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Habitat use patterns and population trends among Shiras moose in a heavily logged region of northwest Montana

Brent Costain
The University of Montana

HABITAT USE PATTERNS AND POPULATION TRENDS
AMONG SHIRAS MOOSE
IN A HEAVILY LOGGED REGION OF NORTHWEST MONTANA

by

Brent Costain

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B.S., University of Montana, 1983

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Most foraging habitat for Shiras Moose (Alces alces shirasi) in the Yaak River drainage has been created by commercial logging. Field studies, 1984-1986, explored the influence of timber management, hunting, and other human activities on moose habitat selection, movements, and population trends.

Most data were derived from tracking and observation of 8 radio-collared moose. Habitat selection was examined through use/availability analysis of 48 field-measured parameters at 400 radio and 188 random locations. Intensive observation of 8 broadly defined habitat components and 24-hour monitoring of individual animals provided supplementary data. Radio points and sightings were used to define home ranges as minimum convex polygons and 99% harmonic ranges. Population size and structure were estimated from fortuitous sightings of marked and unmarked animals. Snow depth and hardness were measured along snow courses and during tracking of individuals.

Uncanopied, logged habitats with abundant high quality forage and good hiding cover were important to moose in all seasons. Forested cover was important during summer heat and deep winter snow. Key habitat components for moose were: secure calving areas, aquatic feeding sites, damp timbered bottoms on summer range, mosaics of timber and browse on low elevation winter range, dense multi-storied timber on mid elevation winter range, and secure uncanopied foraging areas at all elevations. In deep-snow winters, moose minimized energy loss by selecting for low elevation timber stands with coniferous browse and abundant edge and by restricting activity. In light-snow winters, they maximized energy intake by selecting for good quality browse habitats in 12-30 yr old cutting units at low to mid elevation.

Calf production was linked to effective snow depth and consequent accessibility of uncanopied winter browse. Population appears currently to be limited by the combined impact of regulated and unregulated hunting. It should ultimately be limited by the amount of deep-snow winter range.

Suggested management strategy involves protection and enhancement of key components, widespread forest road closures, irregular cutting unit design that breaks up sightlines and maximizes hiding cover, creation of fine-grained timber/forage mosaics on low elevation winter range, and monitoring population through late summer ground surveys and early winter overflights of low and mid elevation clearcuts.

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I have applied the pronoun 'we' liberally throughout this text, not as an editorial affectation, but as a reflection of the number of people who have been part of this project. To begin with, I want to thank Dr. Bart O'Gara for ushering me into the study in the first place. Once there, funding was provided by the Montana Dept. of Fish, Wildlife and Parks; Louisiana Pacific Corporation; and James E. Davis.

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INTRODUCTION

The Yaak River country in NW Montana is a heavily forested region of low, rolling mountains with few large natural openings. Shiras moose (*Alces alces shirasi*) are commonly associated with open shrub communities, and appear not to have been a conspicuous presence in the area during the 19th century, although they were reported in Canadian drainages immediately to the north (Tyrrell 1916). Moose populations began to increase in NW Montana following extensive fires in 1910 and during the 1920's and 1930's (J. Calvi, pers. comm.). A large wildfire in 1931 created a broad swath of early successional vegetation from southern British Columbia down into the Yaak River drainage, and provided a corridor of favorable habitat through which moose apparently migrated south (M. Riedlinger, pers. comm.). The precise character of these population changes was not documented in detail at the time, but the pattern of steady population increase in newly created favorable habitat is consistent with observations from other studies (Peek and Eastman 1983, Geist 1974).

Most of the abundant seral forage generated by these fires has since been replaced by closed forest communities, and early successional habitats are now maintained primarily by widespread commercial logging. Large-scale timber harvest began in the mid 1950's and remains the dominant land use activity. The 1985 5-year plan for the Yaak Ranger District (Kootenai National Forest) projected the removal of approximately 55 million board-feet of timber per year. It has not been clear how timber harvest and associated site treatments compare to wildfire in creating high-quality moose habitat; but the upper Yaak River drainage has continued to support substantial moose populations in association with intensive timber management and roading for the past 30 years.

Although moose readily exploit open seral habitats for high-quality forage, they also use mature forest communities in NW Montana. Other studies in the Northwest suggest that diverse, multi-storied stands of timber are important as wintering areas, as summer refugia, and as calving sites (Pierce and Peek 1984, Doerr 1984, Pierce 1983). Logging operations must be properly managed to avoid excessive timber harvest and maintain an appropriate mosaic of these habitat components.

In spite of persistent logging, much of the Yaak country remains heavily forested. Moose can be regularly observed only in the more open habitats around aquatic sites, in recently logged areas, and along the roads. Dense stands of timber and thick brush in many logged units make consistent observation of moose difficult, and reliable population data on which to base management programs have not been obtainable by standard census methods.

The perception of an adequate resident moose population in the Yaak River drainage led to the re-establishment of moose hunting by the Montana Fish and Game Commission in the early 1960's. A regulated harvest of 15-20 animals per year was maintained through 1983, and was increased to 30 animals in 1984. In addition, members of the Confederated Salish and Kootenai Tribe have begun to exercise treaty hunting rights outside of Reservation boundaries in recent years. Although this is legal harvest, it is essentially unregulated. Poaching is rife, but its annual impact is unknown. The combined impact of regulated, unregulated, and illegal kill has remained speculative into the 1980's in the absence of specific data.

The Yaak Moose Project was initiated in 1981 to explore the relationship between moose populations and land use activities in NW Montana, and to suggest appropriate management strategies.

Objectives were to:

(1) document habitat selection by moose and identify habitat components of significance;

(2) delineate home ranges and define seasonal movements;

(3) estimate population densities and rates of change;

(4) assess the impact of human activities--logging and hunting in particular--on these first three groups of parameters;

(5) develop guidelines that integrate moose habitat management and timber stand manipulation; and

(6) suggest ways of monitoring population trends.

The study has proceeded in two phases. From 1981 to 1983 M.R. Matchett established basic procedures, radio-collared a working sample of 8 moose, and amassed an initial data base (Matchett 1985a, 1985b)

Matchett found that moose made extensive use of small 15-30 year-old clearcuts throughout the year, but retreated into dense, multistoried stands of mature timber in mid and late winter when snow was deep and heavy. He described winter ranges as fairly small, uniformly-used areas at low elevation, and summer ranges as an array of small core areas, often widely separated. In summer, moose moved periodically back and forth between upland core areas and lowland feeding sites. He estimated moderately high calf:cow ratios, but fairly low bull:cow ratios, and a low population density. He felt the population was stable or increasing slightly. He recommended logging to maintain a mosaic of small 15–30 year-old clearcuts and mature closed-canopied stands, protection of aquatic feeding sites, vigorous pursuit of the road-closure program, and more effective population monitoring.

With two years transmission time remaining on most of the radio collars, the second phase of the project was initiated in January 1984 to bolster the initial data base and to further explore ideas developed during the first half of the study. Our agenda included:

(1) extensive field sampling of habitat locations to collect a more reliable and appropriate array of parameters than provided by the USFS data base,

(2) continued observation of special habitats, particularly calving areas and units of winter cover, to provide more detailed characterization of these key sites,

(3) continuous surveilance of individual moose to observe their behavioral response to hunting and logging operations, and

(4) monitoring of movements and habitat use during the fall and throughout a more diverse array of winter conditions.

THE STUDY AREA

The core study area encompasses the Spread, Whitetail, Pete, Lap, and French Creek drainages along the upper Yaak River in the Purcell Mountains in extreme NW Montana (Figure 1). The total study area was defined by movements of the collared moose themselves and was approximately 200 mi^2 in size.

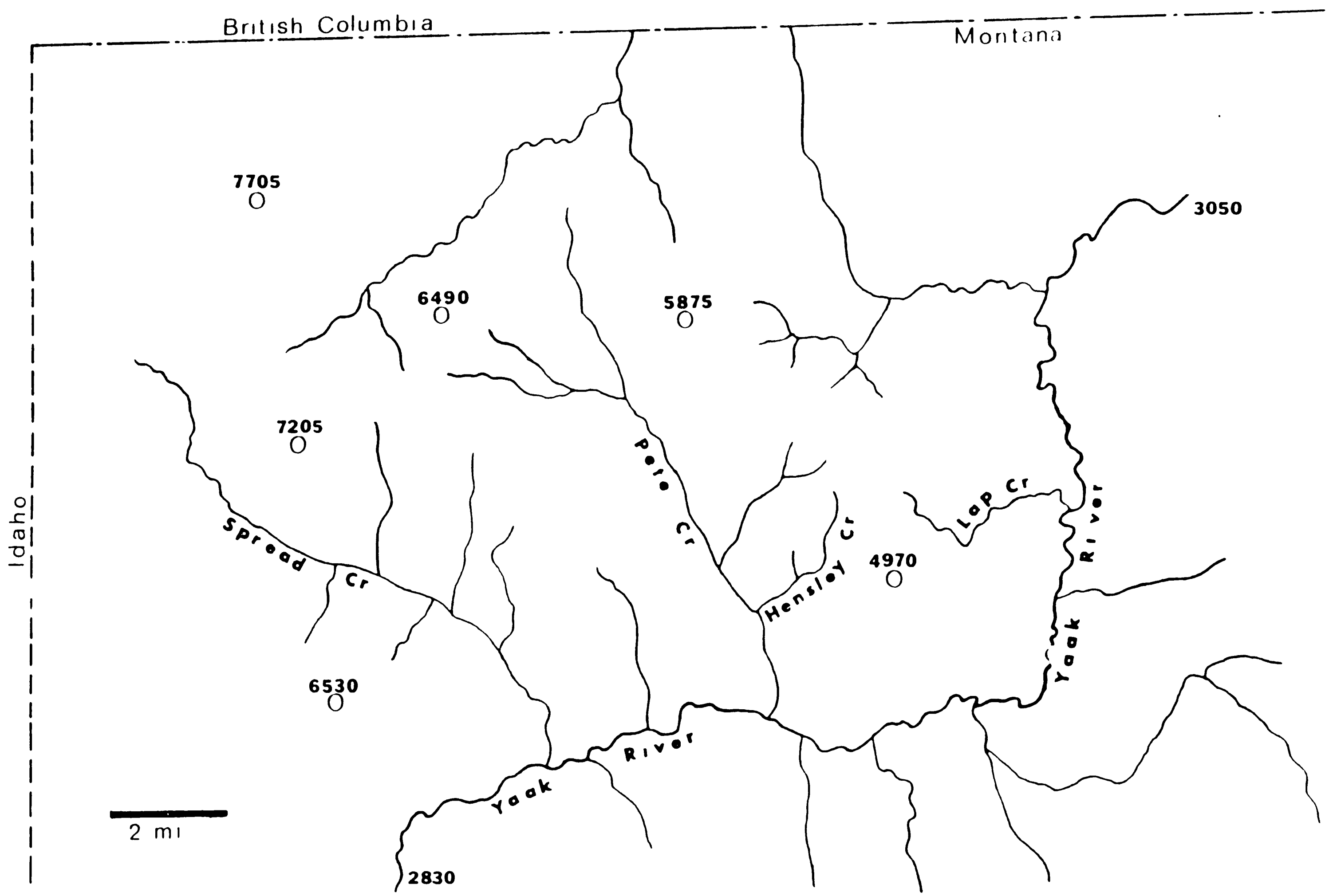

FIGURE 1. Principal topographic features of the study area: drainages and summits. Elevations are in feet.

The topography is characterized by low, rolling mountains. Abrupt slopes and sharp draws are interspersed with broad benches and extensive bottoms in many of the drainages. Swamps and bogs are numerous, though usually small (often less than 1 acre). Elevations on the study area range from around 2950 ft on the Yaak River to about 6500 ft on the higher ridges.

The Yaak region is influenced by moist Pacific air flow, and receives approximately 40 inches of precipitation annually. Snow depths at middle elevations typically exceed 20 inches from late December through mid March and exceed 40 inches at higher elevations during the same period. Accumulated snow is usually light and powdery through mid January, but becomes dense and difficult to move through by February. Precipitation in the latter half of the winter is usually a mixture of rain, sleet, and snow.

The country is heavily forested: most natural openings are small and associated with aquatic areas or with harsh sites at higher elevations. Natural meadows and brushfields occur along the Yaak River, but the broad bottomlands that serve as moose habitat in other parts of North America are generally lacking.

Forest habitat types are dominated by the western hemlock and western redcedar climax series (Pfister *et al.* 1977), which cover nearly 60% of the area. Alpine fir habitat types occur at higher elevations, and Douglas-fir and Engelmann spruce types lower down. Forest stands typically contain a mixture of several codominant conifer species. Western larch (*Larix occidentalis*), western white pine (*Pinus monticola*), Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), alpine fir (*Abies lasiocarpa*), Engelmann spruce (*Picea engelmanni*), and lodgepole pine (*Pinus contorta*) are abundant and widespread. Ponderosa pine (*Pinus ponderosa*), grand fir (*Abies grandis*), aspen (*Populus tremuloides*), and black cottonwood (*Populus trichocarpa*) are common. Many of these forest stands are dense and multi-storied, and significantly moderate the effects of extreme weather and snow accumulation under the canopy.

The Yaak is brushy country, and shrub species palatable to moose are numerous. Open habitats contain serviceberry (*Amelanchier alnifolia*), shiney-leaf ceanothus (*Ceanothus velutinus*), Utah honeysuckle (*Lonicera utahensis*), mountain maple (*Acer glabrum*), upland willows (*Salix* spp.), pachistima (*Pachistima myrsinites*), redosier dogwood (*Cornus stolonifera*), thimbleberry (*Rubus parviflorus*), menziesia (*Menziesia feruginea*), mountain ash (*Sorbus scopulina*), currants (*Ribes*spp.), redstem ceanothus (*Ceanothus sanguineus*), elderberry (*Sambucus* spp.), roses (*Rosa* spp.), Douglas spirea (*Spirea douglasii*), alders (*Alnus* spp.), birches (*Betula* spp.), black cottonwood, and aspen. Huckleberries (*Vaccinium* spp.) and buffalo berry (*Shepherdia canadensis*) are also abundant, but rarely browsed by moose.

The understory in many mature forest communities lacks deciduous shrubs and other broadleaf vegetation. However, coniferous regeneration (western redcedar, western hemlock, and alpine fir) is often abundant, as are arboreal lichens (*Alectoria* spp.). Pacific yew (*Taxus brevifolia*) is uncommon. Lodgepole pine, western larch, Douglas fir, Engelmann spruce, and alpine fir regeneration is variously abundant in open areas.

Associations of grasses and forbs are available in summer, both in cutover areas and throughout damp bottoms in the timber. In newly logged units, fireweed (*Epilobium angustifolium*) is often abundant from mid summer through early fall.

Potential aquatic feeding sites occur both in the backwaters along the Yaak River and in numerous ponds, swamps, and sluggish sections of streams in the uplands. Aquatic sites furnish browse species around the fringes (typically willows, redosier dogwood, alders, and Douglas spirea) as well as submerged aquatic vegetation. Elodea (*Elodea nuttallii*), pondweeds (*Potomageton* spp.), and aquatic buttercups (*Ranunculus aquatilis*) are the most prominent of the submerged aquatics.

Major wildfires prior to 1935 and extensive logging since the mid 1950's have reduced old-growth timber to scattered stands throughout the Yaak drainage. The area has been logged primarily by clearcutting, but also by overstory removal, selection cutting, salvage-sanitation, and, more recently, by seedtree and shelterwood cutting. Thirty years of intensive logging superimposed on the irregularities of mountain topography, local edaphic influences, and a legacy of repeated natural burns, have created a diverse mosaic of habitats available to moose.

Among potential competitors in the area, white-tailed deer (*Odocoileus virginianus*) and mule deer (*Odocoileus hemionus*) are present in substantial numbers, elk (*Cervus elaphus*) are present in moderate numbers, and caribou (*Rangifer trandus*) may be present during some winters. Among potential predators, Black bears (*Ursus americanus*) are numerous, grizzly bears (*Ursus *arctos*) are present in low numbers, mountain lions (*Felis concolor*) are present, and gray wolves (*Canis lupus*) are occasionally reported. In addition, human activities (principally logging and hunting) are important competitive and predatory influences.

Most privately owned land in the upper Yaak is confined to a mile-wide corridor along the main river and some of its principal tributaries. Human occupancy is scant, and open areas along the river are utilized mostly as hay meadows and pastures. Paved roads are limited to the valley proper, near the River. Most of the area is part of the Three Rivers Ranger District (formerly the Yaak Ranger District) on the Kootenai National Forest. Outdoor recreation, particularly hunting in the fall, is a prominent activity, but logging remains the dominant land use. The hills are infused with a complex network of logging roads in all stages of repair and accessibility. Much of the Yaak in its current status is an environment more condusive to vehicle-oriented recreation and hunting than to wildland recreation.

METHODS

Our approach, throughout both phases of the study, has been to monitor a small number of animals intensively, rather than to conduct an extensive survey program over a large area. We followed movements and defined habitat use through radio tracking of 12 adult moose over a 4-year period. We characterized the habitat at each radio location by a variety of parameters, derived both from field sampling and US Forest Service records, and then related habitat use to availability by comparing radio points to random points. We also continuously tracked individual animals for 24 hour periods, and intensively monitored special habitats. Home range and movement patterns were derived from radio locations; and population estimates from fortuitous observation of marked and unmarked individuals in the study area.

COLLARED MOOSE

Between January 1982 and May 1983, Matchett and his field assistants successfully tranquilized and radio-collared 12 moose (8 cows, 4 bulls) in the Spread and Pete Creek drainages and along the Yaak River (Matchett 1985a). They were fitted with Telonics 490 g radio units mounted on butyl rubber collars with long-range dipole antennas. The collars were color-coded with strips of tape for visual identification. Expected life of the radio units was 40-54 months.

Eight of these animals (6 cows, 2 bulls) retained operable transmitters through 1984 and most of 1985 to form the radioed sample for the second half of the study. In addition, a seventh cow with inoperable transmitter remained as part of the visual sample (Table 1).

RADIO TELEMETRY

Daily radio tracking was our primary means of locating moose and determining what habitats they occupied. In winter and fall we normally obtained a radio point for each moose every 1-3 days; in summer every 2-5 days. If a moose wandered beyond the bounds of our normal tracking area, we occasionally employed fixed-wing aircraft fitted with telemetry equipment to determine its

TABLE 1. History of radio-collared moose, 1982-1986.

Moose		Capture Date	Radio Locations 82-83	84-86		Status as of October 1986
00	cow	Jan. 1982	119	146	*	Shot--study area, Sept. 1985
01	cow	Jan. 1982	117	126	*	Still operating, fall 1986
02	cow	Mar. 1982	13	0		Slipped collar, July 1982
03	bull	Mar. 1982	80	151	*	Still operating, fall 1986
04	bull	Mar. 1982	49	0		Died--study area, Mar. 1983
05	cow	Mar. 1982	7	0	*	Transmitter failed June 1982
06	bull	Jun. 1982	9	0		Shot--Canada, Oct. 1982
07	cow	Jul. 1982	84	145	*	Still operating, fall 1986
08	cow	Jan. 1983	60	178	*	Still operating, fall 1986
09	cow	Feb. 1983	67	156	*	Shot--study area, Sept. 1985
10	cow	Apr. 1983	36	157	*	Shot--study area, Oct. 1986
11	bull	May 1983	28	116	*	Shot--Canada, Oct. 1985

* animals monitored in the 2nd phase of the project, 1984-86.

whereabouts; but over 99% of our radio tracking was done on the ground, from truck, snowmobile, mountain bike, or on foot. We used a Telonics (Mesa, Arizona) TR-2 receiver with an RA-2A H-antenna, and measured azimuths with a hand-held Silva Ranger compass.

After determining a general location with the radio receiver, our approach was to move in and conduct our triangulations as close to the animal as possible without disturbing its normal activities. We continued taking readings until we were satisfied that we had accurately located the moose. We used a minimum of 4 compass readings in each case and sometimes as many as 10 to 20. The irregular terrain often impeded signal reception and created signal bounce. In addition, if the moose was moving, considerable time was sometimes needed to derive a valid point or series of points. In general, we assumed that a steady signal indicated a stationary (usually bedded) moose and that a pulsing signal (erratically changing in strength) implied an active moose. Because of the extensive logging road network, we were usually able to move rapidly from one reception point to the next and to construct accurate triangulations with several compass lines at close range. Whenever possible, we attempted to back up our radio locations with sightings, track observations, and other visual evidence. If we felt the moose had moved in reponse to our activities, we attempted to establish the original location by backtracking to the site indicated by initial signals.

We plotted our azimuths on 1:24000 scale ortho-photo maps as we proceeded, and made preliminary decisions in the field as to the precision and accuracy of each radio point. At the end of the day the points were replotted on a large base map, referenced to UTM (universal transverse Mercator) coordinates, and given a final accuracy classification. We defined 4 levels of precision: quality-0, for precise pinpoints backed by visual evidence; quality-1, for small polygons that fit within a 2.5 ac (1 ha) square on the UTM grid; quality-2, for polygons that fit within a 62 ac (25 ha) square; and quality-3, for general locations that fit within a 250 ac (100 ha) block. Over 90% of our locations were quality-0 and quality-1 level points.

HOME RANGES

All sightings of collared moose and most radio points, regardless of quality, were used to delineate home ranges. Because we were interested in tying movement and range to habitat utilization, we chose a descriptive method that emphasizes the *pattern* of use over the absolute size of the area occupied. The harmonic home range system of Dixon and Chapman (1980) computes centers of activity and then surrounds these centers with a hierarchical series of isolines representing different percentages of use. When several activity centers are widely separated, the result may map out as a series of disjunct islands of use rather than as one large unit (see Figures 5-9 and Appendix E).

To calculate and plot ranges I used a FORTRAN program developed by Samuel et al. (1983) at the University of Idaho and modified by Matchett et al. (1984) at the University of Montana. The program plots its isolines with reference to a grid system, the density of which needs to be specified at the outset. The size of the home range that the program calculates will depend upon the density of the grid. A dense grid system more clearly defines compact centers of activity and computes smaller ranges than does a more diffuse grid. Comparisons of home range size can only be made if the same grid density has been used in each case.

Matchett used dense grids (99 x 99 grid lines on a 34 inch plot--at a scale of 1:24000) in calculating his home ranges, and I have done the same in order to make our data comparable. Unless otherwise indicated, all harmonic ranges have a grid density of 99 x 99. For most comparisons I have used the 99% harmonic contour--the area within which 99% of the moose's activity is estimated to occur. Standard t-tests were used to detect significant differences in seasonal range size; Mann-Whitney U (Wilcoxon's two-sample) tests were used for daily ranges.

I also computed home range by the more commonly used minimum convex polygon method (Mohr 1947), which connects peripheral points. The configuration and size of polygons is strongly influenced by outlier points, and is insensitive to the pattern of activity within the range. Because of the dead space included within most polygons, they tend to overestimate the size of the area actually used. However, they do allow for direct comparison with other studies. Appendix E illustrates the relationship between harmonic plots and polygons.

HABITAT SELECTION: USE AND AVAILABILITY

We examined habitat selection principally through use/availability analysis. I pooled 1645 daily radio locations for the 8 moose through the summer of 1985 and extracted a random sample of 400 locations to serve as an indicator of *habitat* *usage* by moose. The sample came from both phases of the study and was stratified by season. Only points with accuracy levels of quality-0 and quality-1 were used. We assumed that these radio points were a representative sample of habitats used by moose and the amount of time they spent in each. We also assumed that the points were reasonably independent of one another, because all of them, for any given moose, were taken at least one day apart.

Habitat availability was based on descriptions of 188 random points within the combined harmonic home ranges (99% contour, 75 x 75 grid, 1:24000 scale) of the 8 instrumented moose, 1981-1985. This defined available habitat as the area normally accessible to the 8 radioed moose, rather than in terms of the entire Yaak drainage. Likewise, we defined seasonally available habitat in terms of the random points that fell within the combined ranges of the 8 moose for the season in question.

All locations were visited in the field, and habitat descriptions compiled. Two sets of descriptions were developed for each location: one for the *site* in the immediate vicinity of the point (an area up to 2.5 ac in size) and a second for the *stand* or silvicultural unit, as defined by the Forest Service, within which the site occurred. If the stand was part of a still larger contiguous unit, either natural or manmade, that unit was inspected as well.

Habitat parameters collected at each radio and random point are listed in Table 2 and defined in Appendix C. The categories within each parameter are shown in Appendices A and B. This array of parameters was designed to characterize habitat relative both to moose and to the *modus operandi* of Forest

TABLE 2. Habitat features measured at moose relocations and at random locations. These parameters are described in detail in Appendix C.

Stand Parameters

Topographic Features: elevation, aspect, percent slope.

Unit Size: unit area, contiguous unit area--open and timbered.

Forage: density of 1st, 2nd, and 3rd-order forage.

Stand Structure: structural type, cover configuration, horizontal dispersion pattern, vertical layering, canopy closure, thermal cover, hiding cover.

Mosaic Pattern: basic mosaic pattern, structural mosaic, hiding cover mosaic, thermal cover mosaic.

Logging Treatments: type of logging, year logged, type of site prep, year of site prep, follow-up treatment, PI type--logging status.

Vegetation Types: habitat type, main cover species, cover type, main regeneration species, regeneration type, PI type--cover class.

Density Measures: PI type--tree density, pole-mature trees/acre, sapling-pole-mature trees/acre, saplings/acre in open, saplings/acre under canopy, understory density, slash and windthrow density.

Tree Size: PI type--size, height of dominants, DBH of dominants.

Special Features: aquatic sites, isolation from human activity.

Site Parameters

General Features: topographic description, ecotone status.

Forage: abundance of 1st, 2nd, and 3rd-order forage.

Stand Structure: structural type, cover configuration, canopy closure, thermal cover, hiding cover.

Distances: to nearest edge, to thermal cover, to hiding cover, to nearest water, to nearest open road.

Service timber management planning, and there is considerable overlap and redundancy among them.

For the sake of efficiency, I used a sampling scheme that relied heavily on estimation, categorization in the field, relative measures, and some previously compiled Forest Service data. The system lacked the fine-grained precision of forest inventory and similar vegetation sampling programs, but has provided accurate information on a scale appropriate to our method of analysis, which requires lumping data into discrete, and often substantial, categories.

The following is a brief synopsis of sampling tactics. My normal procedure was to first walk through the unit and determine the general character of the stand and the amount of variability before going to the sampling point to record site data. In heterogeneous stands I took measurements at several dispersed locations in order to estimate an average condition; in homogeneous units I relied more on information gathered in the vicinity of the random or radio point.

Values for several parameters were obtained from general observation: habitat type, cover type, regeneration type, dominant cover species, dominant regeneration species, types of silvicultural treatment, structural type, horizontal pattern, vertical layering, presence of aquatic sites, mosaic patterns, ecotone status, and topographic description.

Percent canopy closure and thermal cover were measured at several points in the stand with a spherical densiometer. Hiding cover, when not obvious, was guaged by hanging a daypack 4–6 ft above ground level and viewing from 200 ft away. Average height of the dominant overstory was determined with a clinometer at horizontal distances of 75 or 100 ft. Average diameter (DBH) of dominant trees was measured with a standard d-tape. Conifer densities (trees per acre) were estimated with a series of 1/300-acre plots throughout the unit. Average understory and windthrow densities were visually estimated. Forage species were tallied, and the canopy coverage of each species visually estimated and assigned to standard percentage categories (after Daubenmire 1959).

Information taken primarily from maps, aerial photos and the Yaak Ranger District data base included: unit area, elevation, aspect, photo interpretation type, dates of silvicultural treatment, and distances to roads and water. Information taken initially from these sources and then verified or adjusted in the field included: percent slope, habitat type, types of silvicultural treatment, isolation from human activity, and distances to edge, thermal cover, and hiding cover.

Habitat selection was analyzed by comparing the percent use of different habitat categories to their percent availability. We used Marcum and Loftsgaarden's (1980) non-mapping variation of the basic method described by Neu et al. (1974). For each parameter a Chi-square contingency test was used to determine if significant differences existed between the use and availability of the various categories. Calculation of simultaneous confidence intervals (Bonferoni Z tests) then indicated which of the habitat categories were being used out of proportion to their occurrences. This complex of computations was carried out using the Chi-square option of the crosstabs procedure in SPSSx and a FORTRAN program, BONF3.FOR, written by Matchett (1984).

There are two basic problems with this approach to analyzing habitat selection. The first, articulated by Lyon (1985) and McClellan (1985), involves the mathematics of the Bonferoni method. Abundant habitat categories (such as mature timber) may appear unimportant, even at high utilization levels, as long as usage (say, 30%) is not *significantly* greater than availability (say 25%). Use/availability analysis assumes that a moose could show up in this habitat 30% of the time simply by random wandering. However, the fact that an animal spends nearly a third of its time in a particular habitat component suggests that it is probably important. Use/availability comparisons are useful for habitat components that are limiting or unplentiful, but may undervalue components that are not. On the other hand, straight percent use without reference to habitat availability tends to undervalue important resources in short supply.

In evaluating results, I employed two different lines of evidence: (1) significant differences between use and availability within a season and (2) significant changes in use between seasons (excepting cases when availability shifted substantially as well). In order to facilitate these comparisons, I partitioned the year in 2 different ways: (1) into 4 standard seasons and (2) into 2 roughly equal segments--one in which many resources are limiting (November to April) and one in which they are not (May to October).

If most resources are sufficiently abundant from May through October, then the pattern of resource utilization (without reference to availability) during this temperate season should approximate moose habitat preference in the Yaak, and whatever changes in utilization occur during the snow-dominated season may suggest the degree to which moose are limited by particular resources.

A second problem involves the manner in which habitat parameters and categories are defined. Resources need to be defined in a way that reflects the reality of how they are acutally perceived and utilized by animals in the habitat (Johnson 1980). The use/availability approach concentrates on individual habitat parameters rather than on groups of components or on complexes of habitats in juxtaposition (Lyon 1985). I have dealt with this issue by defining several broad parameters (such as structural type, cover configuration, topographic description) that combined the effects of several more narrowly defined measures (such as trees/acre, DBH, canopy closure). I also used the 1022 data management system to create new combinations of parameters after-the-fact, in order to investigate correlations between pairs of habitat categories that were strongly selected for or selected against.

Our within-stand analysis did not deal well with the spatial juxtaposition of large stand-sized components. My only approach to this within the use/availability context was to measure distances from each radio point to nearby contrasting habitats and to provide 4 general descriptors for the local mosaic pattern. Otherwise, I relied on 24-hour monitoring to provide information on between-stand movement and utilization of multi-habitat complexes within a daily range.

In summary, I have attempted to assemble a coherent picture of moose habitat utilization based on (1) the use and availability of individual parameters that overlap and help define one another, (2) comparison of resource use between seasons when resources are limiting and those when they are not, and (3) supplementary information from 24-hour monitoring, investigation of more broadly defined habitat components, and general field observation.

SPECIAL HABITAT COMPONENTS

Field observation during the study, as well as data from other projects, suggested that certain special habitats were likely to be undervalued by use/availability analysis. These were broadly defined habitat components, not well described by our use/availability parameters. In addition, some were used only for short periods of time each year, and accumulated few radio locations. Potential key components that seemed to warrant additional scrutiny included (1) calving areas, (2) aquatic feeding sites, (3) units of winter cover, (4) forested summer feeding areas, (5) travel corridors, and (6) rutting sites.

I located these habitats by tracking moose into them on foot, and then observed behavior and made habitat measurements (sometimes at a later date). I made only casual observations at aquatic sites, since Matchett had already studied these extensively. I located calving areas in 1984 and 1985 by radio tracking collared cows into the sites; I sampled forested summer feeding areas and rutting sites after tracking moose into them, and whenever I encountered them at random; and I examined travel corridors during 24-hour monitoring sessions. Areas of winter cover were identified during 24-hour monitoring and during back-tracking of moose for snow measurements.

CONTINUOUS MONITORING

We initiated continuous 24-hour monitoring of individual moose in the winter of 1984 to see how the animals reacted behaviorally to human activities--hunting and active logging operations in particular. The technique revealed less about response to disturbance than it has about how moose use local habitat in general.

Between February 1984 and August 1985 we conducted 23 monitoring sessions (8 in winter, 7 in summer, and 8 in fall). We employed both visual surveilance and radio tracking. Individual moose were followed at distances close enough for accurate radio tracking and observation, but distant enough to avoid influencing behaviour, as best we could tell. Distances varied from a few hundred feet in dense vegetation to about one half mile in more open country. A map location, habitat description, and activity (either observed or surmised) were recorded each hour for up to 28 hours, and reactions to weather, human disturbance, and other animals were noted. At night we relied on a combination of radio signals, sound, and intuition to provide initial information, and then back-tracked the next day to check our working hypotheses about moose locations and activity. We normally concentrated on a single moose, but if other collared animals were in the vicinity, we monitored as many as possible. This resulted in a total of 33 monitoring sequences in the 23 sessions.

Each monitoring sequence produced 13 to 28 hourly observations per moose. Observations were categorized by habitat, behavior, and time of day, and frequencies involving different combinations of these categories computed for each sample. Mean seasonal frequencies were then derived from this pool of 33 episodes. Standard t-tests were used to detect significant differences between means.

While daily radio tracking (2-5 locations a week for most moose) defined seasonal ranges and indicated the diversity of habitats used throughout a season, intensive tracking in 24-hour blocks provided a more direct, if less statistically rigorous, view of how moose used the local complex of habitats available to them. We were able to delineate daily ranges, and to describe basic activity patterns, day and night, in relation to local habitat features and immediate human activity.

Close-range monitoring worked well for most moose, but it was difficult to apply to the more cautious and evasive animals. We also encountered difficulty in large blocks of unbroken timber and in areas away from the logging roads and maintained trails. Our sample is biased, therefore, toward moose that frequent habitat mosaics within reach of the road and trail system.

SNOW MEASUREMENTS

Snow depth, hardness, and density all influence the ability of moose to move about in winter environments. In order to look at the relationship between snow conditions and winter habitat availability, 3 snow courses were established in the Pete Creek drainage in the winter of 1983. Courses were set along roadbeds inaccesible to vehicles, and consisted of 5 stations in standard habitats: mature timber with >65% canopy closure, a creek bottom in open timber, a grass/forb community, a sapling/brush community, and the roadbed itself. Each course occupied a different topographic position: (1) a relatively high elevation ENE facing slope (3800-3900 ft), a mid elevation drainage (3400-3500 ft), and (3) a mid elevation S facing slope. In 1985 we established an additional course in a series of regenerating clearcuts in Hensley Creek along what we had observed to be a late winter and early spring migration route.

Snow hardness is a measure of the supporting quality of different crust layers, and we assesed this pattern, in addition to total depth, with a snow penetration gauge described by Hepburn (1978). Snow density is a function of water content, but we did not measure it, other than to note when snow was light and powdery (December and January) and when it was wet and heavy (much of February and March).

We ran the courses once a week as long as snow deep enough to impede movement remained on the ground: 6 times in 1984 (Jan.29 to Mar.3) and 10 times in 1985 (Jan.20 to Apr.4). At each habitat station we took 3 readings, intending to compute an average. Total depth was fairly consistent among the 3 measurements, but hardness was not, and the depth to which a walking moose might be expected to sink often varied considerably within an area of a few square feet. Consequently, I have used the deepest of the 3 readings to summarize potential sinking depth at each station.

Kelsall (1969) calculated that a standing adult moose exerted a total foot-loading of about 11 lb/in^2, and that a walking moose (with only 2 feet on the ground at one time) should exert at least twice that. He felt that a snow hardness capable of withstanding 28 lb/in^2 pressure should easily support a walking moose, even when the additional force of locomotion is taken into account. Accordingly, I defined the depth to which the snow guage penetrated at 30 lb/in^2 as the *effective* depth, that is, the depth to which a walking adult moose would be expected to sink.

Based on field observation in the Yaak and on data from other studies (Peek 1976, Petersen 1976, Coady 1974, Kelsall 1969, Nasimovich 1955, Formozov, 1946), I then classified mid to late winter snow depths in the Yaak as:

easily negotiated	<20 in	(<50 cm)
moderately difficult to move through	20-28 in	(51--70 cm)
very difficult to move through	28-35 in	(71--90 cm)
critical: extremely difficult to negotiate	>35 in	(>90 cm)

As we ran the courses, we also tallied the number of fresh moose trails entering and leaving the roadbed, as a rough measure of weekly activity in each area.

During the winters of 1984 and 1985 we back-tracked radioed moose through habitats they had used during the previous few hours, and took measurements at beds, feeding areas, and travel lanes. The number of readings in each tracking series varied from 2 to 12, depending on the homogeneity of the habitat. I later returned to these stands to measure their structural characteristics.

POPULATION ESTIMATES

Population size was estimated by employing the 9 collared moose as a marked sample. All non-radio assisted sightings of moose on the study area were tallied, and the ratio of marked/total animals used to derive population estimates using Bailey's (1952) modification of the Petersen estimator. My assistants and I encountered adult moose over 350 times without use of the radio during our 21 months in the field, 301 of which were within the central study area and used to estimate population. I lumped these sightings into broad sex-age categories (calf, yearling, adult bull, adult cow, unknown) and derived what information I could on population structure and productivity from the resulting sex and age class ratios. Information on mortality and additional data on productivity came from the radio-collared sample itself.

Our emphasis on habitat analysis and home range delineation restricted our ability to analyze population characteristics. The marked sample was small, and our movements throughout the area were irregular and not designed to facilitate systematic moose census. In addition, each sampling period covered several months, and the population underwent changes as we gathered data to measure it. There is no evidence to suggest, however, that these changes (principally migration, hunting losses, and yearling increment) affected the collared segment differently than the unmarked segment of the population. To provide demographic information for the study period, I have combined population estimates into broad seasonal and yearly groupings, and confidence intervals for these estimates are broad.

Many visual observations of collared moose were facilitated to one degree or another by radio readings. Most of these were obvious radio-assisted observations, but occasionally instrumented moose were encountered unexpectedly some time after a brief radio check had indicated that they were in the area. A review of the circumstances in each case resulted in about half being classified as non-assisted sightings.

Density estimates are critically dependent upon delineation of the study area. For this purpose, I defined winter and summer study areas differently and made population estimates for each. I delineated these areas with minimum convex polygons connecting the outermost radio locations and sightings of collared moose for each season (eliminating 2 obvious excursions well beyond the main study area). The resulting areas are those within which we normally operated and within which marked animals could be sighted. Density estimates for these areas are considerably higher than those produced by using the entire 200 mi^2 study area.

In order to correlate ground estimates of moose populations with standard aerial census observations, we made 3 helicopter flights in 1984 and 2 fixed-wing flights of the Yaak River in the summer of 1985.

FIELD SEASONS

The fieldwork for this phase of the study was conducted from January 1984 through April 1986. My field assistants and I were in the field for 21 of the 28 months during the study period. We conducted full-time operations involving daily radio-tracking, sightings, continuous monitoring, and special habitat investigations for the following periods: Winter, summer, and fall 1984; and winter and summer 1985. We carried out a scaled-down operation during fall 1985 and winter 1986 involving some radio locations, sightings, and general observations. I have some data from early and late spring, but have relied mostly on Matchett's data for that season.

SNOW CONDITIONS: RESULTS

SNOW COURSES

Snow conditions capable of modifying habitat availability varied substantially throughout the study area and from one year to the next. Along the Pete Creek snow courses, I found significant differences in snow depth between habitats, between topographic sites, and between years. F-values from ANOVA were significant at $P < 0.05$ for all factors. This was true both for total depth and for the depth to which adult moose were likely to sink, given the snow hardness at each site.

Table 3 presents average snow depths for 3 habitats during the critical period in mid to late winter when accumulated snow has become more dense and may be a factor in habitat selection. In several cases the difference between effective depth and total depth was one of practical significance: total depths may overestimate the potential difficulty that several habitats present to moose in winter. This was particularly true of mature timber in 1985. Snow was supportive enough under the canopy to allow moose to maneuver through what appeared to be prohibitive total accumulations.

The winters of 1984 and 1985 differed significantly, with most accumulations 2 to 3 times greater in 1985. With the exception of the creek bottom on Pete Loop, all 1984 habitats on all 3 courses had average snow accumulations easily negotiated by moose. In 1985, all creek bottoms, open timber, and uncanopied habitats that we measured at these middle elevations (3400–3900 ft) had effective

TABLE 3. *Effective and total snow depths*: late winter averages (late January to early March), 1984 and 1985. Readings were taken in 3 standard habitats along snow courses in Pete Creek drainage. Effective depth is that to which a walking moose is expected to regularly sink (depth at 30 lb/in^2). Total depth is shown for contrast. All depths are given in inches. N = 6 for both years.

	1984 Snow Depths (in)			1985 Snow Depths (in)		
	TOTAL	EFFECTIVE		TOTAL	EFFECTIVE	
	medn	medn	95% CI	medn	medn	95% CI
HENSLEY FACE						
Mature Timber	4	3	1-4	25 .	19	9-28
Creek Bottom	12	9	5-13	31 *	28 *	26-30
Sapling CC	12	10	5-15	42 **	39 **	36-439
PETE BOTTOM						
Mature Timber	16	13	8-18	32 *	20 .	11-28
Creek Bottom	22 .	22 .	19-25	39 **	33 *	28-39
Sapling CC	18	17	14-20	43 **	37 **	34-41
Open Timber	26 .	23 .	17-29	52 **	40 **	31-49
PETE LOOP						
Mature Timber	15	10	3-17	48 **	23 .	7-38
Creek Bottom	30 *	30 *	22-39	51 **	41 **	25-57
Sapling CC	24 .	20 .	15-26	55 **	45 **	32-58

. 20-28 inches depth: difficult to move through
* 29-35 inches depth: very difficult to move through
** >35 inches depth: extremely difficult to move through--critical

mature timber: 65-85% canopy closure; 30-40% slope.
creek bottom: timbered habitat--30-50% canopy closure.
sapling-brush: clearcuts with young saplings in moderate density.
open timber: 40-50% canopy closure; level ground.

Pete Loop: E-NE facing midslope, 3800-3900' elevation.
Pete Bottom: E-NE facing lower slope above creek, 3400-3500' elevation.
Hensley Face: S facing midslope, 3400-3500' elevation.

depths that made movement difficult, if not extremely difficult. Only mature timber provided adequately supportive snow conditions.

The Pete Loop course is particularly instructive in that it traverses higher elevation winter habitat (3800-3900 ft) across a NE facing slope. Creek bottoms in broken cover at this elevation were consistently difficult to move through in both years. Sapling/brush clearcuts were mostly accessible in 1984, in spite of numerous deep snow pockets; but were completely unavailable in 1985. Both of these habitats typically support high-quality deciduous browse that should attract moose unless snow conditions are prohibitive. The adjacent timber, with 70-80% canopy closure and little high-quality forage, was easily negotiated in 1984, and was difficult, but not impossible, to move through in 1985.

Track surveys along the snow course indicated moderate use of the Loop area in 1984 when both timber and many open feeding areas were passable. However, they showed virtually no use at all in 1985 when timbered areas were marginally usable but more open feeding areas were usually impassable. Daily radio tracking and sightings of moose confirmed this pattern. In 1984, 90% of the winter sightings and relocations were between 3500 and 4400 ft, while in 1985, 90% were between 2900 and 3700 ft.

Open stands of timber (less than 50% canopy closure) and many areas near the forest edge did not consistently prevent deep snow accumulation. In fact, saplings and brush in the understories of such stands often caught falling and drifting snow and served to increase snow depth. A small open stand of pole and mature timber regularly sampled along Pete Creek Bottom (Table 3) accumulated deeper snow than nearby clearcuts in both years.

In summary, most habitats up to 3900 ft were available to moose in mid to late winter 1984. Exceptions were creek bottoms with inadequate canopy cover and portions of sapling/brush habitats on N and E slopes. In 1985, snow depths effectively eliminated most N and E slope habitats above 3700 ft, and made movement difficult in open habitats at least down to 3400 ft. Mature forest stands with canopy closures of 65% or more reduced effective snow depths to less formidable levels on middle elevation winter ranges (3400–3900 ft).

TRACKING AND OBSERVATION

Snow measurements taken in habitats actually occupied by collared moose in 1985 corroborate findings from the snow courses. Table 4 shows average snow depths in occupied habitats as well as in a series of unoccupied sapling/brush communities in the same area. Snow depths were fairly consistent from week to week throughout this 8–week period in mid to late winter.

In 1985, when snow accumulations were limiting at higher elevations, most of the collared moose occupied ranges below 3500 ft from early January through late March. At these lower elevations, moose were able to operate in a variety of habitats where the average effective snow depth was about 20–24 inches. They were also able to find snow depths in this range at higher elevations on S facing slopes and in many closed–canopied stands of timber. However, they were unable to exploit most of the sapling/brush clearcuts (used heavily in 1984) due to effective snow depths in the 28–40 inch range from mid January through late

TABLE 4. *Average snow depths* in *habitats occupied by moose*, mid January to late March 1985. Both total and effective depths are given (in inches) for 3 different elevational ranges. Mean values and 95% confidence ranges (in parentheses) are shown. Comparable measurements for a series of 8 sapling-brush clearcuts along Hensley Road are shown to indicate snow conditions in good browse habitats used heavily by moose in the winter of 1984, but used very little in 1985.

