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Habitat Selection Mortality and Population Monitoring of Shiras Moose in the North Fork of the Flathead River Valley Montana

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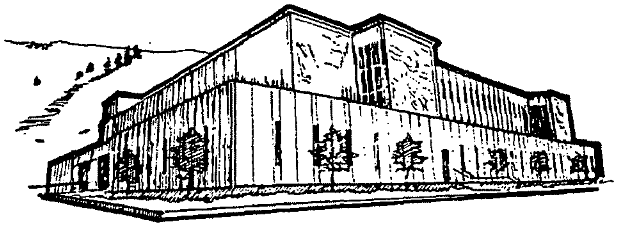

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HABITAT SELECTION, MORTALITY AND POPULATION MONITORING OF SHIRAS MOOSE IN THE NORTH FORK OF THE FLATHEAD RIVER VALLEY, MONTANA

by

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Presented in partial fulfillment of the requirements
for the degree of
Master of Science

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ABSTRACT

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Habitat Selection, Mortality and Population Monitoring of Shiras Moose in the North Fork of the Flathead River Valley, Montana. (162 pp.)

DHP

Director: Daniel H. Pletscher

The North Fork of the Flathead River in northwestern Montana and southeastern British Columbia is used by numerous predator and prey species, including wolves (_Canis lupus_), grizzly bears (_Ursus arctos_), and moose (_Alces alces shirasi_). Moose are the largest sized prey item taken by wolves, grizzly bears and hunters.

During 1989-90 and 1990-91 winters, 32 cow moose were radio-collared to study habitat selection, mortality, population monitoring and calving site selection. Habitat selection and movement patterns were assessed using 1338 locations from 29 moose. Habitat data were overlaid with 75% harmonic mean home ranges and percent coverage was obtained using a GIS software program. Home range values were compared to coverage within available habitat as defined by a 100% minimum convex polygon based on all moose locations. Mortality was determined from motion-sensitive radio-collars. Age and sex composition of the population was estimated by flying survey flights during early winter in 1990-91. Results of surveys conducted by British Columbia Ministry of the Environment were also reported and discussed.

Twenty-one animals exhibited "migratory" behavior between lowland winter range and higher elevation spring and summer range, with movements ranging from 4-84 km. Eleven animals used the same area in both seasons. Moose used habitat at elevations between 1200-1400 meters with moderate slopes. Home ranges of non-migratory cows and summer ranges of migratory individuals contained lengths of 4 road types and 2 river types that were similar to lengths in available habitat, but contained more marsh and sapling dominated cover than expected. Winter ranges of migratory cows contained more primary, secondary and tertiary roads and significantly more length of permanent river and conifer cover than expected. Four mortalities occurred during the study, 1 from wolves, 2 from grizzly bears and 1 from causes other than predation. The proportion of adult cows surviving annually was 0.91 ± 0.08. In December and January, a calf:cow ratio of 61:100 was found with a bull:cow ratio of 69:100 and an overall density of 0.55 moose/km^2. Calving sites were variable but generally had more cover than available habitat.

ACKNOWLEDGMENTS

Funding for this study was provided by Glacier National Park and a McIntire-Stennis grant from the School of Forestry, University of Montana. Logistical support was generously given by the Kalispell office of the Montana Department of Fish, Wildlife and Parks, the Flathead National Forest, the Montana Cooperative Wildlife Research Unit, and the British Columbia Wildlife Branch. Many thanks to Jim Cross, Bruce Campbell, Doug Getz, Bruce Hurd, Joe Ball, Bill Workenton and all the other kind people who provided their expertise and support.

I am most grateful to my committee chairman Dr. Dan Pletscher for his always constructive and helpful support and advice. Dan has been there for me at every step of this project and I will forever value his friendship. I am also appreciative of my other committee members Dr. Bob Ream and Dr. Dick Hutto for their easy going advice and general support. Dr. Bart O'Gara was also a great source of assistance and information as was Dr. Hans Zuuring who was always available to help with statistical design and analysis with a smile. Technical help with the GIS portion of my work was given by Ken Wall, Joe Grigsby, Per Sandstrom and Zhenqui Ma, and I am thankful to them for their time and friendship. Dr. Les Marcum also provided support through his sincere concern and helpful advice.

The flying in this study was done by Eagle Aviation of

Kalsipell, Montana. The expertise of owner and pilot Dave Hoerner was surpassed only by his friendly ways.

Numerous volunteer field assistants were vital to this project. Special thanks to Marc Hodges, Kevin Podruzny, Russell Jackson, Lori Russ, Michelle Kastler, Tina Parrott, and Anne Robertson. I am also indebted to Diane Boyd and Mike Fairchild. Mike continually inspired me and taught me innumerable tricks, he answered all my questions and most importantly, was my best friend throughout this process.

Many North Fork residents took an interest my work and I am thankful to them. Special thanks go out to Lee Secrest, Jacquie and Bob White, and Pat and John Elliot.

Many other friends also lent their time and energy to this study. It would not have been completed without them. They include Larry Reevis, Mollie Matteson, Denise Pengeroth, Mike Pol, Lee Esbenshade, and Mary Brown among others. I am deeply indebted to my wonderful parents, Ruth and Herbert Langley for their support of whatever I have chosen to do and to my son, Nicolas Langley, whose contagious happiness made it all seem worthwhile.

Finally, I want to thank the 37 moose that I collared during this research. Humans tend to take for granted the suffering imposed on research subjects, and while I oppose this approach, I hope that their sacrifice will benefit wildlife in some substantial way.

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CHAPTER I

My study focused on one element of a complicated predator-prey complex in hopes of understanding more about this component as well as the entire system. Specific information about habitat needs is crucial to effective management of any population. Managing wildlife in areas with high species diversity requires consideration of each element separately and in conjunction. The North Fork of the Flathead River runs through a valley (Flathead) where several predator and prey species are common, including wolves (*Canis lupus*), which have only recently recolonized the area (Ream et al. 1991). Research in the Flathead is made all the more informative by the existense of radio-collared grizzly bear (*Ursus arctos horribilis*) and black bear (*U. americanus*), wolf, white-tailed deer (*Odocoileus virginianus*), elk (*Cervus elaphus*) and moose (*Alces alces shirasi*). Uncollared populations of mountain lion (*Felis concolor*), coyote (*Canis latrans*), mule deer (*Odocoileus hemionis*) and humans also inhabit the region.

Very few North American studies have been done in areas with as diverse a predator-prey complex as that found in the Flathead. Studies in the area will improve our understanding of the interdependence of numerous large mammals while providing information that will help managers maintain the native diversity of the region.

With information about moose habitat in the North Fork, land and wildlife managers will be able to protect specific areas. Once important components of moose calving sites are identified, areas that have these components can also be managed with special care. Quantitative information relevant to moose predation may also be very useful in discussions about wolf recovery.

The present study had 4 major objectives: 1) determine seasonal distribution and habitat use of moose in the North Fork valley; 2) gather data relevant to age- and cause-specific moose mortality rates; 3) determine the age and sex composition of the moose population in the North Fork valley and establish an index to moose abundance that may be used for long-term monitoring; and 4) identify critical features of moose calving areas. This study was conducted in conjunction with similar studies of elk and white-tailed deer.

The information in this thesis has been divided into several chapters and each chapter addresses one of the 4 main objectives of my research. To avoid redundancy, information relevant to all chapters was presented in Chapter II only and was referred to in later chapters.

CHAPTER II

HABITAT SELECTION BY MOOSE IN THE NORTH FORK VALLEY OF THE FLATHEAD RIVER

Habitat selection in moose has been studied in a variety of habitat types. These studies have indicated that moose choose habitats that provide large amounts of good quality forage (Peek et al. 1976, Pierce and Peek 1984) and adequate cover (Pierce and Peek 1984).

Moose have been found to use clearcuts that have a high vegetation biomass that are not too large (Eastman 1974, Telfer 1974, Peek at al. 1976, Stelfox et al. 1976, Parker and Morton 1978, Telfer 1978, Doerr 1983, Cederlund and Okarma 1988, Costain 1989). The importance of cover near cuts has been clearly demonstrated (Hamilton and Drysdale 1975, Stelfox et al. 1976, Parker and Morton 1978, Hamilton et al. 1980, Welsh at al. 1980, Monthey 1984, Payne et al. 1988). Habitat created by fire has also been heavily used by moose (Spencer and Hakala 1964, Eastman 1974, Peek 1974a, Irwin 1975, Bailey 1978, Davis and Franzmann 1979, Bangs and Bailey 1980, Franzmann and Schwartz 1985), and nearby cover remains critical in burnt areas (Irwin 1975, Bangs et al. 1985). Other disturbance, such as spruce budworm (*Choristoneura* *occidentalis* Freeman) and mountain-pine beetle (*Dendroctonus* *ponderosa* Hopk.) infestations, may also produce good moose habitat by opening up the canopy and allowing for seral plant growth (Dodds 1974, Krefting 1974).

Considerable variability has been recorded in the annual movements of moose. Individual moose may be migratory or non-migratory. All animals in an area may be migratory (Pierce 1983), but it is more common for some moose within a population to exhibit migratory behavior between seasons whereas other individuals do not move appreciably during the year (Edwards and Ritcey 1956, Houston 1971, Pulliainen 1974, Bailey 1978, Addison et al. 1980, Mytton and Keith 1981). The causes for this variation are not well understood and may reflect a search for specific habitat components.

The role of predators in influencing moose habitat selection is unclear. Cow moose with calves have been found to use less than ideal feeding habitat to avoid wolves (Edwards 1983, Edwards 1984), and wolves have been documented following moose in their elevation changes but not in their migrations (Ballard et al. 1987). Additionally, increases in moose movements have been documented in areas of high grizzly bear density (Ballard et al. 1980).

My objective was to track adult cow moose to document their seasonal habitat selection and movements in a predominately lodgepole pine (Pinus contorta) habitat. I expected moose to use areas that had high forage production and good cover.

STUDY AREA

This research was conducted on lands adjacent to the North Fork of the Flathead River in northwestern Montana and southeastern British Columbia (Flathead). In the United States, this area includes Glacier National Park (GNP) to the east of the river, with the Flathead National Forest (FNF) and various tracts of private land to the west. In Canada, the land on both sides of the river is owned by the British Columbia (BC) Provincial Government (Figure 2.1).

Movements of sedimentary rock along the Lewis and Clark Overthrust fault formed the North Fork Valley early in the Tertiary period. The present rolling topography was created by glacial activity in the Pleistocene era followed by fluvial action that formed broad alluvial terraces above the present floodplain (Koterba and Habeck 1971, Alt and Hyndman 1973).

Vegetation in the Flathead is a mixture of coniferous forests, wetlands and grasslands. The main coniferous species is lodgepole pine. The wetlands consist of a variety of forbs, sedges, and rushes with shrubs scattered throughout the area. Grasslands are dominated by rough fescue (_Festuca_ _scabrella_) and occur above the present floodplain (Jenkins 1985).

Clearcutting is the most common silvicultural technique used on both the FNF and in BC.

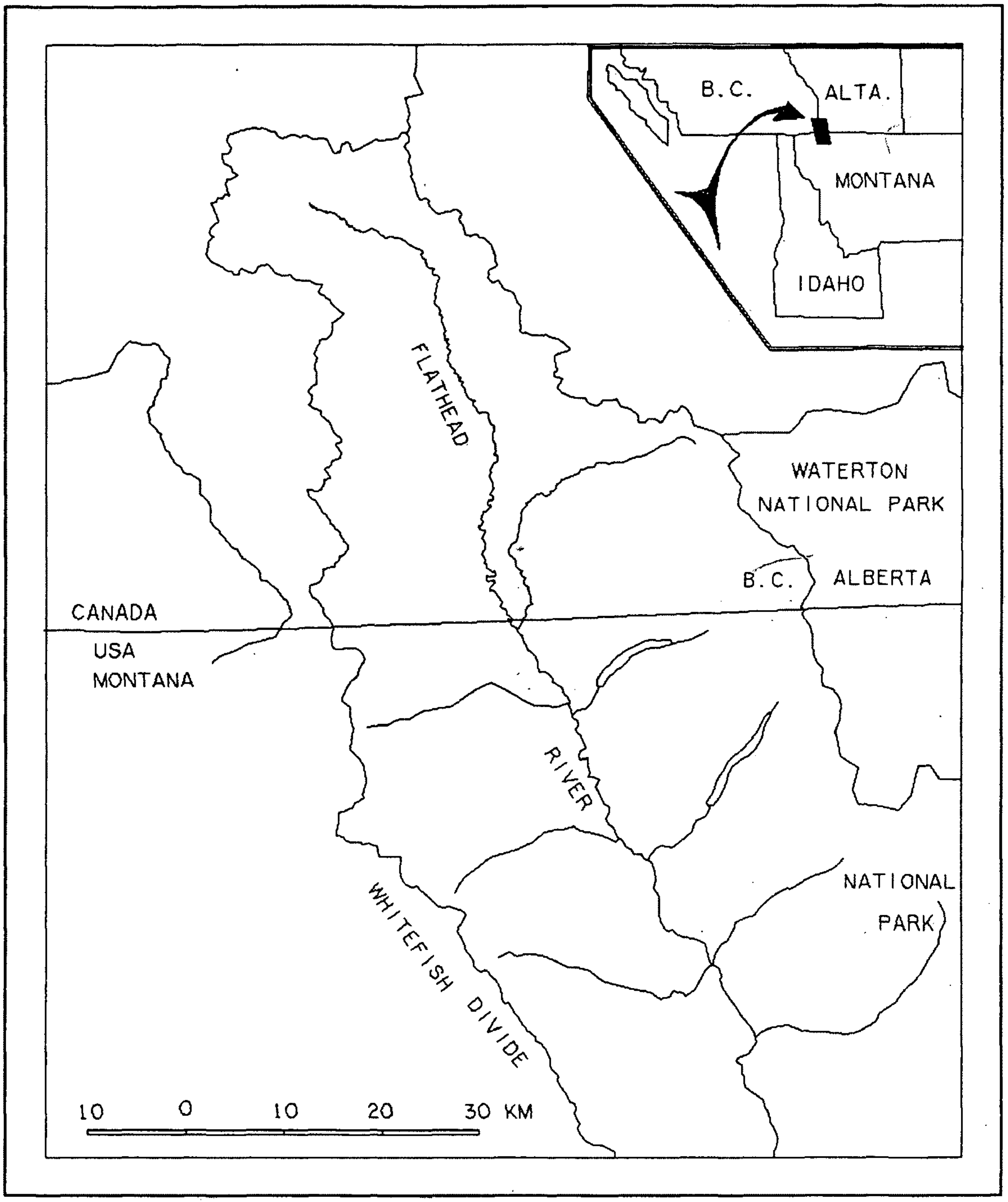

Figure 2.1. Map of the study area

These cuts vary in size and age, with larger cuts existing primarily in Canada. GNP is managed as a natural area and 92% of its area is managed as wilderness with limited human access (Martinka 1976). A portion of the Park (11,400 ha) and the FNF (4,000 ha) were burned by the Red Bench wildfire in 1988 (Dutton and Cooper 1988). Parts of the study area have also been affected by a mountain pine beetle infestation that has resulted in a decrease in canopy cover due to tree death and limb loss.

The Flathead receives an average of 59 cm of precipitation annually, most of this falling as snow. However, snow depths may vary considerably on a local level. The average annual temperature is 4 C with a July mean of 16.1 C and a January mean of -9.3 C. Snow depths vary considerably from year to year but the area is usually snow-covered from mid-November to mid-April (Singer 1979).

A wide variety of wildlife species exist in the Flathead; particularly notable are the high diversity and high density populations of ungulate species found there. In addition to a large number of white-tailed deer (Odocoileus virginiana), smaller populations of elk (Cervus elaphus) and moose inhabit the lowland areas. At slightly higher elevations, mule deer (Odocoileus hemionus) are found while mountain goats (Oreamnos americanus) inhabit areas of still higher elevation. In addition to a growing wolf population, there exists perhaps the highest density of grizzly bears (Ursus arctos horribilis) in the lower 48 states, many black bears (Ursus americanus) and an unknown but substantial number of mountain lions (Felis concolor).

METHODS

Transmitters

All of the transmitters used in this study were purchased from Telonics Inc. (Mesa, Arizona) in October 1989. Each collar was designed to double its pulse rate from 50 beats/minute to 100 beats/minute when motionless for $\geq$4 hours. A doubled rate would theoretically indicate a mortality. The transmitters were mounted on vinyl neck bands, 5 cm wide and adjustable in length. A 20 cm insulated wire antenna protruded from the neck band. Each transmitter weighed 480 grams with dimensions of 4.8 cm by 6.9 cm by 7.6 cm.

Capture and Collaring of Moose

To obtain the necessary information to complete this study, 37 adult cow moose were captured and fitted with radio-collars during two separate winter periods. Twenty-six animals were captured and collared in early January 1990 and an additional 11 animals were collared during mid-December 1990.

Moose were captured from a helicopter in accordance with a capture protocol (Appendix A). Darts (3 cc, with barbed syringes) containing 3.9 mg Carfentanil (Meuleman et al. 1984) and 0.25 mg Rompun, were fired from the aircraft by Dr. Dick Kinyon, DVM, using a Cap-Chur dart gun. Once darted, moose were watched from a distance until they were fully immobilized. At that time Dr. Kinyon and a project affiliate were set down near the moose which they approached on foot for processing. Several procedures were conducted on each animal including pregnancy testing by rectal palpation (Arthur 1964, Haigh et al. 1982), pulling a canine for aging purposes (Sergeant and Pimlott 1959), recording several key body measurement (Karns 1976, Franzmann et al. 1983), and drawing blood for composition testing (Appendix A, B). Carfentanil was reversed using 6cc of Naloxone.

Locating Moose

Radio-collared moose were located from the ground or from the air at least once each week. Three or more azimuths were taken from the nearest road for each ground location using the "loudest-signal method" (Springer 1979). Animals that were inaccessible from the road were located from the air using either a Cessna 182 or 185 fixed-wing airplane outfitted with a 2-element "H" antenna (Telonics) mounted on each strut. Locations were obtained throughout the daylight hours and visuals were obtained whenever possible. Locations were classified according to the size of the error polygon created by intersecting azimuths. Good, fair and poor quality classes were used with error polygons < 0.25 km^2, < 1.0 km^2, and > 1.0 km^2, respectively. Location data recorded included UTM coordinates, time and date of location, quality of triangulation, a verbal description of the location and any other details including visually obtained information. Locations were plotted on 7.5 minute topographic maps and entered into a GIS database (PAMAP) for analysis.

Habitat Use and Availability

Location data were used to create minimum convex polygon (MCP) (Mohr, 1947) and harmonic mean (HHR) home ranges (Dixon and Chapman 1980) using the University of Idaho home Range program (Ackerman et al. 1990). The home range program automatically selected the optimal grid density for each animal. Locations from each animal were separated into 2 seasons, unless no seasonal differences existed. Seasonal lines were drawn based on major movements of individual animals. Points falling between seasonal ranges were dropped before home range calculation. I assumed that locations that were at least 3 days apart were biologically independent and I dropped data that did not meet this criteria (Swihart and Slade 1985).

A Student t-test was used to compare the mean size of 75% HHRs of moose with distinct seasonal ranges (migratory) and those whose seasonal ranges overlapped (non-migratory) and of summer and winter ranges of migratory cows.

Habitats were analyzed using variables available on the

GIS system (Table 2.1). These included slope, aspect, elevation, permanent and intermittent waterways, primary, secondary, tertiary and quaternary roads, and 8 cover types based on my interpretation of a 1991 LANDSAT satellite image.

Table 2.1. Definitions and category descriptions for habitat variables.

Variable	Definition
Slope	Percent slope in 6 classes:0-10%,11-20%, 21-30%, 31-40%, 41-50%, 51-60%
Aspect	Direction faced by slope in 9 classes: N, NE, E, SE, S, SW, W, NW, Flat (no slope)
Elevation (m)	11 classes: <1000,1000-1200,1200-1400,1400-1600,1600-1800,1800-2000, 2000-2200,2200-2400,2400-2600,2600-2800, 2800-3000
Water (m)	Length of each of 2 moving waterway types: Permanent water:present in all seasons and Intermittent water:present in spring only
Roads (m)	Length of each of 4 road types: Major roads:maintained year around Secondary roads:maintained in summer Tertiary roads:open but not maintained Quaternary roads:closed year around
Habitat Cover	8 classes: marsh, bare soil, rock, grassland, shrub dominated, sapling dominated, open conifer, conifer

Habitat use was determined by analyzing habitat components within each animal's 75% harmonic mean home range (Garton et al. 1985). Pamap GIS software was used to determine the area or total length of each habitat variable within each home range. A specially written program

(Zuuring, 1993) determined the percent of each habitat variable within each home range, calculated a mean percent across ranges, compared this to the available habitat's percent coverage and calculated a t-statistic.

Available habitat was defined as the habitat within the collective moose home ranges and included values for every 50 m pixel within a 100% minimum convex polygon created using all moose locations. One available habitat polygon was created for migratory moose and another for non-migratory animals.

RESULTS

Capture Data

Of the 26 moose captured in January 1990, 19 were caught in BC, 5 on the FNF and 2 in GNP; 11 additional cows were captured in BC in December 1990. Much of the western half of GNP was intensively searched for moose but only 2 cows were sighted; 2 bulls were also observed. Special attention was given to the areas burned by the Red Bench fire.

Thirty-three of the moose captured were immobilized with one dart each after an average time of 5 min and 7 sec (range=2 min 15 sec to 13 min 20 sec). The remaining 4 moose were darted twice and were immobilized after an average time of 14 min 19 sec (range=12 min 40 sec to 16 min) from the first hit and 1 min 56 sec (range=30 sec to 2 min 50 sec) from the second hit.

Recovery from Carfentinal took an average of 4 min 45 sec (range=2 min to 15 min 25 sec; N=26) after Naloxone was administered. The ground crew departed before full recovery of 11 animals. All animals were checked from the air to ensure that they had recovered completely.

Pregnancy testing by rectal palpation and by protein B levels produced similar results (Appendix B). Twenty-seven (82%) of the 33 cows aged 2 or older were pregnant based on rectal palpation and 30 (91%) were pregnant based on protein B tests. All moose tested negative for brucellosis, blue tongue and anaplasmosis. Thirty-three of 37 (89%) cows tested negatively for leptospirosis; moose 311 had an antibody level of 1:800, moose 330's level was 1:100, and moose 320 and 337's level was 1:50. Results of blood composition tests were all within normal ranges (Appendix B).

Location Data

Between 17 January 1990 and 3 September 1991, 1395 moose locations were obtained. An average of 52 relocations (range=17-86) were obtained for each of the 22 moose that remained collared as of April 1990. The 11 moose collared in December 1990 were relocated an average of 21 times (range=13-42) each. Most locations were made from the ground (53.0%) between 7:00 a.m. and 4:00 p.m. (60.4%) and were good quality (error polygon <0.25 km^2) locations (74.8%) (Table 2.2). Fifty-eight percent of the locations were made during the summer (between 1 May and 31 October for non-migratory cows and between times of obvious summer season migrations for migratory individuals) and 42% were made during the winter (between 1 November and 31 April for non-migratory cows and between times of obvious winter season migrations for migratory individuals).

Table 2.2. Number of air and ground locations, time class of locations and triangulation quality for radio relocations obtained between 17 January 1990 and 3 September 1991 from 33 cow moose, expressed in raw numbers and percentages.

Collection Method	Number of locations (%)
Ground	739 (53%)
Air	656 (47%)
Total	1395 (100%)
Time class	Number of locations (%)
0700-1600	842 (60%)
1601-2400	553 (40%)
0001-0700	0 (0%)
Total	1395 (100%)
Triangulation Quality	Number of locations (%)
Good	1044 (75%)
Fair	285 (20%)
Poor	66 (5%)
Total	1395 (100%)

Home range and habitat analyses were completed for 29 of the 32 cow moose that had adequate (> 10 relocations) sample sizes (Appendix C). Eleven animals were non-migratory and 18 had distinct winter and summer home ranges separated by 4-83 km (mean=21.9 km, SD=22.3 km). All migratory cows returned to the same general areas for both summer and winter range.

Home range sizes based on 100% minimum convex polygons (mcp) tended to be smaller than 95% harmonic mean home range (95hhr) and larger than 75% harmonic mean home ranges (75hhr). Mean sizes of combined seasonal ranges of migratory moose and ranges of non-migratory moose were not significantly different; summer and winter ranges of migratory animals were also not significantly different (Table 2.3).

Table 2.3. Mean values for 95% and 75% Harmonic Home Range (95HHR and 75HHR respectively) and 100% Minimum Convex Polygon (100MCP) home range estimates and mean number of relocations used for 95HHR and 100MCP estimates.

Home range type	Annual Nonmigratory (N=11)	Annual Migratory (N=18)	Summer Migratory (N=18)	Winter Migratory (N=18)
Ave. 95HHR	119.8 km^2	144.9 km^2	67.2 km^2	77.6 km^2
Ave. N for 95HHR (range)	40 (12-74)	40 (20-70)	22 (10-38)	18 (10-54)
Ave. 75HHR	46.3 km^2	83.2 km^2	36.8 km^2	46.6 km^2
Ave. 100MCP	90.6 km^2	96.5 km^2	58.8 km^2	37.6 km^2
Ave. N for MCP (range)	42 (13-71)	42 (21-70)	23 (10-41)	18 (10-54)

Dates of migration varied among individual animals and ranged between 22 September and 28 February (1991 mean=14

December) for the move to winter range (Appendix D) and between 19 April and 15 July (1990 mean=6 May; 1991 mean=22 May) for the move to summer range (Appendix C).

Elevation Use

On an annual basis, non-migratory cow moose used elevations between 1201 and 1400 m significantly more and elevations below 1000 m or above 1800 m significantly less than would be expected based on availability (Figure 2.2). Winter ranges of migratory moose contained significantly more habitat between 1201 and 1400 m and less area below 1000 m or between 1601 and 1800 m than expected(Figure 2.3). In the summertime, migratory cow moose used areas with elevations below 1000 m or between 2201 and 2400 m significantly less then expected; however, they used elevations between 1601 and 1800 m more than expected (Figure 2.4).

Slope Use

Slopes greater than 21% were significantly less likely to be found within annual home ranges of non-migratory moose than expected based on availability (Figure 2.5). Winter ranges of migratory cows contained significantly more area than expected with slopes between 0 and 10% and significantly less area with slopes greater than 21% (Figure 2.6). Summer ranges contained more area with slopes between 11 and 30% and less areas with slopes between 0 and 10% and between 61 and 70% than expected (Figure 2.7).

