SUSITNA HYDROELECTRIC PROJECT
FINAL REPORT
BIG GAME STUDIES
VOL. II—MOOSE UPSTREAM

Warren B. Ballard
and
Jackson S. Whitman
Alaska Department of Fish & Game
333 Raspberry Road
Anchorage, Alaska 99518

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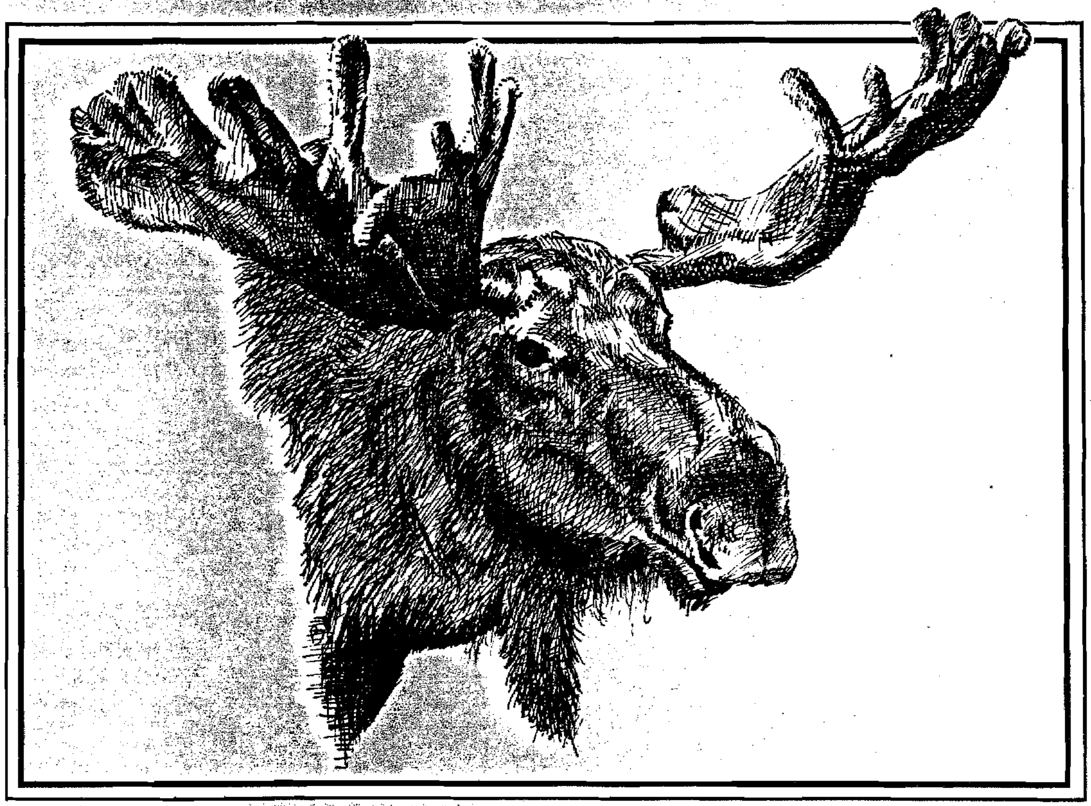

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PREFACE

Between January 1980 and June 1986, the Alaska Power Authority (APA) contracted with the Game Division of the Alaska Department of Fish and Game (ADF&G) to provide field data and recommendations to be used for assessing potential impacts and developing options for mitigating impacts of the proposed Susitna Hydroelectric Project on moose, caribou, brown bear, black bear, Dall sheep, wolf, wolverine, and belukha whales. ADF&G was only one of many participants in this program. Information on birds, small mammals, furbearers, and vegetation was collected by the University of Alaska and private consulting firms.

Formally, ADF&G's role was to collect data which could be used to describe the baseline, preproject conditions. This information was supplemented with data from other ADF&G studies. Baseline conditions were defined to include processes which might be sufficiently senstive to either direct or indirect project-induced impacts to alter the dynamics of the wildlife populations. The responsibility of impact assessment and mitigation planning was assigned by APA to several private consulting firms. ADF&G staff worked closely with these firms, but only in an advisory capacity.

The project was cancelled before the impact assessment and mitigation planning processes were complete. In an effort to preserve the judgments and ideas of the authors at the termination of the project, the scope of this report has been expanded to include material relating to impact assessment and mitigation planning. Statements do not necessarily represent the views of APA or its contractors. Conjectural statements sometimes are included in the hope that they may serve as hypotheses to guide future work, should the project be reactivated.

The following list of reports completely cover all of the Game Division's contributions to the project. It should not be necessary for the reader to consult the many progress reports.

<u>Moose</u>

Modaferri, R. D. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. I - Moose - Downstream. Alaska Dept. of Fish and Game.

Ballard, W. B. and J. S. Whitman. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. II - Moose - Upstream. Alaska Dept. of Fish and Game.

Becker, E. F. and W. D. Steigers. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. III - Moose forage biomass in the middle Susitna River basin, Alaska. Alaska Dept. of Fish and Game.

Becker, E. F. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. V - Moose Carrying Capacity Estimate. Alaska Dept. of Fish and Game.

Caribou

Pitcher, K. W. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IV - Caribou. Alaska Dept. of Fish and Game.

Black Bear and Brown Bear

Miller, S. D. 1987. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. VI - Black Bear and Brown Bear. Alaska Dept. of Fish and Game.

Wolf

Ballard, W. B., J. S. Whitman, L. D. Aumiller, and P. Hessing. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. V - Wolf. Alaska Dept. of Fish and Game. 44pp.

Ballard, W. B., J. S. Whitman, and C. L. Gardner. 1987. Ecology of an exploited wolf population in southcentral Alaska. Wildlife Monographs No. __ (In press).

Wolverine

Whitman, J. S. and W. B. Ballard. 1984. Susitna Hydroelectric Project, Big Game Studies. 1983 Annual Report. Vol. VII - Wolverine. Alaska Dept. of Fish and Game. 25pp.

Dall Sheep

Tankersley, N. G. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. VIII - Dall Sheep. Alaska Dept. of Fish and Game. 91pp.

Balukha Whale

Calkins, D. 1984. Susitna Hydroelectric Project, Big Game Studies. Final Report. Vol. IX - Belukha Whale. Alaska Dept. of Fish and Game. 16pp.

SUSITNA HYDROELECTRIC PROJECT
BIG GAME STUDIES
VOL. II - MOOSE-UPSTREAM

DYNAMICS OF MOOSE POPULATIONS ALONG THE MIDDLE SUSITNA RIVER IN RELATION TO PROPOSED HYDROELECTRIC DEVELOPMENT IN SOUTHCENTRAL ALASKA

BY

WARREN B. BALLARD, Alaska Department of Fish and Game, P. O. Box 1148, Nome, AK 99762

JACKSON S. WHITMAN, Alaska Department of Fish and Game, 333 Raspberry Road, Anchorage, AK 99518

SUMMARY

From 1976 through 1985, moose (Alces alces) demography, movements, and habitat use were studied in relation to a proposed hydroelectric development project along the middle Susitna River in southcentral Alaska. History of the moose population from the 1940s to initiation of these studies was reviewed. The moose population increased in the 1940s and 1950s due to mild winters, favorable range conditions, and low rates of mortality from hunting and predation. The population peaked in 1963 and began declining following a series of severe winters and high predation. Record low levels were reached by 1975.

Between 1976 and 1985, 463 moose (61 5- to 10-month-old calves, 184 adults and 218) neonates were captured, processed, and equipped with either radio-collars or visual collars to aid in determining the causes of population decline and to assess potential impacts of hydroelectric development. Movements of radio-collared animals in relation to two proposed impoundments were used to delineate the boundaries of zones where moose would be impacted. The moose population within the zones was censused in 1980 and 1983, and data concerning sex-age composition were collected annually. Within a 6,522 km² area the moose population was estimated at 4,500 in 1980 (0.69 moose/km²), whereas in 1983, the moose population was estimated at 4,573 within a 7,586 km² area (0.60 moose/km²). Average age of adult cow moose was 7.7 years. Although average age of captured moose increased as the study progressed, differences were attributed to sampling biases associated with study of different subpopulations. Pregnancy rates were initially high, averaging 81%, but apparently declined as the project progressed due to inaccurate diagnoses and study of the same individual moose

which became older and less productive. Parturition occurred between 18 May and mid-June with 96% occurring between 24 May and 10 June. Twinning rates averaged 38%. Overall, neonatal sex ratios were skewed in favor of males, but this difference was due to a large unexplained difference in 1977.

Two hundred and eighteen neonates were captured and radio-collared to determine causes of mortality within 4 areas during 1977, 1978, 1979, and 1984. Predation accounted for 83% of total mortality. Most mortality occurred during the first 6 weeks of life. Brown bears (Ursus arctos) were the greatest (73%) cause of mortality followed by miscellaneous factors (12%). Rates of mortality between collared and uncollared calves were similar. Within the impoundment zones, black bears (Ursus americanus) were more dense than brown bears, but the latter were still the most important source of calf moose mortality. Twin calves had lower survival rates than single calves. Survival through 5 months of age averaged 26%. From 6-12 months of age during severe winters, males had lower survival rates than females. There were no differences in survival rates between sexes during mild winters. Annual calf survival rates averaged 22 and 17% for females and males, respectively. Yearling and adult female annual survival averaged 95%. Lowest annual survival (92%) occurred during a severe winter. Predation accounted for 8 of 11 mortalities when cause of death was known. Mortalities were equally divided between snow and snow-free periods. Adult bulls had lower survival rates than yearling bulls because the latter were protected from human harvest from 1980-86. Adult bulls (≤2 yrs) had low rates of natural mortality (excluding hunting). Mean group size was greatest in October and lowest in August.

Three major periods of moose movement were readily identifiable: autumn, spring, and during the rut. In late September and early October some moose made distinctive movements for breeding purposes. Dates of autumn migration to winter range were variable, but apparently coincided with first major snowfall. Spring migration was also variable and appeared related to snowmelt. Resident moose had overlapping seasonal ranges, whereas migratory moose had nonoverlapping ranges separated by as much as 93 km. Home range use was traditional. Seasonal and total home range sizes of resident moose were correlated with number of relocations and appeared adequately defined when numbers of relocations >13 and >39, respectively. Migratory moose home range sizes were not positively correlated with numbers of relocations. Summer, autumn, and total home range sizes of migratory moose were larger than those of resident moose, but winter home range sizes were not different. Total home range size of migratory moose averaged 505 km², whereas resident home ranges averaged

290 km²; both were larger than those reported in the literature. A more representative method of estimating home range size was described and compared with the traditional method. Average age of separation of offspring from adults was 14 months. Following initial separation, thirty-three percent of offspring temporarily reassociated with parents from 1-6 occasions. Sixty percent of 15 offspring partially or fully dispersed from the parental home range. More males than females dispersed. Home range sizes of parents and offspring were correlated. Males had larger home ranges than females.

Greatest seasonal changes in moose distribution and density within the proposed impoundments occurred in the Watana and Jay Creek drainages. Numbers of moose within the Watana impoundment during winters of moderate severity ranged from 42-580 (0.2-2.3 moose/km²). In comparison, numbers of moose within the Devil Canyon impoundment were relatively low, ranging from 0.5-1.0 moose/mi² (0.2-0.4 moose/km²). Both spruce (<u>Picea</u> spp.) and willow (<u>Salix</u> spp.) vegetation types were used disproportionately to their availability. Moose did not select habitats strictly on the basis of browse availability. During winter, areas with relatively low browse biomass were heavily used by moose, apparently because the browse that was present was more available due to shallower snow depths. Moose occurred at lowest elevations during April and highest elevations during the rut. Elevations from 1,800-3,000 ft (549-914 m) were used by moose disproportionate to availability. Annually, north and south facing slopes were preferred. Relocations of radio-collared moose were heavily biased toward daylight observations during which time they were usually bedded. Highest frequency of feeding observations occurred during summer.

An index for estimating winter severity early in the year and which also allowed comparisons of individual winters was developed and described. Use of different elevations by moose during winter was correlated with winter severity. Lower elevations were used as winters became more severe in terms of total snow depth. It was predicted that during a severe winter 50% of the radio-collared moose would occur within the areas to be inundated.

Potential impacts to moose as a result of the proposed project were classified into 3 categories: important, potentially important, and unimportant. Thirteen important impacts to moose were identified and discussed. These included such impacts as permanent and temporary habitat loss, displacement and disruption of movements, increases in accidental and human-caused mortality, and increased mortality from predation. Of seven identified potentially important impacts, possible changes in climate within an unknown radius of the impoundments could be the most important. Five unimportant impacts were identified and discussed. Several approaches were used in an attempt to quantify the numbers of moose which potentially would be lost if the hydroelectric project were built. A subjective appraisal of the numbers of moose to be lost from 12 moose subpopulations indicated that about 1300 might be lost as a result of the project. This latter estimate was similar to an estimate (second approach) of the habitat carrying capacity within the impoundments during a severe winter. Population modeling (third approach) indicated that minor changes in several key population parameters as a result of the project would be sufficient to either cause or accentuate a population decline and perhaps help to maintain the population at lower levels. Actual losses to the moose population, however, can not be accurately predicted at this time. Importance of the impoundments to moose during severe winters could be significantly different than that observed during this study. A number of post impoundment studies that will be necessary to adequately quantify losses to the moose population as a result of the project are briefly summarized.

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INTRODUCTION

Historically, Game Management Unit (GMU) 13 has been one of the most important moose hunting and viewing areas in Alaska. Between 1963 and 1975 about 18% of the statewide harvest came from the area. The moose herd was thought to have increased during the 1940s and 1950s (Bishop and Rausch 1974). Estimates of sex-age composition were initiated in 1952, and annual surveys have been conducted in selected areas since 1955. Moose numbers were thought to have increased, apparently in response to favorable range conditions, low numbers of predators, and relatively low human harvests. Bishop and Rausch (1974) stated the concensus was human harvests only slightly affected sex and age ratios during that time period.

The moose population apparently peaked in 1960 and then began declining (Bishop and Rausch 1974). There appeared to be an inverse relationship between numbers of wolves (Canis lupus) and moose. Wolf numbers were reduced to about 12 in the entire basin through predator control and aerial hunting activities (Rausch 1967, 1969). Termination of those activities resulted in a large wolf population increase (peaked 1965) and an apparent moose population decline (Bishop and Rausch 1974). Numbers of both brown and black bears were also thought to have been reduced during predator control activities, which may also have contributed to the moose population increase.

Severe winters contributed to the moose population decline (Bishop and Rausch 1974). With the exception of winter 1955-56, moose productivity was thought to be high and mortality low until winter 1961-62 when the population began declining. A severe winter also apparently occurred in 1965-66, but its effects were poorly understood (op. cit.). A severe winter with record snowfall occurred in 1971-72, and mortality was high; subsequent calf production and calf survival in 1972 were low.

Between 1962 and 1974, hunters became more efficient at harvesting moose due to increased use of aircraft and all terrain vehicles. Thus, while the moose population declined, moose harvests remained "almost constant" (Bishop and Rausch 1974). They concluded that, after severe winters, the combined effects of mortality by humans and wolves had the capacity to preclude moose population growth and could have contributed to further moose population declines.

A severe winter occurred during 1974-75, further reducing calf survival, and the moose population appeared to continue its decline. Drastic reductions in human harvests appeared necessary for the moose population to recover. If predation was responsible for keeping the moose population at low levels, reductions in predator numbers would also result in a moose population increase. Predator-prey investigations were conducted from 1976-1985 and have been summarized by Ballard et al. (1981a,b, 1982a, and Ballard and Whitman (1987).

While the GMU 13 moose population was undergoing these fluctuations, studies were conducted concerning the feasibility of hydroelectric development along the Susitna River. In 1948, Kaiser Aluminum Co. first examined the feasibility of hydroelectric development of the Susitna River. Since that time development proposals have ranged from a 2-12 dam system (Taylor and Ballard 1979). Most recently, the Devil Canyon-Watana Creek 2-dam system was selected by the U. S. Army Corps of Engineers (Corps) as the most viable of several development alternatives. Limited funds became available for studies of moose distribution in 1975 in relation to the proposed impoundments (McIlroy 1975). The Corps increased the amount of funding in 1976, and results of these efforts were presented by Taylor and Ballard (1979) and Ballard and Taylor (1980). During the severe winter of 1978-79, few funds were available for studying moose; this became important because the proposed impoundment areas were thought to be important habitat during severe winters.

During the late 1970s, the state of Alaska took over responsibility from the Corps for power development along the Susitna River. The State, recognizing the importance of wildlife resources in the area, initiated a series of studies in 1980. Detailed baseline information on moose numbers and ecology was sought to both adequately predict and monitor the effects of large-scale hydroelectric development on moose populations and to mitigate impacts.

The present study was conducted for two reasons: (1) to determine the causes of moose population decline in portions of GMU 13 since 1960, and (2) to determine the potential impact of Susitna hydroelectric development (2-dam system, Watana, and Devil Canyon impoundments) on moose. This report summarizes the results of studies from October 1976 through January 1986, including data from other GMU 13 studies pertinent to evaluating potential impacts of hydroelectric development.

ACKNOWLEDGEMENTS

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STUDY AREA

The original study area included most tributaries which drain into the Susitna River upstream of the mouth of Portage Creek

(Fig. 1). The boundary generally followed the Denali Highway on the north; the Maclaren River and Tyone, Susitna, and Louise Lakes systems on the east; the Glenn Highway and Little Nelchina River on the south; and drainages upstream of Portage Creek on the west (Ballard et al. 1982b). Reductions in the study area were made in 1983 (Ballard et al. 1983) when different zones of impact were identified.

Data from radio-collared moose, which either seasonally or annually occupied areas to be directly altered by operation and maintenance of the Watana and Devil Canyon impoundments, were used to delineate an area where moose would be directly impacted. Home range polygons (Mohr 1947) were delineated for each moose which utilized either land to be inundated or lands which were to be altered by major facilities, encampments, or borrow pits. Outermost points of all these polygons were connected and used to delineate the border of a primary impact zone (Fig. 1). In addition, a secondary impact zone was delineated on the assumption that moose displaced from the primary impact zone would compete with moose occupying the secondary zone. Although moose in the secondary impact zone were not known to use areas directly impacted by the proposed project, their home range polygons overlapped home ranges of moose that used the primary impact zone. Similarly, a tertiary impact zone was delineated where overlaps with the secondary zone occurred, assuming further competition from displaced moose (Fig. 1).

Vegetation, topography, and general climate of the area were described by Skoog (1968), Bishop and Rausch (1974), Ballard and Taylor (1980), Ballard (1982) and Ballard et al. (1987). Specific vegetation descriptions of the impoundment areas were provided by Becker and Steigers (1987).

METHODS

Tagging and Relocating Moose

Moose were darted from a Bell 206-B (Jet Ranger) helicopter, except neonates which were captured on foot (Ballard et al. 1979). Three combinations of drugs were used to immobilize adult and short yearling moose: (1) succinylcholine chloride with hyaluronidase (Wydase), (2) etorphine hydrochloride (M-99) with and without xylazine hydrochloride (Rompun), and (3) carfentanil (Franzmann et al. 1984).

Captured moose were marked with a radio-collar, a visual numbered canvas collar (Franzmann et al. 1974), or both. Sixty-one 5-10 month old calves, 115 adults, and 218 neonates were radio-collared while 69 adults were equipped with only canvas collars. All adults were aged by extracting a lower incisor tooth which was processed according to methods described by Sergeant and Pimlott (1959). Each moose was ear-tagged with numbered Monel metal tags. During spring, all female yearling and adult moose were rectally palpated (Roberts 1971) to determine pregnancy status.

Two types of receivers were used during the course of the study: (1) 4-band, 48-channel portable receiver manufactured by AVM Instrument Co. (Champaign, IL), and (2) portable programmable 2,000-channel scanning receiver manufactured by Telonics (Mesa, AZ). Radio-collared moose were relocated from either a Piper PA-18 (Supercub) or STOL-equipped Cessna 180 or 185 fixed-wing aircraft. Each aircraft strut was equipped with a 3-element yagi antennae. A control box within the aircraft allowed monitoring of the strength of radio signals from both antennae or from either side of the aircraft. By switching from antenna to antenna, the direction of strongest signal was determined and the aircraft piloted in that direction until the signal became stronger on the opposite antenna. This resulted in an initial series of broad slow turns until the animal was close, at which time the search pattern developed into steep, sharp turns to visually observe the animal.

Moose relocations were plotted on 1:63,360-scale USGS maps. Time, behavior, numbers of associates (group size determined for animals within approximately 1,300 ft (400 m) of instrumented individuals) by sex and age class, and vegetation type according to Viereck and Dyrness (1980) were recorded on standardized forms. Activity patterns were divided into 4 categories: foraging, bedded, standing, and other.

Sixty-five moose originally captured as 5 10-month-old calves and 115 adults were located on 5,421 occasions ($\bar{x}$ = 30 relocations per moose) from October 1976 through January 1986. Numbers of relocations per individual ranged from 2, for radio-collared short yearlings which slipped collars or starved, to 104 for an adult female. Neonate calves were relocated and visually observed on hundreds of occasions and their signals monitored on thousands of occasions (Ballard et al. 1979).

Population Trends and Density

Autumn moose sex-age composition surveys conducted from fixed-wing aircraft have been conducted annually in GMU 13 since 1955 in 16 different count areas (Fig. 2). These low-intensity flights generally last >1 minute (min) per mi^2 (0.4 min/km^2). Flight patterns consist of transects flown at 0.8-1.2 km widths between 300-500 ft (91-152 m) altitude on flat terrain or transects flown along contour intervals in hilly and mountainous regions. Such surveys are conducted after the first major autumn storm which provides complete snow cover usually during late October through early December. Surveys are usually completed before bulls shed their antlers. Moose are sexed and aged according to relative size, presence or absence and configuration of antlers, and vulva patch. Bulls with spiked, forked, or small palmated antlers less than 30 inches wide were assumed to be yearlings. Total moose observed per hour, bull:100 cow ratios, calf:100 cow ratios, and percent of herd comprised of yearling bulls are routinely used by managers as indicators of population trend. Such surveys are not used to estimate population size or density except when minimum estimates are desired.

Stratified random sampling (Gasaway et al. 1981) was used to estimate moose population size and density in autumn 1980 and 1983. Such counts were conducted in the same pattern as those described for sex-age surveys, but search intensity usually exceeded 4 min/mi^2 (1.54 min/km^2). Total counts at search intensities 4 min/mi^2 (1.54 min/km^2) were conducted in selected small areas, particularly the impoundment zones where documentation of winter moose densities in selected habitats was desirable.

Survival and Mortality Rates

Survival rates of radio-collared calf, yearling, and adult moose were calculated using methods described by Trent and Rongstad (1974). Neonates were monitored daily, allowing calculation of daily survival rates up to 1 November. All other rates were estimated on a monthly basis. When dates of last observation and known death spanned several months, the median date was used. Two survival rates were calculated for each age class and time period when appropriate: (1) only those animals whose fate was known, e.g., the animal was either dead or alive when last observed, and (2) the average of two dates--one calculated which assumed all missing animals were alive and another which assumed all missing animals were dead. Moose were excluded from survival calculations if it could not determined whether the radio-collar had fallen off or the animal was dead.

Causes of mortality were determined according to methods described by Ballard et al. (1979) and Stephenson and Johnson (1972, 1973). Monitoring frequency was not sufficient to determine cause of death for most adult mortalities, so cause of death was classified as unknown. When monitoring intensity was frequent, such as once or twice per week, it was often possible to classify cause of death based on ground examination at the site or actual observation of a predator on the carcass. Causes of death were classified as unknown, brown or black bear predation, wolf predation, hunting, miscellaneous (mortalities such as being stepped on by their cow, pneumonia, auto collisions, etc.), or winter-kill. The latter classification included all mortality involving starvation or other winter-related conditions.

Home Ranges, Distributions and Vegetation Use

Yearling and adult home range sizes were calculated using the minimum home range method (Mohr 1947). This method may be adequate for estimating home range sizes of animals occupying flat terrain and homogenous habitat but may not be appropriate when large blocks of nonhabitat, e.g. mountains, areas >4,000 ft (1,219 m) elevation or lakes are included within polygons. Consequently for some analyses Mohr's (1947) method was modified as follows:

1. Seasonal, annual, and total home ranges were calculated.

   a. For home range calculations 3 seasons were recognized:

      Summer - May through August,
      Autumn - September through December, and
      Winter - January through April.

   b. Total and seasonal home range sizes were not calculated when numbers of relocations were ≤ or <24, respectively.

   c. Selected relocations from different seasons were included in another seasons home range calculations if there was a clear relationship with earlier or later points.

2. Linear lines connecting outermost relocations were used except in the following cases:

   a. When elevations >3,600 ft (1,097 m) were involved the boundary followed the contour line.

   b. Slopes >30 degrees were excluded.

   c. For outlying relocations, the polygon was drawn from the closest two perpendicular points to the outlier.

   d. When all relocations occurred on one side of a major drainage, the boundary followed the drainage without crossing it.

Dates and timing of migrations and movements were determined by examining sequential observations of individual radio-collared moose. When sequential moose relocations deviated from a cluster of points, migration or movement to another range was judged to have been initiated. Moose were considered to have arrived at a seasonal range when a point fell within a home range cluster.

Seasonal and total home ranges between resident (overlapping seasonal ranges) and migratory (nonoverlapping) home ranges were compared. Distances between winter and summer home ranges of migratory moose were determined by measuring the closest points between seasonal home range polygons.

Availability of overstory vegetation types as well as elevations, slopes, and aspects were assessed by measuring these variables at section corners of 1:63,360 scale topographic and vegetation maps. Use of these variables by moose was determined from radio relocations plotted on the maps. Elevations were determined by extrapolating between contour lines to the nearest 50 ft (15 m) interval. Slopes were classified into 3 categories: flat = ≤10° with contour line intervals >0.19 inch (0.49 cm), gentle = 11-30° with contour line intervals ranging from 0.03-0.19 inches (0.08 - 0.49 cm), and moderate = >30° with contour line intervals <0.03 inches (0.08 cm). Aspect was classified as flat or one of 8 compass directions from a line perpendicular to the contour lines through the moose location point. Methods used to quantify moose browse and understory vegetation were described by Becker and Steigers (1987). Browse quantities were divided into seven categories, from high to zero, depending on browse quantity. Point locations of radio-collared moose (N = 2,930) were also divided into one of the corresponding browse categories by season of use. Selectivity (preferred or avoided) of habitat types was determined by chi-square analyses similar to Neu et al. (1974).

Relative distribution of moose was determined in 1980 and 1985. Aerial distribution surveys differed from other types of counts and censuses in that less survey effort was expended per unit area, and no precise population estimates could be derived. Between 1-2 min/mi^2 (0.4 - 0.8 min/km^2) was expended searching for moose. All moose observations were recorded on 1:63,360 scale USGS topographical maps. Similar to autumn censuses, winter distribution data were used to stratify areas into relative density strata, i.e. high, medium, low, and zero density. No attempt was made to estimate population size in the study area during late winter, because no reliable density estimates existed. Only the relative differences in density were calculated. In-depth total counts (no variance estimate) of the actual impoundment areas are provided in subsequent sections of this report.

Statistical Tests

Differences between means were compared by t-test and analysis of variance (Snedecor and Cochran 1973). Count data and proportion data were analyzed with Chi-square tests (op. cit.). Relationships between independent variables were examined by correlation analysis. Differences in mortality rates of neonate twins versus singles and between sexes were compared with a Logit model. Unless specifically stated, P 0.05 was required for statistical significance.

DYNAMICS OF THE MOOSE POPULATION

Population Trends

Trends in the moose population were assessed by examining GMU 13 moose sex-age composition count data collected from 1952 through 1984 and correlating survey year with moose/hour, bulls:100 cows, calves:100 cows, and percent yearling bulls in the herd. Prior to 1963, numbers of moose counted per survey hour were variable and not correlated with survey year. However, numbers of moose observed per hour of survey declined annually during the period 1963 through autumn 1975 (Fig. 3). Other moose population indicies such as bulls:100 cows, calves:100 cows, and percent yearling bulls in the herd, began exhibiting declines in the 1950s and declined through autumn 1975 (Figs. 4-6). In addition to the severe winters described by Bishop and Rausch (1974) severe winters occurred in 1974-75 and 1978-79 (see Winter Severity section). Apparently Bishop and Rausch's (1974) assessment of the moose population peaking in 1960 was a subjective appraisal based on their experience in the area. Numbers of moose observed per hour surveyed suggest the population peaked in 1963. Other population indicies suggest the population was already declining when composition counts were started in 1952.

Moose counted per hour of survey, bulls:100 cows, calves:100 cows, and percent yearling bulls in the herd all reached their lowest levels about 1975 (Figs. 4-6). After 1975, all population indicies suggested a moose population increase ($p < 0.01$). Population modeling (see Ballard et al. 1986) suggested that reduced wolf and bear densities, mild winter conditions, and reduced bull harvests resulted in an annual moose population increase of about 3-5%.

