory elk, divided equally between north and south bands.

TRAPPING AND RADIO-COLLARING OF ELK

Elk were trapped in corral traps baited with alfalfa as described by Mace (1971). Trapped yearling or older cow elk were drugged with 17 to 20 mg powdered succinylcholine chloride via a CO_2 powered rifle (Pederson and Thomas 1975). Immobilized elk were fitted with a radio-transmitter collar as described by Pederson (1977). Six adult cow elk were radiocollared: 2 in a north band and 4 in a south band. Analyses of elk movement and habitat use were based on 3,710 radio-locations of the 6 cow elk.

REMOTE LOCATION OF ELK

Radio-collared elk were located during a 12-month period (May 1978-April 1979) with a 2-element, hand-held yagi antenna. Bearings were taken from 2 to 6 stations along roads until the elk's location could be established by plotting bearings on a gridded forest cover type map. Coordinates of points so derived were recorded. The "loudest signal method" was utilized as it is less prone to many of the biases of radiotelemetry methodology (Springer 1979).

Radio-locations were made hourly from first light to dusk for two, 3- to 4-day periods for each band each month. Elk were capable of moving more than a km/hr and thus of availing themselves of almost any portion of their seasonal home range within that time period. Consequently, each hourly location was considered to be independent of the previous location. On most days, simultaneous locations were obtained for both collared elk in the north band or for 2 to 3 collared elk in the south band. Later, plotted radio-locations were described according to slope (flat, 0-25% gradient; moderate, 25-50% gradient; steep, 50+% gradient), aspect (N, NE, E, SE, S, SW, W, NW exposure), elevation, cover type, the 2 closest adjacent cover types and distances to them, distance to and nearest road type, distance to nearest paved road and distance to nearest permanent water source.

Night triangulation was performed in 2- or 3-hour intervals on south band elk 3 nights per month, May-August. These observations were then discontinued because elk were too easily frightened at night: data (cover type utilized and distance moved) thus might not be representative of typical elk behavior. These limited observations provided liberal estimates of night movement. Conservative estimates of night movement were made for each season. These estimates were made by computing the distance between the last radio-location of the evening and the first location of the next morning and represented the minimum distance moved during the night.

Efforts were not made to make visual contact with elk bands because elk were so easily disturbed and this would bias the habitat use patterns which I sought to describe. When elk bands were observed, data recorded were number and composition of elk in the band, number of collared elk present, date and period of day, and elk activities. Elk (not necessarily of the bands being studied) were also encountered while driving along roads to and from fieldwork. When this occurred, the date, location, number and composition of elk were recorded. Incidental data recorded included a listing of elk mortalities and notes on special events such as irregular long distance movements by collared elk.

WEATHER AND VEGETATION DATA

Ambient temperature was obtained from 2 continuously recording thermographs (1 in an old-growth stand, the other in a new clearcut); daily rainfall was measured with a rain gauge. At the time of each radio-location, an ocular estimate of cloud cover was made, precipitation status (heavy rain, light rain, fog, hail, snow, or none) noted and wind conditions recorded (no wind, breezy or windy).

The study area was classified and mapped as 7 cover types: old-growth forest, mixed forest, hardwood, old clearcut, brushy clearcut, new clearcut and road. The first 4 cover types had overstory canopy at least 3 m high and were collectively called "cover," whereas the other 3 did not and were called "openings." Roads were not sampled for vegetation. Certain structural characteristics of stands (upper tree and shrub canopy heights, woody basal area and woody stem density) change slowly over time and consequently were sampled only in the winter of 1977-78. These data were collected from 4 representative stands for all cover types except roads.

Two permanent plots (0.05 ha) were established in each of the 6 cover types and subdivided according to the techniques of Franklin et al. (1970) and Moir and Franklin (1976). Seasonal vegetation characteristics (fern, grass, forb and shrub cover; vertical vegetation density; canopy cover) were sampled bi-monthly from the permanent plots. Ocular estimates of grass, fern, and forb cover were made on 80 1 dm x 5 dm microplots per cover type (Daubenmire 1959). Shrub cover ($\leq$ 2 m) was measured by the line intercept method (Pieper 1973:89) along 97.3 m of tape measure per cover type. Vertical vegetation density to a height of 2 meters (in 0.5 m intervals) was estimated with a randomly placed vegetation cover board (Nudds 1977). Tree canopy cover was measured with a densiometer (Dealy 1960). Notes on plant phenology (Orme and Leege 1980) were recorded every 2 weeks.

DATA ANALYSES

Elk locations were pooled by band for 2-month periods: spring (March/ April), calving (May/June), summer (July/August), rut

(September/October), fall (November/December) and winter (January/February). For diel analyses, the 2-month periods were divided into morning (0700-1059), midday (1100-1459) and late day (1500-2000) segments. Night was considered a single period (2200-0700) except for detailed May-August analyses wherein night elk locations were divided into 3 periods: 2200-0059, 0100-0359 and 0400-0659.

To determine mean availability values of habitat parameters, 200 random coordinates were generated both for the north and for the south band areas. Each coordinate was characterized according to habitat variables recorded per band area. Mean values served as the expected values for elk radio-locations and were used to determine whether elk were using habitat preferentially or randomly (Marcum and Loftsgaarden 1980).

Elk utilization of habitat classified as category variables (slope, aspect, cover type, adjacent cover types, nearest road type) were tested by comparing expected value (frequency of occurrence) with the observed value (frequency of elk use) via Chi-square goodness of fit tests, or where there was no expected distribution, the Chi-square test of independence. Elk utilization of habitat classified as continuous variables (elevation, distances to adjacent cover types, distances to nearest and paved roads, distance to permanent water source) were tested by analysis of variance. Elk habitat use was tested by season and period of day and determined to be significantly more (preference) or less (avoidance) than expected at the 95% confidence level. If neither occurred, the elk were considered to use that habitat parameter as expected, ie. according to availability. It should be noted that because an elk band preferred a particular cover type that it did not mean that other cover types were not being utilized; conversely, a cover type may have received use and still determined to be avoided by elk in the statistical sense. Additionally, elk respond to the environment in toto and to stimuli which probably do not correspond exactly to the categories of individual habitat variables as measured in this study. Assigning preference and avoidance in this manner is subject to some biases so the ranking method proposed by Johnson (1980) was also utilized to evaluate habitat preferences. Analyses were made with the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975).

Variables with significant Chi-square or F- values were further analysed with the Bonferroni Z-test (Neu et al. 1974) or the Scheffe test (Bancroft 1968:101), respectively, to determine in which season(s) or period(s) of day elk utilized parameters at significantly greater or lesser levels than available. Mean values presented in the text are followed by the standard deviation in parentheses, or for percentages, the Bonferroni Z value for the 95% family confidence interval.

Discriminant analyses were performed utilizing SPSS (Radler 1977) to allow the identification of the subset of habitat variables most useful for describing elk habitat use. Assessment of the significance of multiple habitat parameters to elk was made (Hudson 1977).

The Koeppl et al. (1975) program was utilized to generate 95% confidence ellipses of seasonal home ranges for individual elk and for elk bands. Bivariate models such as Koeppl's are generally preferred over univariate home range models (Van Winkle 1975), however, Koeppl's model tends to exaggerate the size of the home range (Madden and

Marcus 1978). Because the model exaggerates home size and also assummes bivariate normal distributions which often do not occur, the minimum area method of home range size determination (Mohr 1947) was also utilized.

On scattergrams of seasonal elk band locations, central cores of activity (Franklin et al. 1975), which corresponded to areas of maximum concentration of seasonal elk locations, were subjectively circumscribed and the enclosed areas (which contained at least 50% of the elk locations) contrasted with the total area of the seasonal home range. This was similar to the method of Craighead et al. (1973).

Seasonal integrity of elk bands was determined by contrasting the number of days pairs of collared elk in a given band were together at least a portion of the day to the number of days in which they were not together at all. Cole's (1949) index of cow association (CA) was used. The CA varies from a value of 0 (no association) to 1 (complete association).

RESULTS

Drugging and Radio-collaring of Elk

Nine and 6 elk were successfully trapped, drugged and radio-collared during the winters of 1976-77 and 1977-78, respectively (Appendix 1). Premature radio failures of the original 9 radio-collars necessitated the second winter of elk trapping. Fifteen to 20 mg of succinylcholine chloride were required to immobilize elk, although some could not be immobilized with 20+ mg and were released without radio-collars. The average reaction time was 4 1/2 minutes; the average recovery time was 34 1/2 minutes. One drug fatality occurred: an adult cow elk which was not immbolized by a 17 mg dosage was given a 20 mg dosage about 15 minutes later. She died 3 minutes after receiving the second dosage.

Seasonal Weather

The incidence of wind and rain increased in the fall and winter and declined during the following summer and rut seasons when cloud cover also declined. Seasonal mean temperature differences between an old-growth stand and a new clearcut ranged from 1.8 to 5.5° C (Tables 1, 2). Old-growth stands tended to be warmer during cool weather and cooler during hot weather than new clearcuts (Figure 2). Temperature and precipitation during the study approximated the long-term average for the area.

VEGETATION ANALYSES

Structural Characteristics

Cover types were distinct: mean values of structural variables, except number of large woody stems, were significantly different at the 95% confidence level (Table 3). Tree and shrub height and woody basal area were significantly greater in old-growth stands than in other stand types. Woody basal area was least in hardwood, brushy and new clearcut units with mixed forest and old clearcut units intermediate in value. Large stem density was comparable in all stands except brushy and new clearcut units which had few large stems. Small stem density was comparable in all cover types except old-growth stands where it was significantly lower.

Seasonal Characteristics

Overstory canopy cover did not vary significantly among seasons for any stands except hardwoods which had lows in fall (32.5%) and winter (31%) and highs in calving (81%) and summer (86.5%) (Table 4). The overstory canopy cover in the fall and winter in hardwood stands was significantly lower than that in any season in all other cover types which had overstory canopy.

Fern cover did not vary significantly among seasons for any cover type (Table 4). Old, less disturbed units such as the old-growth stands had greater fern cover. The least fern cover was found on recently disturbed units; hardwood stands, brushy and new clearcut units.

Grass cover did not vary significantly among seasons for old-growth and mixed forest units (Table 4). There were significant differences of grass cover among seasons for hardwood, old clearcut, brushy clearcut, and new clearcut units, all of which had lowest grass cover during the rutting season. Highest grass cover on brushy and new clearcuts was during spring. Grass cover peaked in hardwood stands during calving season and on old clearcuts during summer. Grass cover was significantly lower in old-growth, mixed forest and old clearcut units than the other cover types. Of the other cover types, new clearcuts had significantly greater grass cover than brushy clearcuts which, in turn, had significantly greater grass cover than hardwood units.

Forb cover varied significantly among seasons for all cover types (Table 4). Lowest forb cover for old-growth and hardwood stands was during fall; highest cover was during spring. Mixed forest, brushy clearcuts and new clearcuts had lowest forb cover during winter, while old clearcuts exhibited lowest value in the rut season. Highest forb cover for mixed forest and brushy clearcuts was during calving season. For old clearcuts and new clearcuts, highest forb cover was during spring. Mean annual forb cover values for brushy clearcut and new clearcut units were significantly greater than for all other cover types even during fall and winter. Old clearcuts had significantly lower mean annual forb cover than all other cover types.

Shrub cover did not vary significantly among seasons for any cover type (Table 4). Shrub cover was significantly greater in old clearcut and mixed forest units than all other cover types. Almost all shrub cover in old clearcuts consisted of coniferous species. Brushy clearcut units were intermediate and all other cover types were significantly lower in shrub cover. Shrub cover was lowest in undisturbed or newly clearcut forest.

Vertical vegetation density (Table 5) varied significantly among seasons only in hardwood stands (1-1.5 and 1.5-2 m height classes) and mixed forest stands (0.5-1 m height class). The exhibited pattern was lower vertical vegetation densities in rut through winter (when leaf fall occurred). Vertical vegetation density below 1 m was comparable in old-growth, old clearcut and brushy clearcut units and greater than the other 3 cover types which were comparable. In the 1-2 m height class, old clearcut units had significantly greater vertical vegetation density than all other cover types. Lowest density values were in hardwood and new clearcut units.

The dates of major phenological events for primary elk forage species varied (Table 6). Among the woody species with early bud swell and active growth were chapparal broom, blackberry, red huckleberry, and myrtle, while these events occurred last in vine maple. Those showing earliest leaf senescence and dormancy were salmonberry, vine maple, red alder and myrtle. Among herbaceous species, spotted cat's-ear and the grasses exhibited earliest growth. Grasses also had a second period of active growth in September and October that is often referred to as "fall greenup." Senescence and dormancy came earliest with swordfern, some grasses and oxalis.

SEASONAL ANALYSES OF HABITAT USE

Home Range, Movements, and Population Dynamics

As expected, the ellipse method gave consistently larger home ranges, often 80% larger than the minimum area method (MAM). By either method, home range sizes were large early in the year, peaked in calving or summer seasons (maximum = 403 ha) and declined the rest of the year (Table 7). Smallest home range sizes occurred in fall or winter (minimum = 59 ha). Band home range sizes usually peaked later (summer) than individual home range sizes (calving).

Home ranges for a given elk band overlapped substantially among seasons, but remained apart from those of the other band during all seasons. Home range centers shifted the most between winter and spring home range areas, but even then the shift was only 600 to 800 m (Table 8) so that the areas still overlapped substantially. Within seasonal home ranges, central cores of activity contained a significantly greater proportion of the elk observations, 53.6% (11.6), than would be expected given the proportion of the total home range areas contained within central cores of activity, 21.7% (6.9).

The home range utilized throughout the course of the year appeared restricted by boundaries comprised of geomorphic features such as ridges or by paved roads.

Subgroups of elk existed for each band. Composition of subgroups shifted as there was free interchange of elk among subgroups. Consequently, while bands consisted of about 20 elk each, actual observations of elk were of subgroups of these bands, with an average size of 4 to 7 elk (Table 9). There was, however, no exchange of collared elk between the north and south bands during the course of the study despite the close proximity of the band areas (Figure 1).

The average cow association index (Table 10) tended to be higher, 0.62 (0.29), for the rut, winter and spring seasons than for the other seasons, 0.36 (0.22).

Daily and nightly distances moved were greatest during calving and summer seasons and substantially reduced in other seasons (Figure 3). The pattern was consistent for both bands. During calving and summer seasons there was also significantly greater daily than nightly movement. Distances moved each day were significantly greater during the calving and summer seasons for north band elk and during the calving season for south band elk than for any other season. These consistent patterns of home range size and distances moved were substantiated by frequency of encounters with elk along roads while driving to and from fieldwork: most encounters were in spring, calving and summer seasons (Figure 4).

The longest known movement of a collared elk was by an adult cow seen near Loon Lake, at least 32 km northeast of the study area. This elk carried one of the nonfunctional radiocollars from the first winter of elk trapping, so its movements were not included in data analysis for the elk trapped in 1978.

Incidental observations of the north and south bands throughout the study allowed an estimate of calf production and mortality during the first year of life (Table 11). Based upon observations of calf: antlerless elk ratios, calf production was probably on the order of 50 calves per 100 anterless elk and the mortality rate during the first year of life was about 60%.

There were 5 known mortalities among the collared elk (Appendix 2). In addition, there was substantial mortality of bull elk during hunting season. Two unmarked cow elk were harvested in December, 1978, during the rifle season of antlerless elk. Three unmarked north band elk were illegally shot during the winter of 1978-79.

Habitat Use---Physical Parameters

Steep slopes were used according to availability by north band elk which tended to use flat slopes more than moderate slopes (Table 12). South band elk preferred flat and/or moderate slopes except during spring when slopes were used according to availability.

Elk of both bands exhibited preference for SE, S, and SW aspects (Table 13). NW, N, and NE aspects were generally avoided although their use increased (irregularly) during the warmer part of the year, calving and summer seasons.