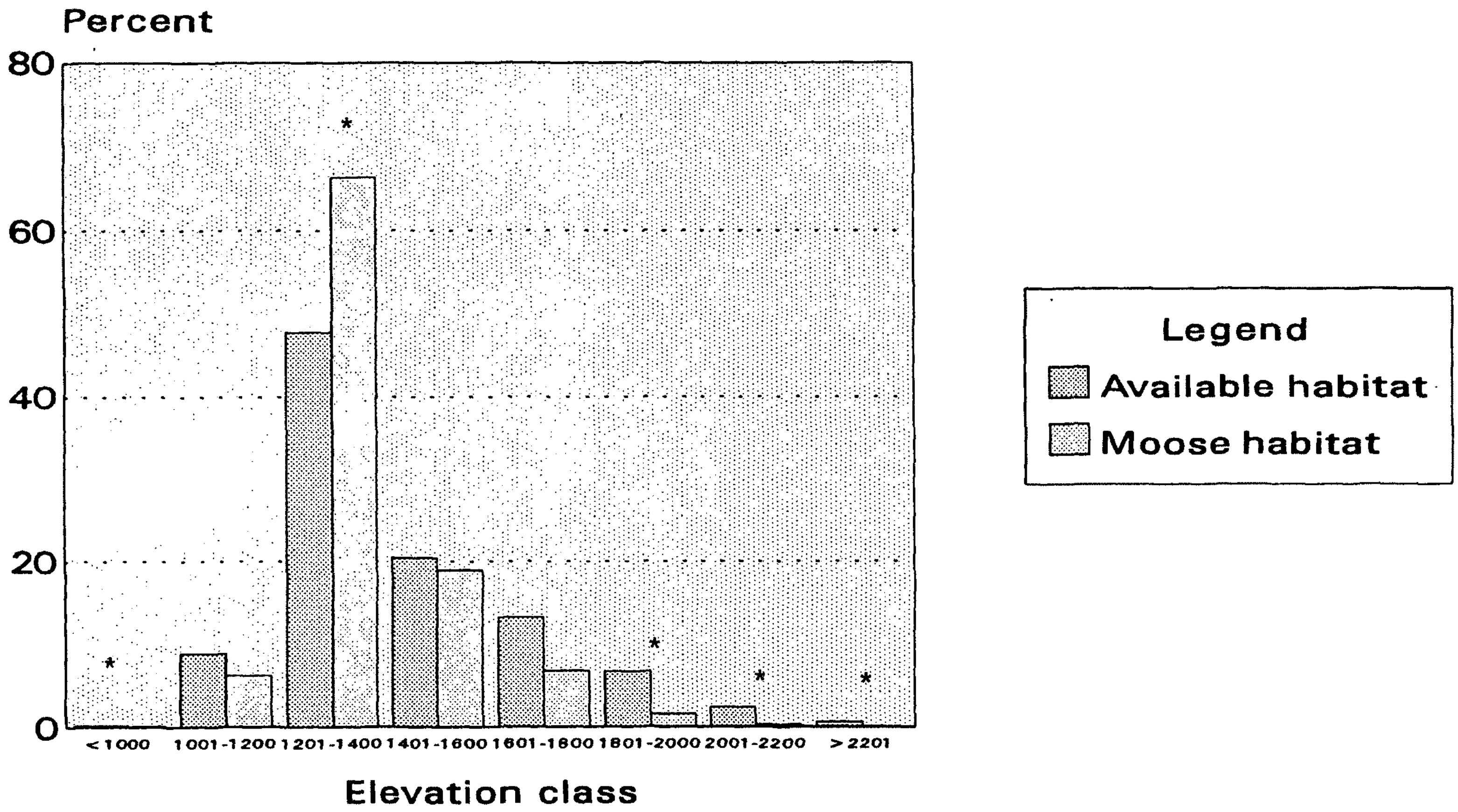

Fig. 2.2. Comparison of percent habitat in 8 elevation classes between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

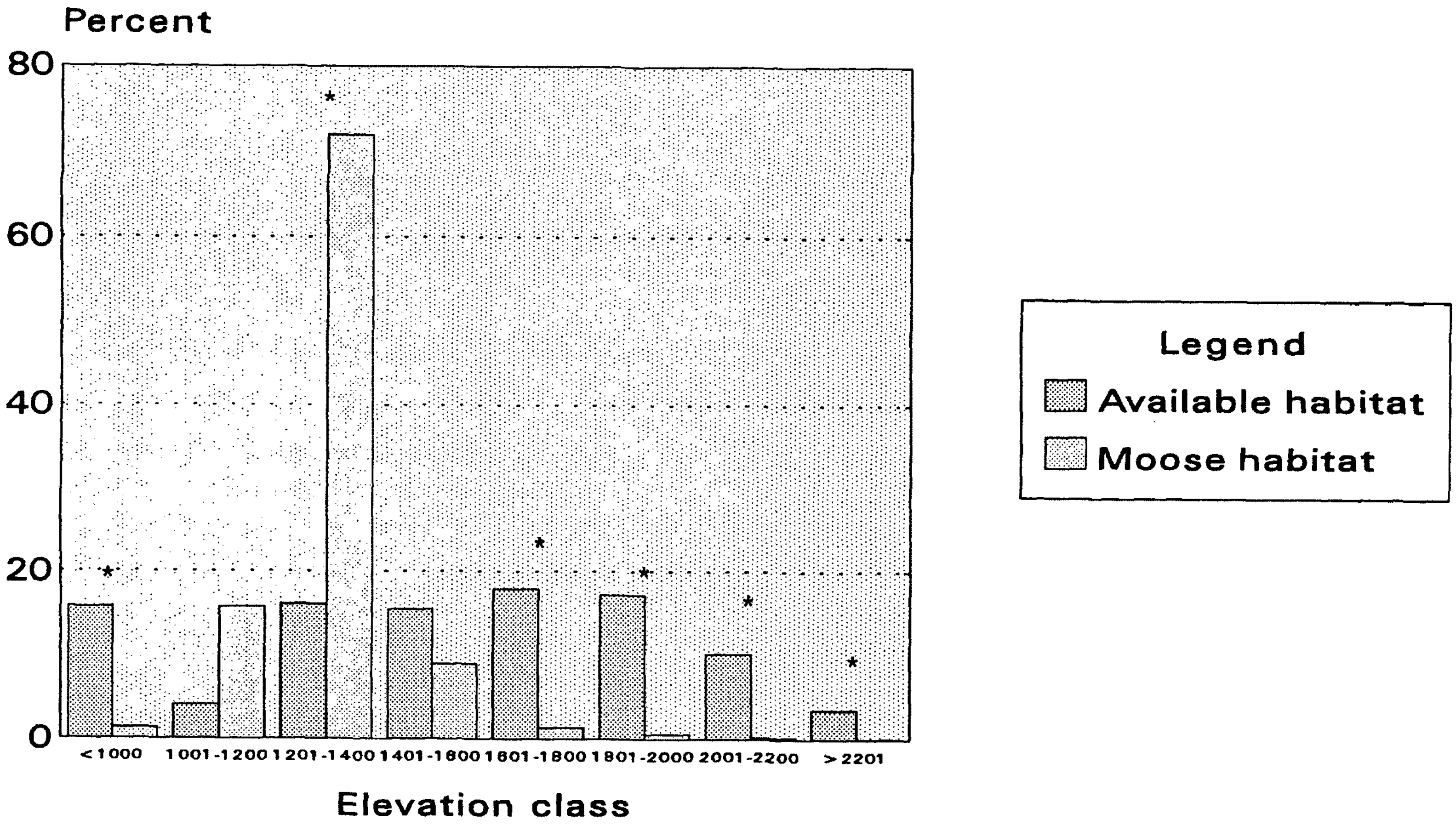

Fig. 2.3. Comparison of percent habitat in 8 elevation classes between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

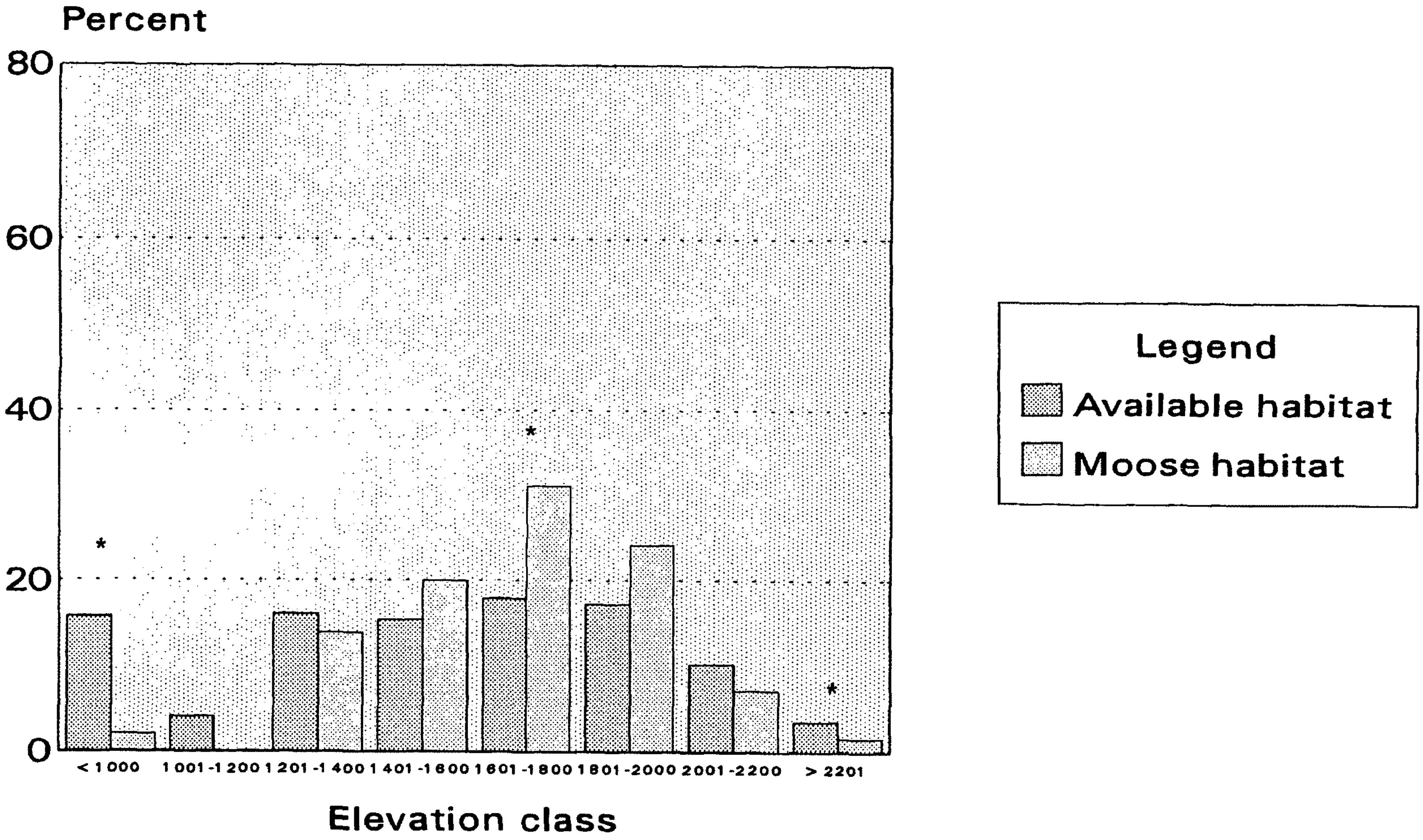

Fig. 2.4. Comparison of percent habitat in 8 elevation classes between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

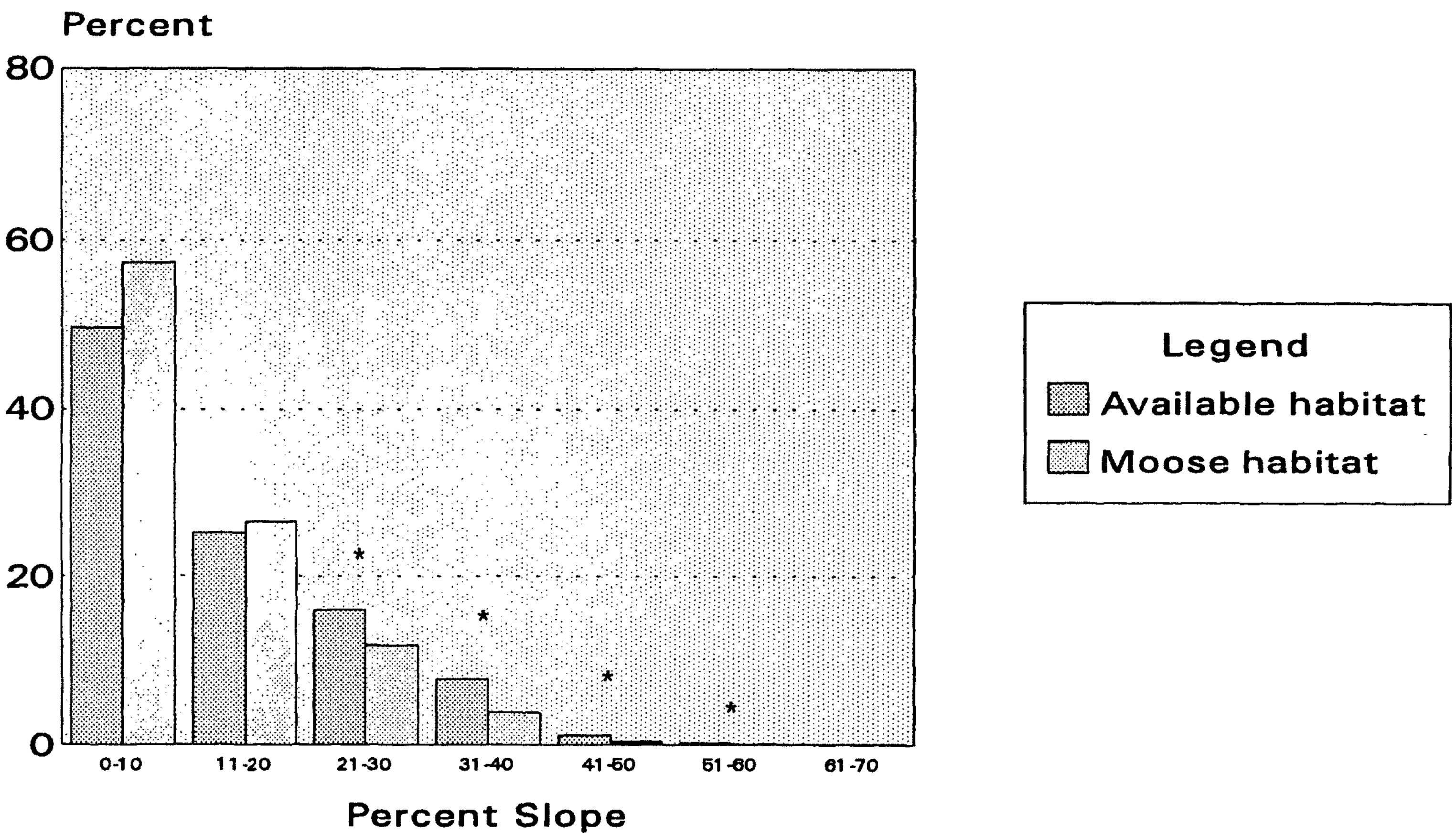

Fig. 2.5. Comparison of percent habitat at 7 slope classes between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

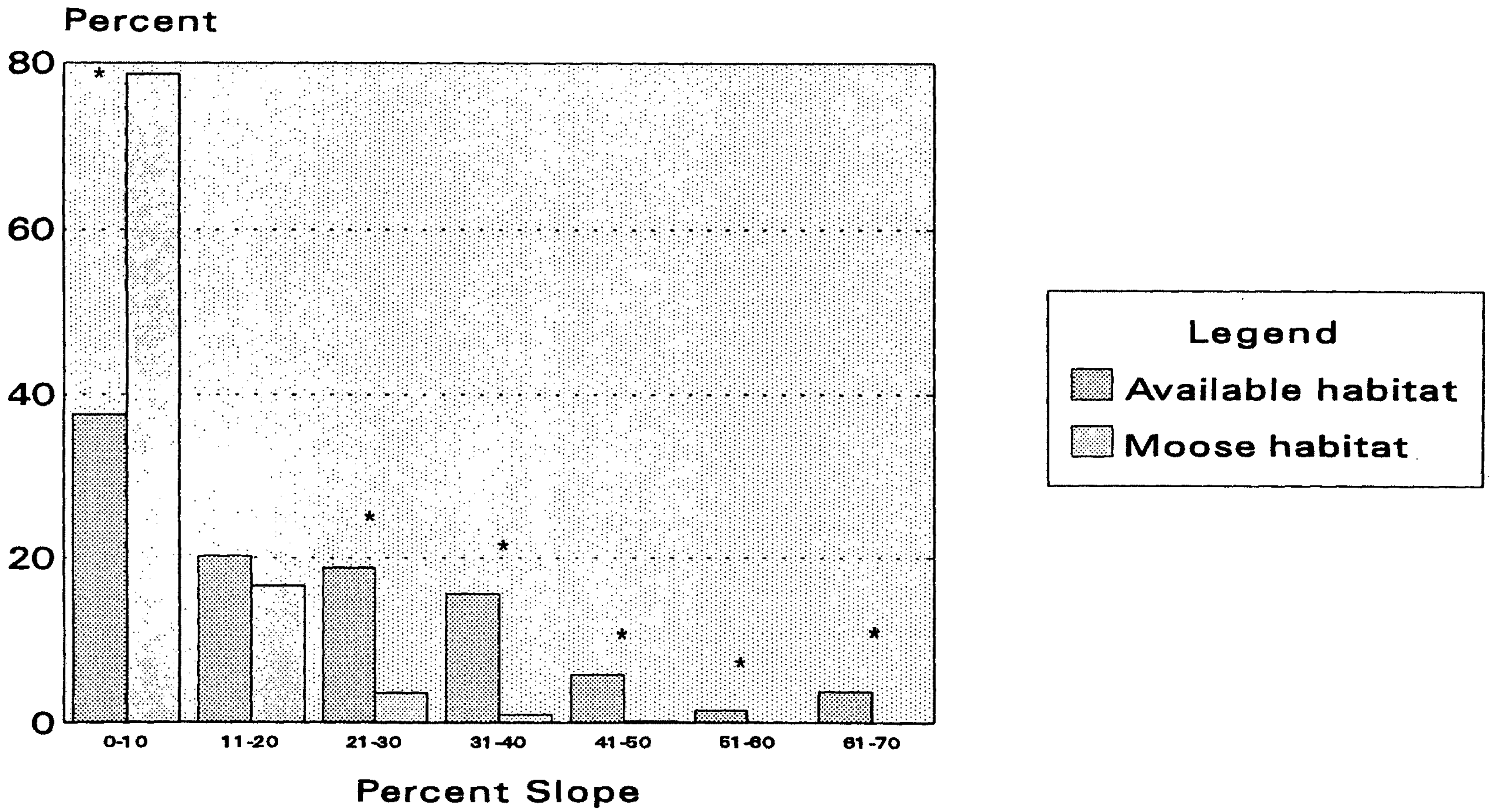

Fig. 2.6. Comparison of percent habitat at 7 slope classes between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

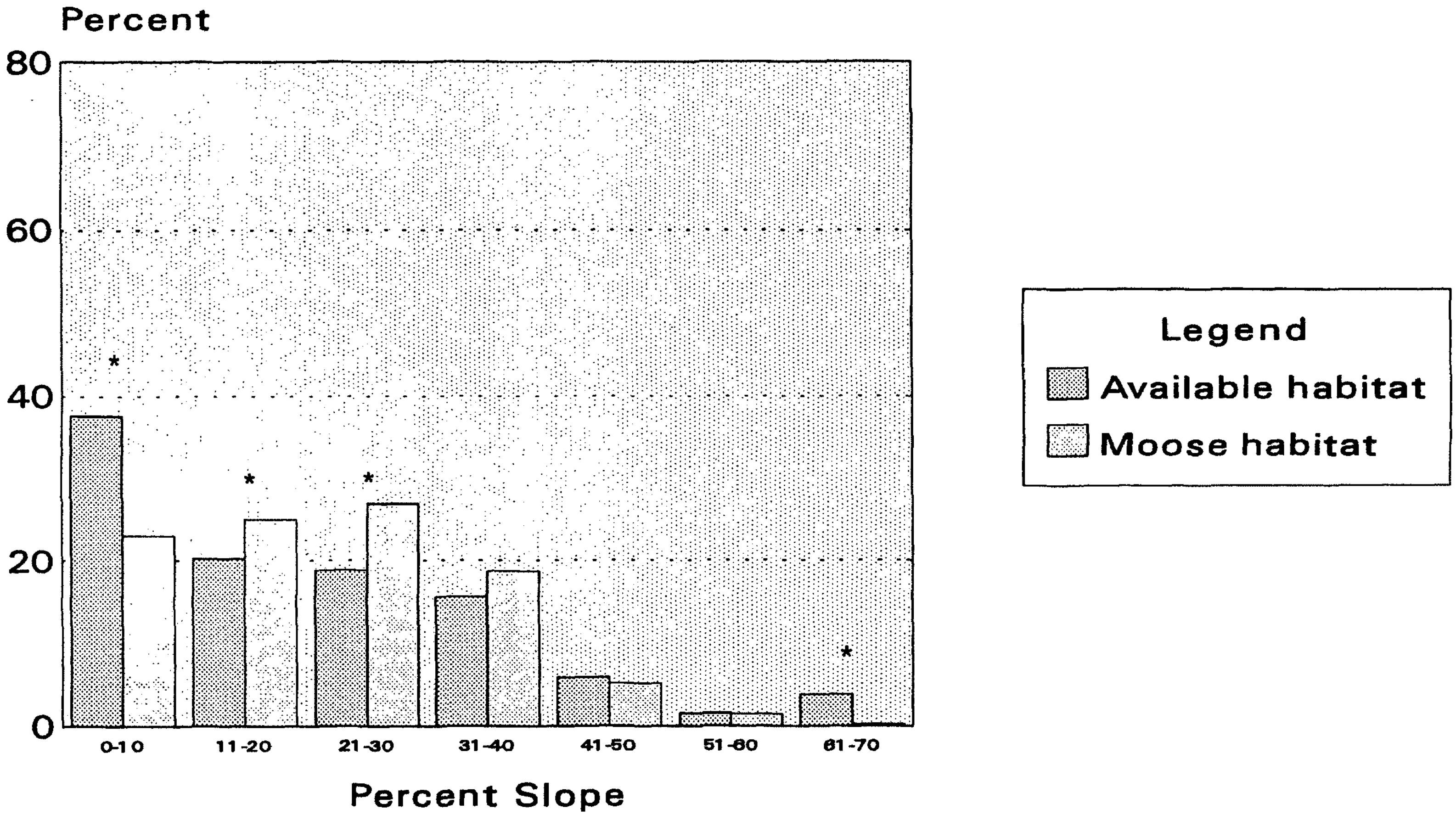

Fig. 2.7. Comparison of percent habitat at 7 slope classes between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

Aspect Use

Nonmigratory moose home ranges contained greater than expected habitat with aspects between 337 and 202 degrees (North-South) and significantly less area between 203 and 336 degrees (Southwest-Northwest) than expected based on availability (Figure 2.8). Migratory moose used more slopes with aspects between 68 and 292 degrees (East to West) than expected and fewer aspects between 293 and 22 degrees (Northwest-North) in the winter (Figure 2.9). A greater portion of migratory summer ranges had aspects between 23 and 247 degrees (Northeast-Southwest) than expected whereas aspects between 248 and 22 degrees (West-North) were used less often than expected (Figure 2.10).

Road Use

Non-migratory moose home ranges contained significantly fewer primary roads than expected based on available habitat (Figure 2.11). Conversely, winter home ranges of migratory cows had more primary roads than available but the difference was not significant. However, significantly fewer closed roads were found in these ranges (Figure 2.12). No significant difference between use and availability existed in summer home ranges of migratory moose (Figure 2.13).

River Use

Annual ranges of non-migratory moose contained approximately the same proportion of both permanent and

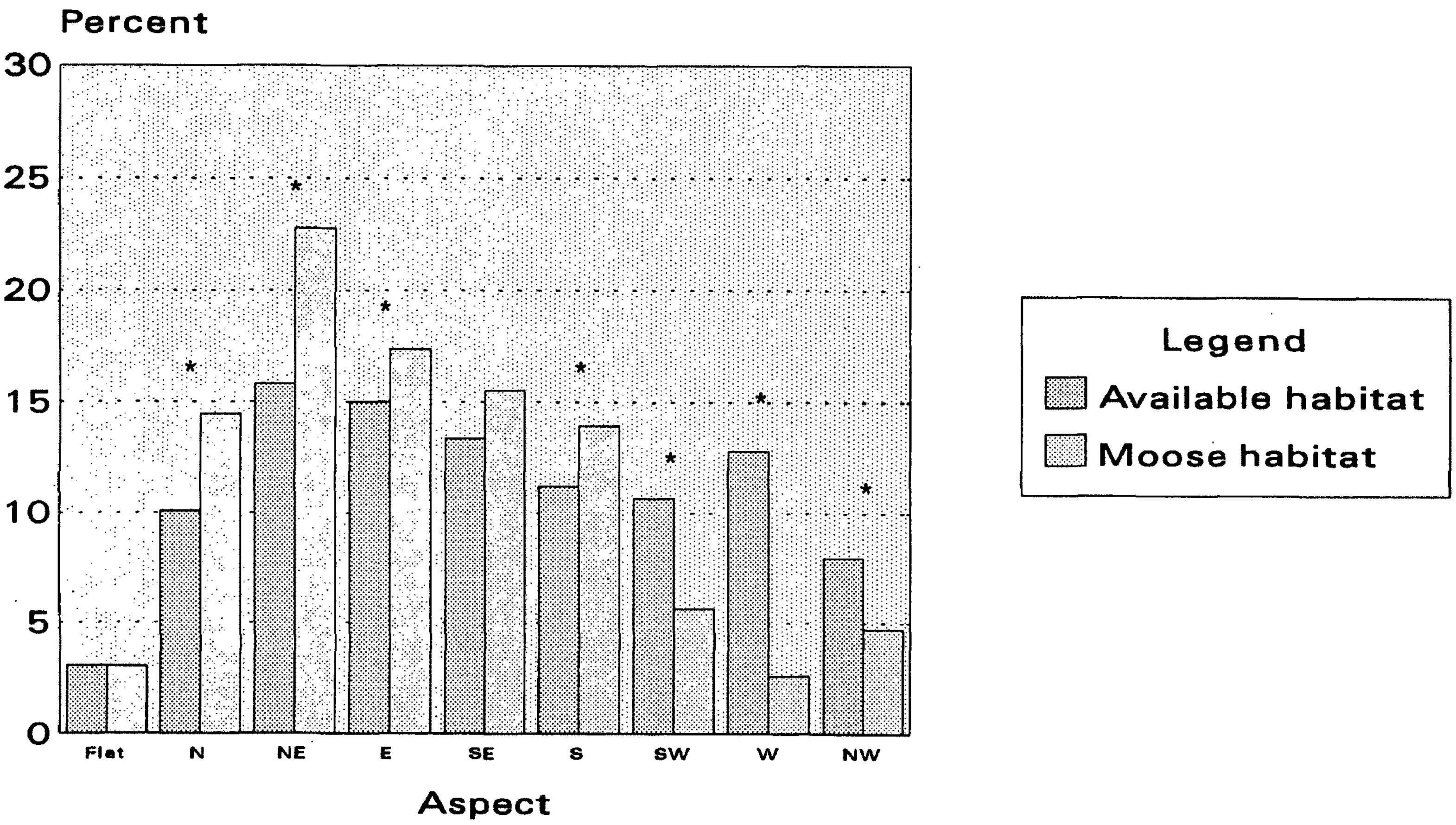

Fig. 2.8. Comparison of percent habitat in 9 aspect classes between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