The moose population within the Susitna River Study Area exhibited virtually the same trend as the GMU 13 population

(Figs. 7 through 10), except that productivity (as expressed by calf:100 cow ratios) was quite variable within the Susitna River Study Area prior to 1976. The moose population reached its lowest level in 1975. Thereafter, the moose population increased, although mortality (as reflected by calf:100 cow ratios and percent yearling bulls) increased during 1 year following the severe winter of 1978-79. Proportionately more calves were produced from 1976-84 than from 1963-75 ($p > 0.005$). Reduced wolf and brown bear densities, mild winter conditions, and reduced human harvests apparently contributed to a moose population increase.

Population Density

Two moose population censuses were conducted using Gasaway et al.'s (1981) survey methods. The first census was conducted in autumn 1980 before the final hydroelectric project study area had been delineated. Moose count areas 7 and 14 (Fig. 2), adjacent to the Susitna River east of Delusion and Kosina Creeks were censused from 5-8 November 1980. The remainder of the hydroelectric study area lying west of Delusion and Kosina Creeks was not censused because of poor snow conditions but was stratified. A moose population estimate was derived by applying density estimates from the census area to the stratified area. In addition, moose count area 3 was censused and count area 6 (Fig. 2) stratified so that a total moose population estimate could be derived for the area where long-term predator-prey studies were conducted (Ballard et al. 1986, 1987). The latter area (SRSA) was censused to partially validate a population model adapted to the hydroelectric study area.

The estimated autumn 1980 moose population for count areas 7 and 14 was 1,986 (Table 1). A total of 743 moose were censused within 26 sample areas comprising 948 km² (39% of count areas 7 and 14). Of 945 mi² (2,448 km²) within the count areas, 35% was classified as low moose density, 38% as medium moose density, and 27% as high moose density. Not all moose were observed during the census where survey intensity was 4.4 min/mi² (1.7 min/km²). Consequently, portions of 10 sample areas were randomly selected and resurveyed at 11.9 min/mi² (4.6 min/km²) to generate a sightability correction factor of 1.03 (Table 2). It was estimated that 98% of the moose were observed at the higher survey intensity. The corrected population estimate for count areas 7 and 14 was 2,046 moose, of which 22% were calves.

Moose densities west of Kosina and Delusion Creeks were estimated following the regular census. One hundred seventy-nine moose were counted, which provided the basis for stratifying the remaining 830 mi² (2,150 km²); 562 mi² (1,456 km²) were classified as low moose density, 256 mi² (663 km²) as medium moose density, and only 12 mi² (31 km²) as high moose density. The size of each stratum was then multiplied by the individual density stratum estimates (Table 1) to derive an approximate population estimate of 1,151 moose. Combining the latter estimate with that obtained for count areas 7 and 14 provided a total population estimate for the hydroelectric project area in autumn 1980 of approximately 3,197 moose.

Stratification flights were also conducted in moose count area 6 (Fig. 2) on 9 Nov 1980 with a Piper Supercub. This area was surveyed because it contained several subpopulations of migratory moose which occasionally utilized the impoundment zones even though the area was not within the boundaries of the hydroelectric project area. Of 470 mi² (1,217 km²) stratified, 204 mi² (528 km²) were classified as low moose density, 207 mi² (536 km²) as medium moose density, and only 59 mi² (153 km²) as high moose density. Extrapolating the average moose densities per stratum for count areas 7 and 14 (Table 1) to count area 6 provided an approximate population estimate of 830 moose.

Moose count area 3 was also censused to help validate the moose population model. Four hundred seventy-three moose were estimated in the area. Combining moose population estimates for count areas 3, 6, and 7 yielded a moose population of 2,772 during autumn 1980 within the 2,804 mi² (7,262 km²) area. Within this area, 1,858 mi² (4,812 km²) lies below 4,000 ft (1,219 m) elevation. Since moose rarely utilize areas above that elevation, moose density on usable habitat in autumn 1980 within SRSA was 1.49/mi² (0.58 moose/km²). Combining all areas which were either censused (count areas 3, 7, and 14) or stratified (area west of Kosina and Delusion Creeks and count area 6) in autumn 1980, a total of 4,500 moose were estimated within 2,518 mi² (6,522 km²) of usable (1,219 m) habitat or 1.79 moose/mi² (0.69 moose/km²).

During 1983 autumn moose population estimates for the hydroelectric primary impact zone, the SRSA, and several other count areas were made. The other areas were censused under other funding sources but are included here for comparative purposes. Distribution of moose in autumn 1983 was different from that in 1980 in that relatively fewer moose were present in open alpine areas. Consequently, moose were harder to observe as reflected by the sightability correction factor (1.19 in 1983 versus 1.03 in 1980).

A total of 2,836 moose were estimated to occur within the hydroelectric primary impact zone during autumn 1983 (Table 3). Within the 1,156 mi² (2,994 km²) of usable habitat within the primary impact zone, 16% was classified as high moose density, 39% as moderate moose density, and 45% as low moose density. Overall, autumn density within the impact zone in autumn 1983 was 1.82 moose/mi² (0.70 moose/km²).

A total of 2,795 moose were estimated within the SRSA (Table 4). The confidence interval about that estimate included the estimate generated by population modeling (see Ballard et al. 1986) and validated the model for use under preproject conditions. Moose densities within this area were similar (1.94 moose/mi² or 0.75 moose/km²) to those in the hydroelectric primary impact zone, further strengthening its application for assessing population trends within and outside of the project area. The census estimates, like the sex-age composition data and the population model, suggest the moose population had increased since 1975.

During autumn 1983 a total of 2,929 mi² (7,586 km²) of usable moose habitat within the SRSA, the primary impact zone, and one other count area was censused and 4,573 moose were estimated to occur (Table 5). Average moose density within this area was 1.55 moose/mi² (0.60 moose/km²). Comparison of these average densities with those found within the hydroelectric project area (east of Tsusena Creek and Stephan Lake) suggests that the area to be impacted by the project contains relatively high densities of moose in relation to many other areas within GMU 13.

Age Structure

Average age of adult cow moose captured during 1976-1982 was 7.7 years (S.D. = 3.8 yr) (Fig. 11). Average ages among years were different ($P > 0.05$). Average ages of cow moose by year of capture were: 1976 = 7.5 years (SD = 3.4), 1977 = 7.0 years (SD = 3.8), 1980 = 9.4 years (SD = 3.8), and 1981 = 7.6 years (SD = 2.9). Cows captured in 1976, 1977, and 1981 were younger ($p \geq 0.05$) than those captured in 1980. Corrected for year of capture, cows ≥10 years of age comprised 25% of the sample in 1976 and 1977, whereas in 1980 they comprised 62%. This suggests that the age structure of the moose population had become composed of older individuals since 1976 and 1977. The exact opposite would have been expected based on autumn calf:cow ratios; 1976-1977 age structure was expected to be relatively old following several years of low recruitment, while a relatively young age structure was expected in 1980 following several years of improved recruitment due to predator reductions and mild winters. The former type of age structure was observed in the eastern portion of GMU 13 in 1975 where Van Ballenberghe (1978) reported 49% of tagged moose were 10 years ≥ old. Although calves and yearlings were avoided during capture, no attempt was made to avoid other age classes and no biases would have been expected. These annual differences are attributed to differences in subpopulations and sampling variation.

Average age of 3 captured adult (<1.5 yrs) bulls was 4.3 years (SD = 0.6 yr). Adult bulls were avoided during capture for radio-collaring because of their relatively high mortality rates from hunting.

Productivity

Pregnancy rates among years were variable, but relatively high during the study; 88% in 1977 (N = 59), 73% in 1980 (N = 37), 79% in 1981 (N = 14), 82% in 1984 (N = 11), and 72% in 1985 (N = 19). Lower pregnancy rates after 1977 were due to inaccurate diagnoses and lower productivity of older recaptured moose. For example, in 1980 four cows which had been diagnosed as not pregnant subsequently had calves. Of eight biologists participating in the tagging effort that year, only 2 were experienced and considered current (palpated >10 moose within previous 2 years) at assessing pregnancy rates. Also, many of the cows examined in latter years were recaptures from previous years. Since older moose are generally less productive than younger individuals (Markgren 1969), the rates reported here should be considered minimal. Overall, pregnancy rates averaged 81%. GMU 13 pregnancy rates were similar to those reported elsewhere in Alaska and North America: 88% for eastern portion of GMU 13 (Van Ballenberghe 1978), 90% for GMU 9 on the Alaska Peninsula (Faro and Franzmann 1978), 90% in GMU 5 near Yakutat (Smith and Franzmann 1979), 88% in GMU 20 of interior Alaska (Gasaway et al. 1983), and 71-90% for other North American moose populations (Blood 1974). Yearling productivity was less than that of adults; 2 (40%) of 5 yearlings physically examined produced calves.

Earliest observations of moose parturition were 18 May in 1979 and 24 May in both 1977 and 1978 for uncollared cows. During 1977, 1978, and 1980 timing of parturition and subsequent calf loss was determined by visually observing radio-collared cows and their calves at 3 5-day intervals beginning on 24 May each year. No attempt was made to determine causes of calf mortality for these animals. The earliest date at which radio-collared cows were observed with calves was 25 May. Sixty percent of all calves were born between 29 May and 3 June of each year. Parturition was 96% percent complete by 10 June each year. In 1 case we observed a calf born in mid-August. The timing of parturition was similar to that reported in Alberta (Hauge and Keith 1981).

Losses of radio-collared calves and calves of radio-collared cows in 1977, 1978, and 1980 were nearly identical (Fig. 12), suggesting that the causes of mortality between the 2 groups were similar. Ninety-four percent of the natural mortality occurred before 19 July each year. After that date nearly all calves survived to at least 1 November each year. Thereafter, survival was dependent on winter severity and predation.

Sex ratios and twinning rates at parturition were determined by examining neonates during calf mortality studies conducted in 1977, 1978, 1979, and 1984 (see calf survival section). Observed twinning rates by year were as follows: 1977-19%, 1978-31%, 1979-52%, and 1984-63%. Overall, observed twinning rates averaged 38%. Pimlott (1959) reported that moose twinning rates in North America ranged from 5-28%, while in Sweden twinning rates ranged from 17-65% (Markgren 1982). Franzmann and Schwartz (1985) suggested that twinning rates reported in the literature had been collected by several different methods over several months and were not comparable. For example, Pimlott's (1959) rates were obtained in autumn after most neonate mortality had occurred (Ballard et al. 1981b, Franzmann et al. 1980). Markgren (1982) attributed differences in twinning rates in Sweden to climate and nutrition. There were no noticeable changes in habitat quality to account for the threefold differences in twinning rates among years for GMU 13 moose. Also, if winter severity prior to parturition had strongly influenced twinning rates, the 1979 (following the severe winter of 1978-79) rate should have been low, while the 1977, 1978 and 1984 rates (following mild winters) should have been high. Only 1 year fit the expected pattern, and consequently the observed annual variations in observed twinning rates could not be explained.

Overall, sex ratios of newborn calves (114 males to 91 females) were skewed in favor of males (X^2=8.8, p=0.07). This difference was due to the heavily skewed ratio which occurred during 1977; 35 of 50 calves (70%) were males (X^2=8.0, p <0.005). Excluding 1977, sex ratios were not significantly different from 50:50 (79 males versus 76 females, X^2=0.8, p=0.85). There were no differences in mortality rates among sexes (X^2=17.4, 14df, p=0.24). Verme and Ozoga (1981) determined that for white-tailed deer (Odocoileus virginianus) there was a relationship between interval following onset of estrus and subsequent insemination to the sex ratio of fawns produced; does bred late in estrus produced higher proportions of male calves. The implication was that in heavily hunted populations where bull densities were greatly reduced, cows may have to wait to mate until they find a bull, resulting in higher male sex ratio at birth. Although speculative, there may have been a relationship between adult sex ratios and neonate sex ratios during this study. The lowest adult bull:100 cow ratio in the calf mortality study areas occurred in 1977 (11 males:100 females). Thereafter, bull:cow ratios increased from 17:100 in 1978 to 18:100 in 1979 and 24:100 in 1984.

Several investigators have expressed concern that low bull:cow ratios could influence conception rates and neonate sex ratios in ungulates (McIlroy 1974, Bishop and Rausch 1974, Bailey et al. 1978, Verme and Ozoga 1981, A. Franzmann pers. comm., and many others). Differences in fetus size have been noted in several Alaskan moose populations where bull:cow ratios have been relatively low (Rausch 1967, J. Didrickson pers commun., V. Van Ballenberghe pers. commun., this study). Whether observations of small fetuses and skewed neonate sex ratios during some years were the result of relatively low bull:cow ratios was not known, but further investigation appears warranted.

Survival and Mortality

Calves 1-5 Months of Age. Causes of neonatal moose calf mortality were studied within 4 areas of GMU 13 during 1977-79 and 1984 (Fig. 13). Area 1 was studied during 1977-79, Area 2 during 1977-78, Area 3 during 1978, and Area 4 during 1984. A total of 218 moose calves were captured and radio-collared (Table 6). Twenty calves (9%) died of being abandoned or trampled by their cow due to capture activities. These calves were excluded from survival and mortality calculations.

Predation by brown bears was the largest cause of calf moose mortality (Table 6) accounting for 73% of total mortality. The second largest cause of mortality was miscellaneous factors (12%) such as injury accidentally inflicted by the cow, drownings, and pneumonia. Wolf predation and unknown causes each accounted for 4% of the mortality. Predation from all causes accounted for 83% of total mortality during the first 5 months of life. Sixty-one percent of the calves died during the first 5 months of life. Ninety-six percent of the natural mortality occurred before 9 July of each year. Because the rates of calf loss between collared and uncollared calves of radio-collared cows were similar (Fig. 9), neither the collars nor the capture process predisposed the calves to death.

There was considerable variation in survival rates among study areas (Table 6). Lowest survival rate occurred within the SRSA (Area 4) during 1984. That area was selected for study because it harbored dense populations of black bear (Miller 1984) which could have been an important source of calf mortality (Franzmann et al. 1980) not previously documented in GMU 13. Because black bears would likely be eliminated as a result of hydroelectric development (Miller 1984), it was conceivable that elimination of black bears could be beneficial to the moose population if they were a significant source of calf mortality. Black bears were found to be responsible for 11% of the total calf mortality in 1984 (Table 6). Similar to previous studies, predation by brown bears was the largest source of calf mortality (62%).

There were differences in calf survival rates among areas and years ($p < 0.05$). Mortality rates in all areas were greater for twins than single calves ($p < 0.01$). Survival rates during the first 5 months of life varied from 3% in Area 4 in 1984 to 56% in Area 1 during 1977 (Table 6). Differences in survival rates among areas and years may have been related to differences in densities of predator species, although not all observed differences could be explained. For example, in 1977 wolf densities were greatly reduced in Area 1, but not in Area 2. Calf survival that year was greater in Area 1 than in Area 2. The same trend was not evident in 1978, but wolf populations in Area 2 had been greatly reduced and wolves were not abundant in Area 3 (Ballard et al. 1981a). In 1979 predation from brown bears was expected to have been greatly reduced in Area 1 since brown bear populations were temporarily reduced by about 60% (Miller and Ballard 1982). Although other data suggested that reductions in bear density greatly increased calf survival (Ballard and Miller 1987), radio-collared calf survival data suggested no improvement. This discrepancy occurred largely because not all bears were removed from Area 1, and 2 bears which had not been removed killed at least 67% of the calves killed by bears. Overall, from 1977 through 1984 calf survival during the first 5 months of life averaged 26% (74% mortality).

Calves 6-12 Months of Age. Starvation (or winter-kill) was the largest overall source of calf mortality from 1 November-May of each year, accounting for 79% (11 of 14) of the deaths. Nine of the winter kills occurred during the severe winter of 1978-79. Predation by brown bears was suspected in 2 cases while an unknown predator made 1 kill.

From 1 November-May of each year, female calves (Table 7) had greater survival rates than male calves (Table 8). This was due largely to differences during the severe winter of 1978-79. During that year, male calf mortality was 72% (1.00 minus survival rate) while known female calf mortality was only 6%; female calf mortality could have been as high as 30% (1 - 0.703) assuming half of the missing calves died. Regardless, during severe winters, male calves suffer higher ($p < 0.05$) rates of mortality than female calves. There were no differences (p 0.05) between male and female calf mortality rates during years of moderate winter severity (5% for each sex).

Annual Calf Survival Rates. Average annual calf survival rates for female and male calves were 22 and 17%, respectively (Table 9: determined by multiplying rate from Table 6 times rates from either Table 7 or Table 8). Although male calf survival rates were lower than female rates from 1 November-May during severe winters, overall annual survival rates were not different ($P > 0.05$).

Combinations of different summer and winter calf survival rates were calculated to estimate ranges of annual survival rates which could occur among different areas and years in GMU 13 (Table 9). Highest calculated calf survival rates for male and female calves was 56% each, while the lowest rates were 2 and <1% for females and males, respectively. The latter situation occurred during a year of high neonatal losses such as in Area 4 in 1984 and following a relatively severe winter such as in 1978-79 (Table 9). Higher survival rates occurred during years of low neonate losses (such as in Area 1 in 1977) followed by low winter losses (such as in either 1979-80 or 1980-81). Summer and winter data were collected consecutively within 1978 and 1979, and the estimated survival rates for those years were within the calculated extreme values (40 and 30% for female calves in 1977 and 1978, respectively, and 12 and 30% for male calves in 1977 and 1978, respectively).

Yearling and Adult Females. Yearling and adult radio-collared cow moose survival rates were based on 43 and 532 moose years, respectively. Overall, yearling and adult cow survival each averaged 95% (Table 7). Lowest adult survival occurred in 1985-86 but that rate was only through Jan 1986 and probably not representative of the entire year. Adult female survival was also relatively low in 1978-79 (a relatively severe winter), 1979-80, and 1981-82, averaging about 92%. Adult survival might have been as low as 77% in 1978-79 if half of the missing animals (N=17) were assumed dead. Lowest yearling survival (75%) occurred in 1981-82.

In general, radio-collared yearlings and adults were not monitored frequently enough to accurately determine causes of mortality. However, there were periods when monitoring intensity was sufficient to allow causes of mortality to be determined: during parturition in 1977 and 1978 when cows were monitored 3-5 times per week, and short yearling mortality studies in 1978-79 when cows were monitored once per week. From October 1976 through January 1986, twenty-one adult radio-collared females died. Of that total, 10 died from unknown causes. Predation accounted for 8 of 11 (73%)

mortalities where cause of death was determined; brown bears killed 5, wolves killed 2, and unknown predators killed 1. Three adults starved. Cause of death for 2 yearlings was starvation and wolf predation. Contact with 37 adult radio-collared females was lost, so their fates were unknown. Dates of lost radio-contact were equally divided between snow-free (1 May-31 October) and snow-cover periods.

Yearling and Adult Males. Yearling and adult radio-collared bull moose survival rates were based on 34 and 72 moose years, respectively (Table 8). Overall, adult bulls had lower survival rates (65 to 74%) than yearling bulls (87 to 90%). Prior to 1980 any bull was legal for human harvest. Following that date only bulls with 3 brow tines on at least 1 antler or antler spreads 36 inches (91 cm) were legal. Also, in 1984 only spiked or forked antlered males were legal in the SRSA, while after that year the regulation applied only to the area lying west of Lake Louise Road in Subunit GMU 13A. Yearling bulls had their lowest survival in 1979-80 when they were legal for human harvest (2 of 3 mortalities). Thereafter, yearling bull survival was relatively high ranging from 86-100%.

Lowest adult bull survival rate occurred in 1985-86 (Table 8). However, the rate applied only through January 1986 and may have been biased. The next lowest rate occurred in 1984-85. Adult bull survival declined as the study progressed ($r=0.94$, $p >0.01$), suggesting increased vulnerability with age when only bulls with antlers 36 inches (91 cm) were legal. Radio-collared bulls had relatively low rates of natural mortality after they attained 2 years of age. Of 13 adult bull mortalities, 12 (92%) were due to human harvest and 1 (8%) was from unknown causes.

MOVEMENTS, DISTRIBUTION AND HABITAT USE

Group Size

Differences in average group size per month were determined for radio-collared adults from 1977-1985. There were no differences among years, so all years were pooled. During January through August, >30% of all observations of instrumented moose were of single animals (Fig. 14). In September that proportion began declining, and by October only 19% of the observations were of lone individuals, reflecting rutting concentrations. Proportions of lone moose again increased in November and December. Average group size exhibited similar trends. Average group size was 2 moose from January through July (Fig. 15). Average group size increased to 3.0 in August, 4.9 in September, and 7.6 in October. After October group size decreased to 3.2.

These results were similar to many other studies indicating that moose are not highly gregarious (except cows with calves) during much of the year. Largest (N = 52) group sizes occur during the rut and in post-rut aggregations. Generally, cows with calves do not associate with the large rutting groups.

Movement Patterns

Moose exhibited all of the movement patterns described by LeResche (1974) and many variations not described. Moose were classified into 2 basic categories based on overlap or nonoverlap of winter and summer home ranges: (1) residents--individuals with movements confined to relatively small areas and with portions of their winter and summer home ranges overlapping, and (2) migratory--individuals which moved over relatively large areas and whose winter and summer home ranges did not overlap.

Three periods of significant movement were identifiable. These included autumn and spring migration and movements to rutting areas. Movements during the rut were most pronounced for resident moose. During late September and October, several moose made distinct movements to upland areas not used during other seasons of the year. These areas appeared to have greater numbers of large-antlered bulls than other areas, and consequently, bull density and behavior may have been an attractant. Both major identified rutting areas within the project area (Clark Creek and Tsisi Creek) had poor human access, and fewer bulls were killed there than in other areas. Migratory moose may also have moved to specific rutting areas, but such areas were not easily identifiable because of the relatively large areas they occupied.

Autumn Migration. Dates of autumn migration were variable. LeResche (1974) and Van Ballenberghe (1978) both reported that weather, particularly snowfall, was a mediating factor in moose migrations. Heavy snow accumulations (>1 ft or 0.3 m) stimulated autumn migration if it had not already been initiated. Response to lesser intensity storms or accumulations was not predictable. During years of low snowfall, migratory and resident moose did not move to lower elevational areas until early winter (January-February). Autumn migration occurred as early as October and as late as January. Most moose appeared to initiate autumn migration at about the same time; however, the speed at which they arrived on winter range was variable, ranging from a few days to several weeks and in some cases not at all. Rapid movement to winter range coincided with heavy initial snowfall, while the slower movements occurred when there was a gradual accumulation of snow.

LeResche (1974) suggested that winter snow depths, forage availability and quality, habitat suitability, and their various combinations determined whether particular winter habitats were used. In years of moderate snowfall, forage and habitat were available at upland sites because snow depths were shallow. During these types of winters, moose did not arrive on winter range until February or March, if at all, and then they may have only remained on winter range for 2-4 weeks. During 1978-79, a relatively severe winter, several moose utilized winter areas they had not used during previous years. For example, from 1976 through 1978 an individual moose maintained a summer range near MaClaren River and a winter range along the Susitna River. Between 21 December 1978 and 14 April 1979, she was relocated 82 km to the south along Mendeltna Creek. In subsequent years (1980-1984) she used her traditional winter and summer ranges and did not return to the winter 1979 location. Although this moose did not use the impoundment zone, it suggests that other moose might use the area during severe winter conditions. The importance of the impoundment zones to moose during a severe winter could be greatly different from that observed during this study when winters were relatively moderate.

Spring Migration. Dates of spring migration were as variable as those observed during autumn months, ranging from March through mid-July. LeResche (1974) suggested that spring movements were in response to disappearance of snow and/or plant greenup. Spring movements during this study apparently were more related to disappearance of snow than to plant greenup. Rate of movement to summer range was also variable. Van Ballenberghe (1978) reported that in the eastern portion of GMU 13 moose departure to summer range occurred from mid-April through mid-June. During some years movements to winter range were completed in 1-2 weeks while in other years, 4-6 weeks were required. Most moose were on summer range by late April or early May where they calved. During some years moose remained on winter range for calving, with migration to summer range not occurring until mid summer; these movements may have been in relation to vegetation greenup.

Seasonal and Total Home Range Sizes

All moose exhibited seasonal movements within their total home ranges. Distances between winter and summer ranges of migratory moose ranged from 0.6-58 mi (1-93 km). The longer distances were associated with moose which summered in the upland areas of the Clearwater Mountains and wintered along the Susitna and MaClaren Rivers.

Use of seasonal home ranges by adult moose was traditional although at least 1 adult changed its home range permanently (see Adult Dispersal section). During severe winters moose may use areas which were not used during winters of moderate severity. LeResche (1974) suggested that traditional use of home ranges persisted over several generations, but whether these conditions persist during severe winters is not known. Also, because yearling bulls disperse more often than females (Dispersal section), traditional usage of parental home ranges as suggested by LeResche (1974) is probably much lower for male than female moose.

Seasonal and total home range sizes of resident adult cow moose increased ($p < 0.05$) with numbers of relocations (Figs. 16, 17, 18, and 19). There was no ($p > 0.05$) relationship for migratory moose between seasonal home range sizes and numbers of relocations, but there was a ($p > 0.05$) negative correlation for total home range size (Fig. 20). Apparently, there were large areas between seasonal ranges not used by moose; additional relocations reduced the amount of unused area included in home range calculations.

Seasonal and total home ranges for resident moose appeared adequately identified when numbers of relocations 13 and 39, respectively, (Table 10). Using these criteria, winter, summer, autumn and total home ranges for resident moose averaged 44, 40, 61, and 112 mi^2 (113, 103, 157, and 290 kms^2), respectively. Home range sizes were compared by ANOVA (Snedecor and Cochran 1973). Resident winter home ranges were not different in size ($p < 0.05$) from summer and autumn home ranges, but autumn home ranges were larger ($p < 0.10$) than summer home ranges.

Winter, summer, and autumn home range sizes of migratory adult cow moose averaged 58, 102, and 124 mi^2 (151, 263, and 322 km^2), respectively (Table 10). Total home range sizes did not appear to be adequately defined until numbers of relocations >40 (Fig. 20). Using those criteria total home ranges averaged 505 km^2 (195 mi^2). There were no differences ($p > 0.05$) between winter and summer ranges of migratory moose, but autumn ranges were larger than both winter ($p < 0.05$) and summer ($p < 0.10$) ranges (Table 10).

Migratory moose had larger ($p < 0.05$) total home range sizes than resident moose (Table 10). They also had larger ($p < 0.05$) autumn and summer home ranges, but there was no difference ($p > 0.05$) between sizes of winter ranges. The larger autumn home ranges of both groups reflected increased movements of moose during the rut (Houston 1968, Phillips et al. 1973, LeResche 1974, Hauge and Keith 1981, this study). LeResche (1974) reported that seasonal home ranges of moose were consistently small regardless of how far a moose moved between seasons. He reported that all studies consistently reported home ranges that seldom exceeded 2-4 mi^2 (5-10 km^2). Home ranges for resident and migratory moose in this study were larger than those reported in the literature.

LeResche (1974) indicated that cows with calves had smaller home ranges than other moose. Ballard et al. (1980b) reported that home ranges of cow-calf pairs in late spring and early summer averaged 9.7 mi^2 (25 km^2). This average was larger than reported in the literature but smaller than those of other sex-age classes, providing additional verification that this group occupies smaller areas.

<u>New Method of Home Range Calculation</u>. Many of the studies reported by LeResche (1974) concerning home range sizes occurred in areas where elevational relief was usually less than that found in GMU 13. Less than 1% of 4,700 relocations of radio-collared adults occurred at elevations >4,000 ft (1,220 m) and only 3% occurred at elevations above 3,600 ft (1,097 m). Thirty-one percent (7,259 mi^2 or 18,800 km^2) of GMU 13 (23,784 mi^2 or 61,600 km^2) is comprised of unusable habitat for moose (lakes, glaciers, or areas >1,220 m elevation). Large areas of nonhabitat are included in seasonal and total home range calculations using Mohr's (1947) method. To provide a refined estimate of actual home range size, Mohr's method was modified by basing calculations on actual habitat use according to methods described earlier.

Home ranges for 13 adult cows (9 residents and 4 migrants) were calculated using the modified method. Estimates of seasonal and total home range sizes were smaller (Table 11) than those calculated using Mohr's method but still larger than those reported in the literature. Winter and summer home ranges calculated by each method were similar ($p > 0.05$), but total home range sizes were not ($p > 0.05$). Winter and summer home ranges did not increase ($p > 0.05$) with numbers of relocations as with Mohr's method of calculation, whereas autumn home ranges were negatively correlated ($p < 0.05$). Winter home range sizes were not different ($p > 0.05$) from summer ranges for resident and migratory moose using Mohr's method but with the modified method winter home ranges were larger ($p > 0.10$) than summer home ranges for resident moose. Also, there was no difference ($p > 0.05$) between winter ranges of migratory versus resident moose. Possibly winter snow depths restrict movements of both types of moose. Both methods indicated that summer and total home ranges of migratory moose were larger ($p < 0.10$) than those of resident moose.

Dispersal and Home Range Formation

During March 1981 sixteen calves (8 males and 8 females) and 1 yearling associated with radio-collared cows were captured and radio-collared in an attempt to investigate timing of parent-offspring separation, rates of dispersal, and home range formation of subadults. Immediately following capture, radio contact with 2 calves was lost due to unknown causes.