North band elk consistently used areas lower in elevation than according to availability, especially during spring and calving seasons (Table 14). South band elk consistently used areas higher in elevation than according to availability except during calving season.

The locations of paved roads may account for this apparent discrepancy between bands. Closely related to the elevation use pattern was the pattern of distance to permanent water from collared elk locations. This distance was significantly less than expected for north band elk in all seasons, but was significantly greater than expected for south band elk for all seasons except calving season (Table 14).

It was possible for the closest road to a collared elk of either band to be paved, gravel or dirt surface. For elk of both bands, the closest road was significantly less often of paved and significantly more often of dirt surface than according to availability of those roads for most seasons (Table 15). Gravel roads were intermediate; during some seasons they were more often the closest road and during other seasons they were less often the closest road than according to their availability.

Elk of both bands were as far or significantly farther from paved roads than expected according to paved road availability for all seasons with the single exception of south band elk during the calving season (Table 14). The annual average distances to a paved road for north and south band elk was 564 and 581 m, respectively, while the expected distance based upon random use of habitat was 511 and 501 m, respectively. The cumulative frequency distribution of elk locations as related to distance to paved roads was significantly different from the expected distribution (Table 16). Combining all elk observations, I recorded 71% fewer elk locations within 126 m of a paved road than expected. Within 245 m, I recorded 54% fewer elk locations than expected, and within 365 m, 33% fewer elk locations than expected.

There were only 28% fewer elk locations than expected within 485 m of a paved road. In using gentler, lower, more wet areas during the calving season, south band elk brought themselves in closer proximity to the paved road bordering their area.

The distance of elk to the nearest road (regardless of surface) was greater than expected for all seasons for north band elk (annual mean = 152 versus expected mean = 124 m) except during winter (mean = 110 m) (Table 14). For south band elk, the distance to the nearest road was less than expected for all seasons (annual mean = 109 versus expected mean = 122 m) except during rut and winter when the distance was similar to that expected (Table 14). The cumulative frequency distribution of elk locations as related to distance to nearest road was not significantly different than the expected distribution for south band elk, but it was for north band elk (Table 16). If one eliminated the first interval (0-60 m) from the analysis, the remainder of the categories had frequencies of elk locations as expected. The first category had significantly fewer elk locations than expected.

Use of cover (old-growth, mixed forest, hardwood and old clearcut units combined) varied significantly among seasons for both north and south band elk (Table 17). Elk of both bands preferred cover during calving season. South band elk also exhibited this preference for cover during summer, rut and fall seasons. Elk of both bands used cover significantly less than expected during the winter and spring seasons. Highest seasonal use of cover was during calving for north band elk and during the rut season for south band elk. Lowest seasonal use of cover was during spring for south band elk and during winter for north band elk.

The adjacent cover type was more often cover than expected for north band elk during spring, calving and fall seasons; while it was least often cover during summer and winter (Table 17). For south band elk, the adjacent cover type was more often cover than expected during calving and summer seasons and least often cover during the rut season (Table 17).

The average distance to the adjacent cover type when elk were in cover was consistently greater than when they were in the open for elk of both bands for all seasons (Table 14). When in cover, the average distance to the edge for north and south band elk was 62.5 and 99 m, respectively. When in the open, the average distance to edge for north and south band elk was 45.3 and 59.5 m, respectively. Except for south band elk during winter, elk of both bands tended to be closer to the edge when in openings than expected (Table 14). Of all elk located in openings 95% were within 130 m of the forest edge, although some were as far as 215 m from the edge. Except for south band elk during spring, fall and winter, elk of both bands tended to be closer to the edge when in cover than expected (Table 14). This tendency to use edges was also evidenced by the distance of elk to adjacent cover type (regardless of whether the elk were in cover or an opening) which was less than expected for the elk of both bands in all seasons except south band elk during the fall season (Table 14).

Habitat Use---Vegetation Parameters

North band elk used old-growth according to its availability in most seasons except during spring when they avoided it and calving when they preferred it (Table 18). South band elk preferred old-growth in all seasons except during spring when they used it according to its availability. The use of old-growth declined from the rut through spring for both bands.

Mixed forest stands did not occur in the north band area, but in the south band area elk exhibited avoidance of that cover type in all seasons (Table 18).

Hardwood stands had a low frequency of occurrence in both areas yet the north and south band elk preferred them during 3 and 2 seasons, respectively. In all other cases the stands were used according to their availability (Table 18).

Old clearcuts were avoided in all seasons by both bands except during spring, calving and rut for the south band when elk used them according to availability (Table 18).

Brushy clearcuts were preferred by north band elk in all but the calving and summer seasons when they were used according to their availability. South band elk preferred brushy clearcuts during the spring and avoided them during the rut season. In other seasons, elk used them according to availability (Table 18).

New clearcuts were avoided during calving, summer, rut and fall seasons by south band elk and during the calving and summer seasons by north band elk. In other seasons elk used them according to their availability (Table 18).

Roads were avoided during all seasons by north band elk and during the summer and rut seasons by south band elk. In other seasons, south band elk were located on roads in proportion to availability (Table 18).

The ranking method confirmed the preference for hardwood stands and for brushy clearcuts and new clearcuts in certain seasons (Table 18). In addition, it confirmed that roads were used more by south band elk than by north band elk even though roads covered somewhat less area in the south band area. The preference for old-growth was not as strong when examined by the ranking method because it was the most available cover type in the study area. Avoidance of old clearcuts was also more evident in the north band area than the south band area because old clearcuts comprise less of the north band area.

The preferred adjacent cover types were old-growth and hardwood stands for both bands in numerous seasons (Table 19). Old clearcuts were avoided as adjacent cover types by elk of both bands in most seasons. In addition, the south band avoided mixed forest stands as adjacent cover type except in spring. Brushy clearcuts were preferred as adjacent cover type by the north band elk during summer and rut and by south band elk during the rut season. Both bands preferred new clearcuts as adjacent cover type during winter with the south band elk also exhibiting that preference during fall. The ranking method basically confirmed this pattern of preferences and avoidances.

Discriminant Analyses

Analyses were performed to determine the predictive capacity of a model to place an elk location into the season of its occurrence. Nine habitat variables (cover type, adjacent cover type, aspect, elevation, slope, distance to nearest road, distance to paved road and distance to water) were utilized in the discriminant analyses. The analyses indicated cover type, adjacent cover type and aspect to be most discriminating of north band elk locations by season and achieved a correct prediction level of 38.3% with 47% of data variability accounted for by the model. For locations by seasons for south band elk, slope, cover type, elevation and adjacent cover type were the most discriminating variables and a correct prediction level of 48.1% was achieved with 50% of the data variability accounted for by the model. With 6 seasons, the expected correct predictive level on a purely random choice basis was 16.7%. The model was least able to correctly discriminate differences in seasonal elk habitat use for rut and fall seasons and most able to discriminate for spring season, north band. For the south band, the model least correctly discriminated for summer season and most correctly discriminated for the fall season (Table 20).

A second analysis was performed to determine the predictive capability of a model to discriminate between an actual elk location for a given band and season, and a random location. The random location data set reflected the availability levels of the 9 habitat variables utilized with the SPSS computer program (listed in the above paragraph). Cover type, aspect and adjacent cover type were the most consistently important discriminating variables. The correct prediction level achieved varied from a low of 74.3% to a high of 95.5% (Table 21). The expected correct prediction level on a purely random choice basis was 50%. The model was least able to correctly discriminate differences from elk habitat use and the random data set for calving season of the south band and for summer season of the north band. The model was generally able to account for >50% of the variability in the data.

DIEL ANALYSES OF ELK HABITAT USE

Movements and Activities

For all seasons combined, except calving, the average amount of movement per hour was significantly different by time of day with elk moving least in midday, 51.1 (18.6) m/hr, versus morning, 79.8 (25.4), or late day, 70.5 (30.3). For calving season, elk were active throughout the day and averaged 132.5 (30.3) m/hr of movement. Distance moved by elk at night increased successively from 49.1 (49) to 62.4 (50.3) to 88.3 (45) m/hr at 3 hr intervals (2200-0100, 0100-0400, 0400-0700), however, the differences were not significantly different at the 95% confidence level.

Just as elk were more active in the morning and late day, so more incidental observations of north and south band elk occurred during these periods (Table 9). The commonest elk activity observed was feeding in the herbaceous layer, followed by elk moving from one place to another (Table 9).

Habitat Use---Physical Parameters

Elk use of slope, elevation, distance to water and distance to paved road rarely exhibited significant differences by time of day. There was a tendency for elevation use and distance to water from elk to be greater earlier in the day. The distance to paved road from elk tended to be greater late in the day.

The distribution of elk use with respect to aspect was significantly different by time of day in 9 of 12 analyses performed (2 elk bands times 6 seasons = 12 analyses). While southerly aspects were preferred in all seasons, a somewhat larger percentage of the southerly elk locations occurred in late day (38%) versus morning (32%) and midday (30%) during the warmer (calving, summer and rut seasons) part of the year. During the colder part of the year, there were more elk locations in southerly aspects in the morning (39.8%) versus midday (33.7%) and late day (26.5%).

The distances of elk to the nearest road were significantly different by time of day in 6 of 12 analyses. The distance tended to be greatest in midday. This may have been related to volume of traffic, however, that parameter was not measured. The nearest road type to the elk also exhibited significant differences by time of day in 6 of 12 analyses, but no consistent pattern was evident.

Daylight use of cover by elk was significantly different by time of day in 6 of 12 analyses. Cover was used most at midday, 72.5% (14.6), versus morning, 66.2% (19.7), or late day, 65.1% (17.5).

Habitat Use---Vegetation Parameters

The use of cover types was significantly different by time of day in 8 of 12 analyses performed. Old-growth was used more by elk in late day during the warmer (calving, summer and rut seasons) part of the year (Table 22). Both bands of elk exhibited this response although the difference was significant only for the north band elk. An opposite tendency occurred during the colder (fall, winter and spring seasons) part of the year when the use of old-growth by elk was significantly greater in the morning and midday.

The pattern of use by elk of old clearcuts was similar to that of old-growth, as was the pattern of use by south band elk of hardwood stands. Elk of the north band used hardwood stands more in midday, although not significantly so.

With one exception, openings of all types (brushy clearcuts, new clearcuts and roads) were used more--and usually significantly so--in early and/or late day than in midday (Table 22). The exception was use of roads by elk of the north band which used roads most in midday during the warmer (calving, summer and rut season) part of the year. The difference was not significant, however, and the small number of observations of elk on roads (n = 15) makes any statement concerning road use in this instance tenuous.

Elk locations with respect to the adjacent cover type exhibited significantly different patterns by time of day in 7 of 12 analyses, but consistent patterns were not evident beyond a tendency for the adjacent cover type to be an opening in the morning and to be an old growth stand in late day. The distance of elk to the adjacent cover type by time of day exhibited no clear patterns other than a weak tendency for the distance to be greater in mid- and late day.

The use of cover types at night was examined only for the calving and summer seasons (combined) and only for the south band elk. Night use differed significantly from the availability of the cover types and also from day use of the cover types (Table 23). The main difference between day and night use was that the use of old clearcuts increased from 2.5% during the day to 18.6% at night. Both figures, however, represent an avoidance of old clearcuts by elk.

Special Intraseasonal Analyses

Three intraseasonal analyses were performed to determine if distinct patterns in the amount of time elk spent in cover and/or in the daily distance moved were evident during: hot summer days (when temperature on clearcuts exceeded that in old-growth by at least 6°C for 3 or more hours); adverse winter days (when precipitation occurred during at least half of the day and there were at least 3 observations of windy conditions); and elk hunting seasons.

Significant differences were not found in elk use of cover or the amount of movement during hot summer days versus mild summer days.

On adverse winter days elk used cover significantly less, 42.6% (8.8), than on mild winter days, 61% (8.4). Elk also moved less on adverse winter days 500 (277) versus 555 (244) m/day, but the difference was not significant at the 95% confidence level. It is important to note, however, that the adverse winter days did not have prolonged freezing temperatures nor more than a trace of accumulated snow.

Elk used cover significantly more on days during hunting seasons, 78.5% (5.9), than on days just before or just after hunting seasons, 63.3% (6.7). They also moved less on hunting days, 568 (293) versus 705 (384) m/day, but the difference was not significant at the 95% confidence level. The increased use of cover during hunting season days was accounted for by increased use of old clearcuts from 0.6% on nonhunting days to 14.1% on hunting days. The longest known single-hour movements by elk of each band (1,023 and 946 m) occurred on days the elk were actively hunted and were in response to known disturbance of the bands by hunters. Elk were not significantly farther from roads on hunting days than the seasonal mean distance from roads.

DISCUSSION

There was much variability in daily and seasonal habitat use by Roosevelt elk. Preferences for, and probably the importance of, various habitat parameters changed over the course of a day and even more so over the course of the year in an environment typified by seasonality of weather and diversity of, and changes in physical and vegetative components. Interspecific competition for space and resources (including that with humans) and intraspecific interactions were not recorded but undoubtedly co-acted with elements of weather and vegetation to influence habitat use and preferences exhibited by the elk (Figure 5). These factors directly and indirectly affect the number and welfare of elk in a population and the size and specificity of areas utilized. It is convenient to consider the factors independently, however, elk are not confronted by them in that way. Ultimately, consideration of the synergistic impact on the patterns of activity and habitat use for Roosevelt elk must be made.

Herd Dynamics

Variability in year to year productivity of Roosevelt elk has been documented and presumed related to severity of winter (Janz 1980), density of the population (Harper et al. 1967) and age structure of the population (Smith 1980, Kuttel 1975). The Alder Creek herd has been considered stable by local biologists for at least a decade (R. King, BLM, pers. comm.). The favorable herd productivity of about 50 calves per 100 cows apparently has been balanced by losses to hunting and illegal shooting and calf mortality. Summer calf numbers per 100 antlerless elk averaged 42 and were similar to those reported for Roosevelt elk in Oregon (Hines and Lemos 1974: ca 40), Washington (Smith 1980: ca 45) and British Columbia (Janz 1980: ca 40), but higher than those reported for Alaska (Batchelor 1965: 32). Additionally, the marked elk of Alder Creek were faithful to their home range area, a phenomenon also reported for marked Roosevelt elk of Olympic National Park (ONP) (Jenkins 1980). It can be inferred from the apparent herd stability and faithfulness to the Alder Creek basin that the habitat has been sufficiently stable and heterogeneous for the herd to meet its requirements there.

Home Range

The non-migratory elk of this study met seasonal requirements on a managed forestland area of 400 ha or less.This was similar to or smaller than home range size reported for Roosevelt elk in managed forests of California (Franklin et al. 1975: ca 300 ha), Oregon (Graf 1943: ca 512 ha), Washington (Schwartz 1943: ca 512 ha) and British Columbia (Janz 1980: 520 ha), but $\geq$50% less than the home range sizes reported by Jenkins (1980: ca 1000 ha) for non-migratory elk of ONP. The home range sizes given by Franklin, Graf and Schwartz were estimates based upon the direct observation of unmarked or ear-tagged elk, while Janz, Jenkins and this study utilized the plotting of radio-collared elk locations to determine the home range sizes. Additionally, Janz basically used the minimum area method while Jenkins used Koeppl's bivariate ellipse method. In this study both methods were employed and the largest seasonal home range (403 ha) resulted from the Koeppl method. The small home range size of these large ungulates was even more dramatic in light of the heavy utilization of central cores of activity which comprised only 22% of the mean home range size. Franklin et al. (1975) recorded over 50% of their Roosevelt elk locations in northern California within 25% of the total home range area. Because managed public forestlands have a variety of stands of different ages in close proximity, they are more heterogeneous than forest wilderness areas such as ONP. Consequently, elk have the potential to obtain their requirements for cover, foraging, ruminating, bedding and calving in a relatively small area.