Elevation:	29-3100 ft		32-3500 ft		36-4000 ft	
Depth in cm:	total depth	effective depth	total depth	effective depth	total depth	effective depth
USED						
Clearings	29 (25-34)	24 (21-27)	29 (26-32)	24 (22-27)	30 (28-33)	25 (19-31)
Open Timber	25 (23-27)	24 (22-25)	27 (19-36)	24 (15-34)	38 (32-43)	31 (26-36)
Closed Timber	24 (22-26)	20 (18-22)	30 (27-34)	24 (20-28)	35 (32-37)	26 (22-30)
All Habitats	26 (24-27)	22 (21-23)	29 (27-31)	24 (22-32)	34 (32-36)	26 (24-29)
AVAILABLE						
Sapling-Brush Clearcuts	32 (30-35)	28 (26-30)	42 (39-44)	36 (33-39)	41 (39-43)	37 (35-39)

March (Table 4).

Tracking and observation indicated that these animals spent considerable time in the timber, but not necessarily in mature, multi-storied stands. Single-storied pole stands were often used, as were mosaics of closed forest and open clearings. Moose often moved along well-packed trails, detouring off these routes short distances to browse. In the timber, they fed heavily on arboreal lichens, less so on conifer regeneration, and whenever possible, on deciduous shrubs along the forest edges. However, few of them moved out into the middle of these open areas in January and February.

The exception was moose no. 03, a 5-6 year-old bull, who moved up onto a broad bench at about 3850 ft in early February, and remained there for 2 months. Effective snow depths in this area exceeded the critical level (35 in) in open habitats and were often in the 24-31 inch range in the timber. Continuous monitoring indicated that this bull occupied a very restricted daily range (normally about 1 ac), seldom moved out of the timber, fed heavily on available conifer saplings (alpine fir, Douglas-fir, western redcedar), and remained bedded much of the time.

A sequence of thawing and freezing sometimes consolidated the upper layers of snow into a hard crust that was capable of supporting moose in open habitats for several hours or for several days at a time. Some moose used these interludes to move substantial distances to new local ranges and to exploit previously inaccessible browse areas. These conditions, however, were transitory and irregular.

In summary, moose were capable of occupying winter habitats with effective snow depths in the 24–35 inch range for several weeks at a time; but most chose to utilize lower elevation habitats with average effective depths of 20–24 inches. Deep snow in 1985 restricted most middle elevation activity to mature timber, except for occasional opportunistic excursions between these sheltered refugia. Moose at lower elevations ranged more widely, and were less restricted as to the size and structure of timbered habitats they occupied. In 1984, when effective depths in the open were less than 20 inches, most moose wintered higher and spent more time in open browse areas.

SNOW CONDITIONS: DISCUSSION

Both deep snow and abnormnally low temperatures may restrict moose mobility in winter (Gasaway and Coady 1974). Temperatures cold enough to induce extended inactivity (less than -40 degrees f) are uncommon in the Yaak, and a hard winter for moose in this region is normally defined by deep, dense, non-supportive snow that remains on the ground for long periods of time. These conditions make movement difficult and restrict access to high-quality deciduous browse in open areas and at higher elevations. In the Yaak, with few large predators capable of taking advantage of a moose's restricted maneuverability and weakened nutritional state, hard winters are most likely to express themselves in lowered productivity the following year, in the manner suggested by Mech and McRoberts (1987) and illustrated by the pattern of calf production in the Yaak, 1982–86 (see Table 8).

Adult moose have been reported to move easily through light, uncrusted snow at depths of 24-28 inches (Nasimovich 1955) and 30 inches (Petersen 1976). But in denser snow, depths approaching 24-28 inches (70% of chest height) may hinder mobility (Nasimovich 1955, Kelsall 1969, Coady 1974). Peek et al. (1976) found that moose moved into forested areas when snow depths in the open were only about 18 inches. The critical limits that preclude long-term winter use of a habitat are in the 35-40 inch range (Formozov 1946, Nasimovich 1955, Kelsall 1969). In the Yaak, moose usually operated in effective snow depths of 20-24 inches or less, and chose whatever combination of habitats, elevations, and aspects prevented those limits from being regularly exceeded.

In a light-snow winter such as 1984, moose frequent open areas at low and middle elevations (2900-4400 ft) with average effective depths below 20 inches. Good quality winter habitat in these years is similar to good-quality spring, summer, and fall habitat: a mosaic of mature timber and open sapling/brush communities with good browse and abundant escape cover The quality of the timbered cover is a secondary concern.

In deep-snow winters, good *lower elevation habitat* would consist of a similar complex of mature timber and high-quality deciduous browse communities. Presently these are in short supply, and adequate lower elevation habitat is provided by a mosaic of forest stands and less productive clearings with deciduous browse along the edges. Forest structure is less important than at higher elevations (pole timber and single-storied stands are often adequate at lower elevations). Ideally, the stands should be adequately stocked with arboreal lichens and young conifers (western redcedar, alpine fir, Douglas-fir, pacific yew), and forest edge (natural clearings, swamps, skid trails, small logged areas) should be abundant. In these lower elevation habitats, moose move along well packed trails, work the edges, bed for long periods, and move into open areas when snow is supportive.

In a difficult winter such as 1985, moose are capable of occupying middle elevation habitats (3500-4000 ft), but lower elevation sites are preferred. If moose populations increase in the Yaak, use of middle elevation sites should also increase. In deep-snow winters, good quality *middle elevation habitat* requires tall, dense (>70% canopy closure) multi-storied mature timber with abundant supplies of arboreal lichens and conifer regeneration in the understory. These characteristics are associated both with old-growth (Kirchhoff and Schoen 1987, Jenkins 1985, Pierce and Peek 1985) and, in the Yaak, with many mature stands which have not yet achieved old-growth status. Access to open sapling/brush communities does not seem to be crucial.

In middle elevation habitats where moose may be maneuvering in snow which is effectively 24-35 inches deep, they maintain small home ranges, conserve energy by moving infrequently and bedding often, remain in the timber, and feed on lower quality forage available in the understory. They may also move out into open browse areas whenever snow temporarily becomes hard and supportive.

POPULATION PROCESSES: RESULTS

POPULATION SIZE AND DENSITY ESTIMATES

Matchett (1985a) initially computed an adult moose population of about 50 animals for an area of 175 mi^2 for 1982-1983. He felt this to be a low estimate, and revised it upward to 50-70 moose, which translates to 0.29-0.40 moose/mi^2. Because I have delineated smaller, season-specific areas for estimating population in 1984-1985, my densities are higher, and my seasonal subpopulations differ from one another in size and composition (Table 5).

Substantially fewer moose were resident on study area winter range than on summer-fall range. The full summer-fall population occupied an area of about 115 mi^2 extending to the Canadian border (Figure 2). In winter, this population split into 2 or more subpopulations that retreated into separate low to middle elevation enclaves. The collared moose occupied a 20-30 mi^2 range centered in the lower Pete, Hensley, and Lap Creek drainages, and my winter estimates apply to this particular subpopulation.

For any given year, densities on winter range were higher than those on summer and fall ranges (Table 5). The mild winter of 1984 did not result in moose exploiting a larger area, thus reducing winter range density; rather, it resulted in most moose shifting their ranges upslope--to concentrate in the good-quality browse units at 3400-4200 ft. Local densities, in fact, exceeded those of the deep-snow winter of 1985 when most animals moved down to less productive lower elevation habitats on either side of the Yaak River.

TABLE 5. *Estimates of adult-yearling population size and density* based on sightings of marked and unmarked moose in the central study area--as defined by the seasonal areas listed below. Bailey's (1952) modification of the Petersen estimator was used to compute population size. 95% confidence intervals (CI) are shown. Densities are the numbers of adult and yearling moose per square mile.

	RANGE SIZE (MI^2)	ESTIMATED NUMBER of MOOSE		ESTIMATED MOOSE per MI^2		
		median	95% CI	median	95% CI	N
Winter 1984	20.0	35	24--46	1.76	1.21--2.31	72
Summer & Fall 1984	111.0	106	72--140	0.95	0.65--1.26	93
Winter 1985	30.5	41	25--57	1.34	0.82--1.88	54
Summer & Fall 1985	128.5	64	44--84	0.50	0.34--0.65	56

For purposes of estimating population, seasons are defined as follows:
Winter 84 = Jan 6 - Mar 25. Summer-fall 84 = May 26 - Nov 16.
Winter 85 = Nov 25 - Apr 2. Summer-fall 85 = Jun 3 - Sept 30.
Winter 86 = Jan 10 - Mar 5.

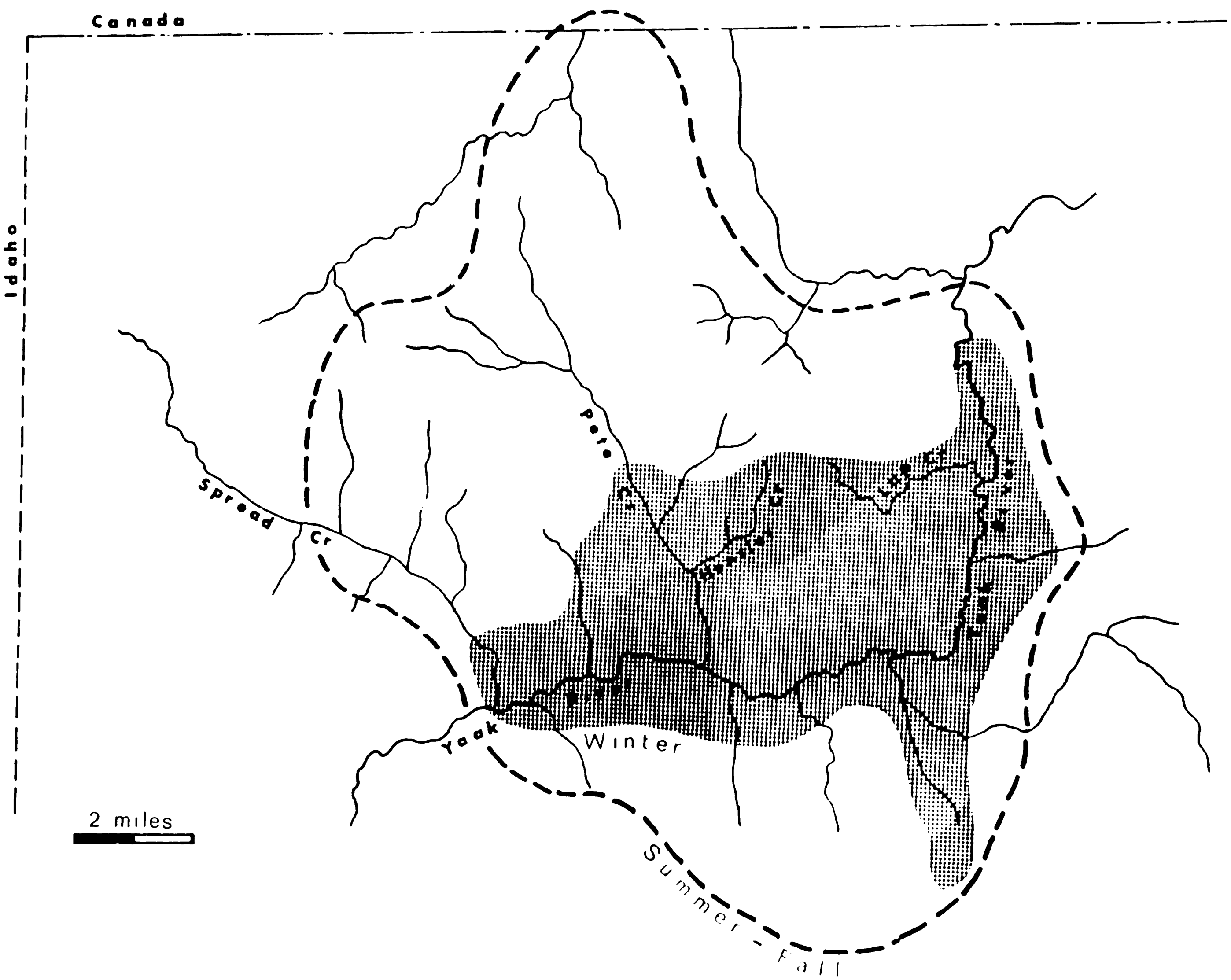

FIGURE 2. Composite ranges for the summer and winter collared moose populations, 1983-1986. Areas of winter occupancy are shaded, those of summer and fall occupancy are enclosed by the broken line. Long expeditions are excluded from this summary.

Table 5 shows a decline in the estimated adult moose population between the summers of 1984 and 1985. Other evidence (high hunting mortality in 1984 and low yearling input in 1985) suggests this decline is real, but these figures overestimate the magnitude. The higher proportion of marked animals in the summer-fall visual sample for 1985 (and thus the lower population estimate) is a function both of fewer moose in the area and of our greater efficiency at encountering collared moose without using the radio receiver that year. The problem did not arise with winter estimates since we were able to locate moose with equal facility in both 1984 and 1985 on compact winter ranges.

In summary, the adult moose population declined between the summers of 1984 and 1985, although broad confidence intervals make more precise conclusions impossible. Moose densities on winter range were higher than on summer range. Snow conditions favoring mobility in 1984 allowed moose access to more productive upslope foraging habitat, but did not result in decreased density on winter range.

SEX RATIOS

Yearly variation in sex ratio estimates from 1982 through 1986 (Table 6) is not sufficient to define a trend (no correlation coefficients are significant at $P < 0.05$). Overall weighted averages for the two halves of the study produce bull:cow ratios of 42:100 in 1982-83 and 41:100 in 1984-85, which indicate a reasonably stable male segment through the 5-year period.

These ratios are low compared to most other moose populations in western North America (Table 7). Although older bulls may be less sightable than cows in

TABLE 6. Sex ratios (bulls:100 cows) from fortuitous sightings, 1982-1985. Ratios include yearlings as well as full adults. Seasonal delineations are the same as in Table 5.

	BULLS per 100 COWS			
Year	Winter	Summer	Yearlong	Sample Size: cows + bulls
1982 *	16	32	25	83
1983 *	70	52	63	64
1984	51	40	44	166
1985	34	40	38	124
1986	40	--	--	7
weighted average	41	42	41	502

* 1982-1983 data are from Matchett (1985a)

TABLE 7. *Sex ratios* from other North American moose populations.

Bulls per 100 Cows	conditions and location	source
41	Winter averages: Yaak	this study
42	Summer averages: Yaak	(1984-86)
81	Hunted, few large predators: NW Wyo.	Houston (1968)
71	Hunted, no large predators: N ctr Idaho	Pierce (1983)
74-77	Hunted, no large predators: SW Montana	Schladweiler (1974)
70	Heavily hunted, no large predators: SE Idaho	Ritchie (1978)
33-79	Light hunting, little predation: central Alberta	Mytton and Keith (1981)
50	Wolf predation and hunting: NE Alberta	Hauge and Keith (1981)
27-64	Heavy wolf and bear predation: S British Columbia	Bonar (1983)

summer and fall in the Yaak (thus depressing bull:cow ratios), there is no evidence from radio tracking, 24 hour monitoring, or general observation to suggest that this is true in winter. I believe that our 1984-86 winter ratios in the 34-51:100 range are reasonably accurate, and the 2-year average of 41:100 is a good median value.

CALF PRODUCTION AND MORTALITY

Cow:calf ratios (Table 8) suggest significant variation in calf production from year to year. The contrast between 1984 and 1985 is particularly striking: cow:calf ratios in the 60-73:100 range (1985) imply a very productive population (Table 9), whereas ratios of 19-22:100 (1984) indicate a calf increment that may not be high enough to offset adult mortality. These yearly swings in calf numbers were evident in the field.

Agents of calf mortality detected and deduced during the study include: birthing problems, malnutrition while nursing, loss of the mother, predation (bears), natural accidents (drowning, injury in rough terrain), vehicle accidents, severe winter weather and deep snow, disease and parasitism, and shooting.

From 1982 onward, mid winter calf:cow estimates are only slightly less than preceding late-summer ratios, which suggests that calves were not lost at an appreciably greater rate than adult cows through fall and winter. Radio tracking and extensive field observation from 1984 through 1986 found little evidence of significant over-winter calf mortality. One collared cow is known to have lost twin calves between late October and late December 1983; and the calves of 2 collared

TABLE 8. Productivity: *calf:cow ratios*, *yearling:cow ratios*, and *twinning rates*--using all non-radio-assisted sightings, 1981-1986. The ratios are numbers of calves or yearlings per 100 full adult cows. Twinning rates (%) are cows with twins divided by all cows with calves. Seasons are grouped into years that begin with the annual calving pulse in early summer.

Year & Season	Calves: 100 cows	Yearlings: 100 cows	Twinning Rate (%)	no. of cows
1981 Summer *	17	--	20	36
1982 Winter *	52	--	--	25
1982 Summer *	62	--	30	42
1983 Winter *	60	--	--	10
1983 Summer *	35	--	37	31
1984 Winter	32	7	--	41
1984 Summer-Fall	22	21	33	68
1985 Winter	19	11	--	37
1985 Summer-Fall	73	11	50	44
1986 Winter	60	--	--	5

* 1981-1983 data are from Matchett (1985a) and pools yearlings with full adult cows.

TABLE 9. *Calf:cow ratios* from other North American moose populations.

Calves per 100 Cows	conditions and location	source
22	late summer--low production year: Yaak	this study
73	late summer--high production year: Yaak	(1984-85)
36	from field observation: central Idaho	Pierce (1983)
64	from collared cows	"
72	uterine counts--6 yr average: British Columbia	Edwards and Ritcey (1956)
167	light predation--early summer: Alberta	Mytton and Keith
122	early winter	(1981)
74-117	wolf and bear predation--winter: S British Columbia	Bonar (1983)
60	wolf predation--summer average: NE Alberta	Hauge and Keith (1981)
54	no predation--fall: SW Montana	Stevens (1970)
53-78	no predation--fall: SW Montana	Knowlton (1960) Peek (1962)
62	no predation--6 yr average: SE Idaho	Ritchie (1978)
49-69	no predation--winter: SW Montana	Schladweiler (1974)
49-66	no predation--early winter: NW Wyo.	Houston (1968
46	wolf predation--5 yr winter average: NE Minnesota	Peek (1976)

cows killed in the fall of 1985 may not have survived the winter on their own. However, moose calves in the Yaak are not subject to the wolf predation that contributes to overwinter mortality on many other North American moose ranges (Bonar 1983, Peek and Eastman 1983, Franzmann and Peterson 1978, Peterson 1977, Peek 1976, Peterson and Allen 1974, Pimlot et al. 1969).

The summer ratios in Table 8 are best interpreted as conservative estimates of the late summer and early fall calf population; and the winter ratios as reasonable mid winter estimates. Early summer calves are often hidden in cover while cows feed in the open, and are much less sightable than older calves. So many of our early summer sightings of cows fail to include the calves, and our more accurate late summer and fall sightings come after most of the summer calf mortality has occurred. Both factors tend to dilute estimated cow:calf ratios to an unknown degree. I assume that this bias is constant from year to year, and that our data accurately reflect trends in productivity.

Comparison of summer-fall calf populations with those of yearlings the following year (Table 8) yields overwinter calf survivorship rates of 60% for 1983-84 and 50% for 1984-85. I suspect survival is better than this, however. Yearlings are often difficult to distinguish from small adults, and may be misclassified as adults or tallied as 'unknowns'. The distinction is particularly difficult for cows from late summer onward. So, while the late summer calf population is only slightly underestimated, the ensuing yearling population is probably significantly underestimated. The average fall-to-spring survivorship of calves is probably similar to that of adults (see Tables 11 and 13), although principal agents of mortality are different in the two cases.

The 1985 twinning rate of 50% (Table 8) is extremely high, and is one facet of the overall high calf production of that year. The range from the 4 previous years of 20-37% twins is still higher than in many other moose populations (Table 10). Estimates of twinning are subject to some of the same biases as cow:calf ratios, and I assume the summer-fall figures presented in Table 8 are characteristic of late summer and early fall populations.

Table 11 provides information on productivity and mortality of the 12 collared moose, 1982-1986. This is a small, but representative sample that complements data from sightings. In particular, calf production is low in 1984 and extremely high in 1985--a consequence both of the high percentage of cows calving and the number of multiple births. In general, cow:calf ratios are higher in the collared sample than in sighting data, since they reflect the early summer calf population rather than overall summer-fall averages (as in Table 8). In this sample, mean annual mortality rate for calves is about 21% over 4 years. Rates of winter mortality are about twice those of summer mortality. Inversely, annual survival to yearling status in this small, but known sample averages 79%. Equivalent survival estimated from the larger, but biased visual sample is only 50-60% (Table 8).

ADULT MORTALITY

Annual mortality among the collared moose has been variable. The average death rate for adult moose in this sample during the study period (1982-1986) was 15% per year. Of 6 moose that succumbed, two were legally shot in British

TABLE 10. *Twinning rates* from other moose populations. These rates are the number of twins divided by the number of cows with calves.

Twinning Rate (%)	survey time and location	source
33%	late summer--low production year: Yaak	this study
50%	late summer--high production year: Yaak	(1984-85)
88%	increasing populn--early summer: Alberta	Mytton and
38-75%	early winter	Keith (1981)
11-22%	winter--6 years: NE Minnesota	Peek (1976)
17-32%	winter--6 years: S British Columbia	Bonar (1983)
22%	fall, winter, spring--6 years: British Columbia	Edwards and Ritcey (1958) *
7-17%	fall--7 years: SE Idaho	Ritchie (1978)
1-12%	winter--6 years: SW Montana	Schladweiler (1974)
10%	summer: NE Alberta	Hauge and Keith (1981)
15%	yearlong--1 year: NW Wyoming	Denniston (1956)
4-5%	early summer--4 years: NW Wyoming	Houston (1968)

* uterine counts

TABLE 11. Known mortality and productivity of the 12 collared moose 1982-86. This summary is derived from the data in Appendix G, Table 2.

	calves: 100 cows	% summer calf mortality	% winter calf mortality	% total calf mortality	% total adult mortality	adult N
1982	40	0	0	0	12%	10
1983	86	17%	33%	50%	12%	10
1984	29	0	0	0	0	9
1985	171	11%	22%	33%	33%	9
1986	100	--	--	--	17%	7
mean annual survival		7%	14%	21%	15%	

Columbia, two were legally shot in Montana, one was killed out of season in Montana, and one died of a bacterial infection from a puncture wound of unknown origin. So, 83% of the mortality in this sample was due to hunting.

Other factors contributing directly or indirectly to adult mortality during the study included: disease and internal parasites, external parasites (ticks), collision with motor vehicles, and other accidents (becoming mired in bog holes).

A major portion of human-induced mortality for 1984 and 1985 resulted from unregulated harvest, both illegal and Indian treaty (Table 12). The lower range of values for each source of mortality is based on known kills; the upper range is deduced from indirect evidence. I set the high estimate for poaching at 100% of the regulated kill based on information from other well-roaded moose ranges (Eason et al. 1981, Ritchie 1978, Schladweiler 1974). The magnitude of hunting mortality in the study population as a whole is imperfectly known. Montana Hunting District 100, for which 15 moose permits are issued, is at least twice the size of the central study area, and the locations of several legal kills are imprecisely reported each year. Experience with collared moose indicates that some of the bulls normally resident in the study area move into Canada during hunting season where they are subject to an entirely different regime of hunting pressure. Some bulls may also move into the Yaak drainage from Canada. Information on Indian treaty harvest and illegal kills was obtained fortuitously in the field and from local residents.

These numbers are applied to the adult-yearling population and expressed as percent loss in Table 13. Considering that the full range of the illegal kill has not

TABLE 12. Estimated sources of *human-induced mortality* in the adult-yearling moose population in the central study area, 1984-1985. Low estimates are based on known kills; upper estimates are surmised from assorted evidence.

	NUMBERS OF MOOSE TAKEN			
year	State Permit	Indian Treaty	Illegal	Total
1984	5 - 9	8 - 12	2 - 9	15 - 30
1985	4 - 8	2 - 5	1 - 8	7 - 21

TABLE 13. *Percent mortality* in the adult-yearling population resulting from *hunter kills* within the central study area. Legal kills include State permit and Indian treaty harvest. Minimum total harvest includes all *known* legal and illegal kills (excluding Canadian harvest). Estimates of the summer-fall population are from Table 5; harvest levels are from Table 12.

1984				1985			
estimated population		% legal harvest	% total kill	estimated population		% legal harvest	% total kill
low	72	18--29%	21--42%	low	44	14--30%	16--48%
medn	106	12--20%	14--28%	medn	64	9--20%	11--33%
high	140	9--15%	11--21%	high	84	7--15%	8--24%

been factored in, the resulting mortality rates are fairly high. Combined with low calf production in 1984, hunting losses in the 10–30% range are sufficient to depress the 1985 yearling–adult population. Natural mortality, although probably low, has yet to be added in to these rates of loss.

SUMMARY

Population size may vary substantially from one year to the next, although no long–term trend, up or down, is evident. Bull:cow ratios are relatively low (winter averages = 41:100) and appear to be holding fairly steady. Calf production is highly variable from year to year, generating late summer calf:cow ratios ranging from 17:100 to 73:100. Twinning rates are normally in the 20–37% range but may exceed 50% in a year that favors high calf production. Early calf survival from birth to mid summer is unknown, but survival of older calves through the fall and winter to yearling status appears to be similar to that of adults for the same period. In essence, the Yaak moose population has the potential for high productivity in certain years, in spite of relatively low bull:cow ratios; and typically brings a high proportion of late summer calves through the winter. Adult death rates are difficult to establish, but evidently average 15% or more per year. Most adult mortality occurs in the fall as a result of hunting, both regulated and illegal.

POPULATION PROCESSES: DISCUSSION

Compared to other North American moose ranges, population densities in the Yaak on both summer and winter ranges are low to moderate (Table 14). Summer range is not limiting and can tolerate densities much higher than our maximum estimate of 1.2 moose/mi^2. During mild winters, good-quality habitat is available in abundance at middle elevations, and could certainly support densities higher than those found in 1984 (median = 1.8 moose/mi^2). Houston (1968) and Stevens (1970) have reported local densities on the order of 28-50 moose/mi^2 on productive winter range in the northern Rockies.

However, in deep-snow winters (which occurred in 4 years out of 6 from 1981 through 1986), most moose move into timber to subsist on lesser quality browse or down to lower elevations where less high-quality browse occurs. In their present status, lower elevation ranges may not be able to support densities much above the 1985 high winter estimate of 1.9 moose/mi^2. Pierce (1983) reported winter densities of about 2.5 moose/mi^2 in old growth forest with abundant pacific yew in the understory in north-central Idaho, and this may serve as a reference density for hard winters in the Yaak. Rather than pack in more tightly at lower elevations, more moose may begin to occupy the mostly vacant stands of mature and old-growth timber at middle elevations (3500-4000 ft) as population pressure increases. At densities of 2.5 moose/mi^2, this area of potential hard-winter range below 4000 ft on the study area should be able to accommodate something on the order of 90-100 adult moose, or 2.2 to 2.5 times the median estimate for the present winter population.

TABLE 14. Moose population *densities* from several studies.

Moose/Km^2	Conditions and Location	Source
1.35 - 1.76	Average densities--winter range: Yaak	this study
0.49 - 0.96	Average densities--summer range: Yaak	(1984-85)
0.47 - 1.06	Low concntr. winter areas: Minnesota	Peek (1976)
1.55 - 2.72	High concntr. winter areas: Minnesota	"
1.11 - 2.02	Overall density: Minnesota	"
0.18 - 4.14	Ave. range of densities--aspen, poplar, and lodgepole: Alberta	Lynch and Morgantini (1984)
0.47	Overall density--boreal forest: NE Alberta	Hauge and Keith (1981)
0.41 - 1.94	Increasing population 1966-79: NE Alberta	Rolley and Keith (1980)
0.44	Relatively low density: Quebec	Messier and
0.57	Moderate density: Quebec	Crete (1984)
0.96	High density: Quebec	
3.80	1948 population peak: Isle Royale	Petersen (1977)
5.23 - 5.72	1969 population peak: Isle Royale	"
about 2.5	Old growth on winter range: Idaho	Pierce (1983)
up to 50	Prime winter range: Jackson Hole	Houston (1968)
28-31	Winter aspen communities: SW Montana	Stevens (1970)
up to 100	Winter willow range: SW Montana	"

Winter mortality is relatively low in the Yaak, both among adults and calves. Deep snow may limit access to good forage, but there are no large predators to capitalize on the low energy reserve and decreased maneuverability of moose during hard winters. Consequently, the primary effect of a hard winter seems to be suppression of calf production the following year. The deep-snow winters of 1982 and 1983 were followed by low calf production in 1983 and 1984, and the mild winter of 1984 was followed by very high production in 1985. Our sequence is of short duration, but Mech and McRoberts (1987) found a good correlation between moose calf production (calf:cow ratios and twinning rates) and snow accumulation the previous year over a 20-year period on Isle Royale.

Peek and Eastmann (1983) and Geist (1974) have concluded that in stable habitats most cows will bear single offspring and live longer than those in unstable environments, where multiple births and shorter lifespan will be the rule. The Yaak is a hybrid situation in that logging maintains a stable supply of open forage, but deep winter snow can limit access to it. Whenever good winter habitat is readily accessible, moose respond with high production.

Sex ratios are fairly low for moose, averaging 41:100 bulls:cows over 4 years. This probably results from hunter selection for bulls over cows in NW Montana (J. Brown, pers. comm.). However, consistently higher bull:cow ratios (70-81:100) are reported from a variety of environments that, like the Yaak, are hunted, but have no large predators (Table 7). Easy road access to much of the fall range in the Yaak may be a factor in lowering the proportion of bulls. Movement of some bulls into British Columbia each fall, where human-induced mortality rates appear higher than in the Yaak, may also be a factor.

Crete et al. (1981) recommended bull:cow ratios of at least 67:100 (40% bulls) to assure high rates of fertilization. This would seem particularly important in the Yaak with its dense forests and low moose densities. We found that both bulls and cows moved frequently in the fall until they encountered a member of the opposite sex, paired up for several days, and then moved on.

Even with a relatively low percentage of males, this system was adequate to produce late summer calf:cow ratios of nearly 75:100 in 1985. A higher bull:cow ratio might have generated even higher numbers. Yearly swings in calf production in the Yaak appear to be primarily a function of maternal nutrition (driven by the availability of winter forage). However, the upper limits of this production may be set presently by the number of mature bulls.

Population simulations with a deterministic model that uses a modified Leslie matrix technique (Metzgar et al. 1984) indicate that the Yaak moose population (with bull:cow ratios well below 1:1, natural mortality in the 3–5% range, and fall calf:cow ratios averaging 35–45%) should not sustain harvest rates much above 12–15% for an extended period. These are moderately conservative estimates, but suggest that the 1984 harvest rates were too high and the 1985 rates marginally so when added to the illegal kill and the Canadian harvest. The fact that natural mortality is low, calf survival relatively high, and most winter habitats in good condition, suggests that the population is depressed below carrying capacity, primarily by human induced mortality.

In certain years, two factors conspire to reduce population levels or to prevent increase: (1) high hunter-induced mortality and (2) low calf production. Rates of natural mortality in the adult population appear low: disease, parasites, malnutrition, predation, and accidents are not now the principal agents of change in this population. The dearth of large predators in winter (primarily wolves) is particularly significant. Calf losses from these same sources probably occur at a higher rate than in adults throughout most of the year. Substantial calf mortality probably occurs in the first few weeks after birth from inadequate nutrition, accidents, and predation, but this will be more than compensated for by a large influx of calves into the population in a productive year, such as 1985.

With the population below carrying capacity, these rates of loss are likely to remain fairly constant. Calf production, however, has the capacity to fluctuate radically from one year to the next, depending on previous winter snow conditions and associated forage availability. Deep-snow winters and low to moderate calf production are the norm in the Yaak. Mild winters and high production on the order of the 1984-1985 sequence occur only once every 3-5 years. Large-scale habitat manipulation to produce high-quality browse at lower elevations should enhance calf production following hard winters, but the prospects are ultimately limited by the amount of appropriate ground available.

Higher, more stable moose populations in the Yaak are most likely to result from manipulating the primary sources of mortality: that is, from depressing unregulated hunting losses and adjusting regulated harvest to coincide with predictable changes in calf production. There is a high probability that calf production will be more than twice normal levels one year after a mild winter--

one in which mid elevation browse units maintain effective snow depths in the 20 inch range.

State permits take a constant number of animals each year, rather than a constant percentage of the fluctuating population. Illegal kill and Indian treaty harvest are opportunistic and unpredictable. A consistent combination of standard regulated harvest, high unregulated kill, and low to moderate increment of yearlings into the adult population has the potential to depress the population or hold it below optimal levels. If unregulated harvest can be kept low, and regulated harvest adjusted annually to account for irregular, but reasonably predictable surges in production, higher moose populations can probably be developed.

HABITAT UTILIZATION: RESULTS

STAND ANALYSIS

The following summary of habitat use and availability is derived from the detailed tabulations in *Appendix A.* The basic sampling units are U.S. Forest Service stands and silvicultural tracts, typically 5–150 ac in size. Parameters are defined in detail in *Appendix C.* I use the terms 'selected for', 'exploited' and 'preferred' to describe use significantly greater than availability and the terms 'selected against', 'underutilized', and 'avoided' to describe use significantly less than availability. On occasion, I have used an index to summarize the relationship between use and availability:

$$I = \frac{\%Use - \%Availability}{\%Availability}$$

Positive values indicate use greater than availability, negative values use less than availability. Particularly strong positive selection produced values of I = 55.0; strong negative selection produced values approaching I = –1.0.

Topographic Features. Collared moose used habitats from about 2900 ft on the Yaak River to about 6000 ft in the uplands. They occupied mostly low elevation habitats in deep-snow winters, low to middle elevation habitats in light-snow winter and in spring, and middle to high elevation habitats throughout summer and most of the fall (Figure 2). During mild winters, moose were able to use middle elevations by favoring S-SW-W aspects.

All winter and spring locations were below 4700 ft, and 65–75% were below 4100 ft. In mild winters, moose selected for middle elevations in the 3500–4300 ft range, and underutilized elevations below 3500 ft. In deep-snow winters, they selected for the lower elevations below 3500 ft and only rarely ventured above 3900 ft. From May through October the low elevations (2900–3500 ft) were notably underutilized in spite of numerous aquatic feeding sites along the Yaak River. Instead, collared moose exploited habitats at middle (4100–4700 ft) and higher (5300–5900 ft) elevations, making periodic treks to aquatic sites on the River. Collared moose consistently inhabitated low elevation habitats only when forced there by deep snow.

Moose selected strongly for S–SW–W facing slopes in late fall, light-snow winter, and spring (54% use; I = 1.45). They used these aspects with relatively lower snow depths to gain access to middle elevation habitats, and they underutilized N–NE–E facing slopes and level ground where snow was deeper. In deep-snow winters S–SW–W facing slopes were used substantially less, and level ground (at lower elevation) substantially more. There was no selection for aspect in summer.

Selection was strong for 25–35% slopes in the light-snow winter of 1984, which reflected heavy use of the accessible mid slope habitats. In deep-snow winters and at other times of the year, there was no selection for any particular slope.

Habitat Unit Size. Over half of the uncanopied openings in the study area were less than 100 ac in size. In spring and in all winters, selection for 20–40 ac openings was particularly strong (27–49% use; I = 1.25 to 3.08). In summer and fall, there was a general shift to larger openings, so that nearly 45% of the uncanopied areas used May through October (Table 15) were larger than 200 ac. The majority of these areas were extensive logged-over pole/sapling/brush communities at middle to high elevations. At the same time, the smallest openings (<20 ac) were underutilized.

Stands of timber smaller than 100 ac were used about in proportion to their availability year-round; but 75–80% of the timbered habitat was in contiguous blocks larger than 100 ac. Moose selected for 100–200 ac stands consistently throughout the year and for 100–500 ac stands in summer. They underutilized stands larger than 500 ac in all seasons.

Forage Abundance. Moose fed primarily on deciduous shrubs, and to a lesser extent on tall forbs, young conifers, arboreal lichens, and submerged aquatic plants. Of 40 forage species and species groups used by moose in the Yaak, 7 were categorized as 1st order (highly preferred) forage, 8 as 2nd order (preferred) forage, and 10 as 3rd order (often-used) forage. This rating system is discussed in detail in Appendix D.

When 1st and 2nd order species were grouped together, selection was strong for habitats with an abundance of this high-quality forage and against habitats in which it was unplentiful, in both temperate and snow-limited periods (Table 16). Moose strongly selected for areas in which abundance of 1st and 2nd order forage was >30% in fall, >45% in winter and spring, and >60% in summer (when such forage was most abundant). Stands with <15% coverage of these

TABLE 15. Use of and selection for different sized habitat blocks by moose. Percent utilization is shown for extended summer (May--Oct) and for extended winter (Nov--Apr). Selection (U/A) for and against various size classes is indicated whenever % use is significantly greater (+) or less than (-) % availability. Each unit is a homogeneous habitat block (open timber, closed timber, sapling-brush association, etc.). Size is given in acres. Data are condensed from Appendix A, Table 2.

	Uncanopied Habitats				Timbered Habitats			
	NOV--APR		MAY--OCT		NOV--APR		MAY--OCT	
Unit Acreage	% Use	U/A	% Use	U/A	% Use	U/A	% Use	U/A
<100	65.6		38.7	-	30.9		20.5	
100-200	19.5		14.3		25.9	++	26.9	++
200-500	11.7		31.6		18.5		37.6	
>500	3.1		13.3		24.7	-	15.1	--

Use/Availability (U/A) notation:
Use > Availability with P < 0.05 (++) and P < 0.10 (+).
Use < Availability with P < 0.05 (--) and P < 0.10 (-).

TABLE 16. Moose use and selection of stand-sized habitat units with regard to the *abundance of 1st and 2nd order forage*. Selection for and against (U/A) different levels of forage abundance are shown wherever % use is significantly more (+) or less (-) than % availability. Abundance of 1st and 2nd order forage is expressed as % canopy coverage, and calculated as the sum of the individual coverages of the 15 species or species groups. Data are from Appendix A, tables 1 and 2.

% COVER 1st+2nd order forage	DEEP-SNOW WINTER		LOW-SNOW WINTER		SPRING		SUMMER		FALL	
	%Use	U/A	%Use	U/A	%Use	U/A	%Use	U/A	%Use	U/A
<15%	63.0		19.6	--	36.9	--	23.4	--	32.4	--
16-30%	18.5		11.8		24.6		31.5		24.3	
31-45%	9.3		5.9		7.7		14.4		18.9	+
>45%	9.5		62.6	++	20.5	++	30.6	++	24.3	+

Selection (Use/Availability):
Use > Availability with $P \leq 0.05$ (++) and $P \leq 0.10$ (+)
Use < Availability with $P \leq 0.05$ (--) and $P \leq 0.10$ (-)

1st-order forage: willows, serviceberry, mountain maple, mountain ash, redosier dogwood, aspen, redstem ceanothus.
2nd-order forage: Utah honeysuckle, menziesia, currants, fireweed (summer), douglas spirea (fall), shiney-leaf ceanothus (winter), young alders, young birches.

species were significantly underutilized in all seasons, in spite of high availability (56–75% of the units sampled).

The progression from underutilization of poor forage areas to heavy exploitation of the best forage units was most striking in the winter of 1984, when low and mid elevation sapling/brush communities were readily accessible. During the winter of 1985, when access to abundant good-quality forage was impeded by deep snow, use was proportional to availability, and moose spent over 60% of their time in the lowest quality forage units. We frequently observed moose feeding on arboreal lichens and certain young conifers (alpine fir, western redcedar, and Douglas-fir) in deep-snow winters, but I found no preference for forest stands that were well stocked with these resources.

When the 10 3rd order forage species were added into this grouping (for a total of 25 species), selection patterns were less well defined (Appendix A), and it appears that an enumeration of the 15 most preferred species will suffice to define good forage units.

Stand Structure. Hiding cover (vegetation capable of hiding a standing moose at 200 ft) was categorized as: complete (>90% of the habitat unit in hiding cover), partial (50–90%), fragmentary (10–50%), and negligible (<10%). In spring and summer, and to a lesser extent in fall and mild winter, moose selected for habitats with complete hiding cover, both in and out of the timber (Table 17). Over 60% of the summer use was in this dense, secure cover. In severe winters, they selected for areas with partial hiding cover, which evidently reflects the amount of time spent on low elevation winter range where partial cover was

TABLE 17. Principal *structural features* selected for and against by moose. Use-availability differences are significant at P < 0.10. Data are from Appendix A, Tables 1 and 3.

Habitat Parameter	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selection For:					
STAND STRUCTURE	lge mature tmbr: tc	sapl: hc	sapl: hc	pole-sapl: hc	x
COVER CONFIGURN	hiding cvr only	hiding cvr only	hiding cvr only	hiding cvr only	hiding cvr only
HIDING CVR	partial	complete	complete	complete	x
THERMAL CVR	x	no cover	no cover	x	x
CANOPY CLSR	x	0%	x	80-100%	x
VERTICAL LAYERING	1-storied	no canopy	no canopy	x	x
Selection Against:					
STAND STRUCTURE	old grwth	pole: hc mature: tc old grwth	seedl: hc pole: hc sm mat: tc	sm mat: tc pole: nc	pole: nc sm mat: tc
COVER CONFIGURN	no cvr	thrm cvr	thrm cvr	no cvr	x
HIDING CVR	no cvr	no cvr	x	no cvr	no cvr
THERMAL COVER	no cvr	good marginal	marginal	marginal	x
CANOPY CLSR	none	60-80%	x	60-80%	60-80%
VERTICAL LAYERING	x	multi-storied weak layering	x	x	x

Notation: hc = hiding cover, tc = thermal cover, nc = no cover.
Parameters with no strong selection pattern are indicated as 'x'.

particularly abundant.

Thermal cover (after Thomas et al. 1979) was categorized as: good (>70% canopy closure in forest stands at least 40 ft, high), marginal (50–70% cc), submarginal (10–50% cc), and negligible (<10% cc). In light-snow winter, moose notably underutilized stands with good or marginal thermal cover and spent over 70% of their time in uncanopied habitats. In the deep-snow winters, use of open areas with little or no canopy dropped to less than 20%, and the remaining degrees of forested cover were used in proportion to their availability in spite of generally lower snow depths in the stands with better cover (>70%). From May through October, moose selected for timber stands with the best thermal cover (>80% canopy closure) and underutilized those with more marginal cover (60–80% closure).

Table 18 integrates hiding and thermal cover into a single classification scheme. Areas with effective hiding cover alone were preferred year-round, and particularly in spring and low-snow winter. These dense, uncanopied habitats were commonly associated (Bonferoni Z, P < 0.05) with abundant high quality forage (Appendix F). Stands with effective thermal and hiding cover together were underutilized in spring and in mild winter, but their use increased significantly in the temperate half of the year (Table 19). Areas without effective cover of any kind were avoided in summer and severe winters.

Moose did not select for multi-storied forest stands in the severe winter of 1985, but rather, spent a disproportionate amount of time in the single-storied stands prevalent on low elevation winter range. They clearly avoided multi-storied

TABLE 18. Moose utilization of the *3 principal cover configurations*: thermal and hiding cover together, hiding cover alone, and no effective cover. Selection (U/A) for and against principal cover types is indicated whenever % use is greater (+) or less (-) than % availability. The basic sampling units are stand-sized habitat blocks.

COVER CATEGORY	DEEP-SNOW WINTER %Use	DEEP-SNOW WINTER U/A	LOW-SNOW WINTER %Use	LOW-SNOW WINTER U/A	SPRING %Use	SPRING U/A	SUMMER %Use	SUMMER U/A	FALL %Use	FALL U/A
Negligible	10.7	--	25.5		18.5		7.1	-	10.9	
Hiding	32.2	+	60.8	++	44.6	++	43.0	+	40.9	+
Thermal	57.2		13.8	--	37.0	--	50.0		48.1	

Use > Availability with P ≤ 0.05 (++) and P ≤ 0.10 (+).
Use < Availability with P ≤ 0.05 (--) and P ≤ 0.10 (-).

Negligible Cover = no effective hiding or thermal cover.
Hiding Cover = partial or complete hiding cover with no overstory.
Thermal Cover = marginal or good thermal cover overhead with partial or complete hiding cover below. (Stands with adequate thermal, but ineffective hiding cover were rare--and not included in this summary).

TABLE 19. *Utilization trends in extended summer*: habitat categories whose use significantly increased or decreased in the temperate half of the year. The shift is from a season when many resources are limited (Nov-Apr) to one in which they are abundant (May-Oct). Differences are significant at $P \leq 0.10$. Significant shifts in use do not necessarily result in use significantly greater or less than availability in summer, although often that is the case. In other cases, use is high in both halves of the year, but no change occurs. See Appendix A, Table 2.