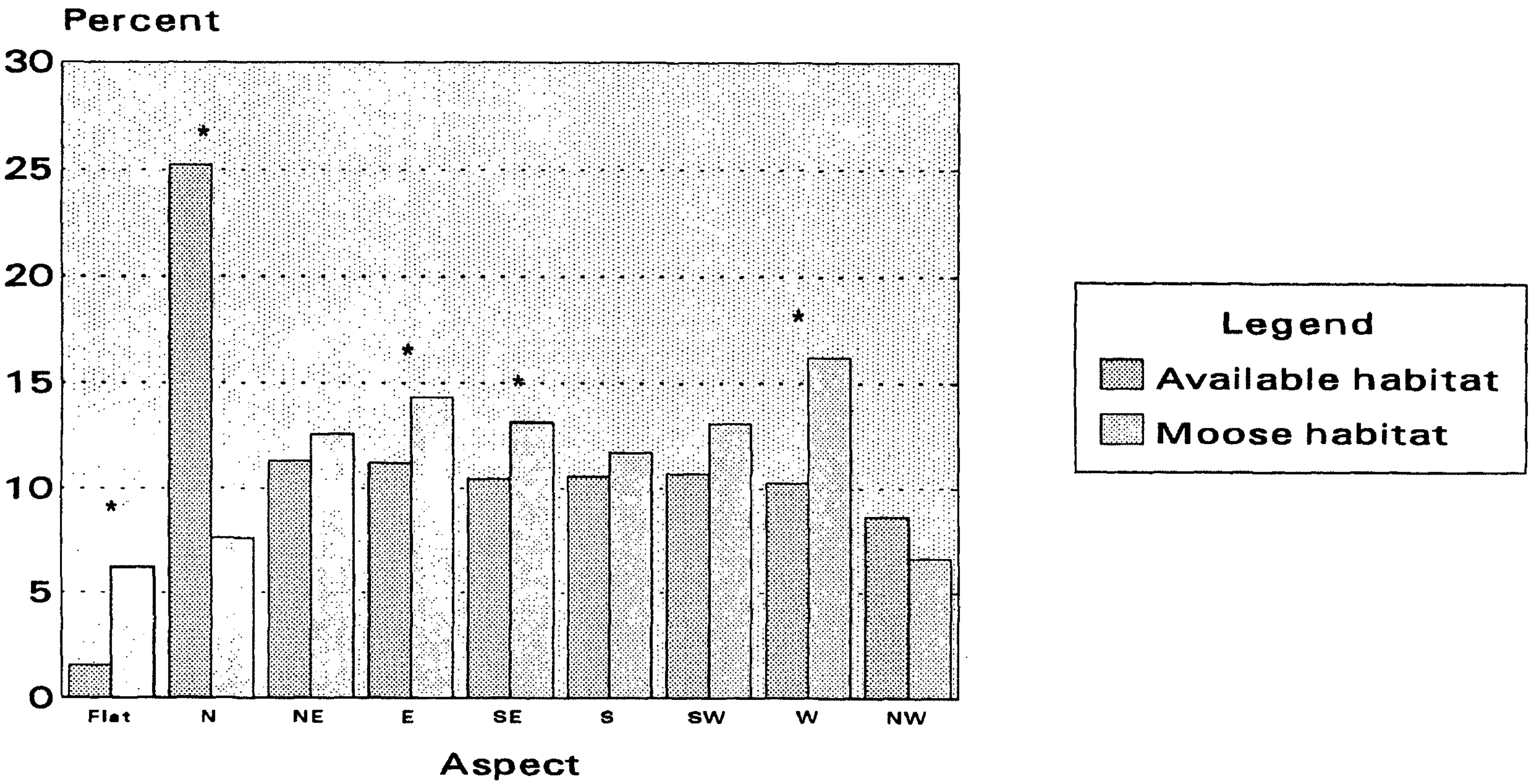

Fig. 2.9. Comparison of percent habitat in 9 aspect classes between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

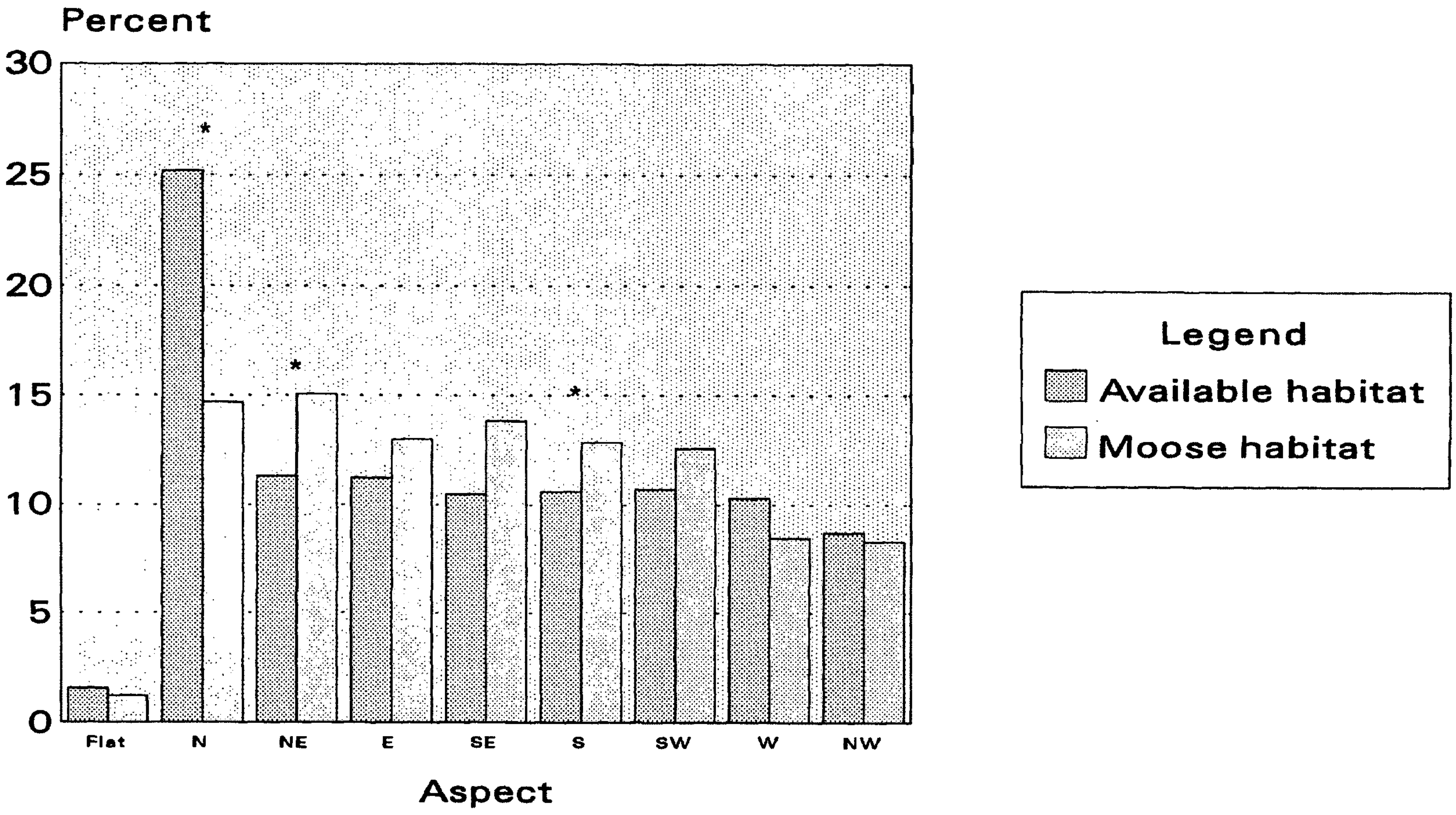

Fig. 2.10. Comparison of percent habitat in 9 aspect classes between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

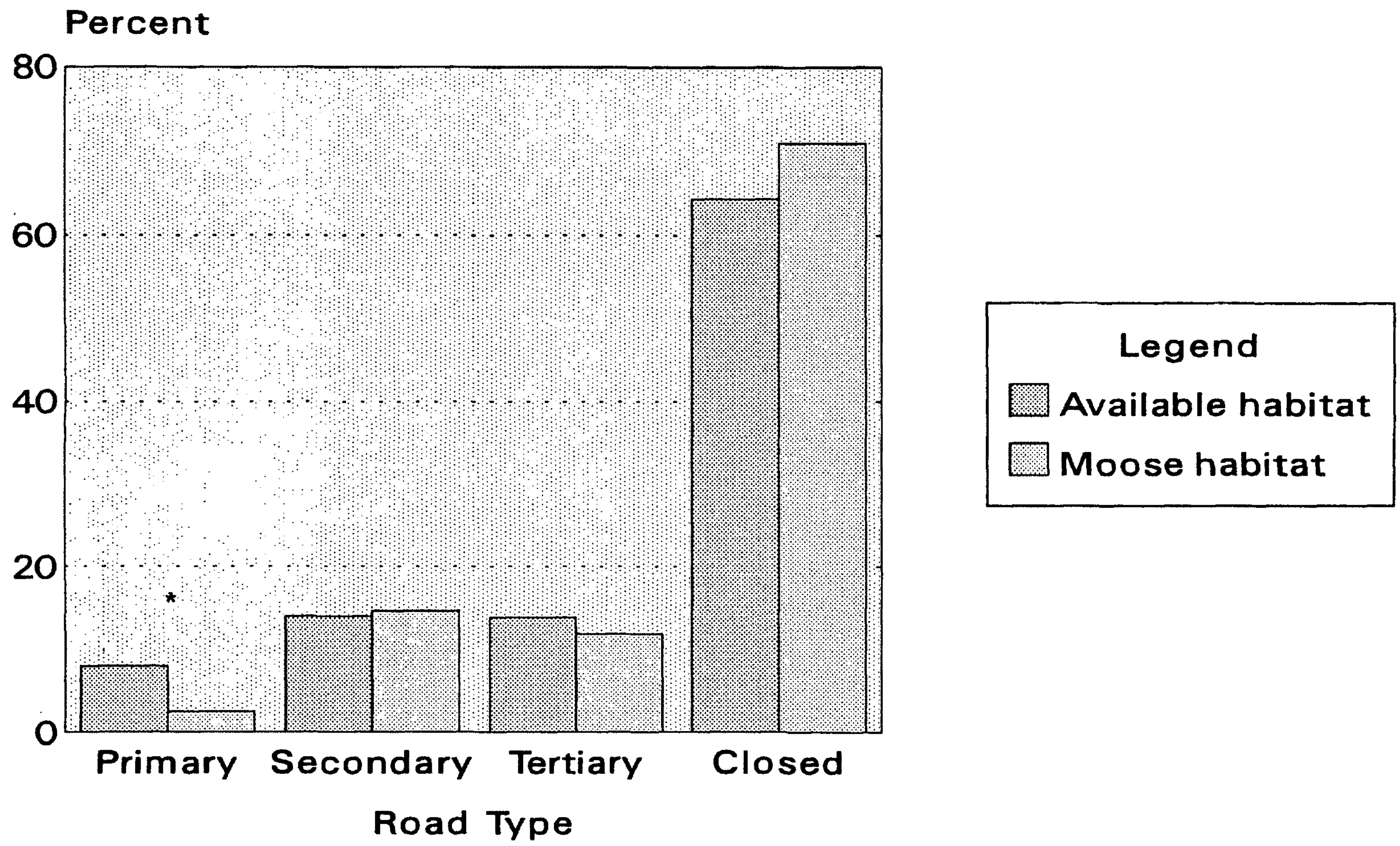

Fig. 2.11. Comparison of percent length of 4 road types between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

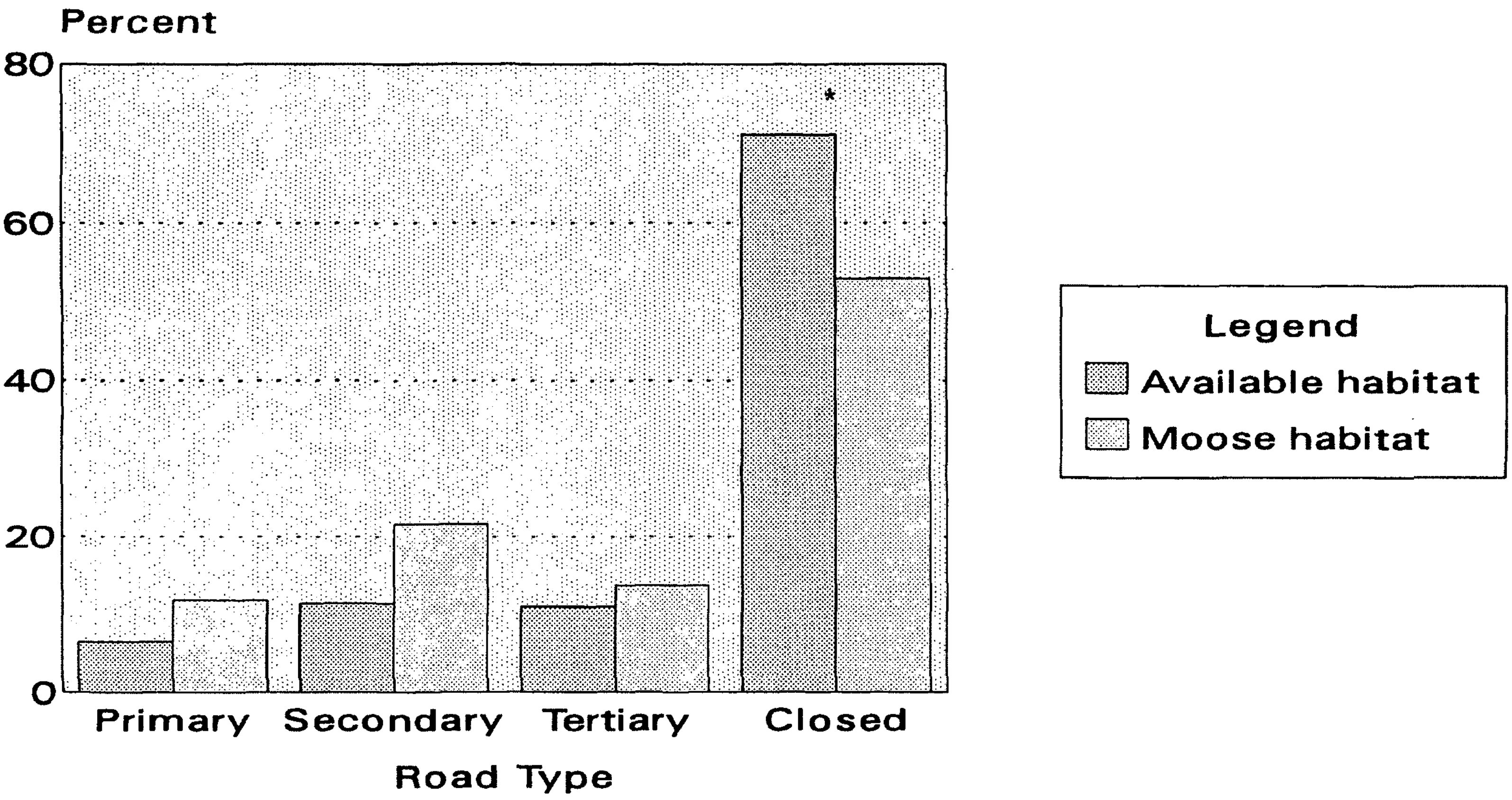

Fig. 2.12. Comparison of percent length of 4 road types between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

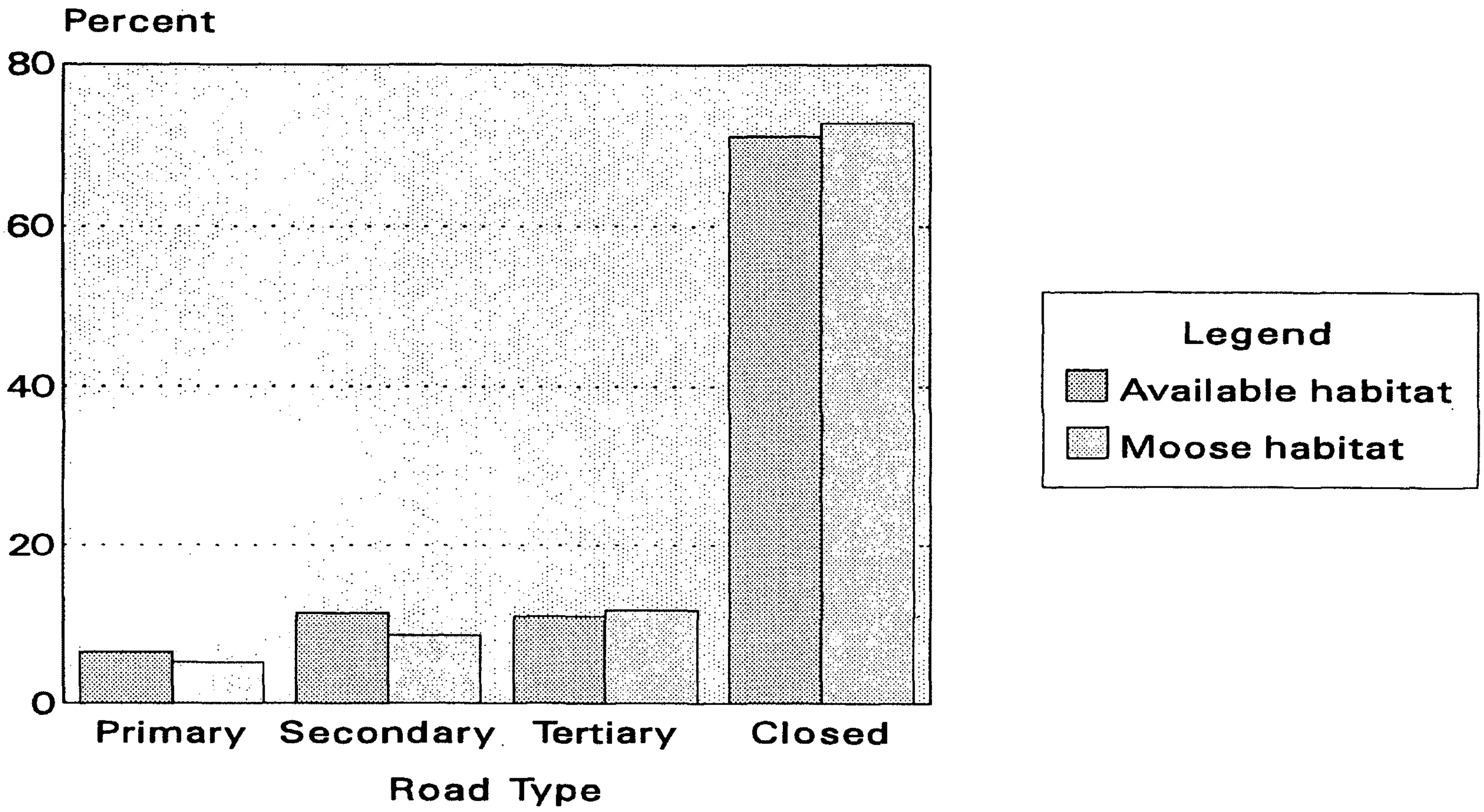

Fig. 2.13. Comparison of percent length of 2 river types between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

intermittent rivers as did the available habitat (Figure 2.14). Winter ranges of migratory animals had significantly more permanent rivers and less intermittent rivers than did the available range (Figure 2.15), whereas no significant differences existed in the summer ranges of these cows (Figure 2.16).

Cover Type Use

Non-migratory moose home ranges included more marshy areas, sapling dominated areas and open conifer cover than did available habitat. Rock covered areas and conifer cover were not used as much as expected. Areas dominated by bare soil, grass, and shrubs were used as expected (Figure 2.17). Migratory moose used conifer cover significantly more than expected during the winter and marshy areas, bare soil, rock and open conifer cover significantly less than expected. Grasslands, shrub dominated areas and sapling dominated areas occured as expected (Figure 2.18). During the summer season, migratory cow home ranges contained significantly more marshy areas and sapling dominated areas than did available habitat. Areas dominated by bare soil and rock occured less than expected and habitats characterized by grass, shrubs, open conifer and conifer cover were used as expected (Figure 2.19).

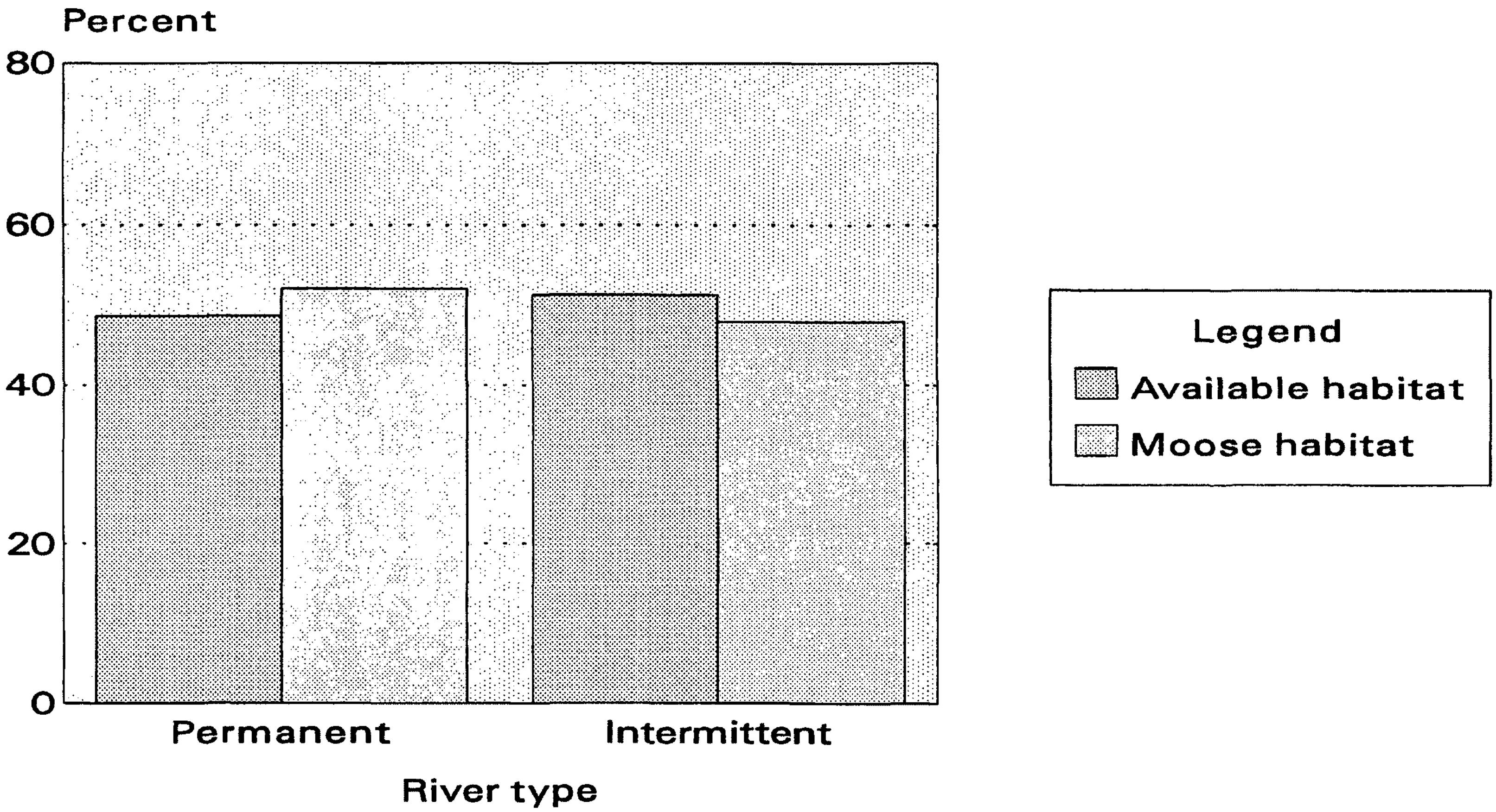

Fig. 2.14. Comparison of percent length of 2 river types between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

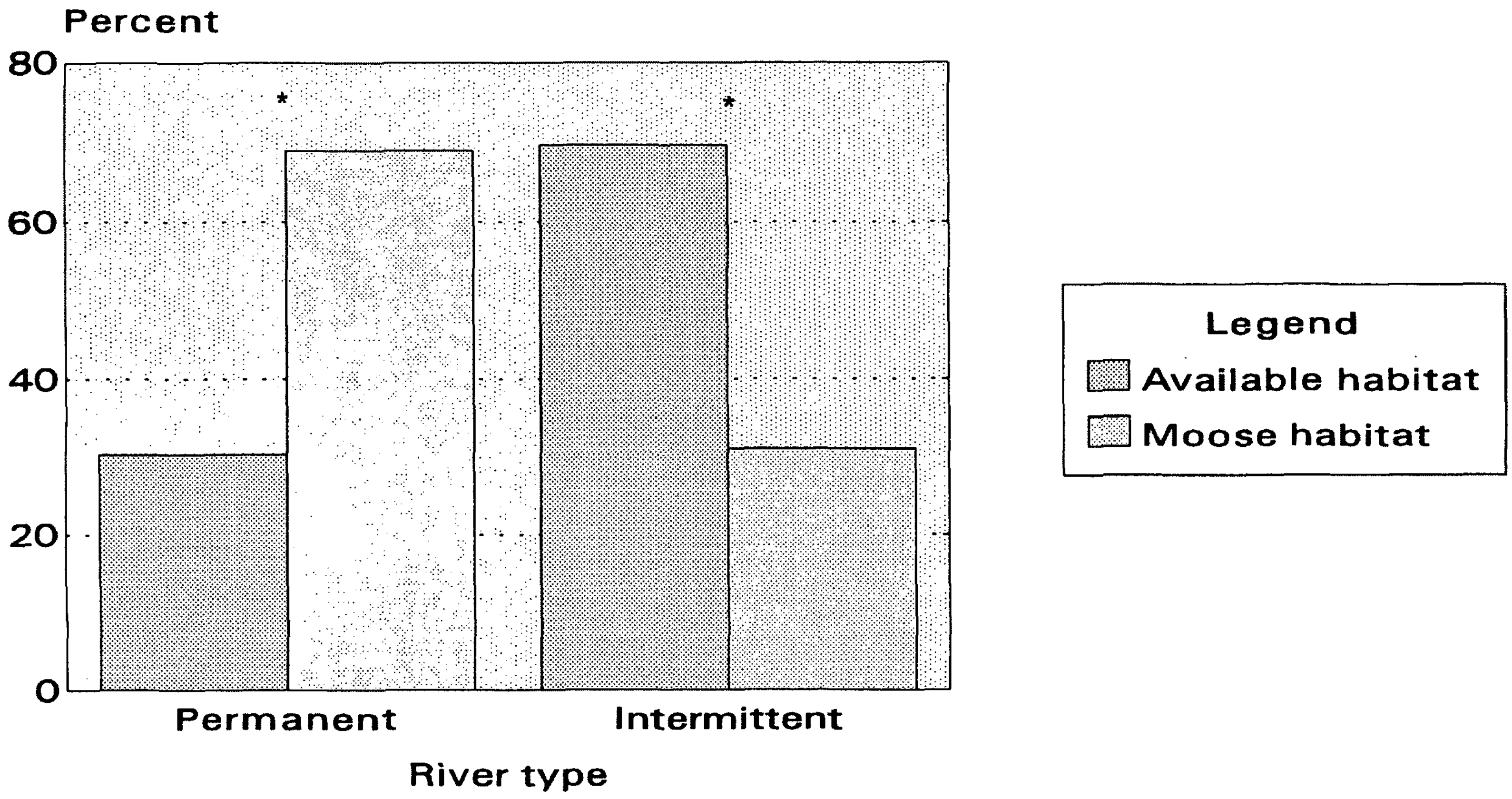

Fig. 2.15. Comparison of percent length of 2 river types between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