A number of factors were probably responsible for the elk of this study utilizing smaller-sized areas in winter than in summer. Food is less abundant as well as of lower quality in winter (Rochelle 1980). It appears that deer in temperate climates may have evolved a strategy of minimizing energy expenditure in winter through restricted activity and lowered forage consumption (Moen 1976, Ozaga and Verne 1970), however the latter may not apply to elk (Dean 1980). Gates and Hudson (1979) found an increased metabolic rate in elk calves as ambient temperature was reduced. In addition, metabolic rate was greater if the animals were standing (instead of lying) and even more so if they were active. They suggested that this was due to greater convective and radiant body heat losses.

Large calving and summer home range sizes probably resulted from cows about to calve seeking solitude and/or favorite calving areas and the disorientation of non-calving cows as the herd dispersed from the smaller winter home range. In addition, weather and vegetation conditions are favorable during this time of the year and ungulates can afford to be more general in their feeding habits, utilizing a larger portion of the environment (Nudds 1980). A final factor which may contribute to the greater amount of movement during these seasons was suggested by Darling (1937: 105-106), who noted increased movement of red deer in response to the wide temperature fluctuations of late spring/summer. He speculated that the deer were seeking a more consistent temperature regime. Greatest daily range in the temperatures from the old-growth and clearcut recording sites was in calving (late spring) and summer seasons, and smallest daily temperature ranges occurred in fall and winter (Tables 1 and 2).

Elk using large areas in non-commercially managed forestlands such as ONP probably rely upon tradition to meet their survival requirements more than elk which utilize a small heterogeneous area of commercially-managed forestland. In the non-commercially managed forest, such as wilderness, areas preferred by elk for seasonal use may be farther apart than in the commercially-managed forest (Jenkins 1980). Consequently, young elk must learn intricate daily and seasonal movement patterns from older elk as postulated by Geist (1974: 209) for social ungulates. This might explain the higher cow associations (CA) reported by Jenkins and Starkey (1981) for elk within ONP (CA = 0.79) than for those outside the park (0.13) and those for this study (0.49). It should be noted, however, that while commercially-managed forestland, in general, has greater inter-stand heterogeneity (Harris 1980)—which is favorable to elk—exceptions can occur. If large areas are clearcut within the short time span of a few years, the result several decades later would be a large area of dense, second-growth forest of little inter- and intra-stand heterogeneity which is not favorable to elk.

Superimposed on the annual average cow association (CA) value of this study were seasonal changes in CA value related to behavioral responses: lower CAs occurred during calving and after the rut. After close association on small winter home ranges, cow elk dispersed to calve. Their association increased again during the rut when bulls established and maitained harems. This pattern was consistent with the findings of Jenkins and Starkey (1981) in ONP and may be implied from data of Harper (1971) for elk on managed forestland in western Oregon.

Influence of Physical Parameters

In winter, elk are presumed to be in a negative energy balance (Dean 1980) and many state and federal agencies emphasize the need to manage for critical winter elk habitat; more specifically, the gentle south-facing slopes commonly used by elk for foraging in winter. The findings of this study suggested that this may be an over-simplification: elk preferred south aspects throughout the year. Elk that used clearcuts on these slopes for foraging in winter also heavily utilized the cover on these slopes during calving and summer seasons. I conclude that these gentle, south-facing slopes are of greater value to elk than current management dogma dictates.

There was somewhat greater use of northerly aspects during the warmer part of the year, although not as dramatic as found by Schoen (1977) who surmised that this was related to plant phenology as well as weather. Elk probably utilized a more favorable microclimate and obtained forage which had not yet begun to cure.

That the elk were not greatly influenced by slope was not surprising. Robbins et al. (1979) and Cohen et al. (1978) found that elk were more efficient in the uphill use of slopes than most other quadrupeds for which data were available (dogs, sheep, squirrels, reindeer and burros). Although Schoen (1977) found elk to prefer flat to moderate slopes, Harper (1971) found elk use unhindered by slopes up to 80%; Ellis (1974) went farther in stating that slope, elevation and aspect were not the determining factors of elk habitat use. Although it was not determined in this study, elk may use topography (a combination of slope, elevation, aspect and geomorphology) to maintain a stable weather regime as suggested for red deer by Grace and Esterbee (1979). They remarked that while the animal may greatly reduce convective heat losses by use of topography, a forest canopy was required to substantially reduce radiant heat losses.

Elk used a variety of available elevations (119-671 m above sea level) through the year, but the trend was to use higher elevations as the year progressed from calving season. It is possible that this pattern corresponded to elk following an elevation-related sequence of phenological development of forage species, however, this aspect of phenology was not investigated. In areas of great elevation variability heavy snows are known to drive elk to lower elevations (Beall 1974), but heavy snows did not occur during this study.

Elk were generally within 190 m of a permanent water source, but as the year progressed after calving season, they were located farther from water sources. This was probably of little consequence because water became much more abundant during the rainy winter. Ungulates often do not require free water when forage is succulent or the surface of forage is wet from rain, dew, fog or snow (Dean 1980). Regardless of season, it was probable that the daily circuit travelled by elk brought them near water several times during the day and/or night. Similar findings were reported by Harper (1971) and Schoen (1977).

I found cow elk to be nearest water during spring and calving seasons; a finding probably closely related to calving behavior as reported by Schoen (1977). The pregnant or lactating ungulate is under increased nutritional demands (Moen 1973: 167) and this, as well as the young calves' vulnerability, may explain the use of flatter, wetter, more secluded, forested areas at lower elevation during this sensitive period. This description of calving areas basically matches those of Janz (1980) and Sweeney (1975). Additionally, during this time of year (calving/summer) maximum temperatures are increasing dramatically and elk may be utilizing water more (externally and internally) for thermal regulation (Taber and Raedeke 1980).

Influences of Weather on Activity Patterns and Use of Cover

Elk exhibited a consistent pattern of several hours of activity followed by several hours of inactivity as reported by Harper (1971) and Jenkins (1976). My limited data (for summer only) suggested that this activity pattern extended through the night as reported by Craighead et al. (1973). Activity increased towards morning as found by Beall (1974). The pattern appeared to be synchronized with the higher midday temperatures and solar radiation at which time elk were less active and utilized thermal cover. This behavior pattern was presumably utilized to alleviate heat stress.

The daily activity pattern was little affected by the mildly adverse winter conditions which prevailed during the study period (1978-79). Most Coast Range winters are dominated by such mild, rainy weather which appear to have little effect on elk activity; a conclusion reached for red deer by Darling (1937: 123). Beall (1974) found activity of Rocky Mountain elk in winter little affected by rain when temperatures were above freezing.

Superimposed upon the 24 hr activity pattern, and the associated use of cover, were seasonal weather influences. Significantly greater use of cover occurred during the warmer calving and summer seasons than during winter and spring seasons. In addition to reducing exposure to heat stress, this increased use of cover was probably related to secretive behavior of pregnant or lactating cows during the calving season.

Influence of Vegetation Parameters

Forest stands may provide elk with: 1) security from predation and harassment (hiding cover); 2) modified and more favorable weather regimes (thermal cover); and, 3) forage. A forest stand will usually provide for one or more of these requirements of elk. The array of forest stands available to elk must provide all these requiements, otherwise elk (and other ungulates) may abandon the area (Stelfox et al. 1976) or be forced to pattern distribution after the pattern of shelter (Grace and Easterbee 1979).

Forest stands in a managed forest are usually not considered important sources of forage for elk because of the presumed greater abundance and higher quality of forage on the clearcuts. However, deep snow may prevent use of forage on clearcuts. During severe winters, survival cover (stands that intercept snow and provide adequate forage) may be required to prevent excessive deer and/or elk mortality (Harestead 1979b, Rochelle 1980). Snow interception by conifers is directly related to canopy density (and presumably to strength of branches) and can be as great as 30% (Kittredge 1973: 140-145).

Coniferous stands of any age will moderate weather conditions, but only those of adequate stem density or with an adquate shrub layer will significantly reduce wind near the ground level (Geiger 1965: 314, Kittredge 1974: 63). Consequently, some second-growth stands, especially those which have been thinned, may not substantailly reduce convective heat loss to elk during adverse winter weather. Conversely, stands with a sparse shrub layer, and with a dense canopy or subcanopy, which reflects solar radiation, would be more efficient as summer thermal cover. More air would circulate over the shaded elk, dissipating body heat and absorption of solar energy would be prevented (D. Leckenby, Oregon Dept. Fish and Wildlife, pers. comm.).

The preference exhibited by south band elk for old-growth during 5 seasons may have been related to vegetation and moisture factors. Prevailing weather conditions are greatly moderated by the deep canopy and its high evaporative water loss (Franklin et al. 1981). Old-growth stands provided more forage than old clearcuts (dense, young conifer stands), excepting grasses, which occurred at low levels in both stand types; moreover old-growth stands appeared relatively easy to travel through. Ungulate forage levels were reported to be quite high in old-growth stands, especially on moist sites (Bailey 1966, Harestead 1979a). Hines and Lemos (1974), Jenkins (1980), Batchelor (1965) and Janz (1980) also found old-growth stands to be highly used by Roosevelt elk.

Supplemental forage (windfall and lichens) is of much higher volume in old-growth stands than younger forest stands (Rochelle 1980). Thus, the provision of an additional forage source during heavy snowfall combined with the ability of old-growth trees to intercept and retain snow in the canopy may explain why old-growth stands have been used as yarding habitat by Roosevelt elk during severe winters in Oregon (Harper and Trainer 1969), Washington (Newman 1956), British Columbia (Janz 1980) and Alaska (Batchelor 1965). Bunnell and Eastman (1976) suggested that survival cover potential was not maximized until sometime after the forest stand reached 80 years of age.

Old-growth appeared to provide preferred calving habitat. The 2 radio-collared cows of the north band, both of which calved, made their greatest seasonal use of old-growth during calving. Old-growth use at this time of year is not just related to calving behavior. Use of old-growth by radio-collared cows of the south band, none of which were known to have calved, also increased during calving season, although not nearly as dramatically as it did with the north band elk.

It may be significant that north band elk, which had much old-growth forest in their area (45%), used old-growth stands according to availability except for calving season. South band elk had 10% less old-growth in their area and exhibited a higher relative preference for it than north band elk. The importance of old-growth to elk may be inferred from this greater relative use by elk when there is less of it available.

Hardwood stands were most often found on wet sites, including riparian zones which are often used by wildlife as travel lanes in addition to providing ample water and forage on a year-around basis. Mature alder stands, when in leaf, moderate weather as effectively as conifer stands (Geiger 1965: chapter VI). Forty-year-old hardwood stands had much greater understory vegetation cover than comparably-aged coniferous stands (Franklin and Pechanec 1968). The flush of grass and herb growth in hardwood stands just before leaf opening and again just after leaf drop may provide an important source of forage to elk. Leslie and Starkey (1980) found mature hardwood stands to have a much greater herbaceous biomass than the mature coniferous forest in summer and fall, however, differences were negligible in winter. North band elk use of hardwood stands peaked in summer and fall, although the pattern was not exhibited by south band elk. Alder has a high protein content in fall and heavy use of these stands in fall may be related to elk nutrition (Leslie and Starkey 1980, Newman 1956).

Mature alder stands had much greater herbaceous biomass than young alder stands in ONP (Leslie and Starkey 1980). In the managed forest, where emphasis is on coniferous fiber production, hardwood stands are rarely allowed to reach maturity before conversion to conifers. Hardwood stands in the Alder Creek basin covered only 3.5 and

1.0% of the north and south band areas, respectively, and most stands were immature. Greater use by elk of these preferred stands may have occurred had there been more and/or older hardwood stands available. Hines and Lemos (1974), Franklin et al. (1975), Jenkins (1980) and Janz (1980) also reported hardwood stands to be highly used by Roosevelt elk.

Old clearcuts were avoided in most seasons by elk, with two important exceptions. The importance of old clearcuts during hunting season was evident. Visibility was very limited in these dark, dense, young conifer stands; hence they provided ideal hiding cover which elk responded to by significantly increased use on hunting days. Their value as hiding cover probably exceeded that of old-growth or hardwood stands where stem density and vertical vegetation density were much lower. The south band elk, which had less old-growth available than north band elk, made greatest use of old clearcuts during calving season. Because temperatures and solar radiation increased in this season and south band radio-collared cows were not known to have calved, it was probable that these elk were responding to thermal stress conditions in their selection of old clearcuts. Second-growth stands significantly moderate weather conditions (Geiger 1965; chapter VI), presumably creating a microenvironment more favorable to elk.

It is possible that the low amounts of forage in old clearcuts precludes preferred use by elk during most seasons. Forage in second growth stands declines dramatically in most instances after 25-40 years and remains at a low level until 90 years or so (Taber 1979, Harestead 1979a). Thinning second-growth stands may increase their volume of forage, but the stand's ability to moderate thermal stress may be sacrificed (Edgerton and McConnell 1976).

Mature mixed forest stands did not occur in the north band area and covered a small portion (5.5%) on the southwestern margin of the south band area. It is perhaps for these reasons that I did not detect much use of this cover type. These stands would appear to have some of the better structural and vegetative (forage) qualities of each of the other canopied forest stands. With adequate age and conifer components, they would moderate weather and contain as much understory vegetation cover as comparably aged hardwood stands (Franklin and Pechanec 1968).

New and brushy clearcuts were important forage areas for elk. Not only do clearcut units provide more preferred forage (Bailey 1966), but they also provide higher quality forage during all seasons, assuming it is not snow covered (Rochelle 1980). Preferred forage production usually peaks between 4 and 30 years (Bailey 1966, Harestead 1979a, Taber 1979), but cover is inadequate until about 10 years (Taber 1979). Brushy clearcuts were the foraging areas most utilized by elk, corroborating the findings of Stevens (1965), Harper (1971), Schoen (1977), Janz (1980) and Jenkins (1980). The added security cover and greater volume of forage which these units offered to elk probably explain their greater use than new clearcuts.

Seasonal patterns in use of foraging areas are probably related in part to plant phenology as the quality of forage changes seasonally and differently for different plant species (Janz 1980, Rochelle 1980, Leslie and Starkey 1980, Packee 1975). Relative to other cover types, new clearcuts still had abundant forage in winter because they were not snowcovered during the winter of the study. New clearcuts were utilized most in late fall, winter and early spring; a period when the elk presumably were in a negative energy balance. Assuming thermal stress was not excessive during the mild winter conditions, the elk were foregoing, to a large extent, the use of cover for the benefits of obtaining forage in new clearcuts. Additionally, there appears to be less human activity in the Coast Range during the long, rainy winter so security cover may have been less essential. Taber (1979) postulated that brushy clearcuts or clearcuts with residual patches of cover are utilized more than new and very exposed clearcuts (especially those which have been burned) in summer because of the greater thermal stress the elk encounter in the latter. This detrimental characteristic of new clearcuts would be inconsequential on most winter days.

The most frequently adjacent cover types were usually the same as the preferred cover types: brushy clearcuts (and new clearcuts in late fall and winter) and old-growth stands. This was probably related to the edge-using habit of these elk: the daily routine was to leave cover to forage for several hours in the morning, retreat to cover for the midday period, return to the forage area in the late afternoon until late evening and so on through the 24 hr cycle. This pattern most often involved an old-growth stand and adjacent brushy clearcuts. Morgantini and Hudson (1979) reported a similar, predictable daily activity pattern in use of adjacent cover types for Rocky Mountain elk in Alberta. These findings are suggestive of the importance of interspersion (juxtaposition) of preferred cover types.

Influence of Edge and Roads

Elk made high use of edge areas and did not venture far into cover or openings. Although some elk locations were as far as 215 m from cover, 95% of all elk locations were within 130 m of cover. Roosevelt elk were found to prefer edges of openings by Janz (1980), Swanson (1970) and Harper (1971). Edge habitat use by elk allows them to utilize the abundant, high quality forage of brushy and new clear-cuts while remaining near protective cover should it be needed to escape adverse weather, predation, or harassment. In addition, edge areas often offer a more favorable microclimate (Geiger 1965: 338-352). All of these benefits are achieved by openings of small size or of a shape with large circumference to area ratio. A square, 7 ha clearcut would provide cover within 130 m to all points in the opening, confirming the findings and recommendations of Harper (1971), regarding clearcut size and shape.