	EXTENDED SUMMER (MAY through OCTOBER)	
habitat parameters	Significant INCREASE in Use	Significant DECREASE in Use
topography		
Aspect	N-NE-E	S-SW-W
Percent Slope		
Elevation	4100-5900 ft	2900-3500 ft
unit area		
Open Habitats	200-500 ac	20-40 ac
Timbered Habitats	200-500 ac	500-1000 ac
forage density		
1st+2nd Order Cover	16-30%	0-15%
1st+2nd+3rd Order Cover	45-60-75%	30-40%
stand structure		
Cover Configuration	thermal + hiding cvr	
Structural Type	poles in hiding cvr	saplings in hiding cvr
Hiding Cover	complete	partial
Thermal Cover	good	none; marginal
% Canopy Closure	80-100%	60-80%
Vertical Layering	multi-storied; mosaic	one-storied; open
mosaic pattern		
Basic Mosaic	fine-grained	no mosaic
Structural Mosaic	sapling:pole	no mosaic
Hiding Cover Mosaic		
Thermal Cover Mosaic	none:submarginal	no mosaic
special features		
Human Disturbance	isolated sites	occas. disturbed sites
Aquatic Site Proximity	streams-rivers	no nearby sites

TABLE 19. continued. Seasonal use trends summer to winter.

habitat parameters	Significant INCREASE in Use	Significant DECREASE in Use
	EXTENDED SUMMER (MAY through OCTOBER)	
logging		
Type of Logging	OSR; salvage-sanitatn	clearcutting
Year Logged	1950-60	1966-70
PI: Logging Status		
Type of Site Prep	no site prep	dozer scarification
Type of Follow-up	no follow-up	thinning-slashing
vegetation types		
Main Cover Species	AF; WRC	no cover; DF; WL
Cover Type	SAF	no cover; MMC
Main Regen Species	AF; WRC	DF; LP
Regen Type	WHC; SAF	LPP; MMC-LPP
PI: Cover Class	SAF	LP
Habitat Type	WRC/CLUN; damp AF	dry DF; mesic DF; ES
vegetation density		
Total t/a	500-1000-1000+	100-300
Pole + Mature t/a	100-300	0-100
Open Saplings t/a	500-1000	0-100
Tmbr Saplings t/a	1000+	100-300
PI: Density Class	good stocking	medium stocking
Eye-level Vegtn Density	v.dense:dense	dense:moderate
Downed Timber Density	moderate; dense	none
tree size		
PI: Size Class	poles	seedl-sapling
Height of Dominants	30-60'	15-30'
DBH of Dominants	6-9"	1-5"

Parameters and categories are defined in Appendix C.

timber in the mild winter of 1984. Use of multi-storied stands increased significantly in the temperate half of the year (Table 19).

From May through October moose selected for sapling/brush communities and for pole/sapling/brush composites, both with good hiding cover (35% use; I = 0.84). Most of these were logged areas, often with good forage (Table 17). Moose avoided open sapling or pole stands with negligible hiding cover (usually recently logged salvage cuts with little forage or cover), and they avoided closed stands of pole and small mature timber (frequently, lodgepole pine stands with depauperate understories). In mild winter, moose heavily exploited sapling/brush habitats (the middle elevation clearcuts with good forage and hiding cover) and underutilized all categories of closed timber. In hard winters they selected for closed stands of large mature timber (although not for pole and small mature timber) and increased use of open mature timber with partial hiding cover. Use of uncanopied sapling/brush and seedling/brush habitats decreased significantly from low-snow to deep-snow winters. Old-growth timber was not abundant, and moose did not select for it at any time of year.

In summary, moose avoided areas with negligible hiding cover year-round. They selected for uncanopied habitats with partial to complete hiding cover in all seasons, but particularly in spring and mild winter. In spring and winter these areas were primarily sapling/brush associations. In summer and fall they were either sapling/brush associations or pole/sapling/brush mosaics. In deep-snow winters, moose selected for large mature timber (most often single-storied stands at low elevation) with no particular canopy closure requirement. In summer, moose increased use of multi-storied timber with dense canopy closure. At all times of the year, they underutilized closed stands of pole and small mature timber.

Mosaic Pattern. In all seasons, moose showed some preference for habitats in which patches of fragmentary, partial, and complete hiding cover were regularly interspersed (Appendix A, Tables 1-3). These mosaics were typically associated with patchy sapling/brush and pole/sapling/brush habitats. In spring, and particularly in deep-snow winter, moose also selected for timber stands in which patches of relatively open (<50% cc) and closed canopy (>50%cc) were regularly interspersed. Use was not high (8-11%), but these networks of timber and forest clearings were not widely available, and selection for them was strong (I = 13.2 in deep-snow winter). The shift to fine-grained mosaics in the temperate half of the year indicated in Table 19 resulted from summer and fall exploitation of the sapling/pole/brush complexes at higher elevations.

Logging Patterns. About 40% of our random locations were within cutting units that had been commercially logged since 1950. Clearcutting accounted for about 45% of the logging, overstory removal for 20%, individual tree and group selection for 13%, salvage-sanitation treatments for 12%, and seedtree and shelterwood cutting for 10%. Since 1980, clearcutting and overstory removal have declined on the study area, and seedtree, shelterwood, and selection cutting significantly increased, particularly on lower and middle elevation winter and spring ranges.

Collared moose were found in logged habitats about 82% of the time in mild winter, 68% in spring, 53% in summer and fall, and 40% in snowy winters (Appendix A: Tables 1 and 3). Logged areas were most important to moose in those seasons when they selected for open habitats: spring and light-snow winter (Table 20). In the winter of 1984, they exploited 12-20 year-old clearcuts, typically those which had been dozer scarified and eventually thinned. In spring, they selected for middle elevation seedtree and shelterwood cuts (all in the 1-10 year-old range) as well as clearcuts. In summer and fall, they decreased use of clearcuts in favor of the 22-35 year-old overstory removal and salvage-sanitation cuts at higher elevations (Table 19). In deep-snow winters all categories were used in proportion to their availability. With the exception of deep-snow winter, moose underutilized unlogged forest stands throughout the year.

Vegetation Types. In the light-snow winter of 1984, moose selected for open habitats (Table 21) and particularly avoided stands dominated by western hemlock (WH), Engelmann spruce (ES), and Douglas-fir (DF), none of which are associated with good forage (Appendix F). In the winter of 1985, they significantly decreased use of open areas, and selected strongly for mixed conifer stands in which western larch (WL) was a predominant component (53% use; I = 1.04). From May through October, there was a significant decrease in the use of WL stands and an increase in the use of western redcedar (WRC) and alpine fir (AF) stands. This represents a shift from winter range stands with moderate quality forage (WL) to the best summer range forage stands (AF), and to good summer thermal cover (mature WRC). In general, stands with overstories dominated by DF and LP were

TABLE 20. Selection for and against habitat characteristics associated with *logging*. Data are from Tables 1 and 3 in Appendix A.

	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selection For:					
PI: LOGGING STATUS	x	logged	logged	logged	logged
TYPE OF LOGGING	x	clearcut	sdtr-shltrwd clearcut	x	x
YEAR LOGGED	x	1966-70	1966-70	x	x
TYPE OF SITE PREP	x	dozer scar	dozer scar	x	x
TYPE OF FOLLOW-UP	x	thinned	thinned	x	x
Selection Against:					
PI: LOGGING STATUS	x	unlogged non forest	unlogged non forest	non forest	x
TYPE OF LOGGING	x	unlogged	unlogged OSR	unlogged	unlogged
YEAR LOGGED	x	x	1951-60 1961-65	x	x
TYPE OF SITE PREP	x	none	none	x	x
TYPE OF FOLLOW-UP	x	none	none	x	x

Selection for or against is significant at P < 0.10
Parameters with no strong selection pattern are noted as 'x'
Notation: OSR = overstory removal, sdtr-shltrwd = seedtree-shelterwood
PI = USFS Photo Interpretation type

TABLE 21. Primary *vegetation types* selected by moose. Data are from Appendix A, Tables 1 and 3. Selection is significant at P < 0.15.

	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selected For:					
MAIN COVER SPECIES	WL	no cover	no cover WL	WRC. AF	x
COVER TYPE	MC	no cover	no cover	x	x
MAIN REGEN SPECIES	LP. AF	LP	LP. WRC	WRC	x
REGEN TYPE	LP	LP/MC	LP/MC	x	x
PI: CVR CLASS	x	MC	MC	MC	x
HABITAT TYPE	non conifer	WH/CLUN	WH/CLUN	WRC/CLUN	x
Selected Against:					
MAIN COVER SPP	DF. WH	DF. ES. WH	DF. LP	DF. LP	LP
COVER TYPE	x	MC/LP SF/LP	SF/LP	x	x
MAIN REGEN SPP	WL. WH	ES	DF	DF	x
REGEN TYPE	MC/WHC	SF. WHC/MC WHC/SF/LP	SF/LP	SF/LP MC/WHC	x
PI: COVER CLASS	x	non conifer	non conifer	non conifer	x
HABITAT TYPE	WRC/CLUN	WRC/CLUN	dry DF ES non conifer	dry DF. ES mesic DF non conifer	ES

MC = mixed conifer, SF = spruce-alpine fir, WHC = westn hemlock/redcedar
WRC/CLUN = westn redcedar/*clintonia uniflora*.
AF = alpine fir, DF = Douglas-fir, LP = lodgepole pine.

underutilized year-round, although they accounted for 27-31% of the cover.

In winter 1984, there was strong selection for habitats dominated by LP seedlings and saplings (63% use; I = 0.47). These units typically included a substantial amount of WL in addition to LP (LP/mixed conifer regeneration type), and were often associated with an abundance of good forage. In winter 1985, moose continued to select for LP regeneration, although without the strong WL component, and increased their use of areas dominated by AF and ES regeneration (often associated with mature timber). From May through October use of openings with LP regneration significantly decreased, and the use of high country AF regeneration (with good forage) and mid elevation WRC regneration (in good thermal cover) increased.

Habitat Type (Pfister et al. 1977) is used by the Forest Service to indicate the potential of a site to produce a particular climax community. Approximately half the study area was dominated by one habitat type: Western Hemlock/*Clintonia uniflora*, primarily a middle elevation type. Moose selected for habitats associated with it in the winter of 1984 and in spring, but in other seasons used it in proportion to its availability. From May through October, moose significantly decreased use of DF habitat types and increased use of the WRC type and of damp AF types (Table 19). This corresponds to a shift away from lower elevation habitat types with poor forage (DF) and toward mid elevation timber (WRC) and higher elevation units with high-quality forage (AF).

In summary, moose selected for uncanopied habitats, particularly those dominated by associations of lodgepole pine and western larch saplings, in mild winters. In severe winters, they selected for stands of timber with western larch predominant in the overstory and for habitats with either lodgepole pine or western larch the dominant regeneration. In the temperate portion of the year, as moose moved to middle and high elevations, use of western larch stands decreased and selection for western redcedar stands (good thermal cover) and alpine fir stands (good forested forage) increased; open areas dominated by alpine fir regeneration were selected instead of those dominated by lodgepole pine. Stands with overstories dominated by Douglas-fir and lodgepole pine were underutilized all year.

Tree Density and Stocking Levels. In general, moose selected habitats with the thickest vegetation in summer and the least dense vegetation in deep-snow winters (Table 22). There was a significant shift from habitats with relatively low vegetation density in the snow-limited part of the year to those with relatively high vegetation density in the temporate half of the year (Table 19).

Timber stands with a high density of overstory trees (300-500 t/ac) were infrequent on winter range, but in deep-snow winters, moose selected heavily for them. At the same time, they selected stands with a rather sparse understory component of saplings (<100 t/a) and of downed timber (Table 22). Associated hiding cover was usually partial (Table 17). In mild winter conditions, they also selected for sparse conifer understories (<100 sapl/ac) when in the timber; but nearly 85% of the locations were in habitats with light or no overstory (<100 t/ac). In these uncanopied habitats they selected for moderate to heavy conifer stocking (300-1000 sapl/ac), which, combined with brush, produced dense eye-level

TABLE 22. *Stand densities* selected for and against by moose. Tree density is expressed as trees/acre (t/ac).

	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selected For:					
PI: TREE DENSITY	medium	medium	medium	x	x
MATURE+ POLE t/ac	300-500	0-100	0-100	x	x
SAPLINGS IN TIMBER t/ac	0-100	0-100	0-100	x	x
SAPLINGS IN OPEN t/ac	100-300	300-1000	300-500 500-1000	500-1000	500-1000
EYE-LEVEL VEGETATION	dense:mod	v.dense:dense	x	v.dense:dense	x
DOWNED TMBR	light	light	x	x	x
Selected Against:					
PI: TREE DENSITY	non stockd	non stocked well stockd	non stocked	non stocked	x
MATURE+ POLE t/ac	x	100-300	100-300	x	x
SAPLINGS IN TIMBER t/ac	x	0-100 >500	x	x	x
SAPLINGS IN OPEN t/ac	0-100	0-100	0-100	0-100	0-100
EYE-LEVEL VEGETATION	light:light	x	light:light	light:light	light:light
DOWNED TMBR	x	dense	x	none	x

Selection is significant at $P < 0.10$. 'x' = no strong selection.

vegetation and complete hiding cover.

In spring, moose continued to exploit uncanopied habitats with high levels of conifer stocking (300–1000 sapl/ac). In summer and fall they selected for even denser stocking (500–1000 and >1000 sapl/ac). Combined with deciduous brush, these regenerating conifer units provided dense hiding cover and abundant browse. Throughout extended summer, moose also increased use of timber stands with abundant regeneration (>1000 sapl/ac) and heavier deadfall in the understory. Moose were able to maneuver through stands with dense accumulations of downed timber, and in all but deep-snow winter, there was no selection for or against slash and windthrow density.

In all seasons, moose underutilized open habitats with sapling densities less than 100 t/ac, which were classified as non stocked photo interpretation (PI) types. In these poorly stocked areas, brush density alone was normally not sufficient to provide adequate hiding cover.

Tree Size. Selection for tree heights and diameters (DBH) in fall, mild winter, and spring reflected preference for habitats dominated by saplings, both large and small (1–5" DBH, 6–30 ft high) (Table 23). Selection in deep-snow winters reflected preference for stands of mature timber (60–100 ft high) and for areas dominated by larger saplings (16–30 ft, 5–9 m high). Moose avoided stands of pole timber (6–9" DBH, 30–60 ft high) in all seasons except summer (when they used open pole/sapling mosaics). They did not select the open habitats dominated by seedlings (<5 ft high) in any season, and selected against them in deep-snow winters and spring. At the other end of the spectrum, they never selected for old–

TABLE 23. *Tree sizes* selected for and against by moose. Data are from Appendix A, Tables 1 and 3.

	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selected For:					
PI: SIZE CLASS	x	seedl-sapl	seedl-sapl	x	x
DBH OF DOMINANTS	1-5"	1-5"	1-5"	x	1-5"
HEIGHT OF DOMINANTS	60-100'	6-15' 16-30'	6-15' 16-30'	x	6-15"
Selected Against:					
PI: SIZE CLASS	pole	medm sawt lge sawt	pole	x	x
DBH OF DOMINANTS	<1" 6-9"	6-9" 10-15" 15-30"	<1"	x	6-9"
HEIGHT OF DOMINANTS	30-60' >100'	30-60' 60-100' >100'	1-5' 30-60'	x	30-60'

Selection is significant at P < 0.10
Parameters with no strong selection pattern are indicated as 'x'

Notation: sawt = sawtimber, seedl-sapl = seedling-sapling growth or for the largest mature timber (>100 ft).

Proximity to Aquatic Sites. Moose were found in habitats adjacent to streams, ponds, or swampy ground 41–52% of the time. In all seasons but fall, moose selected strongly for proximity to swampy areas, which provided access to abundant high-quality browse throughout the year and to succulent forbs in summer (Table 24). In fall, selection for proximity to swampy habitat was marginal. From May through October, use of habitats adjacent to streams and rivers increased significantly (Table 19) as submerged aquatic and herbaceous streamside vegetation became readily available.

Proximity to Human Activity. Habitats with the potential for occasional disturbance by humans comprised about 70% of the winter-spring range and about 60% of the summer-fall range; frequently disturbed areas made up 9–12% year-round. In winter and spring, when moose were confined to lower elevations, they selected for habitats with occasional disturbance (most typically from vehicle traffic on adjacent forest roads) and against frequently disturbed habitats (Table 24). In summer and fall, as higher elevations became accessible, they used areas well isolated from human activity significantly more than in winter and spring (Table 19).

SITE ANALYSIS

The following summary of habitat use and availability at sites immediately surrounding radio and random locations is derived from the tabulations in

TABLE 24. Selection for and against *proximity to various habitat features*. Selection is significant at P ≤ 0.10. Data are from Appendix A, Tables 1 and 2 and Appendix B, Tables 1 and 2.

	DEEP-SNOW WINTER	LOW-SNOW WINTER	SPRING	SUMMER	FALL
Selection For:					
NEARBY AQUATIC SITE	swampy ground	swampy ground	swampy ground	swampy ground	x
DISTANCE TO OPEN WATER	<300 ft	300-600 ft	600-900 ft	<300 ft	x
HUMAN DISTURBANCE	occas disturbed	occas disturbed	occas disturbed	x	x
DISTANCE TO OPEN ROAD	x	x	<300 ft	x	x
DISTANCE TO EDGE	x	<300 ft	<300 ft	<300 ft	<300 ft
Selection Against:					
NEARBY AQUATIC SITE	streams	x	no sites nearby	no sites nearby	x
DISTANCE TO OPEN WATER	>1500 ft	>1500 ft	>1500 ft	>3000 ft	x
HUMAN DISTURBANCE	frequently disturbed	frequently disturbed	x	x	x
DISTANCE TO OPEN ROAD	>1500 ft	x	>3000 ft	x	x
DISTANCE TO EDGE	x	>600 m	>600 m	>600 m	>600 m

'x' denotes no strong selection pattern for the season in question

Appendix B. Sites were defined as 2.5 acre (1 hectare) zones around sample points, unless otherwise delineated by local habitat features, such as small clearings, patches of timber, clumps of brush, bogs, etc.

Topographic Features. From May through October, moose significantly increased use of stream bottoms and draws. This parallels the increment in use of habitats adjacent to open streams detected by the stand analysis for temperate seasons. Otherwise, moose exhibited no strong preference for topographic features in any season.

Ecotone Status. About 10-11% of the availabile sites in the study area were within extensive ecotones, often partially logged zones between open cuts and the timber. Moose showed marginal preference for these habitats in low-snow winter, but used them in proportion to their availability in other seasons.

Structural Features. The use and availability of hiding cover, thermal cover, structural type, and cover configuration were measured both for local sites and for the stand-sized blocks surrounding them. Results were similar in both cases, but site analysis provided some additional information.

In all parts of the range, local sites were more likely to have either complete or negligible hiding cover (the 2 extremes) than the stand-sized blocks surrounding them. This reflects local clumping of hiding cover within the larger units. Moose selected strongly for stand-sized habitat units with dense overall hiding cover in spring and summer, but then showed no preference for *sites* with complete cover within these units. That is, they selected for broad areas in which good hiding cover was readily available but often unevenly distributed; but they were not necessarily found within the patches of densest cover. Selection for habitats with these patchy interspersions of hiding cover, particularly from May through October, was also illustrated by the use patterns of stand-sized mosaics.

Moose showed no preference for sites with any particular degree of thermal cover, except in mild winter, when they selected both for sites and for stand-sized habitats without any effective overhead cover.

Distances to Edges and Cover. About 55% of our random sites were within 300 ft of a primary structural edge. Moose selected strongly for relative proximity to these edges in mild winters, and to a lesser degree in other seasons. They underutilized areas more than 600 ft from an edge at all times of the year (Table 24). In low-snow winter, this affinity for edges translated into greater use of ecotones as well.

Moose spent 70-76% of their time at sites with partial or complete hiding cover in winter and 83-86% in spring, summer, and fall. In summer, they clearly avoided sites more than 300 ft from this cover, but otherwise, they showed no preference for proximity to such cover when not in it, at any time of the year.

In the winter of 1984, moose selected strongly against sites within thermal cover, but selected strongly for sites within 600 ft of these timbered habitats. This parallels selection for ecotones and proximity to edges in general in winter 1984, and follows from heavy exploitation of small to medium sized clearcuts (20-40 ac). In other seasons there were no selection patterns for or against proximity to thermal cover.

In summary, moose spent 75-94% of their time in stand-sized habitat blocks with complete or partial hiding cover. Dispersion of cover within these units was often clumped, and moose used the varying degrees of local cover (fragmentary, partial, complete) more or less in proportion to their availability. When in hiding or forested cover, moose selected, to one degree or another, for relative proximimity to edges in all but deep-snow winters; but when not in cover, they showed no affinity for edges, except in summer.

Distance to Water. Moose selected strongly against sites more than 1500 ft from open water in winter and spring (11–13% use; I = −0.67 to −0.72) and selected for sites within 300 ft of water in harsh winters (Table 24). This appears to be a function of lower elevation winter and spring ranges where the majority of good moose habitat is located along the Yaak River and its tributaries.

In summer, up to 18% of the radio locations were more than 1600 ft from water and only sites beyond 3000 ft were avoided. At the same time, sites within 300 ft of open water were selected for. Selection for draws and stream bottoms in summer, as well as for higher elevations, shows that most of these summer locations were near upland streams rather than lowland bottoms along the Yaak River.

In fall, about 33% of the moose locations were more than 1500 ft from open water, and there was no selection for or against proximity to aquatic sites. The higher proportion of use at some distance from aquatic sites in the temperate half of the year reflects greater mobility and access to upland slopes and ridges. Moose were able to move substantial distances between dry upland sites and aquatic bottoms with a dispatch not possible in the snow-limited half of the year.

Distance to roads. There were no strong, consistent selection patterns for or against proximity to driveable roads. However, moose did not avoid sites near open roads in any season, unless activity was particularly heavy, and they were not averse to using forest roadways and snowmobile tracks as travel lanes, day or night.

Forage Abundance. For the most part, utilization patterns of 1st and 2nd order forage at local sites were similar to those for stands and silvicultural units as a whole. In summer, moose selected for sites with 1st and 2nd order forage abundance as low as 30%, while selecting for broad units with overall coverage only as low as 60%. As with hiding cover, this suggests that moose selected for broad habitat blocks with abundant good quality forage, but were not always found in intimate association with the best patches of forage within the larger mosaic (at least during the day when most radio locations were made).

DIFFERENCES BETWEEN MOOSE

Our sample of radioed moose was small (N=8), and I was unable to detect any clear differences in habitat use between cows and bulls, between cows with and without calves, or between younger and older moose.

However, I was able to divide collared moose into 2 groups based on their general response to human activity and their tolerance of exposed environments. Based on field observation, I classified 2 cows and 1 bull (nos. 01, 07, and 11) as consistently reclusive and intolerant of daytime exposure, and the remaining 5 animals as relatively tolerant. These groupings apply particularly to the temperate half of the year when moose were more able to indulge individual preferences for habitat.

Use/availability analysis indicated that the less tolerant moose selected strongly for isolated habitats (51% use; I = 0.60) while the more tolerant group underutilized these areas (18% use; I = −0.43). The more cautious group also used complete hiding cover (69% use; I = 1.30) significantly more than other moose (47% use; I = 0.56) and almost completely avoided areas of negligible and fragmentary hiding cover. No other clear differences (in use of thermal cover, stand structure, topography, edges, etc.) were evident between the 2 groups.

SPECIAL HABITAT COMPONENTS: RESULTS

CALVING SITES

Moose calves were born from mid May to early June. Of 6 collared cows, 3 made abrupt long-distance moves (4–8 mi) from spring ranges at low and middle elevation to calving areas at relatively high elevation each year. The other 3 cows moved to calving sites closer to or within their spring ranges. Cows remained near these sites for several days after giving birth. Most cows returned to the same general region of a particular drainage each year to calve, but not to a specific site. In spite of heavy logging, cows were able to find alternative sites each year within their traditional calving areas in the middle and upper reaches of all study area drainages.

Some cows preferred more isolated calving sites than others. In our sample (N=10), 80% of the sites were more than 1500 ft from an open road and were separated from human activity by physical barriers, such as rough terrain, heavy blowdown, dense brush, and large streams. The remainder were in areas of occasional human activity.

Minimum requirements for a good calving site appear to be (1) dense hiding cover, (2) the proximity of water, and (3) the proximity of good forage. Most sites were in stands of large mature or old-growth timber, although canopies were frequently open or spotty. All but one of these blocks of contiguous cover were larger than 150 ac, and half were larger than 500 ac. Only one site was in a logged unit (an old overstory removal), although several were near cutover areas. Cows normally foraged in these more open adjacent habitats, leaving the calves hidden in the timber.

AQUATIC FEEDING SITES

Moose fed on submerged aquatic vegetation at regular intervals from May through October. Matchett (1985a) described a pattern of long distance cycling between upland core areas and aquatic feeding sites in the Yaak River, and I observed the pattern regularly in 5 of the 9 collared moose. Sloughs, backwaters, and natural impoundments, generally 1-6 ft deep, with good supplies of rooted aquatic vegetation (pondweeds, elodea, aquatic buttercups) and some hiding cover along the shore provided effective aquatic feeding habitat. Moose typically spent 1-3 days on the river before returning to higher elevation browse habitats, where they remained for up to several weeks.

Four collared moose relied primarily, or entirely, on aquatic sites in the uplands: ponds, slow streams, and swamps with open water. The essential ingredients were (1) a body of open water of sufficient age, depth, and stability to support rooted aquatic plants and (2) an associated buffer of effective hiding cover on shore. In addition to screening open-water activity, the cover provided a refuge for moose using the site during the day and a hiding zone for calves left on shore. They often used these upland sites for only a few minutes at a time before moving on to another site or into adjacent cover. In late summer, as water evaporated, moose came in to chew through the mud at some sites, evidently for algae or soil nutrients.

DAMP FORESTED SITES

Stream bottoms, damp draws, and swampy ground inside stands of mature timber with good canopy closure served as summer feeding areas for moose, particularly on hot days. Moose sign was concentrated here, and radio-tracking, along with 24-hour monitoring, confirmed heavy use. These swaths of moist substrate supported abundant herbaceous forage, as well as high-quality browse, in otherwise forage-poor habitats. Moose frequently foraged along these cool timbered bottoms during the day, and then moved out into open browse areas at night.

All of the heavily exploited sites that I examined were in stands of timber wider than 300 ft. There was no consistency as to habitat type or forest cover type, but all stands had complete hiding cover, as well as good thermal cover. The feeding zones themselves ranged from narrow strips along small streams to broad forested swamps. Few of these bottoms were used in winter because of deep snow and the demise of the herbaceous forage.

RUTTING SITES

I examined only 4 rutting sites where bulls had temporarily established themselves while attempting to attract cows. Each contained a small area of disturbed ground, ranging from disheveled litter and top soil to well-worked dust wallows. One site was in a dense brush/sapling/pole mosaic with no overstory; another was in an open, but brushy stand of mature timber 100 ft from a new cutting unit; and the other two were in closed stands of mature timber within 150 ft of cutover areas dominated by brush and saplings. All sites were on fairly level ground, in partial and complete hiding cover, and were near edges or within some kind of structural mosaic. Otherwise, there appeared to be no stringent requirements with regard to vegetation, topography, or proximity to human disturbance.

TRAVEL LANES

In winter, moose often restricted local movement to well-packed trails in deep snow, and took advantage of snowmobile tracks and packed roadways when moving longer distances. During seasons when mobility was not limited, they still frequently moved along traditional routes in traveling from one local range to another. But I was unable to detect any unifying features that consistently distinguished these corridors from adjacent habitat.

SUMMARY

Calving sites, aquatic feeding sites, and damp forested bottoms with good forage are key habitat components for moose in the Yaak, each defined by a fairly specific array of parameters. The essential elements of rutting areas and travel lanes appear to be more broadly defined and widely available.

CONTINUOUS MONITORING: RESULTS

USE OF COVER

In fall and winter, use of hiding and thermal cover was similar, day and night. Table 25 shows no significant day/night differences in the amount of time moose spent in 3 principal cover configurations during these seasons (no t values are significant at $P > 0.05$). They did not consistently employ darkness as a form of hiding cover to exploit exposed habitats.

In summer, moose spent significantly more time in timbered cover during the day and more time in open environments (hiding or negligible cover) at night ($t = 3.45$, $P < 0.01$). They appear to have been using timber as a thermal umbrella to avoid daytime heat. The timber ranged from classic thermal cover (>70% canopy closure) down through partially open stands (30-40% canopy closure) that provided patchy, but useful shading. In the winter of 1985, moose spent most of their time

TABLE 25. Relative *distribution of activity* by moose among three *different cover configurations*, day and night. Frequencies were computed for each moose for each continuous monitoring session (13-28 hourly observations), and mean seasonal frequencies then derived from this pool of 34 episodes. N = the number of moose monitored at each session. 95% confidence limits are shown ( ).

		% of time in each habitat			
season	time	negligible cover	hiding cover	forested cover	N
Winter 1984	day	23% (±30)	70% (±27)	6% (±8)	8
	night	24% (±28)	72% (±32)	3% (±6)	
Winter 1985	day	7% (±28)	9% (±18)	84% (±32)	5
	night	1% (±2)	12% (±24)	87% (±26)	
Summer 1984-1985	day	8% (±5)	16% (±10)	75% (±11)	10
	night	24% (±21)	39% (±27)	34% (±27)	
Fall 1984	day	16% (±13)	31% (±24)	53% (±24)	10
	night	15% (±18)	45% (±15)	40% (±22)	

Cover Configurations.

Negligible cover includes: grass-forb, seedling-lowbrush, open timber with little understory.

Hiding cover (partial or complete) includes: sapling-highbrush, pole-highbrush, open timber with sapling-highbrush understory.

Forested cover (>30-40% canopy closure) includes: pole, mature, or old-growth timber with at least partially closed-canopy.

winter = mid-late winter (mostly February-March).

in timbered cover (>70% canopy closure), day and night, while in the less snowy winter of 1984, they favored more open habitats. This is evidently a response to snow depth, rather than to temperature or weather conditions. We found that moose often remained in habitats with little or no canopy for several hours during prolonged periods of rain and sleet, heavy snow, high wind, and subzero temperature, even when thermal cover was nearby.

ACTIVITY PATTERNS

In summer, fall, and the winter of 1984, moose allocated roughly 50% of each 24-hour period to bedding, 35-40% to steady feeding and 10-15% to steady traveling or moving and feeding (Table 26). However, in the winter of 1985, when snow depths in many habitats were limiting, they spent significantly ($t = 5.95$, $P < 0.01$) more time bedded (about 75%) than feeding (about 25%) and seldom moved from one local range to another. All winter observations were made during the most restrictive part of the season in February and March.

In winter 1984, moose bedded somewhat more often during the day than at night ($t = 2.31$, $P = 0.05$); but in other seasons, there was little difference in how they distributed their activity between nightime and daylight hours (Table 27). In summer and fall, they were bedded (or active) about 50% of the time, day or night. In winter 1985, when snow was deep, they spent significantly more time bedded than active, but the pattern was similar, day and night. We were unable to detect any significant differences in activity between bright moonlit nights and dark overcast nights. So with the possible exception of winter 1984, moose did not

TABLE 26. Principal *activity patterns* from continuous monitoring. Results are given both as the average number of hours and the percent time observed at each activity per 24-hour period. Frequencies were computed for each moose at each session, and mean seasonal frequencies then derived from these 33 sessions. N = the number of moose followed in each season. 95% confidence intervals are shown ( ).

Season	Number of Hours/Day and % of Time per Activity					
	BEDDED		STEADILY FEEDING		TRAVELING	
	hours	%	hours	%	hours	%
Winter 1984	12.5 (±1.4)	52%	9.1 (±1.0)	38%	2.4 (±0.2)	10%
Winter 1985	17.8 (±2.8)	74%	6.2 (±1.0)	26%	0.0	0%
Summer 84-85	11.8 (±0.7)	49%	8.4 (±0.5)	35%	3.6 (±0.2)	15%
Fall 1984	12.2 (±0.7)	51%	8.9 (±0.4)	37%	2.9 (±0.2)	12%

These behaviors represent the predominant on-going activity at each observation--although they may be interrupted by other behaviors, such as standing alert, retreating to cover, interacting with other animals.

TABLE 27. The percentage of time moose were found *bedded*, night and day, during continuous monitoring. N = the number of moose monitored each season. 95% confidence intervals are shown ( ).

	% daylight hrs bedded	% dark/twilight hrs bedded	% total time bedded
Winter 1984	61% (±16)	42% (±12)	51% (±10)
Winter 1985	76% (±15)	68% (±50) *	74% (±16)
Summers 84-85	50% (±10)	49% (±8)	50% (±5)
Fall 1984	49% (±11)	50% (±6)	49% (±6)

* Winter 1985: 13-14 hr sessions with only 4-5 nighttime observations--marginal for deriving useful frequencies.

consistently take advantage of darkness to mask increased activity in open habitats.

In summer and fall, moose bedded more frequently ($P > 0.05$) when in timbered cover and were more active in uncanopied habitat (Table 28). Sample size is small for timbered habitats in winter 1984, but moose appear to have bedded down less frequently in these habitats than in summer and fall, and were relatively more active when in uncanopied hiding cover. In winter 1985, however, they bedded about 70–90% of the time while in the timber. Sample sizes are small for open habitats with no effective cover, but the observations we do have indicate that moose were not averse to bedding down in these exposed environments on occasion.

Moose regularly alternated bouts of activity and bedding throughout the day and night (Table 29). We found these alternating episodes to be as short as 5 minutes and as long as 7 hours, but typically, they ranged from 1.4 to 3.7 hours in duration. In summer and fall, average rounds of activity were the same length as periods of bedding, all in the 2 hour range. In winter 1984, periods of bedding averaged marginally longer than those of activity. In the winter of 1985, bedding sessions were significantly longer than bouts of activity ($t = 3.35$, $P < 0.05$).

SUMMARY

With the exception of winter 1984, when moose were somewhat more active at night, activity patterns were similar day and night. Moose alternated short periods of bedding and activity regardless of lighting conditions. Lighting

TABLE 28. The percentage of time moose were *bedded* (and, inversely, were active) while in three *different cover configurations*. Data is from continuous monitoring. 95% confidence intervals are shown ( ).

	% time bedded while in different habitats		
	negligible cover	hiding cover	forested cover
Winter 1984	31% (±33)	53% (±19)	17% (-) *
Winter 1985	62% (-) *	31% (-) *	80% (±11)
Summer 84-85	31% (±17)	43% (±14)	57% (±11)
Fall 1984	43% (±20)	41% (±17)	57% (±16)

forested cover = overhead cover + hiding cover; hiding cover = hiding cover only; negligible cover = no effective hiding or overhead cover.

* Very few observations in these habitats (see Table 25)--frequencies of marginal utility. Confidence intervals not computed.

TABLE 29. Average duration of alternating *bedding and activity bouts*, derived from continuous monitoring. The average number of bedding and activity (usually feeding) episodes per 24 hour monitoring session is also shown. 5% confidence limits are indicated ( ).

	ave. duration in hours			
	rounds of activity	bedding sessions	ratio: active/bedded	ave. no. sessions per 24 hrs.
winter 1984	1.6 (±.6)	2.3 (±.7)	0.70	13.5 (+3.5)
winter 1985	1.4 (±.5)	3.7 (1.8)	0.38	10.0 (+2.9)
summer 84-85	1.8 (±.4)	1.7 (±.2)	1.06	14.4 (+2.1)
fall 1984	2.0 (±.3)	2.1 (±.6)	0.95	11.8 (+1.9)

conditions did not appear to consistently influence the manner in which moose used open habitat or hiding cover, but moose did appear to employ timbered cover to avoid daytime heat in summer.

In summer, fall, and mild winter, moose spent approximately 50% of their time bedded, 35–40% feeding, and 10–15% traveling. In summer and fall, an average of 45–60% of this time was in timbered cover (35%+ canopy closure); in mild winters, only 5–15%. In deep-snow winters, moose were bedded about 75% of the time, made few changes of base, and, in February and March, spent about 80% of their time in stands of closed timber.

Our sample suggests that under ordinary conditions moose spend about half their time in timbered cover, divide their time equally between bedding and active pusuits regardless of habitat, and are little influenced by lighting conditions in their activity and habitat use. They modify these patterns significantly in response to hot weather and deep, wet snow.

HABITAT UTILIZATION: DISCUSSION

Moose are basically solitary animals, and I observed an individualism in behavior, movement patterns, and habitat preference that tempered generalization. The following discussion defines those habitat parameters and components that are of primary importance to the Yaak moose population, and then considers secondary parameters that represent variations on these basic themes.

PRIMARY PARAMETERS

All essential habitat components for moose in the Yaak can be characterized in terms of the abundance, distribution , and quality of 4 primary parameters: (1) forage, (2) hiding cover, (3) overhead cover, and (4) aquatic sites. The remaining parameters examined in this study deal with proximate factors associated with these 4 primary elements to one degree or another (see Appendix F). Principal external factors that modified the suitability of habitats defined in this way were: (1) winter snow depth and structure, (2) summer heat, (3) roading associated with timber harvest, and (4) cutting unit design.

Browse abundance has been shown to be a primary determinant of habitat selection for moose in a number of studies (Telfer 1978, Peek et al. 1976, Berg and Phillips 1974, Kelsall and Telfer 1974, LeResche et al. 1974). In the Yaak, moose selected strongly for habitats with abundant high quality forage in both temperate and snow-limited portions of the year. These patterns broke down only under incisive limiting conditions: persistent daytime heat in summer and deep, dense snow accumulation in mid to late winter. In both cases, moose took advantage of forest stands with effective overhead cover (either as a thermal umbrella or snow shield), often abandoning sites with preferred forage until conditions moderated. The mid winter shift from open browse habitats to timbered cover is one of the more frequently documented phenomena among North American moose populations (Jenkins 1985, Pierce 1983, Thompson and Vukelich 1981, NcNicol and Gilbert 1980, Schlegel and Christensen 1979, Ritchie 1978, Eastman 1977, Schladweiler 1974, Peek 1971, Stevens 1970, Telfer 1970). The use of timber as a thermal refuge in summer has also been noted, although less frequently (Leptich 1986, Belovsky 1981, Belovsky and Jordan 1978).

Hiding cover has not been measured as a separate entity on most moose ranges, although its importance is often noted (Leptich 1986, Jenkins 1985, Thompson and Vukelich 1981, McNicol and Gilbert 1980). In the Yaak, moose selected for habitats with effective escape cover, both in and out of the timber, at all times of the year. Hiding cover is important to moose in this area both for its security value and because of its high association with abundant browse (Appendix F: Tables 1 and 2). The secure foraging areas resulting from this association are particularly important in a heavily roaded environment such as the Yaak in which human-induced mortality is a principal decimating factor.

Exploitation of aquatic feeding sites in early and mid summer is a characteristic feature of most, but not all, North American moose populations (Peek 1974b). Submerged and emergent aquatic vegetation provide an easily digested, high energy food source (Belovsky 1978, deVos 1956), as well as supplying minerals (particularly sodium) in short supply in upland browse (Belovsky and Jordan 1981, Fraser et al. 1980, Jordan et al. 1973). In the Yaak, aquatic feeding sites were used regularly by all monitored moose in summer, even when it was necessary to forgo hiding security to do so, and even when a trek of several miles was required.

SEASONAL USE PATTERNS

I recognized 5 seasons of habitat use for moose in the Yaak: (1) *late winter* (approximately Feb–Mar); (2) *spring* (Apr–May); (3) *summer*, including calving (Jun–Aug); (4) *early fall*, including the rut (Sept–Oct); and (5) *late fall/early winter* (Nov–Jan).

Late Winter. Mid to late winter was the most restrictive part of the year: availability of good forage, access to much of the range, and general mobility were restricted to one degree or another by snow depth and structure. In deep-snow winters, moose selected for habitat conditions that minimized snow depth and the energy expenditure associated with maneuvering in deep, heavy snow (Parker et al. 1984) and at the same time provided the best forage possible under the circumstances. These were typically low elevation stands of mature timber with effective thermal cover (>50% cc) and a substantial amount of edge. Ideally this was internal edge provided by small browse-rich clearings (swamps, small meadows, small logged patches, open trails and old roads), although edges along larger cutting units sometimes provided productive margins as well. These fine-grained mosaics in which fringes of good browse were intimately associated with patches of effective overhead cover, occurred irregularly along the Yaak River bottom and provided the best habitat for dealing with deep snow. This pattern increased the amount of good quality browse availabile to moose without forcing them to plow through deep snow in the open areas to get at it.

A number of other studies have recognized the importance of forest margins as key habitat components for moose in late winter (Monthey 1984, Thompson and Vukelich 1981, Davis and Franzmann 1979, Eastman 1974). McNicol and Gilbert (1980) noted that in Maine cutting units, selection was stronger for edges associated with small islands of residual timber rather than for the perimeters of large cuts. Eastman (1974) found that the mosaics of small cover and food producing units created by partial cutting were used more heavily in winter than more coarse-grained mosaics involving clearcuts, burns, and larger blocks of timber.

When deciduous browse was not available in sufficient volume along the edges, moose turned to alternate forage in the timber: primarily arboreal lichens and the more palatable coniferous undergrowth (alpine fir, western redcedar, and Douglas-fir). Lichens are a low protein, high energy food source, easily digested, but lacking essential minerals (Klein 1982, Kubota 1974). Conifer foliage is high fiber browse and relatively difficult to digest (Jenkins 1985, Gasaway and Coady 1974). Moose rely heavily on these food sources in deep-snow winters, but do not select for stands in which they are particularly abundant. Rather, they select for mosaics of timber and open browse first, and make do with whatever lichen and conifer supplies are available. At low elevations, mature, mixed conifer stands dominated by western larch appear to provide the appropriate mix of these elements most often; pole and young mature stands, especially those dominated by lodgepole pine and Douglas-fir, generally do not.

In hard winters, moose did not normally select for stands with the best snow interception and thermal characteristics. Rather, they selected for low elevation, where average snow depths were less formidable and where the broken canopied mosaics with better forage potential were adequate to keep effective snow depths in the 20-24 inch range. At higher elevations, tall, multi-storied, dense-canopied stands of the sort that provide winter habitat on several other moose ranges (Kirchhoff and Schoen 1987, Doerr 1984, Pierce and Peek 1983, Thompson and Vukelich 1981, Eastman 1974) were necessary to provide adequate refugia from deep snow.

Throughout the year, moose normally spent about 9 hours a day feeding and were bedded about 12 hours (Table 26)--observations that are consistent with other studies (Craighead 1973, Geist 1963). In a deep-snow winter, however, we found that moose bedded an average of 18 hours a day. In addition to conserving energy, longer periods of bedding and rumination are required for digestion of less palatable browse, such as conifer foliage (Gasaway and Coady 1974). Schlegel and Christensen (1979) and Stevens (1970) observed that in deep snow, Shiras moose sought shelter in dense timber, ate whatever was available, and restricted movement. This is what we found, to varying degrees, in the winter of 1985.

This process of maximizing the net rate of energy assimilation in snow-limited environments through optimal habitat selection and variable activity budgeting was described by Jenkins (1983) for moose in the North Fork of the Flathead River. He postulated that when total snow depth approached 30 inches, moose were no longer able to maintain positve energy balance foraging on preferred browse in open habitats, and the optimal strategy at that point was to move into forested cover and subsist on lower quality understory vegetation. Total snow depths that triggered a similar response in the Yaak in mid winter were also in the range of 30 inches (and in the range of 20-24 inches effective depth). Continuous monitoring suggests that moose wintering at higher elevation in deeper snow (>28 inches effective depth) spent even more time bedded and maintained smaller daily ranges. Moose further reduced effort in deep snow by moving along trails regularly used by deer and other moose when actively foraging.

In winters with less snow, moose occupied habitats at middle elevations that allowed them to maximize energy intake. These were primarily open-canopied logging units, 20-60 acres, dominated by conifer saplings and abundant deciduous browse, and often by good hiding cover. Effective snow depths in these habitats were less than 20 inches through most of the winter. There was evidently little to be gained in security or energy balance from occupancy of timbered habitats, and moose spent only about 10% of their time there.

The habitats moose exploited most heavily in milder winters contained a high diversity of preferred browse species as well as high abundance. Low browse species diversity may in fact be a significant factor in the deterioration of some moose ranges (Oldemeyer et al. 1977). Miquelle and Jordan (1979) felt that optimal foraging strategy for moose was one of concentrating on areas with good supplies of several preferred species. One result of continual access to these diverse browse communities by the Yaak moose population in winter 1984 was very high calf production one year later.

Although many of these 20-60 ac units were frequently used by 3 to 8 moose at once throughout the winter and spring of 1984, browse condition remained good. The resource was abundant and diverse, the moose population relatively low, and these habitats normally had 2-3 years to recover between periodic mild winters. Good low elevation, hard-winter habitat, on the other hand, was less common and was used more consistently from year to year. Although natural hydric shrub communities occured all along the Yaak River, they were not extensive in the study area, and many were close to human habitatation and well used roads. Most of the good winter feeding habitat in the Yaak was temporary habitat maintained by logging. This is atypical of most Shiras moose winter range and more characteristic of ranges occupied by Canadian subspecies (*A. a. andersoni* and *A. a. americana*) to the north (Peek 1974a).

Spring. In spring, moose were relatively free from thermal and nutritional stress. Most middle elevation habitats became available as snow receded, forage quality was enhanced by spring green-up, temperatures moderated, and human disturbance remained fairly low.

Prime spring habitat was similar to mild winter habitat: mid elevation cutover areas with good browse and hiding cover. Toward the end of a hard winter, moose began to drift up to middle elevations whenever effective snow depths began to drop below about 20 inches. Snow depths less than 20 inches have been associated with spring migration in other areas as well (Coady 1974, Edwards and Ritcey 1956). In early spring, moose often foraged in open seedtree and shelterwood cuts which lost snow cover relatively early and were strewn with windblown branches covered with arboreal lichens. They then moved into browse-rich sapling/brush associations as snow levels in these deep-snow habitats dropped.