Timing of Separation. Average age of separation from parents was 14 months (SD = 4.2). Gasaway et al. (1985) reported that in interior Alaska, only 2 of 20 yearlings remained with their cows after 1 year of age. In this study, 81% of 16 yearlings remained with their cows >1 year (Fig. 21). Thirty-one percent of the separations occurred during late June and July while 50% occurred during September and October. Separations at that time appeared induced by aggressive behavior of either cows or bulls during the rut.

Gasaway et al. (1985) reported that once initial separation of parent-offspring occurred in interior Alaska it was permanent. In this study, 5 of 15 (33%) yearlings and the 2-year-old were observed in temporary reassociations with their cows from 1-6 times ($\bar{x}$ = 2, SD = 2). During parturition, adult cows that were still in association with the previous year's calf exhibited varying degrees of aggressive behavior toward the yearling. If the new calf survived, separation between cow and yearling was usually permanent. However, if the new calf died, there was a tendency for the yearling to remain with the cow at least through summer months.

Types and Rates of Dispersal. Gasaway et al. (1985) reported that offspring selected home ranges that partially overlapped those of their parent; offsprings' home ranges overlapped at least half of parental home range. The maximum distance that offspring were observed from parental home ranges was 6.2 mi (10 km). Subadults in this study exhibited a different pattern. Dispersal was classified into 3 categories based on subsequent movements and home ranges of offspring in relation to those of the parent: (1) No Disperal--Offspring mimicked movements of both summer and winter home range of parent. Exploratory movements outside of traditional home ranges may occur during autumn of 1st and 2nd years following separation; (2) Partial Dispersal--Offspring share either winter or summer range of parent, but at least one of seasonal ranges is separate and distinct from the parent. Offspring may ultimately mimic home range of adult but only after extensive movements outside of historical parental home range for at least 1 year; and (3) Full Dispersal--Offspring established separate winter and summer home ranges which were not shared or, if shared, separated temporarily from that of the parent. Development of new home ranges may occur over several seasons.

Nine of 15 (60%) offspring partially (N = 4) or fully (N = 5) dispersed from the parental home range. More male than female ($p < 0.05$) offspring dispersed. No male offspring remained fully within the home ranges of their dams. Females usually (75%) occupied the home ranges of their dams. Dispersal rates were comparable to those reported by Houston (1968) in Wyoming but higher than those reported for interior Alaska (Gasaway et al. 1985) and portions of Sweden (Cederlund in press).

Several factors influence dispersal in moose populations (Houston 1968, Gasaway et al. 1985, Cederlund in press), but density may be particularly important. In interior Alaska where full dispersal rates were low, moose densities ranged from 0.2 moose/km² in 1975 to 0.3-0.6 moose/km² in 1978 and 1984, respectively (Gasaway et al. 1985). Moose densities during this study ranged from 0.6-0.8 moose/km² and were increasing. Moose densities were 3-4 times greater than those in interior Alaska which may partially account for the higher dispersal rates.

Dispersers appeared to move to areas of lower moose density. The receiving areas had greater hunting pressure and lower bull densities than areas from which dispersal occurred. Most dispersers were bulls which moved to either the Denali Highway or Lake Louise flats. If the proposed hydroelectric project results in lower moose densities and if there is a relationship between moose density and rates of yearling dispersal, then fewer moose will disperse. Therefore, not only will fewer moose be available for harvest in the project area but also in areas far removed from the project where heavy hunting pressure may have depleted a population.

Home Range Formation and Size. Average home range sizes (modified method) of cows and their offspring were positively correlated ($p < 0.05$) (Fig. 22). Offspring of cows with relatively large home ranges also had large home ranges. Male offspring had larger ($p < 0.05$) seasonal and total home ranges than females. Winter, summer and total home ranges for male offspring averaged 13, 10, and 34 mi² (34, 27, and 87 km²), respectively, while females averaged 7, 6, and 29 mi² (19, 16 and 76 km²), respectively. Changes in seasonal offspring home ranges were variable, and some changes did not occur until about 2.5 years following separation from the cow (Table 12).

Adult Dispersal

Use of seasonal home ranges by moose is traditional (LeResche 1974). During this study only 1 of 101 (1%) radio-collared adult females dispersed from their traditional home range. The single dispersing moose occupied a relatively small home range in the vicinity of the Susitna River from March 1977 through mid-August 1978. By 26 October 1978 she was relocated at the Dadina River, 110 mi (177 km) from her previous location. She maintained a resident home range in the Dadina area at least through 1981 when last relocated. Prior to this movement, the longest reported movement was 170 kms (106 miles) from the Northwest Territories (Barry 1961).

River Crossings

Timing. Fifty-nine of 113 (52%) radio-collared moose crossed the Susitna River in the vicinity of the impoundments on at least 170 occasions during 1976-1984 (Fig. 23). Thirty-five (59%) of 59 moose crossed the river at least once or twice. Greatest number of documented crossings was 8 by 4 moose. Monitoring intensity was too low to detect all crossings, particularly when animals crossed over and back within a 10-14 day period.

River crossings occurred during all months of the year, but most occurred during mid late winter (peak number in April) when moose were on winter range at lower elevations (Fig. 24). A second peak in crossings occurred during September and October, presumably because of increased movement during the rut.

Location. Crossing locations in relation to the proposed impoundments were examined by plotting straight lines between consecutive moose locations which crossed the river. Lines bisecting the river were assumed reflective of crossing locations. Although that assumption was less accurate as time interval between relocations and the distances between relocations increased, the analysis provides an indication of areas where crossings were concentrated.

Moose crossed the Susitna River along the impoundment corridor from Devil Canyon damsite to the mouth of the Oshetna River. Crossings were concentrated (Fig. 25) in areas which had characteristics conducive for easy movement.

Several areas in the immediate vicinity of the impoundments were used extensively. These included: the mouth of Tsusena Creek just downstream from the proposed Watana damsite, the area midway between Watana Creek and Jay Creek, and the areas adjacent to the mouths of Kosina and Jay Creeks. On the upper end of the Watana impoundment, crossings were also concentrated just downstream from the mouth of Goose Creek and immediately above the Oshetna River mouth.

Areas where few or no river crossings occurred, such as in Devil Canyon and around the gauging station, were characterized by steep terrain which apparently restricted access. Because river flow characteristics were similar among areas crossed and not used by moose, actual fording areas may be influenced by surrounding terrain. Where adjacent terrain gradually slopes to the river and moose movements are not restricted by cliffs or steep embankments, more crossings were recorded.

Winter Use of the Impact Zones

During winters of moderate severity, radio-collared moose were sedentary on winter range. Comparison of density stratification maps between autumn censuses (with population estimate) and winter distribution surveys (no population estimate) depicts seasonal use of habitats. Comparison of fall 1980 with winter 1981 distribution (Figs. 26 and 27, respectively) and fall 1983 with winter 1985 distributions (Figs. 28 and 29, respectively) suggest that the greatest change in seasonal distributions occurred in the Watana Creek-Fog Creek areas, the Watana Lake-Jay Creek areas, and the vicinity of the big bend of the Susitna River. The latter areas were characterized by low moose densities in autumn, but large densities during winter. This was due to shifts from high elevations in autumn to lower elevations adjacent to the Susitna River during winter.

Watana Impoundment. During winters 1981-1983 and 1985, total counts of moose were conducted within the Watana impoundment zone at an average survey intensity of 3.8 min/mi^2 (1.5 min/km^2). Comparison of annual counts suggests that late winter use of the Watana Impoundment during winters of moderate severity was highly variable, ranging from 42 moose in 1981 to 580 in 1983 (Table 13). Moose densities in the impoundment zone during these years ranged from 0.4-6.0 moose/mi^2 (0.2-2.3 km^2).

Observability of moose in the Watana impoundment zone was low because of large topographical variation and dense overstory vegetation. Also, snow and lighting conditions during the study were rarely optimal. Counts were conducted in spite of poor conditions because telemetry studies indicated that the largest numbers of moose occurred in the impoundments during those time periods. Calculated correction factors were often high because of low observability. Telemetry data support the use of high sightability correction factors during these seasons. For example, only 2 of 7 and 2 of 8 radio-collared moose in 1983 and 1985, respectively, were observed during the counts.

Devil Canyon Impoundment. The Devil Canyon impoundment zone was also counted in late winter but only in 3 years (Table 14). Count conditions were always poor, and moose observability was hampered by dense overstory vegetation. In 1983 and 1985 only 14 and 16 moose were observed, respectively. In comparison to the Watana impoundment zone, moose densities were low, ranging from 0.5-1.0 moose/mi^2 (0.2-0.4/km^2).

Vegetation Use

Preliminary analyses based on overstory vegetation indicated that spruce and willow vegetation types were selected out of proportion to their availability while tundra types were avoided (Ballard et al. 1985). The latter analyses did not indicate why a particular type was selected. If moose select habitats based primarily on the quantity of food, such analyses could provide misleading conclusions. Availability and use of browse species, in addition to overstory vegetation analyses, were compared. The entire moose primary impact zone was divided into 3 subsegments based on proximity of the proposed impoundments. Because differing ($p < 0.05$) quantities of browse occurred between the impoundments and outside them, it was not appropriate to combine the areas for comparison of moose use versus availability (Steigers and Becker 1987).

Outside of Impoundments. Moose used browse vegetation types outside of the impoundments in proportion to their availability (Table 15) except in the following cases: in winter (January-April) and summer (May-August) the medium shrub category was avoided ($p < 0.05$). It was also avoided annually ($X^2 = 28.9$, $P < 0.005$) while the very low strata was preferred ($X^2 = 16.8$, $P < 0.01$).

Watana Impoundment. Similar to areas outside the impoundments, there was no selection for any of the vegetation strata within the Watana Impoundment either by season or pooled (Table 16).

Devil Canyon Impoundment. Because browse productivity was substantially lower within the Devil Canyon Impoundment than further upstream, only 4 categories of browse strata were defined (Table 17). Low use of the area by moose was reflected by only having a total of 40 moose point relocations for utilization calculations. During all three seasons, there was no selectivity for browse by quantity strata (Table 17).

All Areas Combined. Based on the preceding analyses, moose did not appear to be selecting habitat on the basis of browse biomass. A different interpretation of seasonal habitat use was obtained when all 3 populations were pooled. During winter, moose exhibited a ($p < 0.05$) preference for areas with relatively little browse (Low, Very Low, and Scarce browse biomass strata). Within the Watana Impoundment, all browse areas appeared important, although there was no statistical preference or avoidance for High, Medium, or Zero biomass strata. Outside the impoundments during winter, there was an avoidance of all strata except Medium Forest strata, where there was an apparent but nonsignificant preference.

During summer and autumn, the pooled data analyses were similar to those based on individual browse populations presented earlier. Only Very Low and Scarce biomass strata were preferred in summer and only in the Watana Impoundment population.

Winter was the only time period when moose appeared to be selecting particular habitat types based on browse biomass. They did not, however, indicate a preference for areas of high browse biomass (usually upland types), suggesting that other factors were important. During summer moose were widely distributed over the basin and did not avoid upland vegetation types. In autumn, food availability apparently does not limit moose distribution, so areas are apparently selected on the basis of factors other than food.

Moose were not selecting areas based solely on quantities of browse. Other factors, such as thermal and escape cover, traditional use, snow depths, elevation, slope and aspect, and behavior, all affect where moose were located. The only area outside of the impoundments that was not avoided in winter was the Medium-Forest strata while most of the Watana Impoundment area was dominated by spruce. This strongly implies that the areas preferred by moose are dominated by spruce overstory. Earlier analyses based on overstory vegetation alone (Ballard et al. 1985) support the hypothesis that spruce cover types are important habitats for wintering moose in southcentral Alaska. Nineteen percent of the basin is composed of spruce stands and 35% of the total moose observations gathered during 1976 through 1981 were located in spruce overstory habitats (Ballard et al. 1982b).

Elevational Use

Different elevations were used seasonally and annually by Susitna area moose. Use of lowest elevational strata occurred in April. As snow melted and retreated, moose moved to higher elevations in May and June (Fig. 30). After calving, they moved to higher elevations in July, with downward movements during August and September. During the rut, higher elevations were again selected, reaching their highest level by October. In November, moose began movements toward lower elevations which continued into March and April. The latter movements were apparently in response to deepening snows and/or lower browse availability (Fig. 30).

Shifts in elevational use were also evident among seasons when percent frequency of occurrence of relocations were compared with elevation (Fig. 31). Peak elevational use during winter occurred near 2,600 ft (792 m) elevation, while in summer and autumn, the peaks shifted from 2,800 ft (853 m) to 3,000 ft (914 m) elevation, respectively.

Elevational and vegetation use by Susitna moose in winter depends to a large extent on the severity of individual winters. As winter severity increases, the percent of moose utilizing lower elevations increases (see Effects of Snow - Elevational Use section).

Elevations from 1,800-3,000 ft (549-914 m) were used disproportionately to their occurrence (Fig 32). Elevations over 3,000 ft (914 m) were used less, indicating an avoidance of the higher elevations where food and cover were less abundant. Only 16 of 2,984 observations (0.5%) from 1981-1984 were at elevations >3800 ft (1,158 m).

Slope Use

During winter, slopes were used by moose in proportion to their occurrence (X^2 = 0.01 to 0.10, P >0.05) (Fig. 33). During summer, flat areas were preferred (X^2 = 11.73, P = 0.005) and gentle (X^2 = 5.17, P = 0.07) and moderate (X^2 = 6.20, P = 0.04) slopes avoided. During autumn, gentle (X^2 = 10.4, P = 0.01) and moderate (X^2 = 9.00, P = 0.02) slopes were preferred and flat areas avoided (X^2 = 21.41, P = 0.005). During autumn moose utilized higher elevations where terrain was more varied. During winter, snows apparently forced moose to use lower elevations and whatever slopes were available.

Aspect Use

Annually moose preferred north- and south-facing slopes, whereas east, southwest, or west aspects were neither avoided nor preferred (Fig. 34). Other aspects (flat, northeast, southeast, and northwest) were avoided. No significant differences (p >0.05) in aspect use occurred among seasons (Table 18). All seasons combined, southwest-facing slopes were avoided (p <0.05) (Table 18).

Activity Patterns

Daily. Moose activity was recorded on 4,078 occasions during 1977-1985. Because all observations were from fixed-wing aircraft, they were biased toward daylight hours between 0700 and 2400 hrs (Fig. 35), with the majority between 0800 and 1800 hrs.

Moose were observed bedded on over half (52%) of the observations. Standing and foraging activities accounted for only 31 and 12%, respectively, of the activity categories. If moose had been monitored more often during nocturnal and crepuscular hours the percent of foraging observations probably would have increased. There was a slight increase in the proportion of time moose spent bedded during the middle of the day (Fig. 36), with early morning observations more heavily weighted toward other activities.

Monthly. Number of activity observations per month ranged from 665 in March to 167 in January (Figs. 37 and 38). The lowest ($\bar{x}$ = 44%) occurrence of bedded observations occurred during summer, increasing in autumn ($\bar{x}$ = 55%) and winter ($\bar{x}$ = 58%). Conversely, the proportion of observations where moose were observed foraging was greater during summer ($\bar{x}$ = 17%) than at other times of the year ($\bar{x}$ = 7.5%) (Fig. 39). Physiologically, summer is the time of greatest energy intake for moose. Females with calves need high intake of food, both for milk production and for deposition of body fat reserves to sustain them through the winter. Males also take advantage of increased availability of forage to deposit fat reserves for the rut and for overwintering. During winter, moose are relatively sedentary, reflecting a negative energy balance which partially accounts for the higher frequency of bedded activity.

Effects of Snow on Moose Distribution

Assessment of winter severity is critical to understanding movements and population dynamics of moose. In the Susitna Basin, the winter of 1971-72 caused substantial mortality in the population, especially within calf and yearling cohorts. From 1977-1985 elevational use by moose was correlated ($p < 0.05$) with winter severity; during deep snow years moose used lower elevations. To fully assess impacts of the proposed project, moose movements and habitat use during a relatively severe winter will have to be monitored. Because severe winters occur on an average of 3 out of 22 years and very severe winters only 1 of 22 years (see Ballard et al. 1986), it was necessary to develop the capability to predict winter severity by early February each year. The ability to predict winter severity early in the year would be beneficial because it could alert managers and researchers that potentially serious conditions existed. A method for quantitatively assessing winter severity in relation to other winters was developed. The following subsections explain the relationships.

Winter Severity Index. The winter severity index (WSI) for the middle Susitna River Basin was based on Soil Conservation

Service (SCS) snow survey data collected from winter 1963-64 to 1985-86. Four SCS snow sites were used for the index because of their proximity to the moose study area. They included: (1) Fog Lakes, (2) Square Lake (prior to 1982 known as Oshetna Lake), (3) Monahan Flats, and (4) Lake Louise. Three snow depth readings (January-March) from each of the 4 snow courses were summed and divided by the number of courses reporting. The WSI was comprised of the average 3 month cumulative snow depths (Table 19).

The index was based on the following assumptions: (1) the amount of snow cover during mid to late winter (January-April) was more important in terms of moose mortality than early winter snow depths; and (2) snow depths were the most important factor causing malnourishment in moose through 2 mechanisms--as depths increase, browse species are covered, necessitating cratering by the moose and more energy use per unit of food, and movements are restricted, requiring increased energy use to travel.

Three categories of winter were identifiable using the WSI; (1) severe winters when the WSI ≥ 28.0, (2) mild winters when the WSI ≤ 18.0, and (3) moderate winters when WSI ranged from 18.1-27.9 (Fig. 40). Moose mortality data suggested that the 3 categories of winter severity were justified. Winters 1971-72 and 1978-79 were considered severe and resulted in substantial moose mortality (Stephenson and Johnson 1973, Ballard and Gardner 1980, Eide and Ballard 1982). Winter 1974-75 was also thought to have been relatively severe based on autumn moose calf survival (unpubl. data). All 3 severe years had relatively high WSIs (Table 19).

Prediction of winter severity in the Susitna impoundment area during a current winter by early February was obtained by the following method: January snow depths from the 4 SCS snow surveys were averaged for each of 22 years. Annual WSIs were then plotted against January snow depths for the same 22 years. Correlation analysis was used to predict final winter severity (Fig. 41). Revised winter severity predictions could also be made following February snow course readings using the same procedures (Fig. 42).

<u>Elevational Use versus Winter Severity</u>. Monitoring intensity of radio-collared adult moose was increased during winters 1981-1984 to determine winter use of impoundment zones. There appeared to be a relationship between elevational use by moose and winter severity. Proportions of monthly relocations at elevations $\leq 2,200$ ft (671 m) (high pool level of Watana Impoundment) were compared with monthly winter severity indices (Fig. 43). The proportion of radio-collared moose at elevations $\geq 2,200$ ft (671 m) was correlated ($p < 0.05$) with the

WSI. The correlation was used to predict percentages and numbers of moose which would potentially use the area planned for inundation (high water level at 2,200 feet) during winters of varying degrees of severity.

Sixteen percent of radio-collared moose relocations were at elevations ≤2,200 ft (671 m) during May through December. These probably represent year-round resident moose occurring along lower elevations of the middle Susitna River Basin. As snow accumulates, moose which occur at higher elevations move downward and the proportion of the moose population utilizing the impoundment zone increases. During moderate (average) winters, the proportion of radio-collared moose in the impoundment zone increased to 17% in January, 29% in February, 35% in March, but then declined to 17% in April when snows begin to melt and recede. If a severe winter similar to 1971-72 were to occur, the regression predicts that over 50% of the middle basin moose population would utilize the impoundment zones (Fig. 43).

Assuming that the radio-collared moose were representative of the 2,400 estimated within the middle Susitna Basin, the correlation would predict that during moderate winters an average of 590 (January = 17%, February = 29%, March = 35%, April = 17%; Average = 25%; 2,400 X 0.246 = 590) moose would use the impoundment zone. During severe winters, the correlation predicts an average of 1,552 moose would use the impoundments from January through April (January = 61%, February = 55%, March = 67%, April = 71%; Average = 63%; 2,400 X .634 = 1,522). No field data exist to support these estimates except 1 count of the Watana Impoundment in winter 1983 when 580 moose were estimated during a winter of moderate severity (Table 13). Counts conducted during three other winters resulted in estimates of about 40 to 300 moose. To fully test these predictions, radio-collared moose should be monitored and a winter census conducted during a relatively severe winter.

IMPACT MECHANISMS AND PREDICTION OF IMPACTS DUE TO HYDROELECTRIC DEVELOPMENT

The project is expected to affect moose through a number of different mechanisms. These effects would vary greatly over time and space. It is particularly difficult to predict population changes where several mechanisms may have cumulative effects and the magnitude of these effects may vary depending on the size of the population or current environmental conditions. For example, a given set of impact mechanisms might cause a permanent reduction in moose densities in 1 drainage, yet densities in another drainage may decline only during severe winters. The net impact of those mechanisms on the entire population would vary according to patterns of winter severity, location of the mechanisms, and movement patterns of moose.

There is no perfect way of incorporating this variability into impact predictions. We selected 2 separate approaches. The first approach used descriptions of subpopulations to portray spatial variability. The second involved estimating the number of moose which could be supported by the vegetation to be destroyed by the project. The third approach, not covered in this report was to develop a population model that could be used to portray temporal variability (see Ballard et al. 1986).

Impact Mechanisms

Development of hydroelectric power on the Susitna River would impact moose populations both directly and indirectly through a number of different mechanisms. Impacts on moose can be classified into 3 broad categories: (1) habitat alteration, (2) impacts on population dynamics processes, and (3) socio-political-economic consequences. In this discussion we do not attempt to discuss socio-political-economic consequences except as related to reductions in moose hunting and viewing opportunities. Both beneficial and detrimental impacts on moose are likely to occur, but available literature is inadequate to guide assessment of impact magnitude due to many of the mechanisms. Consequently, until comparative pre- and post-impoundment studies document the nature and extent of impacts, prediction of impacts would remain speculative. We formulated hypotheses to aid in assessing how hydroelectric development might impact moose populations. Hydroelectric development was divided into components of the biotic and abiotic environment which directly and indirectly influence factors regulating moose population dynamics. The hypothesized processes are summarized in a matrix-type table (Table 20). Construction and operation aspects of the proposed project were categorized into 12 major project actions. Effects of these actions on the moose's environment were then categorized into major impact mechanisms with predicted negative and beneficial influences on moose population processes. How these impact mechanisms are likely to impact moose and ultimately manifest themselves in the moose population is detailed in subsequent sections of this report.

Most impacts are expected to occur during construction and the first 25 years of operation. However, several impacts would occur over the length of the project. Specific impact mechanisms may impact moose positively or negatively and may involve only certain segments or subpopulations of moose. Changes in a moose herd due to hydroelectric development may be difficult to measure and may occur very subtlety over time. An impact which would have been unimportant under normal healthy preproject situations may become important, particularly if it occurs with other impacts.

Classification And Identification Of Impacts

For discussion purposes, the importance of various types of impacts in relation to this specific project were classified into 3 categories. These categories are based on the potential significance of an impact and on our current ability to detect significant changes in specific moose population parameters. The three categories are:

Important Impacts. Important project-induced impacts are those which available evidence indicates, individually or in summation, have a high probability of causing measurable change in moose population size and/or productivity. Such change is often manifested through reductions in moose natality or increases in moose mortality, or may indirectly alter a process which affects a key moose population parameter; e.g., altering predator/prey ratios may increase moose mortality. Such impacts are usually significant and result in lower population size and/or changes in distribution, ultimately reducing human consumptive and nonconsumptive uses.

Potentially Important Impacts. These are project-induced impacts, which individually or in summation, potentially could alter moose population size or productivity, but for which insufficient evidence exists to confirm their significance or potential to limit the population. Potentially important impacts may be difficult to confirm and quantify because impact mechanisms may mask their effects, or our ability to detect changes may be inadequate.

Unimportant Impacts. Unimportant impacts are those which data and logic indicate would have a low probability of altering moose population size and which would not constitute a significant limiting factor. These impacts may affect the survival or behavior of individual animals.

Based on baseline biological data presented in previous sections and on general classification of impacts described in the previous 2 sections, specific impacts are described (not in order of anticipated magnitude):

Important Impacts (I.I.).

I.I.-1. Permanent habitat loss due to impoundments and other permanent facilities would have an adverse permanent impact on area moose populations.

Rationale--Loss of ungulate habitat is not necessarily detrimental, e.g., habitat lacks components that contribute to potential ungulate carrying capacity. The proposed Susitna Hydroelectric Project impoundments and other facilities would eliminate habitat used by moose during winter and spring. This loss would significantly reduce carrying capacity because winter and early spring are critical periods for moose. Moose usage of wintering areas is highly traditional, so although adequate habitat may be available in other areas, moose would still suffer high rates of mortality. In the long term moose numbers would be permanently lower because of this habitat loss.

Timing of habitat usage is an important consideration when determining relative value of winter habitat. Although some moose subpopulations may utilize the same winter habitat annually, others may only use it during severe conditions. Intensive use during severe winters may vary from a few days to several weeks, during which time the long-term capacity of the habitat may be exceeded. Even if carrying capacity is exceeded, the overall mortality rate of the moose population may be less than if the habitat were not available. Slight reductions in mortality rates during severe winters can allow rapid recovery during subsequent years of mild winters.

Moose Population Parameters to be Altered--If adjacent habitat is either at capacity or not available, e.g., deep snow, several population parameters could be altered. The magnitude of some impacts might be masked because they involve moose not directly affected by an impact mechanism. Both seasonal and year-round residents would be displaced from the project area. Numbers of moose dying from starvation (winter kill) are expected to be relatively high for several years. Winter-weakened moose would suffer higher rates of mortality from predation by wolves in winter and bears in spring. Calf moose mortality would be especially high, and annual recruitment may be less than mortality. Survival rates of displaced adults are expected to be relatively low. Surviving adults would be in poorer physical condition resulting in lower rates of calf production. Calves would be smaller and less viable, hence more vulnerable to predation and increased early spring and summer accident-caused mortality and other nonpredation losses.

Because the current moose population is slowly increasing at a rate of 3-5% annually, increases in mortality would likely cause the population to decline. Reductions in calf survival would preclude dispersal to other areas. The culmination of all events may result in extinction of several subpopulations of moose which reside in impact areas or depend on these areas for critical winter range. Adjacent subpopulations of moose would compete with displaced animals and would suffer increased winter kill and predation but at lesser rates than displaced moose.

Impacts on Human Uses of Moose--A significant decrease in the numbers of moose available for subsistence and recreational harvest in the project vicinity is expected. Dispersals would be reduced, so numbers of moose available for harvest and viewing in surrounding areas would also be reduced. This particularly applies to the Denali Highway bull moose population which is heavily hunted and is partially dependent on dispersals from the Susitna Project area.

I.I.-2. <u>During and following reservoir-filling, displacement of moose and disruption of seasonal movement patterns would create abnormal concentrations of moose adjacent to the impoundments. This displacement would attract and concentrate predators, resulting in higher predation rates</u>.

Rationale--Predation by brown bears and wolves are currently the largest sources of mortality affecting dynamics of the Susitna area moose population (Ballard et al. 1980, 1981, 1985). Typically, the sex and age of moose killed by predators is determined by the vulnerability of the prey. Usually predation focuses on the young and old of a population (Mech 1970). Exceptions to this rule commonly occur when deep snow results in animals becoming vulnerable to surplus killing (Eide and Ballard 1982) by impedence of movement, or especially weakened by malnutrition or disease. Bears are typically facultative predators, whereas wolves are considered obligate predators (Ballard and Larsen 1986). Because moose and predators would be concentrated at abnormal densities, both displaced and resident moose would be subjected to increased levels of predation. Displaced moose would be particularly vulnerable because of stress, weakened condition, and lack of familiarity with escape routes. Although displaced moose may die as a result of other impact mechanisms, moose of all ages are expected to suffer increased mortality from predation. Resident moose would be less vulnerable than displaced moose but more vulnerable than prior to the project due to increased competition for forage and living area and an increased number of predators. Resident calves would be more vulnerable than adults because this age class is usually subjected to higher mortality rates. In conjunction with other mortality factors, increased predation could significantly decrease the moose population and hold it at a lower density. Because there are no fast acting feedback mechanisms between large ungulates and their principal predators (wolves and bears), such population declines and the resulting lower threshold levels could span decades (Gasaway et al. 1983; Ballard and Larsen 1986).

Although black bears can also be significant predators of moose (Franzmann et al. 1980), they are currently significantly less important than brown bear and wolves in the Susitna Project area (Ballard et al. 1985). However, much of the current black bear habitat would be eliminated by the project (Miller 1984), potentially causing displaced black bears to be an additional source of predator mortality. Even though black bears would probably be eliminated from the area, the short-term additive mortality to the moose population could accentuate a moose population decline.

Moose Population Parameters to be Altered--Mortality from predation would increase during all seasons, but particularly during late winter and spring.

Impacts on Human Uses of Moose--Wolf and bear predation are generally considered to be additive sources of mortality, hence these predators compete directly with humans for the moose harvest. If predation contributes to a moose population decline or maintains the population at low densities, human harvests of moose would be greatly curtailed or eliminated unless a harvestable surplus is regained.

I.I.-3. <u>Open water below Watana Dam and downstream from the Devil Canyon Impoundment, in addition to ice shelving, may block access to traditional winter and calving areas</u>.