Harassment can have numerous serious consequences to wildlife. The primary results (Geist 1978) are: 1) elevated metabolism at the cost of energy reserves; 2) death, illness or reduced reproduction due to secondary effects; and 3) avoidance or abandonment of areas and reduced range of the population. Results from my study permit discussion of only the 3rd result.

Because elk appeared indifferent to average coast range winter weather, security needs were probably a more important factor precluding movement of elk far into openings, an idea also postulated for Rocky Mountain elk activity patterns in western Alberta (Morgantini and Hudson 1979). Jenkins (1976) and Schultz and Bailey

(1978) suggested that daily activity patterns of elk use were adjusted to minimize encounters with humans and vehicles. Irwin and Peek (1979) went a step farther and suggested that the size of forest stand required for elk security needs would be larger where there was more human disturbance.

The avoidance exhibited by elk of open roads, especially paved through roads, was also reported for Rocky Mountain elk (Pedersen et al. 1979, Lyon 1979a, Rost and Bailey 1979). Brown (1968) suggested that new all-weather roads on winter range are one of the most serious threats to the future of Rocky Mountain elk herds.

The greatest degree of avoidance of paved roads observed in this study was exhibited by the 2 north band radio-collared cows during the season they bore their calves. South band radio-collared cows, none of which were known to have calved, exhibited greatest avoidance to paved roads during the rut season. Using 245 m as a cut off point for significant loss of habitat to elk by paved road influences, I calculated that about 30% of a section (259 ha) of land is largely foregone to elk when it is bisected by a paved through road. This figure is comparable to that suggested by the data of Rost and Bailey (1979: ca 25%) and Pedersen et al. (1979: 31%), but less than that reported by Lyon (1979a: 50%).

South band elk were found on or near non-paved roads to a greater extent than north band elk. The cumulative frequency distribution for north band elk was not significantly different from that expected if the first category (0-60 m) was eliminated from the analysis. Thus, the negative influence of non-paved spur roads on elk appeared to extend only 60 m from the road. The long spur road through the south band area was most often kept closed to vehicles by a locked gate during the study. Assuming elk use of roads (and adjacent areas) and vehicular disturbance are inversely related as my data suggest, the merit of secondary road closure programs to regain foregone elk habitat as recommended by Harper (1971) is apparent. Marcus (1975), Gruell and Roby (1976) and Schoen (1977), concluded that elk do not avoid primitive roads, they avoid human activity on primitive roads. Road closures may be more important where less cover exists: Lyon (1979b: xii) suggested road closures are most valuable where less than two-thirds of an area is in cover.

Integration of Habitat Factors Influencing Elk

Selected elements of the physical and biological environment surrounding the elk in this study were examined as isolated, individual relationships between them and elk. However, these elements occur in the elk's environment not as single, independent factors but rather as parts of a myriad of combinations of elements, some independent, some not. The response of elk to any one factor is influenced by the particular assemblage of elements extant at the time of observation. Interpretation of elk responses to environemntal variables is thus biased by the particular set(s) of elements to which the elk were exposed: resulting generalizations concerning elk responses to environmental variables must be carefully worded, indeed. Validity of these generalizations is enhanced by corroboration of similar results from other studies of Roosevelt elk use of habitat.

Management of forestlands impacts many elements of the elk's environment, producing a large number of combinations of physical conditions and vegetative habitat configurations. Proper stewardship of forest and elk resources requires the ability to infer elk responses to environmental changes, including those attributable to forest management practices, and to manipulate these practices in a manner consistent with management goals for all resources of the forest. Enlightened management of habitat for elk is difficult because of the almost total ignorance of the combined effects of physical and biological factors on elk. An added dimension of difficulty of management is coordination of different time frames; management of forests for timber resources has a cycle of 5 or more decades, whereas elk are managed on an annual basis, primarily by altering hunter harvest rates.

Discriminant function analysis allowed me to assess the degree to which habitat parameters were associated with seasonal habitat use patterns of elk, and, by inference, to assign relative importance (preference) of the parameter(s) to elk within the restricted range of conditions to which the elk were exposed. The variables having greatest importance were cover type, adjacent cover type and aspect. Of less importance were the variables slope, elevation and distance to water. Little importance was attributed to the variables distance to adjacent cover type and distance to paved or nearest roads (which tended to be large regardless of season). Preferences were not consistent. Because the environment was not static and because elk exhibited social and individual behaviors, variability in habitat use patterns occurred as reported elsewhere (Radler 1977, Schoen 1977, Jenkins 1980, and Janz 1980). Elk preferences for different cover types, vegetative and physical parameters appeared related to season and to associated elk behavior. Thus, impacts of various forest practices must be viewed in the perspective of seasonal requirements of elk.

Certain patterns of activity, preferences and avoidances were consistant on a seasonal basis and distinct from other seasons. These can be grouped for: 1) spring/calving; 2) summer; 3) rut; and 4) fall/ winter habitat use patterns. Several preferences, however, such as the use of old-growth, hardwood and brushy clearcut units and southerly aspects were consistent regardless of season.

Spring and calving seasons were typified by favorable weather and abundant forage. Elk exhibited increased activity and utilization of a larger home range. Increased temperature led to increased use of cover. In addition, pregnant or lactating cows, apparently more sensitive to harassment during this period, avoided roads. Overall, elk used lower elevation areas which tended to be of flat to moderate slope and near water.

In summer, responses to heat stress probably were a primary determinant of elk habitat use. Elk moved less, used a small home range and spent much time in cover. They also were found at somewhat higher elevations and avoided road traffic somewhat less than in spring and calving seasons.

During the rut social behavior likely became a paramount determinant of the habitat use patterns. Elk were highly associated and exhibited little movement, much use of cover and increased avoidance of road traffic.

The fall and winter seasons were periods of relatively adverse weather and presumably poor forage conditions for elk. The conservation of energy was presumably of primary importance to elk as they used a small home range and refrained from moving large distances. Elk used areas of higher elevation and security cover seemed relatively unimportant, except during hunting season(s).

Based on data generated by this and other Roosevelt elk studies, it is evident that basic requirements of elk include preferred foraging areas and cover stands that adequately moderate climatic conditions and provide for security needs. Thermal cover seems most important during hot summer weather and severe winter weather. Hiding cover seems most important when humans actively seek elk (hunting season) or when essential biological functions (breeding, calving) are subject to disruption by human contact. In addition, it appears that juxtaposition is important; elk utilize preferred units which are positioned so as to minimize energy expenditure required of elk as they go about their daily and seasonal habitat patterns.

Forest management activities may affect the environment in which elk derive their requirements for survival and reproduction. Some of the factors important to elk such as aspect are fixed and can not be manipulated by the forest manager. Other factors, such as the age, size, shape, and positioning of foraging areas and cover stands, lend themselves readily to manipulation.

In attempting to manipulate the habitat to benefit elk it must be remembered that elk respond to a variety of environmental factors and that simply altering one factor, i.e. minimizing construction of paved, through roads to minimize harassement of elk, is not adequate when other factors may have equal or greater importance (thermal cover during harsh winters). The whole array of habitat related factors essential for elk survival and reproduction must be integrated with forest planning to successfully achieve elk management goals.

It is equally important to recall that management of forests involves only a part of elk management, that of providing the habitat. The process by which desirable population levels of elk are identified, and regulated, primarily by harvest or trapping and transplanting, are within the province of wildlife management agencies. Ultimately, land and wildlife managing agencies in conjunction with neighboring landowners must coordinate management to insure that integrated, coordinated management of elk is achieved. The following section represents an effort to present some guidelines for this integrated management.

MANAGEMENT RECOMMENDATIONS

The objective of this study was to quantify the daily and seasonal patterns of activity and habitat use by Roosevelt elk and apply these findings to management. The following recommendations should apply generally to the Oregon Coast Range, but may require more or less emphasis or modification for specific areas.

Provision of Specific Requirements

Preferred cover types. Old-growth and hardwood stands should be maintained interspersed among the coniferous, second-growth stands and clearcut units of the managed forest. Elk demonstrated consistent preferences for these 2 cover types which occur in low and dwindling acreages on most commercial forestland.

Forage and cover. Clearcuts designed as foraging areas for elk should be of small size ($\leq$ 7 ha) or of a shape which maximizes edge habitat (i.e. cover within 130 m of any point of the clearcut). Elk made heaviest use of forest clearing edges where cover was nearby and microclimate conditions would be favorable. Abundant clearcut forage which is too far from cover will not benefit elk.

Heavy thinning of stands can be done in some, but should not be done in all dense, second-growth stands. Second-growth stands which have not been heavily thinned provide little forage from about year 30 to year 90 which may explain the low levels of use they receive from elk. Heavy thinning will greatly enhance the forage volume of these stands which will consequently decline in thermal and possibly hiding cover value to the elk. With the liquidation of old-growth stands, dense, older, second-growth stands will be a necessary substitute for the ideal thermal cover provided by old-growth stands.

Calving. Avoid scheduling timber sales in potential or known calving areas. Elk reproduction must balance assorted mortality factors, the most serious of which is the occasional but unpredictable severe coast range winter such as that of 1968-69. Preferred calving areas are generally of low elevation, flat to moderately sloped, wet and in or near old-growth with brushy openings near by for foraging.

Minimal harassment. Minimize logging activities during peak calving (May 15-June 15) and rutting (September 15-October 15) periods in and near areas heavily utilized by elk. Elk are particularly sensitive during these "biological" seasons. The future well-being of a herd depends upon the successful completion of these biological functions.

Restrict harassment of elk from forest road use by: a) keeping forest road constructon to the minimum necessary for forest management; b) avoiding paving roads where possible because this usually leads to increased traffic flows; and c) implementing road closures of non-essential secondary roads. Elk demonstrated a consistent avoidance of roads, especially those of paved surface. Significant amounts of elk habitat were foregone to elk use because of paved roads and it appeared that paved roads actually formed restrictive boundaries of elk home ranges. Presumably, paved roads increase harrassment because they encourage vehicular traffic above that associated only with logging and other aspects of forest management. Elk did use secondary, dirt and gravel surfaced roads as travel lanes when vehicular traffic on those roads was largely prevented by a gate.

Aspect. Where management of elk habitat is to receive special emphasis, efforts should be directed primarily towards gently to moderately sloping southerly aspects. These topographic areas received heaviest and most consistent use by elk throughout the year. Consequently, management plans for these areas should provide for most if not all of the annual requirements of elk for forage and cover.

To provide optimal habitat conditions for elk, the forest manager is faced with the challenge of incorporating all of the above listed requirements on a specified tract of forestland. Additionally, the important units should be positioned in such a way so as to avail them to the elk of a herd with minimum energy expenditure.

Size and Placement of Habitat Blocks

All studies of coastal Roosevelt elk populations have found them to satisfy annual requirements on managed commercial forestland areas of $\leq$ 600 ha. Home ranges of elk herds, such as the Alder Creek Herd, are most often contained within a single drainage basin. Consequently, sustained yield forestry practiced with the drainage basin as the management unit and with elk requirements in mind, will most easily and effectively allow the forest manager to meet the needs of elk. With elk habitat blocks managed in this way and with adjacent blocks similarly managed, the forest manager can expect a greater overall density of elk in the area.

Long Range Management of Elk Habitat

The key to providing habitat that will be suitable for elk over many decades is to establish an appropriate timber harvest schedule. Such a schedule would provide habitat blocks in drainages such that forest openings, old-growth, second-growth and some hardwood stands would be provided. Where elk management is to receive special emphasis, progressive clearcutting should be avoided and 2/3 of the basin should be maintained in cover at all times. Studies of Rocky Mountain elk have demonstrated increased elk sensitivity to harrassment when less than 2/3 of an area was in cover. Clearcutting many units in a short period of time may provide abundant forage for a decade or so but this will be followed by several decades of dense conifer regeneration which will be little utilized by elk.

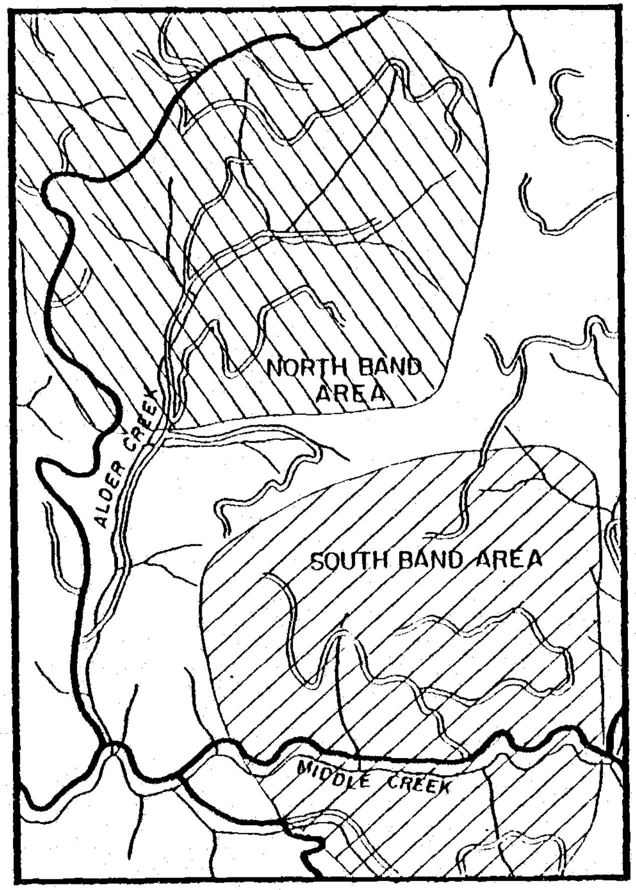
Sufficient travel routes along riparian areas, or through contiguous blocks of mature forest must be maintained over several decades. Such travel routes or corridors will permit elk to travel from one drainage, that may be losing its attractiveness as elk habitat, to another drainage that is developing an attractive assemblage of elk habitat blocks.

Integrating Management for Elk and Other Forest Resources

As a prerequisite to integrating elk and forest management, each public forest district should delineate areas in which they would establish or maintain specific elk densities. Emphasizing elk management will involve trade-offs with other forest resources. In some areas current elk numbers are considered less than optimal, whereas in other areas elk numbers and associated damage to regenerating conifers are considered excessive. The forest manager, in conjunction with public input and the state wildlife managing agency, should set goals for elk densities in forest units that are compatible with overall forest goals.

Forest management plans should be integrated with elk management plans before implementation of practices. Patterns of habitat use by Roosevelt elk are carried out on small management areas within the forest. Habitat manipulations within these small units can affect many aspects of elk biology necessary for survival, so knowledge of current elk herd locations, and of areas proposed for expansion of elk herds is essential to avoid large scale, negative impacts on elk populations. Habitats utilized by elk are a product of basic silvicultural prescriptions and options such as placement and size of clearcuts, rotation length and timing of activities, and it is anticipated that these basic prescriptions will be used in the future to favorably manipulate habitat for elk. Thus, the tools for manipulating elk habitat are at hand, and all that is required for proper elk management is to ensure that changes in forest structure and composition are made after advance planning and consultation to insure that the resulting habitat changes will be compatible with projected elk needs.

The special needs of other forest fauna and flora should be considered in light of the special needs and preferences of elk. Elk share the forest with many other species; management for high densities of elk may benefit some species and be detrimental to others. Conflicts can be minimized and manipulation of habitats on forest units allocated most effectively if patches of old-growth and other habitat blocks are of a size and location to meet the special needs of other featured wildlife species.