Gasaway and Coady (1974) have pointed out the advantage of regular movement by moose to areas with abundant immature plant growth, since these provide the most digestible and nutritious forage. As spring progressed, moose increased their intake of easily digestible high energy food by slowly moving upslope with the spring greenup, using forbs as they became available, and exploiting aquatic vegetation as soon as growth was sufficient later in the season.

Moose made more use of forest stands in spring than in mild winter, but I suspect this was due more to a relaxation of the need to maximize energy intake in the open browse units in winter than to thermal or security needs imposed by the spring environment.

Summer. Factors limiting moose populations on summer range and influencing habitat selection in that season have been less well defined than have winter constraints. Pierce and Peek (1984) felt that moose in central Idaho exhibited weak selection patterns in summer due to a general relaxation of limiting factors; and other studies have drawn the same conclusion (Brusnyk and Gilbert 1983, Hauge and Kieth 1981). However, Leptich (1986) described strong summer selection for cover types by moose in Maine, and argued that different preferences between cows and bulls canceled one another when data were pooled, effectively masking selection patterns. I relied on pooled data, but was able to detect significant summer habitat selection through a combination of use/availability analysis, 24-hour monitoring, and directed field observation.

In summer, access to all parts of the range was unlimited, mobility was unhindered, high quality browse was abundant, and loss of body heat was not a significant problem for moose. However, restrictions on behavior and habitat use were imposed by the need to locate calving sites and protect calves, the need to moderate the effects of high daytime temperatures, the recurrent use of aquatic feeding sites, and the relatively high level of human activity. These were constraints that influenced the suitability of otherwise available habitat, and they differ in kind from the limited resource availability created by deep winter snows.

McClellan (1986) concluded that if an animal is familiar with its home range, and if important resources are reasonably accessible and not limiting, then the sites the animal frequents will be sites it has actively selected. In these circumstances, percent use should directly reflect selection, as long as the habitat features the animals are actually selecting for have been correctly identified. Applied to moose on Yaak summer ranges (Table 30), this system emphasized the importance of several *abundant* habitat features undervalued by use/availability analyses: stands of large mature timber, stands with effective thermal and hiding cover, unlogged P.I. types, mixed conifer cover types, sites subject to occasional human disturbance, and habitats not immediately adjacent to aquatic sites. On the other hand, it underrated the value of several *smaller* categories that many moose key in on: abundant high quality forage, pole/sapling/brush associations, and alpine fir cover types, among others. These percent use distributions provided a good initial map for identifying important summer habitat components, but they required clarification from other sources: in this case, an evaluation of use in relation to availability and of shifts in use from winter to summer.

As moose were gradually released from the restrictions imposed by snow accumulation and lesser forage quality in late spring, the following patterns

TABLE 30. Three lines of evidence for *habitat selection in extended summer* (May--Oct), when most resources are assumed not to be limiting: (a) percent utilization alone, (b) the significance of use/availability differences, and (c) the significance of changes in use from extended winter (Nov--Apr) when many resources are limited.
Percent use significantly greater (+) or less than (-) availability is indicated for $P \leq 0.10$. Significant increase (+) or decrease (-) in percent use from winter is also indicated for $P \leq 0.10$.

Parameters	Habitat Categories	SUMMER HABITAT SELECTION (a) % USE	(b) USE/AVAIL contrast	(c) SMR/WTR contrast
ABUNDANCE OF 1ST AND 2ND ORDER FORAGE	<15% cover	26%	-	-
	15-30% "	31		+
	30-45% "	12		
	45-60% "	15	+	
	>60% "	17	+	
COVER CONFIGURATION	no effective cover	10%		
	hiding cover only	41	+	
	thermal & hiding cvr	49		+
QUALITY OF HIDING COVER	none	3%	-	
	fragmentary	10		
	partial	32		-
	complete	55	+	+
QUALITY OF THERMAL COVER	none	26%		-
	submarginal	25		
	marginal	13	-	-
	good	36	+	+
PROXIMITY TO AQUATIC SITES	none nearby	44%	-	-
	streams	25		+
	ponds	8		
	swampy areas	23	+	+

TABLE 30. Summer habitat selection. Continued.

Parameters	Habitat Categories	(a) % USE	(b) USE-AVAIL contrast	(c) SMR-WTR contrast
AMOUNT OF HUMAN DISTURBANCE	frequent	4%		
	occasional	65		-
	infrequent	31		+
USFS P.I. TYPE: LOGGING STATUS	logged	56%	+	
	not logged	43		
	non-forest	1	-	
USFS P.I. TYPE: COVER CLASS	western hemlock	4%		
	spruce-fir	12		+
	mixed conifer	75		
	lodgepole pine	3	-	-
	non-stocked	6		
	non-conifer	1	-	
STRUCTURAL TYPE	*negligible cover*	10%		
	hiding cover only			
	sapling-brush	20		-
	pole-sapl-brush	15		+
	mature timber-brush	5		
	thermal + hiding cvr			
	pole & sml mature	12	-	
	lge mature timber	32		
	old-growth	5		
ELEVATION	< 2900'	3%	-	-
	3500--4100'	31		
	4100--4700'	40	+	+
	4700--5300'	12		+
	5300--5900'	13	+	+
	> 5900'	2		

developed: (1) they began to exploit the best quality forage habitats at middle and higher elevations (prominently the sapling/brush clearcuts and large sapling/pole/brush mosaics generated by logging in the 1960's); (2) they increased use of isolated areas and dense hiding cover, both in and out of the timber; (3) they increased use of the best thermal cover during the day and began to exploit damp, well-vegetated draws in the timber; (4) they increased use of upland stream bottoms in general; and (5) they decreased use of lower elevation habitats in general.

In summer, many moose exploited higher elevation habitats. These presented newly accessible forage in association with good hiding cover, local aquatic sites, and greater isolation from human interference. These features were of value to cows seeking calving sites and protecting young calves as well as to the more reclusive segment of the population in general. Lower elevations in the Yaak Valley provided numerous aquatic feeding sites, but fewer secure foraging areas and a significantly higher level of human activity. These areas were abandoned by the majority of the population as snow conditions permitted. However, the Yaak River was important enough as a source of aquatic vegetation to draw many moose back down at regular intervals throughout the season.

Calving and maternal care served to limit the range of appropriate habitats for many cows in early summer. Leptich (1986), Rounds (1978), Stringham (1974), and Altmann (1963) all listed isolation and heavy cover as important characteristics of calving sites and of early summer habitat for cows with calves. Protection against intrusion by predators, humans, other moose, and other large animals in general were primary motivating factors. I found that the habitat features defining security for cows with newborn calves varied from one individual to another. In several cases, isolation was a key ingredient; in others, solitude was not essential as long as hiding security was adequate and forage and water accessible.

Summer was the only season in which I detected significant differences in habitat use between day and night. In hot weather, most moose frequented timbered habitats during the day and uncanopied habitats at night and at twilight. Moose were less active under forest canopies than in open habitats, but they did actively forage in the timber. They worked the moist forage-rich bottoms, the forest edges, and the more open-canopied patches within each stand, as well as wandering broadly through forage-poor stands. Although moose invested more time in feeding at night, they continued to alternate periods of activity and bedding about every 1-3 hours during this time, rather than maximizing feeding time out in these browse-rich habitats. The constraints associated with summer heat were apparently insufficient to radically alter daily activity patterns in the manner of deep winter snow. In addition, unlike Best et al. (1978), I found no diminution of foraging effort or of general movement on dark moonless nights, at least in browse-rich habitats.

Moose using the extensive sapling/pole/brush habitats in the upland basins often foraged far from large stands of timber, but were able to find adequate thermal cover in small patches of mature and pole-sized alpine fir and Engelmann spruce. These residual islands of cover, ranging from tight groupings of 3-4 trees to long strips of timber in the creek bottoms, were abundantly dispersed throughout the old cutting units. They provided local thermal pockets sufficient for individual moose bedded down on hot summer days. Dense conifer foliage in sharp draws with flowing water were particularly effective. It appears that moose will use stands of classic thermal cover where logging has created alternating blocks of timber and open foraging habitat, but that large foraging areas with numerous small islands of thermal protection can serve the same purpose in summer.

Early Fall. In early fall, forage quality and diversity deteriorated, but access to all habitats remained unlimited. Principal factors with the potential for modifying behavior and habitat suitability were the large influx of hunters and the aggression and frequent movement associated with the rut.

Early fall range was similar to summer range. Stands of timber and aquatic sites were used somewhat less, but open browse units were used extensively at middle and higher elevations, and moose continued to move throughout broad ranges, both during and after the rut. Habitat features associated with rutting areas did not appear to be limiting or to require patterns of habitat selection different than in summer. Moose no longer selected for thermal cover, and used uncanopied habitats more frequently during daylight hours. Although most moose reacted to human encounters by retreating to escape cover, they did not increase their use of habitats with effective hiding cover or select for areas close to it. Nor did they select for more isolated habitats or sites further from active roads.

In fact, use/availability comparisons indicate that, in terms of habitat selection, early fall was the least restrictive season for moose. Forage was of lesser quality but still abundant, mobility was unrestricted, thermal conditions were moderate, calves were larger and more self-sufficient, the need for aquatic vegetation seemed less pressing, and no significant changes in habitat use were induced by the rut or by the onset of hunting season.

The apparent failure of moose to significantly adjust habitat use in response to hunting may put them somewhat at risk, but the majority were already making good use of effective hiding cover at this point. My observations suggest that moose that had been more reclusive in summer continued to be so in fall, and that the more tolerant individuals continued to forage in more open habitats and to use areas close to active forest roads. Many moose occasionally, and some moose frequently, selected for preferred forage at the expense of hiding cover in areas where the two were not intimately associated. These were often large cutting units less than 15 years old. This, coupled with greater daytime use of uncanopied habitats, made these animals particularly vulnerable to hunting.

Late Fall/Early Winter. In late fall and early winter, access to higher elevation habitats began to be restricted by accumulating snow. Energy balance was influenced by low temperatures, lesser quality forage, and the difficulty of moving through snow. Late fall/early winter snow pack was relatively light and unlayered, but in 1985 most moose moved down out of the high country in November as total snow depths began to exceed 24 inches.

Moose made substantial use of low and middle elevation cutover units with good browse and adjacent timber during this period--habitats similar to those used in the latter half of light-snow winters and in spring. It was not uncommon to find several moose together in a single cutting unit (although evidently not operating as a tight social unit). Moose were relatively more sightable in late fall, due to their concentration at lower elevations, their use of more open habitats than in summer and early fall, and the significant drop in potential human intrustion from the snow-bound road system.

SECONDARY PARAMETERS

Because effective cover and abundant forage may be associated with a broad range of habitat features, several of the parameters commonly used to characterize habitat for management were unsuccessful in consistently sorting out selection patterns. Among these were most systems for describing vegetation type, topographic features, unit size, and logging.

The size of the habitat blocks for which moose selected was largely a function of habitat structure. Moose typically chose (1) large habitat units with internal mosaics of hiding cover, forage, and overhead cover (abundant internal edge) or (2) smaller, more homogeneous units regularly interspersed with other units of contrasting cover and forage quality (abundant external edge). The smaller clearings were typically 20-60 ac; the larger clearings 100-500 ac. The smaller stands of timber were typically 100-200 ac; the larger stands 200-1000 ac. Moose did use large, exposed clearings and uniform forest stands, but mostly toward the edges.

Cover type, regeneration type, and habitat type were important to moose only insofar as they were correlated with good forage, thermal cover, or hiding cover. For example, mixed conifer stands dominated by western larch frequently provided the best forested forage on winter range, while lodgepole pine stands were among the least productive. However, a fine-grained mosaic of mature lodgepole and brushy clearings was also capable of producing the essential result: palatable forage closely associated with overhead cover. On summer range, good forested forage was often found throughout alpine fir stands in damper habitat types. But moose were also able to locate good forage in association with effective thermal cover along the damp bottoms inside dense stands of mature western redcedar with otherwise depauperate understories.

The appropriate mix of food sources, thermal refugia, and hiding security can be generated by several combinations of cover type, stand structure, and topographic position, and the combinations which most frequently provide this mix of habitat features at present are largely a function of land use practices over the last 30 years. The logging systems, cutting unit design, locations, and stand types characteristic of timber harvest between 1955 and 1970 have determined which combinations of secondary parameters are most likely to be associated with good forage and cover. As these factors change, the kinds of cutting units and vegetation types that moose select will also shift to a certain extent.

KEY COMPONENTS

The manner in which moose exploit basic habitat elements and react to modifying influences defines 6 key habitat components. These are: (1) calving areas--isolated sites with dense hiding security and nearby sources of good forage and water; (2) aquatic feeding sites--ponds and streams with submerged aquatic vegetation and good hiding cover around at least half of the shoreline; (3) forested summer feeding sites--cool, damp bottoms and draws in mature timber that supply high-quality herbaceous forage on summer range; (4) Winter cover/forage mosaics--fine-grained interspersions of dense timber (with coniferous understory and lichens) and small clearings (with deciduous browse) on lower elevation winter range; (5) multi-storied winter cover--unevenaged stands of mature or old-growth timber with good canopy closure and abundant coniferous browse on mid elevation winter range; (6) secure foraging areas--uncanopied habitats with abundant (>45% cc) high quality forage and effective hiding cover at middle and higher elevations.

Variation in habitat use within the Yaak population, in addition to the range of habitats occupied by other North American moose populations, suggest that moose are relatively adaptable. The key habitat components defined here reflect optimal use of available resources under present conditions. As such, they should be protected and enhanced by management. However, they do not exaust the viable possibilities open to the population should changes occur in the future, such as greater competition from other ungulates (elk, caribou), higher levels of predation, long-term population increases, or expanded timber harvest.

HOME RANGES AND MOVEMENTS: RESULTS

YEARLONG AND SEASONAL RANGES

All collared moose were migratory, in that they maintained distinct seasonal ranges and moved between them as habitat conditions changed. The degree of overlap among seasonal ranges varied from one moose to another, but in all cases, principal centers of activity in summer and winter were well separated (Figures 3 and 4). Winter ranges were centered at low to middle elevation near the Yaak River, spring ranges at middle elevation, and summer and fall ranges at middle and higher elevation with additional activity centers (aquatic feeding sites and late fall snow refugia) at low elevation. There was considerable home range overlap among the 8 collared moose, and two or more adult moose often used the same local habitat complexes concurrently.

Within their seasonal home ranges, moose maintained an array of smaller subranges and local core areas, sometimes widely separated, which they used with reasonable consistency throughout a season and from one year to the next. Continuous monitoring indicates that they frequently moved between these local centers of activity fairly rapidly, often at night or twilight, and remained for several days before moving on. Some moose remained within large resource-rich subranges for several weeks before suddenly moving to a new site some distance away.

Minimum convex polygons for 8 moose averaged 27.9 mi^2 in 1984 and 19.4 mi^2 in 1985 (Table 31). Matchett (1985a) computed polygons of 28.2 mi^2 and 20.8

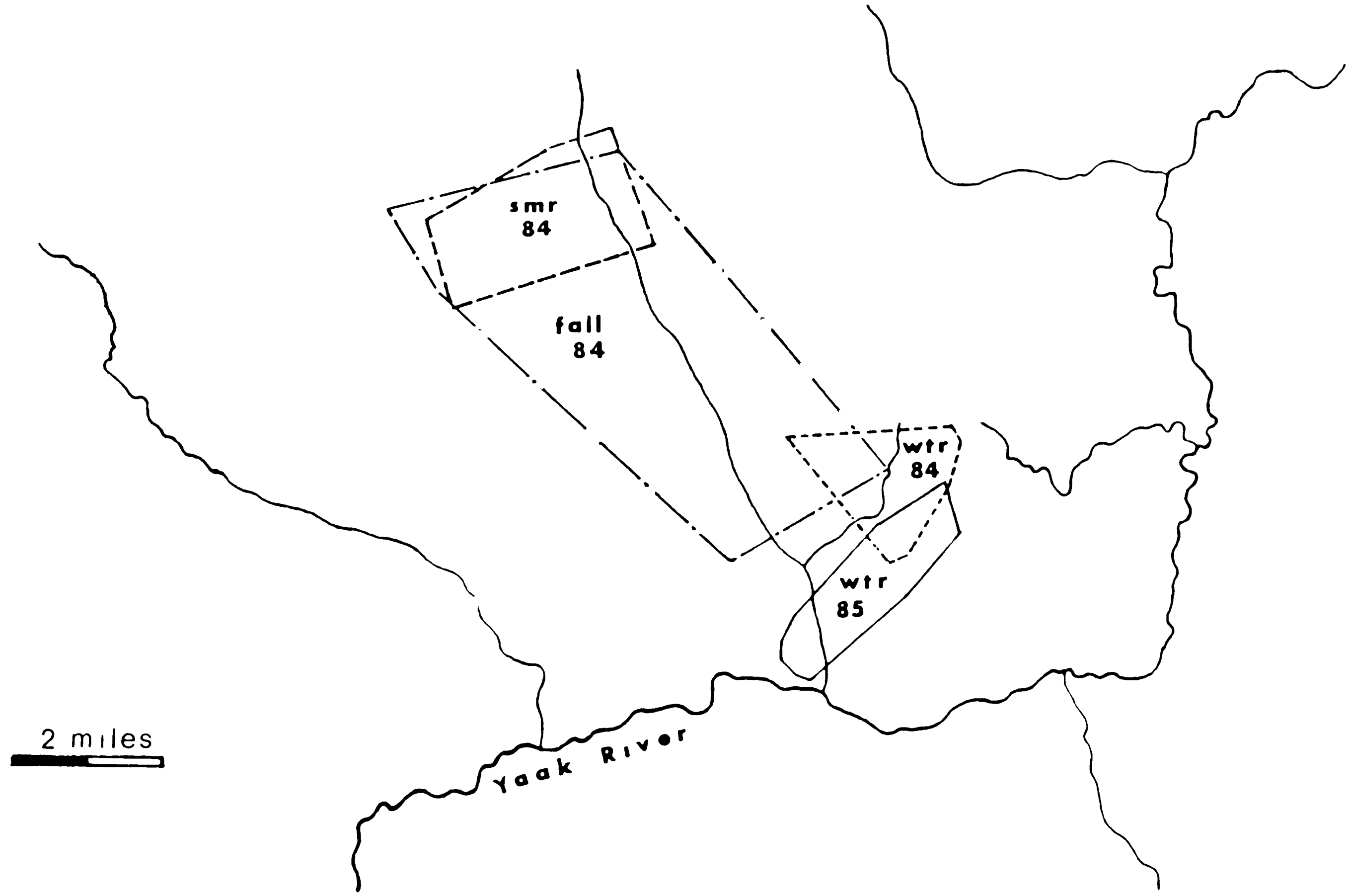

FIGURE 3. **Minimum Convex polygons for adult cow no. 01:** winter, summer, and fall 1984, and winter 1985. The summer polygon represents a mid to high elevation range with upland aquatic feeding sites. The fall polygon encompasses both early fall range at higher elevation and late fall range at middle elevation. Winter polygons are of similar size, but the 1985 range is centered at lower elevation.

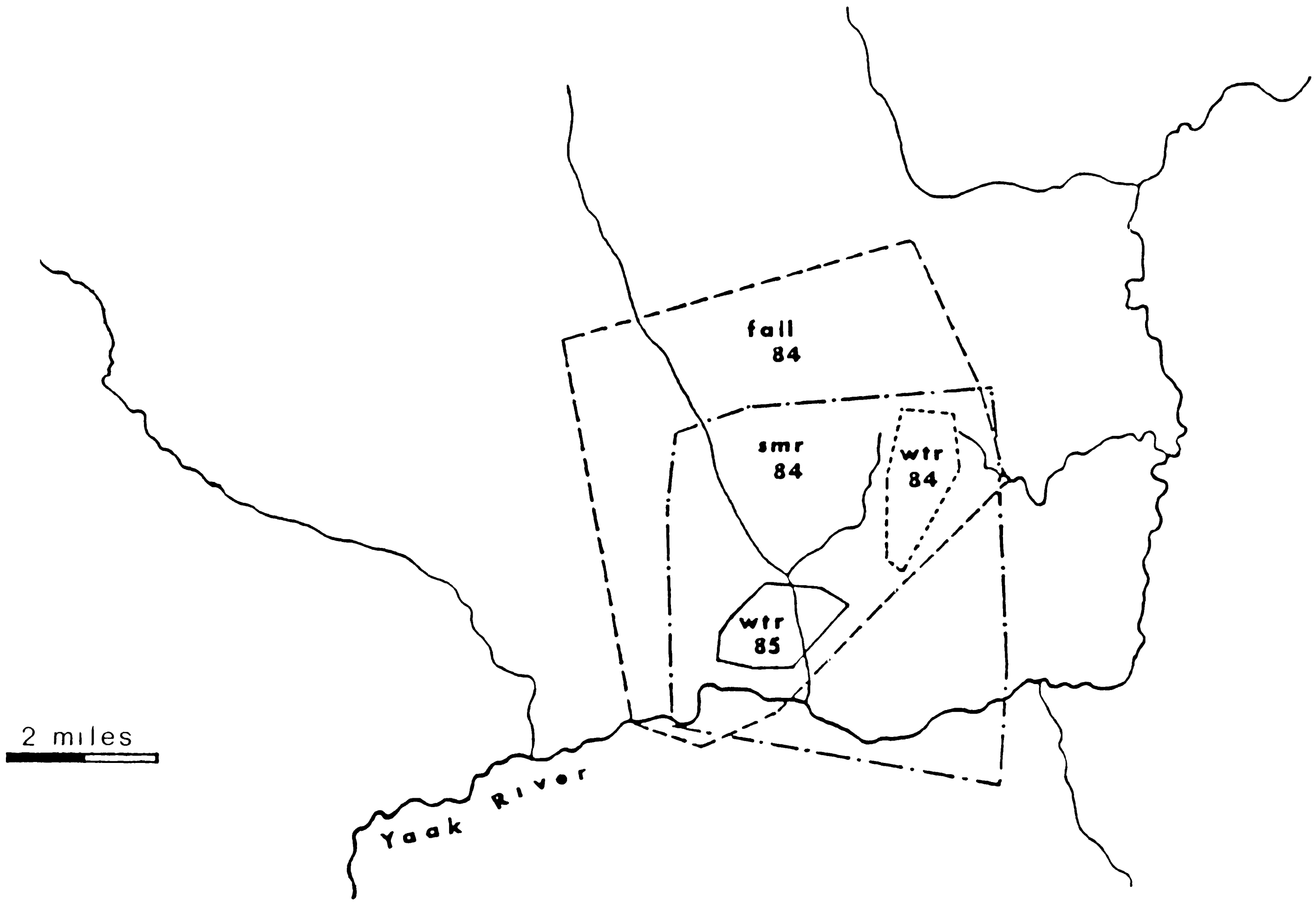

Figure 4. Minimum convex polygons for adult cow no. 08: winter, summer, and fall 1984, and winter 1985. Both winter ranges are located within the summer and fall polygons. The 1985 winter range is at lower elevation just above the river. The summer polygon encompasses mid elevation subranges as well as aquatic feeding sites along the river. The fall polygon is of similar size but also takes in some higher elevation habitat earlier in the season.

TABLE 31. *Yearlong home range size* from daily radio tracking: Comparison of *100% minimum convex polygons* (MCP) and *99% harmonic home ranges* (HHR), 1984-1985. Area is in *sq. miles*. Means are weighted by sample size. The HHR/MCP ratio suggests the percentage of the polygon that receives regular use. 1984 ranges include winter, summer and fall, with a few spring points. 1985 ranges include winter and summer, with a few spring and fall points. Some ranges are plotted in Appendix E.

		sq. miles within ranges					
		1984			1985		
moose		100% MCP	99% HHR	HHR/MCP ratio	100% MCP	99% HHR	HHR/MCP ratio
COWS	00	29.3	10.6	0.36	33.5	5.4	0.16
	01	21.9	6.7	0.30	19.0	2.4	0.12
	07	17.6	15.7	0.89	10.3	5.6	0.54
	08	31.5	22.8	0.72	14.0	11.4	0.82
	09	18.7	19.9	1.06	12.5	4.6	0.37
	10	51.7	30.2	0.58	19.4	5.7	0.29
BULLS	03	20.9	21.6	1.03	21.5	12.6	0.58
	11	29.7	18.6	0.63	29.2	2.6	0.09
MEAN: All		29.9	18.7	0.67	19.4	6.4	0.33
95% CI		(±7.3)	(±6.3)		(±6.6)	(±3.2)	
MEAN: Cows		28.9	18.2	0.63	17.9	5.9	0.33
MEAN: Bulls		24.8	20.3	0.82	24.9	8.2	0.33

Comparison of Mean Range Size (t-test):

MCP	1984:1985	no difference ($P > 0.05$); 1984 larger ($P < 0.15$)
HHR	1984:1985	1984 larger ($P < 0.01$)

mi^2 for the same population in 1982 and 1983 (Appendix E, Table 2). For most moose, minimum convex polygons circumscribed significantly larger home ranges than 99% harmonic contours (t values are significant at $P < 0.05$ for 6 of 8 moose in 1984 and 7 of 8 moose in 1985). Mean harmonic ranges were 2/3 the size of analogous polygons in 1984 and 1/3 the size in 1985 (Appendix E: figures 1-6).

All 1985 yearlong harmonic ranges were significantly smaller than 1984 ranges for each of the 8 moose. Mean 1984 range was 18.7 mi^2 and mean 1985 range was only 6.4 mi^2. The character of these differences is evident in the home range diagrams in Appendix E. Individual moose used much the same areas in both years, and these differences are primarily an artifact of methodology: too few mid elevation fall locations in 1985 to connect isolated winter and summer subranges and produce all-inclusive 99% contours as in 1984.

When seasonal home ranges were delineated (Table 32), both methods produced similar estimates for winter ranges, but minimum convex polygons generated summer and fall ranges significantly larger than 99% harmonic contours. In winter, most moose maintained ranges (polygons) of limited size (an average of 2.8 mi^2 in 1984 and 3.0 mi^2 in 1985), but used these areas more uniformly than summer and fall ranges (Figures 7 and 8). In summer and fall, moose ranged more widely but concentrated activity in more compact local ranges. These frequently mapped out as harmonic islands scattered throughout the larger polygons (Figures 5 and 6).

Neither method showed a difference in mean overall range size between the winters of 1984 and 1985 ($t = 0.30$ and 0.54, $P > 0.05$), in spite of radically

TABLE 32. *Seasonal home range size: 100% minimum convex polygons* (MCP) and *99% harmonic home ranges* (HHR). Means are weighted by sample size. Area is in sq. miles. Winter ranges are for January onward, and do not include December locations. (* cows with calves, # 2-year-old cow)

Sq. Miles within Home Ranges

Moose ID	1984 Winter		1984 Summer		1984 Fall		1985 Winter		1985 Summer	
	MCP	HHR	MCP	HHR	MCP	HHR	MCP	HHR	MCP	HHR
00	3.3*	2.0	18.9	0.2	24.5	1.6	5.5	4.0	12.3*	1.0
01	2.3	1.6	3.4	0.4	15.8	0.6	1.7	1.5	2.0*	0.6
07	6.7*	2.0	8.3*	1.1	11.0*	3.2	2.3*	1.7	7.2*	1.3
08	1.6	1.6	20.3	1.4	21.9	3.3	1.1	2.0	5.4*	4.7
09	3.0	3.4	9.2	1.0	11.5	1.6	5.3	2.2	9.4*	3.4
10	2.9	2.0	33.7#	1.0	24.5#	3.4	1.7	2.7	13.9*	1.9
03	1.9	2.1	9.1	1.5	3.6	2.4	1.2	1.6	10.0	3.6
11	1.9	3.4	0.3	0.4	20.8	0.1	4.9	1.4	2.5	1.6
Mean	2.8	2.4	14.0	0.9	16.6	2.2	3.0	2.2	8.0	2.5
95% CI	±1.3	±0.6	±9.8	±0.4	±6.3	±1.1	±1.7	±0.7	±3.7	±1.3

MEAN RANGE SIZE COMPARISON:

(t-test, $P < 0.05$)	MCP	HHR
Winter 84: Winter 85	no difference	no difference
Summer 84: Summer 85	no difference	Summer 85 larger
Summer 84: Fall 84	no difference	Fall larger
Summer 84: Winter 84	Summer larger	Winter larger
Summer 85: Winter 85	Summer larger	no difference
Fall 84: Winter 84	Fall larger	no difference

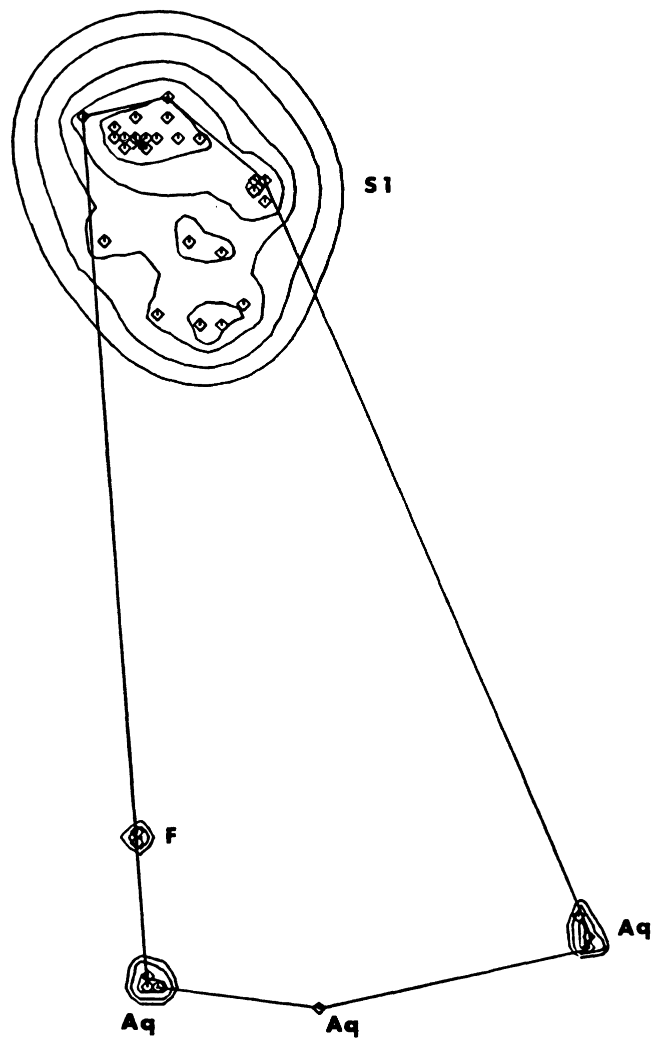

Figure 5. 1985 summer range of adult cow no. 09. Minimum convex polygon = 9.0 mi^2. 99% harmonic range = 3.3 mi^2. Most activity is concentrated in a mid-elevation subrange (S1). Separate centers of activity at low elevation are centered on aquatic feeding sites (Aq) on the Yaak River and temporary foraging areas (F) occupied for no more than a few days.

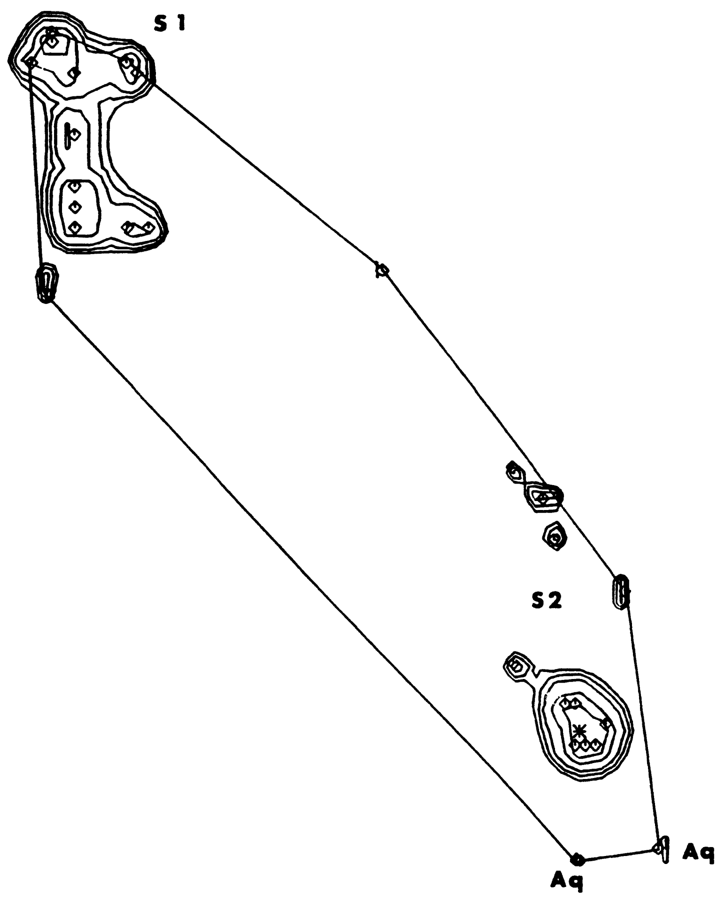

Figure 6. 1985 summer range of adult cow no. 07. Minimum convex polygon = 6.8 mi^2, 99% harmonic range = 1.2 mi^2. The harmonic pattern shows a major subrange at higher elevation (S1), a more loosely consolidated subrange at low-middle elevation (S2), and 2 aquatic feeding sites on the river.

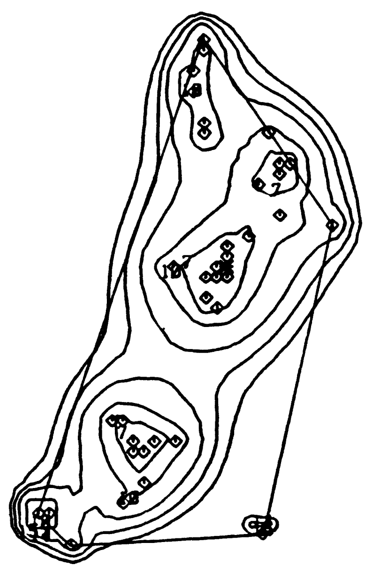

Figure 7. 1984 winter range of adult cow no. 09. Minimum convex polygon = 2.9 mi^2, 99% harmonic range = 3.3 mi^2. The harmonic pattern shows several local ranges in close enough proximity to map out as one large contiguous seasonal range with no distinct subranges. This low-middle elevation habitat is a large-grained mosaic of uncanopied cutting units with good browse and large blocks of timber.

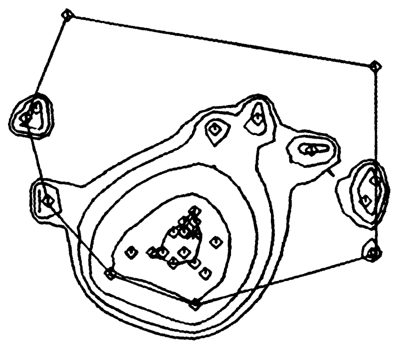

Figure 8. 1985 winter range of adult cow no. 07. Minimum convex polygon = 2.2 mi^2, 99% harmonic range = 1.6 mi^2. All winter activity from mid January through late March occurred within this compact range along and immediately above the Yaak River.

different snow conditions. Most collared moose simply shifted their ranges to higher elevations in 1984 when snow was shallow, rather than expand range size (Figures 3 and 4).

Minimum convex polygons showed no significant difference between 1984 and 1985 summer ranges, nor between summer and fall ranges (Table 32). With 99% harmonic contours, however, 1984 summer ranges were significantly smaller than those of 1985 ($t = 2.84$, $P < 0.05$) This appears to be an artifact of the relatively small number of radio locations from the summer of 1984, a circumstance which severely restricted the size of harmonic areas. With the exception of summer 1984, there was no difference in mean harmonic range size between summer, fall, or winter in either year. Minimum convex polygons, however, produced summer ranges 3 to 5 times larger than winter ranges.

In other words, once variation due to sampling was accounted for, the combined area of the local activity zones and subranges estimated by harmonic contours remained roughly similar from season to season and from year to year (2.2 to 2.5 mi^2), while the size of the territory within which these local ranges were dispersed was significantly larger in summer and fall (8.0 to 16.6 mi^2) than it was in winter (2.8 to 3.1 mi^2).

There were no consistent differences in mean home range size between bulls and cows or between cows with and without calves. Real variation in the sample was due to other factors. Confidence intervals in Tables 31 and 32 confirm that individual deviation from mean range size and from the mean HHR/MCP ratio was substantial. Factors inflating seasonal range size for some moose but not for others included: widely separated centers of activity in fall (bull no.11, 1984); farflung exploration by young animals (cow no.10, 1984); lengthy excursions from upland summer range to aquatic feeding sites on the Yaak River (cows no.00 and 07, 1984-85); broad dispersion of traditional foraging areas in summer (bull no.03, 1984-85); and separation of mid-winter habitat from early and late winter habitat by deep snow (cows no.01, 08, and 09, 1985). Factors condensing seasonal ranges included: concentration of key summer resources in localized areas (bull no.11, 1984; cow no.01, 1984-85), traditional calving areas within or near spring ranges (cows no.08, 09, and 10, 1985); resource concentration on accessible winter range (cow no.08 and bulls no.03 and 11, 1984); and deep winter snow in mid elevation ranges (Bull no.03, 1985).

DAILY RANGES

A total of 33 daily ranges were obtained from continuous monitoring, and expressed as minimum convex polygons (Table 33). Fall and summer 24-hour ranges were largest (fall mean = 64 ac; summer mean = 84 ac), mild winter ranges were significantly smaller (mean = 37 ac), and ranges in severe winter were smallest (mean = <12 ac). Data from Matchett (1985a) suggest that spring ranges were similar to those obtained in mild winter.

In summer, fall, and mild winter, the variation in both 12 and 24-hour ranges was substantial. With little constraint on mobility, some animals shifted base to new local ranges some distance away (0.4 to 1.7 mi, in our sample) while others remained in small, resource-rich areas for several days. In the winter of 1985,

TABLE 33. *Daily ranges: 100% minimum convex polygons* from 24-hour monitoring--average home range size after 12 and 24 hrs of observation. Ranges are given for 2 groups: (1) all moose monitored in a particular season and (2) moose that remained within a local habitat complex during the session without shifting base to a new core area.
Winter data is from February-March. Winter 1984 = low-snow winter. Winter 1985 = deep-snow winter.

Acres within 100% Polygons

	All Monitored Moose				Non-traveling Moose			
	12 HOURS		24 HOURS		12 HOURS		24 HOURS	
	mean	(range)	mean	(range)	mean	(range)	mean	(range)
WINTER 1984	20.3	(2-69)	36.0	(5-128)	5.9	(2-10)	8.9	(5-15)
WINTER 1985	3.5	(1-7)	--	--	3.5	(1-7)	--	--
SUMMERS 1984-85	13.3	(5-30)	83.5	(10-300)	11.1	(5-25)	21.7	(10-35)
FALL 1984	19.3	(2-74)	63.0	(7-242)	10.4	(2-30)	24.5	(7-49)

Comparisons of Range Size (Mann-Whitney U test, signif. at $P < 0.05$):

SEASONS COMPARED	ALL MOOSE	SETTLED MOOSE	HRS
Winter 84: Winter 85	Winter 84 larger	no difference	12
Winter 84: Summers	Summer larger	Summer larger	24
Winter 84: Fall 84	no difference	Fall larger	24
Winter 85: Fall 84	Fall larger	Fall larger	12
Winter 85: Summers	Summer larger	Summer larger	12
Fall 84: Summers	no difference	no difference	24

Comparisons involving winter 1985 are for 12-hour ranges; all others are for 24-hour ranges.

when movement was hindered by deep snow, daily ranges were consistently small throughout our 12-14 hour observation periods, and there was little variation among them (1.2 to 7.4 ac). Follow-up observations suggested that 24-hour ranges were only 2.5 to 12.4 ac .

Table 33 shows that when long-distance excursions were removed from the sample, average daily range size decreased to 21.7 ac for summer, 24.5 ac for fall, and 8.9 ac for a mild winter. The 12-14 hour ranges for deep snow winter remained at 5.9 ac since none of the monitored moose shifted to new core areas under these conditions. The difference between mild and severe winters was no longer significant (Mann-Whitney U, $P > 0.05$) once mild winter excursions were subtracted from the sample. Moose appeared to use about the same amount of territory in the course of normal feeding and bedding activities in both situations. This applies to habitats with effective snow depths in the 12-24 in range (usually timbered habitats in 1985 and open habitats in 1984). Two monitoring sessions in very deep snow (26-35 inches effective depth) at middle elevation detected daily ranges of less than 1.2 ac. Areas of local daily activity were significantly larger in summer and fall than in either winter.

The daily ranges we measured were not necessarily equivalent to local harmonic ranges. Daily ranges normally occupied only a portion of the areas defined by local (25-75%) harmonic isolines, and sometimes covered zones between activity centers as moose traveled between them in the course of a monitoring session.

In summer and fall, longer and more frequent movements between local ranges were reflected both in larger daily ranges and in larger seasonal home ranges than in either winter (Table 33). Conditions for long-distance movement in the winter of 1984 were much more propitious than in 1985, but overall seasonal range size was not significantly greater. Moose responded to favorable winter conditions in 1984 by shifting their winter ranges upslope toward better habitat (Figures 3 and 4) and increasing travel between local core areas within that territory (Table 34). During times of limited mobility in deep snow, moose restricted daily ranges to small areas of appropriate habitat at lower elevation, and moved short distances to new local ranges as conditions allowed. Earlier in the season when snow was more powdery, and toward the end of the winter when depths had diminished, moose were able to move about more freely and to use middle elevation habitats (Figure 9). The net result was average seasonal home ranges of similar size in both mild and severe winters (compare Figures 7, 8, and 9).

MOVEMENTS

Local movement associated with foraging, locating bedding sites, and moving in and out of cover was not substantially different in winter than in summer and fall (Table 34). The mean distance between hourly locations for moose settled in local ranges was 141 ft in winter 1985, 164 ft in winter 1984, 256 ft in fall, and 318 ft in summer (Table 34).

Aside from this normal shifting-about within local ranges, the following kinds of movements were observed: (1) regular movement between discontinuous local

TABLE 34. *Mean distances moved per hour* (feet) within 24-hour ranges. Movements are given both for moose remaining within a local core area and for those making a significant change of base during the 24-hour period. The mean distances of excursions made by traveling moose are also shown. Data are from continuous monitoring.

	MEAN DISTANCE MOVED PER HOUR (feet)			MEAN DISTANCE PER TRIP (miles)	
	all moose	settled moose	traveling moose	traveling moose	
	mean (SD)	*mean (SD)*	*mean (SD)*	*mean*	*(range)*
WINTER 84	318 (216)	164 (72)	554 (148)	0.76	(0.35-1.30)
WINTER 85	141 (79)	141 (79)	0	0	
SUMMER 84-85	472 (210)	318 (59)	702 (131)	0.64	(0.35-1.05)
FALL 84	400 (193)	256 (144)	525 (148)	0.94	(0.60-1.75)

1985 winter distances for traveling moose and for all moose together are significantly smaller than in any other season (Mann-Whitney U tests, $P \leq 0.05$). Otherwise, there are no significant differences either for traveling or resident moose.

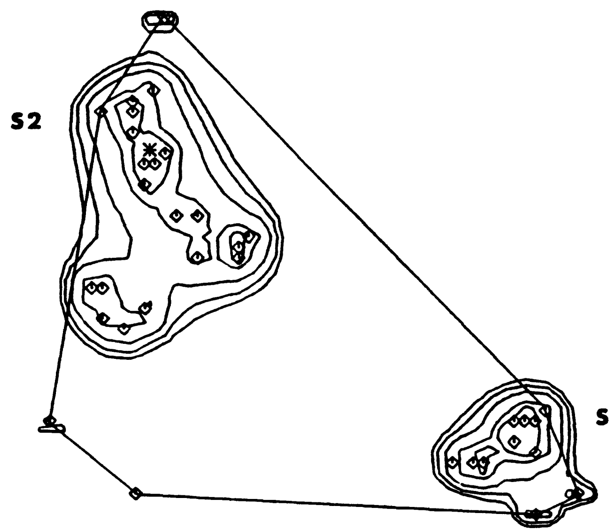

Figure 9. 1985 winter range of adult cow no. 09. Minimum convex polygon = 5.0 mi^2, 99% harmonic range = 2.1 mi^2. The SE subrange (S1) is a low elevation range along the Yaak River used in mid-winter during adverse snow conditions; the NW subrange (S2) is an area at low-middle elevation used both early and late in the winter.

ranges, (2) occasional changes of base between seasonal subranges, (3) occasional long-distance journeys to aquatic feeding sites or other special areas, (4) abrupt movement by cows to calving areas in late spring, (5) both abrupt and gradual movements from spring to summer and from fall to winter ranges, associated with changes in habitat accessibility, (6) extensive long-distance movement by some bulls during breeding season, and (7) long-distance explorations by young moose (2-3 years old), evidently associated with establishment of home ranges. Most of these more extensive movements by moose in the Yaak have been discussed by Matchett (1985a).