Rationale--Presence of open water during winter when ambient air temperatures are relatively low is expected to impede and possibly halt river crossings. Under pre-project conditions moose were found to cross the river during all seasons of the year (<u>see</u> River Crossings section). During periods when ice is either forming or thawing, movements across the river are probably most hazardous. Moose may not cross major rivers when ice is of varying thicknesses, and thawing conditions occur. These types of hazardous conditions would exist in the vicinity of impoundments throughout autumn, winter, and spring.

Opposing views exist as to the potential importance of this impact factor. Bonar (1985) reported that moose crossed open water near Revelstoke Dam at air temperatures of -20 degrees C. However, air temperatures in the Susitna project area are quite often lower than those found in southern British Columbia. Harper (1985) at Fort St. John, British

Columbia (several hundred kms north of Revelstoke), believed that open water downstream from the Bennett Dam was a major barrier to moose movements during winter. He provided observations which suggested that moose were not woulding to cross open water when air temperatures were about -30 to -40 degrees C. During winter 1979-80, moose refused to leave an island which was inundated by 1 meter of slush ice caused by ice jams downstream and surrounded by open water. The net result was that at least 23 moose died from exposure. High moose mortality in the vicinity of reservoirs during and after ice formation has been reported from the Soviet Union (Danilov 1986). These latter observations suggest that blockage of movements may severely impact moose directly by mortality or indirectly by preventing access to important habitat.

Use of seasonal habitats by moose is traditional (LeResche and Davis 1974, Van Ballenberghe 1978, Ballard and Taylor 1980, and Gasaway et al. 1983). This usage pattern suggests that individual moose have developed successful strategies for using seasonal environments. Although remaining habitat surrounding the Sustina project may be capable of supporting more moose, displaced moose with current survival strategies may not adapt quickly enough to the loss of habitat to avoid mortality. A similar scenario exists for white-tailed deer populations which yard up during winter and may stay in an overbrowsed area and starve even though suitable habitat exists in adjacent areas (Taylor 1965).

Moose Population Parameters to be Altered--Mortality due to starvation would increase. Relatively large moose die-offs may occur during severe winter conditions because of blockage to winter range. Eventually moose may adapt to this phenomenon, but populations may be held at low levels by artificially high densities of predators. Lower numbers of moose may become pregnant due to disruption of social behavior and poorer physical condition as a result of malnutrition. Calves are expected to experience greater rates of natural mortality due to accidents, pneumonia, and other nonpredator forms of mortality. Rates of mortality from bear and wolf predation would also be higher due to weakened condition and crowding. Short-term mortality from hunting harvests may increase due to moose concentrating in relatively accessible areas. This latter impact assumes hunting regulations are not modified to reduce moose vulnerability.

Impacts on Human Uses of Moose--Numbers of moose available for harvest would decrease. In addition to reduced densities in the immediate project area, surrounding areas would experience population reductions because of the lack of emigration from the project area.

I.I.-4. Ice shelving, open water, thin ice, and floating debris would cause direct mortality to moose attempting to cross impoundments.

Rationale--Most moose populations experience direct mortality from natural factors such as falling through thin ice or injuries resulting from slipping on ice (W. Ballard, A. Franzmann, R. Modaferri, and others, unpubl. data). Such accidents normally occur when moose encounter bodies of water. This type of mortality is usually insignificant in population dynamics and is considered density independent. These types of accidents would continue to occur regardless of whether the project is built, but because more area would be covered by water and ice, conditions would be less stable.

The Susitna River below the Watana and Devil Canyon dam sites is not expected to freeze as it has under natural conditions. If freezing does occur, thickness and stability of resulting ice would be substantially different than presently occurs. Moose generally cross waterbodies during ice-free periods or when ice is sufficiently thick to support them (this study). Regardless of whether this behavior is learned or innate, moose may not adapt to abnormal thawing and icing conditions. For example, moose may attempt to cross ice-covered areas during time periods when such crossings were normally safe, thereby increasing mortality due to ice-related accidents and drowning.

Ice shelving along impoundment edges may pose hazards to moose attempting to cross open water or ice-covered areas. Depending on steepness and surface characteristics of ice shelves, moose may be unable to escape from open water. They may also be unable to escape if they fall through ice while crossing. Fatal injuries due to slips on ice shelves occur naturally, but frequency would increase as a result of the project. Floating debris may also increase moose mortality due to drowning.

Direct ungulate mortality attributable to thin ice, ice shelves, and floating debris is not well documented because no studies have been conducted to measure differences before and after creation of impoundments in northerly latitudes. However, several references exist which document occurrences of such mortality. In Colorado, R. Lindsey (unpubl. data) documented that about 60 elk (*Cervus elaphus*) fell through ice while attempting to cross Blue Mesa Reservoir. Bonar (1985) indicates at least 10-20 moose fall through the ice each year at Revelstoke Dam in southern British Columbia (BC), where temperatures are considerably more moderate than those found in the Susitna area. In the latter case, Bonar (1985) had not analyzed any data, but he considered such losses insignificant to the population. However, river crossings had been reduced to some unmeasured extent as a result of the hydroelectric project. In the Soviet Union, mortality caused by falling into impoundments during and after ice formation is variable by area and year but may reach 10-45% of the moose population (Danilov 1986). F. Harper (pers. commun.) reports several instances of newborn moose becoming entangled in shoreline debris and being unable to escape from Williston Reservoir, BC.

Under normal circumstances mortalities from these types of impacts are not be significant. However, because this is an additive source of mortality acting on an already stressed population, it should be viewed as a significant adverse impact.

Population Parameters to be Impacted--Accidental mortality rates of adults and calves would be increased. Increased mortality rates within some subpopulations would be sufficient to cause population declines or reduce the rate of population growth.

Impacts on Human Uses of Moose--This impact factor would be an additive source of mortality resulting in fewer moose for harvest or viewing. Fewer moose may also be available for dispersal into other areas which are partially dependent upon Susitna moose populations to replace losses due to heavy hunting pressure.

I.I.-5. Train and highway vehicle collisions due to new transportation access routes and traffic increases on existing routes would result in increased moose mortality.

Rationale--Roads and railroad corridors which are plowed free of snow during winter attract moose because travel is easier than in adjacent unplowed areas (Rausch 1959, Childs 1983). Plowing roads and rail lines results in steep banks and deep snow on either side of the tracks. Moose in snow-free areas seem reluctant to enter deep snow. Moose typically exhibit anti-predator behavior to oncoming trains: because they charge or hold their ground, they are killed by the train (Childs 1983).

Access for the Susitna project would be achieved through a combination of railroad and road construction. A new road would be constructed from the Denali Highway to the Watana construction camp. The existing Anchorage-Fairbanks rail line would be connected by a spur line to the Devil Canyon Campsite. A road would also be constructed from the Devil Canyon dam site to the Watana dam site. Because these new features would be built at elevations used by moose during winter, mortality from collisions may be relatively high during construction and the initial years of operation.

Moose typically migrate or move from high elevation areas in response to the first heavy snowfall each autumn. Depending on magnitude and severity of the first storm, large numbers of moose could congregate on snow-free roads and rail lines. Mortality could be sufficiently high to remove the annual surplus of moose and, in conjunction with other factors, could cause a population decline. Experience with railroad/moose collisions between Houston and Talkeetna support this scenario. During the severe winter of 1984-85, over 300 moose were killed (J. Didrikson, pers. commun.).

Moose Population Parameters to be Altered--Accidental mortality to calf and adult moose would increase. During most years the numbers of collision mortalities would be insignificant. However, during years of deep snow, mortality could be significant. Large losses during relatively severe winters could alter the growth of the moose population in subsequent years. Once moose densities are lowered, other mortality factors such as predation may prevent the population from increasing.

Impacts on Human Uses of Moose--Because mortality from this impact is additive, its importance depends on its magnitude each year and on the population density of both predators and moose. Following severe winters with high losses, hunting harvests may be greatly reduced to allow the moose population to recover. Fewer moose may be available for viewing or disperal to other areas.

I.I.-6. Snow drifts from impoundments and other major developments may impede moose movements and/or subject moose to higher risk of collision mortality and may reduce the value of some areas as winter range.

Rationale--Snow blowing off the impoundments and other major facilities or developments is expected to create substantial snow drifts, particularly along portions of the shoreline. Areas which were prone to drifting prior to the project would likely accumulate more snow with the project. Because moose avoid areas of deep snow, creation of new drifts would result in loss of habitat. If moose movements are impeded and if moose avoid deep snow areas, some additional habitat may be unavailable. Snow drifts in this latter case could also constitute a barrier to moose movements.

Prediction of the exact location and extent of snow drifting is impossible because numerous factors influence its occurrence. LGL (1985) predicts that it would occur only in localized areas and particularly along the south and southwest areas of the impoundments. In relation to the total project area, the term "localized" is appropriate; however, these small, localized impacts may become extremely important to subpopulations of moose if migration corridors are blocked. Snow drifts may also occur along newly created transmission line corridors, but prediction of the importance of this impact is even more difficult than predicting impacts of the impoundments.

Areas covered by snow drifts retain snow longer than nondrift areas. Consequently, greenup of vegetation covered by drifts could be delayed in relation to other areas. Depending on the amount and type of habitat, loss of early spring habitat could be important because moose are typically in relatively poor nutritional condition this time of year.

Moose Population Parameters to be Altered--Mortality from starvation may increase due to disruption or impedance of movements and migration, and to loss of habitat. Some moose may become more vulnerable to predation because their escape may be delayed by snow drifts. Reproduction may be impacted because moose that do not die from starvation would be in poorer physical condition.

Impacts on Human Uses of Moose--The total number of moose may be reduced. Although difficult to measure because the population could be stressed from a number of impacts, this particular impact is an additive source of winter mortality. As with other impacts, fewer moose would be available for human use and dispersal.

I.I.-7. <u>Drifted snow along railroad and road access corridors and roadway berms may impede movements of moose and/or subject them to higher risk of collision mortality</u>.

Rationale--In most respects this particular impact is similar to and closely interwoven with I.I.-5 and 6 which have been discussed in preceding paragraphs. No further discussion is warranted.

I.I.-8. <u>Clearing of vegetation in the impoundment area would reduce carrying capacity prior to filling of the impoundment</u>.

Rationale--Clearing vegetation prior to filling the impoundment would modify and destroy browse which traditionally has served as important moose winter range. Loss of winter range would occur as a result of reservoir filling; therefore, many impacts identified under I.I.-1 would occur here, with a few differences in initial reaction.

Moose may continue to seek traditionally used habitat during winter and spring. The area would be denuded of both escape and thermal cover, so moose may be more vulnerable to predation and exposure to severe weather. Social stress may occur because lack of spruce cover would allow moose at relatively high densities to be in visual contact. Such contact can result in aggressive behavior among moose for available forage (T. Sweanor and F. Sandegren, unpubl. data).

Population Parameters to be Impacted--Same as under I.I.-1.

Impacts on Human Uses of Moose--Same as under I.I.-1. In addition, moose may initially be more vulnerable to hunting and poaching.

I.I.-9. <u>Increases in mortality of moose may occur due to increases in legal subsistence hunting and poaching</u>.

Rationale--Creation of impoundments and roads would create additional, easier access to the project area, so increases in hunting pressure may occur. Total harvests are expected to increase because moose would be more vulnerable due to stress and a combination of project impacts. Whether increased legal harvest is detrimental or even occurs depends on type of season and regulations in effect.

For example, recent moose harvest regulations in the project area only allow harvest of moose with antler spreads of ¶36 inches (91 cm) or with 3 brow tines. The regulation provides protection to yearling and 2-year-old age classes while allowing unlimited hunter participation and assumes that not all large bulls would be harvested. If all larger bulls were harvested, most or all breeding would be done by young bulls, which could create social and possibly genetic problems. Under current hunting pressure not all large bulls have been harvested. Additional access could facilitate harvest of more older bulls which would necessitate revised regulations to limit or redistribute harvest. Increased hunting pressure may increase crippling losses.

Increased access would create a situation more conducive to illegal harvests. Whether increases in moose mortality due to poaching would be of sufficient magnitude to affect a moose population is not known. Because the moose population would be stressed from a number of other impacts, increases in hunting and poaching mortality would be additive sources of mortality which could contribute to a population decline.

Moose Population Parameters to be Altered--Legal hunting mortality, crippling loss, and poaching may increase as a result of the project.

Impacts on Human Uses of Moose--Initially, larger numbers of moose may be harvested in the project area. Unregulated access may create unpleasant hunting conditions because of hunter density. Ultimately, however, the number of moose available for harvest and other uses would decline. Hunter success would initially be high but would also decline. Poaching is likely to increase.

I.I.-10. <u>Both temporary and permanent loss of winter habitat would occur as a result of borrow site development</u>.

Rationale--Creation and excavation of borrow pits would remove all vegetation and destroy summer and winter habitat. Access roads would create additional access for hunting and poaching. LGL (1985) predicted that this loss of vegetation may only last from 2-20 years because all sites would be recovered with topsoil and should become revegetated with useful moose forage species. Regardless, loss of these sites would contribute to a moose population decline through the same processes described under I.I.-1, with some differences.

Although actual loss of vegetation may be short term because of revegetation efforts (LGL 1985), there could be long-term impacts if the areas are revegetated by browse species less palatable to moose, or the areas are unavailable due to drifting snow. Also, once the moose population declines due to loss of habitat and other factors described in the preceding and following sections, the moose population may then be limited by factors other than winter forage. Moose populations are often regulated by factors other than forage (Gasaway et al. 1983; Ballard and Larsen 1986). Numerous threshold levels exist which could keep the moose population below actual range carrying capacity. Therefore, in a theoretical sense this impact would be short term, but in reality, once the population declines, it could be long term unless changes in other factors allow a population increase.

Moose Population Parameters to be Altered--Same parameters as those listed under I.I.-1, 2, 6, 7, and 8.

Impacts on Human Uses of Moose--Initially moose would be more vulnerable to hunting and poaching due to improved access. Loss of habitat with the resulting population decline would result in fewer moose available for hunting and viewing. The latter could be a short-term impact if the moose population is able to recover and take advantage of the revegetated areas.

In the latter case, improved access could allow for increased harvests.

I.I.-11. Permanent loss and alteration of moose habitat would occur as a result of access corridor construction, maintenance, and use.

Rationale--Construction, maintenance, and use of roads and rail facilities would require additional gravel pits and berm construction beyond those needed for actual construction of the dams. Use of the areas, and maintenance, would create disturbances that cause moose to avoid some areas. The problems encountered with this impact are integral parts of those discussed for other impacts.

Moose Population Parameters to be Altered--Similar to those described under I.I.-1, 2, 5, 7, 8, 9, and 10.

Impacts on Human Uses of Moose--Ultimately, the total numbers of moose available for human use would be reduced due to both direct and indirect loss of habitat and increased mortality. Initially greater numbers of moose may be legally and illegally harvested due to increased access.

I.I.-12. Due to improved access created by the project, the entire basin may be subject to increased commercial development which would result in loss of moose habitat and increases in moose mortality.

Rationale--The project area lies within an area surrounded by the Parks, Glenn, Denali, and Richardson Highways. Because of remoteness, the area would probably not be commercially developed for decades. With the advent of the proposed project, Native corporations selected land needed by the project and adjacent areas to take advantage of new access routes. Creation of access and resulting secondary private developments are considered negative impacts on wildlife. In some cases secondary developments could have a greater impact on moose than the actual project itself. Depending on the nature and location of developments (e.g., mining activities, lodge facilities), significant losses of habitat and increases in direct moose mortality due to auto collisions, poaching, and hunting could occur.

Population Parameters to be Impacted--Because additional developments often result in direct loss of habitat and/or direct mortality, the effects on various moose population parameters would be identical to those described under many of the impacts previously described except that the degree of impact would vary.

Impacts on Human Uses of Moose--Impacts would be similar to those described under previous impacts. Ultimately, fewer moose would occur.

I.I.-13. Habitat quantity and quality for moose would improve along the transmission corridor because vegetation would be maintained in early successional stages.

Rationale--Clearing transmission corridors and maintaining early successional states of spruce and mixed spruce-deciduous vegetation are expected to result in an improved browse biomass. This is expected to increase the carrying capacity for moose wintering along the transmission corridor. Winter mortality may be reduced for some subpopulations and increases in productivity may occur. Human access into previously inaccessible areas would be greatly improved.

Moose Population Parameters to be Altered--Due to improved nutrition, some increase in productivity might occur. Mortality due to winter starvation may be reduced. Mortality during severe winters would not be reduced because much of the improved habitat would be inaccessible during a severe winter.

Impacts on Human Uses of Moose--Increased numbers of moose should be available for harvest and viewing. Transmission lines would also provide additional access for all-terrain vehicles, facilitating both additional legal harvests and poaching.

Potentially Important Impacts (P.I.).

P.I.-1. Local climatic changes resulting from the impoundments would include increased summer rainfall, increased winds, cooler summer temperatures, increased early winter snowfall, hoarfrost deposition on vegetation in winter, delayed spring plant phenology, and changes in plant growth and species composition. These changes would reduce habitat carrying capacity for moose and increase vulnerability to a number of forms of mortality.

Rationale--It is well documented that creation of large artificial bodies of water alters the climate of the surrounding area. This "warm-bowl" and "cold-bowl" effect can significantly alter climate to such an extent that large differences in precipitation and temperature can occur. LGL (1985), suggested the effects would be "localized" and would not extend beyond 1-5 miles from the shoreline. If measurable changes in climate occur within this zone the impacts of the potential changes could be significant.

LGL (1985) suggests that because the effects of climatic change would be "localized" the effects would not be measurable. In earlier studies for Rampart Dam and Reservoir, Henry (1965) modeled available climatic data and predicted that a 10% change in precipitation would occur up to several hundred kilometers away from the impoundment. A number of other climatic changes were also predicted. Although the Susitna Project would be considerably smaller than the Rampart proposal, it appears reasonable to assume, based on studies such as Henry's and others (Taber and Raedeke 1976 - Ross Lake in Washington), that measurable changes in some climatic parameters would occur. To determine the magnitude of change, systematic pre- and post-impoundment studies would be necessary to discount this potential impact.

Climatic changes which could potentially be most important to moose include cooler summer temperatures, increased snowfall, increased hoarfrost deposition on vegetation, delayed spring melt, delayed spring plant phenology, and possible changes in plant growth and species composition. Detailed discussion of these potential effects follow:

a. Cooler summer temperatures--This change could make conditions less favorable for survival of newborn moose calves due to exposure to cooler temperatures in conjunction with delayed snow melt and delayed plant phenology.

b. Increased snowfall--Increases in snow depths adjacent to the impoundments due to increased evaporation could make important wintering areas less desirable as winter range. The area adjacent to the impoundments receives higher use than areas where browse may be more abundant but less available due to greater snow depths. Increasing snow depths within a 1-5 mile zone from the reservoir could significantly decrease the value of the remaining important winter range. For example, a 10% increase in snow depth over a 1- to 5-mile-wide zone in critical moose winter range could reduce the capacity of the area to support moose.

c. Hoarfrost deposition on vegetation--Hoarfrost and rime ice naturally occur on vegetation along the Susitna River during some time periods. Where open water would occur year-round due to the impoundments (downstream of Watana and Devil Canyon dam sites), the frequency of frost and rime ice deposition on moose browse would increase. Although difficult to measure, the addition of substantial amounts of frost and rime ice on vegetation requires additional energy for moose to melt the ice. If frosting or icing repeatedly occurs over the winter, this energy expenditure could increase stress on the moose population, given that their physiological condition is downward even during moderate winters. In northern British Columbia, Harper (1985) suggested that the occurrence of ice fog from the creation of the Bennett dam and reservoir on the Peace River may have been an additional factor causing reduced moose populations on the north side of the river. The Peace River Valley is now "fogged-in" most of the winter due to warmer water coming from the dam, effectively eliminating the insulation benefits of south-facing winter ranges (Op. cit.).

d. Delayed spring melt--Cooler temperatures in conjunction with increased snow depths could delay onset of spring thaw and increase length of time necessary for snow melt. This would also delay availability of some food plants. Moose would avoid areas which retain snow, resulting in a change in moose distribution and habitat selection and increasing pressure on adjacent habitats and populations.

e. Delayed spring plant phenology--Plant phenology is influenced by a wide variety of factors (LGL 1985). With lower air temperatures and increased snow depths, plant development would be slower than in areas with high temperatures and less snow. Moose are usually in their poorest physiological state just before onset of greenup. Delay of greenup could significantly affect moose survival. LGL (1985) speculated that greenup would be delayed by a maximum of 3-5 days. The length of this time period would be dependent on the accumulation of snow and spring temperatures.

f. Precipitation and temperature are among several factors which influence composition, distribution, and growth of vegetation. Growth of existing vegetation may be altered due to cooler temperatures, increased snow depths, delayed spring melt, etc., all of which lead to a shorter growing season. This may alter the growth rates of wouldows and reduce the range carrying capacity. Changes in plant species composition would likely be very subtle and take several decades to be detected.

Moose Population Parameters which could be Altered--Due to a loss of critical late-winter/early-spring habitat and delayed greenup of vegetation, survival of calves would be reduced. Poorer physiological condition of cows results in production of less viable calves. Increased mortality may result from exposure to a less suitable climate. Moose may be more vulnerable to predation because of the poorer physical condition and displacement from desirable habitat. Winter mortality from starvation may increase due to loss of habitat and increases in energy expenditures necessary for finding sufficient forage.

Impacts on Human Uses of Moose--Because this impact ultimately reduces habitat carrying capacity and increases mortality, fewer moose would be available for harvest, viewing, and dispersal.

P.I.-2. Warmer water in downstream areas would result in open water and may alter plant phenology and affect spring forage and cover for moose.

Rationale--LGL (1985) speculated that warm water conditions would retard river ice development in late winter and melt existing river ice faster. However, existing hydroelectric developments provide scenarios for projecting impacts on moose. For example, on the Peace River below Bennett Dam in northern BC during 1979-80, flow ice piled up in downstream areas, creating ice dams. These dams then caused flooding and inundation of upstream riparian areas (Harper 1985). The inundated habitat was not suited for moose during the remainder of the winter. We suspect that these areas freeze and thaw more slowly, thus eliminating winter habitat and retarding spring plant growth. Moose that become trapped on the inundated areas suffer increased mortality due to exposure because they do not move from the islands (Harper 1985).

Moose Population Parameters Which Could Be Altered--Overall, carrying capacity for moose would be reduced and rates of mortality would increase (see discussion for I.I.-3 and 4).

Impacts on Human Uses of Moose--Because the total number of moose would be reduced, fewer moose would be available for human use and dispersal.

P.I.-3. Habitat quality may temporarily decrease near the reservoir as a result of locally high densities of moose dispersing from inundated areas.

Rationale--Moose which become displaced due to inundation would concentrate on adjacent habitat and utilize vegetation which currently supports other moose. The amount of forage present in and immediately adjacent to the impoundments is less than that outside the impoundments. However, it receives much greater utilization (Becker and Steigers, unpubl. data), apparently because it is more available due to shallow snow depths. Because this vegetation is heavily used, additional usage by displaced moose would probably exceed annual growth and reduce carrying capacity.

Moose Population Parameters which could be Altered--Starvation mortality would increase due to increased competition and reductions in carrying capacity. Remaining moose would experience decreased productivity along with increased mortality of calves.

Impacts on Human Uses of Moose--Increases in natural mortality and declines in production would result in fewer moose for human uses and dispersal.

P.I.-4. <u>Continued loss of moose habitat due to erosion of impoundment shores</u>.

Rationale--Erosion of shorelines would destroy an unknown quantity of moose habitat. Some areas may become revegetated with species more useful as moose forage. LGL (1985) considered this impact to be a slight adverse impact which could be offset by colonization of new vegetation, assuming the steepness of newly colonized areas would not preclude moose use. This, with other impacts, is an additive impact which would be relatively insignificant but, because it would occur in conjunction with other impacts, may result in additional loss of habitat and accidental deaths. Population parameters and human uses to be impacted are similar to those already discussed under P.I.-1, 2 and 3.

P.I.-5. <u>Drifting snow in the transmission line corridor may preclude use of winter browse</u>.

Rationale--Areas vegetated by short plant species appear more prone to snow drifting. This effect may negate some of the positive benefits derived from increases in browse production as a result of clearing corridors. New browse may be unavailable due to snow drifting.

Moose Population Parameters Which Could Be Altered--Increases in moose productivity due to increased browse supplies described under I.I.-12 may not occur to the degree anticipated. Portions of the increased browse may not be available because of snow drifting. Consequently, starvation mortality during mild winters may not be reduced to the level anticipated under I.I.-12.

Impacts on Human Uses of Moose--There may not be an increase in the numbers of moose available for harvest as a result of improvements in browse quantity predicted under I.I.-12.

P.I.-6. <u>Accidental fires resulting from human activities may rejuvenate decadent moose habitat</u>.

Rationale--Increases in human activities during construction and operation may result in accidental fires. Because many portions of GMU 13 have historically been subjected to wildfire, much of the moose habitat is fire-dependent. If accidental fires occurred, moose habitat quality and quantity would improve resulting in increases in range carrying capacity. Whether the moose population could respond to the improved habitat may dictate whether it becomes used. Improvements in habitat could be expected to last about 25 years before additional habitat improvement would be needed. Assuming vegetation and moose respond as they did to wildfires in Interior Alaska, no short-term detrimental impacts are anticipated (Gasaway and Dubois 1985). However, with increased private and commercial developments fire suppression programs usually intensify and the potential for habitat improvement from wildfire and controlled burning would probably never materialize.

Moose Population Parameters Which Could Be Altered--Depending on the size of the area involved, improvements in quality and quantity of forage could benefit moose. Cow moose could be in better physiological condition resulting in production of vigorous, healthy calves. Moose of all age classes could be in better physical condition and less prone to predation. Numbers of starvation mortalities could decline.

Impacts on Human Uses of Moose--If not limited by other factors, numbers of moose available for harvest and viewing could increase. If annual surpluses are not removed by hunting and predation, surplus animals may disperse to less populated areas serving to restock areas depleted by hunting or other factors.

P.I.-7. <u>Increases in ground-based activity (road traffic, village activities, dam construction) may preclude use of some areas by moose, particularly sensitive areas such as calving sites and winter habitat</u>.

Rationale--Increased human presence, particularly at villages and at areas where major habitat alterations are occurring, would result in disturbance to moose. Disturbance can manifest itself in many forms; e.g., ungulate heart rates and other body functions increase when confronted with unnatural stimuli. Additional stress does not necessarily result in an outward change in behavior or in direct harm to the animal, but is an additive stress factor to be considered in energy dynamics of moose. The most outward result of disturbance would be avoidance of areas where noise and visual stimuli cause harassment. Moose are expected to avoid habitat areas near the damssites during active construction and other areas between dam sites, villages, and gravel borrow pits. Continued high-intensity use of villages, rail facilities, airports, and dam sites may result in permanent avoidance.

Moose Population Parameters Which Could Be Altered--Avoidance of specific sites which historically served as winter habitat is equated with at least a temporary loss of habitat. This loss would affect several moose population parameters, particularly those mentioned under I.I.-1.

Unimportant Impacts (U.I.).

U.I.-1. Alteration of moose distribution may occur due to corridor traffic and disturbance.

Rationale--Initially, activities associated with construction and operation of transportation corridors would cause moose to avoid these areas. This may result in short-term habitat loss if the avoidance occurs during winter. However, moose should become acclimatized to this disturbance, so no long-term impacts are anticipated. The greatest amount of disturbance may occur during hunting season through use of access corridors. Disruption of movements in autumn could alter rutting behavior and force moose into less desirable areas. Potentially, this could affect reproduction and result in a short-term loss of productivity. In the short term, moose may suffer increased rates of starvation mortality until they become accustomed to traffic and noise. Rutting behavior may be temporarily disturbed.

U.I.-2. Prior to filling, clearcut areas in the impoundment may inhibit movements due to slash piles and human disturbance.

Rationale--Because moose may react negatively to creation of open areas without cover, temporary retention of slash piles may mitigate part of the avoidance impact. However, continued human presence may, in the short term, cause temporary avoidance of the area until logging crews and other project personnel leave the area. Although not important in itself, this impact is another additive source of negative stimuli for moose. No long-term impacts on moose, or their uses, are anticipated from this particular impact.

U.I.-3. Impeded drainage caused by road and railroad berms may alter moose habitat as a result of flooding of forest and shrub areas.

Rationale--Water drainage would be altered by construction of berms. In many cases this alteration would be minimized by proper installation of culverts and bridges. However, some alterations (such as temporary inundation of small, localized areas) which would kill vegetation, would occur. LGL (1985) maintains that there would be equal probability of creating higher quality habitat as a result of berm construction.

Although it is probably correct to assume plant species desired by moose would colonize the berm areas, this attractant would make moose more susceptible to death from vehicle collisions.

Impacts on moose forage that are caused by from berm construction would be localized and would probably not result in measurable impact on the moose population. However, like many other impacts associated with this project, it may not be individually important but in summation with other impacts may be significant.

U.I.-4. Increase in aircraft overflights may stress animals or preclude use of some areas.