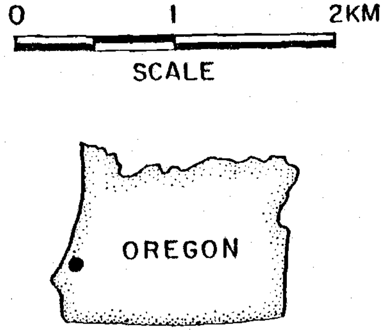


Figure 1. Alder Creek Roosevelt Elk Study Area, Coos County, OR.

Figure 2. Examples of hot summer and cold winter day temperature profiles, Coos County, OR, 1978-79.

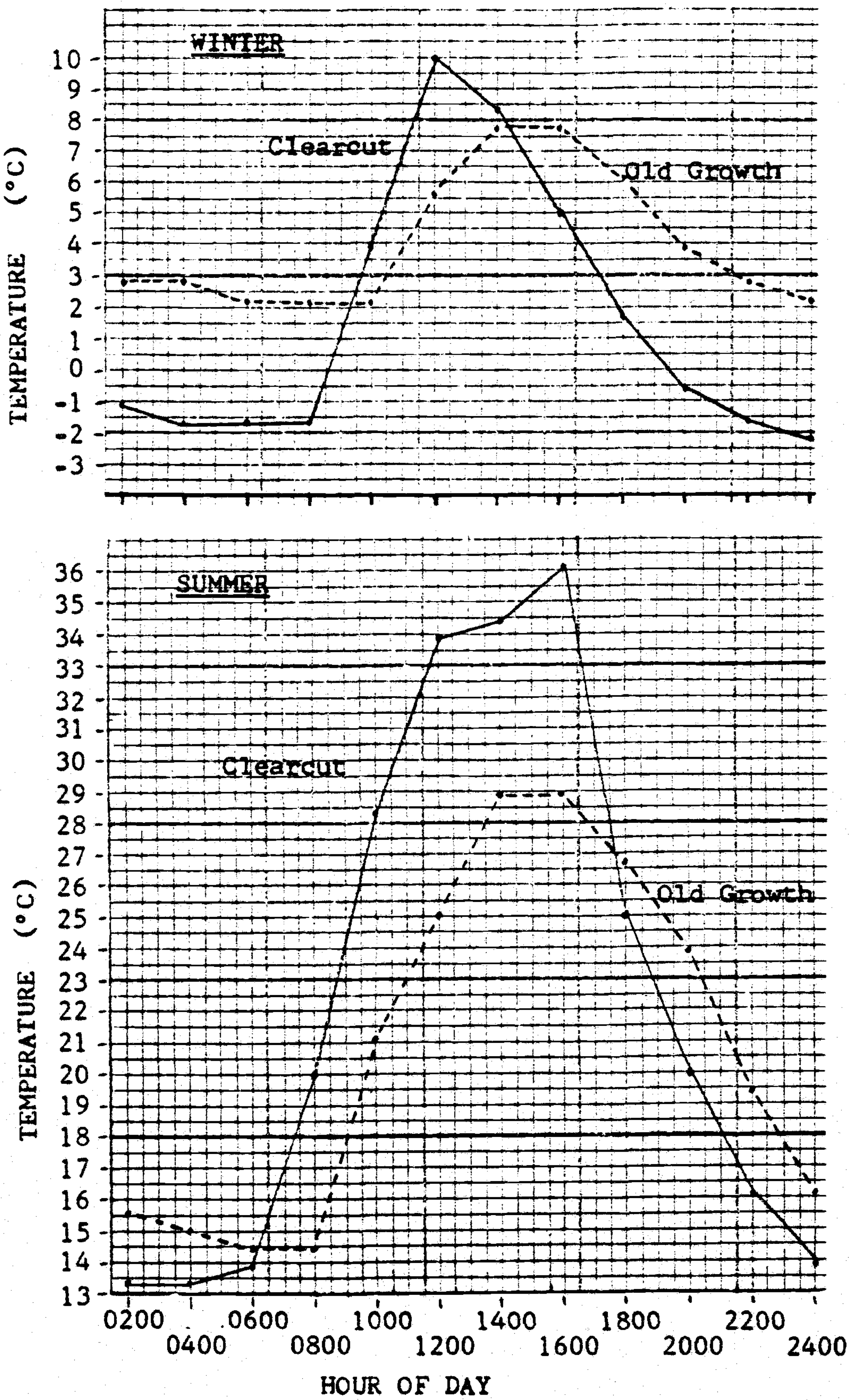

WINTER
10
9
8
7
6
5
4
3
2
1
0
-1
-2
-3
TEMPERATURE (°C)
Clearcut
Old Growth
SUMMER
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
17
16
15
14
13
TEMPERATURE (°C)
Clearcut
Old Growth
0200
0400
0600
0800
1000
1200
1400
1600
1800
2000
2200
2400
HOUR OF DAY

Figure 2.

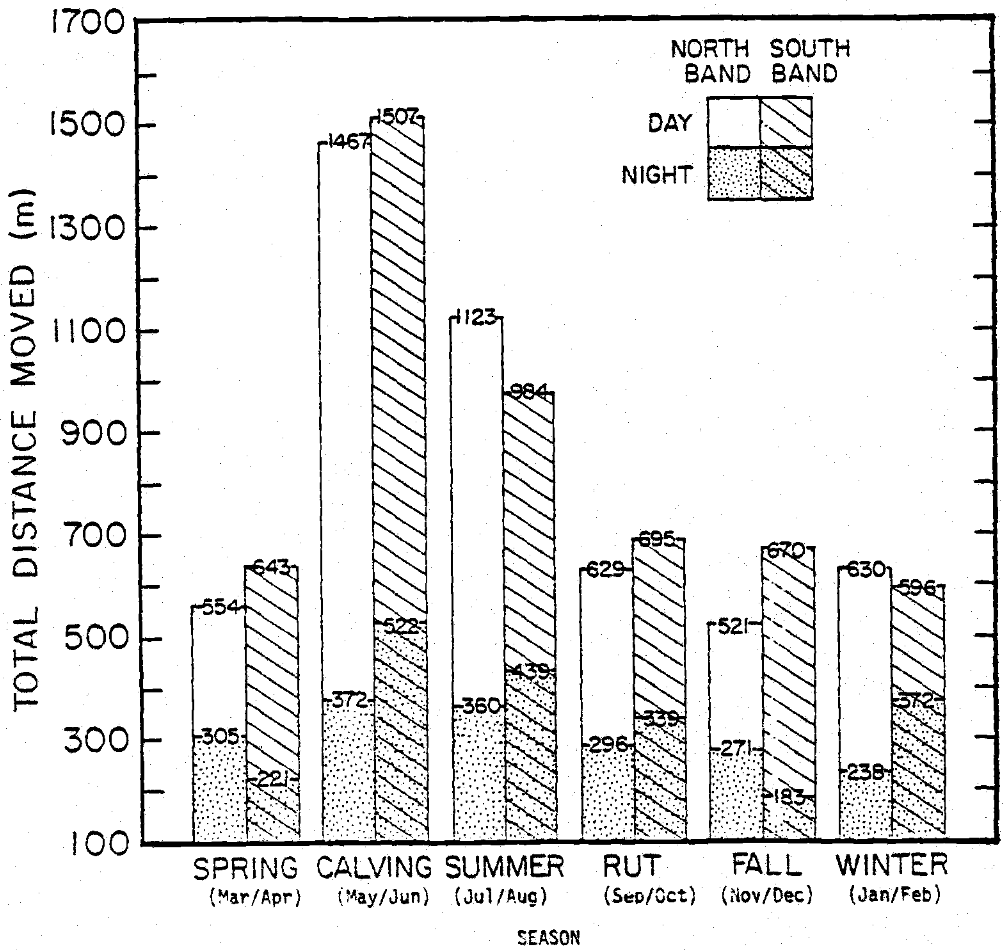


Figure 3. Seasonal daily and nightly movement of cow elk, Coos County, OR, 1978-79.

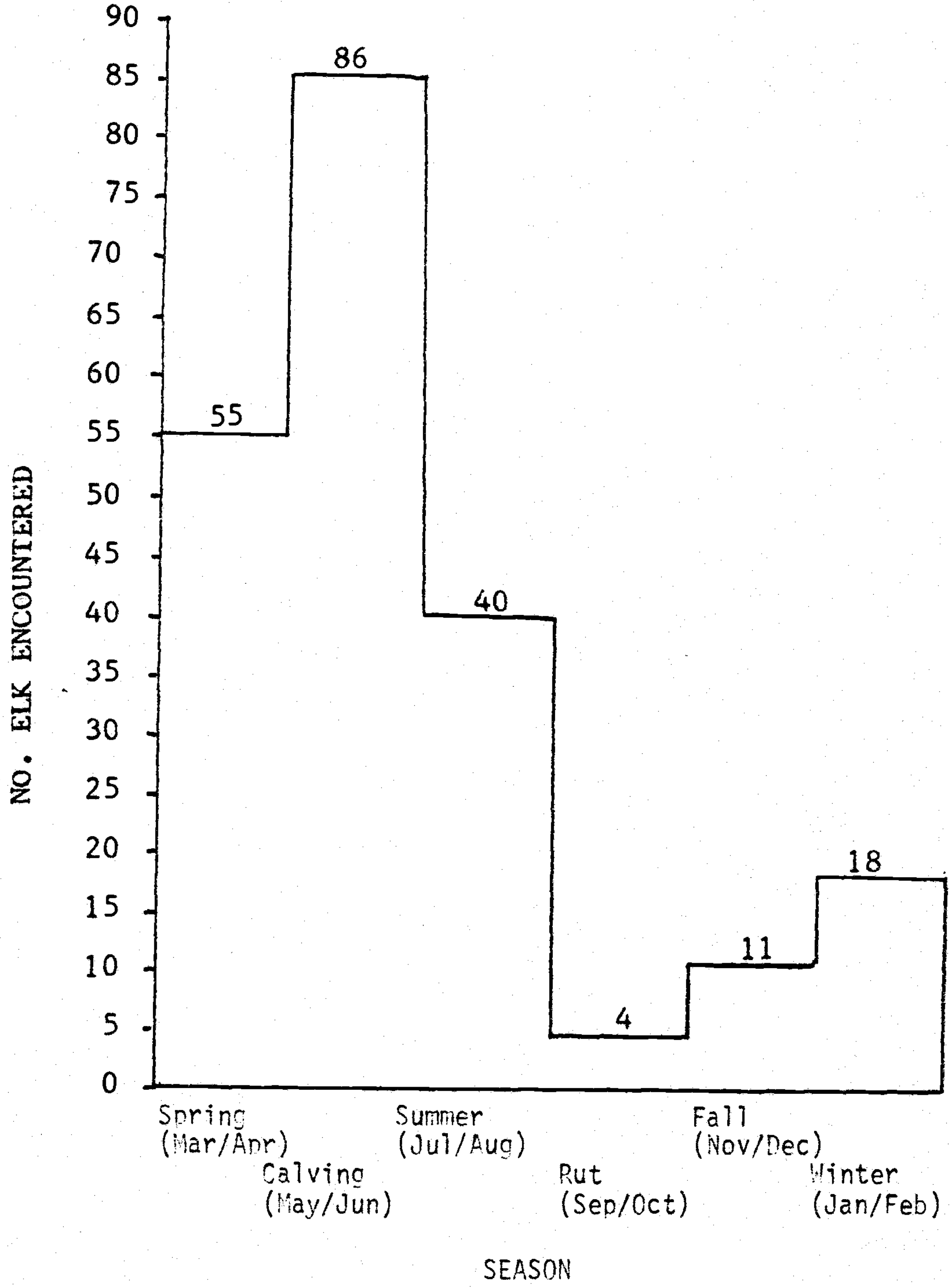


Figure 4. Seasonal encounters with cow elk while driving to and from fieldwork, Coos County, OR, 1978-79, with roughly comparable amounts of driving time each season.

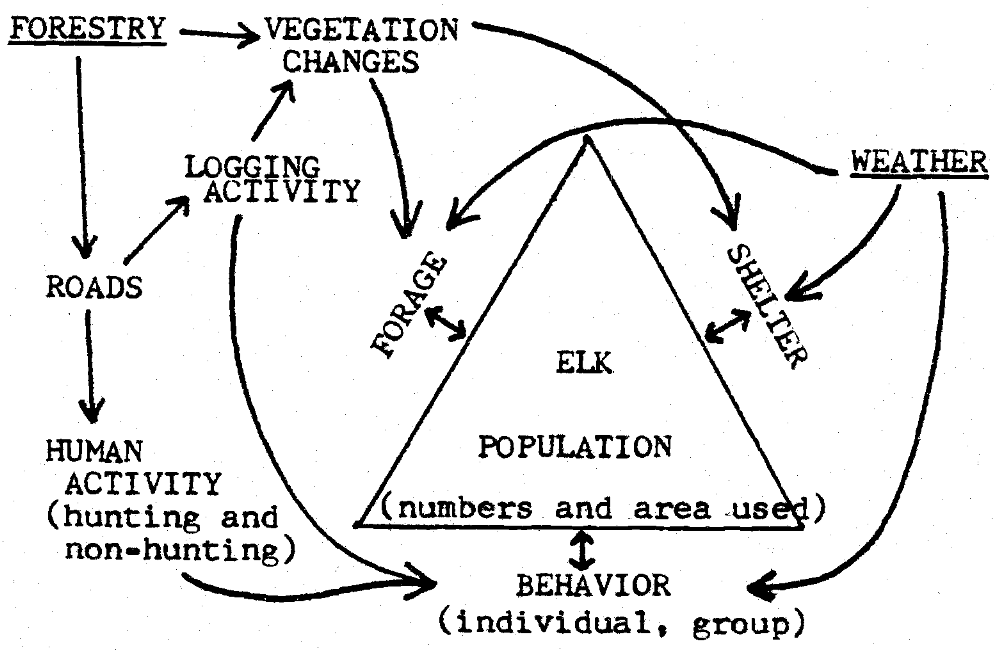


Figure 5. Interactions of some factors significant to Roosevelt elk populations on managed commercial forestlands (adapted from Marcum 1975: 139).

Table 1. Weather parameters, north band elk observation days, Coos County, OR, 1978-79.

	Season					
Weather Paramter	Spring (Mar/Apr)	Calving (May/June)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
Clearcut unit						
Mean daily temp (°C)[a]	11.8 (5.5)[b]	15.4 (4.8)	23.8 (9.2)	15.1 (7.3)	7.0 (3.9)	7.7 (4.7)
Daily max/min (°C)[a]	27.2/3.3	28.9/4.4	40.6/8.3	30.0/-2.7	13.9/-1.6	13.3/-1.1
Mean nightly low (°C)[c]	3.1 (2.4)	8.1 (3.1)	11.3 (2.2)	8.2 (5.7)	1.0 (3.9)	2.5 (3.3)
Old growth stand						
Mean daily temp (°C)[a]	11.1 (2.8)	13.3 (3.4)	21.7 (6.2)	13.4 (3.1)	7.3 (3.2)	5.0 (3.5)
Daily max/min (°C)[a]	18.3/6.1	25.0/6.1	33.9/10.0	21.1/5.0	13.3/-5.0	10.6/-1.1
Mean nightly low (°C)[c]	6.9 (2.4)	9.3 (2.3)	13.2 (1.8)	9.8 (2.6)	3.5 (3.2)	2.8 (2.9)
Mean diff. in daily temp/ |clearcut-old growth| (°C)[a,d]	2.9 (3.0)	2.5 (1.9)	5.1 (5.2)	4.9 (3.1)	1.8 (1.4)	2.8 (4.2)
Mean cloud cover (%)	63.2 (41.4)	77.2 (30.5)	16.7 (31.7)	51.0 (40.4)	55.6 (42.8)	91.7 (19.3)
Mean 24 hr. precip (mm)	3.5 (4.2)	2.1 (3.7)	0.3 (0.8)	0.9 (1.6)	10.5 (37.7)	22.7 (27.3)

Table 1. (continued)

Weather Parameter	Season					
	Spring (Mar/Apr)	Calving (May/June)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
Wind Status[e]						
Windy	3.5	3.5	0	3.6	14.1	29.0
Breezy	48.2	52.7	71.1	50.5	49.8	46.4
No wind	48.2	43.8	28.9	45.9	36.1	24.6
Precipitation status[e]						
Rain	11.3	5.7	0.3	0	9.5	33.7
Lt. rain	12.0	19.4	1.3	12.5	12.4	16.3
Hail	0.7	0	0	0	0	0.8
Fog	1.4	3.5	2.6	2.0	2.1	0.8
Snow	0	0	0	0	0	2.4
No precip.	74.6	71.4	95.8	85.5	76.0	46.0

[a]I utilized temperature readings for which a corresponding daylight elk radio-location was available, hence the mean and daily max/min were restricted to temperature readings between 0700-2000 hr.