The length of these excursions varied depending on their apparent purpose, the dispersion of resources, and seasonal restrictions on mobility. For monitored moose, there was no significant difference between summer, fall, and mild winter in the average distance moved to new sites (0.6 to 0.9 mi). No long-distance movements were observed during continuous monitoring for the winter of 1985, but shifts did occur, especially at times when snow was less deep, less dense, or more supportive. Daily radio tracking indicates that these shifts were of the same magnitude as in other seasons.

SUMMARY

Adult moose typically moved throughout an area of 19.4 to 27.9 mi^2 in the course of a year--about 2.8 to 3.0 mi^2 in winter and 8.0 to 14.0 mi^2 in summer. Within these broad areas of occupancy, moose regularly used an array of subranges totaling an average of 2.2 to 2.6 mi^2 in winter (75-80% of the winter

range) and 0.9 to 2.5 mi^2 in summer (10-20% of the summer range). In the course of a day, moose used areas averaging 60-85 ac in summer and fall, 35 ac in low-snow winter, and less than 12 ac in deep-snow winter. In deep-snow winters moose restricted long-distance movement between local ranges, but maintained local ranges similar in size to those of low-snow winters (3.5 to 5.9 ac). Most significant variation in home range size between seasons, years, and different moose resulted from a variety of excursions, rather than from expansion of local or daily range size.

HOME RANGES: DISCUSSION

The harmonic contours which best delineated key habitat areas for moose varied from season to season and from one animal to the next, depending both on the number of radio locations and on the degree to which different moose concentrated activity within discrete core areas. Frequently, the 25% and 50% contours (at grid density 99x99) roughly defined the local core areas. But harmonic isopleths were imprecise indicators of the habitat complexes used by moose and were too much influenced by sampling variation to provide meaningful comparisons between different animals, seasons, or years. At this level of precision, the same kind of information on the location and arrangement of intensively used areas can be provided by a simple scatter of sample points. More sampling points per moose per season are needed to provide harmonic home range information precise enough for management applications. Daily ranges obtained through continuous monitoring were more precise, but normally too small to define an entire local range.

Daily radio tracking and 24 hour monitoring suggest the following hierarchy of home ranges for moose in the Yaak:

Seasonal Range: The entire area within which a moose moves in the course of a season, roughly circumscribed by the minimum convex polygon or by a 99% harmonic range with an adequate number of sample points. Range size is 8–14 mi^2 in summer, 2.5–3.0 mi^2 in winter.

Seasonal Subrange: A large habitat complex (typically 750–3000 ac) with forage, hiding cover, forested cover, and, perhaps, aquatic sites sufficient to support a moose for several weeks, delineated by anything from the 50% to the

99% harmonic contour.

Local Range: A fairly small core area (typically 25-250 ac), usually centered on a good forage site with abundant hiding cover, and often with adjacent thermal cover or an aquatic site, delineated by anything from the 25% to the 99% harmonic contour.

Daily Range: Whatever portion of the range a moose uses in a given 24-hour period, normally within a local or seasonal subrange, but occasionally between 2 or more of them if the moose is traveling. Daily range size is typically 5-35 ac in winter and 60-85 ac in summer and fall.

Daily range size does provide some indication of the capacity of a local habitat complex to support a moose for the several days it may remain resident. In summer, fall, and mild winters, when moose were normally active for 50% of the day, 24-hour ranges were as small as 5-10 ac. The common denominator for these small ranges was a high-quality forage unit with good hiding cover in or adjacent to the feeding zone. Some kind of thermal cover was important in summer, but not necessarily in fall and mild winter. In deep-snow winter, some daily ranges were less than 1 ac. In these cases, when moose were bedded about 75% of the time, the essential element was timbered cover, often stands of 100-200 ac.

The daily ranges at the upper end of the spectrum in summer and fall (131-148 ac) resulted from movement to new areas, rather than extensive canvassing of large forage-poor local ranges. This frequent movement between high-quality foraging areas is characteristic of moose that depend on seral habitat in patchy environments (Geist 1971, 1974).

In summer and fall, when mobility was unrestricted, two types of subranges were common: (1) large forage-rich habitat complexes with abundant cover and aquatic resources sufficient to support a moose for up to several weeks--in essence, a single, large local range; (2) areas where forage-rich sites were separated by substantial tracts of timber or depauperate openings, and which required moose to maintain an array of several discontinuous core areas, moving between foraging units every few days. In habitat complexes of either kind, with most essential resources readily available, resident moose maintained average daily ranges of 22–25 ac in summer and fall. In winter, many moose maintained a single subrange (750–2200 ac) throughout most of the season, using the available area fairly throroughly, and expanding into new territory only later in the season as snow pack diminished.

Moose return to many of the same habitat complexes several times during the course of a season, but may visit others only once. In a subsequent year, many of the same core areas will be used again and new areas may come into use. Most adult moose seem to be familiar with more local areas than they regularly use in any one season. This provides flexibility for when conditions change in portions of the traditional range: deep winter snows, dehydrated aquatic sites, logging and roadbuilding, or other concentrated human use. As long as the disturbances do not eliminate a major portion of the overall range (as roughly defined by the minimum convex polygon) for long periods of time, moose should be able to find alternative local sites with which they have some experience, at least with the low to moderate population densities in the Yaak, 1982–86.

The extensive wanderings of young moose (cow no. 10 in this case) in summer and fall may play a role in developing this set of potential core areas. Other studies have also noted larger ranges and more extensive movement by yearling and 2-year-old moose than full adults (Roussel et al. 1974, Phillips et al. 1973, Goddard 1970, Houston 1968). Geist (1973) felt that on most moose ranges, where dispersion of the food resource was patchy, the exploratory behavior of young moose was crucial to establishing effective home ranges.

The mean area of regularly used range (as measured by the 99% harmonic contour) remains much the same from one season to the next. Only the configurations change significantly. This suggests that moose in the Yaak require an average of about 2.0 to 2.5 mi^2 of core habitat regardless of the overall extent of the occupied area. When access to this amount of acceptable habitat is limited by deep snow, moose restrict activity to conserve energy, rather than ranging more widely to make fuller use of scanty food resources. This is a strategy different from that predicted by Geist's (1982) 'law of least effort', which suggests that as forage density decreases, roaming by elk and other large ungulates should increase, and that winter and spring ranges should be larger than summer ranges. Lynch and Morgantini (1984) found this to be true for moose in Alberta, but in most moose populations winter ranges are significantly smaller than summer ranges (Table 35). In the Yaak, most moose range extensively in summer because of the patchy dispersion of the food resource and the absence of barriers to movement, but the area of concentrated use is about the same as in winter.

Pierce (1983) applied a combination of peripheral polygons and harmonic contours to moose ranges in central Idaho, and found a pattern similar to what

TABLE 35. *Home range sizes* from several studies. Ranges are Mi^2 within minimum convex polygons, unless otherwise indicated.

HOME RANGE (KM^2) winter	summer	Conditions & Location	Source
3	8-14	Yaak River country 1984-85.	this study
4	10	" " 1982-83.	Matchett (1985)
	6-10	cows: SE Idaho	Ritchie (1978)
	12-20	bulls: SE Idaho	" "
	7	cows: NW Minnesota	Phillips (1973) *
	6	bulls: NW Minnesota	" "
18	13	cows: Alberta	Lynch and
20	9	bulls: Alberta	Morgantini (1984)
8	8	NE Alberta	Hauge and Keith (1981)
5	15	central Idaho	Pierce (1983)
	<2	majority of moose observed: SW Montana	Schladweiler (1974)
	1-2	adult cows with calves: SW Montana	Dorn (1969)
<2	<2	90% of adults: NW Wyoming	Houston (1968)
<2	3-24	yearlings: NW Wyoming	" "
	<2	productive summer: SW Montana	Knowlton (1960)
	<2	Yellowstone NP	McMillan (1954)
1	2-5	overall average: NE Minnesota	Van Ballenberghe
	<1	primary use area: "	and Peek (1971)
	4-123	central Alaska	Taylor and Ballard (1979)

* computer fill technique

Matchett and I have described: large summer polygons enclosing smaller harmonic islands, and winter ranges in which polygons and harmonic patterns are more nearly the same. This same sort of relationship between core areas and overall range was described by Van Ballenberghe and Peek (1971) and by Houston (1968).

When minimum convex polygons alone are used, mean summer ranges of Yaak moose are somewhat larger than those calculated for other populations, and winter ranges are somewhat smaller (Table 35). The diversity in home range size and pattern reported for different populations (Table 35) appears to be a function of the quality and distribution of primary resources. An overview of these studies suggests that, in general, large concentrations of key resources (areas greater than 1.5 mi^2) reduce polygon size, and widely dispersed patches of these resources inflate polygon size. Environments with widely dispersed patches of appropriate forage and cover should generate large summer polygons as moose move between the patches. But they should produce small winter polygons, since moose may be restricted to one patch for much of the season by deep snow.

The distribution of key components in the Yaak allows moose 2 basic strategies as long as mobility is unrestricted: (1) to exploit relatively large, self-contained, forage-rich complexes for most of the season or (2) to wander more broadly between smaller units of forage, cover, and aquatic vegetation. At low to moderate population levels, both strategies are viable. Much of the variation in home range size and pattern among Yaak moose stems from the exercise of one or the other of these options or of some combination of the two. Cederlund and

Okarma (1988) found that when resources were fragmented, but fairly evenly scattered over a flat landscape, there was relatively little individual variation in moose home range size.

Several studies have reported summer core areas in the range of only 1–2 mi^2 (Schladweiler 1974, Van Ballenberghe and Peek 1971, Dorn 1969, Houston 1968, Knowlton 1960, and McMillan 1954). Based on 99% harmonic contours, I estimated the average amount of regularly used summer habitat to be about 1.0–2.5 mi^2 for Yaak moose in 1984–85. Matchett estimated summer harmonic ranges of about 1.0–1.5 mi^2 for the same population in 1982–83. As an estimate of the amount of good quality summer habitat (forage–cover complexes) required by moose in the Yaak, our figures are a bit high, since peripheral harmonic contours normally extended beyond the boundaries of the appropriate habitat complexes. Cederlund and Okarma (1988) also used dense harmonic grids to delineate moose ranges in a forest environment fragmented by logging in Sweden. Their estimate of mean summer range size (3.5 mi^2) was also relatively high, but they estimated core areas to be only about 50% of the home range.

Houston (1968) and Van Ballenberghe and Peek (1971) found that moose confined themselves to small core areas (1–2 mi^2) on winter range as well. Cederlund and Okarma (1988) estimated harmonic winter ranges of about 2 mi^2 with core areas about half that size. Matchett estimated harmonic winter ranges of about 1 mi^2 for Yaak moose in 1982–83, and I estimated about 2 mi^2 in 1984–85. In favorable circumstances, these core areas were secure foraging habitats, vigorously exploited to maximize energy intake; in deep snow, they were some kind of forest-forage association used in a manner that minimized energy loss.

Adjusting for harmonic overestimation, it appears that, in the Yaak, moose normally require a total of about 1-2.5 mi^2) of good quality habitat in any season, either in scattered parcels or in one unified block. This is similar to core area estimates for several other relatively productive moose ranges. In summer and fall, when mobility is unrestricted, moose may move throughout an area of 12-20 mi^2 in order to find sufficient high quality habitat in local core areas. These areas of intensively used, high quality habitat should be the focus of management efforts. The wide distribution of these local habitats, including calving areas, aquatic feeding sites, and rutting areas, provides for a degree of flexibility in the face of habitat alteration by logging and road construction. It is important that high-quality habitat complexes be abundant and well dispersed over a broad area.

MANAGEMENT OPTIONS: SUMMARY DISCUSSION

MANAGEMENT DIRECTION

If the principal management goal for moose in the Yaak drainage is to maintain a healthy population at a relatively low density, the present systems of habitat and population management are adequate. If the goal is to maximize hunting opportunity, an increase in population is desirable. This will require (1) discouraging illegal harvest through road closures, maintenance of hiding cover in logged areas, and increased enforcement efforts, (2) creating more good quality winter habitat at low and middle elevation, and (3) monitoring the population more closely in order to anticipate trends.

MANAGEMENT OF KEY HABITAT COMPONENTS

Most fortuitous observations of moose behavior and habitat use involve individuals more inclined to open habitats and less wary of human presence. Our sample suggests that this is consistently characteristic of only about 1 moose in 5, and occasionally characteristic of about 3 moose in 5 (at aquatic feeding sites, for example). Habitat management needs to account for the degree of security required by these less tolerant segments of the population.

Calving Sites. Minimum requirements for calving sites are: dense hiding cover and the proximity of good forage and water. Ideally, sites should be in roadless blocks of large mature or old-growth timber, greater than 500 ac and no smaller than 150 ac, with good forage either in or adjacent to them. These sites should be buffered from human disturbance either by isolation or by physical barriers (heavy blowdown, dense brush, rough terrain, large streams).

Most cows return to the same general region of a particular drainage each year to calve, but there is enough variation in their choice of specific sites from one year to the next to allow for adaptation to local habitat alterations. However, several large secure areas need to be left intact within each drainage to provide adequate calving areas for cows displaced by logging and roading elsewhere in the drainage.

Aquatic Feeding Sites. On the Yaak River, areas of slow flowing water with abundant underwater vegetation are potential aquatic feeding sites. Maintenance of shoreline hiding cover (minimum width of one sighting distance) should be the primary concern in these areas.

Upland sites are provided by ponds, swamps, and slow streams, particularly those with old beaver ponds. Sites need not be large, and small potholes no more than 100 ft^2 in area and 1–3 ft deep are often sufficient. The essential ingredients are submerged aquatic vegetation with an effective screen of escape cover. A broad zone of hiding cover (at least one sight-distance wide) should be retained around more than half (and preferably all) the shoreline of all aquatic feeding sites in timber sale areas. Adjacent thermal cover is also useful.

As the population increases, aquatic sites on the Yaak River may be insufficient to accomidate a significant portion of the population, and upland sites are likely to become more important. The key management actions should be a continuing pothole blasting program and maintenance of hiding and thermal cover around upland sites.

Forested Summer Forage. Stream bottoms and damp ground inside stands of mature timber with good canopy closure are important feeding areas for moose in summer. A mature timber stand of at least 100 ac with a narrow, but productive zone of understory forage can support at least one moose for the better part of a summer. In planning timber harvest, it is important to leave swaths of timber around these bottoms broad enough and dense enough to maintain a thermal umbrella, as well as hiding security. This generally means a minimum width of 300 ft between cutting units, overall canopy closure of at least 70%, and no individual tree selection cutting in the bottom.

Winter Cover/Forage Mosaics. When effective snow depths in open habitats at low to middle elevations regularly exceed 24–28 inches, most moose move to stands of timber below 3400 ft with canopies capable of moderating snow depths to 24 inches or less. These are most often mature, single-storied forest stands with canopy closure in the 60–80% range, 100–200 ac in size. Moose subsist primarily on arboreal lichens and on alpine fir, western redcedar, and Douglas-fir regeneration in the understory, but move into open areas to obtain higher quality browse whenever snow depth is not limiting. Open areas receiving the most use are S-SW-W facing cutting units, small browsy clearings (often swamps) and sites along the forest margins.

Good hard-winter habitat consists of a mosaic of low elevation timber stands and numerous small clearings with good quality browse. Mature stands, 100–200 ac in size, with canopy closure greater than 65%, medium tree density, and good supplies of arboreal lichens and alpine fir, western redcedar, or pacific yew regeneration in the understory are best. Irregular cutting units of less than an acre, swamps, trails and old roadways can provide deciduous browse and extensive edges. Browse in creek bottoms and damp draws may be unavailable because of deeper snow. The availability of abundant high-quality forage adjacent to timbered cover at low elevations is the key to good calf production the year following deep-snow winters.

Multi-Storied Winter Cover. If moose are to occupy middle elevation habitats during severe winters, they must have access to forest stands capable both of moderating snow depth and providing enough forage to forestall regular movement into uncanopied browsing habitats. In many years, effective mid winter snow depths in open habitats between 3400 and 4200 feet exceed 35 inches for several weeks. Multi-storied stands of mature and old-growth timber with good overhead cover (>70% canopy closure) and abundant forage in the understory (arboreal lichens and preferred conifer species) provide the only viable habitat for moose at these elevations during severe winters. Optimal stand size is in the 50-200 ac range.

Secure Uncanopied Forage. The habitats most frequently exploited by moose in the Yaak at all times of the year (as long as snow is not severely limiting) are uncanopied logged areas dominated by saplings and brush with abundant good-quality browse and effective hiding cover. Most frequently, these are dozer-scarified clearcuts; but any cutting and site preparation scheme that opens up the canopy to less than 100 t/ac and eliminates unpalatable understory species, may produce the desired result. The only unproductive combinations would be individual tree selection and lighter sanitation cuts without site preparation.

Total size of the cutting units is unimportant as long as numerous islands of leave-trees and brush remain throughout to create internal edge. Although moose use hiding cover at all times of the year, it is particularly important for security in hunting season. Because many moose will use a good forage site during the day whether or not cover is present, it is important to design cutting units in which escape cover is readily available from the beginning. This requires either a series of small units rather than one big one, narrow units with irregular edges, or numerous islands of leave-trees and brush. All 3 schemes maximize edge, leave some browse, and provide hiding cover close at hand. Shrubs normally begin to extend into the moose's vertical browsing zone within 5-10 years after logging, but partial hiding cover doesn't develop until at least 15 years.

Adjacent thermal protection is essential only in summer, and dense clumps and strips of leave trees, especially in draws and along streams, can serve the purpose. A good distribution of these areas is needed at middle and high elevations.

HABITAT MANAGEMENT UNITS

Peek et al. (1976) recommended township-sized blocks (36 mi^2) as management units for moose habitat in flat and rolling country in NE Minnesota, with an appropriate mosaic of mature timber, different-aged cutting units, and other key habitat features in each block.

In mountainous country such as the Yaak, management units for habitat planning are more appropriately defined by the larger secondary drainages (such as Pete or Spread Creek) or by groupings of these and smaller adjacent drainages (such as Whitetail, Lap, or French Creek). Each management area should contain a broadly distributed array of key components and other habitat features adequate to sustain a subpopulation of moose throughout the year under all circumstances, including deep-snow winters and large scale roading and logging operations.

Standard Forest Service habitat analysis units, timber compartments, and timber sale areas are too small to serve the purpose. A more extensive area analysis approach, involving management units of at least 30 mi^2 centered around principal drainage systems, is needed. Each unit should contain an elevational gradient sufficient to include all seasonal ranges, a good dispersion of key habitat components within each range, and enough alternative habitat sites to allow for normal moose movement as well as adjustment to habitat disruption.

LIMITING FACTORS

Several factors which have imposed limits on moose populations in other parts of North America appear to be of little consequence in the Yaak at present: natural predation (Hauge and Keith 1981, Franzmann and Peterson 1978, Wolf 1977, Peterson and Allen 1974, LeResche 1968); disease and parasites (Samuel and Barber 1979, Telfer 1967); interspecific competition (Jenkins 1985, Wasem 1967, Flook 1964, Cowan 1950); and intraspecific competition (Peterson et al. 1984, Spencer and Chatelain 1953).

Principal limiting factors for the Yaak moose population at this time are the magnitude of unregulated hunting and, secondarily, the inconsistent availability of good winter habitat.

Excessive poaching and Indian treaty harvest remove a significant portion of the adult population, while the inaccessibility of high quality foraging areas due to deep snow during many winters significantly lowers calf production. In years when low yearling influx and high human-induced mortality coincide, the adult population is likely to decline. In years when the opposite occurs, the population may increase. The net result is a predominantly young population of relatively small animals with a low percentage of mature bulls, whose numbers cycle about an artificially low equilibrium point. There is potential for significant population expansion before habitat limits are reached on spring and winter range. A base level of secure habitat (relatively isolated complexes of forage, cover, and aquatic sites) make catastrophic population collapse unlikely, unless the rate of timber harvest and roading increase dramatically.

Winter habitat constraints are, to a certain extent, a secondary limitation. Moose can successfully occupy higher elevation habitats in deep-snow winters (well developed stands of mature and old-growth timber), but calf production in this segment of the population will probably be low. If human-induced adult mortality is reduced, the population should begin expanding into this upslope habitat in winter, although overall rates of productivity should decline as a result.

Management options for reducing excessive human-induced mortality include:

(1) Reducing the vulnerability of moose to illegal hunting by: (a) effective and widespread road closures and (b) maintenance of readily accessible hiding cover in new cutting units, with islands of brush or leave-trees, narrow and irregular units, or any other design features that block long sightlines and allow moose to reach cover quickly;

(2) Continuing efforts to monitor and stablize the annual Indian treaty harvest;

(3) Adjusting regulated hunting quotas to yearly fluctuations in snow conditions and subsequent calf production;

(4) Discouraging poaching by impromptu checking stations and greater law enforcement presence whenever possible.

Management options for enhancing hard-winter habitat and subsequent calf production include:

(1) Creating more good quality winter habitat at low elevation, particularly fine-grained open forage/forested cover mosaics (numerous small clearings in timber stands likely to produce good browse--swamps; western larch, western redcedar, western hemlock, and alpine fir habitats).

(2) Leaving an adequate supply of mature and old growth stands at middle elevation (3400-4200 ft): multi-storied stands of at least 100 ac with good thermal cover and a good supply of arboreal lichens and preferred coniterous browse (western redcedar, alpine fir, Douglas-fir, pacific yew).

CHANGES WITH INCREASING POPULATION

With reduction in human induced mortality, the ultimate limiting factor for Yaak moose populations should be the amount of acceptable *mid-elevation* winter habitat. Until these limits are reached, the following changes may be expected with increasing population:

(1) Greater use of middle elevation timber stands (3400-4200 ft) in deep-snow winters;

(2) More competition for upland aquatic sites, and more use of less secure sites (unless the number of secure aquatic sites increases);

(3) Greater use of less secure calving sites;

(4) Higher calf mortality, both from bear predation in less secure calving areas and from more stringent conditions on middle elevation winter ranges in deep-snow winters;

(5) Lower overall calf production;

(6) Greater use of open forage areas dominated by forbs and conifer seedlings--areas with good forage but inadequate hiding security;

(7) Deterioration of browse in consistently accessible winter foraging habitats;

(8) Greater flow across the Canadian border--particularly by bulls and young animals--with high hunting mortality;

(9) Increased competion with other ungulates for winter habitats, particularly with woodland caribou, should their populations develop, secondly with elk, and thirdly with both white-tailed and mule deer.

HABITAT SURVEYS

The following habitat features of importance to moose are not easily derived from standard timber and silvicultural measurements used in stand exams and forest inventories, and need to be specifically measured for stand-sized sampling units: (1) the quality and dispersion of *hiding cover*, (2) the quality of *thermal cover*, (3) the abundance and quality of *forage*, and (4) effective *snow depth*. In addition, key components need to be identified: (1) calving sites, (2) aquatic feeding sites, (3) damp forage in timber, (4) low elevation winter cover/forage mosaics, and (5) uncanopied forage with hiding cover.

Interpreting standard timber measurements in terms that reliably describe realized or potential moose habitat proved inefficient and too imprecise for useful management application. It is more useful to simply take a few additional measurements that directly describe the relevant parameters and to identify key components as such in the field, rather than trying to derive them from combinations of timber-oriented parameters.

POPULATION SURVEYS

Detailed information on population structure and precise estimates of population size will not be available for management in the Yaak. However, rough estimates of population trends sufficient for management can be obtained.

Calf:cow ratios, Yearling:cow ratios, twinning rates, and bull:cow ratios can be obtained throughout the summer and fall from ground surveys. A series of standard routes near aquatic sites and uncanopied summer foraging areas should provide the necessary information as long as (1) the survey routes are extensive, (2) several routes are used, (3) surveys are conducted several times throughout the summer and early fall, (4) survey effort is tallied and standardized, and (5) surveys are conducted early and late in the day (before 10:00 AM and after 6:00 PM).

These should provide a rough assessment of the success of calf production for the year (the late summer calf population), and of the contribution of the previous year to the present population (the yearling population). Because of the difficulty of distinguishing small adult cows from yearlings after late summer, a reliable substitute might be spring calf and early summer yearling tallies (late April to early July). Our experience suggests investing enough field time to produce valid sample sizes of at least 50 adult cows, and preferably twice that. This information may best be gathered by Forest Service wildlife biologists and technicians who are out in the area every day.

Aerial surveys of aquatic feeding sites along the Yaak River in the summer of 1985 produced a sample size too small for useful population estimates. Helicopter surveys of open feeding sites conducted by the Dept. of Fish, Wildlife and Parks in late fall and early winter, 1985 and 1986, proved more successful (J. Brown, pers. comm). These surveys can provide useful post-harvest information (relative numbers, calf:cow ratios, sex ratios) if (1) they are conducted over appropriate browse units at low to middle elevations, after the moose have begun to concentrate on early winter range but before snow has become deep and heavy (early December to mid January), and (2) replicate flights are made, so that the variance of the estimate can be computed. Duplicate counts by 2 observers in one plane would also be of value in this regard.

At present population levels, primary early winter habitat in open foraging units should accommodate most moose; but with increasing population, some moose should begin moving into secondary habitats in early winter, principally forest stands with browse. These need to be checked on the ground, using track counts and ground sightings, to pick up shifts in habitat use due to population changes. Monitoring of effective snow depths in mid and late winter (February–March) should be coupled with a survey of use in prime mid elevation browse units and multi-storied timber stands. This should indicate the quality of habitat available to moose and provide a key to calf production the following year.

More precise harvest information is also needed: sex, age estimate, location of kill, and an estimate of hunting effort (hours per kill). General information on Indian harvest is now available for Lincoln County as a whole (R. Matchett, pers. comm.), but precise information for the Yaak area will probably continue to come from fortuitous observation by local residents and resource management personnel (primarily Forest Service field workers). For the time being, information on illegal kill will have to be gleaned in the same manner, and the total result projected.

In summary, the following measures should generate useful information in monitoring moose population trends in the Yaak:

(1) Early winter aerial surveys of open browse units at low-middle elevations to obtain ratios and relative numbers in prime habitat;

(2) Early winter ground surveys of timbered areas with forested forage to sample use trends in secondary habitat;

(3) Ground surveys in late spring and early summer to obtain ratios of yearlings to adults;

(4) Ground surveys in mid-late summer and early fall to obtain calf:cow ratios and bull:cow ratios before hunting season;

(5) Mid winter snow depth measurements in primary moose habitat at low and middle elevation, and ground surveys of moose utilization of selected habitat units;

(6) Questionaires to obtain information on hunter success and hunter-effort per moose kill.

SOME SPECIFIC GUIDELINES

Population Monitoring:

A deep-snow winter is one in which mid elevation (3400-4200 ft) open browse units sustain effective snow depths greater than 28 in (70 cm) through March. A light-snow winter is one in which snow depths in these units are less than 20 in (50 cm).

The year following a deep-snow winter expect late summer calf:cow ratios in the 20-40:100 range and twinning rates of 20-35%. The year after a mild winter expect late summer calf:cow ratios more on the order of 75:100 and twinning rates toward 50%.

Bull:cow ratios of 40:100 are marginal. A more favorable ratio (on the order of 65:100) should increase the proportion of cows calving in a productive year.

Moose densities of 2.5 adults/mi^2 (1.0 /km^2) on winter range during a hard winter in which good quality browse is not readily available, may be close to carrying capacity.

Heavy browsing on less preferred species (such as buffalo berry, huckleberry, Engelmann spruce) in the understory of low and middle elevation timber stands is a sign that the carrying capacity of these hard-winter ranges is being approached. Middle elevation clearcuts will be heavily browsed during light-snow winters, but will then normally have 2-3 years of low use in which to recover.

Combined annual harvest (State, Indian, and illegal) should not consistently exceed 15% of the yearling-adult population.

Cover and Forage Quality:

A high-quality forage unit is one that contains at least 30%, and preferably 45%, total canopy coverage (sum of individual species coverages) of the following species:

service berry	bearberry honeysuckle
redstem ceanothus	aspen
mountain maple	young alders (1-3 ft)
Utah honeysuckle	young birch (1-3 ft)
menziesia	young cottonwood (1-3 ft)
mountain ash	fireweed
most upland willows	geraniums
redosier dogwood	Douglas spirea (late fall)
most currants	shiney-leaf ceanothus (early winter)

Some of these species respond best to broadcast burning and some to mechanical scarification: there is no universal site preparation scheme of preference. Forage quality of new units will benefit from leave-islands of brush and residual conifers in any case.

Good timbered habitat for deep-snow winters should have at least 45% canopy coverage of preferred conifer regeneration in the 1-8 ft browse zone: alpine fir, western redcedar, Douglas-fir, pacific yew. Arboreal lichens should be abundant and accessible. Good ground cover of pachistima provides an additional food source.

The most frequently used subaquatic species groups are: pondweeds, aquatic buttercups, and elodea.

Abundant species consistently ignored include: buffalo berry, huckleberry, grouse whortleberry, snowberry, birch-leaf spirea, coarse sedges, lodgepole pine regeneration, Engelmann spruce regeneration.

Hiding cover/forage ratios available in the Yaak are relatively high: 75/25 overall, 74/26 on summer-fall range, and 66/34 on winter-spring range. Ratios for habitat used by moose are much higher than those normally recommended for elk and deer (Kootenai National Forest Plan) since much of the best moose forage is associated with hiding cover: 84/16 in May--October and 83/17 in November--April.

Timber Management:

Cutting units of highly irregular shape and with numerous islands of leave-trees and brush are most valuable as moose habitat. Long sightlines are blocked, hiding cover is close by, pockets of thermal cover are available, and browse is provided along extensive edges. These benefits are available immediately after logging, and need not wait 12-20 years for vegetation to develop.

With traditional block-like clearcuts, preferred size is 8-24 ha (20-60 ac). Preferred cutting unit age is 15-35 years.

Seed tree cuts are preferable to clearcuts in that fallen branches from seed trees, particularly western larch, provide an additional food source in winter and early spring.

LITERATURE CITED

Altmann, M. 1963. Naturalistic studies of maternal care in moose and elk. pages 233-253 *in* H.L. Rheingold (ed.). Maternal behavior of mammals. J. Wiley, New York.

Bailey, N.T.J. 1952. Improvements in the interpretation of recapture data. J. Anim. Ecol. 21: 120-127.

Belovsky, G.E. 1981. Optimal activity times and habitat choice of moose. Oecologia 48: 22-30.

____________. 1978. Diet optimization in a generalist herbivore: the moose. Theor. Pop. Biol. 14: 105-134.

____________ and P.A. Jordan. 1978. The time-energy budget of a moose. Theor. Pop. Biol. 14: 76-104.

Berg, N.E. and R.L. Phillips. 1974. Habitat use by moose in northwestern Minnesota with reference to other heavily willowed areas. Naturaliste Can. 101: 101-116.

Best, D.A., G.M. Lynch, and O.J. Rongstad. 1978. Seasonal activity patterns of moose in the Swan Hills, Alberta. Proc. N. Am. Moose Conf. Workshop 14: 109-125.

Bonar, R.L. 1983. Winter moose population characteristics during pre-flooding stages of hydro-electric development in British Columbia. Alces 19: 222-237.

Brown, Jerry. 1986. Personal communication.

Byers, C.R., R.K. Steinhorst, and P.R. Krausman. 1984. Clarification of a technique for an analysis of utilization-availability data. J. Wildlife Manage. 48(3): 1050-1053.

Calvi, Jim. 1985. Personal communication.

Caughley, G. 1977. Analysis of vertebrate populations. John Wiley and Sons, London. 234 pp.

Cederlund, G., F. Sandegren, and K. Larsson. 1987. Summer movements of female moose and dispersal of their offspring. J. Wildlife Manage. 51(2): 342-352.

Coady, J.W. 1974. Influence of snow on behavior of moose. Nat. Can. 101: 417-436.

Cowan, I.M. 1950. Some vital statistics of big game on overstocked mountain range. Trans. N.Am. Wildl. Conf. 15: 581-588.

Craighead, J.J., F.C. Craighead, R.L. Ruff, and B.W. O'Gara. 1973. Activity patterns of non-migratory elk of the Madison drainage herd as determined by biotelemetry. Wildl. Monogr. 30: 1-50.

Crete, M., R.J. Taylor, and P.A. Jordan. 1981. Optimization of moose harvest in southwestern Quebec. J. Wildl. Manage. 45: 598-611.

Daubenmire, R. 1959. A canopy-coverage method of vegetational analysis. Northwest Sci. 33: 43-66.

Davis, J.L. and A.W. Franzmann. 1979. Fire-moose-caribou interrelationships: a review and assessment. Proc. N.Am. Moose Conf. Workshop 15: 80-118.

Denniston, R.H. 1956. Ecology, behavior, and population dynamics of the Wyoming or Rocky Mountain moose. Zoologica 41: 105-118.

de Vos, A. 1956. summer studies of moose in Ontario. Trans. N.A. Wildl. Conf. 21: 510-525.

Dixon, K.R. and J.A. Chapman. 1980. Harmonic mean measure of animal activity areas. Ecology 61: 1040-1044.

Doerr, J.G. 1984. Considerations for managing moose habitat in the Petersburg Ranger District, Tongass National Forest, Southeast Alaska. pp. 343-349 *in* W.R. Meehan et al., eds. Proc. Fish and Wildlife Relationships in Old-Growth Forests Symp., Juneau, AK. Apr. 12-15, 1982. Amer. Inst. Fishery Res. Biol., J.W. Reintjes, Moorhead City, NC.

Dorn, R.D. 1969. Relations of moose, cattle, and willows in south-western Montana. M.S. Thesis, Montana State U., Bozeman. 77 pp.

Eason, G., E. Thomas, R. Jerrand, and K. Oswald. 1981. Moose hunting closure in a recently logged area. Alces 17: 111-125.

Eastman, D.S. 1974. Habitat use by moose of burns, cutovers, and forests in north-central British Columbia. Proc. N. Am. Moose Conf. Workshop 10: 1-18.

Edwards, R.Y. and R.W. Ritcey. 1958. Reproduction in a moose population. J. Wildl. Manage. 22: 261-268.

__________ and __________. 1956. The migrations of a moose herd. J. Mammal. 37: 486-494.

Flook, D.R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128 *in* D.J. Crisp, ed. Grazing in terrestrial and marine environments. Brit. Ecol. Soc. No. 4.

Formozov, A.N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. Occ. Pub. 1, Boreal Instit., U.Alberta, Edmonton. 143 pp.

Franzmann, A.W. and R.O. Peterson. 1978. Moose calf mortality assessment. Proc. N.Am. Moose Conf. Workshop 14: 247-269.

Fraser, D., D. Arthur, J.K. Morton, and B.K. Thompson. 1980. Aquatic feeding by moose in a Canadian lake. Holarctic Ecol. 3: 218-223.

Gasaway, W.A. and J.W. Coady. 1974. Review of energy requirements and rumen fermentation in moose and other ruminants. Naturaliste Can. 101: 227-262.

Geist, V. 1982. Adaptive behavioral strategies, Chapt.5 *in* J.W. Thomas and D.E. Toweill (eds.), Elk of North America. Stackpole Books, Harrisburg, Pa. 698 pp.

________. 1963. On the behavior of the North American moose (*Alces alces andersonii*) in British Columbia. Behavior 20(3-4): 377-415.

________. 1971. Traditions and the evolution of social systems: sheep versus moose, Chapt.5 *in* Mountain sheep--a study in behavior and evolution. Univ. Chicago Press, Chicago. 383 pp.

________. 1974. zon the evolution of reproductive potential in moose. Naturaliste Can. 101: 527-537.

Hauge, T.M. and L.B. Keith. 1981. Dynamics of moose populations in northeastern Alberta. J. Wildl. Manage. 45: 573-597.

Hepburn, R.L. 1978. A snow penetration guage for studies of white-tailed deer and other northern mammals. J. Wildlife Manage. 42: 663-667.

Houston, D.B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Nat. Hist. Assoc. Tech Bull. 1. 110 pp.

Jenkins, K.J. 1985. Winter habitat and niche relationships of sympatric cervids along the North Fork of the Flathead River, Montana. PhD dissertation, Univ. Idaho, Moscow. 183 pp.

Johnson, D.H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecology 61: 65-71.

Kelsall, J.P. 1969. Structural adaptations of moose and deer in snow. J. Mammal. 50: 302-310.

____________ and W. Prescott. 1971. Moose and deer behavior in snow in Fundy National Park, New Brunswick. Can. Wildl. Serv. Rep.15. 25 pp.

Kirchhoff, M.D. and J.W. Schoen. 1987. Forest cover and snow: implications for deer habitat in southeast Alaska. J. Wildlife Manage. 51: 28-33.

Klein, D.R. 1982. Fire, lichens and caribou. J. Range Manage. 35: 390-395.

Knowlton, F.F. 1960. Food habits, movements, and populations of moose in the Gravelly Mountains, Montana. J. Wild. Manage. 24: 162-170.

Krefting, L.W. 1974. The ecology of the Isle Royale moose with special reference to the habitat. Univ. Minnesota Agr. Exp. Stn. Tech. Bull. 297.

Kubota, J. 1974. Mineral composition of browse plants for moose. Naturaliste Can. 101: 291-305.

Leptich, D.J. 1986. Summer habitat selection by moose in northern Maine. M.S. Thesis. Univ. Maine, Orono. 42 pp.

LeResche, R.E. 1968. Spring-fall calf mortality in an Alaskan moose population. J. Wildl. Manage. 32(4): 953-956.

____________, R.H. Bishop, and J.W. Coady. 1974. Distribution and habitats of moose in Alaska. Naturaliste Can. 101: 143-178.

Lynch, G.M. and Morgantini. 1984. Sex and age differential in seasonal home range size of moose in north-central Alberta, 1971-1979. Alces. 20: 61-78.

Lyon. L.J. 1985. A new approach to habitat selection modelling. Paper presented at the Ann. Meeting NW Section, the Wildlife Society, Apr. 3-5, Missoula, Mont. 12 pp.

Marcum, C.L. and D.O. Loftsgaarden. 1980. A non mapping technique for studying habitat preferences. J. Wildlife Manage. 44: 963-968.

Matchett, M.R. 1986. Personal communication.

____________. 1985a. Moose-habitat relationships in the Yaak River drainage, northwestern Montana. M.S. Thesis, Univ. Montana, Missoula. 229 pp.

____________. 1985b. Habitat selection by moose in the Yaak River drainage, northwestern Montana. Alces 21. 29 pp.

____________. 1984. BONF3.FOR--simultaneous confidence interval program. Univ. Montana, Missoula.

_____________, M. Haroldson and J. Glassy. 1984. MARK.FOR--a modified version of HARM.FOR, program for computing and plotting harmonic home range. Univ. Montana, Missoula.

McLellan, B.N. 1986. Use-availability analysis and timber selection by grizzly bears. pp. 163-166 *in* G.P. Contreras and K.E. Evans, eds. Proc. Grizzly Bear Habitat Symp., Missoula, MT. Apr 30-May 2, 1985. For. Serv. Intermtn. Res. Stn., Ogden, UT. Gen. Tech. Rep. INT-207.

McNicol, J.G. and F.F. Gilbert. 1980. Late winter use of upland cutovers by moose. J. Wildlife Manage. 44: 363-371.

Mech, L.D. and R.E. McRoberts. 1987. Relationship of deer and moose populations to previous winters' snow. J. Anim. Ecol. 56: 615-627.

Metzgar, L.H. 1981. LSWK11.FOR - a computer population simulation model. Dept. Zool., Univ. Montana, Missoula.

Messier, F. amd M. Crete. 1984. Body condition and population regulation by food resources in moose. Oecologia 65(1): 44-50.

Mohr, C.O. 1947. Table of equivalent populations of North American mammals. Am. Midl. Nat. 37: 223-249.

Monthey, R.W. 1984. Effects of timber harvesting on ungulates in northern Maine. J. Wildlife Manage. 48: 279-285.

Mytton, W.R. and L.B. Keith. 1981. Dynamics of moose populations near Rochester, Alberta, 1975-1978. Can. Field-Nat. 95: 39-49.

Nasimovich, A.A. 1955. The role of snow cover conditions in the life of ungulates in the U.S.S.R. Unedited translation, Boreal Instit., U. Alberta, Edmonton. 288 pp.

Neu, C.W., C.R. Byers, and J.M. Peek. 1974. A technique for analysis of utilization-availability data. J. Wildlife Manage. 38(3): 541-545.

Oldemeyer, J.L., A.W. Franzmann, A.L. Brundage, P.D. Arneson, and A. Flynn. 1977. Browse quality and the Kenai moose population. J. Wildlife Manage. 41: 533-542.

Parker, K.L., C.T. Robbins, and T.A. Hanley. 1984. Energy expenditures for locomotion by mule deer and elk. J. Wildlife Manage. 48: 474-488.

Peek, J.M. 1971. Moose-snow relationships in northeastern Minnesota. Pages 39-49 *in* A.O. Haugen (ed.), Proc. Symp. on snow and ice in relation to wildlife and recreation. Iowa Coop. Wildl. Res. Unit, Iowa State Univ. Press, Ames. 280 pp.

________. 1974a. On the nature of winter habitats of Shiras moose. Naturaliste. Can. 101: 131-141.

________. 1974b. A review of moose food habits studies in North America. Naturaliste Can. 101: 195-215.

________ and D.S. Eastman. 1983. Factors which naturally control moose populations. Pages 175-193 *in* F.L. Bunnell et al, eds. Symposium on natural regulation of wildlife populations. For., Wildl. and Range Exp. Stn., Univ. Idaho, Moscow.

________, E.L. Urich, and R.J. Mackie. 1976. Moose habitat selection and relationships to forest management in northeastern Minnesota. Wildl. Monogr. 48. 65 pp.

Peterson, R.O. 1977. Wolf ecology and prey relationships on Isle Royale. National Park Service. Scientific Monograph 11.

____________ and D.L. Allen). 1974. Snow conditions as a parameter in moose-wolf relationships. Naturaliste Can. 101: 481-492.

____________, R.E. Page, and K.M. Dodge). 1984. Wolves, moose, and the allometry of population cycles. Science 224: 1350-1352.

Phillips, R.L., W.E. Berg, and D.B. Siniff. 1973. Moose movement patterns and range use in northwestern Minnesota. J. Wildl. Manage. 37: 266-278.

Pierce, D.W. 1983. Food habits, movements, habitat use and populations of moose in central Idaho and relationships to forest management. M.S. Thesis, Univ. Idaho, Moscow. 205 pp.

__________. 1984. Shiras moose forage selection in relation to browse availability in north-central Idaho. Can. J. Zool. 62: 2404-2409.

__________ and J.M. Peek. 1984. Moose habitat use and selection patterns in north-central Idaho. J. Wildlife Manage. 48: 1335-1343.

Pimlott, D.H., J.A. Shannon, and G.B. Kolenosky. 1969. The ecology of the timber wolf in Algonquin Provincial Park. Ontario Dept. Lands and For. pub. 92 pp.

Riedlinger, Martin. 1985. Personal communication.

Ritchie, B.W. 1978. Ecology of moose in Fremont county. Idaho Dept. Fish and Game, Boise. Wildl. Bull. 7. 33 pp.

Rolley, R.E. and L.B. Keith. 1980. Moose population dynamics and winter habitat use at Rochester, Alberta 1965-77. Can. Field-Nat. 94: 9-18.

Samuel, W.M. and M.J. Barker. 1979. The winter tick, *Dermacentor albipictus*, on moose, *Alces alces*, of central Alberta. Proc. N.Am. Moose Conf. Workshop 15: 303-348.

Samuel, M.D., D.J. Pierce, E.O. Garton, L.J. Nelson, and K.R. Dixon. 1983. User's manual for program home range (revised January 1985). For., Wildl. and Range Exp. Stn. Tech. Rep. 15. Univ. Idaho, Moscow. 64 pp.

Schladweiler, P. 1974. Moose ecology in southwestern Montana. Job Final Rep. Res. Proj., Montana Dept. Fish and Game, Helena. 100 pp.

______________ and D.R. Stevens. 1973. Reproduction of Shiras moose in Montana. J. Wildl. Manage. 37: 535-544.

Schlegal, M. and A. Christensen. 1979. Moose habitat cooperative cooperative survey. Ann. Rep. Idaho Dep. Fish and Game and Clearwater Nat. For, Orifino. 13 pp.

Spencer, D.L. and E.F. Chatelain. 1953. Progress in the management of moose in south central Alaska. Trans. N.Am. Wildl Conf. 18: 539-552.

Stevens, D.R. 1970. Winter ecology of moose in the Gallatin mountains, Montana. J. Wildl. Manage. 34: 37-46.

Stewart, R.R. 1985. A sex- and age-selective harvest strategy for moose management in Saskatchewan. Pages 229-238 *in* S.L. Beasom and S.F. Roberson, eds. Game harvest management. Caesar Kleberg Wildlife Research Inst., Kingsville Texas.

Taylor, K.P. and W.B. Ballard. 1979. Moose movements and habitat use along the Susitna River near Devil's Canyon. Proc. N.Am. Moose Conf. Workshop 15: 169-186.

Telfer, E.S. 1967. Comparison of moose and deer winter range in Nova Scotia. J. Wildl. Manage. 31: 418-425.

Thompson, I.D. and M.F. Vukelich. 1981. Use of logged habitats in winter by moose cows with calves in northeastern Ontario. Can. J. Zool. 59: 2103-2114.