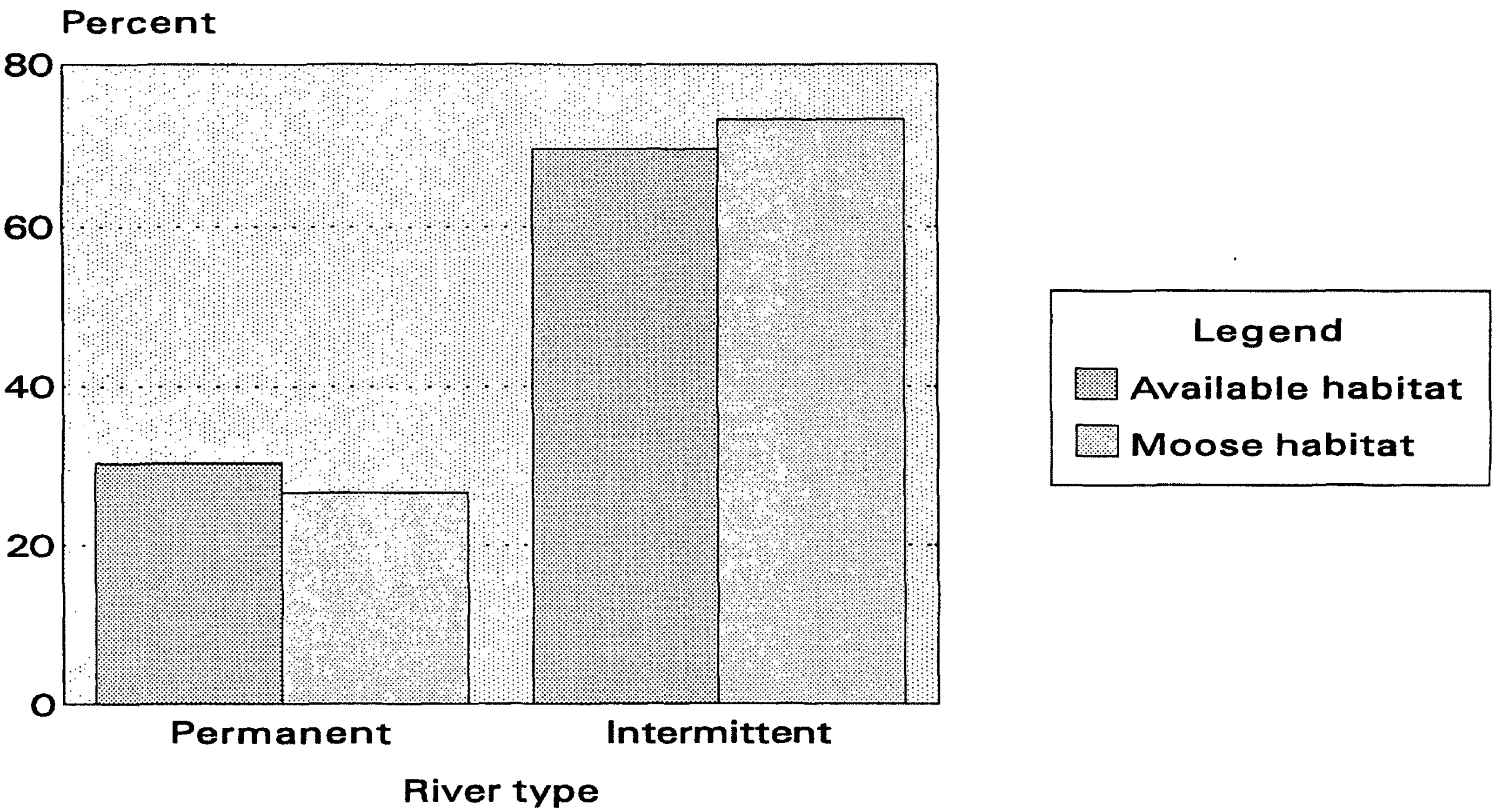

Fig. 2.16. Comparison of percent length of 2 river types between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

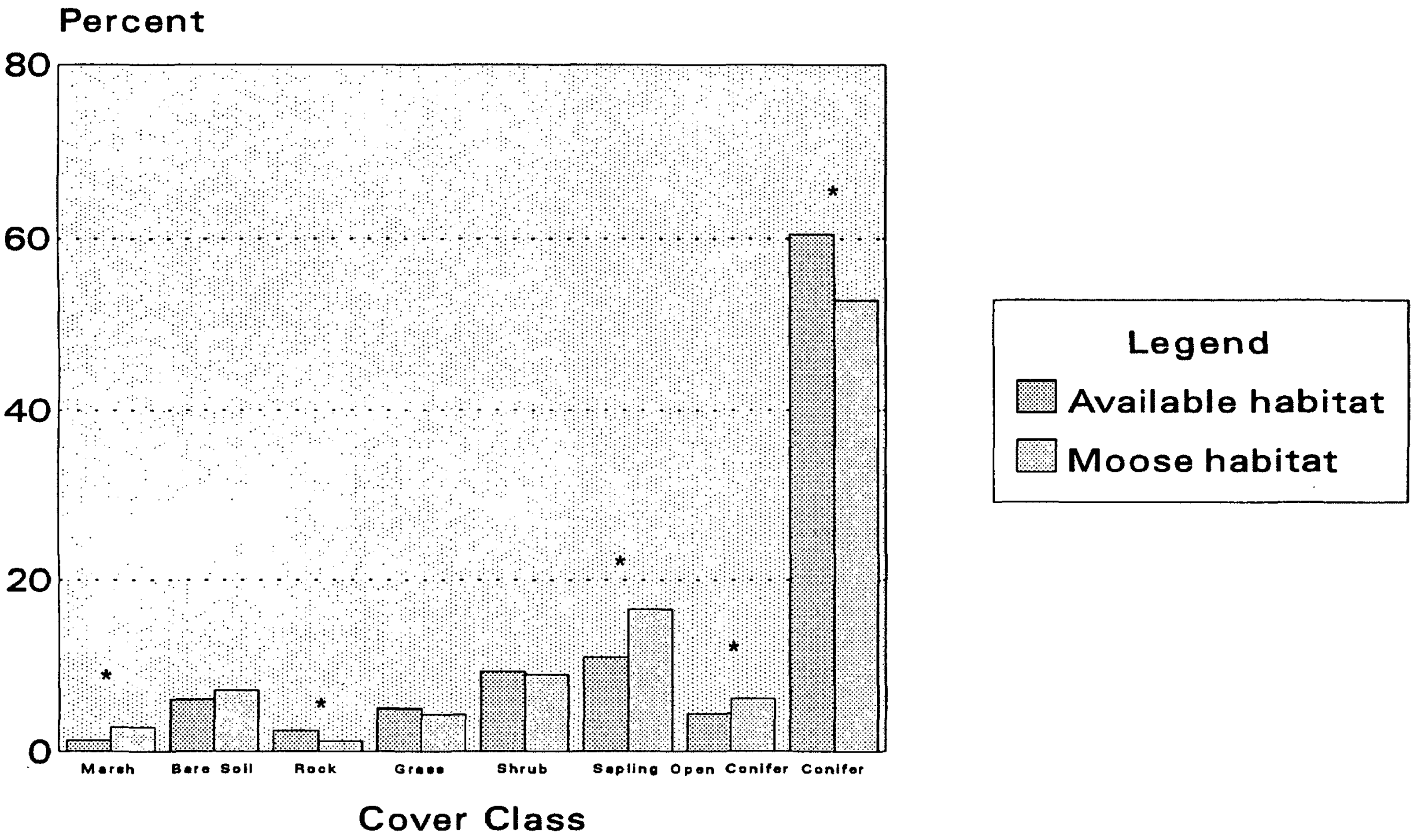

Fig. 2.17. Comparison of percent habitat in 8 cover classes between available habitat and annual (1/90-9/91) 75% harmonic home ranges of 11 non-migratory cow moose in the the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

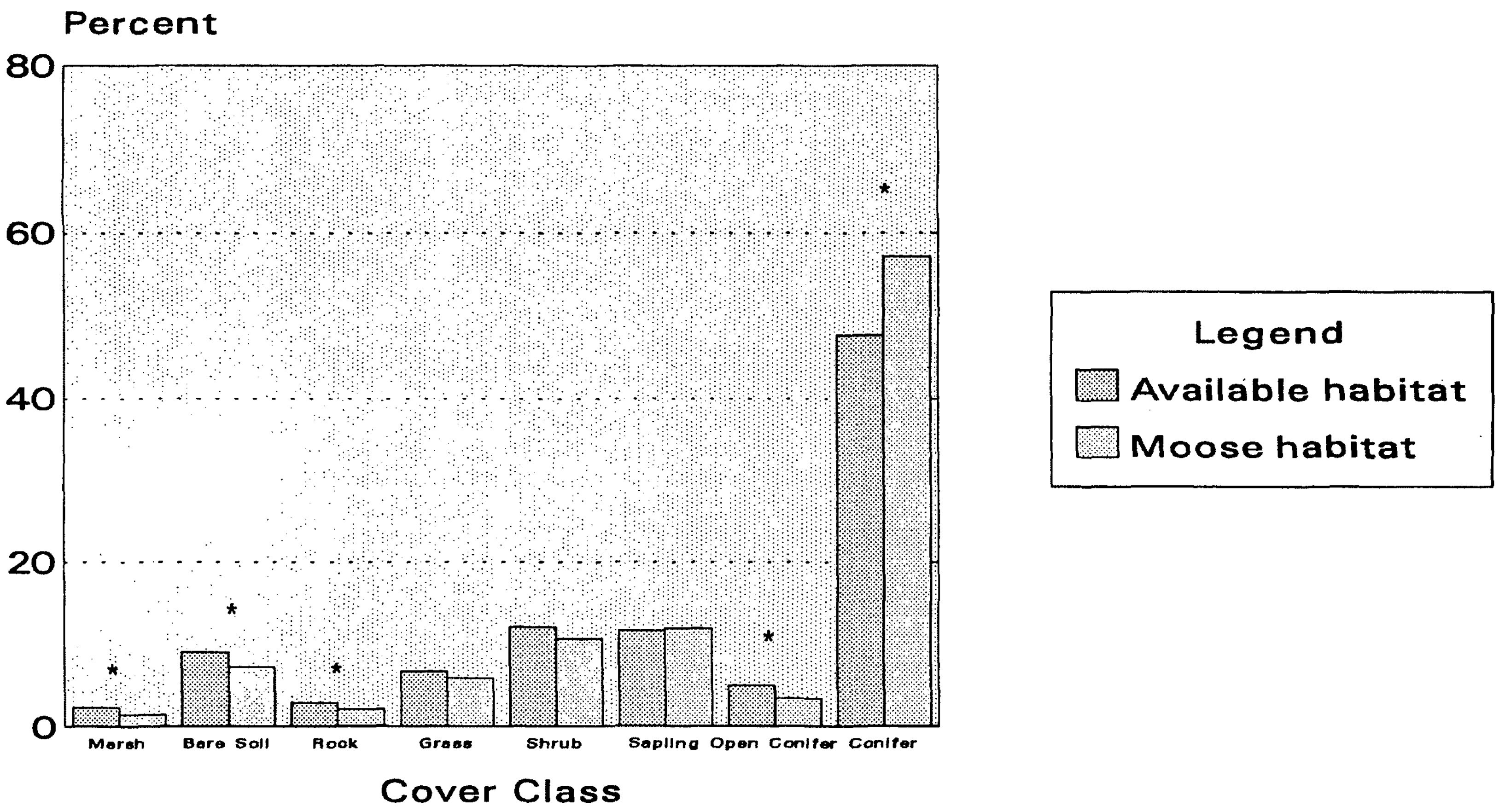

Fig. 2.18. Comparison of percent habitat in 8 cover classes between available habitat and winter (1/90-4/90,10/90-4/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at $P<0.05$

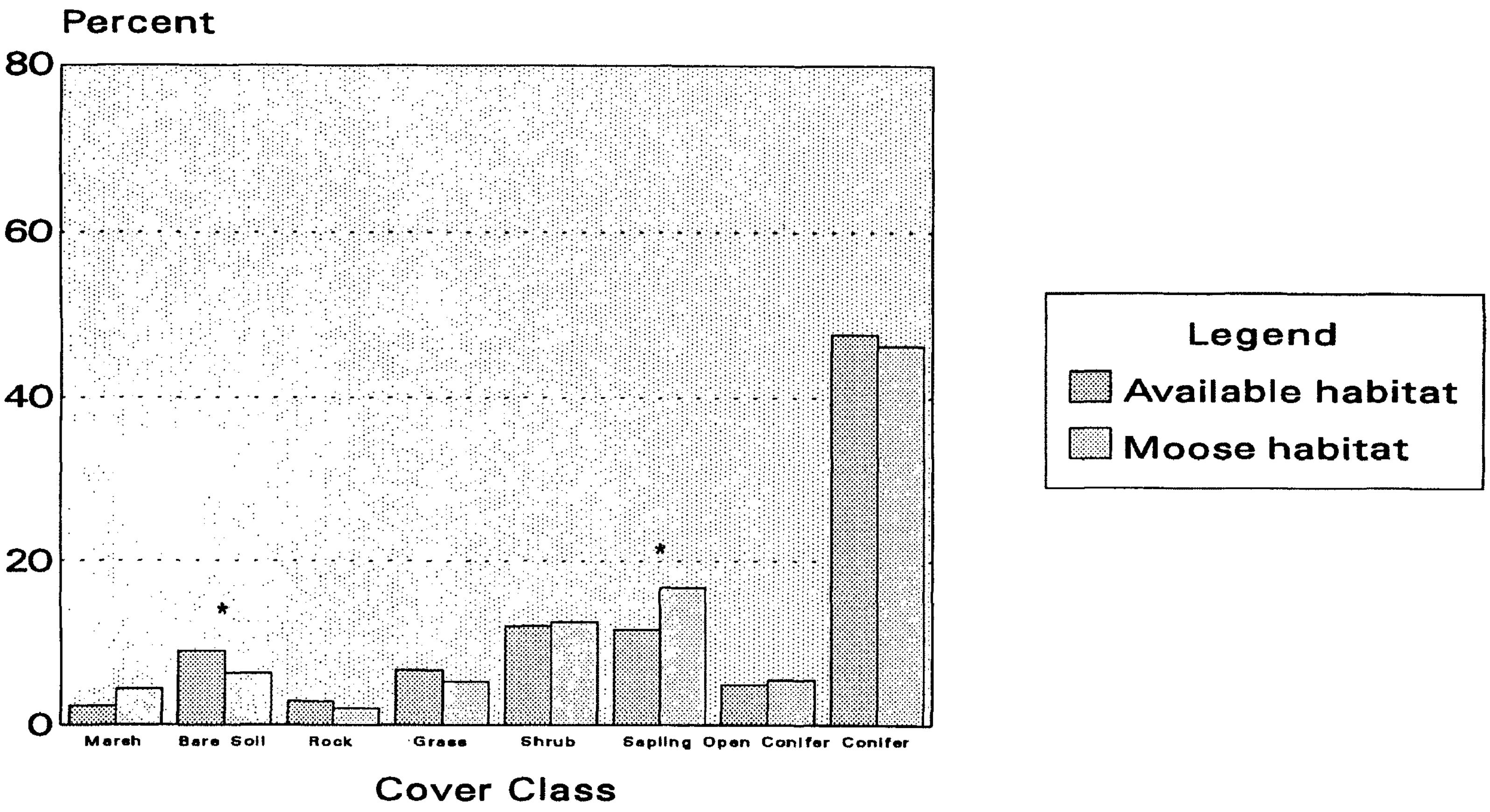

Fig. 2.19. Comparison of percent habitat in 8 cover classes between available habitat and summer (5/90-9/90,5/91-9/91) 75% harmonic home ranges of 18 migratory cow moose in the valley of the North Fork of the Flathead River, Northwestern Montana.
* indicates differences that are significant at P<0.05

DISCUSSION

We successfully used a combination of Carfentinal and Rompun to sedate moose and verified that these drugs can be used safely in moose research. Carfentanil has been used by other researchers with similar results (DeVos 1978, Larsen and Gauthier 1987) and I believe that it is currently the best choice. Carfentanil can cause human mortality and extreme caution in dart preparation, storage, and handling is required (D. Kinyon, DVM, Conrad, Montana, pers. commun.).

Flathead moose fall into 2 distinct types; those that migrate seasonally and those that use the same habitat all year round. Bailey (1978) found a similar situation in Alaska and postulated that migratory individuals were in better physical condition. Pulliainen (1974) and Sandegren et al. (1982) suggested that moose migrate to find better food and shelter sources and that the presence of a migratory segment of a population may be related to moose density. Moose density in the Flathead is not unusually high (See Chapter III), however the area is shared with several other ungulate species and the density at which some moose choose to migrate may thereby be affected.

Flathead moose that migrated tended to travel relatively great distances between summer and winter ranges when compared to other North American moose populations (Table 2.4). This could reflect a tendency to return to familiar range since all of the migratory moose that I tracked used the same general areas for both winter and summer range.

Table 2.4. Minimum and maximum distances travelled between seasonal home ranges from selected North American moose populations.

Distances travelled (km)	Location	Source
4-83	North Fork of Flathead	this study
2-13	Northwestern Ontario	Addison et al. 1980
≤ 170	Northwest Territories	Barry 1961
≤ 64	British Columbia	Edwards and Ritcey 1956
6-20	Northeastern Alberta	Hauge and Keith 1981
14-34	Northwestern Minnesota	Phillips et al. 1973

Houston (1971) observed high fidelity to established home ranges among both non-migratory and migratory animals and Mytton and Keith (1981) found that calves returned to the same winter range as their mothers. Cederlund et al. (1987) found that all of the 42 cows they collared returned to the same summer range annually and that 9 of 14 moose collared as calves established summer ranges in their natal area. High winter range fidelity was also found in Minnesota (Phillips et al. 1973). I believe that fidelity to the area used by parent cows may occur in Flathead moose since good quality habitat could have been found by moose without travelling as far as some of them did. However, apparently good habitat may have been previously occupied by other moose, thus forcing some of the radio-collared animals to travel great distances.

Home range sizes calculated using 75% harmonic home ranges were not significantly different for migratory and non-migratory moose or for summer and winter ranges of migratory animals. No comparisons will be made with other populations because of the potential differences between home range calculation methods and sample sizes.

Home range estimates made in my study had relatively few relocation points and this affects the accuracy of both harmonic mean measures (Dixon and Chapman 1980, Garton et al. 1985) and minimum convex polygon estimates (Schoener 1981, Anderson 1982, Bekoff and Mech 1984). Thus my home range estimates should be viewed as minimum use areas.

Elevation use for non-migratory cows was similar to that of migratory cows during the winter. However, in the summer, migratory cows used higher elevations. Both Edwards and Ritcey (1956) and Rounds (1978) observed the same trend in the migratory segment of the population they studied and attributed the change to the need to avoid deep snows. Moose in northcentral Idaho also used higher elevations in the summer months and used lower elevations particularly in severe winters (Pierce and Peek 1984). Moose in the Yaak River drainage in Montana were found below 1067 m in the winter and above 1524 m in the summer (Matchett 1985). However, Stevens (1970) observed moose in the Gallatin Mountains in Montana using clearcuts at elevations between 2000 and 2300 m during December. The non-migratory segment of the Flathead population was found at relatively low elevations all year and was apparently able to meet its needs without moving to higher grounds in the summer.

Nonmigratory cows used more east facing aspects than west facing aspects (Figure 2.8). At low elevations, vegetation production would be greater at these aspects and therefore both browse and cover would be more accessible. Migratory cows did not exhibit this trend. These animals used flat areas and south facing aspects more and used less north facing aspects than available in both summer and winter. Avoiding north aspects in the winter would equate to avoiding deep snows and bitter winds; using flat areas reflects time spent in willow flats along the river. The available habitat of migratory moose was made up of more than 25% north facing slopes (Figure 2.9, 2.10). Winter ranges tended to contain less north aspect than other aspects indicating avoidance of north aspects. However, the various aspects were more evenly distributed on summer ranges and the statistical avoidance of north aspects appears to be a result of the high availability of north facing slopes. Prescott (1968) found that moose were concentrated on southwest facing slopes in the winter. This study found high use of disturbed areas which may have been more common at this aspect.

My data show that annual ranges of non-migratory moose contained fewer primary roads than available habitat. This was not the case for migratory animals, though summer ranges contained less primary road length than winter ranges. Primary roads in the Flathead receive relatively little winter use and may be used by moose for travel. Sandegren et al. (1982) observed moose use of dirt roads for migration, and roads may provide excellent pathways for all ungulates if cars are absent. However, Rolley and Keith (1980) documented that moose locations were often a greater distance from roads than that expected by chance reflecting avoidance of dwellings and other disturbances. Welsh et al. (1980) found that the number of primary and secondary roads did not affect moose distributions but that moose were significantly more likely to use tertiary roads, especially those with vegetative cover. Since roads in the Flathead are not necessarily associated with increased human activity, especially in the winter, their use by moose could save considerable energy and benefit individual animals.

Water is abundant in the Flathead and was used as available by non-migratory animals and by migratory animals during the summer. Winter habitat of migratory animals contained significantly more permanent water than available, reflecting their concentration in the Flathead river bottoms where willow is abundant.

The cover types considered in my study were general in nature and reflect areas dominated by the particular cover type. Areas that were clearcut more than 15-25 years ago would generally fall into the shrub or sapling categories. While the shrub type was used as available there was significant selection for sapling dominated habitats by both non-migratory cows and migratory cows in the summer. Moose used cuts that had time for good browse production. This time period varies regionally but most studies find that cuts between 8 and 20 years old are used more than selected due to chance (Prescott 1968, Telfer 1974, Peek et al. 1976, Stelfox et al. 1976, Parker and Morton 1978).

Good browse production may be the main determinant of moose habitat selection (Cederlund and Okarma 1988) especially during winter months (Irwin 1975, Crete 1988). Moose are considered a generalist herbivore but choose energy rich foods (Belovsky 1978) that are easily digested (Heljord et al. 1982). Preferred moose foods include willow (Salix spp.)(Robinson 1940, Spencer and Chatelain 1953, Denniston 1956, Knowlton 1960, Stevens 1970, Peek 1971, Stevens 1971, Peek 1974b, Berg and Phillips 1974, Peek et al. 1976, Ritchie 1976, Chadde and Kay 1988), mountain maple (Acer glabrum)(Peek 1971, Brassard et al. 1974), and red-osier dogwood (Cornus stolonifera) (Knowlton 1960, Peek 1971) and their diet may also include coniferous and deciduous trees, forbs and grasses (Butler 1986). However, Dorn (1970) found that 98-99% of the diet of moose in southwestern Montana consisted of the above shrubs. Sapling dominated habitats would have ample forage while also providing some cover.

Moose have been found to select cutover areas within close proximity of cover by numerous studies (Hamilton and Drysdale 1975, Hamilton et al. 1980, Bangs and Bailey 1980, Monthey 1984, Bangs et al. 1985) and conifer cover was a major component of moose ranges in this study. Conifer cover made up more than 50% of non-migratory ranges but was used significantly less than expected. This was not the case for winter ranges of migratory moose which contained significantly more conifer cover than available. Good cover can be very valuable in protecting moose from severe weather which has been found to severely affect moose productivity (Edwards 1956, Peek 1971, Bangs and Bailey 1980, Mech et al. 1987). Eastman (1974) found that moose frequently defecated in forested areas but rarely browsed there and Telfer (1978) reported that moose did not use areas with good browse and poor cover indicating the importance of adequate cover. Cover may be needed to temper the effects of heat, cold, deep snow and predation (Timmermann and McNicol 1988).

Snow can have major impacts on moose distributions. Moose are perhaps the most adapted to snow of all north American ungulates (DesMeules 1964, Telfer and Kelsall 1979, 1984). Nevertheless, snow depths that exceed 2/3 chest height make moose more vulnerable to predation and require more energy to travel through (Coady 1974, Dodds 1974). When deep snow occurs early in the season moose will migrate suddenly (Coady 1974). An increased reliance on conifer cover during the winter may reflect the need to avoid deep snows.

Habitat within the 1988 Red Bench fire fell into the bare soil, grass and shrub cover types. There was no apparent selection for any of these cover types in my study. Fire in Alaska usually creates favorable habitat for moose and is often followed by an increase in reproductive rates and, subsequently, moose densities (Bangs and Bailey 1980). Fires increase the amount of edge while increasing both forage quantity and quality (Davis and Franzmann 1979). Prior to the 1988 Red Bench fire, the area had relatively low forage value (Dutton et al. 1988) which was improved as a result of the fire which created considerable edge and stimulated plant production (Dutton and Cooper 1988). Moose may not be displaced during fires (Gasaway and Dubois 1985) and the effects of the Red Bench fire may have been very positive for moose. However, any benefits to moose may require some time to become apparent. Spencer and Hakala (1964) and Franzmann and Schwartz (1985) found that burnt areas in Alaska were most productive between 15 and 20 years after the burn whereas Oldemeyer and Regelin (1987) found the greatest density of browse on burnt sites that were 8-30 years old. However, Peek (1974a) documented increased use of burnt sites within 6 months after a fire in Minnesota with a 5 fold increase in moose numbers after 2 growing seasons. Continued monitoring of moose activity in the area burnt in 1988 may reflect increased moose densities by 1998 or later.

Other disturbance sources that open up overstory canopies may lead to an increase in browse production that favors moose (Krefting 1974). These might include areas disturbed by heavy winds, intense beaver activity and disease, including mountain pine beetle and spruce budworm. Areas affected by spruce budworm fell into the open conifer cover group. Non-migratory moose selected open conifer cover, perhaps because it provides a mixture of hiding and thermal cover and browse. Conversely, open conifer cover was selected against by migratory moose in the winter, perhaps indicating that despite improved browse production, the loss of cover made these areas undesirable.

Significant selection for marshy habitats was reflected in annual ranges of non-migratory cows and summer ranges of migratory animals, however this cover type only comprised 2.77% and 4.40%, respectively, of the overall range used. Though moose in Nova Scotia were not found to frequent aquatic areas (Telfer 1967), use of these areas has been documented by many moose researchers (VanBallenberghe and

Peek 1971, Timmermann and McNicol 1988, Costain 1989), and moose are often seen as associated with wet areas. While aquatic plants may be a critical component of their diet, the relative importance of wet habitats does not appear to be very great for Flathead moose.

The variables considered in my study give a general impression of moose habitat use in the Flathead. Annual home ranges of non-migratory cows were generally at low elevation with gradual east facing slopes, few primary roads, and the expected amounts of permanent and intermittent water. Though dominated by conifer cover, annual ranges contained greater amounts of marsh, sapling, and open conifer cover than expected. In the winter, migratory moose used low elevations with flat and south facing slopes, with more than expected length of primary roads, definite water, and conifer cover. In the summer, higher elevations were selected with fairly steep south and northeast slopes and the expected length of all road and water types. Marsh and sapling cover types were more common than expected. Elevation and slope are correlated with each other and with primary roads and definite water, both of which tend to be in valley bottoms. It is not possible to conclusively say which of these variables is being selected for from my research.

Valuable information could be gained with additional databases, including species composition for both the overstory and understory vegetation, and human development and activity information. The value of future use of GIS systems in wildlife habitat work will be a function of the accuracy of the data provided to the system. I attempted to use only data that I felt reflected reality, and my choices were thereby limited. Focusing on development of high quality databases is a prerequisite to valuable use of GIS systems in wildlife work.

CHAPTER III

CAUSE- AND AGE-SPECIFIC MOOSE MORTALITY IN THE NORTH FORK VALLEY OF THE FLATHEAD RIVER

Humans traditionally chose to eliminate large predators to "protect" prey species and to make the woods safer for our own use (Leopold 1949, Lopez 1978). Over time, these practices led to the eradication or near-eradication of numerous species. The 1973 Endangered Species Act mandated that we attempt to rebuild populations classified as threatened or endangered and, as a result of gradually increasing predator numbers, wildlife biologists, managers and the general public have become increasingly interested in the impact that predators may have on their prey. Ungulate species are of particular interest due to their role as prey of large carnivores and their additional value to human hunters.

Most previous studies of predator-moose relationships have been undertaken in areas with 1 principal predator and 1 primary prey species (Chatelain 1950, Peterson 1975, Fuller and Keith 1980, Bergerud et al. 1983, Gasaway et al. 1983, Peterson and Page 1983, Edwards 1984, Messier 1985, Messier and Crete 1985). These studies have indicated that wolf predation can limit a moose population, especially if their numbers are already low due to other factors.

Multiple predator and prey complexes have been studied in Alaska. Moose there are subject to predation by both wolves and bears, and calves are especially vulnerable to both black and grizzly bears (Franzmann and Peterson 1978, Franzmann et al. 1980, Ballard et al. 1987). A mortality study in the Yukon (Larsen et al. 1987) concluded that grizzly bear predation was the main factor limiting moose numbers and the main cause of mortality of both adult and calf moose, despite equally high densities of both black bears and wolves in the area.