[b]Figure in parentheses is the standard deviation.

[c]I utilized the lowest temperature readings for all nights for which continuous thermograph recordings were available to determine the mean.

[d]I subtracted each old-growth temperature from the simultaneous clearcut temperature, took the absolute values of these differences and determined the mean. Consequently, this is a measure of the absolute difference in temperature between these two cover types and does not correspond to the mean daylight clearcut temperature minus the mean daylight old-growth temperature.

[e]Numbers are percent of observations by category.

Table 2. Weather parameters south band elk observation days, Coos County, OR, 1978-79.

Weather Paramter	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
	Season					
Clearcut unit						
Mean daily (°C)[a]	8.3 (3.3)[b]	17.2 (6.2)	18.8 (6.2)	18.3 (8.6)	4.2 (4.1)	6.5 (3.1)
Daily max/min (°C)[a]	18.3/0.0	31.7/5.0	34.4/8.3	37.8/-0.6	16.7/-5.0	13.9/-2.2
Mean nightly low (°C)[c]	3.1 (2.4)	8.1 (3.1)	11.3 (2.2)	8.2 (5.7)	1.0 (3.9)	2.5 (3.3)
Old growth stand						
Mean daily temp (°C)[a]	8.8 (2.4)	13.7 (3.8)	17.5 (4.3)	15.2 (4.1)	4.6 (2.9)	6.0 (2.6)
Daily max/min (°C)[a]	14.4/2.8	26.1/6.1	28.9/10.0	25.0/7.2	10.0/-1.7	10.6/2.2
Mean nightly low (°C)[c]	6.9 (2.4)	9.3 (2.3)	13.2 (1.8)	9.8 (2.6)	3.5 (3.2)	2.8 (2.9)
Mean diff in daily temp/ |clearcut-old growth| (°C)[a,d]	2.2 (1.7)	3.8 (3.8)	2.3 (2.2)	5.5 (4.2)	2.1 (1.7)	2.6 (1.9)
Mean cloud cover (%)	87.2 (20.4)	63.4 (40.2)	63.6 (41.9)	42.6 (37.0)	40.1 (43.7)	60.1 (38.0)
Mean 24 hr precip (mm)	8.0 (7.5)	2.2 (3.6)	3.4 (4.9)	0.1 (0.3)	1.4 (2.5)	9.0 (13.8)

Table 2. (continued)

Weather Parameter	Season					
	Spring (Mar/Apr)	Calving (May/June)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
Wind Status[e]						
Windy	3.5	3.5	0	3.6	14.1	29.0
Breezy	48.2	52.7	71.1	50.5	49.8	46.4
No wind	48.2	43.8	28.9	45.9	36.1	24.6
Precipitation status[e]						
Rain	11.3	5.7	0.3	0	9.5	33.7
Lt. rain	12.0	19.4	1.3	12.5	12.4	16.3
Hail	0.7	0	0	0	0	0.8
Fog	1.4	3.5	2.6	2.0	2.1	0.8
Snow	0	0	0	0	0	2.4
No precip.	74.6	71.4	95.8	85.5	76.0	46.0

[a]I utilized temperature readings for which a corresponding daylight elk radio-location was available, hence the mean and daily max/min were restricted to temperature readings between 0700-2000 hr.

[b]Figure in parentheses is the standard deviation.

[c]I utilized the lowest temperature readings for all nights for which continuous thermograph recordings were available to determine the mean.

[d]I subtracted each old-growth temperature from the simultaneous clearcut temperature, took the absolute values of these differences and determined the mean. Consequently, this is a measure of the absolute difference in temperature between these two cover types and does not correspond to the mean daylight clearcut temperature minus the mean daylight old-growth temperature.

[e]Numbers are percent of observations by category.

Table 3. Mean values for physical characteristics of cover types, Coos County, OR, 1978-79.

Cover Type	Characteristic Age (yrs)	Tree Ht (m)	Shrub Ht[a] (m)	Wood Basal[a] Area (m^2/ha)	No. Large Stems > 2.54 cm (no./acre)	No. Small[a] Stems < 2.54 cm (no./acre)
Old-Growth	200	61 (—)	12 (5.3)[b]	146 (40)	15.4 (4.4)	4.7 (3.9)
Mixed Forest	100	25 (7.2)	3 (1.0)	73 (43)	26.8 (12.5)	46.8 (33.4)
Hardwood	10-40	8 (3.8)	4 (2.3)	15 (6.5)	24.0 (8.8)	27.3 (21.9)
Old Clearcut	15-30	15 (—)	1 (—)	61 (7.6)	24.8 (7.8)	51.0 (28.1)
Brushy Clearcut	7-14	3 (0.9)	ND[c]	2.3 (0.4)	ND	30.5 (4.9)
New Clearcut	1-6	ND	1 (—)	ND	0	ND

[a]Significant differences occurred between cover types for this variable at the 95% confidence level.

[b]Figure in parenthesis is the standard deviation; where no standard deviation is given, estimates for the parameter were essentially equivalent in all sample plots.

[c]ND = Parameter not observed within plots.

Table 4. Mean annual vegetation cover values (%) for each cover type[a], Coos County, OR, 1978-79.

Cover type	Ferns	Grasses	Forbs	Shrubs	Overstory Canopy
Old-Growth	33.2 (26.4)[b]	3.1 (0.8)	26.3 (17.9) sp	13.2 (10.3)	82.0 (2.6)
			8.4 (8.2) fa		
Mixed Forest	18.2 (23.0)	3.9 (3.4)	27.1 (24.8) ca	60.7 (24.1)	69.0 (5.6)
			7.0 (6.5) wi		
Hardwood Stand	9.2 (16.5)	8.1 (8.7) ca	22.6 (15.6) sp	18.4 (10.3)	86.5 (5.6) su
		4.4 (3.8) ru	4.9 (5.5) fa		31.0 (6.7) wi
Old Clearcut	14.5 (22.0)	6.2 (9.5) su	11.2 (15.1) sp	80.5 (17.9)	75.2 (2.9)
		1.5 (1.5) ru	2.1 (3.3) ru		
Brushy Clearcut	10.2 (17.4)	14.5 (11.7) sp	43.5 (30.3) ca	36.4 (14.9)	none
		6.4 (6.3) ru	16.8 (14.2) wi		
New Clearcut	8.3 (15.6)	26.0 (17.0) sp	32.5 (17.6) sp	11.3 (8.4)	none
		11.2 (11.8) ru	15.4 (14.5) wi		

[a]Where 2 values are given the cover value varied significantly between seasons; the highest and lowest seasonal value are given with the season of their occurrence: sp = spring, ca = calving, su = summer, ru = rut, fa = fall, wi = winter.

[b]The figure in parenthesis is the standard deviation.

Table 5. Mean vertical vegetation density values, by height class and cover type[a], Coos County, OR, 1978-79.

	0-0.5 m Height class							0.5-1 m Height class						
Cover type	Sp[b]	Ca	Su	Ru	Fa	Wi	Ann. Mean	Sp	Ca	Su	Ru	Fa	Wi	Ann. Mean
Old-growth	4.7	4.8	4.6	4.3	4.7	4.4	4.6	3.7	3.8	3.7	3.5	3.9	3.5	3.7
Mixed forest	3.5	4.3	3.6	3.6	3.6	3.5	3.7	2.7	4.0	3.1	3.0	2.7	2.5	3.0[c]
Hardwood	3.4	3.9	3.6	3.3	3.2	3.9	3.6	2.3	2.8	2.9	2.0	2.4	2.8	2.5
Old clearcut	5.0	4.9	4.2	4.2	4.7	4.9	4.7	4.6	4.5	4.2	4.2	4.5	4.7	4.5
Brushy clearcut	4.7	4.9	4.9	4.8	4.5	4.8	4.8	3.9	3.8	4.4	4.1	4.3	3.8	4.1
New clearcut	3.9	3.9	3.8	3.7	3.7	3.9	3.8	2.3	2.5	2.6	1.8	2.5	2.7	2.4

	1-1.5 m Height class							1.5-2 m Height class						
Cover type	Sp	Ca	Su	Ru	Fa	Wi	Ann. Mean	Sp	Ca	Su	Ru	Fa	Wi	Ann. Mean
Old-growth	2.3	2.0	2.5	1.8	2.1	2.4	2.2	2.1	1.7	2.0	1.4	1.5	1.8	1.8
Mixed forest	2.5	3.2	2.5	2.3	2.1	2.4	2.3	2.6	2.7	2.5	2.3	2.1	2.4	2.4
Hardwood	2.1	1.8	2.0	1.4	1.7	1.5	1.8[c]	2.0	1.4	1.9	1.7	1.4	1.4	1.6[c]
Old clearcut	4.1	4.1	3.7	3.6	4.3	4.2	4.0	4.1	3.9	4.0	3.2	4.3	4.1	3.9
Brushy clearcut	3.3	2.3	3.0	2.8	2.8	3.1	2.9	2.3	1.9	2.8	2.2	2.4	2.7	2.4
New clearcut	1.5	1.3	1.4	1.1	1.4	1.7	1.4	1.1	1.0	1.1	1.0	1.4	1.3	1.2

[a]Percentile scale of vegetation density: least dense = 1 (0-20% cover board obscured), 2 (21-40%), 3 (41-60%), 4 (61-80%), and most dense = 5 (81-100%).

[b]Sp = spring (Mar/Apr), Ca=calving (May/Jun), Su=summer (Jul/Aug), Ru=Rut (Sep/Oct), Fa=fall (Nov/Dec), Wi=winter (Jan/Feb).

[c]There was significant variation in seasonal means of this height class and cover type.

Table 6. Dates of major phenological events of key elk forage species, Coos County, OR, 1978-79.

	Bud swell		Active growth		Flowering		Fruit development		Leaf senescence		Dormancy		Bud set	
Woody Species	Begin[a]	End[b]	Begin	End	Begin	End	Begin	End	Begin	End	Begin	End	Begin	End
Chapparal broom <u>Baccharis pilularis</u>	2/18	3/30	3/18	7/31	8/26	10/18	10/18	11/18	9/26	11/18	12/1	2/18	-	-
Salmonberry <u>Rubus spectabilis</u>	3/2	3/18	3/18	7/11	3/18	3/30	3/30	-	8/16	10/18	10/18	3/2	12/1	1/3
Blackberry <u>R. ursinus</u>	2/18	3/18	3/18	8/16	3/30	6/15	6/15	-	9/12	10/28	12/1	2/18	9/26	11/18
Evergreen huckleberry <u>Vaccinium ovatum</u>	3/2	3/30	4/15	8/16	3/30	5/30	5/30	-	11/18	12/1	12/1	3/2	10/18	10/28
Red huckleberry <u>V. parvifolium</u>	2/18	3/18	3/18	8/16	4/15	5/16	5/16	-	8/26	11/18	11/18	2/18	11/18	12/1
Vine maple <u>Acer circinatum</u>	3/18	4/30	4/30	7/11	4/15	5/16	5/16	-	7/31	10/28	10/18	3/18	8/26	10/18
Myrtle tree <u>Umbellularia californica</u>	12/1	2/6	4/30	8/16	2/6	4/15	4/15	-	8/26	9/26	10/18	12/16	8/26	9/26
Red alder <u>Alnus rubra</u>	2/18	3/18	3/30	7/31	3/2	3/18	4/15	-	8/16	8/26	9/12	2/18	7/31	9/26
Douglas-fir <u>Pseudotsuga menziesii</u>	3/2	5/16	4/30	7/31	4/30	5/16	5/16	-	-	-	8/26	4/18	7/31	9/26
Whipple vine <u>Whipplea modesta</u>	3/2	3/18	3/30	7/11	4/30	5/30	6/15	6/28	9/12	11/18	10/28	2/18	-	-

Table 6. (continued)

Woody Species	Bud swell Begin[a]	Bud swell End[b]	Active growth Begin	Active growth End	Flowering Begin	Flowering End	Fruit development Begin	Fruit development End	Leaf senescence Begin	Leaf senescence End	Dormancy Begin	Dormancy End	Bud set Begin	Bud set End
Herbaceous Species														
Candy flower <u>Montia sibirica</u>	-	-	3/2	10/28	4/15	6/15	6/28	7/31	8/16	8/26	11/18?	2/18?	-	-
Oxalis <u>Oxalis oregana</u>	3/2	3/30	3/20	5/16	4/15	5/16	5/30	6/15	9/12	-	10/18	2/18	-	-
Spotted cats-ear <u>Hypochaeris radicata</u>	3/2	-	3/18	8/16	5/16	8/26	9/12	10/28	11/18	2/6	12/1	2/18	-	-
Sword Fern <u>Polystichum munitum</u>	3/2	3/30	4/15	7/11	-	-	-	-	8/16	11/18	10/18	3/2	-	-
Grasses (<u>Deschampsia</u>, <u>Aira</u>, <u>Holcus</u>, <u>Bromus</u>, <u>Luzula</u>)	3/2	-	3/18 9/12	5/30 10/18	5/16	6/15	6/15	-	6/28 10/28	8/26 2/18	11/18	2/18	-	-

[a]First date the event was observed.

[b]Last date the event was observed.

Table 7. Seasonal home range sizes (ha) of elk bands and individual cow elk, Coos County, OR, 1978-79.

Band or Individual	Method	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb	Annual Average
North Band	min. area	170.8	197.3	216.7	127.4	125.5	115.6	158.9 (42.3)[a]
	ellipse	271.0	302.9	329.1	159.9	236.5	158.1	242.9 (72.0)
Cow #2	min. area	111.0	197.1	147.5	90.2	61.2	58.7	111.0 (53.7)
	ellipse	307.5	299.4	263.7	126.9	117.2	116.4	205.2 (94.5)
Cow #4	min. area	123.7	142.0	164.1	101.8	78.1	59.6	111.6 (39.4)
	ellipse	178.2	266.9	278.9	181.0	220.4	93.5	203.2 (68.2)
South Band[b]	min. area	132.7	285.5	190.3	111.6	119.6	142.3	163.7 (65.8)
	ellipse	248.2	340.5	403.4	206.9	207.8	250.1	276.2 (79.1)
Cow #8	min. area	126.0	208.6	136.7	91.7	78.0	126.3	127.9 (45.6)
	ellipse	258.9	379.8	340.9	219.1	150.0	238.0	264.5 (83.7)
Cow #14	min. area	110.9	238.9	95.0	128.6	118.4	122.9	135.8 (51.8)
	ellipse	256.8	361.3	205.3	209.7	246.3	210.1	248.3 (59.4)

Table 7. (continued)

Band or Individual	Method	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)	Mean of Seasonal Average
Seasonal Average[c]:								
	min. area	129.2 (22.1)	211.6 (47.9)	158.4 (42.3)	108.6 (16.9)	96.8 (27.5)	104.2 (36.0)	134.8 (43.7)
	ellipse	253.4 (42.3)	325.1 (42.6)	303.6 (69.1)	183.9 (35.4)	196.4 (51.4)	177.7 (65.1)	240.0 (63.9)

[a]Figure in parentheses is the standard deviation

[b]Includes observations of cow elk #1 and #00, for which too few locations were obtained to determine individual home ranges.