Tyrrell, J.B. (ed.) 1916. David Thompson's narrative of his explorations in western America, 1784-1812. The Champlain Society, Toronto. 582 pp.

Van Ballenberghe, V. and J.M. Peek. 1971. Radio telemetry studies of moose in northeastern Minnesota. J. Wildl. Manage. 35: 63-71.

Wasem, C.R. 1967. The history of elk and elk management in Glacier National Park. Unpubl. manuscript, Glacier Nat. Park, MT. 24 pp.

Wolfe, M.L. 1977. Mortality patterns in the Isle Royale moose population. Am. Midl. Nat. 97: 267-279.

"Pages 167-172 omitted in numbering."

APPENDICES

APPENDIX A: STAND TABLES (TABLES 1-3)

Habitat use and availability of USFS stands and silvicultural units: average stand condition for 42 parameters estimated from a data base of 400 radio locations and 188 random locations.

Data are organized as follows: Table 1 compares habitat utilized to that available in each of 4 standard seasons; Table 2 makes the same comparisons, but with the year partitioned into 2 seasons (expanded winter and expanded summer); and Table 3 compares use of several parameters between winters of significantly different character.

The use and availability values for each habitat category are expressed as percentages of N (the sample size for that parameter). The appropriate values of N are given at the bottom of each column.

Chi-sq contingency tests:

These indicate significant deviation of percent use from percent availability within each habitat *parameter*.
A valid test for any parameter requires that at least 80% of the expected cell frequencies contain 5 or more observations. All expected cells must contain at least 1 observation.

Notation (adjacent to N values at the bottom of each column):

* denotes significant Chi-sq with $P \leq 0.05$

Simultaneous confidence intervals:

These indicate which habitat *categories* within each parameter are used significantly more or less than their availability.

Notation (adjacent to the appropriate % use and availability):

++	denotes	Use > Availability	with	$P \leq 0.05$
+	"	" "	"	$P \leq 0.10$
--	denotes	Use < Availability	with	$P \leq 0.05$
-	"	" "	"	$P \leq 0.10$

< > indicates the direction of significant increases in use between years or seasons with $P \leq 0.10$

APPENDIX A: TABLE 1

Habitat Use by *Season*: *standard 4-season* break-down.
Radio points were stratified by length of season and distributed as follows: Winter=110, Spring=65, Summer=114, Fall=111.

Seasonal divisions were defined for individual moose first of all by their movements between seasonal ranges. In those cases where no abrupt migration occurred, average values were applied. These average dates varied from year to year, but in general seasons fell out: Winter = mid-December to late March; Spring = early April to mid-May; Summer = mid-May to early September; Fall = early September to mid-December.

Winter-to-spring and fall-to-winter movements were usually associated with changes in snow depth and structure. Spring-to-summer range shifts by cows were normally abrupt moves to calving areas. The summer-to-fall demarcation was defined by behavior changes associated with the start of the rut, usually about the first week in September.

Seasonal habitat availability was based on the group of random points that fell within the combined home ranges of the 8 moose for the season in question. These points fell out as follows: Winter=130, Spring=133, Summer=170, Fall=188.

Notation:	Significant Chi-sq	with	$P \leq 0.05$	*
	Use > Availability	with	$P \leq 0.05$	++
	" "	"	$P \leq 0.10$	+
	Use < Availability	with	$P \leq 0.05$	--
	" "	"	$P \leq 0.10$	-

APPENDIX A: TABLE 1. Habitat Use/Availability within USFS *stands* and other silvicultural units with the year divided into *4 standard seasons*.

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
PERCENT SLOPE								
0-7 %	21.8	20.0	12.3	19.5	8.8	15.3	18.0	14.9
8-15	15.5	20.0	16.9	20.3	19.3	18.2	15.3	19.7
16-25	20.9	23.1	24.6	24.1	20.2	22.4	21.6	22.3
26-35	28.2++	13.8	24.6	13.5	30.7	17.6	28.8	18.1
36-45	9.1	12.3	15.4	12.0	14.9	13.5	4.5-	12.8
46-55	3.6	6.2	3.1	6.0	3.5	7.1	7.2	6.9
55+	0.9	4.6	3.1	4.5	2.6	5.9	4.5	5.3
N	110	130	65	133	114	170	111	188
ASPECT								
N-NE-E	10.9--	26.4	16.9	25.7	30.7	32.2	28.8	30.7
SE	9.1	8.5	7.7	9.1	9.6	12.5	8.1	11.3
S-SW-W	57.2++	31.8	52.2++	31.9	38.6	41.5	44.1+	30.7
NW	5.5	9.3	9.2	9.1	6.1	7.1	6.3	8.1
level	17.3	24.0	13.8	24.2	14.9	16.7	12.6	19.4
N	110*	129	65*	132	114	168	111*	188
ELEVATION								
2900-3500 ft	41.8	39.9	24.6	39.9	1.8--	39.9	21.6--	39.9
3500-4100	35.5	26.1	41.5	26.1	28.1	26.1	32.4	26.1
4100-4700	22.7	16.5	33.8+	16.5	44.7++	16.5	24.3	16.5
4700-5300	0.0--	12.8	0.0--	12.8	14.9	12.8	8.1	12.8
5300-5900	0.0-	3.7	0.0-	3.7	9.6	3.7	11.7+	3.7
5900+	0.0	1.1	0.0	1.1	0.9	1.1	1.8	1.1
N	110*	188	65*	188	114*	188	111*	188

elevation: seasonal use is compared to year-round availability

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
CONTIGUOUS UNIT AREA: OPEN HABITAT								
1-20 acres	4.3-	13.6	9.8	12.1	0.0--	12.2	8.6	12.2
21-40	35.7++	11.9	48.8++	12.1	19.3	9.8	13.8	9.8
41-60	24.3	18.6	2.4--	19.0	14.0	14.6	15.5	14.6
61-80	4.3	10.2	4.9	10.3	7.0	8.5	0.0-	8.5
81-100	0.0-	8.5	0.0-	8.6	0.0-	6.1	3.5	6.1
101-200	18.5	13.6	24.4	13.8	16.8	14.6	22.4	14.6
201-500	11.4-	22.0	7.3-	22.4	26.3	26.8	24.1	26.8
500+	1.4	1.7	2.4	1.7	15.8	7.3	12.1	7.3
N	66*	59	41*	58	57*	82	58*	82
CONTIGUOUS UNIT AREA: TIMBERED HABITAT								
1-20 acres	5.0	2.8	12.5+	2.8	7.0	2.9	6.3	6.9
21-40	2.5	1.4	8.3	1.4	1.8	1.0	8.1	4.8
41-60	25.0+	9.7	0.0	9.5	10.5	6.7	10.8	10.1
61-80	7.5	4.2	4.2	4.1	0.0	2.9	2.7	5.9
81-100	5.0	6.9	0.0-	6.8	1.8	5.7	0.9	5.9
101-200	20.0+	9.7	37.5++	9.6	21.1+	8.6	21.6+	11.2
201-500	20.0	29.2	16.7	29.8	40.4+	29.5	31.5	28.2
500+	15.5--	36.1	20.9-	36.5	17.5--	42.9	18.0	27.1
N	39*	72	24*	74	57*	88	53	105

Contiguous Unit Area: the acreage of the USFS unit plus all adjacent habitat of roughly similar structure--as determined from aerial photos.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
ABUNDANCE OF 1ST + 2ND-ORDER FORAGE								
0-15% cover	38.7--	75.4	36.9--	73.7	23.4--	56.5	32.4--	67.0
16-30%	17.9	13.8	24.6	14.3	31.5	21.2	24.3	18.6
31-45%	8.5	9.2	7.7	9.0	14.4	10.0	18.9+	8.5
46-60%	10.4++	0.8	16.9++	2.3	11.7	8.8	11.7+	3.7
>60%	24.5++	0.8	13.8++	0.8	18.9++	3.5	12.6++	2.1
N	106*	130	65*	133	111*	170	111*	188
ABUNDANCE OF 1ST + 2ND + 3RD-ORDER FORAGE								
0-15% cover	12.3--	34.6	7.7--	33.8	5.4--	24.1	9.9--	28.7
16-30%	11.3--	33.8	10.8--	33.8	6.3--	30.0	14.4--	33.0
31-45%	25.5++	11.5	26.2	12.0	12.6	10.6	18.0	11.2
46-60%	6.6	8.5	20.0	8.3	23.4++	11.2	19.8	11.2
61-75%	8.5	10.0	3.1	9.8	19.8	11.8	11.7	9.6
75-90%	6.6+	0.8	4.6	1.5	11.7	7.6	14.4++	4.3
>90%	29.2++	0.8	27.7++	0.8	20.7++	4.7	11.7++	2.1
N	106*	130	65*	133	111*	170	111*	188

Percent cover = the sum of the cover values of individual species.

1st + 2nd-order forage = 7 'highly preferred' species + 8 'preferred' species. 1st + 2nd + 3rd-order forage = the initial 15 species + 10 'often used' species. Ratings are defined and species listed in Appendix D.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>HORIZONTAL PATTERN</u>								
OS randm: US randm	36.4	46.2	30.8-	45.9	46.5	43.5	40.5	46.3
OS randm: US clmpd	1.8	6.2	4.6	6.0	1.8	4.1	4.5	4.3
OS randm: US negl	1.8	1.5	3.1	1.5	3.5	2.4	4.5	2.1
OS clmpd: US randm	2.7	6.2	3.1	6.0	8.8	5.3	5.4	5.3
OS clmpd: US clmpd	9.1	7.7	9.2	9.0	10.5	12.9	8.1	12.2
OS negl: US randm	36.4++	15.4	36.9++	15.0	21.1	15.9	17.1	14.9
OS negl: US clmpd	8.2	6.9	9.2	6.8	7.9	8.2	18.9+	8.0
OS negl: US negl	3.6	10.0	3.1	9.8	0.0--	7.6	0.9--	6.9
N	110*	130	65*	133	114	170	111*	188
<u>VERTICAL LAYERING</u>								
No Canopy	42.7+	30.0	44.6+	29.3	27.2	27.1	25.2	25.0
Mosaic	7.3	15.4	7.7	16.5	18.4	22.9	24.3	22.3
One-Storied	19.1+	9.2	13.8	9.0	3.5	10.0	8.1	9.6
Weak Layering	12.7	20.0	16.9	19.5	12.3	12.4	15.3	16.0
Multi-Storied	18.2	25.4	26.9	25.5	38.6	27.6	27.0	27.1
N	110*	130	65*	133	114	170	111	188

Horizontal Pattern: OS = overstory, US = understory.
randm = random/regular dispersion pattern, clmpd = clumped pattern, negl = negligible vegetation.

Vertical Pattern: Mosaic = interspersion of different layering patterns throughout the stand.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
PERCENT CANOPY CLOSURE								
none	37.3	27.7	36.9	27.1	25.4	25.3	22.5	23.4
0-20 %	10.9	4.6	7.7	4.5	5.3	7.6	11.7	7.4
21-40	6.4	10.0	10.8	10.5	15.8	10.6	13.5	9.6
41-60	9.1	8.5	6.2	9.0	7.0	10.0	9.9	10.6
61-80	28.2	36.9	24.6	36.8	15.8--	28.2	18.0--	32.4
81-100	8.2	12.3	13.8	12.0	30.7+	18.2	24.3	16.5
N	110	130	65	133	114*	170	111	188
THERMAL COVER								
None	44.5+	30.8	43.9+	30.1	25.0	30.0	27.7	28.2
Submarginal	18.2	16.9	19.7	17.3	23.2	17.6	25.9	20.7
Marginal	24.5	30.8	13.6--	29.3	12.5-	22.4	20.5	28.2
Good	12.7	21.5	22.7	23.3	38.9	30.0	25.9	22.9
N	108	130	65*	133	114	170	112	188
HIDING COVER								
None	3.7--	13.8	4.6	13.5	2.7--	10.0	2.7--	10.1
Fragmentary	17.4	20.0	12.3	20.3	9.8	16.5	9.9	16.0
Partial	53.2	45.4	43.1	44.4	33.0	34.1	46.8	43.1
Complete	25.7	20.8	40.0++	21.8	60.7++	39.4	40.5	30.9
N	109*	130	65*	133	112*	170	111*	188

Thermal Cover: Good = trees 40+ ft high with >70% canopy closure, Marginal = 50-70% cc, Submarginal = 10-50% cc, None = <10% cc.

Hiding Cover: Vegetation adequate to hide 90% of a standing moose at 200 ft (about 60 m). Complete = >90% of unit in hiding cover, Partial = 50-90%, Fragmentary = 10-50%, Negligible = <10%.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>COVER</u> <u>CONFIGURATION</u>								
Ineffective Cvr	17.2	21.7	18.5	22.0	7.1-	17.6	10.9	16.1
Hiding Cvr only	46.4++	20.9	44.6++	21.3	43.0+	28.3	40.9+	27.4
Hiding + Thermal	36.4--	57.4	37.0--	56.9	50.0	52.3	48.1	56.5
N	110*	129	65*	132	114*	170	110*	187
<u>STRUCTURAL</u> <u>TYPE</u>								
negligible cover								
Grass-Forb	1.8	6.2	3.1	6.1	1.8	4.7	0.9	4.3
Seedl-LowBrush	3.6	4.7	0.0-	4.5	3.5	3.5	2.7	3.2
Sapl or Pole	2.7	5.4	3.1	5.3	0.0-	4.1	0.0-	3.7
Mature	9.1	5.4	12.3	6.1	1.8	5.3	7.3	4.9
hiding cvr only								
Sapl-Brush	35.5++	9.3	35.4++	9.1	21.9	12.4	22.7	11.8
Pole-Brush	0.9	6.2	0.0--	6.1	15.8	7.1	9.1	7.5
Mature-Brush	10.0	5.4	9.2	6.1	5.3	8.8	9.1	8.1
thermal + hiding								
Pole or Sml Mature	9.1--	27.9	3.1--	27.3	11.4--	26.4	13.6--	30.1
Lge Mature	27.3	25.6	30.8	25.8	32.5	22.9	28.2	23.2
Old Growth	0.0-	3.9	3.1	3.8	6.1	3.5	6.3	3.2
N	110*	129	65*	132	114*	170	110*	187

Structural Type: Sml Mature = mixture of poles & small mature trees.
Lge Mature = mature trees only.
Mature = Lge + Sml categories combined.
(further clarification is in Appendix C)

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
USFS PI TYPE: LOGGING STATUS								
Logged	60.0++	41.5	67.7++	42.1	54.4+	42.9	55.0+	42.6
Not Logged	38.2	49.2	32.3-	48.9	45.6	50.0	43.2	51.1
Non Forest	1.8--	9.2	0.0--	9.0	0.0--	7.1	1.8-	6.4
N	110*	130	65*	133	114*	170	111	188
TYPE OF LOGGING								
Clearcut	40.0++	16.9	35.4++	16.5	27.2	18.2	25.2	17.2
SeedTr ShelterWd	10.0	5.4	20.0++	5.3	3.5	4.1	4.5	3.7
Overstory Removl	2.7	2.3	0.0--	6.8	10.5	8.2	7.2	8.0
Salvage-Sanitatn	0.9	2.3	3.1	2.3	6.1	4.7	7.2	4.8
Indv Tree Selctn	5.5	5.4	7.7	6.8	7.0	4.1	9.9	5.3
not logged	40.9--	63.1	33.8--	62.4	45.6-	60.6	45.9-	61.2
N	110*	130	65*	133	114	170	111*	188
YEAR LOGGED								
1951-1960	3.2	10.6	0.0--	10.2	19.4	19.4	33.3	18.1
1961-1965	14.5	19.1	2.3--	18.4	21.0	22.4	13.3	23.6
1966-1970	43.5++	10.6	45.5++	10.2	21.0	11.9	13.3	11.1
1971-1975	6.5	10.6	4.5	10.2	9.7	9.0	10.0	9.7
1976-1980	11.3	21.3	13.6	20.4	14.5	13.4	13.3	15.3
1981-1985	21.0	27.7	34.1	30.6	14.5	23.9	16.7	22.2
N	62*	47	44*	49	62	67	60	72
TYPE OF SITE PREPARATION								
Dozer Scarifcn	62.2++	39.7	71.7++	40.0	50.0	42.0	44.4	36.8
Broadcast Burn	13.5	8.8	2.2	8.6	7.4	9.9	15.9	8.4
Thinned-Slashed	0.0	0.0	0.0	0.0	4.4	1.2	3.2	1.1
No Site Prep	24.4--	51.5	26.1--	51.4	38.2	46.9	36.5	53.7
N	74*	68	46*	70	68	81	63	95

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>YEAR OF SITE PREP</u>								
1961-1965	10.5	15.6	0.0--	15.2	20.0	21.4	30.8	23.3
1966-1970	52.6++	15.6	52.9++	15.2	37.5+	16.7	25.6	16.3
1971-1975	1.8	12.5	8.8	12.1	0.0--	9.5	15.4	9.3
1976-1980	12.3	21.9	8.8	21.2	35.0	21.4	10.3	20.9
1981-1985	22.8	34.4	29.4	36.4	7.5--	31.0	17.9	30.2
N	57*	32	34*	33	40*	42	39	43
<u>TYPE OF FOLLOW-UP TREATMENT</u>								
Thinned-Slashed	17.6	10.3	29.5++	10.0	16.7	8.8	16.1	7.4
Burned	1.4	1.5	4.5	1.4	3.0	2.5	3.2	2.1
No Follow-up	81.1	88.2	65.9--	88.6	80.3	88.8	80.6	90.4
N	74	68	44*	70	66	80	62	94
<u>HABITAT TYPE</u>								
non conifer	1.8	4.6	0.0	4.5	0.0	4.1	1.8	3.7
mesic DF series	13.6	12.3	10.8	12.0	1.8--	9.4	7.2	9.0
dry DF series	9.1	10.8	0.0--	10.5	0.9--	8.2	9.0	7.4
ES series	7.3	13.1	0.0--	12.8	0.0--	6.5	0.0--	9.0
WRC/CLUN type	11.8	6.2	3.1	6.8	22.8++	5.9	6.3	5.3
WH/CLUN type	52.7	46.9	83.1++	47.4	57.0	48.2	56.8	49.5
damp AF series	0.0-	3.8	1.5	3.8	14.9	11.8	14.4	10.6
dry AF series	3.6	2.3	1.5	2.3	2.6	5.9	4.5	5.3
N	110	130	65*	133	114*	170	111	188

notation: DF = douglas-fir, ES = engelmann spruce, AF = alpine fir,
WRC = western redcedar, WH = western hemlock.

Habitat Types (after Pfister et al 1977): dry DF = DF/SYAL, DF/CARU; mesic DF = DF/LIBO, DF/VACA, DF/VAGL; dry AF = AF/XETE, AF/VASC, AF/VAGL, AF/LIBO; damp AF = AF/MEFE, AF/CLUN, AF/OPHO (see Appendix C)

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>COVER</u> <u>TYPE</u>								
no cover	42.7++	25.4	36.9	24.8	26.3	23.5	22.5	21.8
WHC	0.0	1.5	1.5	1.5	3.5	3.5	4.5	3.2
SAF	0.0	0.8	1.5	0.8	13.2	8.8	9.9	8.0
MC	23.6	14.6	21.5	15.0	9.6	12.4	20.7	12.2
LP	4.5	7.7	1.5	7.5	1.8	1.2	2.7	9.0
WHC-SAF-LP	0.9	2.3	0.0	2.3	8.8	2.9	12.6+	3.7
SAF-LP	0.9	3.8	0.0-	3.8	1.8	4.7	4.5	4.3
MC-WHC	9.1	11.5	10.8	12.0	17.5	12.9	12.6	11.7
MC-SAF	9.1	19.2	21.5	15.0	14.0	12.4	13.5	16.0
MC-LP	9.1	7.7	4.6	12.8	3.5	9.4	5.4	10.1
N	110*	130	65	133	114*	170	111	188
<u>PREDOMINANT</u> <u>COVER</u> <u>SPECIES</u>								
no cover	42.7++	25.4	36.9	24.8	26.3	23.5	22.5	21.8
Alpine Fir	0.0	1.5	0.0	1.5	15.8	8.2	9.0	2.7
Douglas-fir	2.7--	16.2	3.1-	15.8	2.6	8.8	12.6	11.2
Engelm Spruce	4.5	6.9	4.6	6.8	7.9	5.9	5.4	6.9
Lodgepole Pine	9.1	14.6	1.5--	14.3	5.3-	15.3	7.2-	16.0
Wstn Redcedar	2.7	3.8	4.6	3.8	11.4	4.1	7.2	3.7
Wstn Hemlock	0.0	3.1	1.5	3.0	6.1	5.9	8.1	5.3
Wstn Larch	38.2+	26.1	43.1+	27.8	22.8	26.5	27.9	25.5
White Pine	0.0	2.3	4.6	2.3	1.8	1.8	0.0	1.6
N	110*	130	65*	133	114*	170	111	188

Cover Type notation:
WHC = western hemlock/western redcedar. LP = lodgepole pine.
MC = mixed conifer (douglas-fir, ponderosa pine, western white pine, western larch, grand fir). SAF = engelmann spruce/alpine fir.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
USFS PI TYPE: COVER CLASS								
Wstn Hemlock	0.9	1.5	1.5	1.5	2.6	3.5	4.5	3.2
Spruce-Alp Fir	0.0	0.8	0.0	0.8	11.4	8.8	9.0	8.0
Mixed Conifer	80.9	70.0	84.6+	70.7	78.9++	61.2	73.9	64.4
Lodgepole Pine	10.0	10.8	7.7	10.5	1.8--	12.9	6.3	12.2
Non Conifer	1.8--	9.2	0.0--	9.0	0.0--	7.1	1.8	6.4
Non Stocked	6.4	7.7	6.2	7.5	5.3	6.5	4.5	5.9
N	110	130	65*	133	114*	170	111	188
PREDOMINANT REGENERATION SPECIES								
Alpine Fir	7.8	7.8	3.3	7.9	21.9	17.8	24.5	17.1
Douglas-fir	19.4	28.5	15.0	27.8	5.3--	19.0	19.1	21.0
Engelm Spruce	4.9	10.6	3.3	10.3	5.3	8.6	3.6	9.4
Lodgepole Pine	51.5++	23.6	36.7	23.8	17.5	18.4	12.7	18.2
Ponderosa Pine	0.0	0.8	3.3	0.8	0.0	0.6	1.8	0.6
Wstn Redcedar	10.7	11.4	21.7	11.9	31.6++	16.0	21.8	14.4
Wstn Hemlock	1.0--	9.8	6.7	9.5	8.8	12.9	5.5	12.2
Wstn Larch	4.9	8.1	10.0	7.9	9.6	6.7	10.9	7.2
N	103*	123	60	126	114*	163	110	181
REGENERATION TYPE								
no regen	6.4	5.4	7.7	5.3	0.0-	4.1	1.8	3.7
WHC	5.5	10.0	9.2	9.8	21.1	14.1	9.0	13.3
SAF	0.9	6.9	1.5	6.8	21.9	12.4	15.3	12.8
MC	13.6	13.1	15.4	19.5	7.0	15.3	18.0	15.4
LP	12.7	7.7	12.3	7.5	1.8	7.6	4.5	6.9
WHC-SAF-LP	13.6	20.0	18.5	14.3	23.7	16.5	21.6	16.0
SAF-LP	4.5	8.5	0.0--	8.3	0.0--	5.3	9.0	5.9
MC-WHC	0.0--	6.9	4.6	6.8	0.0--	8.2	7.2	7.4
MC-SAF	7.3	7.7	1.5	7.5	5.3	6.5	7.2	8.0
MC-LP	35.5++	13.8	29.2+	14.3	19.3	10.0	14.4	12.8
N	110*	130	65*	133	114*	170	111	188

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
USFS PI TYPE: SIZE CLASS								
Seedl-Sapl	42.0++	13.9	37.7++	13.5	24.1	17.7	25.0	16.4
Pole-Sml Sawtmbr	7.0--	20.4	8.2-	19.8	21.3	24.5	14.4	24.2
Medm Sawtmbr	35.0	40.7	24.6-	41.4	36.1	35.1	41.3	41.3
Large Sawtmbr	16.0	25.0	29.5	25.2	18.5	22.4	19.2	19.2
N	100*	108	61*	111	108	147	104	165
AVERAGE HEIGHT OF DOMINANTS								
1-5 ft	0.0--	8.4	0.0--	8.2	4.4	6.3	4.6	5.6
6-15	18.5++	5.9	14.3	5.7	8.8	6.3	15.6+	5.6
16-30	23.1++	7.6	22.2++	7.4	15.8	10.7	10.1	10.2
31-60	7.4--	20.2	9.5	19.7	18.4	27.7	14.7-	26.6
61-100	50.0	46.2	41.3	47.5	41.2	39.6	42.2	43.5
100+	0.9--	11.8	12.7	11.5	11.4	9.4	12.8	8.5
N	108*	119	63*	122	114	159	109*	177
AVERAGE DBH OF DOMINANTS								
less 1"	6.4--	16.2	3.2--	17.2	5.3	12.4	5.4	11.2
1-5"	39.1++	13.1	36.5++	13.9	24.6	17.1	28.8+	16.0
6-9"	7.3--	17.7	7.9	18.9	18.4	19.4	7.2--	20.2
10-15"	34.5	33.8	27.0	36.1	30.7	31.8	39.6	34.0
15-30"	12.7	19.2	28.6	23.0	21.1	19.4	18.9	18.6
N	110*	130	65*	122	114	170	111*	188

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
TREES/ACRE: SAPLINGS + POLES + MATURE								
<100 t/ac	15.5	22.3	10.8-	21.8	7.0--	17.1	6.3--	15.4
101-300	35.5++	17.7	27.7	18.8	15.8	18.2	18.0	17.6
301-500	33.6	40.8	38.5	39.8	38.6	32.9	39.6	36.7
501-1000	13.6	17.7	21.5	17.3	32.5	20.6	29.7	20.2
>1000	1.8	1.5	1.5	2.3	6.1	11.2	6.3	10.1
N	110*	130	65	133	114*	170	111	188
TREES/ACRE: POLES + MATURE								
<100 t/ac	60.0++	43.1	58.5+	43.6	48.2	45.9	46.8	43.1
101-300	36.4--	53.8	38.5-	53.4	42.1	42.9	46.8	46.8
301-500	3.6	1.5	3.1	1.5	8.8	6.5	5.4	5.9
501-1000	0.0	1.5	0.0	1.5	0.9	4.7	0.9	4.3
N	110*	130	65	133	114	170	111	188
TREES/ACRE: SAPLINGS UNDER CANOPY								
<100 t/ac	31.6++	13.9	31.4+	13.7	9.9	15.0	16.4	13.0
101-300	45.6	50.6	40.0	50.0	46.5	43.0	44.3	43.5
301-500	17.5	26.6	20.0	26.2	15.5	18.0	19.7	22.6
501-1000	3.5	7.6	8.6	7.5	26.8	16.0	18.0	13.9
>1000	1.8	1.3	0.0	2.5	1.4	8.0	1.6	7.0
N	57	79	35	80	71	100	61	61
TREES/ACRE: SAPLINGS IN OPEN								
<100 t/ac	20.8--	54.8	13.3--	56.6	20.9--	44.3	22.0--	42.5
101-300	35.8+	17.6	30.0	17.0	14.0	15.7	18.0	16.4
301-500	26.4	17.6	33.3+	17.0	25.6	22.9	24.0	23.3
501-1000	15.1	8.0	23.3+	9.4	30.2++	10.0	24.0	11.0
>1000	1.9	1.9	0.0	0.0	9.3	7.1	12.0	6.8
N	53*	51	30*	53	43*	70	50	73

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>USFS PI TYPE: DENSITY CLASS</u>								
Non Stocked	5.1	16.9	6.2--	16.5	5.3-	13.5	6.3	12.2
Poor (10-49%)	10.9	13.1	15.4	13.5	7.9	15.3	10.8	14.4
Medium (50-79%)	45.5++	21.5	41.5++	21.8	35.1	26.5	36.0	27.1
Well (80-100%)	34.5	48.5	36.9	48.1	51.8	44.7	46.8	46.3
N	110*	130	65*	133	114*	170	111	188
<u>UNDERSTORY VEGETATION DENSITY</u>								
light: light	16.4--	30.0	15.4-	29.3	11.4--	26.5	9.1--	25.5
moder: light	12.7	14.6	15.4	15.0	10.5	14.7	17.3	13.8
dense: moder	32.7	26.2	33.8	27.1	29.8	25.9	33.6	27.7
v.dense: dense	32.7	26.9	32.3	26.3	41.2+	27.6	36.4	28.2
v.dense: v.dense	5.5	2.3	3.1	2.3	7.0	5.3	3.6	4.8
N	110	130	65	133	114*	170	110*	188
<u>SLASH & DOWNED TIMBER DENSITY</u>								
none	35.5	45.4	44.6	44.4	21.9	34.1	31.5	34.6
light	50.9++	30.8	33.8	32.3	41.2	35.9	44.1	35.6
moderate	10.9	16.9	18.5	16.5	26.3	22.9	17.1	21.8
dense	2.7	6.9	3.1	6.8	8.8	5.9	7.2	6.9
very dense	0.0	0.0	0.0	0.0	1.8	1.2	0.0	1.1
N	110*	130	65	133	114	170	111	188

Understory vegetation: 1st term = density 3-4 ft above ground. 2nd term = density 6-7 ft above ground. Light = 0-25% cover, moderate = 26-50%, dense = 51-75%, very dense = 76-100%.

Downed Timber & Slash Density: Densities are the average number of obstructions per 100 feet in any direction (average of 4 directions). Light = 0-1, moderate = 1-2, dense = 2-3, very dense = 3+.

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>MOSAIC PATTERN</u>								
Homogeneous	81.8	83.8	86.2	83.5	70.2	76.5	67.6	77.1
Fine-Grained	10.9	13.1	10.8	13.5	24.5	19.4	23.4	19.1
Large Blocks	7.3	3.1	3.1	3.0	5.3	4.1	9.0	3.7
N	110	130	65	133	111	170	111	188
<u>MOSAIC: STAND STRUCTURE</u>								
no mosaic	80.0	80.8	84.6	80.5	67.5	72.9	61.3	73.9
Seedl: Sapl	11.8	10.8	6.2	10.5	14.0	14.1	18.0	13.8
Seedl: Mature	1.8	3.8	6.2	4.5	7.9	5.9	10.8	5.3
Sapl: Pole	0.0	3.1	0.0	3.0	8.8	3.5	8.1	3.2
Sapl: Mature	6.4	1.5	3.1	1.5	1.8	3.5	1.8	3.7
N	110	130	65	133	111	170	111	188
<u>MOSAIC: HIDING COVER</u>								
no mosaic	60.9--	80.8	69.2	79.7	62.1	73.5	55.9--	75.0
None: Fragmntry	0.0-	4.6	1.5	4.5	0.9	3.5	2.7	3.2
None: Partial	3.6	4.6	3.1	5.3	0.9-	5.9	4.5	5.9
None: Complete	0.9	1.5	0.0	1.5	4.4	5.3	1.8	4.8
Fragm: Partial	6.4	3.8	15.4+	4.5	10.5	5.9	10.8	5.3
Fragm: Complete	18.2++	2.3	3.1	2.3	9.0++	1.2	12.6++	1.6
Partl: Complete	10.0+	2.3	7.7	2.3	12.2	4.7	11.7	4.3
N	110*	130	65*	133	114*	170	111*	188

APPENDIX A: TABLE 1. continued. Use/Availability: STANDS, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>MOSAIC: THERMAL COVER</u>								
no mosaic	86.4	88.4	86.2	88.7	78.1	82.4	82.9	83.0
none: submargnl	3.6	6.2	1.5	6.8	10.5	10.6	6.3	9.6
none: marg/good	3.6	4.6	4.6	4.5	6.1	5.3	6.3	5.9
submarg: marg/good	6.4++	0.8	7.7++	0.1	5.3	1.8	4.5	1.6
N	110*	130	65*	133	114	170	111	188
<u>ISOLATION FROM HUMAN ACTIVITY</u>								
Well Isolated	10.0	17.7	10.8	18.0	36.0	33.5	26.1	31.9
Occas Disturb	89.1++	70.0	89.2++	69.9	60.5	57.1	69.4	59.6
Frequent Distrub	0.9--	12.3	0.0--	12.0	3.5	9.4	4.5	8.5
N	110*	130	65*	133	114	170	111	188
<u>PROXIMITY OF AQUATIC SITES</u>								
none	55.5	63.8	50.8	64.7	47.4-	65.9	58.6	64.9
Stream-River	8.2--	20.8	15.4	20.3	24.6	19.4	16.2	19.7
Pond-Open Bog	11.8	5.4	7.7	5.3	5.3	4.1	7.2	4.8
Swampy Areas	24.5++	10.0	26.2++	9.8	22.8++	10.6	18.0	10.6
N	110*	130	65*	133	114*	170	111	188

Thermal Cover Mosaic: Chi-sq significance suspect, since 25% of the expected cells have less than 5 observations.

Aquatic Sites: Sites are within or immediately adjacent to the units and include sites iced-over or dessicated at time of the relocation.

APPENDIX A: TABLE 2

Habitat Use in *Two Seasons*: *Snow-limited* and *Temperate*. The snow-limited season normally runs from early November to late April when access to many habitats is restricted, and a variety of resources is in short supply. The temperate season, May through October, involves a general relaxation of habitat restrictions--a fact which diminishes the utility of use/availability analysis for many habitat features. If most resources are not limiting during the temperate season, then *straight percent use* by moose might indicate preference; and the degree to which usage changes as winter comes on might suggest which resources are limiting on the Yaak moose range.

For expanded winter: 209 radio points were compared to the 130 random points that fell within the combined home ranges of the 8 moose during that time period. For expanded summer: 191 radio points were compared to all 188 random points.

Notation:	Significant Chi-sq	with	$P \le 0.05$	*
	Use > Availability	with	$P \le 0.05$	++
	" "	"	$P \le 0.10$	+
	Use < Availability	with	$P \le 0.05$	--
	" "		$P \le 0.10$	-
	Significant change in use between seasons with $P \le 0.10$			< >

APPENDIX A: TABLE 2. Habitat Use and Availability within USFS *stands* and other silvicultural units, with the year partitioned into 2 seasons: *extended winter* (late Fall--Winter--early Spring) and *extended summer* (late Spring--Summer--early Fall).

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
PERCENT SLOPE	0-7 %	15.3	20.0		15.7	14.9
	8-15	15.3	20.0		18.3	19.7
	16-25	20.1	23.1		23.0	22.3
	26-35	30.1++	13.8		26.7	18.1
	36-45	9.6	12.3		11.5	12.8
	46-55	6.2	6.2		2.6	6.9
	55+	3.3	4.6		2.1	5.3
	N	209	130		191	188
ASPECT	N-NE-E	16.7	26.4	>	27.7	30.7
	SE	9.6	8.5		7.9	11.3
	S-SW-W	53.6++	21.8	<	40.8	30.7
	NW	5.7	9.3		7.3	8.1
	level	13.4-	24.0		16.2	19.4
	N	209 *	129		191 *	186
ELEVATION	2900-3500 ft	39.2	39.9	<	3.1--	39.9
	3500-4100	35.9	26.1		30.9	26.1
	4100-4700	23.0	16.5	>	40.3++	16.5
	4700-5300	1.9--	12.8	>	11.5	12.8
	5300-5900	0.0-	3.7	>	12.6++	3.7
	5900+	0.0	1.1		1.6	1.1
		209 *	130		191 *	188

elevation: seasonal use is compared to *year-round* availability.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
USFS STAND AREA	1-20 acres	3.9-	15.4		11.0	12.8
	21-40	39.2++	24.6	<	21.5	23.4
	41-60	21.1	16.2		23.0	17.6
	61-80	11.0-	20.8		14.7	20.7
	81-100	3.3	6.9		5.2	7.4
	101-150	4.8	8.5	>	18.3+	9.6
	151-200	6.7	5.4		6.3	4.8
	201-500	0.0	2.3		0.0-	3.7
	N	209 *	130		191 *	188
CONTIGUOUS UNIT AREA: OPEN HABITAT	1-20 acres	7.8	13.6		2.0--	12.2
	21-40	36.7++	11.9	<	17.3	9.8
	41-60	16.4	18.6		14.3	14.6
	61-80	3.9	10.2		5.1	8.5
	81-100	0.8--	8.4		0.0--	6.1
	101-200	19.5	13.6		14.3	14.6
	201-500	11.7--	22.0	>	31.6	26.8
	501-1000	3.1	1.7		10.2	6.1
	1000+	0.0	0.0		3.1	1.2
	N	128 *	59		98 *	82
CONTIGUOUS UNIT AREA: TIMBERED HABITAT	1-20 acres	3.7	2.8		8.6	2.9
	21-40	3.7	1.4		2.2	1.0
	41-60	14.8	9.7		7.5	6.7
	61-80	6.2	4.2		1.1	2.9
	81-100	2.5	6.9		1.1	5.7
	101-200	25.9++	9.7		26.9++	8.6
	201-500	18.5	29.2	>	37.6	29.5
	501-1000	19.8	25.0	<	10.8--	24.8
	1000+	4.9-	11.1		4.3--	18.1
	N	81 *	72		93 *	105

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
ABUNDANCE OF 1ST+ 2ND-ORDER FORAGE	0-15% cover	39.3--	75.4	<	25.7--	67.0
	16-30%	18.9	13.8	>	30.9++	18.6
	31-45%	13.6	9.2		12.0	8.5
	46-60%	9.7++	0.8		14.7++	3.7
	>60%	18.4++	0.8		16.8++	2.1
	N	206 *	130		191 *	188
ABUNDANCE OF 1ST+2ND+ 3RD-ORDER FORAGE	0-15% cover	11.7--	34.6		5.8--	28.7
	16-30%	11.7--	33.8		10.5--	33.0
	31-45%	26.7++	11.5	<	12.0	11.2
	46-60%	12.6	8.5	>	22.0++	11.2
	61-75%	7.3	10.0	>	16.8	9.6
	76-90%	7.8++	0.8		12.6++	4.3
	>90%	22.3++	0.8		20.4++	2.1
	N	206 *	130		191 *	188
HORIZONTAL PATTERN	OS rdm: US rdm	36.4	46.2		42.9	46.3
	OS rdm: US clmp	4.3	6.2		1.6	4.3
	OS rdm: US ngl	2.4	1.5		4.2	2.1
	OS clmp: US rdm	2.9	6.2		7.9	5.3
	OS clmp: US clmp	8.1	7.7		10.5	12.2
	OS ngl: US rdm	34.4++	15.4	<	18.3	14.9
	OS ngl: US clmp	9.6	6.9		13.1	8.0
	OS ngl: US ngl	1.9--	10.0		1.6-	6.9
	N	209 *	130		191 *	188

Forage: percent cover = the sum of cover values of individual species. 1st order forage = 7 'highly preferred' species; 2nd order forage = 8 'preferred' species; 3rd-order forage = 10 'often-used species'. See Appendix D for a discussion of the rating system and species list.

Horizontal Pattern: OS = overstory, US = understory.
clmp = clumped, rdm = random, ngl = negligible.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
PERCENT	none	34.9	27.7		24.1	23.4
CANOPY	0-20 %	9.6	4.6		8.4	7.4
CLOSURE	21-40	8.6	10.0		15.2	9.6
	41-60	8.6	8.5		7.9	10.6
	61-80	25.8	36.9	<	16.2--	32.4
	81-100	12.4	12.9	>	28.3++	16.5
	N	209	130		191 *	188
THERMAL	none	41.2+	30.8	<	25.8	28.2
COVER	Submarginal	19.6	16.9		25.3	20.7
	Marginal	23.5	30.8	<	13.2--	28.2
	Good	15.7	21.5	>	35.8++	22.9
	N	204	130		190 *	188
HIDING	none	2.9--	13.8		3.1-	10.1
COVER	fragmentary	14.1	20.0		10.2	16.0
	partial	53.9	45.4	<	32.1	43.1
	complete	29.1	20.8	>	54.6++	30.1
	N	206 *	130		196 *	188

Thermal Cover: Good = trees 40 ft high with >70% canopy closure, Marginal = 50-70% cc, Submarginal = 10-50% cc, None = <10% cc.