Rationale--Experience with moose populations occurring in close proximity to airports suggests that this impact should not have permanent, long-term effects. However, there may be differences between air traffic at airports and that which might occur with the project. Although moose become accustomed to aircraft overflights at airports, these areas are usually fenced, so little additional human disturbance occurs. The proposed Watana airport would be adjacent to village sites, transportation corridors, gravel extraction, etc., possibly resulting in some avoidance due to other disturbances in addition to aircraft.

Prediction of Project Impacts on Moose Subpopulations

Based on studies of movements of radio-collared moose from 1976 through 1986 (data presented earlier), at least 12 subpopulations of moose were identified which either utilize the proposed impoundments or could be impacted by the project. For purposes of this report a subpopulation is defined as a group of moose which utilize similar winter and summer range and which move to and from such areas in general synchrony. Generally, members of subpopulations breed and calve in the same area, but subpopulations are not discrete and many gradations exist. Certain subpopulations of moose would be impacted more than others and discussion concerning specific subpopulations follows. For subpopulations with similar exposure to the project, discussion of project impacts were pooled.

Size of moose subpopulations was determined by examining locations of radio-collared moose from each subpopulation during the 1983 census. The entire impact zone had been divided into discrete 12-20 mi^2 sample units. Each unit was stratified into one of 4 density classifications based upon sign and numbers of moose observed (Gasaway et al. 1981; Ballard et al. 1982, 1983; see Population Density section).

Following this process, randomly selected quadrats were intensively surveyed and the population densities of moose were estimated within each density classification. By adding the numbers of quadrats where radio-collared members of each subpopulation were located and then using average density estimates we were able to estimate the relative size of each subpopulation based on autumn distributions. All estimates were corrected to exclude radio-collared moose which did not reside in the primary impact zone.

Descriptions of characteristics, size, and predicted impacts of the proposed Susitna Hydroelectric project on 12 identifiable subpopulations of moose:

1. DEVIL CANYON TO FOG AND DEADMAN CREEKS MOOSE SUBPOPULATION

   Characteristics--This subpopulation is composed of resident individuals which generally have overlapping summer and winter range. Moose from this group move to a rutting area along Clark Creek each autumn. Elevational movements occur apparently in response to climatic factors, particularly snow depths. A significant relationship exists between winter severity and use of various elevations by moose, with lower elevations being utilized more frequently during years of deep snows. Moose utilization of the Devil Canyon impoundment is primarily restricted to the area east of Devil Creek. Several moose apparently calve in or immediately adjacent to the impoundment each year. Only a few moose use the lower Devil Canyon impoundment area, apparently due to the steepness of the canyon walls. Moose often cross the Susitna River during January through April to utilize south-facing slopes located between Deadman Creek and opposite Stephan Lake.

   This subpopulation occurs within the territories of at least 2 wolf packs (Portage Creek and Stephan Lake Packs) which prey heavily on moose (Ballard et al. 1982, 1983). Black bears are quite numerous in this area (Miller 1985) and consequently this particular subpopulation of moose probably receives the greatest amount of predation by black bears of any of those studied. However, brown bears are the most important predator. The area is lightly hunted by humans because of poor access. Consequently, the area has a relatively higher proportion of large-antlered bulls than many other moose subpopulations. Based upon censuses conducted in 1980 and 1983 and on interpretation of radio-collared moose movement data, this subpopulation is estimated to comprise 420 individuals (18% of the primary impact zone population). At least 70% of this subpopulation resides east of Devil Creek, with most occupying the area between Deadman Creek and the area opposite Stephan Lake.

Impacts--Because a large number of developments such as the Watana Dam, village facilities, railroad and access road corridors, several borrow sites, etc., would occur within the range of this subpopulation, it would be one of the most severely impacted. Loss of habitat would increase mortality due to winter-related starvation. The amount of habitat lost would be greater than reported because moose would likely avoid additional areas due to disturbance, harassment, increases in snow depths brought about by changes in microclimate, drifting snow, etc. Also, year-round open water below the Watana Dam site would bisect the annual ranges of many individuals, making portions of the range unavailable in winter. Although moose are known to cross open water at air temperatures of about 0° F, they apparently have an aversion to crossing at colder temperatures. If open water during late autumn and winter results in increased snow depths within several hundred meters of the impoundment, additional habitat would be lost.

During construction and early operation of the project, the physiological condition of wintering moose would decline, resulting in an increase in winter mortality. Moose that do not die from winter-related causes would be in poorer physical condition, resulting in production of fewer calves through reductions in pregnancy and twinning rates. Calves would be less healthy and would suffer higher rates of natural mortality.

Development of the Tsusena Creek borrow site, road development from the Denali Highway and Devil Canyon, and establishment of camp facilities are likely to disrupt use of the Clark Creek rutting area. Increased access would result in increased poaching and hunting activity. As a result, the relatively high proportion of large-antlered bulls in this subpopulation would decline.

Although black bear predation does not limit the moose population, inundation of black bear den sites and habitat would concentrate bears in the same habitats in which moose are forced to concentrate. Miller (1985) suggested that black bear populations would eventually decline in the area. However, until those declines occur, predation by black bears would become a significant source of moose mortality. Brown bears and wolves would also take advantage of the increased prey concentrations.

In the absence of increased predation, lowered productivity and increased mortality resulting from habitat loss and avoidance would cause the population to decline.

Development of borrow sites would result in loss and avoidance of moose habitat. Although this habitat may eventually be replaced through natural recolonization or revegetation following retirement of the site, it is unlikely that the moose population would be able to respond to the increased and improved forage. Once productivity declines and mortality increases, this moose subpopulation may never be able to increase because factors other than vegetation would prevent population growth. Only through drastic changes in predator-prey ratios, changes in waterflow regimes to allow freezing of open water below the dam sites, and large reductions in the levels of human disturbance can this subpopulation be expected to recover.

The area may serve as a "sink" by attracting moose from adjacent areas of high density, but these incoming moose would be subjected to the same factors that caused the original population decline. The subpopulation is expected to eventually stabilize at a very low level in comparison with pre-project conditions. We predict that this subpopulation of 420 moose would decline by at least two-thirds as a result of the project.

2. UPPER FOG AND TSISI CREEKS MOOSE SUBPOPULATION

Characteristics--This subpopulation is composed primarily of a migratory group of individuals which occupies Tsisi and upper Fog Creeks during late summer and autumn. Depending on timing and extent of snowfall, these moose move to lower elevations within or adjacent to the Watana impoundment zone where they may remain through all or part of winter. In many cases they calve on wintering areas before returning to summer range. A segment of this subpopulation resides year-round in the Watana Lake-Kosina Creek area where they share winter range with a migratory segment.

This subpopulation lies primarily within the range of the Watana wolf pack. Other wolf packs sometimes exist to the south of the Watana pack but are usually eliminated by aircraft-assisted hunting. Although black bears occur along the Susitna River, they are not currently a significant source of moose mortality. Brown bears occur throughout the area and are the most important mortality factor. Hunting pressure is generally light due to limited access; however, heavy hunting pressure sometimes occurs at Watana and Fog Lakes due to floatplane access.

Based upon moose censuses and interpretation of radio-collared moose movements, this subpopulation was estimated at 350 individuals. Most, if not all, of these moose winter in or adjacent to the proposed impoundment.

Impacts--Loss of winter habitat from direct inundation plus losses from drifting snow and climatic changes are likely to be the most important impacts initially affecting this subpopulation. As mentioned earlier, these impact mechanisms would likely manifest themselves through increased winter- and early-spring mortality and through decreased natality brought about by nutritional stress. The exact magnitude would be dependent on the quantity of forage lost through drifting snow and changes in microclimate.

Moose displaced from the impoundment and the snow-drift zone would be subjected to increased crowding competition from adjacent moose. They would also be subject to increased levels of predation from displaced predators. Both types of impacts and others not specificly discussed here would be sufficient to cause the subpopulation to decline and to eventually stabilize at a lower level.

Fluctuating water levels and resultant ice shelving may pose a problem for this particular subpopulation because many members cross the Susitna River where they share winter range with other subpopulations. This impact mechanism would be an additional source of mortality to a group already suffering declines from other project-induced causes.

Due to improved boat access from the impoundment and improved access created by road construction to the dam site, both legal and illegal harvest of moose would increase. In addition, private commercial developments are likely to occur with resulting impacts such as loss of habitat and disturbances.

Based on our evaluation of impact mechanisms, this subpopulation of 350 individuals would decline by 50%. Short-term losses may be even greater during severe winter conditions. Population response to a severe winter would be different from that prior to the project due to lower rates of reproduction and poorer overall health of the subpopulation.

3. KOSINA CREEK MOOSE SUBPOPULATION

Characteristics--This subpopulation consists of nonmigratory moose which occupy the lower elevational drainages and mainstem of Kosina Creek. Moose from this subpopulation demonstrate altitudinal movements similar to those of other subpopulations in the study area; high elevational areas are occupied during summer and autumn and low elevational areas are used during winter and early spring. Typically, most moose in this group move short distances up and down creek bottoms.

The overall winter habitat carrying capacity of this area is relatively low in relation to that of many other areas, due to heavy snow accumulations. This subpopulation has probably remained relatively stable over the past decade. Dispersal of 1 radio-collared yearling suggests that the population may contribute emigrants to other areas. Hunting pressure in the area is light due to the relatively low moose population and poor access. We estimate this subpopulation at from 100-200 individuals.

Impacts--No direct impacts as a result of the project are anticipated. However, several indirect impacts could occur. Moose dispersing from the area and attempting to cross the Susitna River might suffer higher rates of mortality by falling through thin ice or they could be blocked by ice shelving. If climatic changes were to occur at greater distances away from the impoundment than are currently predicted, additional habitat may be unavailable to moose.

Perhaps the greatest threat to this subpopulation is increased commercial development, such as mining and lodge development, which could result from the boat and road access provided by the project. Loss of habitat, increased disturbance, increased poaching and hunting activity, etc., could be of sufficient magnitude to cause this marginal subpopulation to decline. Because all of the possible impacts are speculative and beyond prediction, no attempt has been made to quantify them.

4. WATANA CREEK - MONAHAN FLATS MOOSE SUBPOPULATION

Characteristics--This subpopulation consists of a group of individuals which occasionally migrate to the impoundment zones during some winters. During years the impoundment zone is used, moose migrate to Monahan flats (60 kms to the north) in late spring where they calve and remain through summer. Between late summer and early spring these moose may migrate to the impoundment zone where they overwinter. During other years they overwinter between Monahan flats and the divide between Brushkana and Deadman Creeks. Why they only periodically utilize the impoundment zone is not known.

The total range occupied by this subpopulation falls within the range of 3 wolf packs (Watana, Jay, and Seattle Creek Packs). Brown bears occur throughout the area and have been documented as the most important source of moose mortality (Ballard et al. 1981). Black bears occur infrequently in the Monahan flats area but are relatively numerous along the mainstem of the Susitna River; they are often denning at the time that they could potentially come in contact with this moose subpopulation. Recreational and subsistence hunting pressure is heavy along the Denali Highway.

Impacts--Because moose from this subpopulation appear to utilize the impoundment zone as a wintering area, loss of critical range would result in increased starvation of both calves and adults during winter. Reduced physical condition of surviving cows would result in reduced natality due to lower twinning and pregnancy rates. This particular subpopulation would also be directly impacted by the Denali-to-Watana Camp road system through direct loss of habitat and collision mortality, and indirectly through changing snow patterns brought about by drifting. Additional access created by this system would subject this subpopulation to increased levels of legal and illegal hunting harvest.

Because this subpopulation was not present during autumn censuses, no count data exist for estimating relative size. Based on numbers of animals associated with 1 radio-collared animal and on other miscellaneous observations, the group was estimated to contain no more than 50 individuals. Loss of winter range may result in an average reduction of 50%.

5. DEADMAN-WATANA CREEK MOOSE SUBPOPULATION

Characteristics--This group of moose comprises migratory and nonmigratory individuals. The nonmigratory subpopulation is a continuation of the group at Deadman Creek which exists throughout the project area. The migratory group (which winters along Watana Creek but migrates to Butte Creek during summer and autumn) was clumped with the nonmigratory moose for discussion purposes.

Moose from this group utilize the impoundment zone adjacent to Watana Creek primarily during winter and in early spring for calving. Elevations above the proposed high pool level are used in late summer. Winter range is shared with the migratory Watana-Coal Creek subpopulation. Upper subalpine and tundra vegetation are used in autumn during the rut.

The group occurs within the territory of the Watana wolf pack which preys almost entirely on moose (Ballard et al. 1982, 1983). A second pack may occasionally prey on these moose when in the Butte Creek area. Brown bears are the most important mortality factor, accounting for the deaths of about 46% of the moose calves produced (Ballard et al. 1985). Black bears also occur within the range of this subpopulation but only account for 8% of the calf mortality. The area currently receives light hunting pressure because of poor access.

Based on interpretations of radio-collared moose movements and autumn censuses in 1980 and 1983, this group of 2 subpopulations was estimated at 290 individuals with migratory moose numbering about 150. This subpopulation comprises 12% of the moose population which comes in contact with the proposed impoundments.

Impacts--The greatest impact on this subpopulation is direct loss of winter habitat due to inundation and climatic changes resulting in deeper snow accumulations and drifting snow. Loss of winter habitat would result in relatively large increases in winter mortality. Moose which do not die from starvation would be in poor physiological condition, resulting in lower calf production due to lower rates of pregnancy and twinning. Calves which are produced would be less likely to survive because of their lower physical condition.

Moose displaced from the impoundment would concentrate next to the impoundments. Predators, which would also be concentrated, would cause increased mortality and contribute to a population decline. High densities of predators could maintain moose numbers at lower levels (Ballard and Larsen 1986) than would have occurred otherwise.

Moose attempting to cross the Susitna River during winter and late spring may suffer higher rates of mortality. Blockage of movements because of fluctuating ice levels and accidental mortality associated with crossing this ice, would contribute to a subpopulation decline. The southwest shoreline and other areas are predicted to exhibit increased snow drifting (LGL 1985). Snow drifting could have the same effect as direct losses of habitat because the existing habitat would be less available.

Because this moose subpopulation depends heavily on the riparian habitat of Watana Creek, this moose subpopulation may decline an average 50-75%, from 290 to about 75 individuals.

6. WATANA-COAL CREEK MOOSE SUBPOPULATION

Characteristics--This group of migratory moose uses the proposed Watana impoundment from middle Watana Creek to the mouth of Jay Creek as winter range. This winter range is shared with at least 4 other subpopulations which include the migratory and nonmigratory Watana Creek subpopulations, the upper Fog-Tsisi Creek moose, and nonmigratory moose from Jay-Kosina Creek east. This particular group probably utilizes the impoundment zone more than any other subpopulation studied except for nonmigratory moose from Kosina-Jay Creek east to Clearwater Creek. Use of the area appears governed by winter severity as reflected by snow depth. During years of below-average snow, these moose may not use the impoundment zone but confine their wintering activities to the knobs along the north side of the river immediately adjacent to the impoundments. During some years they may stay on summer range at and near Coal Creek. During average snowfall years, they utilize the impoundments from 1-3 months depending on snow depths and other factors. Habitat use during a severe winter has not been documented, but heavy usage of the impoundment zone is predicted.

Moose typically leave the impoundment zone in April or May. Movement to the calving grounds on Coal Creek usually occurs within 2 weeks. There are few calving concentration areas in GMU 13; however, Coal Creek is one of the most important. Calving occurs in late May through early June. These moose remain on the calving area through summer. During autumn they occupy the upland knobs along Jay to Watana Creek. Several dispersals by subadults have been documented for this subpopulation which may help restock areas heavily hunted or depleted by other factors.

The subpopulation occurs within the range of at least 2 and sometimes 3 wolf pack territories. These include the Watana Creek, Jay Creek, and B-S Lakes wolf packs (Ballard et al. 1982, 1983). Winter range of the moose subpopulation is predominantly within the Watana pack territory while summer range lies within the B-S Lake and Jay Creek packs. All of these packs depend primarily on moose, and wolf predation is the largest cause of winter mortality. Predation by brown bears on calves is high in this area, and roughly half the calves are killed by them annually (Ballard et al. 1981). No black bears have been observed on the calving grounds, although they occur in timbered areas along Watana Creek. They are not a significant source of mortality at the present time. Unlike the Watana Creek subpopulation, this subpopulation is heavily hunted. Access occurs from the Denali Highway from several all-terrain-vehicle trails.

Based on autumn 1983 census data, the area has the highest density of any of the subpopulations studied: 2.7 moose per mi^2 ($1.04/km^2$) in autumn 1983. The subpopulation is estimated at 610 individuals or about 25% of the moose occurring within the primary impact zone.

Impacts--The greatest impact on this subpopulation would be loss of important winter habitat, hence large increases in winter-related mortality. Calving and twinning rates are expected to decline, and the total population would be reduced. Competition for forage, in addition to increases in predation and other direct mortality, may increase mortality rates until mortality exceeds natality. Many other impacts described for the resident and migratory Watana subpopulation are expected to occur on this group as well. Because much of the winter habitat for this subpopulation is immediately adjacent to the impoundments, changes in browse availability due to changes in climate, snow drifting, etc. could have serious effects on this moose subpopulation. This subpopulation is expected to decline by an average of 50% from 610 to about 300 moose.

7. JAY-KOSINA CREEK TO CLEARWATER CREEK MOOSE SUBPOPULATION

Characteristics--This subpopulation consists primarily of nonmigratory moose with relatively small home ranges. Considerable overlap in both seasonal and total home ranges among individuals occurs. Many of these moose have home ranges which are bisected by the Susitna River. Although nonmigratory, they move seasonally from higher elevations in autumn to low elevations during winter. A large number of moose remain on or close to winter range where they calve. Probably more individuals from this subpopulation calve in the impoundment zone than any other groups studied. Approximately half of the locations within the impoundment zone for this group occur during May through August. Several subadults have dispersed from this area, thus it may also be important for recruitment to other areas.

The area located between the Susitna River Gauging Station and the mouth of Clearwater Creek serves as a wintering area for several subpopulations of migratory moose. Resident moose from this subpopulation share winter range with moose from the upper Clearwater-Maclaren subpopulation, the Butte Creek-Susitna subpopulation, the upper Oshetna-Black River subpopulation, and the Lake Louise-Susitna subpopulation. Moose from the latter subpopulation concentrate north of the Susitna

River above the big bend during autumn. Moose which do not winter in the impoundment zone appear to overwinter on knobs immediately adjacent to the proposed impoundments.

This subpopulation area may be occupied by up to 4 different wolf packs, all of which prey heavily on moose (Ballard et al. 1982, 1983). At least 3 packs have territorial boundaries which meet at the upper end of the impoundment where several moose subpopulations winter. Wolf predation is an important source of adult and calf mortality. However, predation by brown bears is the largest source of calf mortality (Ballard et al. 1981, 1985). Black bears are present in timbered areas along stream bottoms, but they are not numerous and do not constitute an important source of moose mortality. The area is heavily hunted, with access provided by numerous all-terrain-vehicle trails in addition to float plane access at several small lakes.

Based on autumn census data, the subpopulation was estimated at 700 individuals: 1.9 moose per $mile^2$ ($0.7/km^2$).

Impacts--Loss of winter habitat and calving areas would be the most significant impact affecting this subpopulation. These and other impacts described earlier would affect this subpopulation but to a much lesser degree than other subpopulations. The magnitude of the impacts would be less because the impoundment becomes substantially smaller as it reaches the big bend where several subpopulations concentrate. However, the degree of climatic change and the amount of snow drift could be as important as inundation in the amount of habitat made unavailable. This subpopulation may decline by an average of 25% (N=175) as a result of the project. If the important winter habitat immediately adjacent to the impoundment is also impacted, the subpopulation could decline by more than 50%.

8. BLACK AND OSHETNA RIVER MOOSE SUBPOPULATION

Characteristics--This migratory group of moose was not studied as part of the Susitna Hydroelectric Project. However, it was studied earlier as part of a winter calf mortality study (Ballard et al. 1982) so limited movement information is available. Moose from this subpopulation share winter range with several others in and adjacent to the impoundment zone along the Susitna River from Goose Creek to the mouth of the Tyone River. Depending on snow melt, these moose move to the upper portions of the Black and Oshetna Rivers where they calve and remain through summer and autumn.

The subpopulation occurs mostly within the territories of 2 wolf packs, both of which prey heavily on moose (Ballard et al. 1982, 1983). Like other subpopulations in the study area, predation by brown bears accounts for most calf mortality (Ballard et al. 1981, 1985). The area is heavily hunted. Access is provided by numerous all-terrain-vehicle trails, several airstrips, and by float plane.

The subpopulation was censused in 1985 and has been surveyed annually to determine sex and age composition. The subpopulation was estimated at 400.

Impacts--The largest impact to this particular subpopulation could be crowding on winter range created by the presence of displaced moose from other subpopulations. This could result in high rates of mortality due to winter-related causes and predation. Loss of habitat, incidental mortality, and increases in poaching and hunting activity could also contribute to declines in this subpopulation. This subpopulation may decline by an average of 10% as a result of the project.

9. CLEARWATER CREEK-MACLAREN RIVER MOOSE SUBPOPULATIONS

Characteristics--This group of moose is composed of 2 separate subpopulations which breed in different drainages: Clearwater Creek and the upper Maclaren River. However, because both groups utilize the impoundment zone similarly, they are considered jointly. These 2 subpopulations of moose winter along lower Clearwater Creek and the lower Maclaren River to the big bend in the Susitna River.

Both subpopulations are highly migratory. During some years moose calve on the wintering area and then slowly move northward to summer range in the Clearwater Mountains. These moose remain in alpine areas through September and October. Heavy snow storms appear to stimulate migration and movement to winter range. Several subadults from the Watana-Coal, Fog-Tsisi, and Watana Creeks subpopulations have dispersed to this area.

Because of the migratory nature of this subpopulation, it is exposed to predation by several wolf packs (Ballard et al. 1982, 1983). Predation by brown bears accounts for most summer calf mortality (Ballard et al. 1981) while wolves account for most winter mortality not attributable to starvation. Black bears are rare in the area. This subpopulation is heavily hunted primarily because of its proximity to the Denali Highway.

Based on autumn moose composition surveys and a census conducted in 1983, this subpopulation was estimated at 675. However, movements of radio-collared adults suggested that not all of the moose from this subpopulation winter near the impoundment zone. Two (15%) of 13 radio-collared cows utilized the impoundment area. Based on this ratio it was estimated that 100 moose winter in or adjacent to the proposed impoundment.

Impacts--This subpopulation of moose would be impacted similarly to the Black-Oshetna River subpopulation. Increased rates of mortality due to crowding, increased predation, and elimination of dispersal into the area may contribute to a decline. Number of moose which utilize the impoundment area may decline by an average of 50% (50 of 100 moose).

10. BUTTE CREEK-SUSITNA RIVER MOOSE SUBPOPULATION

Characteristics--Movements of 2 radio-collared moose suggested that a relatively small subpopulation calved on Butte Creek where it remains through summer. During late autumn or early winter the group migrates to winter range along the big bend of the Susitna River. Winter range was shared with several other subpopulations. During some years, moose from this group spend winter on summer range.

The subpopulation occurs within the territories of 2 wolf packs (Ballard et al. 1982, 1983). However, brown bears were the most important cause of moose calf mortality. Black bears were rarely observed. Hunting pressure along the Denali Highway is heavy. Census data suggest this subpopulation numbers about 135.

Impacts--This subpopulation would be impacted similarly to other migratory subpopulations wintering along the upper impoundment zone and may decline by about 10% (N=14).

11. LAKE LOUISE FLATS-SUSITNA RIVER MOOSE SUBPOPULATIONS

Characteristics--During autumn, moose from this subpopulation move to areas along the big bend of the Susitna River where they remain through winter. During some years they do not migrate. Parturition occurs on the Lake Louise flats, particularly along waterways.

The subpopulation lies within the territorial boundaries of at least 4 wolf packs (Ballard et al. 1982, 1983). Brown bears annually kill about half of the calves.

Black bears were rare and not an important mortality factor. The area is heavily hunted with access provided principally by boat, float plane, or road.

The Lake Louise flats were partially censused in autumn 1983, and the moose population within a 632 mi² (244 km²) area was estimated at 430. Not all of these moose are migratory and only about 50 utilize the impoundment zone.

Impacts--This subpopulation would be impacted similarly to the other migratory subpopulations which utilize the upper Watana impoundment zone and may decline by about 10%.

Importance of Impoundment Areas

During 1984 and 1985, browse quantity and quality were determined within and outside the impoundment zones (Becker and Steigers 1987).

Browse production was greater outside the impoundment zones than within them (Fig. 44). About half of the total browse production occurred between elevations of 2,450-2,970 ft (747-905 m) but greatest browse utilization by moose occurred at lower elevations where less browse was producted (Fig. 45). Utilization of browse within the impoundments (2,200 ft) during 1985 (a winter of moderate severity) was about 70%. Browsing intensity was greater within both impoundment zones than outside (Fig. 46). The impoundment zones may even be more important to moose during severe or moderately severe winters. Unfortunately, severe winter conditions never occurred during years when radio-collared moose were adequately monitored. During 1978-79 (a relatively severe winter) low-intensity monitoring indicated that moose utilized different wintering areas than those used during years of mild or moderate winters (Ballard and Taylor 1980). This suggests that moose from other subpopulations which normally do not use the impoundments may use them during severe winters.

Most (97%) relocations of radio-collared moose occurred at elevations $\leq$3,400 ft (1,036 m) (Fig. 47). Moose rarely utilize habitat elevations over 4,000 feet; such that did use occur took place during summer months. Moose use was correlated ($p > 0.05$) with browse production at different elevations, with proportionately more moose use than expected occurring at elevations $\leq$2,200 ft (671 m).

Winter use of the impoundment zones appeared partially dependent on snow depth. Browse appeared less available at higher elevations during years of moderate snowfall. When snow accumulations made browse unavailable at high elevations, moose moved into the impoundment zones where browse was more available. As snow receded in spring, moose moved out of the impoundment zones.

Annual use of the impoundment zones by moose was variable. Average elevation of 74 radio-collared adults was lowest during winter and spring and highest during autumn. Use of impoundment zones by individual moose was also variable, ranging from no use to 1-3 months use. Mild winter conditions were probably responsible for the large amount of annual variation in numbers of moose observed during winter censuses and distribution flights (approximately 40-600 moose estimated from censuses during 1-2 day periods during March). During a severe winter the impoundments are expected to support larger numbers of moose.

A winter moose distribution survey and snow measurements (Steigers et al. 1985) conducted during late winter 1985 supported the general concept that moose were avoiding areas of deep snow. Although moose seek areas of high browse production, availability during winter may be the most important factor determining moose distribution.

Estimates of the numbers of moose that could be sustained for a 90-day winter period within habitats that would be lost by construction of the project were variable, depending on assumptions concerning diet composition and degrees of browse utilization (Tables 21 and 22). The 50 and 60% browse utilization categories were intended to represent the long-term carrying capacity. The 100% utilization estimates were intended to represent the severe winter capacity.

Although estimates of the numbers of moose which could be sustained by the habitat under a given set of assumptions were useful for attempting to interpret differences between population and habitat based data, potential for under- or over-estimating the importance of an area existed.

Between 40 and 600 moose were estimated from counts within the impoundment zones during at least 1- to 2-day periods in March during the study. Actual use of an area by moose, and their physical condition at the time can alter estimates of habitat carrying capacity. Also, high rates of winter mortality might be interpreted as indicating a particular habitat was not important to the population. However, small differences in winter survival due to the presence or absence of key winter habitats can drastically alter the recovery of an ungulate population in future years.

Historical counts of moose and tracks within the Susitna impoundments (McIlroy 1975) suggest that the area is important as winter habitat during severe winters. The hypothesis has not been tested that the impoundment zones provide key winter range that allows the moose population to recover more quickly from severe winters than if the habitat did not exist. Actual carrying capacity of the area could be several times larger than estimated if moose utilize the areas for either shorter periods or at different levels of physical condition. If browse resources become overutilized during severe winters and if those conditions only occur once or twice every 25 years, there may be no long-term harm to the plant community from overbrowsing. However, loss of critical habitat could be so important that the size and health of the moose population in future years could be substantially altered.

Summary Of Project Impacts

Three different methods were used for predicting the impacts of the proposed project on moose. The first method estimated specific project actions on specific moose subpopulations. This method predicted that a total of about 1,300 moose would be lost as a result of the project. The latter figure included not only direct losses but losses attributable to secondary effects. These estimates were similar to the estimated numbers of moose which might be supported by habitat (the 2nd method) within the impoundments during severe winter conditions (assuming 100% use of annual browse and a digestibility factor of 1.00, about 1,182 moose could be supported for 90 days). The 3rd method, population modeling, would have demonstrated that the decline would not be a static number. The population would continue to fluctuate but over alower range of sizes. All of the methods suggest that losses to the moose population could be great. This finding is consistent with the hypotheses of biologists in other areas of North America where riparian habitats important to moose have been inundated or altered (E. Warren, pers. comm.; K. Childs, pers. comm.; F. Harper, pers. comm.). Actual losses can not be predicted and would not be known until pre- and post-impoundment data can be compared. If built, this project offers the best opportunity for comparing preproject populations with those occurring after the project becomes operational. To document with accuracy and precision the expected impacts on moose, several studies should be conducted during construction or after the project is operational.