[c]I utilized home range sizes of bands and individuals.

Table 8. Seasonal shift between elk band home range centers, Coos County, OR, 1978-79.

	Center shift distance (meters)	
Seasons[a]	North Band	South Band
Spring → Calving	434	413
Calving → Summer	372	455
Summer → Rut	351	186
Rut → Fall	269	227
Fall → Winter	207	207
Winter → Spring	579	806

[a]Spring = Mar/Apr, calving = May/Jun, summer = Jul/Aug, rut = Sep/Oct, fall = Nov/Dec, winter= Jan/Feb.

Table 9. Observations of elk by category and activity, Coos County, OR, 1978-79.

Season Period of day	Total # elk	Composition (Of identified elk) (cows:calves:bulls)	Ave. group size	Total # collared elk observed	Activities[a] (elk per category) bed	shr	her	mov	sta	ale
Spring (Mar/Apr)										
Morning[b]	60+	26:5:1	4.6 (3.0)[c]	5	8	2	30	10	4	1
Afternoon	22	12:0:0	3.7 (3.3)	0	5	0	12	2	2	0
Evening	39+	7:2:0	6.0 (3.4)	5	2	0	40	0	8	8
Calving (May/Jun)										
Morning	21+	20:1:0	5.3 (3.3)	5	0	0	3	2	18	18
Afternoon	11	9:2:0	3.7 (3.1)	2	0	2	7	2	0	0
Evening	81+	74:6:1	5.8 (3.5)	17	7	13	39	19	3	6
Summer (Jul/Aug)										
Morning	56+	40:14:2	5.1 (2.1)	8	0	1	5	26	2	15
Afternoon	4	4:0:0	4 (-)	0	0	1	3	0	0	0
Evening	52+	33:16:1	4.0 (2.5)	10	7	7	35	1	2	0

Table 9. (continued).

Season Period of day	Total # elk	Composition (Of identified elk) (cows:calves:bulls)	Ave. group size	Total # collared elk observed	Activities[a] (elk per category) bed	shr	her	mov	sta	ale
Rut (Sep/Oct)										
Morning[b]	77+	43:12:2	5.9 (4.8)[c]	4	24	4	9	12	8	18
Afternoon	0	-	-	-	-	-	-	-	-	-
Evening	58+	34:19:3	6.9 (4.1)	7	0	2	25	10	1	10
Fall (Nov/Dec)										
Morning	35+	18:5:0	5.0 (3.5)	4	0	0	2	20	10	30
Afternoon	19+	14:5:0	4.8 (2.4)	-	0	3	2	8	1	9
Evening	33	24:1:0	4.7 (1.9)	5	0	1	10	12	2	8
Winter (Jan/Feb)										
Morning	74+	58:8:0	4.6 (3.1)	1	2	1	16	23	23	29
Afternoon	22	17:2:0	3.7 (2.4)	0	3	1	3	0	12	11
Evening	20	17:3:0	3.3 (2.1)	2	0	2	11	0	7	5

[a]Abbreviations for activities: bed = bedded, shr = feeding in shrub layer, her = feeding in herb layer, mov = moving, sta = standing, ale = alert.
[b]Morning = 0700-1059 hours, afternoon = 1100-1459, evening = 1500-2000.
[c]Figure in parentheses is the standard deviation.

Table 10. Seasonal cow elk associations, Coos County, OR, 1978-79.

Season	Cow elk pair				Seasonal Average
	2/4	1/8	1/14	8/14	
Spring (Mar/Apr)	0.26	0.75	0.67	0.95	0.66 (.29)[a]
Calving (May/Jun)	0.42	0.12	0.13	0.76	0.36 (.30)
Summer (Jul/Aug)	0.42	0.59	0.11	0.21	0.33 (.21)
Rut (Sep/Oct)	0.17	0.86	0.91	0.86	0.70 (.35)
Fall (Nov/Dec)	0.17	0.25	0.63	0.50	0.39 (.21)
Winter (Jan/Feb)	0.18	0.56	0.44	0.83	0.50 (.27)
Annual Average	0.27 (.12)	0.52 (.29)	0.48 (.32)	0.69 (.28)	

[a]Figure in parentheses is standard deviation.

Table 11. Alder Creek herd elk calf production and first year mortality, Coos County, OR, 1978-79.

Season	No. cows observed	No. calves observed	Calves per 100 cows: This study	Calves per 100 cows: Olympic Penninsula[a]
Summer (Jul/Aug)	71	30	42	58
Fall (Nov/Dec)	57	11	19	45
Spring (Mar/Apr)	39	7	18	17
		Percent calf decline summer to spring:	57%	71%

[a]Data of Schwartz and Mitchell (1945).

Table 12. Seasonal utilization (%) of slopes by cow elk, Coos County, OR, 1978-79.

Slope	Band	Availability %	Spring (Mar/Apr)		Calving (May/Jun)		Summer (Jul/Aug)		Rut (Sep/Oct)		Fall (Nov/Dec)		Winter (Jan/Feb)	
Steep														
(> 50%)	North	47.5	54.2 (7.8)[a]	0[b]	51.1 (7.9)	0[b]	42.1 (7.8)	0[b]	52.3 (7.6)	0[b]	51.4 (7.9)	0[b]	54.8 (7.9)	0[b]
	South	42.5	44.6 (7.3)	0	27.2 (6.6)	+1	22.2 (5.9)	+2	32.5 (6.5)	+1	29.3 (6.9)	+1	37.9 (6.9)	+1
Moderate														
(25-50%)	North	30.5	18.3 (6.1)	+1	23.2 (6.7)	+1	36.7 (7.6)	0	19.1 (6.0)	+1	24.0 (6.7)	+1	27.0 (7.0)	0
	South	39.0	37.6 (7.1)	0	26.3 (6.5)	+1	47.2 (7.0)	-1	45.9 (7.0)	-1	27.6 (6.8)	+1	47.1 (7.1)	-1
Flat														
(< 25%)	North	22.0	27.5 (7.0)	-1	25.7 (6.9)	-1	21.2 (6.4)	0	28.6 (6.8)	-1	24.3 (6.8)	-1	18.3 (6.1)	0
	South	18.5	17.8 (5.6)	0	46.6 (7.4)	-2	30.7 (7.2)	-1	21.6 (5.7)	0	43.1 (7.5)	-2	15.0 (5.1)	0

[a]Figure in parenthesis is the Bonferroni Z value for the 95% confidence interval.

[b]Ranking Difference = usage rank - availability rank; greater negative value indicates greater preference.

Table 13. Seasonal utilization (%) of aspects by cow elk, Coos County, OR, 1978-79.

Aspect	Band	Availability %	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
N	North	13.0	0.7 (1.5)[a] +3.5[b]	7.4 (4.6) +2[b]	10.9 (5.2) +0.5[b]	2.0 (2.4) +1.5[b]	1.7 (2.2) +3[b]	1.6 (2.3) +3.5[b]
	South	16.0	0 (0) +5.5	1.3 (1.9) +5	0.6 (1.2) +6	0 (0) +5.5	2.6 (2.7) +4	0 (0) +6
NE	North	6.0	0.7 (1.5) -0.5	4.2 (3.5) -1	1.0 (1.7) 0	0 (0) 0	0 (0) 0	0 (0) -0.5
	South	8.0	0 (0) -0.5	1.9 (2.3) -2	12.3 (5.2) -4	2.8 (2.3) -2	0 (0) -0.5	7.9 (4.3) -4
E	North	10.5	8.1 (4.8) -1	2.5 (2.7) +3	11.3 (5.3) -2	10.5 (5.2) -1	13.5 (5.9) -1	2.8 (3.1) -1
	South	12.5	5.7 (3.9) +1	10.3 (5.0) -1	9.1 (4.5) +1	18.2 (6.0) -2	5.9 (4.0) +1	7.1 (4.1) +1
SE	North	6.5	27.1 (7.8) -5	24.3 (7.5) -6	30.5 (7.7) -6	37.8 (8.2) -6	39.9 (8.5) -5	22.6 (7.8) -5
	South	13.0	17.5 (6.3) 0	17.2 (6.2) -1	14.0 (5.5) 0	13.7 (5.4) +0.5	33.2 (8.0) -2	30.3 (7.4) -1
S	North	23.5	41.9 (8.6) 0	15.8 (6.4) +3	22.2 (7.0) +1	31.9 (7.9) +1	24.7 (7.5) +3	17.5 (7.1) 0
	South	18.0	34.7 (7.9) 0	52.7 (8.2) -5	40.0 (7.7) 0	40.1 (7.7) 0	29.9 (7.7) +1	39.7 (7.8) 0
SW	North	15.0	14.8 (6.2) 0	10.2 (5.3) +2	10.9 (5.2) +1.5	14.1 (5.9) 0	8.3 (4.8) -2	27.0 (8.3) 0
	South	10.5	23.6 (7.1) -4.5	9.7 (4.9) -2.5	15.4 (6.7) -4.5	13.7 (5.4) -3	20.1 (6.8) -3.5	9.1 (4.6) -3.5
W	North	16.5	2.8 (2.9) +4	16.9 (6.6) +1	7.5 (4.4) +4	1.6 (2.1) +5.0	7.6 (4.6) +1	21.8 (7.7) +4
	South	11.5	16.6 (6.2) -1	6.9 (4.2) 0	4.6 (3.3) +1	11.5 (5.0) 0	8.2 (4.6) -1	5.6 (3.7) +1
NW	North	9.0	3.9 (3.4) -1	18.7 (6.8) -4	5.8 (3.9) +1	2.0 (2.4) -0.5	4.2 (3.5) -1	6.7 (4.6) -1
	South	10.5	1.9 (2.3) -0.5	0 (0) +1.5	4.3 (3.2) -0.5	0 (0) +1	0 (0) +1	0.3 (0.9) +0.5

[a]Number in parentheses is the Bonferroni Z value for the 95% confidence interval.

[b]Ranking difference = usage rank - availability rank; greater negative value indicates greater preference.

Table 14. Seasonal mean distances (m) to or use of specific parameters by cow elk, Coos County, OR, 1978-79.

Parameter	Band	Expected value	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
Dist. to adjacent cover type (when in opening)	North	57.4	42.4 (30.1)[a]	53.5 (30.9)	46.9 (27.1)	42.8 (24.3)	47.5 (27.5)	38.8 (23.7)
	South	65.6	58.8 (37.2)	59.6 (44.2)	49.2 (42.2)	28.1 (15.4)	29.4 (15.7)	72.1 (47.8)
Dist. to adjacent cover type (when in cover)	North	96.6	65.5 (60.1)	75.5 (57.1)	48.0 (37.4)	58.1 (40.8)	55.9 (46.3)	71.8 (54.2)
	South	89.8	98.2 (90.5)	89.4 (68.2)	87.6 (64.6)	88.8 (70.2)	127.0 (86.4)	102.8 (64.3)
Dist. to adjacent cover type	North	73.0	50.4 (46.8)	70.9 (54.5)	46.3 (34.2)	51.2 (35.3)	53.3 (42.4)	52.0 (42.6)
	South	95.0	79.3 (79.8)	83.2 (66.7)	80.9 (63.0)	81.6 (69.1)	108.0 (87.9)	90.6 (62.8)
Dist. to nearest road	North	124.4	165.7 (76.4)	184.6 (99.0)	142.8 (77.4)	155.5 (76.6)	151.2 (91.8)	110.3 (76.7)
	South	122.0	97.1 (68.9)	107.8 (65.4)	107.9 (73.1)	123.6 (71.2)	97.1 (52.0)	120.2 (75.9)
Dist. to paved road	North	511.4	524.2 (279.0)	752.9 (348.4)	485.8 (283.0)	488.4 (232.1)	524.3 (225.9)	628.9 (240.5)
	South	501.2	601.0 (304.0)	407.4 (316.4)	563.8 (353.6)	689.2 (189.1)	534.8 (311.5)	671.8 (320.4)
Dist. to water	North	254.6	115.9 (84.8)	150.1 (94.2)	189.3 (144.2)	171.0 (89.2)	176.9 (128.2)	208.8 (119.9)
	South	160.0	196.7 (146.4)	146.4 (119.5)	183.4 (127.5)	195.2 (99.4)	190.9 (134.9)	225.8 (144.3)
Elevation	North	365.7	280.4 (60.5)	299.8 (72.5)	351.1 (101.8)	306.2 (67.6)	337.9 (100.1)	350.1 (86.3)
	South	267.4	288.7 (112.0)	242.8 (93.1)	291.3 (122.6)	304.4 (37.8)	314.2 (93.7)	363.0 (107.6)

[a]Figure in parentheses is the standard deviation.

Table 15. Expected and observed occurrence of road surface type nearest to cow elk locations, Coos County, OR, 1978-79.

Road Type	Band	Expected Occurrence (%)	Frequency of occurrence (%) Spring (Mar/Apr)		Calving (May/Jun)		Summer (Jul/Aug)		Rut (Sep/Oct)		Fall (Nov/Dec)		Winter (Jan/Feb)	
Paved	North	29	22.5 (6.5)[a]	0[b]	1.1 (1.6)	+1[b]	13.8 (5.2)	+1[b]	14.5 (5.3)	+1[b]	7.3 (4.0)	+1[b]	0.8 (1.5)	+1[b]
	South	22	4.5 (3.1)	0	16.6 (5.5)	0	3.4 (2.6)	0	0.0	0	10.9 (4.7)	0	5.3 (3.2)	0
Gravel	North	8	3.9 (3.0)	0	20.4 (6.3)	-1	18.0 (5.8)	-1	16.8 (5.7)	-1	8.0 (4.2)	-1	4.0 (3.3)	-1
	South	35.5	11.1 (4.7)	0	45.8 (7.4)	-1	60.1 (6.9)	-1	33.6 (6.6)	0	33.6 (7.2)	0	32.9 (6.7)	0
Dirt	North	63	73.6 (6.9)	0	78.5 (6.4)	0	68.2 (7.0)	0	68.8 (7.0)	0	84.7 (5.6)	0	95.2 (3.6)	0
	South	42.5	84.4 (5.4)	0	37.6 (7.1)	+1	36.5 (6.9)	+1	66.4 (6.6)	0	55.6 (7.5)	0	61.8 (7.0)	0

[a]Figure in parentheses is the Bonferroni Z value for the 95% confidence interval.

[b]Ranking difference = usage rank - availability rank; greater negative value indicates greater preference.

Table 16. Cumulative frequency (%) distributions for expected and observed distances of cow elk to roads, Coos County, OR, 1978-79.

Paved road			Nearest road		
Distance interval (m)	North band N = 1686 (cum. %)	South Band N = 1949 (cum. %)	Distance interval (m)	North band N = 1699 (cum. %)	South band N = 1966 (cum. %)
0-126	3[a]	8	0-60	17	27
	22.5	18		35.5	35.5
127-245	13	20	61-138	48	69
	40	34		63.5	66.5
246-365	31	32	139-209	71	91
	48.5	46.5		78	85
366-485	45	39	210-281	93	98
	63	54		89.5	93
486-604	56	51	282-353	99	100
	71	66.5		96	97.5
605-724	71	61	354-419	100	100
	74	71.5		100	100
725-844	83	73			
	76	81			
845-963	92	90			
	82	83.5			

Table 16. (continued)

Paved roads			Nearest road		
Distance interval (m)	North band N = 1686 (cum. %)	South Band N = 1949 (cum. %)	Distance interval (m)	North band N = 1699 (cum. %)	South band N = 1966 (cum. %)
964-1083	95	96			
	85.5	89			
1084-1855	100	100			
	100	100			

[a]Upper number of each pair is the observed cumulative frequency; lower number is the expected cumulative frequency based on availability.