Studies in Manitoba (Carbyn and Kingsley 1979, Carbyn 1981, Carbyn 1983) and Minnesota (Mech 1975, Mech and Frenzel 1971, Mech and Karns 1977, Fritts and Mech 1981) have focused on the relationship between wolves and numerous prey species. These studies have also indicated that wolves can limit ungulate populations but that they will turn to alternate prey species when primary prey populations decline.

The overwhelming conclusion of all of these studies is that predators may limit prey populations but only in combination with other factors.

Relatively few studies have involved collared individuals of a variety of both predator and prey species and more information is needed on the impacts numerous predators may have on moose in an area where other prey species are abundant.

A wide variety of both predator and prey species inhabit the North Fork area and a number of these species are presently under study. The North Fork Grizzly Project began studying both black bears and grizzly bears in 1976. As of the summer of 1991, approximately 18 black bears and 20 grizzly bears were radio-collared. The Wolf Ecology Project has been trapping and collaring wolves since 1979 and there were 9 collared individuals within the study area during the summer of 1991. Coyotes and mountain lions are common but no individuals were collared at the time of my study. Finally, a large number of humans hunt in the North Fork area. During the 1990 hunting season, 12,000 hunter days were recorded in the United States portion of the North Fork drainage and 30 permits were issued for moose.

The prey base in the North Fork is equally complex and also being studied using radio-telemetry. In December of 1989, studies were undertaken involving the collaring of 30 white-tailed deer, 30 elk, and 30 moose. One of the objectives of each of these ungulate studies was to gather information about cause-specific and age-specific mortality. The presence of a wide variety of predator species, plus the fact that numerous collared individuals existed, made this area ideal for studying mortality in prey species.

Both black and grizzly bears have occupied the study area since man arrived. Wolves, however were extirpated in the 1930's and have only recolonized the area in the last 10 years (Ream et al. 1991). Concerns exist among hunters and other groups about the impact that recovering wolf populations, in conjunction with other predators, will have on prey populations (Tucker and Pletscher 1989). Management agencies wish to maintain deer, elk, and moose populations, while allowing the number of wolves and bears to increase. This study was undertaken in response to this desire and to learn more about both cause-specific and age-specific moose mortality along the North Fork of the Flathead River. The study area is described in Chapter II (pp. 5-7).

METHODS

Moose capture and collaring procedure and the equipment used were described in Chapter II. Radio collars were designed such that the pulse rate doubled to approximately 100 beats per minute if the collar had not moved for $\geq$ 4 hours (strongly suggesting mortality). We listened daily for signals of individual moose to detect moose mortalities as soon after they occurred as possible. It was not always possible to hear every animal daily.

When a mortality signal was heard, a group of investigators located and analyzed the carcass according to a protocol approved by University of Montana and Glacier National Park officials (Rachael et al. 1992). Carcasses were skinned and examined for indications of the cause of death (O'Gara 1978, Wade and Bowns 1982, Acorn and Dorrance 1990). The area surrounding the carcass was also thoroughly examined for signs of an attack and hair or scat left by the predator (Gauthier and Larsen 1987). Femur marrow was examined to estimate condition at time of death (Franzmann and Arneson 1976). All relevant information was recorded on a mortality form for later reference.

Mortality data were analyzed using the MICROMORT program (Heisey and Fuller 1985).

Weather data were collected at Polebridge, Montana from a U.S. Weather Service station (NOAA 1992).

RESULTS

In January 1990, 26 mortality collars were fitted on adult cow moose. Eleven more collars were fitted in December 1990. Approximately 44 moose years were open to predation over the 21 months of my study.

Almost half (15) of the animals radio collared were under 4 years of age and less than one fifth (6) of the sample was over 10 years of age (Figure 3.1). In general, the health of the sample population was very good (Appendix B).

Four non capture-related mortalities occured during the study period (Table 3.1). Two other cows died from capture-related causes. In addition to the mortalities, 3 radio-collars came off of moose in 1990. One came off in February, one in April and one in June.

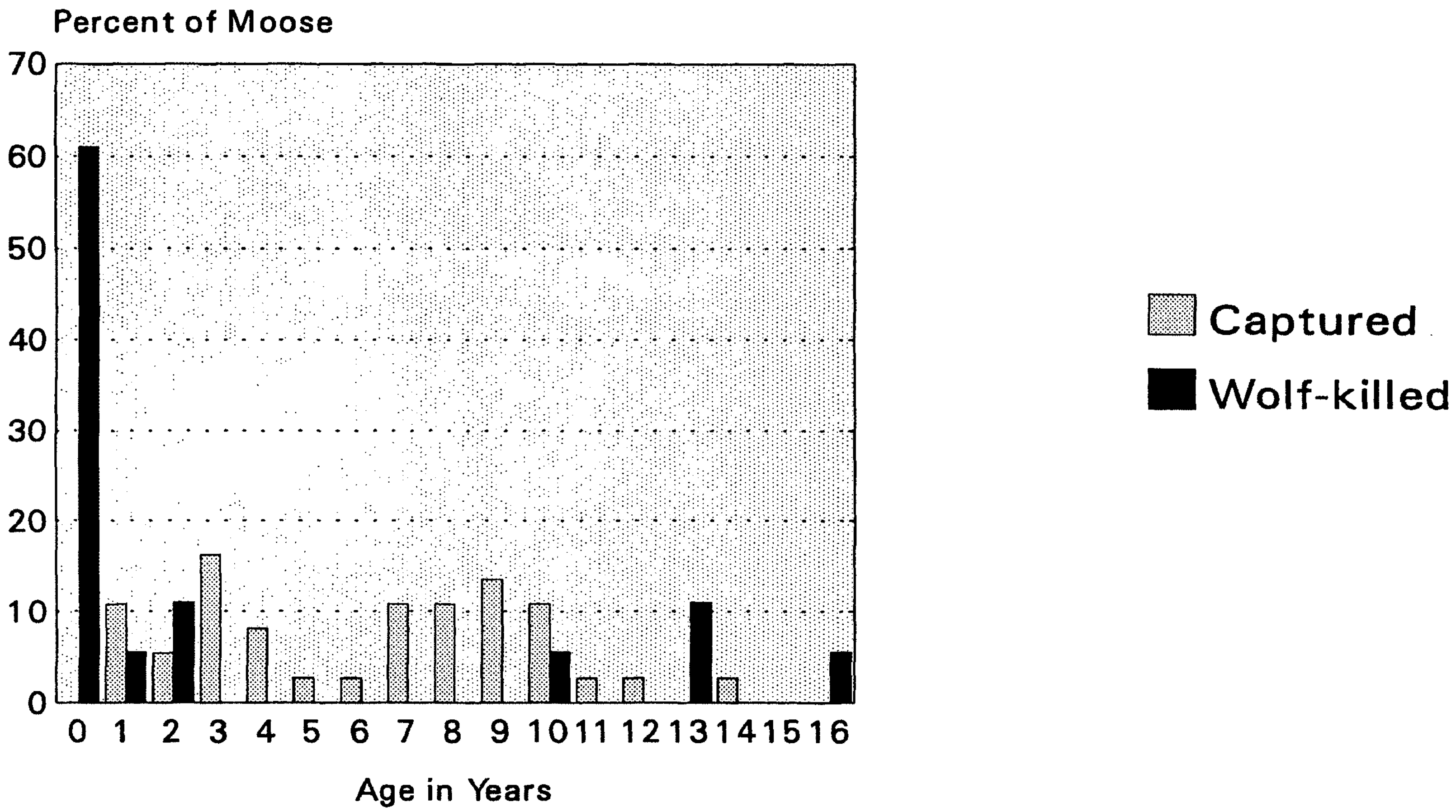

Fig. 3.1. Age distribution of 37 adult cow moose collared in January 1990 and 1991 in the Flathead and age distribution of 18 moose found killed during the winter by wolves between 1985 and 1991. Ages based on cemmentum annuli of lower incisor teeth pulled at time of capture or necropsy.

Table 3.1. Moose number, animal age, estimated date of death, probable cause of death, relative size based on 5 body measurements (Appendix B), condition at capture based on visual assessment, number of young at time of death and elevation of mortality site for four cow moose found dead during the study.

#	age	date	cause	size	cond	young	elev
313	2	07-23-90	G.bear	<ave.	good	0	1200m
325	5	07-29-90	G.bear	>ave.	exc	2	1244m
321	10	03-13-91	wolf	<ave.	good	1	1320m
336	3	06-24-91	not pred	<ave.	exc	0	1268m

On 13 January 1990, moose #314 was heard in mortality mode 5 days after being captured. The carcass was located intact, a few meters from the capture location and a necropsy was performed on site. A femur, lung, kidney, the heart and a vaginal mass were initially delivered to Dr. Bart O'Gara for examination. The animal had been in relatively good condition except for the vaginal mass and numerous cysts. Samples of cysts were sent to the Wyoming State Veterinary Lab in Laramie, Wyoming and the Montana State Department of Livestock's Diagnostic Lab in Bozeman, Montana. Neither of these labs were able to positively identify the many cysts seen on the tissues.

A dart was found in the animal's left rear hock during the field necropsy. During darting, we thought we had shot and missed this animal on the first attempt, but apparently we did not miss. She received the usual dose of 6cc of Naloxone and appeared normal when we left the scene but she probably died of an overdose of Carfentanil.

On 13 February 1990, moose #323 was heard in mortality mode. Her coyote-scavenged carcass was located a few meters from her capture location. Apparently, she had died soon after capture but her collar did not transmit in mortality mode, perhaps due to movement by scavengers. This moose had been darted twice. She did not react to the first dart and was darted again 12 minutes later. We administered a larger than normal (8cc instead of 6cc) dose of Naloxone and she recovered in 4 minutes. Her gums appeared pale during processing and her death is presumed to be capture-related.

On 23 July 1990, moose #313 was heard in mortality mode. When we went into the lower Sage Creek drainage to locate her carcass, a radio-collared female grizzly bear was at the same location. We returned a week later to find the carcass buried and surrounded by considerable bear sign. The skull had been crushed, strongly suggesting that it was a bear kill.

Moose #313 was a yearling at the time of capture and was not pregnant. She had a small patch of lice along her spine about mid-back. She tested negatively for disease and her fecal sample did not contain any abnormalities. This moose measured about average for a yearling on all dimensions (Appendix B) sampled.

On 29 July 1990, a mortality signal was received, from moose #325. We located the carcass on the northern shore of the small lake north of Garnet Lake (a.k.a. Mud Lake) in the Flathead National Forest. We were unable to determine the cause of death with complete certainty. The hide was inverted and relatively intact, the carcass was not buried and there were no tracks (it had rained heavily the 2 previous days). Ninety percent of the carcass had been eaten. There were a few bear scats in the area but none of them contained hair or flesh; no canid scat was found. The cow had been seen earlier with twin calves and the only remains of these animals were 2 "skull plates". No other bones or hides were in the area. Based on the inverted, intact hide, the kill was most likely made by a Grizzly bear.

Moose #325 was 4 years old at time of capture and was pregnant. She was in excellent condition and tested negatively for disease. This moose measured above average on all dimensions sampled (Appendix B).

On 13 March 1991, a dead moose calf was found near the Flathead road in BC by WEP employees. Approximately 70% of the calf had been consumed and tracks of 2 wolves were present. A live, but wounded, collared cow (#321) was laying 30m SE of the calf, beneath a tree. On the following day, the cow was dead but had not been consumed. Both haunches had been traumatized by wolves and no other injuries were evident.

Moose #321 was 9 yrs old at the time of her capture in

January, 1990. She was pregnant at that time and at the time of her death. When collared, she was in good condition except for the presence of a small patch of dried lice on her back. She was below average on all dimensions except for her neck and chest which were slightly larger than the sample mean (Appendix B).

A final mortality occured on 24 June 1991. Moose #336 was found in open woods on a small bench north of Trail Creek; a black bear was feeding on her. The carcass was largely intact and showed no sign of trauma. There was no scat in the area, the vegetation was not trampled and there was no evidence of a chase. Based on this information, we concluded that death was due to natural causes other than predation.

Moose #336 was captured in December 1990 and was in excellent condition. She was 2 years old and was not pregnant when captured or at her time of death. She was below average on all body measurements (Appendix B).

Mortalities not caused by researchers were used to determine the survival rate for the sample. Based on data from 32 moose (16,185 radio days) the daily and annual survival rates were 0.9997529 ± 0.0002422 and 0.9137318 ± 0.0773271, respectively.

Cumulative snow depths in the North Fork area during the 2 winters covered by this study were above the average for the period of 1981-1991. Mean winter temperatures were very close to the average for this period (Table 3.2).

Table 3.2. Cumulative snow depth (sum of daily snow depths) and mean temperature for 6 winter months (11/1-4/30) in the North Fork of the Flathead valley, 1981 through 1991.

Year	Cumulative Snow Depth (cm)	Mean Temperature (°C)
1981-82	9159	-3.9
1982-83	4669	-1.9
1983-84	1971	-2.7
1984-85	6380	-4.9
1985-86	4087	-2.7
1986-87	4783	-2.8
1987-88	2644	-2.3
1988-89	4557	-4.3
1989-90	5639	-3.8
1990-91	5794	-3.9
Mean	4968	-3.3
SD	2004	-1.0

DISCUSSION

From our sample of 32 adult cows, four were lost to non-capture causes over a 21-month period. One was a yearling, one was a 2-year old and 2 were prime-aged adults. My annual survival rates were higher than that reported by Hauge and Keith (1981) or Mytton and Keith (1981) and indicate that moose cows in the Flathead are not severely effected by predation.

It is well established that ungulates are the primary prey of wolves in both summer and winter (Pimlott 1967, Fuller and Keith 1980) and high moose calf mortality rates have been reported (Jordan et al. 1971 (73%) Messier and Crete 1985 (19%), Hayes et al. 1991 (64%)). However, the overall impact of wolves on ungulate populations is variable and depends on many factors.

Numerous studies have evaluated the impact of wolf predation in ecosystems with a variety of prey species. In a number of these, moose have been the primary prey and considerable debate has focused on the ability of wolves to limit and/or control moose populations. In some areas, moose populations are apparently regulated by wolf predation (Bishop and Rausch 1974, Bergerud et al. 1983, Keith 1983, MacGregor 1987). In Quebec, Messier (1985) found that wolf and moose numbers stabilized when both species were at low densities. Other studies have indicated that wolves may only limit moose populations that are already low due to overhunting or environmental factors (Frenzel 1974, Peterson 1975, VanBallenberghe 1980, Gasaway et al. 1983, Messier and Crete 1985, Gasaway et al. 1990).

The impact of wolves on moose and other ungulates may be increased during harsh winters (Frenzel 1974). Deep snow affects the movements of both moose and wolves and contact between the 2 species may be increased when wolves travel along shorelines frequented by moose forced into these areas by deep snow. Additionally, moose defense is impaired by deep snow and they become more susceptible to predation

(Peterson and Allen 1974).

While no data are available for wolf success rates in the North Fork area, the percent of moose in the wolf diet remained fairly consistent between 1986 and 1991 (Boyd et al. in press), despite unusually deep snows during my study.

Wolves have been documented in some areas taking mainly young, old and sickly individuals (Peterson 1975, Fuller and Keith 1980, Mech and Frenzel 1971, Hayes et al. 1991); in other studies, age and condition of wolf-killed animals reflected the distribution in the general population (Franzmann and Arneson 1976, Ballard et al. 1987). In Alaska, Gasaway et al.(1983) found that wolf-killed moose were in good health but tended to be older animals. Winter tracking by the Wolf Ecology Project between 1985 and 1991 located 21 wolf-killed moose. Of the 18 kills that could be aged, 14 were 2 years old or younger and 4 were 10 years old or older. When compared to the age distribution in my sample of adult cows, these data reflect a strong selection for young and old animals by Flathead wolves (Figure 3.1).

In addition to possibly limiting moose numbers through predation, wolves may also indirectly affect moose populations. In the Isle Royale area, solitary moose selected areas with preferred and highly nutritious forage, whereas cows with calves used areas with less nutritious foods where wolves were absent (Edwards 1983, Edwards 1984). This type of indirect impact may have a serious negative effect on moose populations by decreasing recruitment through malnutrition. As detailed in Chapter II, 19 of 32 cows in my study moved to higher elevations, generally outside of wolf range, for spring and summer. Use of these areas may indicate an avoidance of wolves and could affect offspring viability. A detailed study of available forage, moose health, and calf survivorship would shed more light on this possibility.

In Alaska, wolves followed non-migratory moose in their elevation changes but did not follow the movements of migratory individuals. Ballard et al. (1987) found a significant correlation between average monthly elevations of moose and wolf locations throughout the year. In Alberta, Fuller and Keith (1980) found that 88% of winter moose kills were made in the lowlands, despite an equal presence of moose at higher elevations. In my study, there was no indication that wolves "followed" moose; the mortality caused by wolves occured below 1320 meters in a lowland area, well within wolf home ranges (Table 3.1). It is very likely that wolves came to this area in response to large prey populations, especially white-tailed deer, and our findings do not indicate that prey have left the area in response to their arrival.

Considerably less research has been done on the impacts of black and grizzly bears on moose. Most documented predation has been from black bears, though grizzly bears have been implicated to varying degrees (Franzmann and Peterson 1978, Franzmann et al. 1980, Ballard et al. 1981, Ballard et al. 1987). Most of the predation has been on moose calves (Chatelain 1950, Franzmann and Peterson 1978, Franzmann et al. 1980, Ballard et al. 1979, Ballard et al. 1981) though adult remains have also been found in scats (Chatelain 1950).

The taking of neonate moose by ursids is greatest during the first 6-8 weeks of life (Chatelain 1950, Franzmann and Schwartz 1983) and therefore occurs in late spring and summer. Bear and moose ranges may overlap considerably during this time due to their shared preference for seral stage growth and riparian areas (Tisch 1961, Kowal and Runge 1982, Wilton 1983).

The North Fork has large populations of both bear species. Overlaying bear and moose home ranges shows considerable overlap in the North Fork area and 2 adult moose were taken by grizzly bear in my study. Very little use of any mammals was indicated by an analysis of grizzly bear scats by Mace and Jonkel (1981). However, Wilton (1983) found that black bear predation was underestimated due to bears inverting the hide of their prey before feeding, thereby ingesting little or no hair to be found later in their scats.

Like wolves, bears may indirectly affect moose. Cow-calf home ranges and movements were greater in areas with high grizzly bear densities and decreased after bear removal in Alaska (Ballard et al. 1980). In another Alaskan study, moose cows ran at the sight of grizzly bears in 3 observations but did not run in 5 encounters with black bears (LeResche 1968). Indirect impacts are almost impossible to measure quantitatively, but their existence should be documented whenever possible and considered before management actions are taken.

Numerous studies have been done of predation in ecosystems where moose are not the primary prey of bears or wolves. When elk are available, wolves will take them in much larger numbers than moose (Carbyn 1975, Carbyn and Kingsley 1979, Carbyn 1983); however, moose may increase in importance if elk are displaced, especially in winter (Carbyn 1981).

Where deer and moose coexist, white-tailed deer are usually the preferred prey for wolves (Pimlott et al. 1969, Mech and Frenzel 1971, Frenzel 1974, VanBallenberghe et al. 1975, Fritts and Mech 1981), although use of moose may increase in late spring (Fritts and Mech 1981). Moose and white-tailed deer have similar winter food preferences and may compete in some areas (Prescott 1974) making moose more accessible to predation than they would otherwise be. In response to a sharp deer population decline in Minnesota, wolves consumed considerably more moose as well as beaver (Castor canadensis) when available (Mech 1975, Mech and

Karns 1977). Similar results were found in Ontario (Voigt et al. 1976).

After reviewing numerous predation studies, Keith (1983) concluded that wolves select their prey based on available biomass. Data from studies cited above and the Wolf Ecology Project (Ream et al. 1990) tend to support this conclusion, with moose totaling approximately 7% of wolf kills in winter and making up a small, but unknown percent of the total ungulate population of the North Fork area.

Another important source of mortality is hunting by humans. Impacts can be considerable where moose harvest rates are greater than 19% (Gasaway et al. 1983) and may affect the population long after hunting is discontinued (Walters et al. 1981). In a model of moose/wolf/bear/human interactions, hunting emerged as one of the most significant controlling factors, especially when cows and bulls were both taken (VanBallenberghe and Dart 1982). The moose population in central Newfoundland was successfully reduced by allowing the take of moose of any sex or age during fall and early winter (Bergerud et al. 1968).

During my study in the North Fork area, there was no season on cow moose in Canada and 30 tags for moose of either sex were issued annually in the United States. No radio-collared moose were taken by hunters during my study. It is critical that precise estimates of moose numbers, as well as effects of all sources of natural mortality, be considered if quotas are to be set with confidence in their impact on moose numbers.

A final consideration is that of additive versus compensatory mortality. Mortality from wolf predation, harvesting and severe weather were additive in an Alaska study (Gasaway et al. 1983) and after a review of North American studies, VanBallenberghe (1987) concluded that calf predation was additive while predation on adults was compensatory. It is very difficult to accurately weigh the relative effects of various mortality sources but it is important to consider the possibility of additive impacts. Since harvest is a factor that we directly control, we must be prepared to limit it, especially on females, in the face of increased predation, especially after severe winters.

Numerous considerations exist when evaluating the various impacts on moose populations. Conditions vary with different areas and without long-term research we can say little about the impacts in specific locations. It is clear from the literature that wolves, bears and man can each significantly affect moose numbers. The degree of impact and its role in limiting moose populations is not completely understood for the North Fork area. Since long-term population estimates are lacking for moose in the North Fork it is impossible to look at relative numbers. My study strongly suggests that neither predation nor hunting seriously affect adult cow moose populations at the present time. More information will be gained from continuing to track the presently collared moose. However, collaring calves would be necessary to adequately assess the true extent of the impact of predation on moose, especially by bears.

Whether or not more research on moose mortality is conducted in the North Fork, the continued presence of large predators has been mandated by law in the United States and must be respected. There is nothing we can do to eliminate all predation but we can limit human predation to sustainable levels. I believe that our focus should be on conducting regular moose censuses to monitor numbers (See Chapter IV). We must accept our limited control over non-human predation and look at other areas of concern, including hunting and habitat quality, if we are to maintain moose populations over the long term.

CHAPTER IV

MOOSE POPULATION MONITORING IN THE NORTH FORK VALLEY OF THE FLATHEAD RIVER

Considerable research has been conducted to determine the most precise method of monitoring moose population trends and age and sex structures. Despite these efforts, a "best" method has not been agreed upon and a variety of techniques, including pellet-group counts, direct observation, hunter harvest statistics and, aerial surveys (Timmermann 1974), continue to be used.

Problems exist for each of the above techniques. Pellet-group counts are very labor intensive and susceptible to human error due to incorrect classification, bias and fatigue (Neff 1968, Franzmann et al. 1976, MacCracken and VanBalenberghe 1987). Reports of the average daily defecation rate of moose vary widely (Timmermann 1974, Franzmann et al. 1976, Joyal and Ricard 1986), and it is difficult to obtain large enough sample sizes to detect trends in population size.

Direct observations of moose from the ground can yield information on population trends but it does not provide accurate information on population size, largely due to the difficulty in seeing and sexing moose in dense cover (Timmermann 1974).

By far the most common monitoring method is the aerial survey. These surveys may be conducted in a fixed-wing aircraft along transects (Pennycuick 1969, LeResche and Rausch 1974, Novak 1975, Thompson 1979, Biggins and Jackson 1982) or within quadrats (Siniff and Skoog 1964, Evans et al. 1966, Bergerud and Manuel 1969, Timmermann 1974, Laws et al. 1975, Gasaway et al. 1986). Quadrats may also be stratified according to thickness of cover (Jolly 1969, Caughley 1974) or according to animal densities (Siniff and Skoog 1964, Sinclair 1972, Gasaway et al. 1986). Stratification may decrease variability in the data and provide density estimates for different habitats.

Helicopters can also be used for surveys and the increased versatility they afford may make this method preferable, despite the expense. Quadrat surveys using helicopters are especially well suited to mountainous terrain (Kufeld et al. 1980), areas with thick cover, and regions with poor winter weather.

Quadrant surveys are currently seen as the best method due to the possibility for large sample sizes and limited errors, many of which can be corrected. Sex and age ratios can also be determined from the air, thereby increasing the value of this technique.

My objective was to develop an index of trends in moose population size and to determine age and sex ratios for the population in the Flathead. I selected a quadrant technique that seemed appropriate for our needs and resources. I also obtained data from helicopter surveys conducted in the same area by other researchers. The study area is described in Chapter II (pp. 5-7).

METHODS

Four areas with relatively high moose densities were chosen based on my knowledge of densities from doing telemetry flights. Four aerial surveys were conducted in each area between December 20, 1990 and January 23, 1991, after snow cover was complete.

Flights were conducted between 1000 and 1400 h. on clear, calm days by one of 3 experienced observers using the same pilot and aircraft (Cessna 185). Flights were planned to be a minimum of 4 days apart to ensure independence. A flight speed of 200 kilometers/hour at 150 meter elevation was maintained for all surveys.

Surveys of 3 distinct clear cut areas and one 8-km^2 area of river bottom were conducted. Each area was searched until all visible moose were counted. All moose seen were recorded, as was their sex and age class, when possible. Sex was determined by presence of antlers or observation of a vulval patch in the female (Mitchell 1970, Roussel 1975). Animals were grouped as either adults or calves based on their size. Since size differences are evident throughout the first year (Franzmann and Schwartz 1983), full-sized animals were considered adults and small individuals were classified as calves. Values from all 4 flights were summed to provide sex and age ratios.

Presence of radio-collars was also recorded and the percent of female animals seen that had radio-collars was calculated and used to estimate the total population in the area using the Petersen Index (Caughley 1977a).

A revised method was developed for the 1991-1992 winter surveys due to the high variability obtained during the first winter. During the second winter, 2 surveys were flown during which 6 areas of high moose density were searched and all moose sighted were recorded. As previously, sex and age class of each animal was also recorded when possible as was the presence of radio collars.

Every area was divided into an interior and surrounding unit; searchers initially surveyed the interior unit (clearcut or riparian) as defined on a laminated map; they then surveyed the surrounding area, also as defined on the map. This was followed by circling the interior unit and then the surrounding unit on the exterior edge. During these circles, searchers listened for moose suspected to be in the area and recorded the number of radio signals within the areas searched.

The unit surrounding the interior unit was surveyed in an effort to decrease variability between flight repetitions. This was based on the assumption that moose move into this surrounding area in response to changes in weather and snow depth between flights. Theoretically, the sum of animals in the interior unit and the surrounding unit should vary minimally between flights.

Since animals were more difficult to sight in these surrounding areas, an index of sightability was needed for both the surrounding and interior areas. This index was based on the number of collared animals seen in the units, relative to the number of collared animals detected during the circles around the survey areas. For example, if 2 collared moose were sighted in the surrounding area and 4 were heard, then the sightability would be 50%, and the number of moose in the timber would be recorded as double that actually sighted.

As during 1990-91, every effort was made to ensure that flights were conducted between 1000 and 1400 h. on clear, calm days using the same pilot and aircraft (Cessna 185). In addition to the pilot, two observers looked for moose. Flight speed, elevation, and flight intervals were the same as during 1990-91.

I also obtained data from helicopter surveys completed by the B.C. Ministry of the Environment between 1969 and 1991. Surveys were conducted during February or March until 1988, primarily to monitor elk numbers. These surveys covered parts of the Flathead area and moose were recorded when seen but were not specifically searched for. Surveys specifically for moose were begun in 1990. An attempt was made to count all moose present in the North Fork area north of the border during the 1990-91 and 1991-92 winters. Moose winter range was flown at around 1800 meters above ground level; if moose or sign were sighted, the helicopter dropped to 180 meters. When an animal was seen, the helicopter further dropped to whatever elevation was needed to confidently sex the animal. Antlers were used for sexing when present and otherwise a vulval patch was checked for. On 3 consecutive days in January 1991, 1570 km^2 of moose winter range was covered, 420 km^2 of which were intensively searched. In December 1991, one flight was completed, covering approximately the same area as the 3, January 1991 flights. This flight was completed by a private contractor and the techniques used may have been inconsistent with those used in January 1991 (B. Workenton, B.C. Ministry of the Environment, pers. commun.).