Monitoring Programs Necessary For Refinement Of Impact Assessment

The impacts of hydroelectric development on wildlife, and particularly moose, have never been quantified because either post- impoundment studies were not comparable to data prior to inundation, or because no pre-inundation studies were conducted. Consequently, estimates of losses have been speculative, as are the estimates presented in this study. To properly assess actual losses, it would be necessary to conduct in-depth post-impoundment studies for comparison.

A large number of potential mechanisms of impact have been identified as a result of this study. Unfortunately, many of the specifics would remain speculative, but the net results of several impacts should be measurable. For example, any effects on the moose population from drifting snow would be difficult to separate from other types of habitat loss or alteration. However, the cumulative effects of those impacts could be quantified by comparing estimates of numbers of moose in the study area, before and after the project, with those in control populations. Therefore, for efficiency of study, several similar impact mechanisms should be grouped and evaluated by similar study methods.

A time table of when various impacts on moose might first be observable and when those impacts might be most severe is summarized in Table 23. All estimates are speculative and serve as guides for initiating post-impoundment studies. To properly document the impacts from this project, post-impoundment studies should use similar methods, of an intensity equal to those used in pre-impoundment studies. Types of studies needed for proper documentation of impacts on moose are also presented.

The most important components of post-impoundment studies consist of moose censuses, maintenance of a pool of radio-collared calf and adult moose, and predation rates studies (Table 23). This level of study would allow documentation of total losses of moose and identification of major impact mechanisms. Proper and adequate documentation of impacts due to this project could guide future assessments for other projects which should then require less exhaustive studies for adequate prediction of impacts.

LITERATURE CITED

Bailey, T. N., A. W. Franzmann, P. D. Arneson, and J. L. Davis. 1978. Kenai Peninsula moose population identity study. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration. Final Rep. Proj. W-17-3, W-17-5, W-17-6, W-17-7, W-17-8, and W-17-9. 84pp.

Ballard, W., B. 1982. Gray wolf-brown bear relationships in the Nelchina Basin of southcentral Alaska. Pages 71-80 in F. H. Harrington and P. C. Paquet, eds. Wolves of the world. Noyes Publ., Park Ridge, N. J.

___________, A. W. Franzmann, K. P. Taylor, T. Spraker, C. C. Schwartz, and R. O. Peterson. 1979. Comparison of techniques utilized to determine moose calf mortality in Alaska. Proc. North Am. Moose Conf. Workshop 15:363-387.

___________, and C. L. Gardner. 1980. Nelchina yearling moose mortality study. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-17-11 and W-21-1. 22pp.

___________, ___________, and S. D. Miller. 1980a. Influence of predators on summer movements of moose in southcentral Alaska. Proc. North Am. Moose Conf. Workshop 16:339-359.

___________, ___________, and S. D. Miller. 1982a. Nelchina yearling moose mortality study. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep., Proj. W-21-1 and W-21-2. 37pp.

___________, ___________, J. H. Westlund, and J. R. Dau. 1982b. Susitna Hydroelectric Project. Phase I Final Report, Big Game Studies, Vol. V, Wolf. Alaska Dep. Fish and Game. Anchorage. 220pp.

___________, and D. Larsen. 1988. Implications of predator-prey relationships to moose management. Viltrevy:in press.

___________, and S. D. Miller. 1987. Effects of reducing brown bear density on moose calf survival in southcentral Alaska. Trans. Int. Congr. Game Biol. In press.

___________, ___________, and T. H. Spraker. 1980b. Moose calf mortality study. Alaska Dep. Fish and Game. P.R. Proj. Final Rep., W-17-9, W-17-10, and W-21-1. 123pp.

___________, S. M. Miller, and J. S. Whitman. 1986. Modeling a southcentral Alaskan moose population. Alces 22:201-243

___________, R. O. Stephenson, and T. H. Spraker. 1981a. Nelchina Basin Wolf Studies. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Rep., Proj. W-17-9 and W-17-10. 201pp.

___________, T. H. Spraker, and K. P. Taylor. 1981b. Causes of neonatal moose calf mortality in southcentral Alaska. J. Wildl. Manage. 45:335-342.

___________, and K. P. Taylor. 1980. Upper Susitna Valley moose population study. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Rep., Proj. W-17-9, W-17-10, and W-17-6. 102pp.

_____________, and J. S. Whitman. 1987. Susitna Hydroelectric Project Final Report. Big Game Studies. Vol. III. Moose-upstream. Alaska Dep. Fish and Game. Anchorage. In press.

_____________, _____________, and C. L. Gardner. 1985. Susitna Hydroelectric Project. 1984 Annual Report. Big Game Studies. Moose Upstream. Alaska Dep. Fish and Game. Anchorage. 48pp.

_____________, _____________, N. G. Tankersley, L. D. Aumiller, and P. Hessing. 1983. Susitna Hydroelectric Project. 1983 Annual Report. Big Game Studies. Vol. III. Moose-Upstream. Alaska Dep. Fish and Game. Anchorage. 147pp.

Barry, T. W. 1961. Some observations of moose at Wood Bay and Bathurst Peninsula, Northwest Territories. Can. Field Nat. 75:164-165.

Becker, E., and W. Steiger. 1987. Browse report. Alaska Dep. Fish and Game. Anchorage. In Press.

Bishop, R. H., and R. A. Rausch. 1974. Moose population fluctuations in Alaska, 1950-1972. Naturaliste Can. 101:559-593.

Blood, D. A. 1974. Variation in reproduction and productivity of an enclosed herd of moose (Alces alces). Trans. Int. Congr. Game Biol. XI:59-66.

Bonar, R. 1985. Interview with W. Steigers and R. Fairbanks, April 18, 1985. Jackson Hole, Wyoming. LGL, Anchorage.

Cederlund, G., K. Larsson, and F. Sandegren. 1987. Summer movements and dispersal of female moose and their offspring in a migratory population in Sweden. J. Wildl. Manage.:in press.

Child, K. N. 1983. Railways and moose in the central interior of British Columbia: a recurrent management problem. Alces 18:118-135.

Danilov, P. I. 1988. Population Dynamics of moose in the USSR. Viltrevy. In press.

Eide, S., and W. B. Ballard. 1982. Apparent case of surplus killing of caribou by gray wolves. Can. Field-Nat. 96:87-88.

Faro, J., and A. W. Franzmann. 1978. Productivity and physiology of moose on the Alaska Peninsula. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Rep., Proj. W-17-9 and W-17-10. 29pp.

Franzmann, A. W., P. D. Arneson, R. E. LeResche and J. L. Davis. 1974. Developing and testing new techniques for moose management. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep., Proj. W-17-2, W-17-3, W-17-4, W-17-5 and W-17-6. 54pp.

____________, and C. C. Schwartz. 1985. Moose twinning rates: a possible population condition assessment. J. Wildl. Manage. 49:394-396.

____________, ____________, and R. O. Peterson. 1980. Causes of summer moose calf mortality on the Kenai Peninsula. J. Wildl. Manage. 44:764-768.

____________, ____________, D. C. Johnson, J. B. Faro, and W. B. Ballard. 1984. Immobilization of moose with carfentanil. Alces 20:259-281.

Gasaway, W. C., and S. D. DuBois. 1985. Initial response of moose, Alces alces, to a wildfire in interior Alaska. Can. Field-Nat. 99:135-140.

____________, ____________, and K. L. Brink. 1980. Dispersal of subadult moose from a low density population in Interior Alaska. Proc. N. Amer. Moose Conf. and Workshop 16:314-337.

____________, ____________, and S. J. Harbo. 1981. Moose survey procedures development. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep., Proj. W-17-11, W-21-1, and W-21-2. 66pp.

____________, R. O. Stephenson, J. L. Davis, P. E. K. Shepherd, and O. E. Burris. 1983. Interrelationships of wolves, prey and man in Interior Alaska. Wildl. Monogr. 84. 50pp.

Harper, F. E. 1985. Personal correspondence to W. Ballard. 3pp.

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

Henry, D. M. 1965. Possible precipitation changes resulting from the proposed Rampart dam reservoir. Cold Regions Res. and Eng. Lab., U. S. Army Tech. Rep. 147. 17pp.

Houston, D. B. 1968. The Shiras moose in Jackson Hole, Wyoming. Grand Teton Nat. Hist. Assoc. Tech. Bull. No. 1. 110pp.

Hubbert, M. E., and C. C. Schwartz. In prep. Ruminant Simulation model to predict intake based on body condition. J. Wildl. Manage.

Kruuk, H. 1972. Surplus killing by carnivores. J. Zoology. 166:233-244.

LeResche, R. E. 1974. Moose migrations in North America. Naturaliste Can. 101:393-415.

__________, and J. L. Davis. 1973. Importance of nonbrowse foods to moose on the Kenai Peninsula, Alaska. J. Wildl. Manage. 38:279-287.

LGL Alaska Resource Assoc. Inc. 1985. Mitigation plan for wildlife and botanical resources, moose species account. Contract to Narza-Ebasco Susitna Joint Venture. Anchorage. 42pp.

Markgren, G. 1969. Reproduction of moose in Sweden. Viltrevy 6(3):1-299.

Mech, L. D. 1970. The Wolf: the ecology and behaviour of an endangered species. The Natural History Press, New York, N. Y. 384pp.

McIlroy, C. 1974. Moose survey-inventory progress report-1972, Game Management Unit 13. 66-74pp. In D. E. McKnight, (Ed.) 1974. Annual report of survey-inventory activities, Part II. Moose, caribou, marine mammals and goat. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-17-5. 269pp.

__________. 1975. Preauthorization of the Susitna River Hydroelectric Projects: a limited wildlife study. Alaska Dep. Fish and Game. Anchorage. 17pp.

Miller, S. D. 1984. Big game studies. Vol. VI. Black Bear and Brown Bear. Susitna Hydroelectric Project, 1983 Annual Report. Alaska Dep. Fish and Game. Anchorage. 174pp.

__________. 1985. Susitna Hydroelectric Project. 1984 Annual report. Big game studies. Black bear and brown bear. Alaska Dept. Fish and Game. Anchorage.

__________, and W. B. Ballard. 1981a. Homing of transplanted Alaska brown bears. J. Wildl. Manage. 46:869-876.

____________, and ____________. 1982b. Density and biomass estimates for an interior Alaskan brown bear Ursus arctos population. Can. Field-Nat. 96:448-454.

____________, E. F. Becker, and W. B. Ballard. 1986. Density estimates using modified capture-recapture techniques for black and brown bear populations in Alaska. Int. Conf. Bear Res. and Manage. In press.

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

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

Phillips, R. L., W. E. Berg, and D. B. Sniff. 1973. Movement patterns and range use of moose in northwestern Minnesota. J. Wildl. Manage. 37:266-278.

Pimlott, D. H. 1959. Reproduction and productivity of Newfoundland moose. J. Wildl. Manage. 23:381-401.

Rausch, R. A. 1959. Some aspects of population dynamics of the railbelt moose populations, Alaska. M.S. Thesis. Univ. Alaska. Fairbanks. 81pp.

____________. 1967. Some aspects of the population ecology of wolves, Alaska. Am. Zool. 7:253-265.

____________. 1969. A summary of wolf studies in southcentral Alaska, 1957-1968. Trans. North Am. Wildl. and Nat. Resour. Conf., 34:117-131.

Roberts, S. J. 1971. Veterinary obstetrics and genital diseases. Edwards Brothers, Inc., Ann Arbor, MI. 776pp.

Sergeant, D. W., and D. H. Pimlott. 1959. Age determination in moose from sectioned incisor teeth. J. Wildl. Manage. 23:315-321.

Schlegel, M. 1976. Factors affecting calf elk survival in northcentral Idaho. A progress report. Proc. 56th Ann. Conf. W. Assoc. State Game and Fish Comm. pp342-355.

Skoog, R. O. 1968. Ecology of caribou (Rangifer tarandus granti) in Alaska. Ph.D. Thesis. Univ. California, Berkeley. 699pp.

Smith, C. A., and A. W. Franzmann. 1979. Productivity and physiology of Yakutat Forelands moose. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep., Proj. W-17-10 and 11. 18pp.

Snedecor, G. W., and W. G. Cochran. 1973. Statistical methods. Iowa State Univ. Press, Ames. 593pp.

Steigers, W. P. , W. B. Ballard, and E. F. Becker. 1985. March 1985 Snow Depth Survey in the middle Susitna River Basin, Alaska. Harza-Ebasco Susitna Joint Venture. Draft Report. 33pp.

Stephenson, R. O., and L. J. Johnson. 1972. Wolf report. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-17-3. 51pp (Mimeogr.).

____________, and ____________. 1973. Wolf report. Alaska Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-17-4. 52pp (Mimeogr.).

Taber, R. D., and K. Raedeke. 1976. Biotic survey of Ross Lake Basin. Seattle, Wash. 46pp.

Taylor, W. P. 1965. The deer of North America. The Stackpole Co., Washington, D. C. 668pp.

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

Trent, T. T., and O. J. Rongstad. 1974. Home range and survival of cottontail rabbits in southwestern Wisconsin. J. Wildl. Manage. 38:459-472.

Van Ballenberghe, V. 1978. Final report on the effects of the Trans-Alaskan pipeline on moose movements. Alaska Dep. Fish and Game. Special Rep. Anchorage. 44pp.

Verme, L. J., and J. H. Ozoga. 1981. Sex ratio of white-tailed deer and the estrus cycle. J. Wildl. Manage. 45:710-715.

Viereck, L. A., and C. T. Dyrness. 1980. A preliminary classification system for vegetation of Alaska. U.S.D.A. Forest Service. Pac. N. W. Forest and Range Expt. Sta. Report. PNW-106, 38pp.

Wallmo, O. C. (eds). 1981. Mule and Black-tailed Deer of North America. Univ. of Nebraska Press. Lincoln. 605pp.

Table 1. Summary of moose census data and subsequent population estimates for Count Areas 7 and 14 derived from surveys conducted 5-8 November 1980 along the Susitna River in southcentral Alaska.

Moose Density Stratum	Low	Medium	High
No. sample areas censused	11	9	6
Total S.A. per stratum	26	27	18
Area of each stratum	333.8	355.3	256.1
Moose density per stratum	1.125	1.847	3.726
Pop. estimate per stratum	375	656	954

90% confidence interval = 1986 ± 371
Sightability correction factor = 1.03
Corrected population estimate = 2046 ± 382

Table 2. Summary of sample areas resurveyed to determine sightability correction factor for the Susitna moose census conducted 5-8 November 1980 in southcentral Alaska.

Stratified Density	Sample Area	Date	Survey Time	No. Moose Observed First Count	Intensive Count	Percent Observ.
L	21	11/7/80	10	0	0	100
M	49	11/8/80	11	12	13	92.3
H	15	11/8/80	31	7	7	100
M	34	11/5/80	19	4	4	100
L	9	11/5/80	5	0	0	100
H	16	11/5/80	5	0	0	100
M	71	11/6/80	20	10	10	100
H	64	11/5/80	5	4	4	100
L	47	11/6/80	5	3	3	100
L	23	11/6/80	19	0	0	100
TOTALS	10		130	40	41	98
SIGHTABILITY		CORRECTION		FACTOR	=	1.03

Table 3. Moose census results from 4-9 November 1983 and subsequent population estimates for the primary impact zone.

High			Medium			Low		
Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)
30	67	19.6	48	43	13.9	41	25	8.1
51	55	13.2	45	24	17.7	3	9	11.3
42	80	8.7	6	27	11.2	9	4	13.5
36	32	13.5	4	2	10.0	21	3	12.3
27	41	15.9	5	37	14.9	10	2	12.9
18	42	13.1	28	35	21.5	32	10	11.2
34	29	14.7	29	18	11.6	150	3	10.8
53	69	9.8	22	12	10.9	154	7	11.9
135	9	11.9	13	32	16.3	125	3	11.8
139	30	12.5	11	12	12.5	133	7	11.0
168	72	13.7	39	76	11.6	130	12	12.4
140	38	12.9	123	12	19.9	158	10	10.0
184	41	11.6	129	30	9.7	205	2	10.0
			131	25	11.8	202	0	15.9
			172	19	13.7	56	10	15.1
			177	18	11.0	88	0	11.8
			204	8	15.5	60	18	13.1
			170	18	14.1	203	5	11.3
			58	33	24.0	187	12	13.8
			153	29	13.3			
			190	14	11.4			
TOTALS								
13	605	171.1	21	524	296.5	19	142	228.2

	HIGH	MEDIUM	LOW	TOTAL
TOTAL SAMPLE UNITS	19	45	58	122
TOTAL AREA	248.9	602.3	704.8	1556
MOOSE DENSITY	3.536	1.767	0.623	1.53
MOOSE POPULATION ESTIMATE	880	1064	439	2383

TOTAL MOOSE POPULATION ESTIMATE ± 90% C.I. = 2130-2636
SIGHTABILITY CORRECTION FACTOR = 1.19
CORRECTED TOTAL MOOSE POPULATION ESTIMATE = 2836 ± 301 (10.6%) = 2,535 TO 3,137.

Table 4. Moose census data and subsequent population estimate for the Susitna River Study Area, November 1983.

High			Medium			Low		
Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)
30	67	19.6	48	43	13.9	41	25	8.1
51	55	13.2	45	24	17.7	3	9	11.3
42	80	8.7	6	27	11.2	9	4	13.5
36	32	13.5	4	2	10.0	21	3	12.3
27	41	15.9	5	37	14.9	10	2	12.9
18	42	13.1	28	35	21.5	32	10	11.2
34	29	14.7	29	18	11.6	14	0	20.6
4	48	17.8	22	12	10.9	18	1	17.2
1	49	19.0	13	32	16.3	19	3	19.1
9	64	22.2	11	12	12.5	16	0	10.8
12	57	19.3	39	76	11.6	10	0	8.3
17	39	21.5	7	15	15.0	8	7	17.4
13	71	14.5	12	9	22.2	18	0	7.1
14	25	15.0	6	47	22.5	5	4	14.7
1	72	9.6	8	33	20.1	16	2	19.7
			25	13	23.9	3	7	20.0
			11	24	11.6			
			9	3	12.1			
			19	20	9.9			
			15	74	13.5			
			6	55	13.7			
			2	6	13.9			
TOTALS								
15	771	237.6	22	617	330.5	16	77	224.2

	HIGH	MEDIUM	LOW
TOTAL NUMBER OF SAMPLE UNITS	20	43	36
AREA OF EACH STRATUM	320.5	606.5	515.2
MOOSE DENSITY PER STRATUM	3.245	1.867	0.343
MOOSE POPULATION ESTIMATE PER STRATUM	1040	1132	177

TOTAL MOOSE POPULATION ESTIMATES ± 90% C.I. = 2349 ± 256
SIGHTABILITY CORRECTION FACTOR = 1.19
CORRECTED TOTAL MOOSE POPULATION ESTIMATE = 2795 (2491 - 3101) OR
2795 ± 306 (11.0%)

Table 5. Summary of moose census data and population estimate for Composition Count Areas 3, 6, 7, and 12 and the Primary Moose Impact Zone within GMU 13 of southcentral Alaska, November 1983.

Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)	Samp. Unit	No. Moose	Area (mi^2)
30	67	19.6	48	43	13.9	41	25	8.1
51	55	13.2	45	24	17.7	3	9	11.3
42	80	8.7	6	27	11.2	9	4	13.5
36	32	13.5	4	2	10.0	21	3	12.3
27	41	15.9	5	37	14.9	10	2	12.9
18	42	13.1	28	35	21.5	32	10	11.2
34	29	14.7	29	18	11.6	150	3	10.8
53	69	9.8	22	12	10.9	154	7	11.9
135	9	11.9	13	32	16.3	125	3	11.8
139	30	12.5	11	12	12.5	133	7	11.0
168	72	13.7	39	76	11.6	130	12	12.4
140	38	12.9	123	12	19.9	158	10	10.0
184	41	11.6	129	30	9.7	205	2	10.0
12	57	19.3	131	25	11.8	202	0	15.9
17	39	21.5	172	19	13.7	56	10	15.1
13	71	14.5	177	18	11.0	88	0	11.8
14	25	15.0	204	8	15.5	60	18	13.1
1	72	9.6	170	18	14.1	203	5	11.3
4	48	17.8	58	33	24.0	187	12	13.8
1	49	19.0	153	29	13.3	10	0	8.3
9	64	22.2	190	14	11.4	8	7	17.4
12	77	18.6	11	24	11.6	18	0	7.1
14	53	19.5	9	3	12.1	5	4	14.7
26	44	17.1	19	20	9.9	16	2	19.7
			15	74	13.5	3	7	20.0
			6	55	13.7	14	0	20.6
			2	6	13.9	18	1	17.2
			7	15	15.0	19	3	19.1
			12	9	22.2	16	0	10.8
			6	47	22.5	2	17	19.3
			8	33	20.1	4	12	20.4
			25	13	23.9	6	8	21.2
			8	24	18.7	11	0	19.5
			10	19	21.2	19	4	16.6
			22	26	18.5	24	9	15.2
			23	24	18.6	25	7	17.6
						27	8	14.8
						31	0	16.3
						32	0	19.5
						34	0	19.4
TOTALS								
24	1,204	365.2	36	916	551.9	40	231	582.9

Table 5. Continued.

	HIGH	MED	LOW
TOTAL NUMBER OF SAMPLE UNITS	34	66	102
AREA OF EACH STRATUM	514.5	941.7	1473.5
MOOSE DENSITY PER STRATUM	3.297	1.660	0.396
POPULATION ESTIMATE/STRATUM	1696	1563	584

TOTAL MOOSE POPULATION ESTIMATE - 90% C.I.=3843 (3562-4124)
SIGHTABILITY CORRECTION FACTOR = 1.19
CORRECTED POPULATION ESTIMATE = 4573 (4239-4908) 4573 ± 335 (7.3%)

Table 6. Numbers of moose calves collared and subsequent causes of mortality and survival rates in GMU 13 of southcentral Alaska during 1977-79 and 1984.

Calves	AREA 1 1977	AREA 1 1978	AREA 1 1979	AREA 1 TOT	AREA 2 1977	AREA 2 1978	AREA 2 TOT	AREA 3 1978	AREA 4 1984	ALL AREAS 1977	ALL AREAS 1978	GRAND TOTAL N	GRAND TOTAL %
Radio-collared	25	31	29	85	31	26	57	24	52	56	81	218	
Abandoned	2	4	1	7	4	2	6	1	6	6	7	20	
Remaining	23	27	28	78	27	24	51	23	46	50	74	198	100.0
Death from:													
Brown bear predation	8	11	12	31	16	10	26	7	24	24	28	88	72.7
Wolf predation	0	0	0	0	1	0	1	1	3	1	1	5	4.1
Unknown predation	0	0	0	0	1	1	2	1	0	1	2	3	2.5
Miscellaneous	1	1	4	6	2	1	3	1	5	3	3	15	12.4
Unknown	0	1	0	1	2	0	2	1	1	2	2	5	4.1
Black bear predation	0	0	0	0	0	0	0	0	4	0	0	4	3.3
Coyote predation	0	0	0	0	0	0	0	0	1	0	0	1	0.8
All causes	9	13	16	38	22	12	34	11	38	31	36	121	61.1
Surviving to 1 Nov.	14	14	12	40	5	12	17	12	8	19	38	77	39.9
Calf days	2,384	2,259	2,174	6,817	1,186	2,175	3,361	2,033	1,612	3,570	6,467	13,823	
Daily survival rate 1 June-31 October	.996	.994	.993	.994	.982	.995	.990	.995	.976	.991	.994	.991	
Survival rate 1 June-31 October	.561	.414	.323	.425	.057	.429	.211	.436	.026	.263	.426	.260	

Table 7. Survival rates of radio-collared cow moose in GMU 13 of southcentral Alaska during 1976-86.

Year	Adults			Yearlings			Calves[a]		
	No.	Method 1[b]	Method 2[c]	No.	Method 1	Method 2	No.	Method 1	Method 2
1976-77	39	1.000	1.000	2	1.000	1.000			
1977-78	44	0.976	0.965				1		0.567
178-79	45	0.922	0.768				25	0.936	0.703
1979-80	53	0.924	0.890	18	1.000	0.9701	16	0.938	0.938
1980-81	77	0.966	0.931	15	1.000	0.966	9	1.000	0.884
1981-82	84	0.920	0.889	8	0.749				
1982-83	81	0.968	0.939						
1983-84	48	0.957	0.947						
1984-85	39	0.944	0.931						
1985-86	22	0.849	0.849						
$\bar{x}$	53	0.943	0.911	11	0.937	0.921	13	0.958	0.773
POOLED	122	0.948	0.907	43	0.949	0.925	51	0.871[d]	0.883[d]

[a] Seven month rate from 1 November through May.
[b] Survival rate calculated only for those animals whose final fate is known.
[c] Survival rate calculated for both those animals whose fate was known, and for those whose fate was unknown, the average of two dates were used: one calculated which assumed all missing animals were dead and another which all assumed all were alive.
[d] Rates excluding severe winter of 1978-79 were 0.949 and 0.906, respectively.

Table 8. Survival rates of radio-collared bull moose in GMU 13 of southcentral Alaska during 1978-86.

Year	Adults			Yearlings			Calves[a]		
	No.	Method[b]	Method[c]	No.	Method 1	Method 2	No.	Method 1	Method 2
1978-79							26	0.279	0.279
1979-80	3	1.000	1.000	11	0.643	0.611	18	0.942	0.918
1980-81	10	0.835	0.722	17	1.000	1.000	7	1.000	0.856
1981-82	22	0.803	0.668	6	1.000	1.000			
1982-83	19	0.734	0.598						
1983-84	8	0.738	0.738						
1984-85	6	0.641	0.641						
1985-86	4	0.397	0.397						
$\bar{x}$	17	0.735	0.681	11	0.881	0.870	17	0.740	0.684
POOLED	32	0.735	0.649	34	0.900	0.874	51	0.684[d]	0.669[d]

[a] Seven month rate from 1 November through May.

[b] Survival rate calculated only for those animals whose the final fate is known.

[c] Survival rate calculated for both those animals whose fate was known and for those whose fate was unknown, the average of two dates were used: one calculated which assumed all missing animals were dead and another which all assumed all were alive.

[d] Rates excluding severe winter 1978-79 were 0.949 and 0.907, respectively.

Table 9. Calculated annual survival rates of radio-collared calf moose in GMU 13 of southcentral Alaska, 1977-84 (from Tables 7 and 8).

	Survival Rates					
	June through October		November through May		Annual	
			Method 1[a]	Method 2[b]	Method 1	Method 2
FEMALES	Pooled (1977-84) 0.260	x	Pooled (1976-86) 0.871	Pooled (1976-86) 0.833	0.226	0.217
	Lowest (Area 4-1884) 0.026	x	Lowest (1978-79) 0.936	Lowest (1978-79) 0.703	0.024	0.018
	Highest (Area 1-1977) 0.561	x	Highest (1980-81) 1.000	Highest (1979-80) 0.938	0.561	0.526
	Pooled (1977-84) 0.260	x	Lowest (1978-79) 0.936	Lowest (1978-79) 0.703	0.243	0.183
	Lowest (Area 4-1984) 0.026	x	Pooled (1976-86) 0.871	Pooled (1976-86) 0.833	0.023	0.022
MALES	Pooled (1977-84) 0.260	x	Pooled (1978-81) 0.684	Pooled (1978-81) 0.669	0.178	0.174
	Lowest (Area 4-1984) 0.026	x	Lowest (1978-79) 0.279	Lowest (1978-79) 0.279	0.007	0.007
	Highest (Area 1-1977) 0.561	x	Highest (1980-81) 1.000	Highest (1979-80) 0.918	0.561	0.515
	Pooled (1977-84) 0.260	x	Lowest (1978-79) 0.279	Lowest (1978-79) 0.279	0.073	0.073
	Lowest (Area 4-1984) 0.026	x	Pooled (1978-81) 0.684	Pooled (1978-81) 0.669	0.018	0.017

Table 9. Continued.

Seven month rate from 1 November through May.

[a] Survival rate calculated only for those animals for which the final fate is known.

[b] Survival rate calculated for both those animals whom fate was known, and for those whose fate was unknown, the average of two dates were used: one calculated which assumed all missing animals were dead and another which all assumed all were alive.

Table 10. Mean seasonal and total home range sizes for adult resident and migratory cow moose studied during 1976-1984 in GMU 13 of southcentral Alaska.