Table 17. Seasonal utilization (%) and proximity of cover to cow elk, Coos County, OR, 1978-79.

Parameter	Band	Availability (%)	Utilization (%) Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
OCCUPIED								
Cover type:								
Cover	North	58	43.7 (7.2)[a]	76.3 (6.3)	62.7 (7.0)	55.6 (7.1)	58.5 (7.3)	41.3 (7.1)
	South	76	64.0 (6.9)	85.3 (5.1)	86.1 (5.0)	88.5 (4.6)	82.1 (5.5)	69.1 (6.7)
Opening	North	42	56.3 (7.2)	23.7 (6.3)	37.3 (7.0)	44.4 (7.1)	41.5 (7.3)	58.7 (7.1)
	South	24	36.0 (6.9)	14.7 (5.1)	13.9 (5.0)	11.5 (4.6)	17.9 (5.5)	30.9 (6.7)
ADJACENT								
Cover type:								
Cover	North	51.5	64.1 (7.0)	64.8 (7.0)	52.1 (7.0)	56.3 (7.0)	62.2 (7.0)	53.2 (7.0)
	South	78	79.9 (6.0)	88.8 (4.0)	84.3 (5.0)	63.3 (7.0)	68.8 (6.0)	68.2 (6.0)
Opening	North	48.5	35.9 (7.0)	35.2 (7.0)	47.9 (7.0)	43.8 (7.0)	37.8 (7.0)	46.8 (7.0)
	South	22	20.1 (6.0)	11.2 (4.0)	15.7 (5.0)	36.7 (7.0)	31.3 (6.0)	31.8 (6.0)

[a]Figure in parentheses is the Bonferroni Z value for the 95% confidence interval.

Table 18. Frequency of seasonal use (%) of cover types by cow elk, Coos County, OR, 1978-79.

Cover Type	Availability (%)	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
NORTH BAND							
Old-Growth	44	33.8 (8.2)[a] +1[b]	67.6 (8.1) 0[b]	47.3 (8.2) 0[b]	48.7 (8.3) 0[b]	45.1 (8.5) 0[b]	38.9 (8.9) 0[b]
Mixed Forest	0	-	-	-	-	-	-
Hardwood	3.5	9.9 (5.2) -2	8.1 (4.7) -3	11.3 (5.2) -3	6.3 (4.1) -2	11.5 (5.5) -2	2.4 (2.8) -2
Old Clearcut	10.5	0.0 (0) +2	0.7 (1.4) +1.5	4.2 (3.3) +1	0.7 (1.4) +1	2.4 (2.6) +1	0.0 (0) +2
Brushy Clearcut	19	37.0 (8.3) -1	18.3 (6.7) 0	23.8 (7.0) 0	32.9 (7.8) 0	27.4 (7.6) 0	46.0 (9.1) 0
New Clearcut	15	16.9 (6.5) 0	4.6 (3.6) +1	9.6 (4.9) +1	11.2 (5.3) 0	11.8 (5.5) 0	11.1 (5.8) 0
Road	8	2.5 (2.7) 0	0.7 (1.4) +0.5	3.9 (3.2) +1	0.3(0.9) +1	1.7 (2.2) +1	1.6 (2.3) 0
SOUTH BAND							
Old-Growth	35	28.3 (7.4) +1	43.3 (8.1) 0	56.3 (7.7) 0	80.7 (6.1) 0	68.8 (7.7) 0	44.4 (7.8) 0
Mixed Forest	5.5	1.9 (2.2) +1	1.9 (2.2) 0	0.0 (0) +1	0.0 (0) +1	0.0 (0) +1	0.0 (0) +1
Hardwood	1	4.8 (3.5) -2	0.3 (0.9) 0	1.1 (1.6) -1	4.8 (3.3) -4	1.0 (1.7) -1	1.2 (1.7) -1
Old Clearcut	34.5	29.0 (7.5) -1	39.8 (8.0) 0	28.7 (7.0) 0	3.1 (2.7) +3	12.2 (5.5) 0	23.5 (6.7) 0
Brushy Clearcut	10.5	21.7 (6.8) 0	8.5 (4.5) 0	9.7 (4.6) 0	6.4 (3.8) -1	9.5 (4.9) 0	15.0 (5.6) 0
New Clearcut	7.5	4.5 (3.6) +2	2.8 (2.7) +1	2.3 (2.3) 0	4.2 (3.1) 0	3.0 (2.4) +1	11.2 (5.0) 0
Road	6	9.9 (4.9) -1	3.4 (2.9) -1	2.0 (2.2) 0	0.8 (1.4) +1	5.6 (3.8) -1	4.7 (3.3) 0

[a] Number in parentheses is the Bonferroni Z value for the 95% confidence interval.

[b] Ranking difference = usage rank - availability rank; greater negative value indicates greater preference.

Table 19. Frequency of occurrence (%) of cover types adjacent to cow elk locations, Coos County, OR, 1978-79.

Cover Type	Availability (%)	Spring (Mar/Apr)	Calving (May/Jun)	Summer (Jul/Aug)	Rut (Sep/Oct)	Fall (Nov/Dec)	Winter (Jan/Feb)
NORTH BAND							
Old-Growth	23.5	42.6 (8.5)[a] -1[b]	22.2 (7.1) 0[b]	28.6 (7.4) 0[b]	33.6 (7.8) 0[b]	37.2 (8.2) -1[b]	26.2 (7.9) 0[b]
Mixed Forest	0	-	-	-	-	-	-
Hardwood	14	21.5 (7.0) -1.5	42.3 (8.4) -3.5	17.7 (6.2) -1.5	19.4 (6.5) -1.5	23.6 (7.2) -1.5	24.6 (7.9) -1.5
Old Clearcut	14	0.0 (0) +0.5	0.4 (1.1) +0.5	6.1 (3.9) +0.5	3.3 (2.9) +0.5	1.4 (2.0) +0.5	2.4 (2.8) +0.5
Brushy Clearcut	26.5	23.9 (7.3) +1	18.7 (6.6) +2	34.2 (7.7) 0	35.2 (7.9) 0	25.3 (7.4) +1	12.3 (5.9) +3
New Clearcut	22	12.0 (5.5) +1	10.2 (5.2) +1	13.8 (5.6) +1	8.6 (4.6) +1	12.5 (5.6) +1	34.5 (8.4) -2
SOUTH BAND							
Old-Growth	35.5	31.2 (7.5) 0	44.8 (8.0) 0	33.9 (7.3) 0	19.3 (6.0) +3	29.9 (7.5) 0	44.1 (7.7) 0
Mixed Forest	6	3.5 (3.0) +1	3.1 (2.9) +1	0.0 (0) +1	0.0 (0) +1	0.0 (0) +1	0.0 (0) +1
Hardwood	10	28.3 (7.3) -2	19.2 (6.3) -1	20.5 (6.2) -1	21.3 (6.2) -1	29.6 (7.5) -2	13.2 (5.3) 0
Old Clearcut	26.5	16.9 (6.1) +1	21.6 (6.6) 0	29.9 (7.0) 0	22.7 (6.4) 0	9.2 (4.8) +3	10.9 (4.9) +3
Brushy Clearcut	16.5	12.1 (5.3) +1	4.1 (3.2) +2	8.5 (4.3) +1	27.5 (6.8) -2	9.9 (4.9) +1	14.4 (5.5) 0
New Clearcut	5.5	8.0 (4.4) -1	7.2 (4.1) -2	7.1 (3.9) -1	9.2 (4.4) -1	21.4 (6.8) -3	17.4 (5.9) -4

[a]Number in parentheses is the Bonferroni Z value for the 95% confidence interval.

[b]Ranking difference = usage rank - availability rank; greater negative value indicates greater preference.

Table 20. Predictive capacity of the discriminate function model to correctly assign an elk location to the season of its occurrence.

Actual Season of elk location	Band	No. elk locations	Assigned Season (%)					
			Spring	Calving	Summer	Rut	Fall	Winter
Calving (May/Jun)	North	283	9.5	44.2	8.8	14.8	12.4	10.2
	South	319	13.8	48.3	5.0	11.6	15.4	6.0
Summer (Jul/Aug)	North	311	13.5	10.6	33.8	10.3	21.9	10.0
	South	352	8.5	21.0	30.4	19.0	8.5	12.5
Rut (Sep/Oct)	North	304	29.3	4.3	12.2	28.9	16.1	9.2
	South	357	4.2	5.6	12.0	54.6	18.2	5.3
Fall (Nov/Dec)	North	284	27.1	9.9	12.7	10.2	26.1	14.1
	South	308	6.5	8.1	5.2	7.1	55.5	17.5
Winter (Jan/Feb)	North	252	8.3	16.7	4.8	6.0	17.1	47.2
	South	340	10.0	1.8	11.5	12.1	15.0	49.7
Spring (Mar/Apr)	North	284	51.8	8.5	8.5	12.0	13.0	6.3
	South	314	51.3	15.0	5.1	9.6	8.6	10.5

Table 21. Predictive capacity of the discriminant function model to distinguish actual elk locations of a given season from random data set locations.

Season of elk locations	Band	No. of elk locations	Correct assignment (%) as actual elk location	Variability of data accounted for by model (%)
Calving (May/Jun)	North	283	89.0	64.5
	South	319	77.7	55.3
Summer (Jul/Aug)	North	311	74.3	49.3
	South	352	86.6	55.6
Rut (Sep/Oct)	North	304	89.8	66.7
	South	357	95.5	71.7
Fall (Nov/Dec)	North	284	85.6	61.6
	South	308	94.5	69.7
Winter (Jan/Feb)	North	252	81.7	63.0
	South	340	90.6	63.1
Spring (Mar/Apr)	North	284	89.4	67.1
	South	314	88.2	58.6

Table 22. Frequency of day use (%) by cow elk of each cover type by period of day, Coos County, OR, 1978-79.

Combined Seasons[a]	Period of day[b]	Old Growth	Mixed Forest	Hardwood	Old Clearcut	Brushy Clearcut	New Clearcut	Road
NORTH BAND								
Calving Summer, Rut	Morning	28.3 (5.4)[c]	-[d]	31.2 (13.9)	23.5 (27.1)	26.5 (7.8)	42.9 (14.9)	26.7 (30.2)
	Midday	31.8 (5.6)	-	39.0 (14.7)	29.4 (29.2)	26.5 (7.8)	18.2 (11.6)	40.0 (33.4)
	Late Day	39.8 (5.9)	-	29.9 (13.8)	47.1 (32.0)	46.9 (8.8)	39.0 (14.7)	33.3 (32.1)
Fall, Winter, Spring	Morning	39.8 (7.2)	-	25.4 (14.0)	42.9 (14.9)	39.3 (7.4)	37.3 (12.1)	81.3 (25.7)
	Midday	38.0 (7.1)	-	40.3 (15.8)	57.1 (21.2)	32.3 (7.1)	31.8 (11.7)	0 (0)
	Late Day	22.2 (6.1)	-	34.3 (15.3)	0 (0)	28.3 (6.9)	30.9 (11.6)	18.8 (25.8)
SOUTH BAND								
Calving, Summer Rut	Morning	31.1 (4.9)	50.0 (53.9)	18.2 (21.7)	31.8 (8.0)	16.4 (10.6)	53.1 (23.3)	47.6 (28.8)
	Midday	33.2 (5.0)	33.3 (50.8)	18.2 (21.7)	28.9 (7.7)	35.3 (13.7)	9.4 (13.6)	9.5 (16.9)
	Late Day	35.6 (5.1)	16.7 (40.2)	63.6 (27.1)	39.3 (8.3)	48.2 (14.3)	37.5 (22.6)	42.9 (28.5)
Fall, Winter, Spring	Morning	38.5 (6.1)	50.0 (53.9)	81.8 (21.7)	27.9 (8.2)	38.5 (10.6)	67.2 (15.9)	32.8 (15.5)
	Midday	33.9 (5.9)	50.0 (53.9)	9.1 (16.2)	44.2 (9.1)	35.8 (10.4)	8.2 (9.3)	26.6 (14.6)
	Late Day	27.6 (5.6)	0 (0)	9.1 (16.2)	27.9 (8.2)	25.7 (9.5)	24.6 (14.6)	40.6 (16.2)

[a]Calving through rut = May through October; fall through spring = November through April.

[b]Morning = 0700-1059 hours, afternoon = 1100-1459, late day = 1500-2000.

[c]Number in parentheses is the Bonferroni Z value for the 95% confidence interval.

[d]This cover type did not occur in the north band's area.

Table 23. Night versus day use (%) by cow elk of cover types,[a] Coos County, OR, 1978-79.

Cover type	Availability (%)	Frequency of night use[b] (%)			Frequency of day use[b] (%)		
Old Growth	35.0	55.9	(14.1)[c]	0[d]	57.0	(5.8)	0
Mixed Forest	5.5	0	(0)	1	0	(0)	1
Hardwood	1.0	3.9	(5.5)	-2	9.7	(3.5)	-4
Old Clearcut	34.5	18.6	(11.1)	0	2.5	(1.8)	3
Brushy Clearcut	10.5	13.7	(9.8)	0	21.2	(4.8)	-1
New Clearcut	7.5	3.9	(5.5)	1	7.2	(3.0)	0
Road	6.0	3.9	(5.5)	0	2.4	(1.8)	1

[a]Calving and summer season observations of south band elk only, May-August.

[b]This distribution of cover type use is significantly different than the availability distribution at the 95% confidence level.

[c]Number in parentheses is the Bonferroni Z value for the 95% confidence interval.

[d]Ranking difference = usage rank - availability rank; greater negative value indicates greater preference.

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APPENDICES

Appendix 1. Elk capture and responses to drug administration, Coos County, OR, 1977-78.

Date	Sex/age	Collar[b] no.	Dosage (mg)	Reaction[e] time (min)	Recovery time (min)
2/26/77	male calf	7[a]	15	2	28
2/26/77	adult female	4	15	4	33
2/28/77	yearling male	9[a]	17	5.5	26
3/6/77	adult female	5	17+17+17	3	28
3/6/77	male calf	-	15	6	17
3/11/77	adult female[c]	8	17	2.5	26
3/11/77	adult female	2	17	7	20
3/13/77	adult female	00	17	4.5	43.5
3/25/77	adult female	6	15	8	22
3/25/77	male calf	1	15	1	32
1/16/78	adult female	1	20	5	35
1/16/78	adult female	8	17	8	40
1/16/78	adult female[f]	-	17+20	-	-
1/16/78	yearling female	-	17	-	-
2/17/78	adult female	2	20	4	35
2/20/78	adult female	00[d]	20	5	35
2/20/78	yearling female	-	20+5 5+5	-	-

Appendix 1. (continued)

Date	Sex/age	Collar[b] no.	Dosage (mg)	Reaction[e] time (min)	Recovery time (min)
2/26/78	adult female	-	20	-	-
3/2/78	female calf	-	10	2.75	34
3/6/78	adult female	-	20	-	-
3/17/78	yearling female	14	20+20	5	109
3/27/78	adult female	4	20	5	23

[a]These bull elk were recaptured later in the same trapping season.

[b]Dash (-) indicates collar not placed on animal.

[c]All elk were darted in the rump except this one which was darted in the neck.

[d]This cow was recaptured the second trapping season and given a new collar with the same number.

[e]Dash (-) indicates animal had no reaction to drug.

[f]Cow died 3 min. after 2nd dart administered.

Appendix 2. Known collared elk mortalities, Coos County, OR 1977-80.

Date	Sex and age	Comments
11/77	2 yr old, 3 pt. bull	shot opening morning of bull elk rifle season (Saturday)
11/77	yearling bull	shot opening morning of bull elk rifle season (Saturday)
11/77	yearling bull	shot second morning of bull elk rifle season (Sunday)
2/80	adult cow	illegally shot along Middle Creek Access Road (paved) near Park Creek
12/80	adult cow	shot during archery season (either-sex) in south band area