Hiding Cover: defined as vegetation concealing 90% of a standing adult moose at 200 ft (about 60 m). Complete = >90% of the unit in cover; Partial = 50-90%; Fragmentary = 10-50%; Negligible = <10%.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	% Avail		MAY--OCTOBER % Use	% Avail
VERTICAL LAYERING	No Layers	41.1	30.0	<	25.7	25.0
	Mosaic	9.6	15.4	>	21.5	22.3
	One-storied	16.7	9.2	<	4.2	9.6
	Weak Layering	14.4	20.0		13.6	16.0
	Multi-storied	18.1	25.4	>	35.1	27.1
	N	209 *	130		191	188
COVER CONFIGURATION	Ineffective Cvr	14.8	21.6		10.5	16.0
	Hiding Cvr only	46.4++	20.8		40.5+	27.4
	Hiding + Thermal	38.8--	57.9	>	48.9	55.6
		209 *	130		191	188
STRUCTURAL TYPE	*negligible cover*					
	Grass-Forb	1.4	6.2		2.1	4.3
	Seedl-LowBrush	1.9	4.6		3.7	3.2
	Sapl or Pole	2.4	5.4		0.0-	3.7
	Mature	9.1	5.4		4.7	4.8
	hiding cvr only					
	Sapl-Brush	34.9++	9.2	<	20.5	11.8
	Pole-Brush	0.5-	6.2	>	14.8	7.5
	Mature-Brush	11.0	5.4		5.2	8.1
	thermal + hiding					
	Pole or Sml Mature	8.1--	27.7		12.1--	29.2
	Lge Mature	27.8	25.4		31.6	23.2
	Old Growth	2.9	4.8		5.2	3.2
	N	209 *	130		191 *	188

Structural Type: Sml Mature = mixture of poles & small mature trees.
Lge Mature = mature trees only.
Mature = Lge + Sml categories combined.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parareter	Category	NOVEMBER--APRIL % Use	% Avail		MAY--OCTOBER % Use	% Avail
COVER TYPE	no cover	38.8+	25.4	<	23.6	21.8
	WHC	0.5	1.5		4.7	3.2
	SAF	0.5	0.8	>	13.6	8.0
	MC	24.4+	14.6	<	12.0	12.2
	LP	2.9	7.7		2.6	9.0
	WHC-SAF-LP	1.4	2.3		6.3	3.7
	SAF-LP	1.0	3.8		3.1	4.3
	MC-WHC	10.0	11.5		15.7	11.7
	MC-SAF	12.0	19.2		15.7	16.0
	MC-LP	8.6	13.1		2.6--	10.1
	N	209 *	130		191 *	188
PREDOMIN COVER SPECIES	no cover	38.8+	25.4	<	23.6	21.8
	Alpine Fir	0.0	1.5	>	14.6	8.0
	Douglas-fir	8.1-	16.2	<	2.6--	11.2
	Engelm Spruce	3.8	6.9		7.9	6.9
	Lodgepole Pine	6.2-	14.6		6.3-	16.0
	Westn Redcedar	1.9	3.8	>	12.0++	3.7
	Westn Hemlock	3.3	3.1		5.2	5.3
	Westn Larch	36.4+	26.2	<	26.7	25.5
	White Pine	1.4	2.3		1.0	1.6
	N	128 *	97		146 *	147

Cover Type notation:

WHC = Western Hemlock/Western Redcedar
SAF = Engelmann Spruce/Alpine Fir
LP = Lodgepole Pine
MC = Mixed Conifer (western larch, douglas-fir, ponderosa pine, grand fir, western white pine)

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
REGENERATION TYPE	none	6.2	5.4		0.5	3.7
	WHC	5.7	10.0	>	17.8	13.3
	SAF	1.4	6.9	>	21.5	12.8
	MC	16.7	20.0		9.4	15.4
	LP	12.4	7.7	<	1.6-	6.9
	WHC-SAF-LP	14.8	13.1		24.6	16.0
	SAF-LP	2.9	8.5		0.0-	5.9
	MC-WHC	3.3	6.9		2.1	7.4
	MC-SAF	5.3	7.7		6.3	8.0
	MC-LP	31.1++	13.8	<	16.2	12.8
	N	209 *	130		191 *	188
PREDOMIN REGEN SPECIES	Alpine Fir	7.7	7.3	>	24.6	17.1
	Douglas-fir	21.4	28.5	<	7.3--	21.0
	Engelm Spruce	4.1	10.6		4.7	9.4
	Lodgepole Pine	41.8++	23.6	<	14.1	18.2
	Ponderosa Pine	1.0	0.8		1.0	0.6
	Westn Redcedar	11.7	11.4	>	31.9++	14.4
	Westn Hemlock	4.6	9.8		6.3	12.2
	Westn Larch	7.7	8.1		9.9	7.2
	N	196 *	123		191 *	188
HABITAT TYPE	non conifer	1.4	4.6		0.5	3.7
	mesic DF series	13.9	12.3	<	1.6--	9.0
	dry DF series	9.1	10.8	<	1.0--	7.4
	ES series	3.8--	13.1	<	0.0--	9.0
	WRC/CLUN type	6.7	6.2	>	17.8++	5.3
	WH/CLUN type	61.2+	46.9		49.5	49.5
	damp AF series	0.5	3.8	>	17.3	10.6
	dry AF series	3.3	2.3		3.1	5.3
	N	209 *	130		191 *	188

Habitat Types (after Pfister et al 1977): dry DF = DF/SYAL, DF/CARU; mesic DF = DF/LIBO, DF/VACA, DF/VAGL; dry AF = AF/XETE, AF/VASC, AF/VAGL, AF/LIBO; damp AF = AF/MEFE, AF/CLUN, AF/OPHO (see Appendix C)

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
USFS PI TYPE: COVER CLASS	WH: W.Hemlock	1.4	1.5		3.7	3.2
	SAF: Spruce-A.Fir	0.0	0.8	>	12.0	8.0
	MC: Mixed Conifer	82.8++	70.0		74.9	64.4
	LP: Lodgepole	9.6	10.8	<	2.6--	12.2
	NF/NC: Non Conifer	1.4--	9.2		0.5--	6.4
	NS: Non Stocked	4.8	7.7		6.3	5.9
	N	209 *	129		191 *	188
USFS PI TYPE: LOGGING STATUS	L: Logged	59.8++	41.5		56.5++	42.6
	Not Logged	38.8	49.2		42.9	51.1
	Non Forest	1.4--	9.2		0.5--	6.4
	N	209 *	130		191 *	188
TYPE OF LOGGING	Clearcut	37.3++	16.9	<	25.1	17.0
	Seedtr-Sheltrwd	11.0	5.4		5.2	3.7
	OverStory Removl	2.9	2.3	>	8.9	8.0
	Salvage-Sanitatn	1.4	2.3	>	7.9	4.8
	Indv Tree Selctn	6.2	5.4		8.9	5.3
	not logged	41.1--	64.1		44.0-	61.2
	N	209 *	130		191 *	188
YEAR LOGGED	1951-1960	6.6	10.6	>	24.3	18.1
	1961-1965	13.2	19.1		14.0	23.6
	1966-1970	39.7++	10.6	<	18.7	11.1
	1971-1975	7.4	10.6		8.4	9.7
	1976-1980	10.7	21.3		15.9	15.3
	1981-1985	22.3	27.7		18.7	22.2
	N	121 *	47		107	72

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
TYPE OF SITE PREP	Dozer Scarifcn	61.8++	39.7	<	49.6	36.8
	Broadcast Burn	12.5	8.8		7.8	8.4
	Thin-Slashing	1.5	0.0		3.5	1.1
	No Site Prep	24.3--	51.5	>	39.1	53.7
	N	136 *	68		115	95
YEAR OF SITE PREP	1961-1965	9.7	15.6	>	23.9	23.3
	1966-1970	52.4++	15.6	<	28.4	16.3
	1971-1975	6.8	12.5		4.5	9.3
	1976-1980	9.7	21.9	>	26.9	20.9
	1981-1985	21.4	34.4		16.4	30.2
	N	103 *	32		67	43
TYPE OF FOLLOW-UP TREATMENT	Thinned-Slashed	23.9++	10.3	<	13.4	7.4
	Burned	3.7	1.5		1.8	2.1
	No Follow-up	72.4--	88.2	>	84.8	90.4
	N	134 *	68		112	94

Type of Site Prep and Type of Follow-up Treatment: Chi-sq significance suspect since 20%+ of the available cells contain fewer than 5 observations.
'No site prep' and 'no follow-up' refer to logged stands only.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
USFS	1: Seedl-Sapl	39.0++	13.9	<	23.0	16.4
PI TYPE:	2: Poles	7.2--	20.4	>	20.2	24.2
SIZE	3: Medm Sawtmbr	34.4	40.7		36.5	38.2
CLASS	4: Large Sawtmbr	19.5	25.0		20.2	21.2
	N	195 *	108		178	165
AVERAGE	1-5 ft	0.5--	7.7		4.8	5.6
HEIGHT OF	6-15	16.0++	5.4		12.2	5.6
DOMINANTS	16-30	22.3++	6.9	<	11.7	10.2
	31-60	8.3-	18.5	>	18.1	26.6
	61-100	45.6	42.3		42.0	43.5
	100+	7.3	10.8		11.2	8.5
	N	206 *	130		188	177
AVERAGE	less 1"	4.3--	16.2		6.3	11.2
DBH OF	1-5"	37.5++	13.1		25.1	16.0
DOMINANTS	6-9"	6.7--	17.7	>	14.7	20.2
	10-15"	34.9	33.8		31.9	34.0
	15-30"	16.7	19.2		22.0	18.6
	N	209 *	130		191	188

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	% Avail		MAY--OCTOBER % Use	% Avail
TREES/ACRE:	>100 t/ac	11.5-	22.3		7.9	15.4
SAPLINGS +	101-300	29.7++	17.7	<	17.3	17.6
POLES +	301-500	38.3	40.8		36.6	36.7
MATURE	501-1000	20.1	17.7		29.8	20.2
	>1000	0.5	1.5	>	8.4	10.1
	N	209 *	130		191	188
TREES/ACRE:	0-100 t/ac	58.4++	43.1	<	46.6	43.1
POLES +	101-300	38.8--	53.8	>	44.0	46.8
MATURE	301-500	2.9	1.5		8.4	5.9
	501-1000	0.0	1.5		1.0	4.3
	N	209 *	130		191	188
TREES/ACRE:	<100 t/ac	29.1++	13.9	>	12.3	13.0
SAPLINGS	101-300	45.5	50.6		43.9	43.5
IN TIMBER	301-500	17.3	26.6		18.4	22.6
	501-1000	8.2	7.6	>	22.8	13.9
	>1000	0.0	1.3		2.6	7.0
	N	110	79		114	115
TREES/ACRE:	<100 t/ac	15.2--	54.0		26.0-	42.5
SAPLINGS	101-300	31.3	17.2	<	15.6	16.4
IN OPEN	301-500	32.3	17.2		19.5	23.3
	501-1000	20.2	9.7		26.0	11.0
	>1000	1.0	1.9	>	13.0	6.8
	N	99 *	51		77	73

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
USFS	NS: Non-Stocked	6.7--	16.9		6.8	12.2
PI TYPE:	P: Poor Stocking	11.5	13.1		9.9	14.4
DENSITY	M: Medm Stocking	45.0++	21.5	<	33.0	27.1
CLASS	W: Good Stocking	36.8-	48.5	>	50.3	46.3
	N	209 *	130		191	188
UNDERSTORY	light:light	13.9--	30.0		11.5--	25.5
VEGETATION	moder:light	13.9	14.6		13.6	13.8
DENSITY	dense:moder	38.0+	26.2	<	26.2	27.7
	v.dense:dense	30.3	26.9	>	42.4++	28.8
	v.dense:v.dense	3.8	2.3		6.3	4.8
	N	208 *	130		191 *	188
DOWNED	none	38.9	45.4	<	24.6	34.6
TIMBER	light	46.6++	30.8		40.3	35.6
& SLASH	moderate	13.0	16.9	>	24.1	21.4
DENSITY	dense	1.9	6.9	>	9.9	6.9
	very dense	0.0	0.0		1.0	1.1
	N	208 *	130		191	209

Understory Vegetation: 1st term = density at 3-4 ft above ground level.
2nd term = density at 6-7 ft above ground level.
light = 0-25% cover, moderate = 26-50%, dense = 51-75%,
very dense = 76-100%.

Slash & Downed Timber Density: Densities are the average number of obstructions per 100 ft in any direction (average of 4 directions).
Light = 0-1, Moderate = 1-2, Dense = 2-3, Very dense = 3+.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
MOSAIC	no mosaic	82.8	83.8	<	67.0-	77.1
PATTERN	Fine-grained	12.0	13.1	>	25.1	19.1
	Large Blocks	5.3	3.1		7.9	3.7
	N	209	130		191	188
MOSAIC:	no mosaic	79.4	80.8	<	63.9	73.9
STAND	Seedl: Sapl	11.0	10.8		15.7	13.8
STRUCTURE	Seedl: Mature	5.3	3.8		8.4	5.3
	Sapl: Pole	0.0-	3.1	>	9.9++	3.2
	Sapl: Mature	4.3	1.5		2.1	3.7
	N	209	130		191 *	188
MOSAIC:	no mosaic	64.1--	80.8		58.1--	75.0
HIDING	None: Fragmtry	0.5	4.6		2.1	3.2
COVER	None: Partial	3.8	4.6		2.1	5.9
	None: Complete	1.4	1.5		2.6	4.8
	Fragm: Partial	8.1	3.8		12.6+	5.3
	Fragm: Complte	13.9++	2.3		8.9++	1.6
	Partl: Complte	8.1+	2.3		13.6++	4.3
	N	209 *	130		191 *	188
MOSAIC:	no mosaic	88.0	88.4	<	77.5	83.0
THERMAL	none: submarginal	2.9	6.2	>	9.4	9.6
COVER	none: effective	2.9	4.6		7.9	5.9
	submarginal effective	6.2+	0.8		5.2	1.6
	N	209 *	130		191	188

Thermal Cover Mosaic: Chi-sq significance suspect, as 25% of available cells have less than 5 observations.

APPENDIX A: TABLE 2. continued. Use/Availability: Stands, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
ISOLATION	Well Isolated	13.9	17.7	>	30.9	31.9
FROM	Occas Disturb	84.7++	70.0	<	65.4	59.6
HUMAN	Freq Disturb	1.4--	12.3		3.7	8.5
ACTIVITY						
	N	209 *	130		191	188
PROXIMITY	none nearby	61.7	63.8	<	44.0--	64.9
OF	Stream-River	8.1--	20.8	>	25.1	19.7
AQUATIC	Pond-Open Bog	8.1	5.4		7.9	4.8
SITES	Swampy Areas	22.0++	10.0		23.0++	10.6
	N	209 *	130		191 *	188

Aquatic Sites: The sites are within or immediately adjacent to the stands or units.

Isolation: Frequently disturbed = sites near well-traveled roads, human habitation, active timber sales; Well isolated = sites >500 m from roads & buffered by dense vegetation, physical obstructions, etc; Occasionally disturbed = sites near occasionally-used roads, etc.

APPENDIX A: TABLE 3

Resource utilization in USFS stands and silvicultural units during *significantly different winters*. The winter of 1984 was a short winter with mid-elevation snow depths in the 40-60 cm range in open habitats. The winter of 1985 was a relatively long winter with mid-elevation snow depths in the 70-120 cm range. The winter of 1983 was of moderate length, but with snow depths approaching those of 1985 and wet, dense snow in the latter half of the season.

A combined total of 54 radio points from 1983 and 1985, and 51 points from 1984 are compared to 130 random points located within the combined winter ranges of the 8 collared moose. Data is presented for those stand parameters that seemed likely to provide instructive comparison between the 2 types of winter.

Notation: < > indicates direction of significant increases in % utilization between the 2 winters, with $P \leq 0.10$ with $P \leq .10$

++	denotes	use > availability	with	$P \leq 0.05$
+	"	"	"	"	$P \leq 0.10$
--	denotes	use < availability	with	$P \leq 0.05$
-	"	"	"	"	$P \leq 0.10$

APPENDIX A: TABLE 3. Use and Availability of resources in USFS stands and silvicultural units in 2 *contrasting types of winter*: 1984 was a relatively shallow-snow winter; 1983 & 1985 were deep-snow winters.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
ELEVATION	2900-3500 ft	13.7--	<	66.7++	39.9
	3500-4100	39.2		31.4	26.1
	4100-4700	47.1++	<	1.9--	16.5
	4700-5300	0.0--		0.0--	12.8
	5300-5900	0.0-		0.0-	3.7
	5900+	0.0		0.0	1.1
	N	51		54	188
ASPECT	N-NE-E	7.9--		15.1	26.4
	SE	7.8		9.4	8.5
	S-SW-W	72.5++	<	41.5	31.8
	NW	3.9		7.5	9.3
	level	7.8--	>	26.4	24.0
	N	51		53	129
PERCENT SLOPE	0 - 7 %	17.6		26.4	20.0
	8 - 15	13.7		17.0	20.0
	16 - 25	9.8--	>	28.3	23.1
	26 - 35	52.9++	<	5.7	13.8
	36 - 45	5.9		13.2	12.3
	46 - 55	0.0-		7.5	6.2
	>55	0.0-		1.9	4.6
	N	51		53	130

Elevation: Winter use is compared to elevations availabile over the entire study area--rather than just on winter range.

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984	% Utilization Deep snow 1983/85	% Availability on winter range
CONTIGUOUS	1-20 acres	4.5--	0.0-	13.6
UNIT AREA:	21-40	40.9++	27.3+	11.9
OPEN	41-60	31.8	9.1	18.6
HABITAT	61-80	4.5	4.5	10.2
	81-100	0.0-	0.0	8.4
	100-200	6.8	45.5++	13.6
	200-500	9.1-	13.6-	22.0
	>500	2.3	0.0	1.7
	N	44	22	59
CONTIGUOUS	1-20 acres	0.0	6.2	2.8
UNIT AREA:	20-40	0.0	3.1	1.4
TIMBERED	40-60	28.6	25.0+	9.7
HABITAT	60-80	0.0	6.2	4.2
	80-100	0.0	6.2	6.9
	100-200	28.6	18.8	9.7
	200-500	28.6	18.8	29.2
	>500	14.3	15.6-	36.1
	N	7	32	72

A contiguous unit is a habitat block of unified structure (closed timber, open timber, sapling-brush association, grass-forb clearing, and so on), that may be equivalent to a USFS stand or silvicultural unit or may be larger.

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
MOSAIC PATTERN	Homogeneous	76.5		81.3	83.8
	Fine-grained	13.7		10.4	13.1
	Large Blocks	9.8		6.3	3.1
	N	59		48	130
PROXIMITY OF AQUATIC SITES	none	56.8		50.9-	63.8
	Stream-River	2.0		13.2	20.8
	Pond-Open Bog	13.7		11.3	5.4
	Swampy Ground	27.5++		24.5++	10.0
	N	51		53	130
ABUNDANCE OF 1ST + 2ND ORDER FORAGE	0-15% cover	19.6--	>	63.0	75.4
	16-30%	11.8		18.5	13.8
	31-45%	5.9		9.3	9.2
	46-60%	17.6++	<	3.7	0.8
	>60%	45.0++	>	5.6	0.8
	N	51		54	130
HIDING COVER	none	3.9-		3.8-	13.8
	Fragmentary	21.6		15.1	20.0
	Partial	41.2	>	62.3+	45.4
	Complete	33.3	<	18.9	20.8
	N	50		53	130

Forage: Percent cover = the sum of cover values of individual species. 1st-order forage = 7 'most preferred' species; 2nd-order forage = 8 'preferred' species; Forage ratings are discussed in Appendix D.

Hiding cover: Defined as vegetation hiding 90% of a standing moose at 200 ft (about 60 m). Complete = >90% of the unit in hiding cover; Partial = 50-90%; Fragmentary = 10-50%; Negligible = <10%.

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
THERMAL COVER	None	72.0++	<	18.9--	30.8
	Submarginal	12.0	>	24.5	16.9
	Marginal	8.0--	>	39.6	30.8
	Good	8.0--	>	17.0	21.5
	N	50		53	130
PERCENT CANOPY CLOSURE	none	62.7++	<	13.2--	27.7
	1-20 %	11.8		11.3	4.6
	21-40	3.9		9.4	10.0
	41-60	5.9		11.3	8.5
	61-80	11.8--	>	45.3	36.9
	81-100	3.9		9.4	12.3
	N	51		53	130
VERTICAL LAYERING	One storied	15.7	>	24.1++	9.2
	Multi storied	5.9--	>	29.6	25.4
	Mosaic	5.9		9.3	15.4
	Weak Layering	7.8--		14.8	20.0
	No Overstory	64.7++	<	22.2	30.0
	N	51		54	130
COVER CONFIGURATION	Ineffective Cvr	25.5	<	10.7--	21.7
	Hiding Cvr only	60.8++	<	32.2+	20.9
	Thermal + Hiding	13.8--	>	57.2	57.4
	N	51		56	129

Thermal Cover: Good = trees 40 ft high with 70-100% canopy closure.
Marginal = 50-70% cc, Submarginal = 10-50% cc, None = 0-10% cc.

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
STRUCTURAL TYPE	*negligible cover*				
	Grass-Forb	2.0		1.8	6.2
	Seedl-LowBrush	7.8	<	0.0	4.7
	Sapl or Pole	3.9		1.8	5.4
	Mature	11.8		7.1	5.4
	hiding cvr only				
	Sapl-Brush	54.9++	<	16.1	9.3
	Pole-Brush	0.0--		1.8	6.2
	Mature-Brush	5.9	>	14.3	5.4
	thermal + hiding				
	Pole or Sml Mature	2.0--	>	14.3-	27.9
	Lge Mature	11.8--	>	42.9++	25.6
	Old Growth	0.0-		0.0-	3.9
	N	51		56	129
USFS PI TYPE: LOGGING STATUS	L: Logged	82.4++	<	39.6	41.5
	Not Logged	17.6--	>	56.6	49.2
	Non Forest	0.0--		3.8	9.2
	N	51		53	130
TYPE OF LOGGING	Clearcut	62.7++	<	20.0	16.9
	SeedTr-ShelterWd	11.8		10.0	5.4
	Overstory Removal	2.0		2.0	2.3
	Salvage-Sanitation	0.0		0.0	2.3
	Indv Tree Selectn	5.9		6.0	5.4
	not logged	17.6--	>	62.0	63.1
	N	51		50	130

Structural Type:
Sml Mature = mixture of poles & mature trees. Lge Mature = mature trees only. Mature = Lge + Sml Mature categories combined.

APPENDIX A: TABLE 3 continued. Use/Availability: Stands, *Winters*

Habitat Parameters	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
USFS	WH: Hemlock-Cedar	0.0		1.9	1.5
PI TYPE:	SAF: Spruce-A.Fir	0.0		0.0	0.8
COVER	MC: Mixed Conifer	84.3+		77.4	70.0
CLASS	LP: Lodgepole Pine	3.9	>	15.1	10.8
	NF/NC: Non Conifer	0.0--		3.8	9.2
	NS: Non Stocked	11.8	<	1.9	7.7
	N	51		53	130
COVER	no cover	64.7++	<	14.3	25.4
TYPE	WHC	0.0		0.0	1.5
	SAF	0.0		0.0	0.8
	MC	15.7	>	34.0++	14.6
	LP	3.9		5.7	7.7
	WHC-SAF-LP	0.0		1.9	2.3
	SAF-LP	0.0-		1.9	3.8
	MC-WHC	7.8		9.4	11.5
	MC-SAF	7.8		11.4	19.2
	MC-LP	0.0--	>	13.2	17.7
	N	51		53	130
PREDOMIN	no cover	64.7++	<	22.6	25.4
COVER	Alpine Fir	0.0		0.0	1.6
SPECIES	Douglas-fir	2.0--		4.1--	16.1
	Engelmn Spruce	0.0--	>	10.2	6.9
	Lodgepole Pine	3.9	>	14.3	14.6
	Westn Redcedar	2.0		4.1	3.9
	Westn Hemlock	0.0-		0.0-	3.1
	Westn Larch	27.5	>	53.1++	26.2
	White Pine	0.0		0.0	2.3
	N	51		49	130

Cover Type: WHC = Westn Hemlock/Westn Redcedar. LP = Lodgepole Pine. MC = Mixed Conifer (Douglas-fir, Ponderosa Pine, Western Larch, Grand Fir, Western White Pine). SAF = Engelmann Spruce/Alpine Fir).

APPENDIX A: TABLE 3. continued. Use/Availability: STANDS, *Winters*

Habitat Parameters	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
REGENERATION TYPE	no regen	3.9		9.4	5.4
	WHC	3.9		3.8	10.0
	SAF	0.0--		1.9	6.9
	MC	15.7		11.3	13.1
	LP	5.9	>	18.9++	7.7
	WHC-SAF-LP	5.9--	>	22.6	20.0
	SAF-LP	3.9		5.7	8.5
	MC-WHC	0.0--		0.0-	6.9
	MC-SAF	2.0	>	11.3	7.7
	MC-LP	58.9++	<	15.1	13.8
	N	51		53	130
PREDOM REGEN SPECIES	Alpine Fir	2.0	>	14.3	7.8
	Douglas-fir	20.4		18.4	28.5
	Engelmn Spruce	0.0--	>	8.2	10.6
	Lodgepole Pine	63.2++	<	42.9++	23.6
	Ponderosa Pine	0.0		0.0	0.8
	Westn Redcedar	7.8		12.2	11.4
	Westn Hemlock	8.2	<	2.0--	9.8
	Westn Larch	6.1		2.0--	8.1
	N	49		49	123
HABITAT TYPE	non conifer	6.0	>	18.5++	4.6
	mesic DF series	6.0		11.1	12.3
	dry DF series	4.0		11.1	10.8
	ES series	14.0		7.4	13.1
	WRC/CLUN type	0.0--		0.0--	6.2
	WH/CLUN type	62.0++		48.1	46.9
	damp AF series	8.0	<	0.0	3.8
	dry AF series	0.0		3.7	2.3
	N	51		54	130

Habitat Type: DF = douglas-fir, WH = western hemlock, AF = alpine fir, WRC = western redcedar, ES = engelmann spruce. See also Appendix C.

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
USFS	1: Seedl-Sapl	62.2++	<	24.5	13.9
PI TYPE:	2: Poles	6.7--		2.0--	20.4
SIZE	3: Medm Sawtmbr	24.4-	>	46.9	40.7
CLASS	4: Large Sawtmbr	6.7--	>	26.5	25.0
	N	45		49	108
AVERAGE	1-5 ft	2.0		1.9	8.4
HEIGHT	6-15	33.3++	<	5.6	5.9
OF	16-30	31.4++	<	13.0	7.6
DOMINANTS	31-60	3.9--		7.4-	20.2
	61-100	29.4--	>	70.4++	46.2
	>100	0.0--		1.9--	11.8
	N	51		54	130
AVERAGE	less 1"	11.8		2.1--	16.2
DBH OF	1-5"	54.9++	<	29.2++	13.1
DOMINANTS	6-9"	5.9--		8.3	17.7
	10-15"	21.6	>	37.5	33.8
	15-30"	5.9--	>	22.9	19.2
	N	51		48	130
USFS	NS: Non Stocked	0.0--		0.0--	16.9
PI TYPE:	P: Poor (10-49%)	15.6		8.2	13.1
DENSITY	M: Medium (50-79%)	53.3++		49.0++	21.5
CLASS	W: Well (80-100%)	31.1--		42.9	48.5
	N	45		49	130

APPENDIX A: TABLE 3. continued. Use/Availability: Stands, *Winters*.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
TREES/ACRE:	0-100 t/ac	23.5	<	9.3-	22.3
SAPLINGS +	101-300	27.5		38.9+	17.7
POLES +	301-500	29.4		40.7	40.8
MATURE	501-1000	17.6		9.3	17.7
	>1000	2.0		1.9	1.5
	N	51		54	130
TREES/ACRE:	0-100 t/ac	84.3++	<	35.2	43.1
POLES +	101-300	15.7--	>	57.4	53.8
MATURE	301-500	0.0	>	7.4+	1.5
	501-1000	0.0		0.0	1.5
	N	51		54	130
UNDERSTORY	light: light	17.6-		13.2--	30.0
VEGETATION	moder: light	9.8		15.1	14.6
DENSITY	dense: moder	19.6	>	43.4+	26.2
	v.dense: dense	47.1+	<	22.6	26.9
	v.dense: v.dense	5.9		5.7	2.3
	N	51		53	130
DOWNED	none	31.4_		38.9	45.4
TIMBER	light	62.7++	<	42.6	30.8
& SLASH	moderate	5.9-		13.0	16.9
DENSITY	dense	0.0-	>	5.6	6.9
	very dense	0.0		0.0	0.0
	N	51		54	130

APPENDIX B: TABLES 1-3

HABITAT USE AND AVAILABILITY: SITE TABLES

Use and availability of resources in *sites* immediately surrounding radio and random points.

Some sites were delineated by obvious structural features of the habitat--small clearings, patches of timber, clumps of high brush, bogs, and so on. Where no natural boundaries existed, the site was sampled out to a radius of about 165 ft (50 meters) from the radio point. This defined an area of approximately 2.5 acres (1 hectare), which was the size of our standard error polygon for quality-1 moose relocations. Quality-0 locations and random points could be located more precisely, but these sites were also sampled as 2.5 acre units for the sake of sampling consistency.

Thirteen parameters were examined. Six were in common with the stand analyses in Appendix A: structural type, thermal cover, hiding cover, cover configuration, and the 2 measures of forage abundance. Seven were more appropriately examined in small, site-sized units and were not analyzed at the stand level: topographic site, ecotone status, and the distances to various habitat features.

Data is organized as follows: Table 1 presents use and availability in 4 standard seasons; Table 2 does the same for a 2-season year (with a temperate season and a snow-limited season); and Table 3 compares resource use in the low-snow winter of 1984 with the deep-snow winters of 1983 and 1985.

APPENDIX B: TABLE 1

Use and availability of resources at *sites* immediately surrounding radio and random points--with the year partitioned into *4 standard seasons* Seasonal divisions and range delineations are the same as for the stand analyses in Appendix A.

Notation:			
	Significant Chi-sq with	$P \leq 0.05$	*
	Use > Availability with	$P \leq 0.05$	++
	" " "	$P \leq 0.10$	+
	Use < Availability with	$P \leq 0.05$	--
	" "	$P \leq 0.10$	-

APPENDIX B: TABLE 1. Use & Availability at local *sites* around radio and random points; the year partitioned into *4 standard seasons*.

Habitat Categories and Parameters	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
TOPOGRAPHIC CLASS								
Flatland-Basin	7.2	10.7	6.2	10.1	2.6	7.1	4.6	6.9
Gentle Main Slope	22.5	23.3	21.5	23.3	28.7	25.9	27.5	24.5
Mod Main Slope	27.0	21.7	23.1	21.7	26.1	28.2	22.9	27.1
Steep Main Slope	4.5	6.2	9.2	6.2	3.5	9.4	11.0	8.5
Bench on Slope	12.6	8.5	9.2	8.5	8.7	6.5	11.0	5.9
Ridge-Saddle	3.6	6.2	4.6	6.2	5.2	5.9	4.6	6.9
Slope in Draw	6.3	11.6	7.7	11.6	10.4	8.2	4.6	10.1
Draw-Stream Bottom	8.1	7.0	12.3	7.0	13.9	5.9	10.1	5.9
Gently Rolling	8.1	5.4	6.2	5.4	0.9	2.9	3.7	4.3
N	111	129	65	129	115	170	109	188
ABUNDANCE OF 1ST + 2ND ORDER FORAGE								
0-15% cover	40.4--	76.0	47.7--	76.0	24.3--	59.4	33.9--	66.5
16-30%	19.3	17.8	20.0	17.8	22.6	25.3	22.9	22.3
31-45%	9.2	3.9	4.6	3.9	17.4++	5.3	22.0++	4.3
46-60%	11.9++	1.6	9.2	1.6	18.3++	3.5	11.9++	3.2
>60%	19.3++	0.8	18.5++	0.8	11.3	6.5	9.2	3.7
N	109*	129	65*	129	115*	170	109*	188

Forage: Percent cover = sum of cover values of individual species. See Appendix D for a discussion of the forage rating system.

Topography: gentle = 10-30% slope, moderate = 30-50%, steep = >50%.

APPENDIX B: TABLE 1. continued. Use/Availability: SITES, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
<u>THERMAL COVER</u>								
none	43.6	37.2	43.1	37.2	29.6	35.9	31.2	34.0
Submarginal	19.1	10.1	20.0	10.1	18.3	11.8	21.1	12.8
Marginal	23.6	26.4	13.8	26.4	14.8	21.2	22.0	24.5
Good	13.6--	26.4	23.1	26.4	37.4	31.2	25.7	28.7
N	110*	129	65	129	115	170	109	188
<u>HIDING COVER</u>								
none	5.5--	19.4	6.2--	20.2	6.0-	14.7	2.7--	14.4
fragmentary	20.0	10.1	10.8	10.9	7.8	12.9	11.8	10.6
partial	50.0	41.1	46.2	40.3	27.6	26.5	40.0	34.0
complete	24.5	29.5	36.9	28.6	58.6+	45.9	45.5	41.0
N	110*	129	65	129	116*	170	110*	188
<u>DISTANCE TO NEAREST EDGE</u>								
0-300 feet	65.7+	54.3	61.7	54.3	67.8+	54.4	66.0+	55.3
300-600	18.0	19.4	26.2	19.4	16.5	20.0	21.1	18.6
600+	10.8--	26.4	6.2--	26.4	15.7	25.3	12.8--	26.1
N	111*	129	65*	129	115*	170	109*	188

Thermal Cover: none = 0-10% canopy closure, submarginal = 10-50%, marginal = 50-70%, good = 70-100%. Canopy height must be 40+ ft.

Hiding Cover: none = 0-10% of site contains hiding cover, fragmentary = 10-50%, partial = 50-90%, complete = 90-100%.

APPENDIX B: TABLE 1. continued. Use/Availability: SITES, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
DISTANCE TO HIDING COVER								
in cover	76.6	71.3	81.5	71.3	87.0++	74.1	83.5	76.6
<300 feet	17.1	20.9	13.8	20.9	13.1	19.4	13.8	17.6
300-600	3.6	5.4	4.6	5.4	0.0-	4.7	2.8	4.3
>600	2.7	2.3	0.0	2.3	0.0	1.8	2.8	1.6
N	111	129	65	129	115*	170	109	188
DISTANCE TO THERMAL COVER								
in cover	38.7	51.2	35.4	51.2	49.6	48.2	45.0	51.1
<300 feet	37.9	33.4	26.9	33.4	26.1	32.4	29.4	31.4
300-600	16.2	10.1	20.0	10.1	7.0	10.6	12.8	9.6
>600	8.1	5.4	7.7	5.4	17.4	8.8	12.8	8.0
N	111	129	65*	129	115	170	109	188
DISTANCE TO DRIVEABLE ROAD								
<300 feet	15.5	11.6	26.1	11.6	20.9	20.0	12.9	18.1
300-600	16.4	14.7	15.4	14.7	15.7	21.8	19.3	21.3
600-900	12.7	10.1	15.4	10.1	17.4	15.3	12.8	16.5
900-1200	8.2	4.7	13.8	4.7	17.4	11.2	14.7	11.2
1200-1500	7.3	6.2	7.7	6.2	7.8	4.1	11.0	5.9
1500-3000	23.6	23.3	15.4	23.3	16.5	19.4	17.4	19.7
>3000	16.4-	29.5	6.2--	29.5	4.3	8.2	11.9	7.4
N	110	129	65*	129	115	170	109	188

Distance to Hiding Cover: Hiding Cover defined as partial or complete.
Distance to Thermal Cover: Thermal Cover defined as marginal or good.
Distance to Road: Driveable Road = nearest road receiving some vehicle use--including regular snowmobile use--at the time of the radio spot.

APPENDIX B: TABLE 1. continued. Use/Availability: Sites, 4 Seasons

Habitat Parameters and Categories	WINTER % Use	WINTER % Avail	SPRING % Use	SPRING % Avail	SUMMER % Use	SUMMER % Avail	FALL % Use	FALL % Avail
DISTANCE TO WATER								
<300 feet	30.0	19.4	23.2	19.4	32.2+	18.8	19.2	19.2
300-600	22.7	14.0	21.5	14.0	15.7	14.7	15.6	14.4
600-900	13.6	10.9	23.1++	10.9	11.3	10.0	13.8	10.1
900-1200	12.7	10.9	6.2	10.9	11.3	10.0	11.0	10.6
1200-1500	9.1	7.0	15.4	7.0	11.3	9.4	7.3	8.5
1500-3000	8.2--	23.3	9.2--	23.3	16.5	22.4	22.9	23.4
>3000	4.5--	14.7	1.5--	14.7	1.7--	14.7	10.1	13.8
N	110*	129	65*	129	115*	170	109	188
ECOTONE STATUS								
Not in Ecotone	86.5	89.8	92.3	89.9	87.8	88.8	84.4	88.8
Within Ecotone	13.5	10.1	7.7	10.1	12.2	11.2	15.6	11.2
N	111	129	65	129	115	170	109	188
COVER CONFIGURATION								
no cover	13.9-	25.0	15.7	25.0	9.9--	21.9	10.3	19.6
hiding cvr only	46.5++	20.0	48.5++	20.0	39.6+	26.9	42.1+	26.4
thermal cover	39.7-	55.0	36.0--	55.0	50.4	51.3	47.6	53.8
N	111*	129	65*	129	115*	170	109*	188

Distance to Water: Water = nearest open or flowing water at the time of the radio location (not necessarily an aquatic feeding site).

Cover Configuration: Hiding cvr only = complete + partial hiding cover; Thermal cvr = good & marginal thermal cvr + hiding cover.

APPENDIX B: TABLE 2

Use and availability of resources at *sites* immediately surrounding radio and random points, with the year divided into 2 seasons: *extended winter* (late fall--winter--early spring) and *extended summer* (late spring--summer--early fall).

For extended winter: 209 moose sites were compared to 130 random sites that fell within the combined home ranges of the 8 collared moose during that time period. For extended summer: 191 moose sites were compared to all 188 random sites.

Notation:	Significant Chi-sq	with	$P \leq 0.05$	*
	Use > Availability	with	$P \leq 0.05$	++
	" "	"	$P \leq 0.10$	+
	Use < Availability	with	$P \leq 0.05$	--
	" "	"	$P \leq 0.10$	-
	Use significantly different between the 2 seasons	with	$P \leq 0.10$	<>

APPENDIX B: TABLE 2. Use and availability of resources at local *sites* around radio and random points. The year is organized into 2 functional seasons: November--April (limiting) and May--October (non-limiting).

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
TOPOGRAPHIC CLASS	Flatland-Basin	6.2	10.0		3.7	6.9
	Gentle Main Slope	22.5	23.1		28.8	24.5
	Mod Main Slope	28.7	22.3		20.9	27.1
	Steep Main Slope	7.7	6.2		5.8	8.5
	Bench on Slope	11.5	8.5		9.4	5.9
	Ridge-Saddle	3.3	6.2		5.8	6.9
	Slope in Draw	6.7	11.5		7.9	10.1
	Draw-Stream Bottom	6.2	6.9	>	16.2++	5.9
	Gently Rolling	7.2	5.4		1.6	4.3
	N	209	129		191	188
ABUNDANCE OF 1ST + 2ND-ORDER FORAGE	0-15% cover	44.2--	76.1	<	27.7--	62.8
	16-30	19.4	17.7		25.1	24.5
	31-45	11.2++	3.8		17.3++	4.8
	46-60	8.3++	1.5	>	18.8++	3.2
	60+	17.0++	0.8		11.0	4.8
	N	209 *	129		191 *	188
COVER CONFIG-URATION	no cover	13.6-	24.8		10.3	19.6
	hiding cvr only	46.9++	19.8		40.2++	26.3
	thermal cover	39.6-	55.4		49.5	54.1
	N	205 *	121		185 *	178
ECOTONE STATUS	Not in Ecotone	86.1	90.0		88.5	88.8
	Within Ecotone	13.9	10.0		11.5	11.2
	N	209	129		191	188

Percent slope: gentle = 10-30%, moderate = 30-50%, steep = >50%.
Forage: percent cover = the sum of cover values of individual species.

APPENDIX B: TABLE 2. continued. Use/Availability: Sites, 2 Seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
THERMAL	none	41.6	36.9	<	29.3	33.5
COVER	Submarginal	19.6++	10.0		19.4	12.2
	Ma.ginal	21.5	26.2		16.2	24.5
	Good	17.2	26.9	>	34.6	29.8
	N	209 *	129		191	188
HIDING	none	4.8--	20.0		5.2--	13.3
COVER	fragmentary	16.3	10.8		9.3	11.7
	partial	48.8	40.8	<	30.1	31.4
	complete	30.1	28.5	>	55.4	43.6
	N	209 *	129		193 *	188
DISTANCE	<300 feet	68.5+	54.6		68.1+	55.3
TO	300-600	20.1	19.2		19.4	18.6
NEAREST	>600	11.5--	26.2		12.6--	26.1
EDGE						
	N	209 *	129		191 *	188
DISTANCE	in cover	79.4	71.5		85.3	76.6
TO	<300 feet	15.8	20.8		13.1	17.6
HIDING	300-600	3.3	5.4		1.6	4.3
COVER	>600	1.4	2.3		0.0	1.6
		209	129		191 *	188

Thermal Cover: none = 0-10% canopy closure, submarginal = 10-50%, marginal = 50-70%, good = 70-100%. Canopy height must be 40+ ft.
Hiding Cover: none = 0-10% of area in hiding cover, fragmentary = 10-50%, partial = 50-90%, complete = 90-100%.
Distance to Hiding Cover: Hiding Cover defined as partial or complete.

APPENDIX B: TABLE 2. continued. Use/Availability: Sites, 2 seasons

Habitat Parameter	Category	NOVEMBER--APRIL % Use	NOVEMBER--APRIL % Avail		MAY--OCTOBER % Use	MAY--OCTOBER % Avail
DISTANCE	in cover	38.8-	51.5		47.6	51.1
TO	<100 meters	35.4	33.1		27.7	31.4
THERMAL	100-200	17.2	10.0	<	8.9	9.[illegible]
COVER	>200	8.6	5.4		15.7+	8.0
	N	209 *	129		191 *	188
DISTANCE	>300 feet	16.0	11.6		19.9	18.1
TO	300-600	19.2	14.6		14.7	21.3
DRIVEABLE	600-900	11.9	10.0		17.8	16.3
ROAD	900-1200	11.9	4.6		15.7	11.2
	1200-1500	8.3	6.2		8.9	5.9
	1500-3000	19.2	23.1		17.3	19.7
	>3000	14.5--	30.0	<	5.8	7.4
	N	193 *	129		191	188
DISTANCE	<300 feet	22.0	19.3	>	31.4+	19.2
TO	300-600	20.6	13.8		16.2	14.4
WATER	600-900	17.2	10.8		11.5	10.1
	900-1200	10.5	10.8		11.0	10.6
	1200-1500	10.5	7.7		9.9	8.5
	1500-3000	13.4	23.1		16.2	23.4
	>3000	5.7-	14.6		3.7--	13.8
	N	209	129		191 *	188

Distance to Thermal Cover: Thermal Cover defined as marginal or good.
Distance to Road: Driveable Road = nearest road receiving some vehicle use--including regular snowmobile use--at the time of the radio spot.
Distance to Water: Water = nearest open or flowing water at the time of the radio location (not necessarily an aquatic feeding site).

APPENDIX B: TABLE 3

Resource utilization at *sites* immediately surrounding radio and random locations: comparison of *2 winters of decidedly different character*. The winter of 1984 was a short, shallow-snow winter; the winters of 1983 and 1985 were relatively long, deep-snow winters.

A combined total of 54 moose sites from 1983 and 1985, and 51 sites from 1984 are compared to 130 random sites located within the combined winter ranges of the 8 collared moose.

Notation:	indicates the direction of a significant increase in percent Use between winters with $P \leq 0.10$	> or <
	Use < Availability with $P \leq 0.05$	++
	" " " $P \leq 0.10$	+
	Use > Availability with $P \leq 0.05$	--
	" " " $P \leq 0.10$	-

APPENDIX B: TABLE 3. Use & Availability of resources at *sites* immediately surrounding radio and random points in *winters* of decidedly different character.

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
TOPOGRAPHIC CLASS	Flatland-Basin	9.8		5.6	10.7
	Gentle Main Slope	23.5		22.2	23.3
	Mod Main Slope	29.4		24.1	21.7
	Steep Main Slope	5.9		3.7	6.2
	Bench on Slope	1.4	>	9.3	8.5
	Ridge-Saddle	5.9		1.9	6.2
	Slope in Draw	2.0-	>	11.1	11.6
	Draw-Stream Bottom	5.9		11.1	7.0
	Gently Rolling	3.9		11.1	5.4
	N	51		54	129
ABUNDANCE OF 1ST + 2ND-ORDER FORAGE	0-15% cover	26.0--	>	55.6--	76.0
	16-30	8.0	>	27.8	17.8
	31-45	8.0		7.4	3.9
	46-60	22.0++	<	3.7	1.6
	>60	36.0++	<	5.6+	0.8
	N	50		54	129
ECOTONE STATUS	not in ecotone	77.8		88.9	89.8
	within ecotone	22.2		11.1	10.1
	N	51		54	129
COVER CONFIG- URATION	no cover	23.6	<	11.2-	25.0
	hiding cvr only	60.8++	>	27.8	20.0
	thermal cover	15.7--	>	61.1	55.0
	N	51		54	129

Percent slope: gentle =10-30%, moderate = 30-50%, steep = >50%.
Forage: percent cover = the sum of cover values of individual species.

APPENDIX B: TABLE 3. continued. Use/Availability: Sites, *Winters*

Habitat Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
THERMAL COVER	none	66.7++	<	22.2	37.2
	Submarginal	21.6		18.5	10.1
	Marginal	5.9--	>	37.0	26.4
	Good	5.9--	>	22.2	26.4
	N	51		54	129
HIDING COVER	none	5.9--		5.6--	19.4
	fragmentary	23.5+		18.5	10.1
	partial	43.1		53.7+	41.1
	complete	27.5		22.2	29.5
	N	51		54	129
DISTANCE TO NEAREST EDGE	<300 feet	70.4++		62.9	54.3
	300-600	13.7		24.1	19.4
	>600	5.9--	>	16.7	26.4
	N	51		54	129
DISTANCE TO HIDING COVER	in cover	68.6		81.5	71.3
	<300 feet	23.5	<	13.0	20.9
	300-600	5.9		1.9	5.4
	>600	2.0		1.9	2.3
	N	51		54	129

Thermal Cover: none = 0-10% canopy closure, submarginal = 10-50%, marginal = 50-70%, good = 70-100%. Canopy height must be 40+ ft.
Hiding Cover: none = 0-10% of area in hiding cover, fragmentary = 10-50%, partial = 50-90%, complete = 90-100%.
Distance to Hiding Cover: Hiding Cover defined as partial or complete.

APPENDIX B: TABLE 3. continued. Use/Availability: Sites, *Winters*

Parameter	Category	% Utilization Low snow 1984		% Utilization Deep snow 1983/85	% Availability on winter range
DISTANCE	in cover	15.7--	>	59.3	51.2
TO	<300 feet	53.0++	<	18.5--	33.4
THERMAL	300-600	25.5++	<	9.3	10.1
COVER	>600	3.9		13.0	5.4
	N	51		54	129
DISTANCE	<300 feet	13.8		16.7	11.6
TO	300-600	13.8		18.5	14.7
DRIVEABLE	600-900	7.8	>	18.5	10.1
ROAD	900-1200	9.8		5.6	4.7
	1200-1500	2.0	>	11.1	6.2
	>1500	52.9	<	26.0--	52.8
	N	51		54	129
DISTANCE	<300 feet	25.5		35.1	18.4
TO	300-600	27.5+	<	13.0	14.0
WATER	600-900	13.8		13.0	10.9
	900-1200	11.8		14.8	10.9
	1200-1500	9.8		9.3	7.0
	>1500	11.8--	<	1.9--	38.0
	N	51		54	129

Distance to Thermal Cover: Thermal Cover defined as marginal or good.
Distance to Road: Driveable Road = nearest road receiving some vehicle use--including regular snowmobile use--at the time of the radio spot.
Distance to Water: Water = nearest open or flowing water at the time of the radio location (not necessarily an aquatic feeding site).

APPENDIX C: HABITAT PARAMETERS

APPENDIX C. TABLE 1. A description of habitat parameters used to characterize stands and sites.

Elevation.
Average stand elevation taken from USFS/USGS ortho photos. Given in feet, rather than meters, to conform to standard Forest Service (USFS) usage, and partitioned into 600 ft intervals, starting at 2900 ft. For use/availability comparisons, *seasonal* use is compared to *year-round* availability in order to illustrate seasonal shifts in elevation.

Aspect.
General compass orientation of the slope--measured in the field and expressed as standard 45 degree compass directions (N, NE, E, etc.).

Percent Slope.
Standard USFS slope measurement (45 degrees = 100% slope), lumped into 10% categories. Average stand values measured in the field with a clinometer.

USFS Stand Area.
The size of stands and silvicultural units defined by the Forest Service. Taken from the Sylvanite RD data base or calculated from aerial photos. Given in acres to conform to USFS usage.

Contiguous Unit Area.
Habitat blocks of similar gross structure (contiguous units) within which sample locations occur. Devised as a more realistic guage of habitat unit size, since the USFS stand designation often divides contiguous stands of timber into several smaller units.

Predominant Cover Species.
The overstory species in the plurality: applies only to pole and mature timber, not seedlings or saplings. It can be misleading in NW Montana, where 2-5 overstory species often share codominance in a single stand.

DF = douglas-fir	ES = engelmann spruce
WP = western white pine	AF = alpine fir
WL = western larch	WH = western hemlock
LP = lodgepole pine	WRC = western redcedar

APPENDIX C. TABLE 1. Habitat parameters. continued.

Predominant Regeneration Species.
The seedling or sapling species in the plurality. It oversimplifies the common phenomenon of codominance among 2 or more regen species.