In addition to census data, population information was derived from ages of adult cows, pregnancy rates, twinning rates and calving success rates from the collared segment of the population. All moose were pregnancy tested when collared using rectal palpation. Twinning rates were calculated based on the percent of cows seen with calves sighted with twins. Calving success was determined by calculating the number of cows sighted with calves divided by the number of known pregnant cows sighted. The difference in this value was calculated between early summer

(June and July), late summer (August and September) and fall (October-December).

RESULTS

The temperature for all flights was between -8 and 0 C. Flight times varied, due in part to weather and in part to airplane availability (Table 4.1). Because of poor flying conditions, the spacing between flights was greater than planned, ranging from 5 to 17 days. Despite the long lapses between flights, snow depths on the ground (recorded at Polebridge, MT) were between 20 and 28 cm for all flights. No information on snow hardness or crust thickness was gathered.

Table 4.1. Weather and times for the 4 flights completed during the 1990-91 winter.

Date	Weather	Time
12/20/90	Windy and clear/ 8 C	1100-1140
01/02/91	Calm, clear and sunny/ -2 C	0900-1000
01/19/91	Calm and clear/ -8 C	1100-1200
01/23/91	Cloudy/ 0 C	1600-1700

Only 4 moose were seen in one of the 4 areas and it was therefore not included in the analysis. A total of 69 moose were seen on 4 flights (Table 4.2).

Table 4.2. Classification and total number of moose counted on 4 flights completed during 1990-91 winter.

Date	Bulls	Cows	Calves	Unknown	Total
1990-91	9	13	8	39	69

Four (31%) of the 13 adult females wore radio collars. This leads to a rough estimate of 97 adult cow moose within the 400 km^2 study area which translates to a density estimate for adult females of 0.24/km^2.

A sex ratio of 69 bulls:100 cows was obtained from the four flights. The large number (56%) of "unknown sex" animals makes this ratio questionable. A calf:cow ratio of 61:100 was also obtained. Using these 2 ratios and the percent of collared cows yields a total population estimate of 0.55 moose/km^2.

Variability between the flights was high, with decreasing numbers observed on later flights (Appendix D). This declining trend was not observed in the riparian area, where numbers seen remained high even in late January (Table 4.3).

Table 4.3. Total number of moose seen in 2 clearcut areas and one riparian area on 4 flights completed during 1990-91 winter.

Date	Total moose in 2 clearcuts	Total moose in 1 riparian area
12/20/90	13	15
01/02/91	15	3
01/19/91	1	7
01/23/91	0	15

During the second winter, 2 flights were completed in February 1992. The weather had not permitted flying during December or January and because of the extremely low numbers of moose seen during the February flights, only 2 were completed. No population estimate was made using these data because too few individuals were sighted (Appendix D).

While moose were not the primary focus of the flights completed by the B.C. Ministry of the Environment before 1989, the search effort was similar each year as was the area covered. However, no consideration of variability or sightability was made and these values are therefore only useful for very rough trend estimates (Table 4.4).

Table 4.4. Moose counts and flight dates for surveys completed by B.C. Ministry of the Environment between 1969 and 1988.

Date	Bulls	Cows	Calves	Unknown	Total
03/69	4	23	10	5	42
03/70	5	20	8	1	34
02/71	13	37	19	4	73
03/72	7	16	11	0	34
02/73	4	18	5	3	30
02/75	8	21	10	0	39
03/76	6	8	2	0	16
03/77	2	5	2	0	9
03/78	3	10	6	0	19
03/79	11	24	13	0	48
03/80	6	17	11	0	34
03/81	14	13	7	0	34
03/84	8	12	7	2	29
02/85	15	37	2	0	54
03/86	4	8	4	0	16
03/88	3	8	2	0	13

During the winters of 1990-91 and 1991-92, the B.C. Wildlife Branch attempted to count all moose wintering in the North Fork area. These surveys covered an area of approximately 525 km^2. In January 1991, 215 moose (0.41/km^2) were counted with 28 bulls:100 cows and 25 calves:100 cows (Table 4.5). In December 1991, 222 moose (0.42/km^2) were sighted with 49 bulls:100 cows and 22 calves:100 cows (Table 4.5). Without a sightability index, it is difficult to use these data to estimate total populations though they are valuable as an index of trend and for classification.

Table 4.5. Number of moose counted during helicopter survey completed by B.C Ministry of the Environment, winter, 1990-91 and 1991-92.

Date	Bulls	Cows	Calves	Unknown	Total
1990-91	38	134	33	10	215
1991-92	63	129	28	2	222

Age Structure

The mean age of cows collared in my study was 6.15 years (Figure 3.1). At the time of capture, 16 cows were 5 or younger, 16 were between 6 and 10, and 2 were 11 or older.

Pregnancy Rate

The pregnancy rate from rectal palpation among cows aged 2 years or older at the time of capture was almost identical each year. The data were combined to yield a rate of 82% for the entire sample (Appendix B).

Twinning Rate

Only 2 (15.4%) of the 13 collared cows seen with calves during the first winter were observed with twin calves. One of these cows was also seen with 2 yearlings at the time of her capture, indicating that she twinned in consecutive years. Very few summertime visuals were obtained of the cows captured during the second winter so a twinning rate was not calculated.

Calf Survival

Pregnant cows sighted with calves were grouped for June and July (early summer), August and September (late summer) and for October, November and December (fall). Sixty-two percent of cows determined to be pregnant by rectal palpation were observed with calves in early summer. A 7% decrease in pregnant cows with calves was found between early and late summer. A further decrease of 10% was noted between late summer and fall. Thus 45% of the cows that were pregnant in the winter still had calves at the end of December (Figure 4.1).

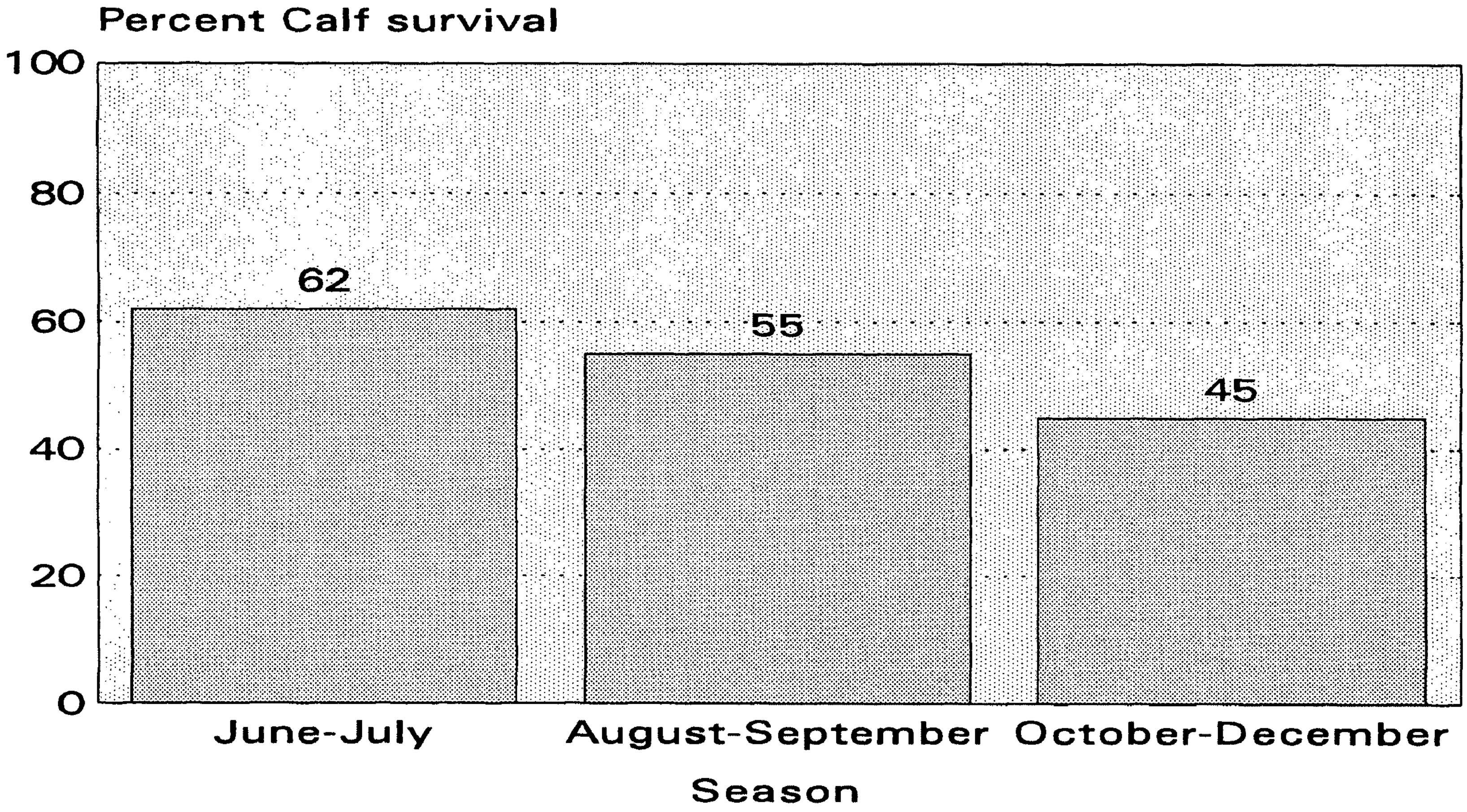

Fig. 4.1. Calf survival in the Flathead from early summer to late fall based on percent of known pregnant cows seen with calves.

DISCUSSION

Census Technique

My attempt to develop an index of moose population trends has enlightened me to the difficulties inherent in any census effort and particularly those of moose. While I was able to derive a density estimate from the flights we completed, I do not feel that a suitable technique was developed that should be pursued in the future.

I have no doubt that it is possible to obtain an accurate estimate of population sizes for moose, but such an estimate would require large sums of money for extensive flying coupled with the development of a sightability index. Due to the dense habitat and the unpredictable weather in the Flathead, more precise counts would be obtained from a helicopter, further raising the amount of money required.

The variability between our moose survey flights was substantial. Some of this variability can be attributed to the time that lapsed between flights and thus moose movements; as winter progressed unknown changes in snow hardness, and temperature occurred. Many other potential sources of error existed, including observer experience and alertness, time of day, lighting conditions, microclimate changes, and migratory and random movements (Evans et al. 1966, LeResche and Rausch 1974, Caughley et al. 1976, Caughley 1977, Gasaway et al. 1986). More flights over more areas would be needed to properly quantify this variability.

The sighting of moose in riparian areas in late January (Table 4.3) indicates that these areas may be useful for surveys well after moose have left open clearcuts.

Weather patterns in the Flathead vary from day to day and from year to year. We attempted to fly every 4 days but were unable to do so because of poor flying conditions. Moose usually leave open areas when snow depth reaches 45-80 cm (Des Meules 1964, Dodds 1974, Peek et al. 1976). Because of this we intended to begin flying on December 7, 1991 (one week following the closing of hunting season) but the weather was so poor that we were unable to fly until February by which time very few moose were seen. The best way to avoid delays caused by bad weather (especially low cloud ceilings) would be to do helicopter surveys. Helicopters can fly in most weather conditions and are not as restricted by a low cloud ceiling as a fixed wing aircraft is.

The data I collected had a large number of unknown sex animals (49%). Male moose lose their antlers by late December (J. Brown, Montana Department of Fish, Wildlife and Parks, pers. commun.) though antlerless males have been sighted as early as November (Peek et al. 1976, Hauge and Keith 1981). Since most of our flights were after this time, we had to rely on sighting of a vulval patch for positive sexing. It can be very difficult to see a vulval patch from a fixed-wing aircraft due to limitations in elevation, speed and angle. A helicopter, however, is more maneuverable making it much easier to gain the proper angle and elevation needed to see the rear end of a moose.

I feel that the surveys completed by B.C. Ministry of the Environment are a step in the right direction. These surveys saw numerous animals ($\bar{X} = 218$) over a fairly large area and they had very few unknown sex animals (3%). Also, they were able to work with the weather and the terrain with the help of a helicopter. The B.C. data would benefit immensely if numerous, repetitive surveys were done to quantify overall variability, and if a sightability index was developed (Caughley and Goddard 1972, Caughley et al. 1976, Floyd et al. 1979, Thompson 1979, Biggins and Jackson 1982, Floyd et al. 1982). These data would be very useful in both tracking population changes and estimating the actual number of moose in the area.

Completing only one survey per year does not consider variation in moose seen due to weather changes, migratory movements (See Chapter II), random movements, pilot and observer accuracy, lighting conditions, etc. When all sources of error are not taken into account, the usefulness of the data is diminished substantially. While it is nearly impossible to eliminate some error sources, determining the variability that errors create in the data allows researchers to present a range of results with greater certainty that reality lies within this range. Without knowledge of variability, results could easily be ambiguous and thus misinterpreted.

Population estimation should occur over many years to determine reliable confidence intervals and to detect substantial changes in the population (Gasaway and Dubois 1987). Once variability is established, single annual flights could be considered relative to a confidence interval and trend could be monitored with some certainty (Eberhardt 1978).

If these data are to be used to estimate actual population sizes, a sightability index must be developed. In retrospect, it would have been ideal to have begun such an effort when I radio-collared moose in the area. Contact should have been made at the outset of our research as greater coordination between the 2 countries is critical with populations that cross the border regularly.

Once sightability and variability are determined with a helicopter, the B.C. Government could develop an index that would translate animals seen from a fixed-wing aircraft to actual numbers on the ground and thereby reduce their costs significantly (Crete et al. 1986).

Population Composition

For the purpose of comparing the North Fork moose population to other populations, I will briefly discuss my data but I will primarily use the sex and age ratios from the B.C. survey completed in December 1991. I have made this choice because the small sample size and large number of unsexed animals in my surveys make my data less reliable than the Canadian data.

My census data indicate that Flathead moose populations are healthy and thriving. Both my bull:cow and calf:cow ratios are high when compared to other North American studies (Table 4.6 and 4.7, respectively). These ratios may be biased high due to the large number of "unknown" moose, many of which were likely cows. However, the ratios are large enough to withstand some decrease and still reflect a healthy moose population.

Table 4.6. Bull:cow ratios from selected North American moose populations.

Bulls per 100 cows	Location	Source
69	North Fork of Flathead	this study
49	North Fork of Flathead, B.C.	B.C. Ministry of the Environment 1992
41	Yaak, Montana	Costain 1989
46	Gallatin Mtns., Montana	Stevens 1970
23	Northeastern Alberta	Rolley and Keith 1980
35-49	Northeastern Alberta	Hauge and Keith 1981
29-37	Central Alberta	Mytton and Keith 1981
63	Saskatchewan	Kowal and Runge 1982
80	Northcental Minnesota	Fuller 1986
75	Northeastern Minnesota	Peek et al. 1976
43-59	Southwestern Quebec	Messier and Crete 1985
49	Southern Yukon	Larsen 1982
11-44	Kenai Peninsula, Alaska	Bailey 1978

Table 4.7. Winter calf:cow ratios from selected North American moose populations.

Calves per 100 cows	Location	Source
61	North Fork of Flathead	this study
22	North Fork of Flathead, B.C.	B.C. Ministry of the Environment 1992
22-73	Yaak, Montana	Costain 1989
54	Gallatin Mtns., Montana	Stevens 1970
106	Northeastern Alberta	Rolley and Keith 1980
50-93	Northeastern Alberta	Hauge and Keith 1981
76-98	Central Alberta	Mytton and Keith 1981
88	Saskatchewan	Kowal and Runge 1982
75	Northcental Minnesota	Fuller 1986
54	Northeastern Minnesota	Peek et al. 1976
37-65	Southwestern Quebec	Messier and Crete 1985
22	Southern Yukon	Larsen 1982
138	East Central Alaska	Gasaway et al. 1990

The predicted calf:cow ratio based on pregnancy and survival data is also considerably higher than in other studies. My sample of adult cows had a 82% pregnancy rate (Table 4.8). Twinning rates were low (Table 4.9) and calf survival data indicate a 27.5% loss of calves by December. Based on these figures a calf:cow ratio of 60:100 would be expected. This value corresponds very well to that found in my surveys but is much higher than the ratio found in the B.C. surveys.

Table 4.8. Percent pregnancy among cows >12 months of age from selected North American moose populations.

Percent of cows pregnant	Location	Source
82	North Fork of Flathead	this study 1991-92
94	Saskatchewan	Kowal and Runge 1982
88	South Central Alaska	Ballard et al. 1981
100	East Central Alaska	Gasaway et al. 1990
50-76	Kenai Peninsula, Alaska	Bailey 1978

Table 4.9. Twinning rate from selected North American populations.

Twinning rate (%)	Location	Source
15	North Fork of Flathead	this study
33-50	Yaak, Montana	Costain 1989
41	Northeastern Alberta	Rolley and Keith 1980
10	Northeastern Alberta	Hauge and Keith 1981
38-75	Central Alberta	Mytton and Keith 1981
11-22	Northeastern Minnesota	Peek et al. 1976
22-70	Kenai Peninsula, Alaska	Franzmann and Schwartz 1985
2-11	Kenai Peninsula, Alaska	Bailey 1978

The sample sizes and age ratios of the 2 years of Canadian data were very close, but the sex ratios were quite different. In January 1991, 28 bulls were seen per 100 cows; in December 1991, 49 bulls per 100 cows were sighted. This large difference may possibly be explained by the drastic reduction in moose hunting in 1991 versus previous years. In response to low bull:cow ratios, the B.C.

Ministry of the Environment imposed a limited entry bull season in 1991. A reduction of 70% was desired and only 6 bulls were taken in 1991. This may have led to more bulls being seen in the flight after hunting season (B. Workenton, British Columbia Ministry of the Environment, pers. commun.). However, even if only 6 bulls were taken in 1991, numerous additional bull moose would have had to enter the population to result in the 1991-92 sex ratio.

The bull:cow ratio from 1991-92 (49:100) B.C. survey was average when compared to other North American populations (Table 4.6). Moose are a serially monogamous species (Denniston 1956) so bull numbers are crucial to healthy populations. Crete et al. (1981) recommended a bull:cow ratio of 67:100 for good fertilization rates. The B.C. survey bull:cow ratios of 28:100 and 49:100 are well below this recommendation and may have contributed to their low calf:cow ratios.

Unlike the bull:cow ratios, the calf:cow ratios were very close during the 2 years of surveys. The December 1991 ratio of 22 calves:100 cows is lower than that reported by most other North American studies (Table 4.7). Though great variability has been found in calf:cow ratios (Costain 1989), there is no apparent cause for unusually low calf production or survivorship in 1990 or 1991.

Low calf survival could result from many sources, including disease, poor nutrition, and/or predation. I did not directly measure food quality or availability in the Flathead. However, plant species preferred by moose are common in the area. Moose calves may suffer from malnutrition when deep snow limits their access to food (Peterson and Allen 1974, Prescott 1974).

Wolves and bears in the Flathead take an unknown number of moose calves annually. Other researchers have found that predators can significantly impact moose populations through calf predation (Ballard et al. 1981, Franzmann and Schwartz 1986, Franzmann and Petersen 1978) and the impacts in the Flathead may also be significant. However, given the high adult survival rates documented for my sample (Chapter III), even the low calf:cow ratios reported here could maintain a stable moose population in the Flathead.

Both the density of 0.42 moose/km^2 from the B.C. data and my estimate of 0.55 moose/km^2 are within the ranges from other North American studies (Table 4.10). Numerous sources of error exist in these estimates and I feel it is premature to conclude that the moose density in the Flathead is known with certainty.

In conclusion, moose numbers and population parameters in the Flathead indicate that the population is relatively healthy. Moose numbers were historically low in the North Fork drainage (Chadbourne 1943) though they have apparently been in the area since documentation began (Bergerud and Elliot 1986). Their expansion into much of British Columbia

Table 4.10. Density estimates from selected North American moose populations.

Density Moose/km^2	Location	Source
0.55	North Fork of Flathead	this study
0.42	North Fork of Flathead, B.C.	B.C. Ministry of the Environment 1992
1.35-1.76	Yaak, Montana	Costain 1989
0.16-0.75	Northeastern Alberta	Rolley and Keith 1980
0.47	Northeastern Alberta	Hauge and Keith 1981
0.64-1.40	Central Alberta	Mytton and Keith 1981
1.50-2.70	Isle Royale, Michigan	Petersen 1977
0.02	Northcental Minnesota	Fuller 1986
0.88-1.96	Northeastern Minnesota	Peek et al. 1976
0.17-0.37	Southwestern Quebec	Messier and Crete 1985
1.51	Southern Yukon	Larsen 1982
0.16	East Central Alaska	Gasaway et al. 1990
0.20-3.00	Kenai Peninsula, Alaska	Bailey 1978

and parts of Montana may have been in response to clearcutting and fire (Stevens 1971, Kelsall and Telfer 1974). Their apparently low numbers within Glacier National Park support this assertion. Outbreaks of Spruce budworm will help to open up the overstory and encourage the seral stage growth that moose thrive upon (Krefting 1974).

In an area where moose are only one of many ungulate species, numbers would be expected to be lower than in areas where they are the only ungulate species. While hunters may wish to see moose numbers increase, higher numbers may not be natural or desirable in the North Fork area.

CHAPTER V

MOOSE CALVING SITE SELECTION IN THE NORTH FORK VALLEY OF THE FLATHEAD RIVER

Many researchers have determined calf:cow ratios and calving success rates, both values that can be obtained with variable accuracy during census flights. Such information can be used to chart trends in recruitment rates and has been used to support management decisions for predator control (e.g. Ballard et al. 1987, MacGregor 1987, Hayes et al. 1991). An alternative to removing moose predators may be to ensure that suitable calving habitat exists. Moose have evolved with wolf and bear predation and their choices for calving sites should reflect this evolution. Calves should have a higher probability of survival if sufficient, high quality calving habitat is maintained. More knowledge about the habitat needs of calving moose would be useful in efforts to preserve these areas.

Determining what habitat features moose select for calving has been attempted by some researchers; the results of these studies vary considerably. Some studies of birth sites have concluded that hiding cover and proximity to forage and water are essential site characteristics (Altmann 1958, 1963; Costain 1989, Leptich and Gilbert 1986). Other researchers have documented that moose use small islands away from predators for calving (Seton 1927, Clarke 1936, Peterson 1955, Stephens and Peterson 1984). A study on the Kenai Peninsula found that calving sites were invariably close (<200m) to water whether or not they were on islands (Bailey and Bangs 1980).

Other studies have not found that water or forage are important features of calving sites. Markgren (1969) found no indication of selection for forage or water though all the calving sites he studied were secluded from their surroundings. In an Alaskan study, calving sites were also in moderate to dense cover but were not close to water or good forage sources (Stringham 1974). A study in Ontario that looked at calving sites on islands and near water found tremendous variability and no clear indication of habitat preference (Addison et al. 1990). Further analysis of the Ontario data concluded that most sites were at high elevations relative to the surrounding terrain and that access to escape routes was preferred (Wilton and Garner 1991).

Studies in areas where clearcuts are common have found that moose use islands of cover (Cederlund et al. 1987) and rock outcrops (B. Dalton, Ontario Ministry of Natural Resources, pers. commun.) and do not stay in these areas for very long before moving out into the clearcuts themselves.

The results of all of these studies reflect the variety of predator avoidance strategies employed by calving moose in different habitats. Matchett (1985) and Costain (1989) studied moose habitat use in the Yaak Valley where the climate is wetter than in the Flathead. No other studies of calving site selection have been done in the inter-mountain west and predator avoidance strategies of moose in this region are not well understood.

I compared characteristics of calving areas to other sites within annual moose home ranges to determine what specific habitat characteristics were preferred in the North Fork of the Flathead. The study area is described in Chapter II (pp. 5-7)

METHODS

Calving Site Determination

During January and December 1990, 32 cow moose were captured and radio-collared (See Chapter II). Each moose was rectally palpated at the time of capture to determine pregnancy (Arthur 1964). Moose were subsequently followed using radio telemetry techniques. Thirteen pregnant cows who were accessible for ground-based telemetry were selected for calving site determination. Calving site locations were determined through intensive monitoring from early May to mid June. These animals were located daily and cessation of daily movement for at least 4 consecutive days was taken to indicate calving activity. Two cows were approached on the ground after 4 days without movement to verify that calving had occurred.

Habitat Data Collection

Calving areas were designated around the central calving site using a circle with an area of 16 ha (radius = 226m). Ten 0.4 ha (0.1 acre) plots were completed within each calving area. One plot was located at the center of the circle, 3 were located within a circular band between 71 and 143 m from plot center (30% of the total area) and 6 plots were located within a circular band between 144 and 226 m from plot center (60% of the total area). Exact plot locations were determined from a random number table that fell within the limits detailed above. The first distance was assigned a random azimuth and subsequent distances were located systematically such that plots in the 1st band were 120 degrees apart and those in the outer band were 60 degrees apart. Data from these 10 plots were averaged to obtain single values for each calving area.

Ten plots were systematically designated within each moose's annual 95 % harmonic mean home range to compare calving areas with available habitat.

Habitat data were collected using a revised ECODATA (USDA 1987) format. A data sheet was designed that would facilitate comparison of our data with habitat values collected on ecodata plots sampled in the Flathead National Forest (FNF) and Glacier National Park (GNP). Some variables were eliminated and others were added to meet our study objectives.

Two types of variables were collected: position (Table 5.1), and vegetation structure and cover (Table 5.2). Two of the position variables (Table 5.1), slope and aspect were recorded in the field. Values for elevation, distance to nearest road, distance to nearest water and distance to nearest human habitation were taken from USGS 7.5 minute quadrangle maps.

Table 5.1: Description of 6 position variables used to decribe moose calving sites and habitat within annual moose home ranges. S and AS were collected in the field, the remaining variables were taken from USGS 7.5 minute quadrangle maps.

Variable	Description
EL	Elevation (m)
S	Slope (degrees)
AS	Aspect [1]
DRD	Distance to nearest road (m)
DWA	Distance to nearest water (m)
DHA	Distance to nearest human habitation (m)

1/Aspect was assigned using the following categories:
1) level or rolling 2) north:337-22 degrees
3) northeast:23-67 degrees 4) east:68-112 degrees
5) southeast:113-157 degrees 6) south:158-202 degrees
7) southwest:203-247 degrees 8) west:248-292 degrees
9) northwest:293-336 degrees (USDA 1987:4.42--25)

Table 5.2: Alphabetic listing and description of vegetation structure and cover variables used to describe moose calving sites and habitat within annual moose home ranges. (See text for details unless noted below).

Variable	Description
ADHT	Average height of downfall (cm)
BAF	Basal Area Factor
CC	Canopy cover [1]
DBH	Mean diameter breast height of dominant tree layer
E	Presence or absence of edge [2]
GC	Ground cover [3]
HC1L	Hiding cover at 30.5 m below 1 m from ground [4]
HC1H	Hiding cover at 30.5 m between 1-2 m from ground [4]
HC2L	Hiding cover at 71.0 m below 1 m from ground [4]
HC2H	Hiding cover at 71.0 m between 1-2 m from ground [4]
LSH	Canopy cover for low shrubs (< 15.2 cm) [5]
MSH	Canopy cover for medium shrubs (15.2 - 137.2 cm) [5]
PNC	Potential natural community (Habitat type)
PP+	Canopy cover for pole size and larger trees (>12.4 cm dbh) [5]
SAP	Canopy cover for sapling sized trees (2.5 - 12.4 cm dbh) [5]
SEED	Canopy cover for seedling size trees (<2.5 cm dbh) [5]
SIGN	Number of moose pellet groups
SNAGS	Number of snags
SS	Slope shape [6]
STR	Structural class of vegetation within plot [7]
STUMP	Number of stumps
TDC	Total downfall cover [5]
TFC	Total forb and fern cover [5]
TGC	Total graminoid cover [5]

Table 5.2. continued.