Type of Home Range	No. locations	Winter Home Range				Summer Home Range				Fall Home Range				Total Home Range				
		No. moose	$\bar{x}$	SD	Range	No. moose	$\bar{x}$	SD	Range	No. moose	$\bar{x}$	SD	Range	No. Locations	No. moose	$\bar{x}$	SD	Range
Resident	4-13	35	67	57	4-217	11	46	35	19-121	33	105	141	6-720	25-39	25	209	123	63-545
	14-23	6	93	53	10-146	34	87	77	23-456	20	144	103	43-462	40-54	14	261	149	113-568
	24-33	4	106	77	34-209	7	168	88	29-262	1	440	00	-	55-69	7	280	231	123-787
	34-43	7	137	157	35-430	2	144	111	65-222	-	-	-	-	70-84	2	301	50	266-337
	44-53	2	107	6	101-111	-	-	-	-	-	-	-	-	85-104	6	366	234	111-739
Total or Ave[a]		19	113	101	10-430	43	103	84	23-456	21	157	115	43-462	39-104	29	290	182	111-787
Migratory	4-13	8	173	144	15-375	2	389	330	156-622	12	333	224	89-435	25-39	5	1061	510	454-1703
	14-23	-	-	-	-	9	248	211	73-605	3	280	128	133-371	40-54	3	603	171	411-740
	24-33	3	193	155	38-347	4	234	210	60-266	-	-	-	-	55-69	4	497	170	263-667
	34-43	4	75	24	48-106	-	-	-	-	-	-	-	-	70-84	1	398	-	-
Total or Ave[a]		15	151	127	15-375	15	263	213	60-622	15	322	205	89	40-104	10	505	165	263-740

[a] For resident moose only individuals with 14-53 total relocations were used while for migratory moose all relocations were used.

Table 11. Comparison of mean seasonal and total home range sizes by method of calculation for radio-collared resident and migratory adult cow moose studied in GMU 13 of southcentral Alaska during 1978-1984 (standard deviation in parentheses).

Season	Residents (N=9)		Migratory (N=4)	
	Mohr's Method (km^2)[a]	New Method (km^2)[b]	Mohr's Method (km^2)	New Method (km^2)
Winter	58.0 (29.8)	36.5 (16.3)	134.9 (144.8)	52.6 (65.0)
Summer	55.9 (32.6)	21.0 (15.3)	152.6 (79.8)	43.8 (7.8)
Total	258.0 (204.6)	81.8 (33.7)	507.9 (168.4)	173.5 (59.6)

[a] Minimum home range or convex polgon method (see Mohr 1947).
[b] Modified minimum home rnage method (see methods sections).

Table 12. Comparison of moose offspring seasonal home range use with that of parents studied in GMU 13 of southcentral Alaska from 1981-1984.[a]

ID No. sex: Season	Dispersal Status							
	Partial							Full
	690-m	693-f	696-m	672-m	675-m	676-m	677-m	685-f
Summer 81	0	0	-	0	0	X	0	0
Winter 82	0	0	-	X	-	X	-	X
Summer 82	0	X	-	-	X	X	-	-
Winter 83	0	X	-	-	X	X	X	X
Summer 83	X	0	-	-	X	X	X	
Winter 84	0	X	X	-	X	X		
Summer 84	X	0		-		X		

[a] 0 = same home range as parent, X = different home range from parent, - = home range partially overlaps with parent.

Table 13. Comparison among years of moose counts conducted each March within the Watana Impoundment Zone, 1981-85.

Year	Survey time (min.)	No. moose observed	S.C.F.[a]	Estimated no. moose	Estimated moose/mi^2
1981	374	42	1.00[b]	42	0.4
1982	264	174	1.67	290	2.9
1983	396	161	3.600	580	5.0
1984			NO SURVEY		
1985	436	173	1.703	295	3.0

[a] Sightability correction factor.
[b] Fewer moose were observed on recount.

Table 14. Comparison among years of moose counts conducted each March within the Devil Canyon Impoundment Zones from 1981-85.

Year	Survey time (min.)	No. moose observed	S.C.F.[a]	Estimated no. moose	Estimated moose/mi^2
1981	190	28	1.06	30	1.0
1982	---	--	----	--	---
1983	123	14	1.0	34	.5
1984	NO SURVEY				
1985	166	16	1.40	22	.7

[a] Sightability correction factor.

Table 15. Comparison of browse quantity with usage by radio-collared moose outside of Watana and Devil Canyon Impoundments in the Susitna River Basin of southcentral Alaska, 1976-1985.

Strata	Area(ha)	Expected number of moose relocations	Expected number of moose relocations	Chi^2	Selection
WINTER					
High	14,420	57	67.5	1.6	Not Significant
Med-For	4,486	28	21.4	2.0	Not Significant
Med-Shr	12,644	31	59.0	13.3	AVOIDED P=0.04
Low	52,065	286	242.3	7.9	Not Significant
Very Low	56,647	307	263.7	7.1	Not Significant
Scarce	80,674	337	376.3	4.1	Not Significant
Zero	9,070	26	41.8	6.0	Not Significant
SUMMER					
High	14,420	60	65.5	0.5	Not Significant
Med-For	4,486	26	20.8	1.3	Not Significant
Med-Shr	12,644	25	57.1	18.0	AVOIDED P=0.005
Low	52,065	225	234.8	0.4	Not Significant
Very Low	56,647	310	255.6	11.6	Not Significant
Scarce	80,674	348	364.7	0.8	Not Significant
Zero	9,070	45	40.5	0.5	Not Significant
AUTUMN					
High	14,420	59	51.6	1.1	Not Significant
Med-For	4,486	23	16.4	2.7	Not Significant
Med-Shr	12,644	37	45.0	1.4	Not Significant
Low	52,065	211	185.1	3.6	Not Significant
Very Low	56,647	214	201.5	0.8	Not Significant
Scarce	80,674	237	287.5	8.9	Not Significant
Zero	9,070	38	31.9	1.2	Not Significant
TOTAL					
High	14,420	176	184.6	0.4	Not Significant
Med-For	4,486	77	58.6	5.8	Not Significant
Med-Shr	12,644	93	161.2	28.9	AVOIDED P=0.005
Low	52,065	722	662.2	5.4	Not Significant
Very Low	56,647	831	720.8	16.8	PREFERRED P=0.05
Scarce	80,674	922	1028.4	11.0	Not Significant
Zero	9,070	109	114.3	0.2	Not Significant

Table 16. Comparison of browse quantity with usage by radio-collared moose Watana Impoundment area along the Susitna River of southcentral Alaska, 1976-1985.

Strata	Area(ha)	Expected number of moose relocations	Expected number of moose relocations	Chi^2	Selection
WINTER					
High	1,290	2	2.9	0.3	Not significant
Med	8,197	10	17.5	3.2	Not significant
Low	32,858	61	69.6	1.1	Not significant
Very Low	66,795	142	141.4	0.0	Not significant
Scarce	81,870	193	173.5	2.2	Not significant
Zero	5,978	9	12.5	1.0	Not significant
SUMMER					
High	1,290	3	1.5	1.5	Not significant
Med	8,197	9	8.8	0.0	Not significant
Low	32,858	27	35.1	1.9	Not significant
Very Low	66,795	79	71.2	0.9	Not significant
Scarce	81,870	90	87.4	0.1	Not significant
Zero	5,978	2	6.3	2.9	Not significant
AUTUMN					
High	1,290	0	0.3	0.3	Not significant
Med	8,197	1	1.9	0.4	Not significant
Low	32,858	10	7.5	0.8	Not significant
Very Low	66,795	15	15.3	0.0	Not significant
Scarce	81,870	19	18.7	0.0	Not significant
Zero	5,978	0	1.4	1.4	Not significant
TOTAL					
High	1,290	5	4.7	0.0	Not significant
Med	8,197	20	28.2	2.4	Not significant
Low	32,858	98	112.2	1.8	Not significant
Very Low	66,795	236	227.8	0.3	Not significant
Scarce	81,870	302	279.6	1.8	Not significant
Zero	5,978	11	20.2	4.2	Not significant

Table 18. Chi-square analysis of aspect selection during 3 seasons in the primary moose impact zone of the Susitna River Basin, southcentral Alaska, 1977-1984.

Season	WINTER		SUMMER		FALL		TOTAL	
	Chi^2	SEL*	Chi^2	SEL*	Chi^2	SEL*	Chi^2	SEL*
ASPECT								
FLAT	99.9	A	78.1	A	68.6	A	243.9	A
N	290.0	P	330.0	P	234.5	P	858.1	P
NE	17.0	A	44.0	A	19.4	A	78.0	A
E	5.6		6.1		1.6		12.7	
SE	57.6	A	75.0	A	29.7	A	159.4	A
S	446.1	P	395.6	P	281.4	P	1118.0	P
SW	11.6		9.0		14.5		33.6	A
W	0.3		1.8		11.2		8.1	
NW	58.0	A	25.1	A	21.1	A	98.9	A

*SEL Selection is denoted by A for avoidance and P for preference. All significance levels are at $P < 0.05$ with 8 degrees of freedom.

Table 19. Soil Conservation Service snow survey data from 4 snow courses in the middle Susitna River Basin, 1964-1985.

		YEAR																						
	Month	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86
LOCATION																								
Fog Lakes	Jan	10	16	10	11	31	13	12	30	35	32	15	33	14	28	17	24	29	11	15	21	19	19	13
	Feb	14	15	21	16	33	14	15	38	31	31	20	29	18	27	17	27	32	14	22	23	22	33	14
	Mar	11	15	22	26	34	18	14	37	34	34	24	30	22	32	18	35	32	20	30	24	24	32	
	Apr	16	12	24	19	29	0	6	33	37	27	15	31	14	29	11	32	16	10	23	21	25	21	
Square Lk.	Jan	14	13	17	17	14	13	12	18	26	23	14	19	12	17	16	19	16	16	28	22	13	16	19
	Feb	16	19	16	26	16	17	11	20	27	23	21	22	13	20	17	29	19	18	30	25	15	21	25
	Mar	20	20	18	24	20	16	12	19	28	23	20	25	16	25	18	25	18	22	32	26	16	18	
	Apr	20	14	16	14	14	10	6	15	28	14	13	25	10	21	16	14	16	17	31	17	15	17	
Monahan	Jan	24	23	24	19	32	18	21	30	36	35	17	36	22	30	28	33	30	24	20	30	28	24	18
	Feb	30	26	32	25	39	22	19	40	33	35	22	36	25	32	30	35	32	31	19	33	36	27	26
	Mar	23	25	27	26	38	20	20	44	38	34	22	40	32	42	32	41	30	32	23	33	35	33	
	Apr	30	24	30	24	38	13	23	41	43	31	19	43	24	38	30	39	27	26	23	30	35	36	
Louise	Jan	16	14	18	18	19	16	13	16	30	24	14	23	12	18	20	20	22	11	16	17	17	16	18
	Feb	31	15	20	24	22	16	14	16	30	22	25	24	14	21	22	23	26	14	19	20	21	22	19
	Mar	18	16	22	30	28	17	14	20	33	22	25	27	19	29	21	28	24	15	20	21	20	21	
	Apr	14	11	8	22	20	0	5	16	30	10	15	21	10	20	12	12	17	7	18	14	14	20	
TOTAL WSI[a]		18.9	18.1	20.6	21.8	27.2	16.7	14.8	27.3	31.8	28.2	19.9	28.7	18.3	26.8	21.3	28.3	25.8	19.0	22.8	24.6	22.2	23.5	

[a] Winter severity index

TABLE 20 SUMMARY OF ACTIONS AND IMPACTS OF THE EFFECTS OF HYDROELECTRIC DEVELOPMENTS ON MOOSE POPULATION DYNAMICS IN NORTH AMERICA.

PROJECT ACTIONS — CONSTRUCTION & OPERATION OF HYDROELECTRIC PROJECTS / ENVIRONMENTAL IMPACTS

staging areas, camps	spoil sites	borrow areas	temporary access roads	reservoir clearing	permanent village facilities	permanent roads & railroads	airports & support facilities	transmission lines	dam construction	operation of impoundments	comm. & rec. developments	Environmental impact			
								X				winter	temp	IMPROVEMENT OF RANGE	HABITAT CHANGES
								X				spring	temp	IMPROVEMENT OF RANGE	HABITAT CHANGES
								X				summer	temp	IMPROVEMENT OF RANGE	HABITAT CHANGES
								X				fall	temp	IMPROVEMENT OF RANGE	HABITAT CHANGES
			X	X								winter	perm	IMPROVEMENT OF RANGE	HABITAT CHANGES
			X	X								spring	perm	IMPROVEMENT OF RANGE	HABITAT CHANGES
			X	X								summer	perm	IMPROVEMENT OF RANGE	HABITAT CHANGES
			X	X								fall	perm	IMPROVEMENT OF RANGE	HABITAT CHANGES
				X	X	X	X		X	X	X	winter	temp	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
				X	X	X	X		X	X	X	spring	temp	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
				X	X	X	X		X	X	X	summer	temp	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
				X	X	X	X		X	X	X	fall	temp	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
X	X	X	X								X	winter	perm	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
X	X	X	X								X	spring	perm	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
X	X	X	X								X	summer	perm	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
X	X	X	X								X	fall	perm	LOSS OR AVOIDANCE OF RANGE	HABITAT CHANGES
								X		X		snow depth increases			GEOLOGIC & CLIMACTIC CHANGES
										X		humidity increases			GEOLOGIC & CLIMACTIC CHANGES
										X		open water or thin ice			GEOLOGIC & CLIMACTIC CHANGES
										X		ice shelving			GEOLOGIC & CLIMACTIC CHANGES
										X		vegetation icing or loss of insulation			GEOLOGIC & CLIMACTIC CHANGES
										X		increased mud flats			GEOLOGIC & CLIMACTIC CHANGES
										X		increased erosion			GEOLOGIC & CLIMACTIC CHANGES
X			X		X	X			X		X	vehicle collisions			DIRECT MOOSE MORTALITY
X			X		X	X	X	X			X	increased poaching			DIRECT MOOSE MORTALITY
X	X	X	X		X	X		X		X	X	off-road vehicles use			INCREASED HUMAN USE OF AREA
X			X		X	X	X	X		X	X	increased hunting			INCREASED HUMAN USE OF AREA
								X		X	X	camping, fishing & nonconsumptive uses			INCREASED HUMAN USE OF AREA
X					X		X	X			X	aircraft			INCREASED HUMAN USE OF AREA
										X	X	boats			INCREASED HUMAN USE OF AREA

RESULTS OF IMPACTS / EFFECTS ON MOOSE[1] POPULATION DYNAMICS

Environmental impact	Results of impacts	reproduction	accidental deaths	winter kill	predation & predator population	general health, parasitism, disease	
HABITAT CHANGES — IMPROVEMENT OF RANGE	increased concentrations of moose					—	INCREASE IN POPULATION
	increased concentrations of predators				—		INCREASE IN POPULATION
	increased quantity/quality of vegetation	+		+		+	INCREASE IN POPULATION
HABITAT CHANGES — LOSS OR AVOIDANCE OF RANGE	increased concentrations of moose					—	DECREASE IN POPULATION
	increased concentrations of predators				—		DECREASE IN POPULATION
	decreased quantity/quality of vegetation	—		—		—	DECREASE IN POPULATION
	increased moose vulnerability				—		DECREASE IN POPULATION
GEOLOGIC & CLIMACTIC CHANGES	more severe & longer lasting winters	—		—	—	—	DECREASE IN POPULATION
	decreased quality of vegetation	—		—		—	DECREASE IN POPULATION
	delayed spring green-up	—		+		—	DECREASE IN POPULATION
	barriers to movements		—	—	—		DECREASE IN POPULATION
DIRECT MOOSE MORTALITY		—					DECREASE IN POPULATION
INCREASED HUMAN USE OF AREA	increased disturbance	—	—				DECREASE IN POPULATION

[1] + Positive Change
— Negative Change

Table 21. Ranges of estimates of numbers and densities (moose/mi^2 in parentheses) of moose which could be sustained for a 90-day period in late winter within the proposed Watana Impoundment Zone (≤2,200 ft elevation) along the Susitna River in southcentral Alaska based on a model of habitat carrying capacity (based on area of 53.4 mi^2, digestibility = 1.0, and use of upper 80% confidence interval of browse biomass estimates, modified from Becker, in prep.).

Diet Composition	Percent Utilization of Annual Growth		
	50	60	100
Willow (Salix spp.)	431 (8.0)	517 (9.6)	861 (16.0)
Paper birch plus willow	436 (8.1)	523 (9.7)	872 (16.2)
20% resin birch plus paper birch and willow	474 (8.8)	568 (10.6)	947 (17.6)

Table 22. Ranges of estimates of numbers and densities (moose/mi^2 in parentheses) of moose which could be sustained for a 90-day period in late winter within the proposed Devil Canyon impoundment zone based on a model of habitat carrying capacity (based on area of 10.8 mi^2, digestibility = 1.0, and use of upper 80% confidence interval of biomass estimates, modified from Becker, in prep.).

Diet Composition	Percent Utilization of Annual Growth		
	50	60	100
Willow	53 (4.9)	63 (5.9)	106 (9.8)
Paper birch plus willow	105 (9.8)	126 (11.7)	210 (19.5)
20% resin birch plus paper birch and willow	118 (10.9)	141 (13.1)	235 (21.8)

Table 23. Timing of expected impacts of Susitna hydroelectric development on moose, and actions and studies necessary to refine magnitudes of impacts.

Impact I.D. No.	Predicted dates of occurrence	Predicted dates occurrence first observable	Predicted dates by which maximum impact likely to occur	Actions or monitoring necessary to refine quantifications of impacts
I.I.-1	Construction and operation	1st winter	5 years after initial operation	Replication of 1980 and 1983 moose population census
I.I.-2	Construction and operation	1st winter	5 years after initial operation	Wolf and bear predation rates study, calf mortality study. Maintain sample of radio-collared adult moose
I.I.-3	Post-impoundment	1st winter of fill	10 years after initial fill	Monitor radio-collared adult and calf moose during winter and migration
I.I.-4	Fill and operation	Initiation of fill	5 years	Monitor radio-collared adult moose
I.I.-5	Construction and regular use of access routes	1st winter	Continual	Record number and frequency of collisions
I.I.-6	Operation	1st winter of fill	1st severe winter	Monitor radio-collared adult moose
I.I.-7	Construction and use of access routes	1st winter	Continual	Record number and frequency of collisions

Table 23. Continued.

Impact I.D. No.	Predicted dates of occurrence	Predicted dates occurrence first observable	Predicted dates by which maximum impact likely to occur	Actions or monitoring necessary to refine quantifications of impacts
I.I.-8	Construction	1st year	Pre-impoundment	Monitor radio-collared adult moose
I.I.-9	Construction and operation	1st year	Continual	Monitoring poaching and harvest
I.I.-10	Construction	1st year	5 years	Monitor radio-collared adult moose distribution surveys
I.I.-11	Construction and	1st year	5 years	Replication of 1980 and 1983 moose population census
I.I.-12	Operation	5 years	Continual	Unknown
I.I.-13	Construction and maintenance	3-5 years	Continual	Browse production studies
P.I.-1	Operation	1st winter	10 years	Replication of 1980 and 1983 moose population census
P.I.-2	Operation	1st year	25 years	Browse production studies
P.I.-3	At fill	At initiation of fill	25 years	Monitor radio-collared adult and browse use studies

Table 23. Continued.

Impact I.D. No.	Predicted dates of occurrence	Predicted dates occurrence first observable	Predicted dates by which maximum impact likely to occur	Actions or monitoring necessary to refine quantifications of impacts
P.I.-4	Operation	1st winter	1st severe winter	Map snow, conduct moose distribution and availability studies
P.I.-5	Operation	1st winter	5 years	Map snow, conduct moose distribution and availability studies
P.I.-6	Operation	5 years	10-20 years	Monitor erosion and browse studies
P.I.-7	Operation	1st winter	20 years	Browse availability study
P.I.-8	Operation	1st winter	1st severe winter	Monitor adult moose
P.I.-9	Unknown	5 years	25 years	Map areas burned by fire

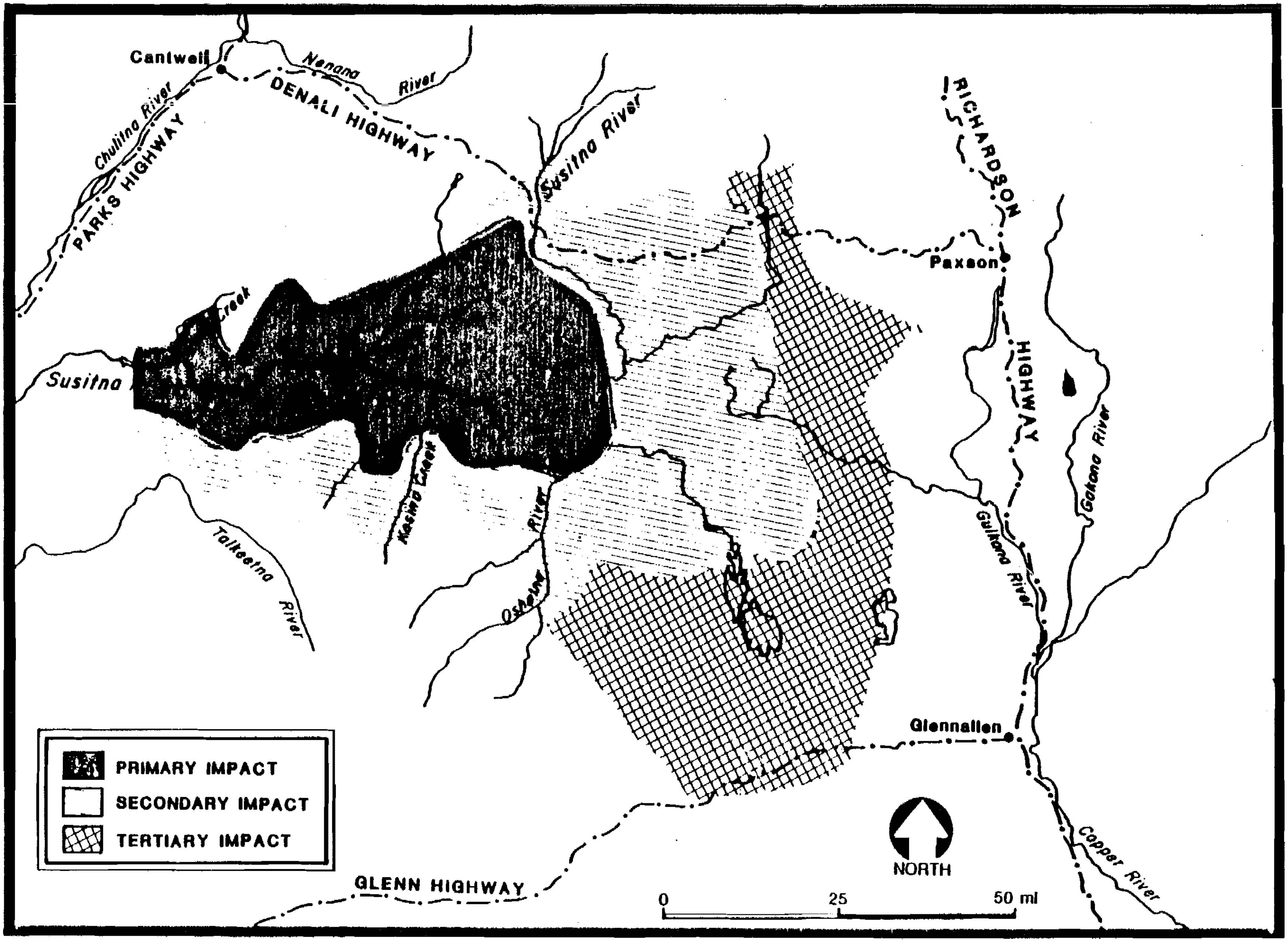

Figure 1. Boundaries of primary, secondary and tertiary zones of impact for the Susitna Hydroelectric Project based upon movements of radio-collared moose from 1976-1982 in Game Management Unit 13 of southcentral Alaska.

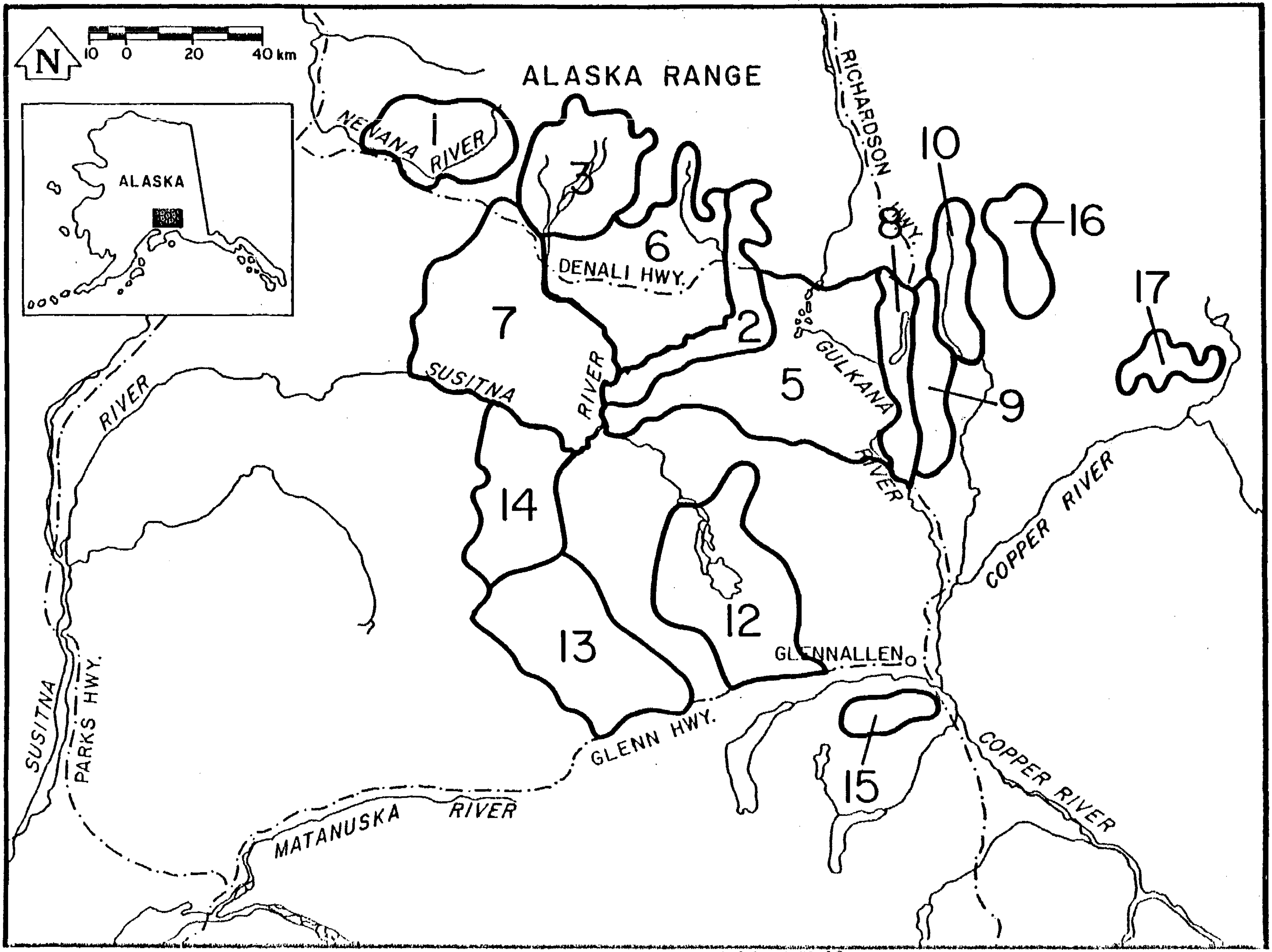

Fig. 2. Boundaries of fall moose sex-age composition count areas within GMU 13.