Cover Type.
Groupings of cover species that include different associations of codominants as well as clear dominants. The basic combinations are:

WHC = westn hemlock, westn redcedar
SF = engelmann spruce, alpine fir
LP = lodgepole pine
MC = mixed conifer (douglas-fir, ponderosa pine, grand fir, westn larch, westn white pine)

Regeneration Type.
Same concept and categories as cover type.

Habitat Type.
Habitat types and series according to Pfister (1977). Used as indicators of potential stand character. Grouped as follows:

mesic DF series:	DF/VACA	PSME/*Vaccinium caespitosum*
	DF/VAGL	PSME/*Vaccinium globulare*
	DF/LIBO	PSME/*Linnea borealis*
dry DF series:	DF/SYAL	PSME/*Symphoricarpus albus*
	DF/CARU	PSME/*Calamagrostis rubescens*
ES series:	ES/CLUN	PICEA/*Clintonia uniflora*
	ES/VACA	PICEA/*Vaccinium caespitosum*
WRC series:	WRC/CLUN	THPL/*Clintonia uniflora*
WH series:	WH/CLUN	TSHE/*Clintonia uniflora*
damp AF series:	AF/OPHO	ABLA/*Oplopanax horridum*
	AF/CLUN	ABLA/*Clintonia uniflora*
	AF/MEFE	ABLA/*Menziesia ferruginea*
dry AF series:	AF/LIBO	ABLA/*Linnea borealis*
	AF/XETE	ABLA/*Xerophyllum tenax*
	AF/VAGL	ABLA/*Vaccinium globulare*
	AF/VASC	ABLA/*Vaccinium scoparium*

APPENDIX C. TABLE 1. Habitat parameters. continued.

Photo Interpretation Type.

USFS system which employs aerial photos to delineate and classify all areas within the timber base with a 4-unit code.

Cover Type: SAF, MC, WH, LP, PP
Conifer Size: 1 = seedl & sapl, 2 = pole & sml sawtmbr,
3 = medm sawtmbr, 4 = lge sawtmbr, 5 = 2-storied
Conifer Stocking: P = poor (10-49% cc), M = medium (50-79% cc),
W = well (80-100%)
Stand Development: L = cutover
additional information: NF = nonforest, NS = nonstocked,
NC = noncommercial, PL - plantation

Hiding Cover.

Hiding cover is defined as vegetation capable of hiding 90% of a standing adult moose at 200 ft (60 m) (Thomas et al 1979). Since hiding cover is often irregular throughout a habitat unit, I further classified it as follows:

Complete	>90% of the unit in cover		
Partial	50-90%	"	"
Fragmentary	10-50%	"	"
Negligible	<10%	"	"

I generally refer to complete and partial cover as 'effective' hiding cover. These percentages may need to be adjusted for other areas, but they worked well in the Yaak where escape cover was dense and widespread.

Thermal Cover

Overhead cover capable of modifying thermal conditions normally has a minimum canopy closure in the 65-75% range and average stand height of at least 40 ft (12 m). I categorized thermal cover in the Yaak as:

Good	>70% ave. canopy closure in stands > 40 ft.			
Marginal	50-70%	"	"	"
Submarginal	10-50%	"	"	"
Negligible	<10%	"	"	"

I refer to good and marginal cover as 'effective' thermal cover. Thomas et al (1979) used 40-70% cc for submarginal cover.

APPENDIX C. TABLE 1. Habitat parameters. continued.

Canopy Closure.
Percent canopy closure, measured by spherical densiometer, and divided into 5 categories (20% each) that provide a more precise estimate of the principal determinant of thermal cover.

Cover Configuration.
Basic combinations of thermal and hiding cover:

Negligible:	No effective hiding or thermal cover.
Hiding:	Partial or complete hiding cover with no overstory.
Thermal:	Marginal or good thermal cover together with partial or complete hiding cover. (Stands with effective thermal but negligible hiding cover were rare).

Structural Type
Combinations of forest successional stages and cover types:

No effective cover:
- *Grass-Forb* associations
- *Seedling-Low* Brush associations
- open *Sapling* or *Pole* stands (normally <100 t/ac)
- open stands of *Mature* timber (normally <100 t/ac)

Effective Hiding cover alone:
- *Sapling-High Brush* associations
- *Pole*-Sapling-High Brush associations
- open stands of *Mature* timber with Sapling-Brush understory

Effective Thermal and Hiding cover together:
- closed stands of *Small Mature* or *Pole* timber
- closed stands of *Large Mature* timber
- *Old Growth* stands

Horizontal Dispersion Pattern.
A categorical description of clumping and structural homogeneity, both in the overstory and the understory. An anatomy of the pattern.

APPENDIX C. TABLE 1. Habitat parameters. continued.

Vertical Layering.
A visual estimate of distinct vertical layering in the overstory. Mosaic: irregular layering, normally due to patchy distribution of the dominant overstory. Weak layering: due either to a light 2nd layer or to widely spaced old growth trees above the main bulk of canopy.

Basic Mosaic Pattern.
A visual estimate of the structural grain of the habitat: interspersion of small clumps, juxtaposition of large blocks, or general homogeneity.

Hiding Cover Mosaic.
The regular interspersion of different degrees of hiding cover (none, fragmentary, partial, complete). Clumping of eye-level vegetation.

Thermal Cover Mosaic.
The regular interspersion of different canopy densities. Clumping of the forest overstory.

Structural Mosaic.
A composite of thermal and hiding cover mosaic.

Type of Logging.
Principal logging systems, grouped according to the similarity of the result:

Seedtree/Shelterwood cuts: Shelterwood cuts on the Yaak District normally resemble dense seedtree cuts--both leaving <100 t/ac. The primary harvest method on the study area, 1980-85.
Salvage-Sanitation Treatments: These vary from fairly light individual tree removals to severe extractions resembling seedtree cuts. Most are somewhere between, and thus classified seperately.
Clearcutting: The dominant harvest method in the Yaak, 1950-1980.
Individual Tree Selection: An amalgamation of logging methods that, in the end, result in a few large trees being removed--often transforming good thermal cover to marginal thermal cover.
Overstory Removal: Elimination of thermal cover, retention of hiding cover. Bad silviculture, good moose habitat manipulation.
No logging: Includes old or light logging with little effect on stand structure.

APPENDIX C. TABLE 1. Habitat parameters. continued.

Year Logged.
Taken from Sylvanite Ranger District stand files and partitioned into 5-year periods. Logging prior to 1950 was uncommon on the study area, and its effects no longer evident.

Year Logged	Potential Age of Cut 1982-85
1951-1960	22 - 35 years
1961-1965	17 - 25
1966-1970	12 - 20
1971-1975	7 - 15
1976-1980	1 - 10
1981-1985	0 - 5

Site Preparation.
Treatment to eliminate slash and prepare the seedbed, normally 1-2 years after harvest. Information taken from Sylvanite District stand files and verified in the field.

Dozer Scarified: Slash dozer piled and burned, with the seedbed prepared primarily by mechanical scarification.
Broadcast burned: Slash burned in place, with the seedbed prepared by fire.
Thinned-Slashed: Additional cutting in selection cuts immediately after initial harvest.

Follow-up Treatment.
Silvicultural work several years after logging and site prep--most frequently, precommercial thinning of sapling or pole units.

Height of Dominants.
Average height of whatever canopy layer defines the character of the stand--not always the tallest trees. Estimated in the field and given in feet to conform to USFS usage.

0 - 5 feet	0 - 1.5 meters	seedlings
6 - 15	1.6 - 4.6	small saplings
16 - 30	4.9 - 9.1	large seedlings
31 - 60	9.4 - 18.1	poles
61 -100	18.3 - 30.0	mature
>100	>30.0	large mature

APPENDIX C. TABLE 1. Habitat parameters. continued.

DBH of Dominants.
Average Diameter at breast height of the predominant canopy layer. Measured in the field, and given in inches to conform to USFS usage.

0 - 1 inch	0 - 2 cm	seedlings
1 - 5	2 - 13	saplings
6 - 9	14 - 23	poles
10 - 15	24 - 38	small mature
16 - 30	39 - 76	large mature
>30	>76	old growth

Total Trees/Acre.
Stems/acre of mature trees, poles, and saplings--but not seedlings. Estimated by fixed plots and average inter-tree distances.

Trees/Acre: Poles + Mature.
Stems/acre of overstory trees, estimated by ave. inter-tree distances.

Trees/Acre: Saplings.
Stems/acre of saplings--both as understory and as dominants in open stands--estimated by fixed plots.

Understory Vegetation Density.
Estimated density of all green vegetation at about 3-4 ft and 6-7 ft above ground level--which correspond roughly to sightlines into the moose bedding and standing zones. The contribution of conifer foliage deciduous brush, and tall forbs to hiding cover. Does not include mature tree trunks, downed timber, and topographic obstructions.

light = <25% vertical coverage; moderate = 25-50%;
heavy = 50-75%; very heavy = >75%.

Slash and Downed Timber Density.
Visual estimate of the impediment to mobility and the contribution to hiding cover made by downded timber and slash. Densities are the ave. number of significant obstructions (>1 m above ground level) per 100 ft in any direction (4 cardinal directions averaged).

light = <1, moderate = 1-2, dense = 2-3, very dense = >3.

APPENDIX C. TABLE 1. Habitat parameters. continued.

Forage Abundance.
The total % canopy coverage (after Daubenmire 1959) of different combinations of moose forage plants--primarily browse--found in each sampling unit. An indicator of the abundance and quality of forage required to draw moose into a habitat unit.

Two groupings were examined: group 1 = 1st + 2nd order forage (highly preferred + preferred--15 species); group 2 = 1st + 2nd + 3rd order forage (highly preferred + preferred + often used--26 species). Forage species are listed and preference ratings discussed in Appendix D.

Proximity to Aquatic Sites.
Presence or absence of an aquatic site in or adjacent to the sampling unit. I tallied any site I thought substantial enough to draw the attention of moose: Streams and rivers; ponds and marshes with open water; and swampy ground with little open water, but lush vegetation.

Proximity to Human Activity.
Field and map estimate of the relative potential for regular human disturbance close enough to alter moose behavior and habitat use.

Frequently disturbed: areas near frequently-used roads, human habitation, active logging sites.
Occasionally disturbed: usually sites near forest roads with moderate-light traffic or trails and closed roads used by hunters in fall,
Isolated areas: Sites >3000 ft from open roads and shielded by dense vegetation, rugged terrain, bodies of water, etc.

Topographic Class.
Topographic character of the local site, classified in the field. Some clarifications not evident in Appendix B:

gentle main slope: 10-30% slope
moderate main slope: 30-50% slope
steep main slope: >50% slope
slope in draw: any slope >20% partway into a draw

APPENDIX C. TABLE 1. Habitat parameters. continued.

Ecotone Status.
Field classification as to whether or not a site is in a significant transition zone between 2 types of habitat (as opposed to an 'edge', which is an abrupt border).

Distance to Nearest Edge.
Distance to the nearest principal structural edge--those that define boundaries between habitat units, and not internal edges within fine-grained structural mosaics. Determined in the field and from maps. Expressed in feet. The smallest distance is 300 ft (about 90 m)--the best that can be accurately detected for many quality-1 radio locations, with a 2.5 ac (1 ha) range of error. Quality-0 locations (sightings) were originally separated out and classified down to 50 ft (15 m) distances. However, sample size for these points alone proved too small.

Distance to Hiding Cover.
Distance (in feet) to the nearest block of effective hiding cover (complete or partial cover).

Distance to Thermal Cover.
Distance (in feet) to the nearest block of effective forest cover (good or marginal thermal cover).

Distance to Nearest Road.
Distance (in feet) to the nearest road receiving some vehicle use during the season of the radio location. Regular snowmobile traffic was considered vehicle use in winter.

Distance to nearest Water.
Distance (in feet) to the nearest open water at the time of the radio location. This parameter is more narrowly defined than the stand parameter 'proximity to aquatic site', which included frozen and dessicated sites as well (that could provide good adjacent browse, if not open water).

APPENDIX C. TABLE 1. Habitat parameters. continued.

Standard distance categories:

feet	meters
<300	<90
300-600	91-183
600-900	183-274
900-1200	274-366
1200-1500	366-457
1500-3000	457-914
>3000	>914

APPENDIX D· FORAGE PREFERENCE

I evaluated the role of forage as a factor in habitat selection in two stages: first, by developing relative preference ratings for individual plant species through observation of foraging moose and examination of feeding areas; and then by employing use-availability analysis to see if stands stocked with the more highly rated forage species were being used out of proportion to their availability. Preference ratings indicate the degree to which specific plants were consistently browsed; use-availability comparisons indicate how often moose were found in silvicultural units containing these species at particular levels of abundance.

I did not attempt to rigorously quantify food habits, but rather to broadly categorize species preference on a relative scale. Ratings were assigned by the following procedure: A preliminary list of forage species and preference values was gleaned from the literature. Preference ratings were then adjusted for the Yaak as field observations accumulated: foraging moose were observed during continuous monitoring and random sightings; and feeding areas were inspected during close-in radio-tracking, 24-hour monitoring, snow-tracking, and fortuitous observation.

Plants in the following tables include most browse species we found to be used to one degree or another in addition to those seasonal forbs and submerged aquatics for which we could detect consistent individual use. Use/availability comparisons are not reported for aquatic plants and for forbs and grasses as groups. Moose were seldom observed foraging on grasses and forbs, and with the exception of fireweed and a few species in the damp timbered draws, their degree of utilization was difficult to detect from a cursory examination of the flora.

The following rating scale was employed:

1	highly preferred	1st-order	forage species
2	preferred	2nd-order	"
3	often used	3rd-order	"
4	occasionally used	4th-order	"
5	incidentally used	5th-order	"

"Highly preferred" species were consumed liberally regardless of their scarcity or of the abundance of other forage species. Species in the remaining categories were eaten to a greater or lesser degree depending on the availability of more preferred species. "Incidentally used" species were rarely eaten, even when extremely abundant.

Consumption of some species occurred primarily in winter: shiney-leaf ceanothus, pachistima, western redcedar, alpine fir, pacific yew, and arboreal lichens. This seasonal shift in preference is mainly a function of the unavailability of more palatable species due to snow conditions. Submergent aquatic plants, most forbs, and some soft shrubs, such as thimbleberry, are unavailable during the snow season. Fireweed is a preferred species only for a few weeks in July and August as it flowers.

APPENDIX D: TABLE 1. Yearlong use and availability of silvicultural units classified by the abundance of individual forage species. Tabled values are the percentages of stands containing the indicated species at abundances (canopy coverage) of 1% and 5%. Percent use significantly greater or less than availability is indicated for $P \leq 0.05$ as + or -.

Forage Species	Preference Rating s	Preference Rating w	1%+ COVER %Use		1%+ COVER %Avail	5%+ COVER %Use		5%+ COVER %Avail
Salix spp.	1	1	48.5	+	27.6	21.0	+	7.4
Cornus stolonifera	1	1	19.5		11.7	6.0		3.2
Amelanchier alnifolia	1	1	46.5	+	27.1	22.5	+	4.8
Acer glabrum	1	1	18.6	+	5.8	2.8		0.5
Ceanothus sanguineus	1	1	17.7	+	1.0	6.5	+	0.5
Populus tremuloides	1	1	24.0	+	3.7	8.8	+	0.5
Sorbus scopulina	1	1	5.0		3.7	1.2		0.5
Lonicera utahensis	2	2	71.0	+	52.6	32.5	+	15.4
Menziesia ferruginea	2	2	28.5		22.3	15.0	+	8.5
Ribes spp.	2	2	23.5	+	6.4	1.0		2.1
Epilobium angustifolium	2	-	9.8		14.9	4.5		5.9
Ceanothus velutinus	3	2	17.7	+	1.0	6.5	+	0.5
Rosa spp.	3	3	62.0	+	43.6	20.5	+	7.4
Lonicera involucrata	3	3	5.5	+	0.1	2.0		0.1
Populus trichocarpa	3	3	29.5	+	8.0	10.5	+	1.1
Sambucus racemosa	3	3	4.2	+	0.1	0.0		0.0
Rubus parviflorus	3	-	9.8		14.9	4.5		5.9
Betula spp.	4	2	13.2	+	4.2	1.0		2.1
Alnus spp.	3	2	61.0	+	33.5	34.5	+	18.1
Spirea douglassi	4	2	2.4		1.6	1.2		1.1
Thuja plicata	4	3	38.7		36.7	26.0		21.8
Abies lasiocarpa	4	3	35.8		35.6	15.5		19.7
Taxus brevifolia	4	3	1.3		1.8	0.8		1.1
Alectoria spp.	5	2	53.3		61.7	35.5		38.8
Pachistima myrsenites	5	3	68.3	+	42.6	41.3	+	18.1
Pseudotsuga menziesii	5	4	23.8		24.5	9.3		12.8
Tsuga occidentalis	5	5	21.2		21.8	6.0		10.6
Pinus contorta	5	5	37.0		25.0	26.5	+	12.2
Larix occidentalis	5	5	26.0	+	13.3	14.0	+	7.4
Picea engelmanni	5	5	22.5		22.9	7.7		9.6
Vaccinium spp.	5	5	70.9	+	54.2	47.7	+	31.9
Shepherdia canadensis	5	5	56.5	+	38.8	43.0	+	19.1

From Table 1 it is evident that the presence of a preferred or highly preferred forage species is often correlated with greater than expected use of the stand in which it occurs. However, the correlation does not hold for such highly regarded species as fireweed, menziesia, mountain ash, and red-ozier dogwood; and stands with a profusion of such little-consumed species as huckleberry, buffaloberry, and lodgepole pine are also used significantly more than expected--which suggests correlation with other pertinent resources. In an area such as the Yaak, with a diversity of good quality browse, the abundance of individual forage species is not a reliable index to moose utilization of habitat units. Useful patterns begin to emerge when species are combined into preference groups as in Appendices A and B: combined abundance of 1st-order species; of 1st and 2nd-order species; and of 1st, 2nd and 3rd-order species.

This approach to analyzing the impact of food availability somewhat confounds the process of defining categories with that of testing the use/availability hypothesis. The Chi-square and Bonferoni tests become more a means of quantifying and refining hypotheses about forage preference already partially tested and resolved, in an informal way, by the development and application of the rating system. Be that as it may, the result is a useful one: a field-tested system for predicting forage patterns beneficial to moose in a managed forest environment.

APPENDIX E: HOME RANGE TABLES AND PLOTS

HARMONIC HOME RANGES & MINIMUM CONVEX POLYGONS

Harmonic contours are isolines surrounding different percentages of the home range. The size of a harmonic range is significantly influenced by the density of grid units used to draw the contours. Unless otherwise indicated, the following specifications apply to the harmonic home ranges in this appendix:

Scale = 1: 24000

Plot Size = 34 x 34 inches

Grid Density = 99 x 99 grid lines/plot

Minimum measured distance
between observations = 3.0 grid units

Meaningful comparison of harmonic home range sizes between this and other studies is dependent on comparable grid densities. Our standard density of 99x99 grid units is higher than that used in other studies--and is designed primarily to illustrate patterns of use and to detect changes over time within this study population.

Ranges constructed with *minimum convex polygons* are independent of grid resolution and density, but are sensitive to sample size and to outlier points.

APPENDIX E: TABLE 1. *Yearlong home ranges*: harmonic home ranges and minimum convex polygons for 8 individual moose, 1984 and 1985. Harmonic contours are isolines surrounding the indicated percentage of the home range. Means are weighted by sample size. Area is in square miles.

	Moose No.	sq. miles within harmonic contours 99%	90%	75%	50%	sq.miles within polygons	no. of points
1984	COWS 00	10.6	8.9	6.6	3.6	29.3	87
	01	6.7	5.6	3.9	2.0	21.9	76
	07	15.7	13.0	9.0	4.1	17.6	79
	08	22.8	17.7	11.4	5.4	31.5	95
	09	19.9	15.6	10.4	5.0	18.7	98
	10	30.2	22.3	13.6	4.9	51.7	95
	BULLS 03	21.6	15.0	8.3	3.0	20.9	93
	11	18.6	14.5	9.0	3.3	29.7	74
	MEAN	18.7	14.4	9.2	3.9	28.0	87
	(± 95% CI)	(6.3)	(4.4)	(2.5)	(1.0)	(7.2)	
1985	COWS 00	5.4	5.0	3.8	2.1	33.3	63
	01	2.4	2.0	1.4	0.7	19.0	51
	07	5.6	4.6	3.1	1.4	10.3	61
	08	11.4	9.1	6.0	2.7	14.0	72
	09	4.6	3.9	2.7	1.3	12.5	70
	10	5.7	4.8	3.4	1.5	19.4	51
	BULLS 03	12.6	9.6	6.0	2.4	21.5	60
	11	2.6	2.2	1.6	0.9	29.2	47
	MEAN	6.6	5.3	3.6	1.7	19.4	63
	(± 95% CI)	(3.4)	(2.5)	(1.6)	(0.6)	(6.6)	

Specifications: Scale = 1: 24000.
Grid Density = 99 x 99.
Minimum Measured Distance between observations = 3.0 grid units.

APPENDIX E: TABLE 2. *Mean home range size, 1982-1985*: minimum convex polygons (MCP) and 99% harmonic home ranges (HHR). Area is in square miles. Seasonal mear_ are weighted by sample size. 1982-83 data is from Matchett (1985).

sq. miles within home ranges

	1982 *		1983 *		1984		1985		4-year mean	
	MCP	HHR	MCP	HHR	MCP	HHR	MCP	HHR	MCP	HHR
WINTER	5.05	1.3	2.8	1.1	2.8	2.4	3.0	2.2	3.4	1.7
SPRING	-	-	2.3	0.8	-	-	-	-	2.3	0.8
SUMMER	12.2	0.9	8.6	1.4	14.0	0.9	8.0	2.5	10.7	1.4
FALL	-	-	-	-	16.6	2.2	-	-	16.6	2.2
yearlong range	28.3	3.6	20.7	8.2	28.0	18.7	19.4	6.4	24.1	9.3

*data from Matchett (1985)

APPENDIX E: FIGURES 1-6. *Home range plots* for individual moose: Representative *yearlong* ranges, 1984 and 1985, plotted both as minimum convex polygons and as groupings of harmonic isolines.

Harmonic specifications are: plot size = 10 x 10
scale = 1: 81600
grid density = 99 x 99

5 harmonic contours are shown: 99%, 90%, 75%, 50% and 25%

Figure 1. Adult Cow 01, 1984.

Figure 2. Adult Cow 01, 1985.

Figure 3. Adult Cow 07, 1984.

Figure 4. Adult Cow 07, 1985.

Figure 5. Adult Cow 09, 1984.

Figure 6. Adult Cow 09, 1985.

These plots illustrate how collared moose distributed their activity throughout the year. The minimum convex polygons roughly outline the area within which the animals operated during the course of a year, and the harmonic contours indicate the pattern of dispersion and the centers of activity. Most important local ranges map out clearly as disjunct islands of use: some are delineated by 99% contours, others by less inclusive isolines.

Ranges for 1984 are based on a full array of winter, summer, and fall locations, with a few spring points. Ranges for 1985 are based mostly on winter and summer locations, with a few points from spring and fall. Because many spring and fall locations occur in the transition zone between winter and summer range, the 1985 winter and summer ranges tend to map out as more distinct islands than in 1984 (when a full set of fall locations was included).

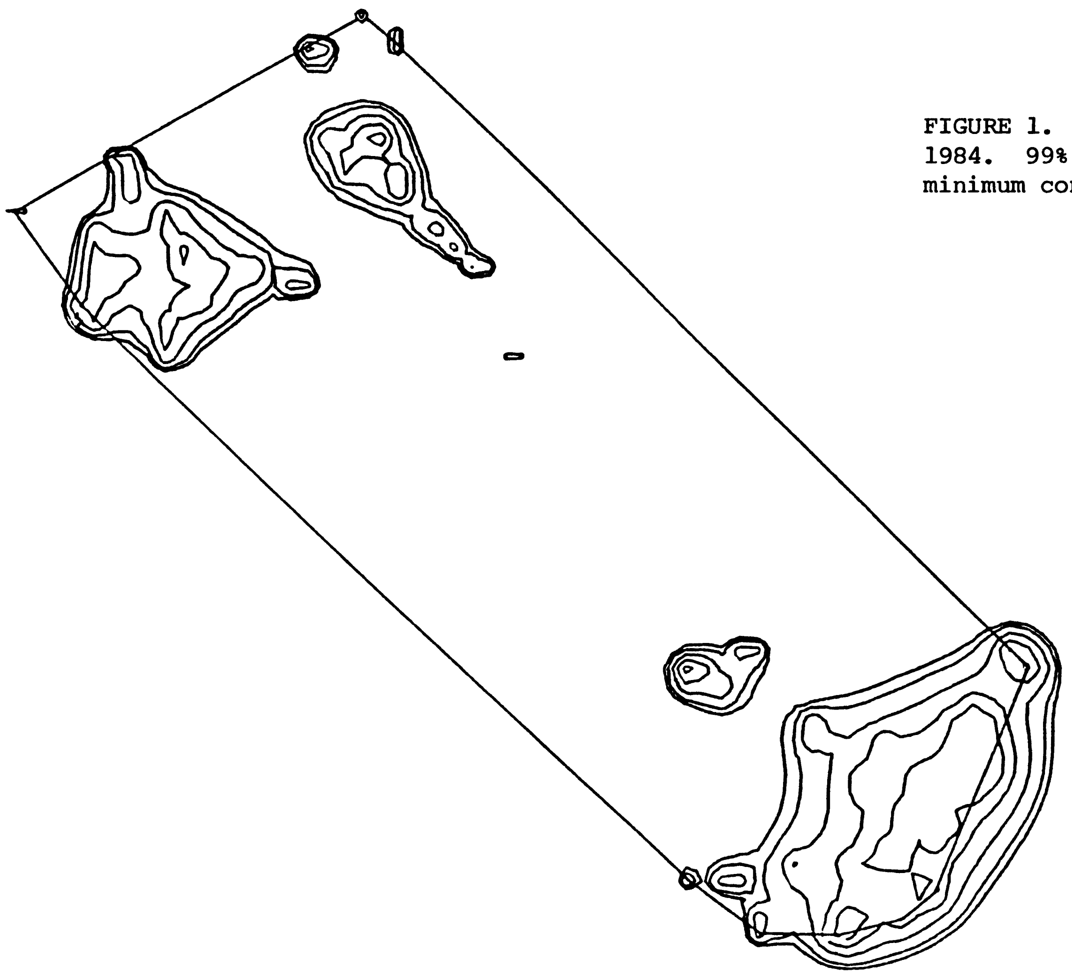

FIGURE 1. Cow no. 01, yearlong range 1984. 99% harmonic contour = 6.4 mi^2, minimum convex polygon = 20.9 mi^2.

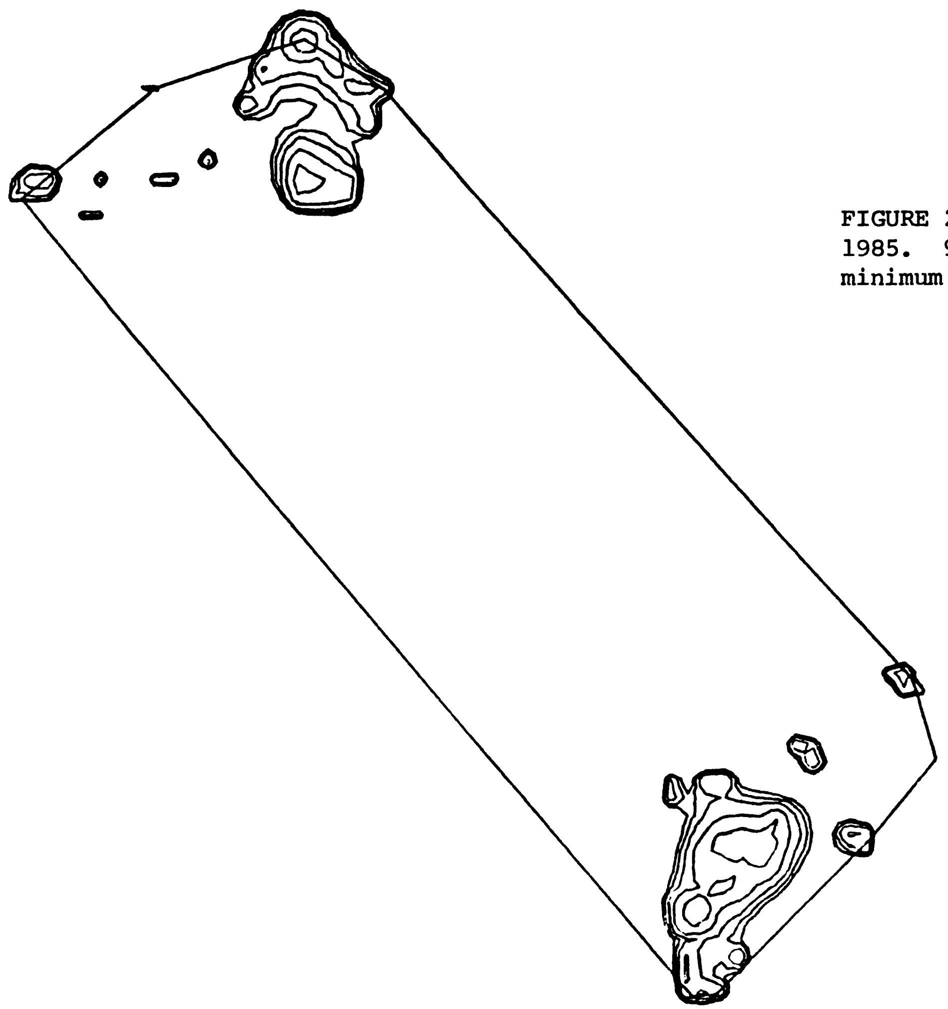

FIGURE 2. Cow no. 01, yearlong range 1985. 99% harmonic contour = 2.3 mi^2, minimum convex polygon = 18.1 mi^2.

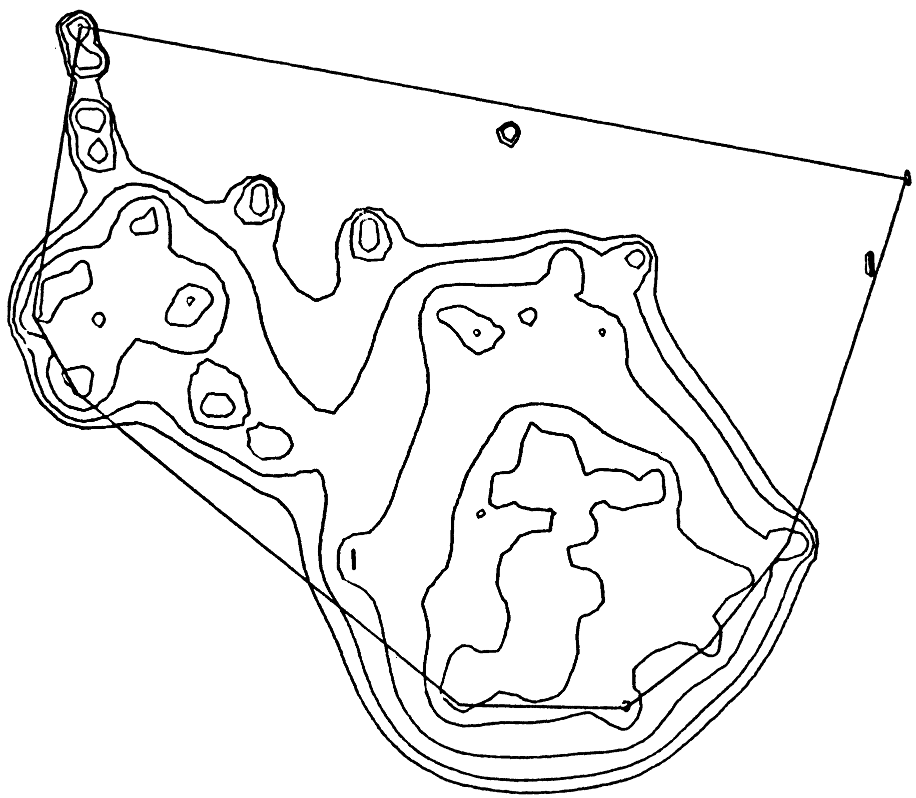

FIGURE 3. Cow no. 07, yearlong range 1984. 99% harmonic contour = 14.9 mi^2, minimum convex polygon = 16.7 mi^2.

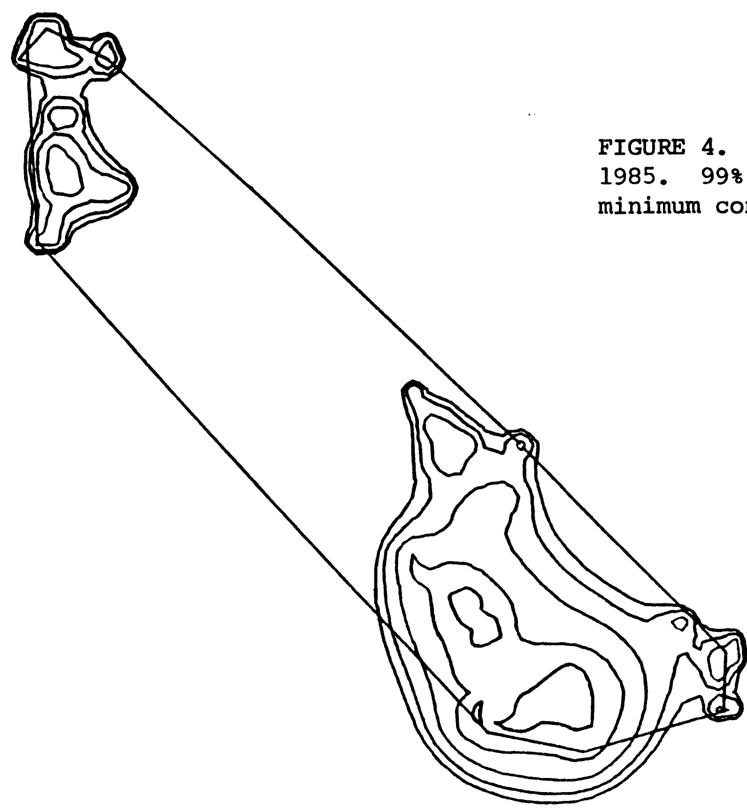

FIGURE 4. Cow no. 07, yearlong range 1985. 99% harmonic contour = 5.3 mi^2, minimum convex polygon = 9.8 mi^2.

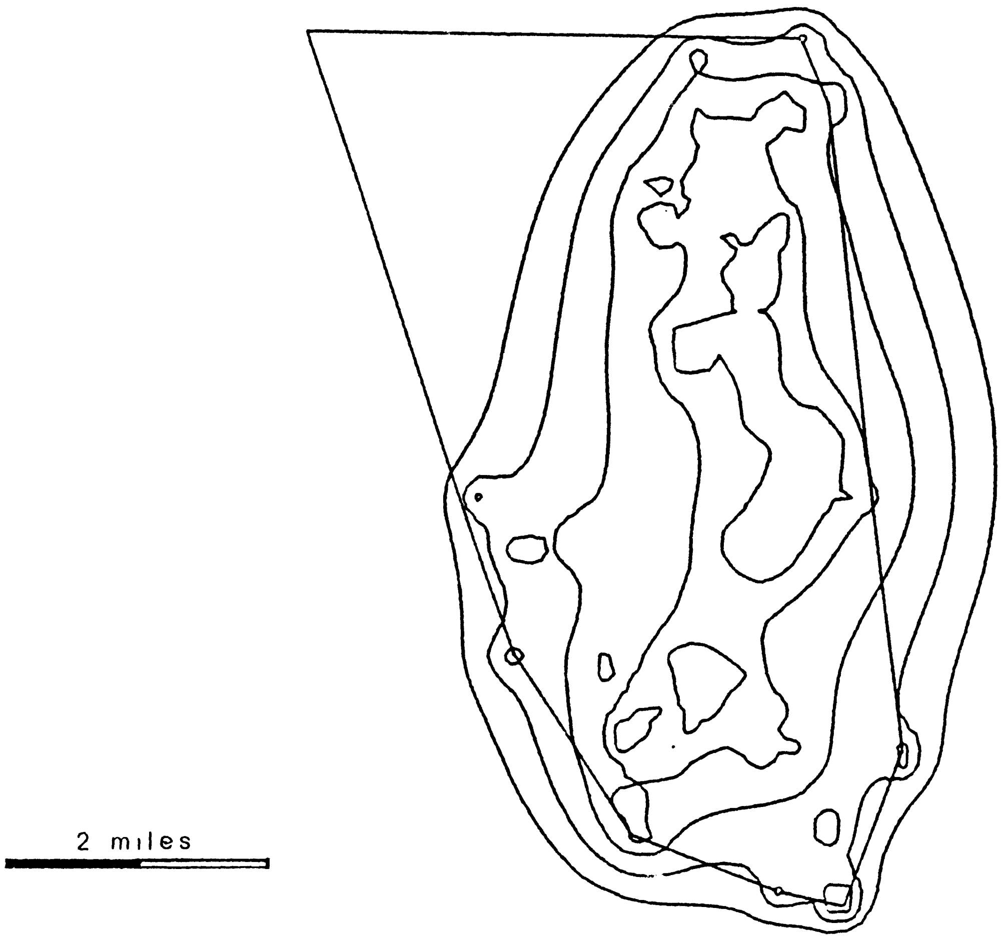

FIGURE 5. Cow no. 09, yearlong range 1984. 99% harmonic contour = 19.0 mi^2, minimum convex polygon = 17.9 mi^2.

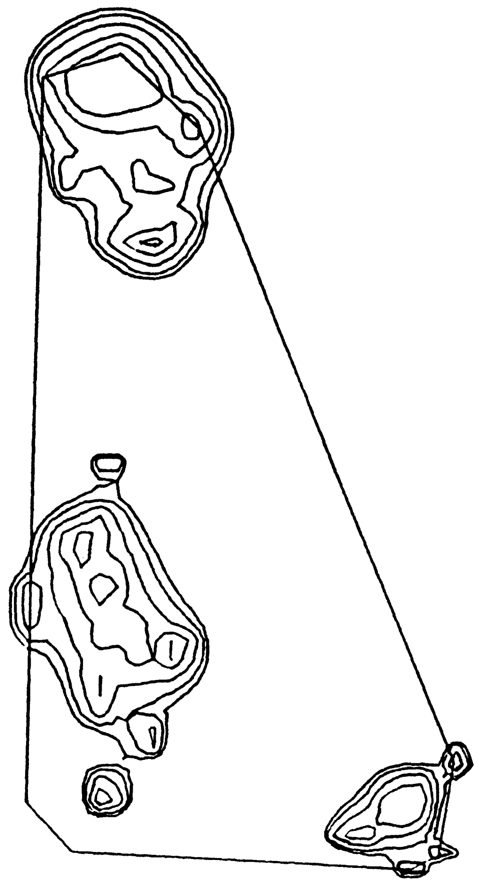

FIGURE 6. Cow no. 09, yearlong range 1985. 99% harmonic contour = 4.4 mi^2, minimum convex polygon = 11.9 mi^2.

APPENDIX F, TABLE 1. Habitat features associated with high abundance (>45% canopy cover) of 1st and 2nd-order forage significantly *more* than expected and significantly *less* than expected ($P < 0.05$). Association was determined by Chi Sq and Bonferoni Z tests. 45% abundance is the level above which moose normally select heavily for the 1st + 2nd order forage group.

<u>HIGH ASSOCIATION with Abundant Good Quality Forage</u>:

Higher elevation (>4700 ft).

N-NE-E aspect; SE aspect to a lesser degree.

Timber stands dominated by AF.
Habitats with regeneration dominated by AF or WL.

Damp AF habitat type series (AF/MEFE, AF/CLUN, AF/OPHO).

Complete hiding cover.

Negligible and Submarginal thermal cover.

Habitats dominated by saplings & brush, with partial-complete hiding cover, and open or no overstory.

USFS PI types: logged areas.
units with medium density conifer stocking.
units dominated by saplings.
units with AF-ES cover types.

<u>LOW ASSOCIATION with Abundant Good Quality Forage</u>:

Stands with overstories dominated by DF, LP, WH, or WRC.
Habitats with regeneration dominated by ES or WRC.

Habitat types in the dry DF series (DF/SYAL, DF/CARU); or the dry AF series (AF/LIBO, AF/XETE, AF/VAGL, AF/VASC).

Closed stands dominated by poles or small mature timber.

USFS PI types: WH and LP cover types.

APPENDIX F, TABLE 2. Habitat features associated with partial and complete hiding cover significantly more than expected ($P < 0.05$).

High Association with COMPLETE Hiding Cover:

Good thermal cover.

N-NE-E aspect.

Habitats at higher elevation (>4700 ft).

Units logged before 1960.

Abundant (>45% cc) 1st & 2nd order forage.

Timber stands with overstories dominated by WH or WRC.
Timber stands with understories dominated by WH or WRC regen.

Timber stands with overstory densities >300 t/ac.
Habitats with total conifer densities >500 t/ac (saplings and up).

USFS PI types: well-stocked (80-100%) units.
WH cover class.

High Association with PARTIAL Hiding Cover:

Marginal thermal cover.

Habitats at lower elevation (<3500 ft).

Units logged 1960-1970.

USFS PI types: units with seedling-sapling size class.
LP cover class.

Open habitats with sapling densities of 300-1000 t/ac.
Timber stands with overstory densities of 100-300 t/ac.

Habitats with total conifer densities of 300-500 t/ac (excluding seedlings).

Parameters and habitat categories are clarified in Appendix C.

APPENDIX F, TABLE 3. Habitat features associated with *good thermal cover significantly more than expected, with P ≤ 0.05 and P ≤ 0.10 (those features in parentheses*. Good thermal cover occurs in stands of timber greater than 40 ft high with canopy closure of at least 70%.

<u>HIGH</u> <u>ASSOCIATION</u> <u>with</u> <u>Good</u> <u>Thermal</u> <u>Cover</u>:

Multi-storied stands; (stands with weak vertical layering).

Dominant trees >100 ft; (dominant trees 60-100 ft).

USFS PI type: large sawtimber; (medium sawtimber).
western hemlock cover class; (mixed conifer cover class).

Complete hiding cover.

Overstory density >200 t/ac.

Moderate to heavy density of downed timber.

Low abundance (<15% cc) of high-quality forage.

Western hemlock/*Clintonia uniflora* habitat type.
Conifer regeneration dominated by WRC and WH.

<u>LOW</u> <u>ASSOCIATION</u> <u>with</u> <u>Good</u> <u>Thermal</u> <u>Cover</u>.

Stands with a mosaic of vertical layering.

Overstory densities (poles + mature) <100 t/ac.

Fragmentary and negligible hiding cover.

USFS PI types: SAF cover types.

Stands with overstories dominated by Alpine Fir.
Areas dominated by Lodgepole Pine or Western Larch regeneration.

Abundant (>45% cc) good quality forage

Parameters and habitat categories are clarified in Appendix C.

APPENDIX G: POPULATION TABLES

APPENDIX G: TABLE 1. *Valid sightings* in the Study Area, 1984-1985. Total sightings = 355; Valid sightings (those within the areas defined in Table 5) = 301. Of the valid sightings listed below, 33 involved some degree of radio assistance or were non-independent sightings of the same animal, and were not used to estimate population.

NUMBERS OF MOOSE

sex/age class	1984 wtr	1984 smr/atm	1985 wtr	1985 smr/atm	1986 wtr	Total
Single Adult Cow	28	41	30	25	3	126
Cow with 1 Calf	13	8	7	9	1	38
Cow with 2 Calves	0	3	0	7	1	11
Adult Bull	22	25	10	20	2	78
Adult Unidentifd	12	1	2	0	2	17
Yearling Cow	2	4	1	5	0	11
Yearling Bull	0	4	3	0	0	8
Yearling Unidentifd	1	6	0	0	0	7
Calf without Cow	0	2	0	3	0	5
TOTAL	78	94	53	67	9	301
(collared)	(21)	(8)	(13)	(11)	(2)	(55)

For purposes of estimating population, seasons are defined as follows:
Winter 84 = Jan 6--Mar 25. Summer-fall 84 = May 26--Nov 16.
Winter 85 = Nov 25--Apr 2. Summer-fall 85 = Jun 3--Sept 30.
Winter 86 = Jan 10--Mar 5.

APPENDIX G: TABLE 2. Vital statistics of collared moose, 1982-1986.

Moose		Calves produced/Yearlings generated 1982	1983	1984	1985	1986	Mortality status Oct. 1986
00	cow	1/1	1/1	0/0	1/0	x	unreg. kill 85
01	cow	0/0	0/0	0/0	2/1	-	alive
02	cow	0/0	-	-	-	-	unknown
03	young bull	------------------------------------					alive
04	bull	-------------		x	x	x	natl. death 83
05	young cow	-/-	1/1	1/1	3/-	-	unknown
06	young bull	-----	x	x	x	x	legal kill 82
07	cow	0/0	1/1	1/1	2/2	-	alive
08	cow	1/1	2/0	0/0	2/2	2/-	alive
09	old cow	-/-	1/0	0/0	1/0	x	legal kill 85
10	young cow	-	0/0	0/0	1/1	0/0	legal kill 86
11	young bull	-----------------------------				x	legal kill 85
calves: 100 cows		40	86	29	171	100	
clf mortality (%)		0	50	0	33	-	32% /yr
ad mortality (%)		12	12	0	33	17	15% /yr

Notation: - no information. --- inapplicable. x dead.