Variable	Description
TSC	Total shrub cover [5]
TSH	Total shrub cover [5]
TTC	Total tree cover [5]
#P+	Number of trees larger than pole (> 22.6 cm dbh)
#P	Number of pole sized trees (12.4-22.6 cm dbh)
#SAP	Number of sapling sized trees (2.5-12.4 cm dbh)
#SEED	Number of seedling sized trees (< 2.5 cm dbh)

1/Canopy cover was estimated for the entire plot as an actual percentage value

2/Edge was recorded as either 1)present or 2)absent

3/Ground cover estimated for bare soil, gravel, rock, litter, wood, moss and basal vegetation. Percent coverage grouped into 1)0% 2)>0-<1% 3)1-<5% 4)5-<15% 5)15-<25% 6)25-<35% 7)35-<45% 8)45-<55% 9)55-<65% 10)65-<75% 11)75-<85% 12)85-<95% 13)95-100% (USDA 1987:4.42, pg. 29)

4/Hiding cover was recorded as the percent of a person standing at plot center visible to an observer positioned as described in the text.

5/All cover estimates were made for each of four quadrants and then averaged for the whole plot. Percent coverage for all categories was estimated as 1)0% 2)>0%-<5% 3)5%-<25% 4)25%-<55% 5)55%-<75% 6)75%-<95% 7)>95%

6/Slope shape classified as 1)even or straight 2)convex 3)concave 4)patterned (USDA 1987:4.42, pg. 24)

7/Structure classified as: 0)nonvegetated or moss 1)herbaceous or herbaceous/tree seedling 2)shrub or shrub/tree seedling 3)sapling 4)pole/sapling 5)young mature trees 6)old growth trees 7)krumholtz trees (USDA 1987:4.42, pg. 32)

Thirty-one structure and cover variables were assessed (Table 5.2). Basal area factor was calculated by counting the number of trees visible from plot center that had a width at breast height greater than the angle projected by a prism with factor 10 (USDA 1987:4.42. pg.31). Canopy cover was estimated ocularly for the plot and mean diameter at breast height (dbh) of the dominant tree layer was estimated in inches for the plot after 2 or more trees were measured manually. Edge was considered present if a distinct change in successional stage could be seen from plot center. Hiding cover was estimated for the plot by averaging values from the 4 cardinal directions. Values were obtained by estimating what percent of a person at plot center could be seen by an observer standing at 30.5 m and 71.0 m from plot center (Krahmer 1989). Percent coverage was estimated for the area below 1 m from the ground and the area from 1 to 2m from the ground. I estimated the 11 vegetation cover variables in each quadrant of the plot separately and then averaged these values to obtain one value for the entire plot. Potential natural community was determined according to Pfister et al. (1974). The actual number of trees in the plot were counted according to their dbh class and the number of snags, stumps and moose pellet groups was also recorded.

Data Analyses

Continuous variables were plotted to determine their distribution using normal probability plots (Wilkinson 1989). The natural log was taken of variables that were not normally distributed and their distribution reconsidered. Comparisons were made between normally distributed variables obtained from calving areas and available habitat plots using paired Student's t-tests. T-test values were considered significant at $\underline{P} \leq 0.10$.

Categorical variables were compared between calving areas and available habitat plots using Chi-square tests for homogeneity. In cases where > 20% of the category cells of a variable had < 5 observations, I combined similar categories prior to analysis. For variables with significant Chi-square values, I constructed Bonferroni z confidence intervals (Neu et al. 1974, Marcum and Loftsgaarden 1980, Byers et al. 1984) to determine which specific categories held significant differences between calving areas and available habitat plots. Chi-square test values were considered significant at $\underline{P} \leq 0.10$.

Discriminant Function Analysis (Edge 1985, Wilkinson 1989) was used to develop a model that would classify habitat representing calving areas. All habitat variables were used in the initial discriminant analysis. Categorical variables were transferred to a continuous scale where possible. This was done by replacing the category value with the numerical midpoint represented by that category. All continuous variables were plotted to assess normal distribution and were transformed if necessary before being included in the analysis. Remaining categorical variables were entered after collapsing categories to reduce sparse cells. Predictive variables (Univariate F test ratios with $\underline{P}$

values ≤ 0.15) were included in a reduced model.

RESULTS

Calving times and locations were determined for 11 cows during the spring of 1990 and 2 cows during the spring of 1991. The average length of stay in one spot for calving cows was 6.2 days (SD=2.1 days, range=4-9 days). Calving began between May 13 and June 3 (mean=May 24) for all cows that I monitored.

The 2 cows that were approached on foot both had calves. One of them moved upon our approach and was seen with a calf. The second one behaved very defensively and persistently herded us out of the area. She was assumed to be with calf despite the lack of a visual confirmation. Eight of the 13 animals that were included in the calving site analysis were seen with calves from the air shortly after settling down. Two of these were seen with twin calves.

During the summer months of 1990 and 1991, 13 calving areas and 130 available habitat plots were sampled.

Position Characteristics

Calving sites had significantly different aspects than available habitat ($X^2 = 76.48$, df = 7, $\underline{P} < 0.001$ (Table 5.3)). Calving areas were more likely to be on Northwest, Northeast, and Southwest slopes than available habitat plots but these differences were not significant (Table 5.4).

There was no significant difference in elevation, distance to road, distance to water, distance to human habitation (Table 5.5) between areas.

Table 5.3. Position characteristics of moose calving areas and available habitat plots based on categorical position variables.

	Calving Areas (n=13)	Available Areas (n=130)		
Variable[1]	Dominant Class (%)	Dominant Class (%)	P	df
S	0-10% (38.5)	0-10% (48.5)	0.690	4
AS	NE,NW,SW (25%each)	North (26.1)	<0.001	7

1/ Variables are defined in Table 5.1

Table 5.4. Occurrence of calving site and random site plots with various aspect classes

Aspect class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant diff. at 0.10 level *
North	0.000	0.358	Not applicable	
Northeast	0.250	0.000	$-0.169 < P_o < 0.669$	
East	0.125	0.168	$-0.195 < P_o < 0.445$	
Southeast	0.000	0.116	Not applicable	
South	0.125	0.242	$-0.195 < P_o < 0.445$	
Southwest	0.250	0.000	$-0.169 < P_o < 0.669$	
West	0.000	0.116	Not applicable	
Northwest	0.250	0.000	$-0.169 < P_o < 0.669$	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.5. Position characteristics of moose calving areas and available habitat plots based on continuous position variables.

	Calving Areas (n=13)		Available Areas (n=130)		
Variable[1]	Mean	SD	Mean	SD	P value
EL (m)	1419	179	1418	207	0.925
DRD (m)	645	729	1067	1132	0.124
DWA (m)	437	299	679	660	0.542
DHA (m)	3719	2810	3007	2737	0.485

1/ Variables are defined in Table 5.1

Calving areas had significantly more seedling-sized trees (_t_ = 1.600, 141 df, _P_ = 0.099) and significantly more moose sign (_t_ = 2.667, 141 df, _P_ = 0.009) than available habitat plots. Calving areas also had significantly more hiding cover from 30.5 m, both below 1 m (_t_ = 2.053, 139.9 df, _P_ = 0.042) and above 1 m from the ground (_t_ = 2.203, 108.2 df, _P_ = 0.030). However, there was no significant difference in Basal Area Factor, diameter at breast height of the dominant tree layer, canopy cover, number of snags or stumps, hiding cover from 70.0 m, average diameter of downfall between the 2 habitats sampled, or number of trees of any size class except seedlings (Table 5.6).

Table 5.6. Vegetation structure of moose calving areas and available habitat plots based on continuous structure variables.

	Calving Areas (n=13)		Available Areas (n=130)		
Variable[1]	Mean	SD	Mean	SD	P value
BAF	45.9	42.9	39.9	40.3	0.252
DBH (cm)	13.1	6.2	13.0	9.0	0.541
CC (%)	27.7	12.4	25.4	19.4	0.680
#P+	1.3	1.5	1.6	2.6	0.824
#P	10.6	6.4	12.6	14.2	0.367
#SAP	54.0	68.0	39.1	43.9	0.219
#SEED	50.9	34.8	45.0	63.1	0.099
#SNAGS	2.7	6.0	5.2	10.5	0.508
#STUMPS	4.5	6.6	3.2	7.7	0.105
SIGN	2.0	2.3	0.9	1.8	0.009
HC1L	94.9	4.6	91.1	16.7	0.042
HC1H	91.2	7.9	86.8	20.8	0.030
HC2L	98.9	2.1	98.5	9.4	0.369
HC2H	98.6	2.9	97.8	10.6	0.304
ADHT	33.6	15.4	37.1	21.9	0.624

1/ Variables are defined in Table 5.2

Edge was present significantly less often at calving areas than in available habitat (Table 5.7; Table 5.18). Significant differences were found for a number of classes of ground cover (Table 5.7). Calving areas had significantly more bare soil (Table 5.8), gravel (Table 5.9), rock (Table 5.10) and basal vegetation (Table 5.11) than available habitat. However, calving areas had significantly less litter and duff (Table 5.12), than available habitat.

Table 5.7. Vegetation structure and cover at moose calving areas and available habitat plots based on categorical variables.

	Calving Areas (n=13)	Available Areas (n=130)			
Variable	Dominant Class(%)	Dominant Class(%)	X^2	P	df
E	absent (92)	absent (60)	5.28	0.021	1
GC-bare	1-<5% (77)	>0-<1% (64)	22.58	<0.001	4
GC-gravel	1-<5% (54)	>0-<1% (46)	20.69	<0.001	3
GC-rock	>0-<1% (69)	0 (46)	14.52	0.006	4
GC-litter & duff	45-<55% (23) 55-<65% (23)	75-<85% (37)	29.52	<0.001	7
GC-wood	5-<15% (46)	1-<5% (35)	13.82	0.008	4
GC-moss	1-<5% (54)	1-<5% (32)	9.44	0.093	5
GC-basal veg	15-<35% (69)	5-<15% (48)	16.64	<0.001	2
LSH	5-<25% (61)	>0-<5% (55)	8.07	0.045	3
MSH	5-<25% (61)	5-<25% (56)	2.11	0.715	4
PNC	Abla (67)	Abla (64)	0.63	0.889	3
PP+	5-<25% (69)	5-<25% (36)	7.15	0.128	4
SAP	5-<25% (69)	5-<25% (38)	5.75	0.331	5
SEED	5-<25% (54)	>0-<5% (58)	9.04	0.060	4
SS	Even (100)	Even (91)	1.19	0.275	1
STR	Sapling (46)	Pole/sap(38)	3.75	0.586	5
TDC	>0-<5% (54)	>0-<5% (50)	8.95	0.030	3
TFC	5-<25% (61)	5-<25% (42)	1.87	0.393	2
TGC	>0-<5% (54)	>0-<5% (44)	3.76	0.289	3
TSC	25-<55% (69)	5-<25% (41)	9.44	0.051	4
TSH	5-<25% (61)	>0-<5% (41)	16.80	0.002	4
TTC	25-<55% (69)	5-<25% (38)	7.08	0.069	3

1/ Variables are defined in Table 5.2

Table 5.8. Occurrence of calving site plots in areas with various percentages of bare soil

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.000	0.054	Not applicable	
>0-<1%	0.077	0.638	$-0.113 < P_o < 0.267$	-
1-<5%	0.769	0.208	$0.468 < P_o < 1.070$	+
5-<15%	0.154	0.077	$-0.104 < P_o < 0.412$	
15-<55%	0.000	0.023	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.9. Occurrence of calving site plots in areas with various percentages of gravel

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.231	0.385	$-0.070 < P_o < 0.532$	
>0-<1%	0.231	0.462	$-0.070 < P_o < 0.532$	
1-<5%	0.538	0.092	$0.182 < P_o < 0.894$	+
5-<45%	0.000	0.061	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.10. Occurrence of calving site plots in areas with various percentages of rock

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.000	0.461	Not applicable	
>0-<1%	0.692	0.315	$0.362 < P_o < 1.022$	+
1-<5%	0.308	0.131	$-0.022 < P_o < 0.638$	
5-<15%	0.000	0.054	Not applicable	
15-<35%	0.000	0.038	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.11. Occurrence of calving site plots in areas with various percentages of basal vegetation

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0-<5%	0.000	0.323	Not applicable	
5-<15%	0.308	0.477	$0.002 < P_o < 0.614$	
15-<35%	0.692	0.200	$0.386 < P_o < 0.998$	+

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.12. Occurrence of calving site plots in areas with various percentages of litter and duff

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0-<25%	0.000	0.038	Not applicable	
25-<35%	0.154	0.015	$-0.120 < P_o < 0.428$	
35-<45%	0.154	0.015	$-0.120 < P_o < 0.428$	
45-<55%	0.231	0.038	$-0.089 < P_o < 0.551$	
55-<65%	0.231	0.154	$-0.089 < P_o < 0.551$	
65-<75%	0.077	0.300	$-0.126 < P_o < 0.279$	-
75-<85%	0.154	0.369	$-0.120 < P_o < 0.428$	
85-<95%	0.000	0.069	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Calving areas had more downed wood (Table 5.13) and moss (Table 5.14) than available habitat but differences between individual cells were not significant. Low shrub cover was more common at calving areas (Table 5.7) and cover over 5-<25% of the plot was significantly more common (Table 5.15). Seedling trees were more common at calving areas (Table 5.7) but the differences between individual cells were not significant (Table 5.16). Calving areas and available habitat had significantly different amounts of downfall (Table 5.7) but cell differences were not significant (Table 5.17). Total shrub cover was significantly greater at calving areas (Table 5.7) where significantly more areas had 25-<55% coverage (Table 5.19). Tall shrub cover was more common in calving areas than in available habitat (Table 5.7) and the differences were significant for plots with 5-<25% coverage; significantly fewer calving areas had no tall shrub cover (Table 5.20). Total tree cover was significantly different at the 2 areas (Table 5.7) and significantly more calving areas had 25-<55% coverage than did plots in available habitat (Table 5.21). Differences between habitats in medium shrub cover, potential natural community types, pole-sized and larger tree cover, sapling- sized tree cover, slope shape, structural class, and graminoid or forb cover were not significant (Table 5.7).

Table 5.13. Occurrence of calving site plots in areas with various percentages of downed wood

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0-<1%	0.385	0.346	$0.037 < P_o < 0.732$	
1-<5%	0.000	0.354	Not applicable	
5-<15%	0.461	0.261	$0.105 < P_o < 0.817$	
15-<25%	0.154	0.015	$-0.104 < P_o < 0.412$	
25-<45%	0.000	0.023	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.14. Occurrence of calving site plots in areas with various percentages of moss

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0	0.000	0.085	Not applicable	
0-<1%	0.385	0.185	$0.029 < P_o < 0.741$	
1-<5%	0.077	0.069	$-0.118 < P_o < 0.272$	
5-<15%	0.000	0.023	Not applicable	
15-<25%	0.000	0.315	Not applicable	
25-<75%	0.538	0.323	$0.174 < P_o < 0.902$	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.15. Occurrence of calving site and random plots in areas with various percentages of low shrub cover.

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.000	0.123	Not applicable	
0.1-<5%	0.385	0.554	$0.048 < P_o < 0.722$	
5-<25%	0.615	0.261	$0.278 < P_o < 0.952$	+
25-<75%	0.000	0.061	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.16. Occurrence of calving site and random plots in areas with various percentages of seedling size tree cover

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.077	0.208	$-0.113 < P_o < 0.267$	
0.1-<5%	0.385	0.577	$0.037 < P_o < 0.732$	
5-<25%	0.538	0.185	$0.182 < P_o < 0.894$	
25-<55%	0.000	0.023	Not applicable	
55-100%	0.000	0.008	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.17. Occurrence of calving site and random plots in areas with various percentages of total downfall cover.

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.000	0.269	Not applicable	
0.1-<5%	0.538	0.500	$0.193 < P_o < 0.830$	
5-<25%	0.461	0.177	$0.116 < P_o < 0.806$	
25-<100%	0.000	0.054	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.18. Occurrence of calving site and random site plots from which edge can and cannot be seen

Edge visible	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
yes	0.077	0.400	$-0.089 < P_o < 0.243$	-
no	0.923	0.600	$0.757 < P_o < 1.089$	+

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.19. Occurrence of calving site and random plots in areas with various percentages of total shrub cover

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0-<5%	0.000	0.046	Not applicable	
5-<25%	0.231	0.415	$-0.070 < P_o < 0.532$	
25-<55%	0.692	0.285	$0.362 < P_o < 1.022$	+
55-<75%	0.077	0.169	$-0.113 < P_o < 0.267$	
75-100%	0.000	0.085	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.20. Occurrence of calving site and random plots in areas with various percentages of tall shrub cover.

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0%	0.077	0.315	$-0.113 < P_o < 0.267$	-
0.1-<5%	0.231	0.408	$-0.070 < P_o < 0.532$	
5-<25%	0.615	0.161	$0.267 < P_o < 0.962$	+
25-<55%	0.154	0.054	$-0.104 < P_o < 0.412$	
55-<95%	0.000	0.061	Not applicable	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Table 5.21. Occurrence of calving site and random plots in areas with various percentages of total tree cover

Cover class	Proportion of calving sites (P_o)	Proportion of random sites (P_e)	Bonferroni confidence intervals for P_o	Significant difference at 0.10 level *
0-<5%	0.077	0.123	$-0.107 < P_o < 0.261$	
5-<25%	0.154	0.377	$-0.096 < P_o < 0.404$	
25-<55%	0.692	0.323	$0.372 < P_o < 1.011$	+
55-<95%	0.077	0.177	$-0.107 < P_o < 0.261$	

* + indicates greater use than expected and - indicates less use than expected, where expected values are derived from random sample

Discriminant Function Analysis

When all the variables (N=43) were included in the discriminant model, 87.4% of the plots were correctly classified as either available habitat or calving areas. The ten most predictive (Univariate F test ratio values with $\underline{P}<0.15$) variables (slope, bare soil cover, litter and duff cover, downed wood cover, basal vegetation cover, edge presence, # stumps, # seedlings, distance to road and moose sign) were used in the reduced model. This model correctly classified 89.5% of the sample as either calving or available habitat (Table 5.22). Several higher order interaction variables were considered but were not included because they did not improve the predictive value of the model.

Table 5.22. Correct classification of calving habitat and available habitat using the discriminant function equation.

Group	% correctly classified	Calving areas	Available habitat
Calving hab.	92.3	12	1
Available hab.	86.9	14	116
Total	89.5	26	117

The discriminant function equation that includes these variables is:

$$y= -0.269 \text{ SLOPE} + 0.554 \text{ BARE SOIL COVER} - 0.102 \text{ LITTER AND DUFF COVER} + 0.455 \text{ DOWNED WOOD COVER} + 0.505 \text{ BASAL VEGETATION COVER} - 0.500 \text{ EDGE} + 0.007 \text{ STUMPS} + 0.043 \text{ SEEDLINGS} + 0.051 \text{ DISTANCE TO ROADS} + 0.178 \text{ MOOSE SIGN}$$

where y=the probability that a given site will be selected as a calving site.

DISCUSSION

Coevolution of predator and prey has led to numerous, often subtle, changes in behavior that improve the chances for survival of prey individuals. Since predation is often heaviest on newborn and young individuals, strategies that reduce the chances for encounters between neonates and predators would confer a large advantage to these individuals and would be strongly selected for. Selection of a safe area for birthing could potentially limit predation if calving areas were either in areas where predators were rare, or in places that provided thick cover or a good vantage point from which predators could be sighted.

Stephens and Peterson (1984) found that moose with calves at Isle Royale, Michigan chose habitat where the chance of encountering wolves was reduced. Moose in this study were much more likely to be found on small islets which wolves only visited in the winter when ice bridges provided easy access. More moose with calves were also observed near human camps, perhaps because wolves tended to avoid humans and thereby the moose as well. Wilton and Garner (1991) concluded that moose selected higher elevation sites with little cover and easy access to escape routes. They suggested that such sites allow early detection and escape from predators, unlike sites with dense vegetation or sites in depressions. Moose calves tend to follow their mothers and going downhill requires less energy than going uphill. Similarly, Bergerud et al. (1984) found that caribou avoided neonate predation by moving to higher elevation sites specifically for calving.

Elevation was not significantly different at calving sites when compared to available habitat in my study. However, my sample was limited to calving areas that were accessible from the road. At least 9 pregnant moose migrated to higher elevations where they spent most of the spring and summer months and could only be monitored by airplane (See Chapter II).

The importance of water to moose cows with calves appears clear in areas where islands, peninsulas or large water bodies are present (Seton 1927, Clarke 1936, Peterson 1955, Bailey and Bangs 1980, Stephens and Peterson 1984). The escape value of water to moose presumably makes such sites preferable. While considerable water existed in my study area, it was primarily in relatively small rivers, streams and lakes. Water was not significantly closer to calving areas than it was to available habitats, perhaps because the escape value of small water bodies with few islands is not significant.

Selection for dense cover has been seen in some calving site research (Altmann 1958, 1963; Stringham 1974, Leptich and Gilbert 1986, Costain 1989). In areas where the terrain is either flat or densely vegetated, such sites may be the best choice for moose with neonates. In my study, several significant variables indicate that moose selected areas with heavy cover. Calving areas had more hiding cover, more tree cover, more low and tall shrub cover, more basal vegetation, and a greater number of seedling trees. Thick vegetation near the ground would hide calves and perhaps cows when they were reclining. The relatively greater hiding cover and greater tree cover would help to hide the animals at all times.

Available forage may be important to calving moose (Altmann 1963, Leptich and Gilbert 1986), however, accessible shrubs (between 15 cm and 1.35 meters) were no more common at calving sites than elsewhere in my study. Palatable shrubs are common throughout the North Fork valley, especially in clearcut areas. As a result, moose may not have needed to select for sites with a greater amount of forage than elsewhere to meet their feeding needs.

While I found considerable variation between calving areas, 12 of the 13 areas had thick cover. The route taken to becoming densely vegetated differs between sites but the end products are similar. Seven of the moose used areas that had been clearcut since the 1940's. Four of these areas had significant regeneration and stumps were the only sign of what had occurred there. The 3 other clearcut sites, were more recent and dominated by early seral stage growth. Five of the moose calved in thick forests that had not been cut. These sites ranged from seedling and sapling sized lodgepole forest to pole and greater than pole-sized spruce forest. The only calving area within Glacier National Park was in a marshy area with relatively little vegetative cover.

Considerable variability in calving sites was found by Markgren (1969) in Sweden and Addison et al. (1990) in Ontario. While significant hiding cover does appear important to North Fork moose, a much greater sample size than that in my study would be needed to determine other significant features of calving habitat. I sampled a 16-ha area within which I felt certain that calving had occurred. Examination of the precise birthing location may reveal more consistent trends on the part of moose. However, since moose calves are mobile shortly after birth but tend to remain in a restricted area for their first 20 days (Altmann

1958), the calving areas analyzed in this study seemed appropriate.

The final model of the discriminant function analysis identified 10 variables that best discriminated calving areas from available habitat. This indicates that moose have certain criteria when choosing an area for calving and that these areas are measurably different from available habitat.

In conclusion, my research indicated that moose in the North Fork select areas with considerable cover to calve. While a larger and more precise sample of calving sites would better pinpoint specific requirements, I have provided a starting point from which land managers can work to protect critical moose calving habitat.

MANAGEMENT RECOMMENDATIONS

1) Avoid darting moose twice during capture.

Two capture-related mortalities occurred, and both of these moose received 2 darts. Only take a shot when conditions are ideal and the liklihood of missing is minimal. Employ only trained and accomplished marksmen and experienced pilots for darting.

2) Maintain sapling to pole dominated stands.

Landsat data suggests that these stands are heavily used throughout the year. Schedule clearcuts so that a consistent source of these habitats remains available over the long-term.

3) Continued Census

Due to poor weather, low densities, and diffculty sexing moose, fixed-wing census efforts were unsuccessful. Agencies should support the census effort initiated by the B.C. Ministry of the Environment and encourage the development of an index of variability and sightability.

Particular attention should be given to calf:cow ratios to verify the status of the segment of the population.

4) Make hunting quotas flexible

Adult cow mortality was low but calf mortality remains unknown. Agencies should be flexible and conservative with their annual moose hunting quotas to maintain healthy sex ratios and an available prey base for other predators in the area.

5) Protect habitat with high cover value.

Calving habitat was consistently in areas with good hiding cover. Protection of potential calving sites is critical to the long-term viability of the Flathead moose population.

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APPENDICES

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APPENDIX E. Raw Census Data
- Table 1. 1990 Census results
- Table 2. 1991 Census results

APPENDIX A

Protocol for the helicopter capture and handling of moose

I. Capture method:

Due to the lack of information about moose locations in the area, a fixed-wing aircraft will be used to initially locate animals. A helicopter will be used as a firing platform and to deliver a handling crew to each immobilized animal. The proposed capture sequence is as follows:

A. Fix-wing aircraft with pilot and observer will locate moose for darting and direct the helicopter containing pilot, shooter and animal handler to the moose.

B. The helicopter will attempt to herd the moose, if necessary, to an open area.

C. The animal will be immobilized with drugs delivered via barbed syringe fired from a specially modified shotgun.

D. The animal will be observed at a distance until the drug takes effect.

E. The helicopter will deliver the handling team as close to the moose as possible.

F. Glacier Park officials will be notified prior to and following all flights.

II. Animal Immobilization and Handling

A. Moose will be immobilized with 3.9 mg Carfentanil and 2.5 mg Rompun.

B. The rectal temperature of moose will be monitored. If it exceeds 104 F, a cold water enema will be administered.

C. The moose will be treated with:

1) an antibiotic ophthalmic solution to prevent damage to the cornea;
2) a local antibacterial ointment (nitrofurazone) for the impact site;
3) an intramuscular injection of the long-acting antibiotic oxytetracycline to prevent bacterial infection;
4) an intramuscular injection of sodium selenite and Vitamin E to prevent capture myopathy.

D. Immobilized moose will be blindfolded.

E. Moose will be fitted with a motion-sensitive radio collar.

F. A lower canine tooth will be removed for aging purposes.

G. Moose will be briefly examined for abnormalities and parasites.

H. Measurements of chest girth, head length, total length, and hock length will be taken.

I. Animal handlers will administer 4 cc of Naloxone as an antagonist to Carfentanil.

J. Animals will be observed from 20-30 meters until the animal leaves the scene.

III. Injured animals:

Any animals suffering severe injury during drugging will be euthenized. The carcass of any dead moose will be left where it lies if it is at least 200 m from the road. Glacier Park officials will be promptly informed of the location of the carcass.

IV. Firearm safety:

Shooting from the helicopter will be the responsibility of Dr. Dick Kinyon, DVM. Dr. Kinyon has considerable experience in immobilizing ungulates from a helicopter. The gun will be transported unloaded and cased.

APPENDIX B

Table 1. Number of darts, induction time, time to respond to naloxone and temperature, where available, for all moose captured in this study.

Animal #	Number of darts	Induction time (min:sec)	Time to respond to Naloxone (min:sec)/amount of Naloxone given	Temperature (°C)
301	1 hit	5:50	4:00/6cc	NA
303	1 miss 1 hit	5:00	3:00/6cc	38.3
304	1 hit	3:00	4:00/6cc	38.3
305	1 hit	5:00	4:00/6cc	40.7
306	1 hit	3:50	4:00/6cc	38.9
307	1 hit	4:40	NA/6cc	NA
308	1 miss 2 hits	14:25 from 1st; 2:25 from 2nd	5:00/6cc	NA
310	1 hit	4:30	6:00/6cc	NA
311	1 hit	3:30	NA/6cc	NA
312	1 hit	10:00	NA/6cc	NA
313	1 hit	4:00	3:00/6cc	38.6
314	1 miss 1 lost 1 hit	4:00	4:00/6cc	39.6
315	1 hit	8:00	3:00/6cc	38.6
316	1 miss 1 hit	5:00	4:00/6cc	39.0
317	1 hit	2:30	9:00/6cc	38.2
318	1 hit	2:30	4:00/6cc	38.6
319	1 hit	4:00	5:00/6cc	39.2
320	1 hit	4:00	NA/6cc	38.8
321	1 hit	4:00	NA/6cc	38.8
322	1 hit	10:00	NA/6cc	39.0

Table 1. continued.

Animal #	Number of darts	Induction time (min:sec)	Time to respond to Naloxone (min:sec)/amount of Naloxone given	Temperature (°C)
323	2 hits	16:00 from 1st; 2:00 from 2nd	4:00/8cc	39.4
324	1 hit	4:20	3:00/6cc	NA
325	1 hit	2:30	4:15/6cc	NA
326	1 hit	5:00	2:00/6cc	NA
327	1 hit	3:25	3:10/6cc	NA
328	2 hits	12:40 from 1st; 0:30 from 2nd	3:30/8cc	NA
329	1 hit	2:15	2:25/6cc	38.9
330	1 blank 1 miss 1 hit	8:00	7:40/6cc	39.2
331	1 hit 2 miss 1 hit	14:10 from 1st; 2:50 from 2nd	15:25/8cc	40.9
332	1 miss 1 hit	5:40	9:40/6cc	40.7
333	3 miss 1 hit	4:00	2:40/6cc	40.6
334	1 hit	3:25	NA/6cc	38.8
335	1 hit	4:18	NA/6cc	40.0
336	1 hit	7:00	NA/6cc	39.4
337	1 hit	13:20	NA/6cc	40.6
338	1 hit	8:15	NA/6cc	38.3
339	1 hit	4:00	3:45/6cc	38.9

Table 2. Age and measurements from 37 adult cow moose captured in this study.

Animal #	Age	Total length (cm)	Head length (cm)	Neck circ. (cm)	Hock length (cm)	Chest girth (cm)
313	1	222	65	75	69	161
315	1	218	64	75	71	175
319	1	222	64	74	68	165
333	1	250	62	72	66	178
329	2	253	68	80	66	177
336	2	245	65	72	71	180
305	3	287	62	85	69	197
306	3	280	72	82	72	192
312	3	268	60	78	72	183
331	3	268	71	83	73	NA
335	3	258	71	77	73	202
337	3	248	79	79	69	185
316	4	257	73	88	75	189
324	4	240	72	68	77	193
325	4	260	72	83	75	197
339	5	265	68	70	76	190
332	6	275	71	83	71	195
304	7	247	64	73	67	176
307	7	275	74	90	73	186
338	7	250	69	90	76	194
310	7	265	59	83	77	202
314	8	255	72	85	NA	202
320	8	259	72	83	74	190
327	8	265	70	76	72	182
334	8	269	69	80	74	NA
301	9	256	73	77	71	185
303	9	267	66	76	76	181
308	9	271	63	72	73	205

Table 2. continued.

Animal #	Age	Total length (cm)	Head length (cm)	Neck circ. (cm)	Hock length (cm)	Chest girth (cm)
321	9	235	64	87	72	194
322	9	243	69	88	70	192
318	10	257	70	76	75	204
323	10	227	69	78	73	190
326	10	259	75	77	75	198
328	10	258	71	77	76	190
311	11	259	60	76	71	197
330	12	275	71	89	58	199
317	14	250	71	79	71	192
Mean	6.2	256	68	79	72	189
SD	3.5	16.3	4.7	5.8	3.8	10.5

Table 3. Moose ages, results of pregnancy tests done by rectal palpation and blood test and sightings with young for all moose captured in this study.

Animal #	Age (years)	Results of rectal palpation	Results of blood test	Visual sightings
313	1	negative	positive	no calf 1990
315	1	negative	negative	no calf 1990;calf 1991
319	1	negative	negative	no calf 1990;calf 1991
333	1	negative	negative	no visuals
329	2	positive	positive	no calf 1991
336	2	negative	positive	no calf 1991
305	3	positive	positive	calf 1990
306	3	positive	positive	calf 1990
312	3	positive	positive	no calf 1990;calf 1991
331	3	positive	positive	no calf 1991
335	3	positive	positive	no calf 1991
337	3	negative	positive	no calf 1991
316	4	positive	positive	calf 1990
324	4	positive	positive	no calf 1990
325	4	positive	positive	calves 1990
339	5	positive	positive	no visuals
332	6	positive	positive	no calf 1991
304	7	negative	negative	dropped collar
307	7	positive	positive	calf 1990
310	7	positive	positive	calf 1990
338	7	positive	positive	no calf 1991
314	8	negative	positive	capture mort.
320	8	positive	positive	calf 1990
327	8	positive	positive	calves 1990
334	8	positive	positive	no calf 1991
301	9	positive	positive	dropped collar

Table 3. continued.

Animal #	Age (years)	Results of rectal palpation	Results of blood test	
303	9	positive	positive	calf 1990;1991
308	9	positive	positive	no calf 1990
321	9	positive	positive	calf 1990
322	9	positive	positive	calf 1990
318	10	positive	positive	calf 1990
323	10	positive	positive	capture mort.
326	10	positive	positive	no calf 1990
328	10	negative	positive	no calf 1990
311	11	negative	negative	no calf 1990
330	12	positive	negative	no visuals
317	14	positive	positive	calf 1990

Table 4. Results of blood composition tests for 37 adult cow moose. Note abbreviation explanation at end of table.

#	WBC	RBC	HGB	HCT	MCV	Segs	Lymph	EOS	BASO
301	4.9	6.2	14.4	42.3	69	NA	NA	NA	NA
303	3.4	6.3	15.0	44.8	71	28	64	6	2
304	2.9	6.7	14.4	43.7	66	16	68	16	NA
305	2.1	7.5	17.7	48.5	65	NA	NA	NA	NA
306	8.5	6.6	14.5	49.2	75	NA	NA	NA	NA
307	3.4	7.5	16.6	49.1	66	24	60	14	2
308	2.8	6.2	14.7	45.7	74	24	44	28	4
310	7.9	7.6	17.2	55.1	72	20	49	30	1
311	3.7	7.8	17.6	50.7	65	40	50	8	2
312	4.7	7.8	18.7	52.4	68	20	60	20	NA
313	8.5	7.0	14.1	48.0	70	28	50	22	NA
314	7.5	7.4	15.9	49.4	68	4	40	52	4
315	4.6	6.6	15.4	44.0	67	35	64	1	NA
316	3.7	6.7	16.5	45.4	68	30	70	NA	NA
317	1.7	5.9	15.4	41.7	72	16	82	NA	NA
318	3.6	8.1	18.0	54.2	67	42	56	2	NA
319	3.4	6.7	16.6	47.2	71	20	72	4	4
320	4.3	7.0	17.2	51.1	73	36	58	8	NA
321	2.2	6.1	13.6	42.7	70	16	68	14	2
322	3.0	5.9	14.6	42.4	72	16	72	12	NA
323	8.8	7.6	16.5	52.3	70	16	46	38	NA
324	9.7	6.0	15.0	43.3	73	22	40	36	2
325	7.2	7.7	18.0	52.3	69	28	40	30	2
326	4.2	6.2	14.3	42.7	70	31	60	6	3
327	sample clotted								
328	6.2	6.8	16.5	47.4	70	20	48	32	NA
329	2.2	9.1	18.0	56.4	62	32	58	8	2

Table 4. continued.

#	WBC	RBC	HGB	HCT	MCV	Segs	Lymph	EOS	BASO
330	6.1	8.1	17.4	53.8	66	17	48	33	2
331	3.5	7.6	17.6	53.9	71	15	57	27	1
332	4.7	8.9	18.8	60.1	68	27	57	15	1
333	4.8	8.8	17.8	56.4	64	22	72	6	NA
334	3.8	8.4	18.6	57.4	68	11	85	4	NA
335	4.2	7.5	16.6	51.0	68	30	52	18	NA
336	5.5	8.4	17.3	54.0	64	22	48	22	2
337	2.7	7.6	16.6	50.9	67	18	58	24	NA
338	3.8	8.5	19.2	57.6	68	18	72	10	NA
339	3.4	8.0	17.8	53.6	67	30	58	8	4

WBC=white blood cells
RBC=red blood cells
HGB=hemoglobin
HCT=hematocrit
MCV=mean corpuscular volume
Types of white blood cells:
SEGS=segmented neutrophils
Lymph=lymphatic cells
EOS=eosyniphiles-good indicator of parasites
BASO=basophiles

Table 5. Results of blood composition tests for 37 adult cow moose. Note abbreviation definitions at end of table.

Moose #	BUN	TPRO	ALB	CA	PHOS	ALKP
301	5	9.2	3.7	9.8	3.0	63
303	7	7.1	4.5	10.0	4.8	104
304	6	7.2	4.3	9.5	4.4	525
305	4	7.2	4.8	10.5	3.8	443
306	6	10.8	3.3	9.5	6.7	6
307	9	7.1	4.5	10.7	5.0	45
308	4	7.4	4.1	9.8	5.0	456
310	10	7.4	4.4	10.4	7.4	134
311	6	7.4	4.5	10.8	6.7	327
312	9	9.5	3.9	10.7	6.9	225
313	9	9.8	3.1	9.6	7.0	138
314	6	10.9	3.8	10.7	8.4	316
315	4	6.8	4.7	10.5	5.7	241
316	11	7.8	4.7	10.3	4.9	339
317	6	7.8	4.8	11.1	4.7	326
318	6	7.7	4.8	11.1	8.2	46
319	6	7.2	4.6	11.0	6.0	143
320	5	7.6	4.8	11.0	5.2	94
321	5	8.8	4.4	10.5	5.4	221
322	6	8.8	4.2	9.8	5.4	203
323	5	9.6	4.3	10.3	5.0	82
324	5	12.1	3.8	10.4	6.8	314
325	7	9.0	4.1	10.8	5.6	391
326	6	7.6	3.6	9.7	3.9	13
327	4	7.8	4.4	11.0	5.7	242
328	4	7.8	4.3	9.3	3.6	30
329	7	6.4	4.9	9.8	10.5	213
330	4	8.7	4.5	8.9	8.3	179
331	8	7.5	4.9	10.0	8.4	206

Table 5. continued.

Moose #	BUN	TPRO	ALB	CA	PHOS	ALKP
332	6	7.8	4.9	9.8	9.7	52
333	8	6.5	4.7	10.5	9.4	309
334	7	7.3	4.6	9.3	6.7	375
335	7	7.1	4.8	9.5	7.6	10
336	7	6.7	4.9	9.6	8.6	460
337	13	7.7	5.0	8.9	5.4	286
338	10	6.9	5.2	10.2	11.2	84
339	6	6.4	4.6	9.4	12.1	18

BUN=blood urea nitrogen
TPRO=total protein
ALB=albumen
CA=calcium
PHOS=phosphorous
ALKP=alkaline phosphatase

APPENDIX C

Table 1. Dates of winter locations included in homerange calculations. Data from 1990 and 1991 were combined in homerange calculations.

Moose #	1990 Winter	1991 Winter
303	02-11-90 to 04-19-90	12-15-90 to 05-04-91
305	02-13-90 to 04-03-90	12-15-90 to 03-23-91
306	02-11-90 to 04-23-90	01-02-91 to 05-04-91
307	01-01-90 to 12-15-90	12-15-90 to 05-04-91
311	02-13-90 to 04-30-90	12-15-90 to 04-19-91
312	02-19-90 to 04-03-90	12-15-91 to 05-04-91
315	01-19-90 to 04-03-90	12-15-90 to 05-04-91
316	01-21-90 to 04-19-90	09-22-90 to 04-19-91
317	02-28-90 to 04-12-90	04-07-91 to 04-20-91 no data 01-04-91
318	01-19-90 to 04-11-90	12-15-90 to 04-19-91
319	01-18-90 to 05-22-90	11-07-90 to 06-25-91
320	01-18-90 to 04-10-90	02-07-91 to 04-07-91
321	02-23-90 to 04-19-90	10-29-90 to 02-04-91
322	01-19-90 to 04-03-90	no data
329	no data	02-20-91 to 05-17-91
330	no data	12-20-90 to 06-04-91
331	no data	12-20-90 to 05-31-91
332	no data	12-20-91 to 05-29-91
337	no data	12-20-91 to 05-04-91

Table 2. Dates of summer locations used in homerange calculations. Locations from 1990 and 1991 were combined for homerange calculations.

Moose #	Summer 1990	Summer 1991
303	04-30-90 to 10-29-90	05-14-91 to 08-16-91
305	4-30-90 to 10-29-90	04-07-91 to 08-16-91
306	05-09-90 to 12-15-90	05-14-91 to 08-1691
307	04-30-90 to 10-29-90	05-14-91 to 08-16-91
311	05-19-90 to 10-29-90	05-14-91 to 08-16-91
312	05-26-90 to 10-08-90	05-22-91 to 08-16-91
315	04-19-90 to 10-29-90	05-14-91 to 08-16-91
316	05-23-90 to 09-12-90	05-14-91 to 08-29-91
317	04-30-90 to 10-17-90	05-14-91 to 08-16-91
318	04-19-90 to 10-29-90	05-14-91 to 08-16-91
319	05-31-90 to 10-17-90	07-15-91 to 08-16-91
320	05-09-90 to 10-17-90	05-06-91 to 08-16-91
321	04-30-90 to 10-17-90	killed March 91
322	04-19-90 to 06-14-90	drop collar June 90
329	no data	05-22-91 to 09-12-91
330	no data	06-18-91 to 08-16-91
331	no data	07-02-91 to 08-16-91
332	no data	06-01-91 to 08-16-91
337	no data	05-14-91 to 08-16-91

Table 3. Individual moose home range sizes and number of locations used in each (N).

moose #	N-HHR	95% HHR (km^2)	75% HHR (km^2)	N-MCP	100% MCP (km^2)
308	74	108	41	75	512
310	44	64	31	51	43
325	32	35	26	32	37
326	67	18	11	71	17
327	59	53	30	62	48
328	63	736	224	66	109
333	24	37	22	27	23
334	28	17	13	28	52
335	16	84	42	16	51
336	12	129	52	13	59
338	22	14	11	12	20
339	12	14	12	12	20
Mean	38	109	43	39	83
SD	23	201	59	25	138
303sum	33	173	91	35	119
305sum	38	49	27	41	30
306sum	38	97	57	39	71
307sum	28	49	30	30	39
311sum	31	33	20	34	25
312sum	22	105	59	24	57
315sum	30	209	104	31	123
316sum	16	41	26	16	32
317sum	35	46	16	36	40
318sum	28	56	27	33	31
319sum	20	70	57	20	51
320sum	30	74	36	35	333
321sum	17	109	51	20	38
322sum	9	2	0.8	9	1

Table 3. continued

moose #	N-HHR	95% HHR (km^2)	75% HHR (km^2)	N-MCP	100% MCP (km^2)
329sum	10	58	39	10	38
330sum	11	1	0.7	11	4
331sum	12	17	14	12	15
332sum	10	34	12	10	33
337sum	10	38	25	11	17
Mean-sum	22	66	36	24	58
SD	10	54	28	11	749
303win	22	133	85	23	92
305win	12	37	19	12	27
306win	17	27	16	17	17
307win	19	89	41	20	37
311win	17	15	7	17	8
312win	12	79	20	13	34
315win	13	25	13	13	16
316win	54	67	40	54	53
317win	10	1	0.7	10	1
318win	20	23	14	20	19
319win	33	435	167	36	108
320win	19	246	124	20	68
321win	25	128	63	26	83
322win	8	6	4	8	7
329win	10	19	17	10	62
330win	10	12	9	10	7
331win	10	33	13	11	18
332win	12	16	11	12	13
337win	11	14	7	11	13
Mean-win	18	74	35	18	36
SD	11	106	45	11	32

APPENDIX D

Table 1. Percent of 8 elevation classes found in available habitat and mean percent values from 11 non-migratory moose home ranges, with associated t-values. * indicates t-values that are significant at the 0.05 level.

Elevation class (m)	% in available habitat	Ave. % in moose habitat	t-value
<1000	0.18	0.05	-2.97*
1000-1200	8.82	6.20	-1.10
1201-1400	47.82	66.36	3.69*
1401-1600	20.42	18.90	-0.52
1601-1800	13.19	6.74	-2.80*
1801-2000	6.66	1.50	-7.14*
2001-2200	2.36	0.25	-10.96*
>2201	0.55	0.00	-131.81*

Table 2. Percent of 8 elevation classes found in available habitat and mean percent values from winter ranges of 18 migratory moose with associated t-values. * indicates t-values that are significant at the 0.05 level.

Elevation class (m)	% in available habitat	Ave. % in moose habitat	t-value
<1000	15.70	1.30	-11.77*
1000-1200	4.03	15.72	1.68
1201-1400	16.04	71.96	7.38*
1401-1600	15.43	8.91	-1.98
1601-1800	17.91	1.33	-21.05*
1801-2000	17.21	0.55	-39.85*
2001-2200	10.20	0.21	-64.27*
>2201	3.48	0.03	-153.07*

Table 3. Percent of 8 elevation classes found in available habitat and mean percent values from summer ranges of 18 migratory moose with associated t-values. * indicates t-values that are significant at the 0.05 level.

Elevation class (m)	% in available habitat	Ave. % in moose habitat	t-value
<1000	15.70	2.03	-6.75*
1000-1200	4.03	0.00	0.00
1201-1400	16.04	13.88	-0.36
1401-1600	15.43	19.95	1.77
1601-1800	17.91	31.21	3.99*
1801-2000	17.21	24.14	1.97
2001-2200	10.20	7.14	-1.99
>2201	3.48	1.56	-3.13*

Table 4. Percent of 7 slope classes found in available habitat and mean percent values from 11 annual non-migratory moose home ranges with associated T-values. * indicates T-values that are significant at the 0.05 level.

Slope class	% in available habitat	Ave. % in moose habitat	T-value
0-10%	49.65	57.35	1.70
11-20%	25.23	26.59	0.63
21-30%	15.95	11.76	-2.15*
31-40%	7.78	3.83	-3.63*
41-50%	1.13	0.34	-6.46*
51-60%	0.21	0.07	-7.83*
61-70%	0.06	0.06	0.41

Table 5. Percent of 7 slope classes found in available habitat and mean percent values from winter ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Slope class	% in available habitat	Ave. % in moose habitat	T-value
0-10%	37.58	78.69	13.42*
11-20%	20.24	16.50	-2.10
21-30%	18.84	3.57	-14.86*
31-40%	15.62	0.98	-22.86*
41-50%	5.85	0.20	-39.89*
51-60%	1.48	0.05	-41.89*
61-70%	3.79	0.02	-32.29*

Table 6. Percent of 7 slope classes found in available habitat and mean percent values from summer ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Slope class	% in available habitat	Ave. % in moose habitat	T-value
0-10%	37.58	22.98	-2.88*
11-20%	20.24	24.99	2.65*
21-30%	18.84	26.95	3.06*
31-40%	15.62	18.70	1.45
41-50%	5.85	5.09	-0.72
51-60%	1.48	1.39	-0.20
61-70%	3.79	0.22	-2.35*

Table 7. Percent coverage of 9 aspects found in available habitat and mean percent values from 11 non-migratory moose home ranges with associated T-values. * indicates T-values that are significant at the 0.05 level.

Aspect	% in available habitat	Ave. % in moose habitat	T-value
Flat	3.04	3.01	-0.04
N	10.10	14.46	5.05*
NE	15.83	22.78	3.87*
E	15.00	17.37	3.61*
SE	13.38	15.53	1.70
S	11.22	13.92	2.26*
SW	10.66	5.62	-5.88*
W	12.81	2.59	-19.36*
NW	7.96	4.72	-5.59*

Table 8. Percent coverage of 9 aspects found in available habitat and mean percent values from winter ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Aspect	% in available habitat	Ave. % in moose habitat	T-value
Flat	1.55	6.19	5.92*
N	25.21	7.61	-12.33*
NE	11.32	12.58	0.60
E	11.23	14.33	2.41*
SE	10.46	13.14	2.72*
S	10.58	11.69	0.63
SW	10.71	13.10	1.13
W	10.27	16.22	2.30*
NW	8.67	6.62	-2.08

Table 9. Percent coverage of 9 aspects found in available habitat and mean percent values from summer ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Aspect	% in available habitat	Ave. % in moose habitat	T-value
Flat	1.55	1.21	-0.86
N	25.21	14.71	-4.54*
NE	11.32	15.07	3.85*
E	11.23	13.01	1.70
SE	10.46	13.83	1.57
S	10.58	12.85	3.97*
SW	10.71	12.57	1.16
W	10.27	8.43	-1.35
NW	8.67	8.27	-0.38

Table 10. Percent of 4 road types found in available habitat and mean percent values from annual ranges of 11 non-migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Road type	% in available habitat	Ave. % in moose habitat	T-value
Primary	7.97	2.51	-4.55*
Secondary	13.98	14.64	0.32
Tertiary	13.84	11.84	-0.77
Closed	64.31	71.01	1.71

Table 11. Percent of 4 road types found in available habitat and mean percent values from winter ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Road type	% in available habitat	Ave. % in moose habitat	T-value
Primary	6.47	11.77	1.84
Secondary	11.39	21.58	2.02
Tertiary	10.97	13.66	1.01
Closed	71.17	52.99	-3.30*

Table 12. Percent of 4 road types found in available habitat and mean percent values from summer ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Road type	% in available habitat	Ave. % in moose habitat	T-value
Primary	6.47	5.15	-0.70
Secondary	11.39	8.56	-1.45
Tertiary	10.97	11.76	0.86
Closed	71.17	72.80	0.33

Table 13. Percent of 2 river types found in available habitat and mean percent values from annual ranges of 11 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

River type	% in available habitat	Ave. % in moose habitat	T-value
Definite	48.69	52.05	0.70
Intermittent	51.31	47.95	-0.70

Table 14. Percent of 2 river types found in available habitat and mean percent values from winter ranges of 18 non-migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

River type	% in available habitat	Ave. % in moose habitat	T-value
Definite	30.38	68.94	11.21*
Intermittent	69.62	31.06	-11.21*

Table 15. Percent of 2 river types found in available habitat and mean percent values from summer ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

River type	% in available habitat	Ave. % in moose habitat	T-value
Definite	30.38	26.70	-0.91
Intermittent	69.62	73.30	0.91

Table 16. Percent of 8 cover classes found in available habitat and mean percent values from annual ranges of 11 non-migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Cover class	% in available habitat	Ave. % in moose habitat	T-value
Marsh	1.26	2.77	3.58*
Bare Soil	5.99	7.11	1.78
Rock	2.40	1.14	-7.35*
Grass	4.93	4.24	-0.59
Shrub	9.25	8.94	-0.23
Sapling	10.95	16.60	2.96*
Open Conifer	4.37	6.10	2.69*
Conifer	60.49	52.86	-2.79*

Table 17. Percent of 8 cover classes found in available habitat and mean percent values from winter ranges of 18 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Cover class	% in available habitat	Ave. % in moose habitat	T-value
Marsh	2.30	1.41	-2.97*
Bare Soil	9.03	7.19	-3.00*
Rock	2.88	2.07	-3.91*
Grass	6.66	5.89	-0.95
Shrub	12.05	10.66	-1.21
Sapling	11.62	11.92	0.20
Open Conifer	4.95	3.38	-3.49*
Conifer	47.69	57.21	4.48*

Table 18. Percent of 8 cover classes found in available habitat and mean percent values from summer ranges of 17 migratory moose with associated T-values. * indicates T-values that are significant at the 0.05 level.

Cover class	% in available habitat	Ave. % in moose habitat	T-value
Marsh	2.30	4.40	2.44*
Bare Soil	9.03	6.30	-3.75*
Rock	2.88	2.00	-2.56*
Grass	6.66	5.32	-2.19
Shrub	12.05	12.56	0.34
Sapling	11.62	16.73	3.30*
Open Conifer	4.95	5.48	1.41
Conifer	47.69	46.27	-0.34

APPENDIX E

Table 1: Raw values and totals from 5 flights over 4 areas in the North Fork of the Flathead River, Winter 1990-91. Numbers in parentheses refer to the number of radio-collared individuals in the sample.

Date	obser[1]	location[2]	male	female	calf	unknown
12/15/90	L	A	3	5 (2*)	3	6
12/20/90	L	A	2	1	0	3
01/02/91	F	A	1	2 (1*)	2	4
01/19/91	B	A	0	1	0	0
01/23/91	F	A	0	0	0	0
Total			6	9 (3*)	5	13
12/15/90	L	B	2	3	0	0
12/20/90	L	B	1	3 (1*)	2	1
01/02/91	F	B	2	1 (1*)	0	2
01/19/91	B	B	0	0	0	0
01/23/91	F	B	0	0	0	0
Total			5	8 (2*)	2	3
12/20/90	L	C	3	2 (1*)	2	9
01/02/91	F	C	0	0	0	3
01/19/91	B	C	0	1	0	5
01/23/91	F	C	0	1	2	12
Total			3	4 (1*)	4	29
12/20/90	L	D	0	0	0	0
01/02/91	F	D	1	1 (1*)	0	2
01/23/91	F	D	0	0	0	0
Total			1	1 (1*)	0	2

1/ Observers: B=Diane Boyd
F=Mike Fairchild
L=Margaret Langley

2/ Description of Locations:
Area A: large clearcut east of Flathead Rd and north of Upper Sage Ck Rd.
Area B: large N-S clearcut w of Flathead Rd.
Area C: River bottom S of Flathead bridge to Howell Creek
Area D: Clearcut N of Whale Creek Rd, S of Hornet Creek Rd.

Table 2. Raw data and summary statistics for 2 flights over 6 areas and their surrounding areas (sur) in the North Fork of the Flathead River, Winter 1991-92. Where no data are listed, ie. areas A,B, and D no moose were seen or heard. See Chapter IV, methods section for technique descriptions.

Date	Observer[1]	Location[2]	Male	Female	Calf	Unknown
01/31/92	F-A	C	0	2+1*	2	3
02/03/92	F-A	C	0	0	0	1
Total			0	3	2	4
01/31/92	F-A	E	0	1	1	2
02/03/92	F-A	E	0	0	0	5
Total			0	1	1	7
01/31/92	F-A	A-sur	0	0	0	1
02/03/91	F-A	A-sur	0	0	0	1
01/31/92	F-A	C-sur	0	0	0	3
02/03/91	F-A	C-sur	0	2*	0	0
01/31/92	F-A	E-sur	0	0	0	2
02/03/91	F-A	F-sur	0	1*	0	0

Weather and times from the 2 flights follow:

Date	Weather	Cloud Cover	Time
01/31/91	High overcast	95%	14:00-18:00
02/03/92	Clear blue sky/35 F	0%	09:10-13:15

1/ Observers: A=Jerry Altermatt F=Mike Fairchild

2/ Description of Locations:

Area A: Large clearcut east of sharp curve in Lower Flathead Rd. and west of Sage Ck.

Area B: Long and narrow clearcut west of Lower Flathead Rd. and northwest of Sage Ck. -Flathead Rd. intersection

Area C: Clearcut north of Whale Ck. Rd., west of Tepee Ck. Rd. and south of Kintla Overlook Loop Rd.

Area D: Riparian area along Flathead River, south of Flathead Bridge and north of mouth of Howel Ck.

Area E: Riparian area along Flathead River north of mouth of Middlepass Ck. and south of mouth of Kate Ck.

Area F: Riparian area along Sage Ck. north of Sage Ck. Bridge to the north end of Sage Ck. Airstrip.