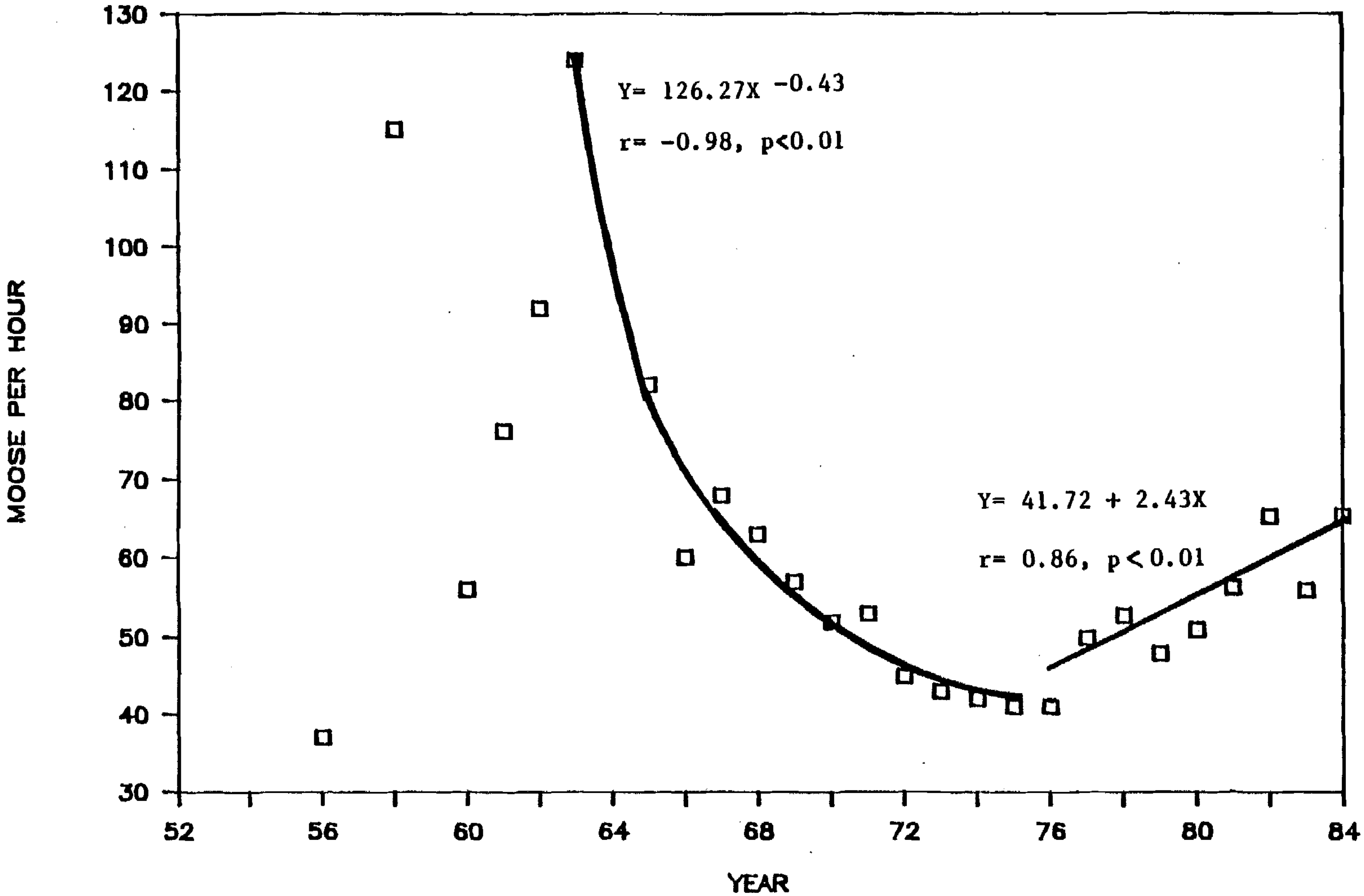

Fig. 3. Moose observed per hour during sex-age composition surveys conducted within 15 count areas in GMU 13 of southcentral Alaska, 1956-1984. Note: Fitted curves does not include data points from 1956 through 1962.

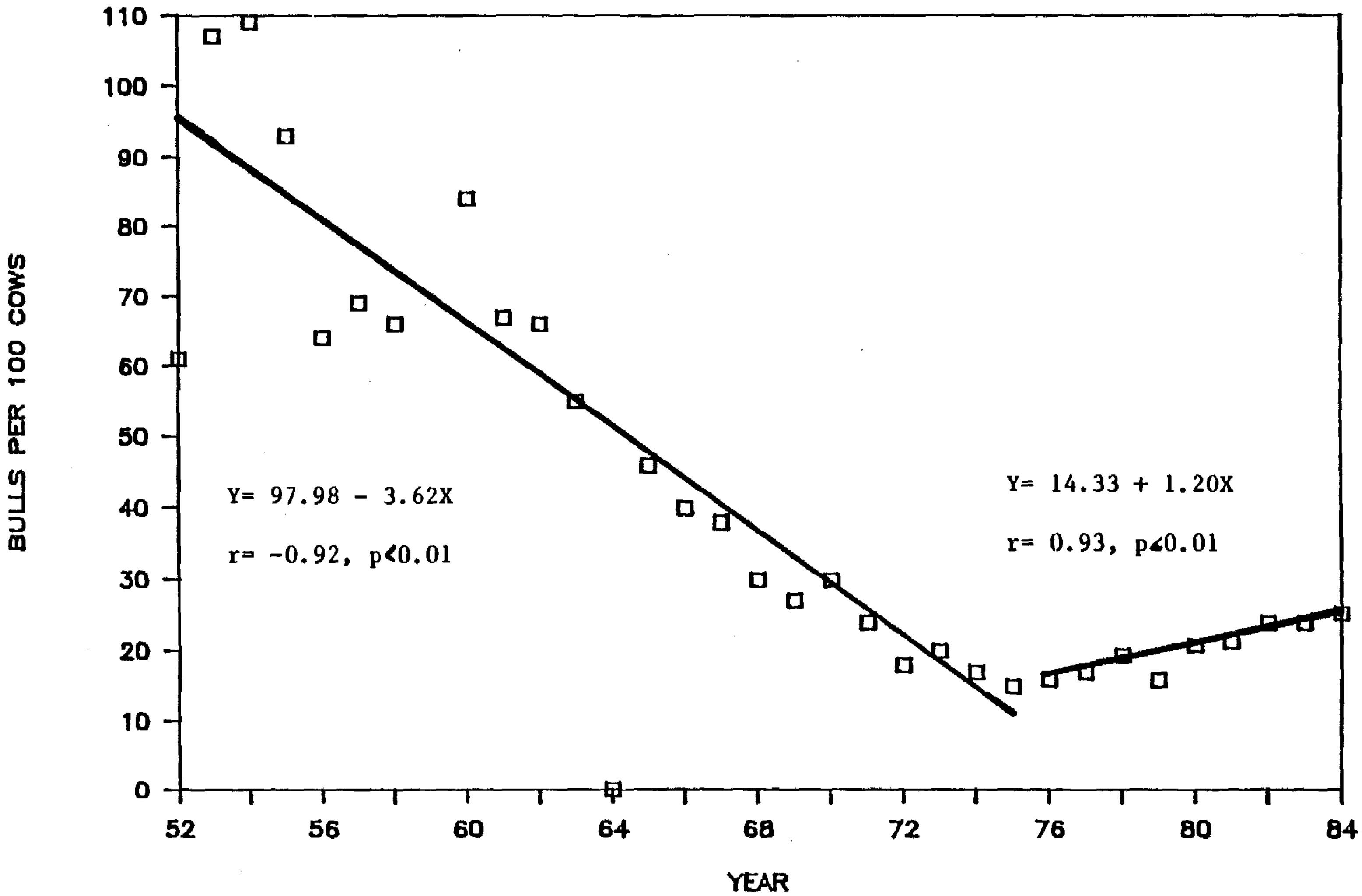

Fig. 4. Bulls per 100 cows counted during moose sex-age composition surveys within 15 count areas in GMU 13 of southcentral Alaska, 1952-1984.

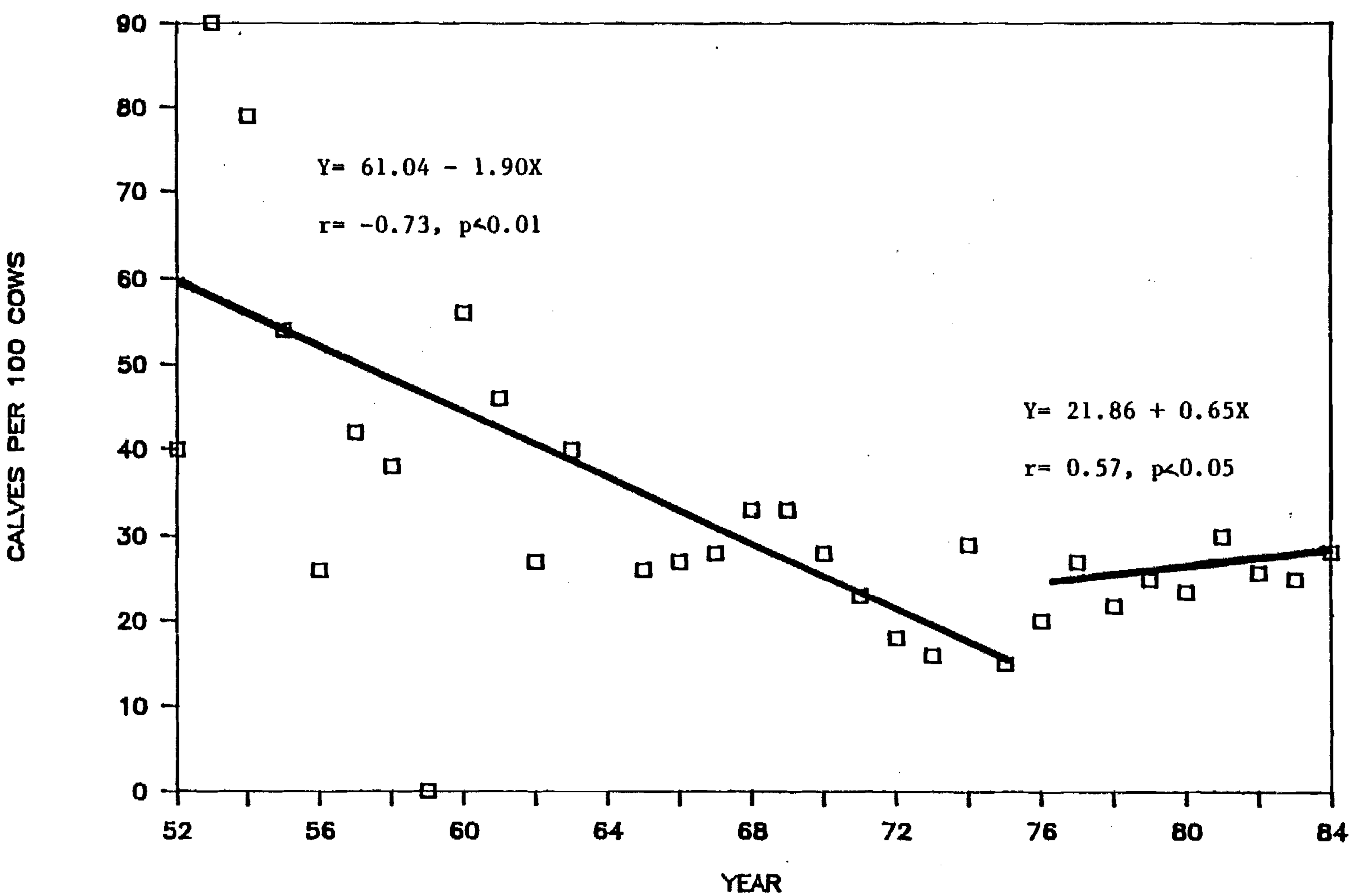

Fig. 5. Calves per 100 cows counted during moose sex-age composition surveys within 15 count areas in GMU 13 of southcentral Alaska, 1952-1984.

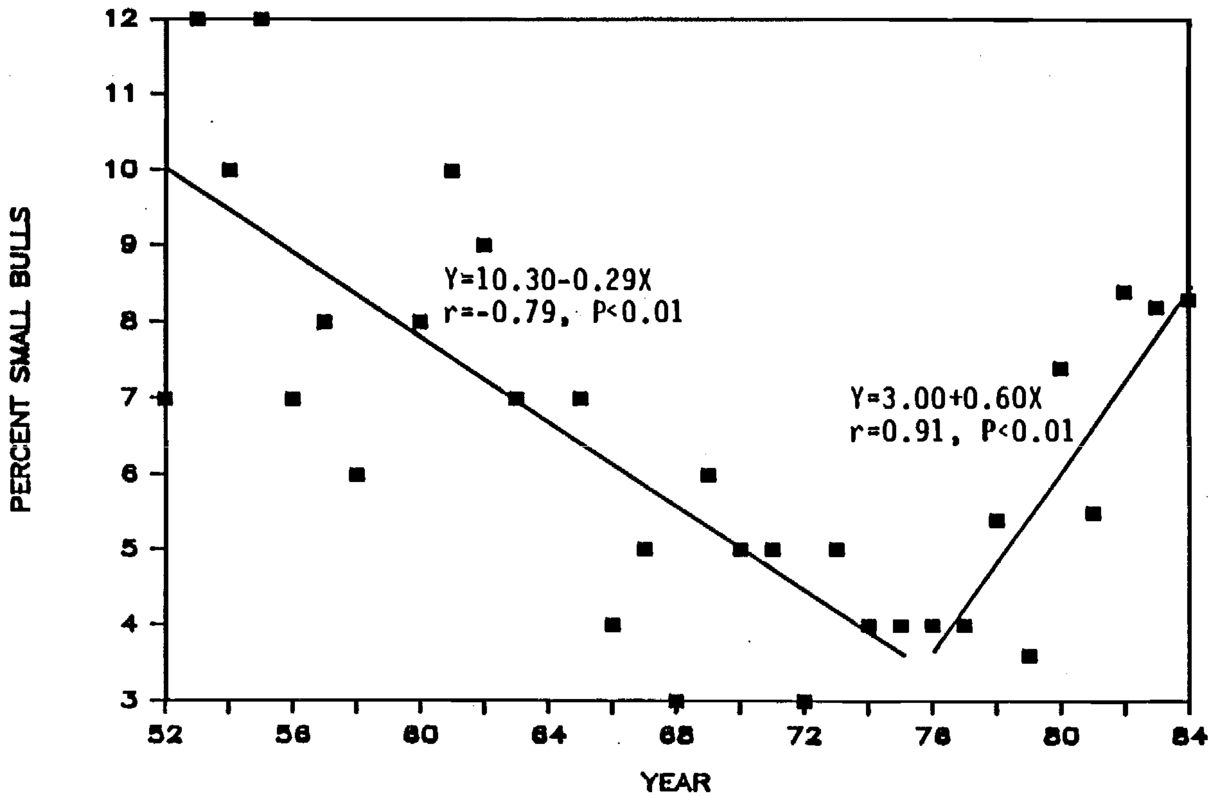

Fig. 6. Percent small bulls within the moose population as determined from sex-age composition surveys conducted in GMU 13 of southcentral Alaska, 1952-1984.

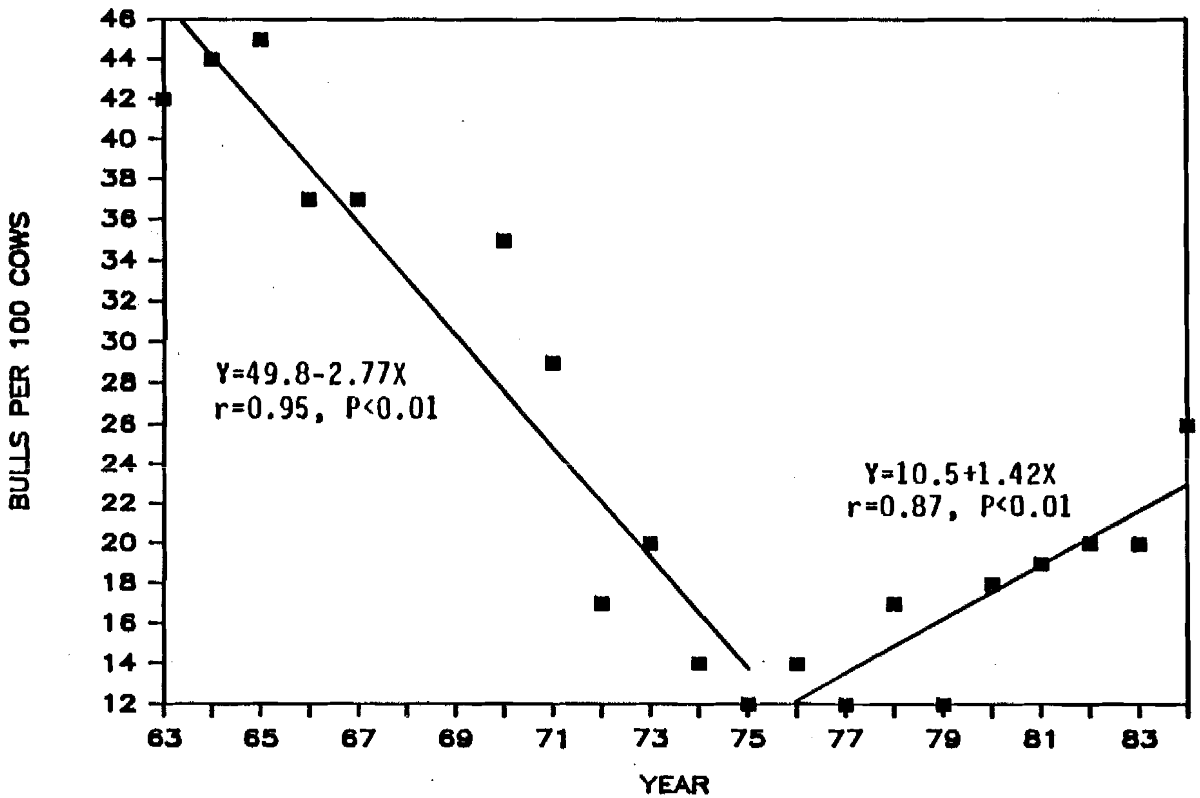

Fig. 7. Bulls per 100 cows observed during moose sex-age composition surveys in the Susitna River Study Area of GMU 13 of southcentral Alaska, 1963-1984.

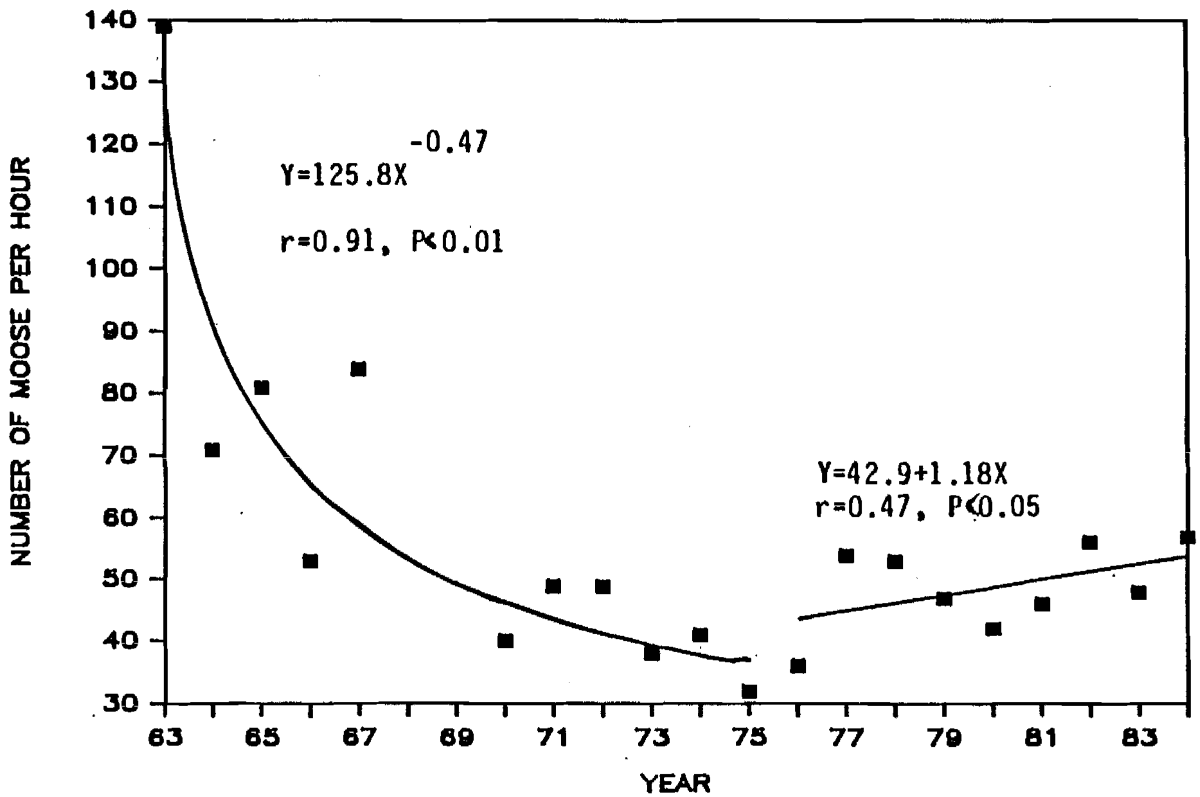

Fig. 8. Moose observed per hour during sex-age composition surveys in the Susitna River Study Area of GMU 13 of southcentral Alaska, 1963-1984.

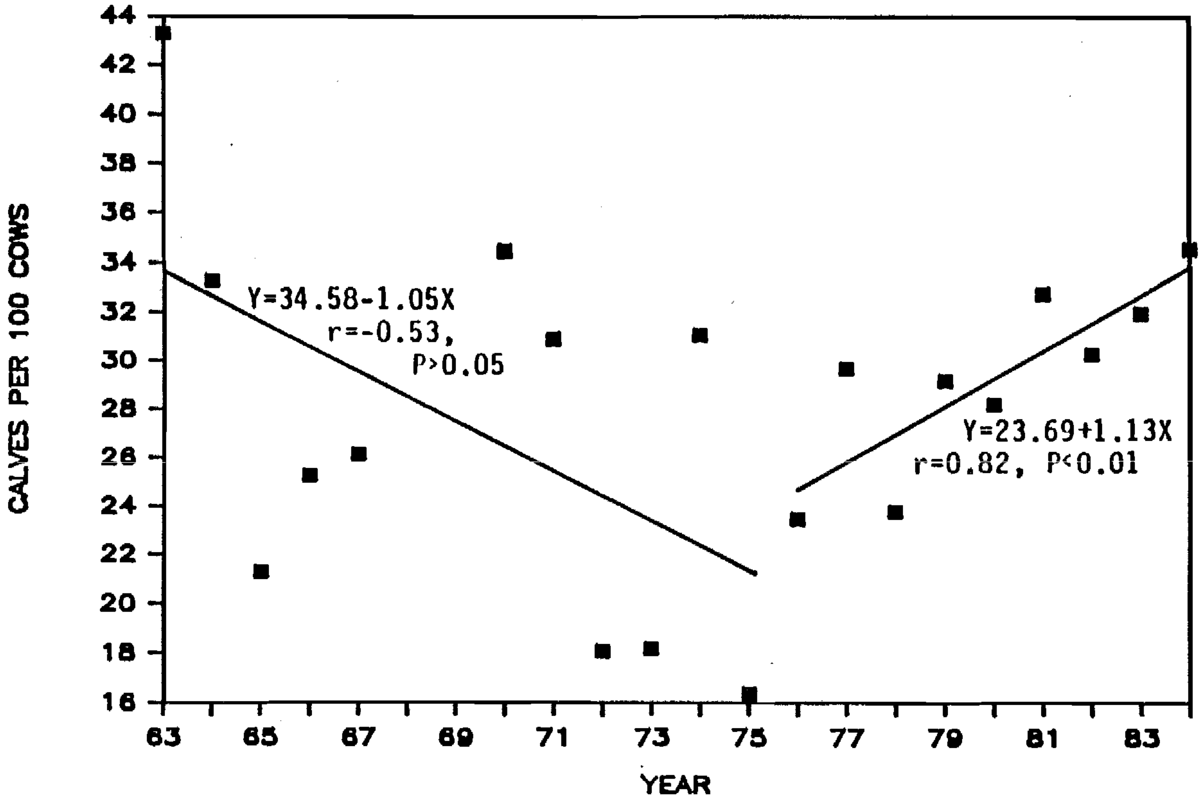

Fig. 9. Calves per 100 cows within the Susitna River Study Area of GMU 13 of southcentral Alaska as determined during moose sex-age composition surveys, 1963-1984.

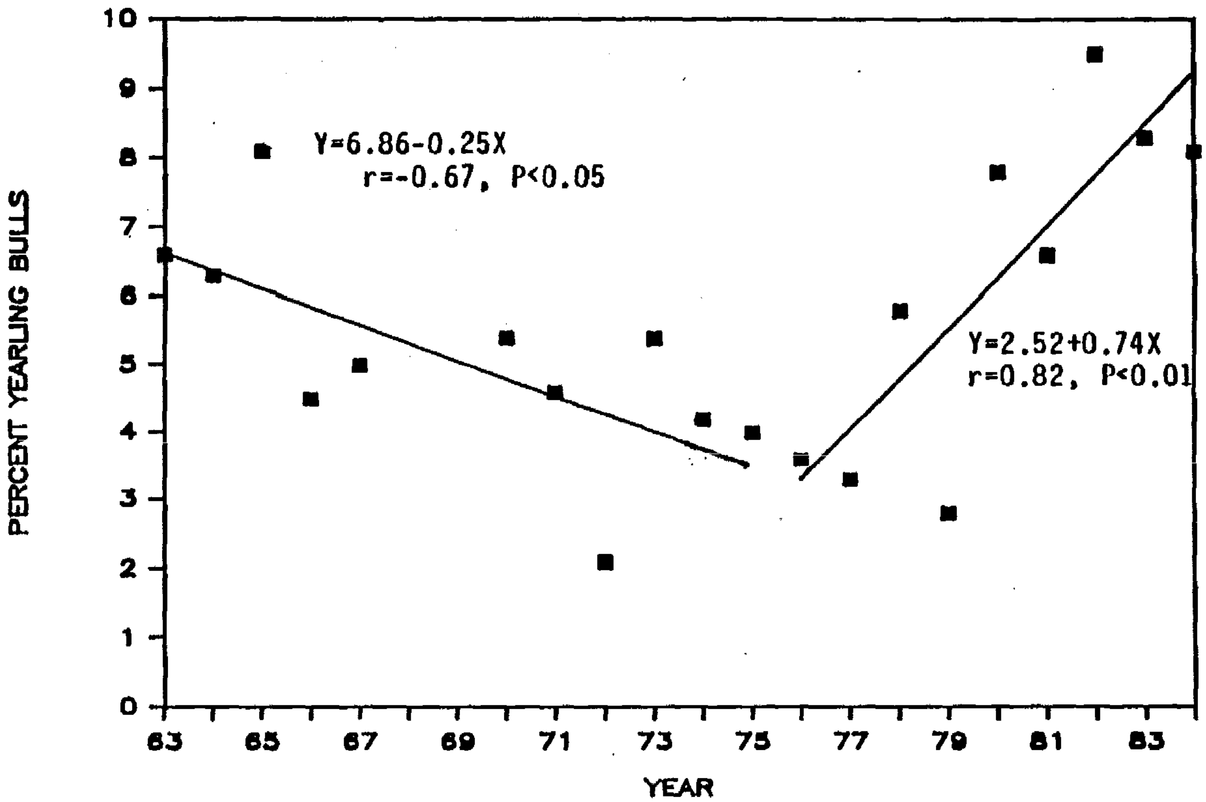

Fig. 10. Percent of yearling bulls within the moose population in the Susitna River Study Area of GMU 13 of southcentral Alaska as determined from sex-age composition surveys, 1963-1984.

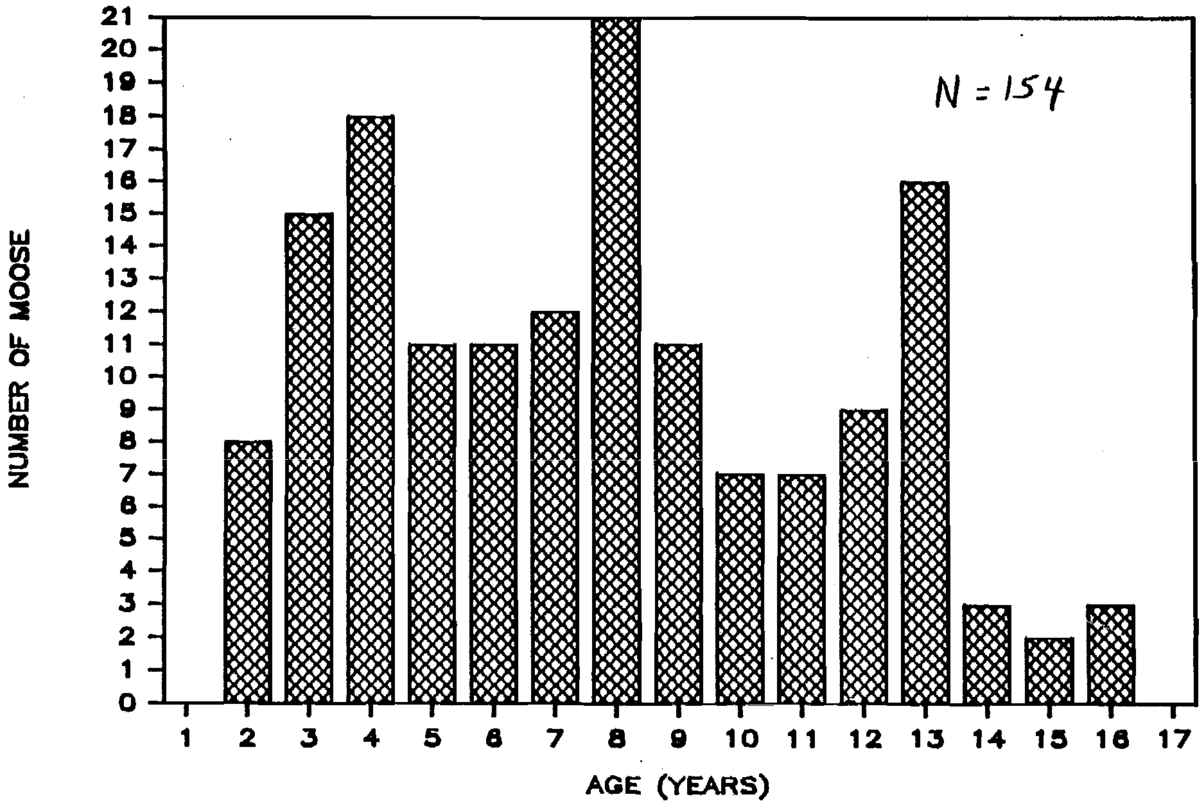

Fig. 11. Age structure of adult moose captured within GMU 13, 1976-1984.

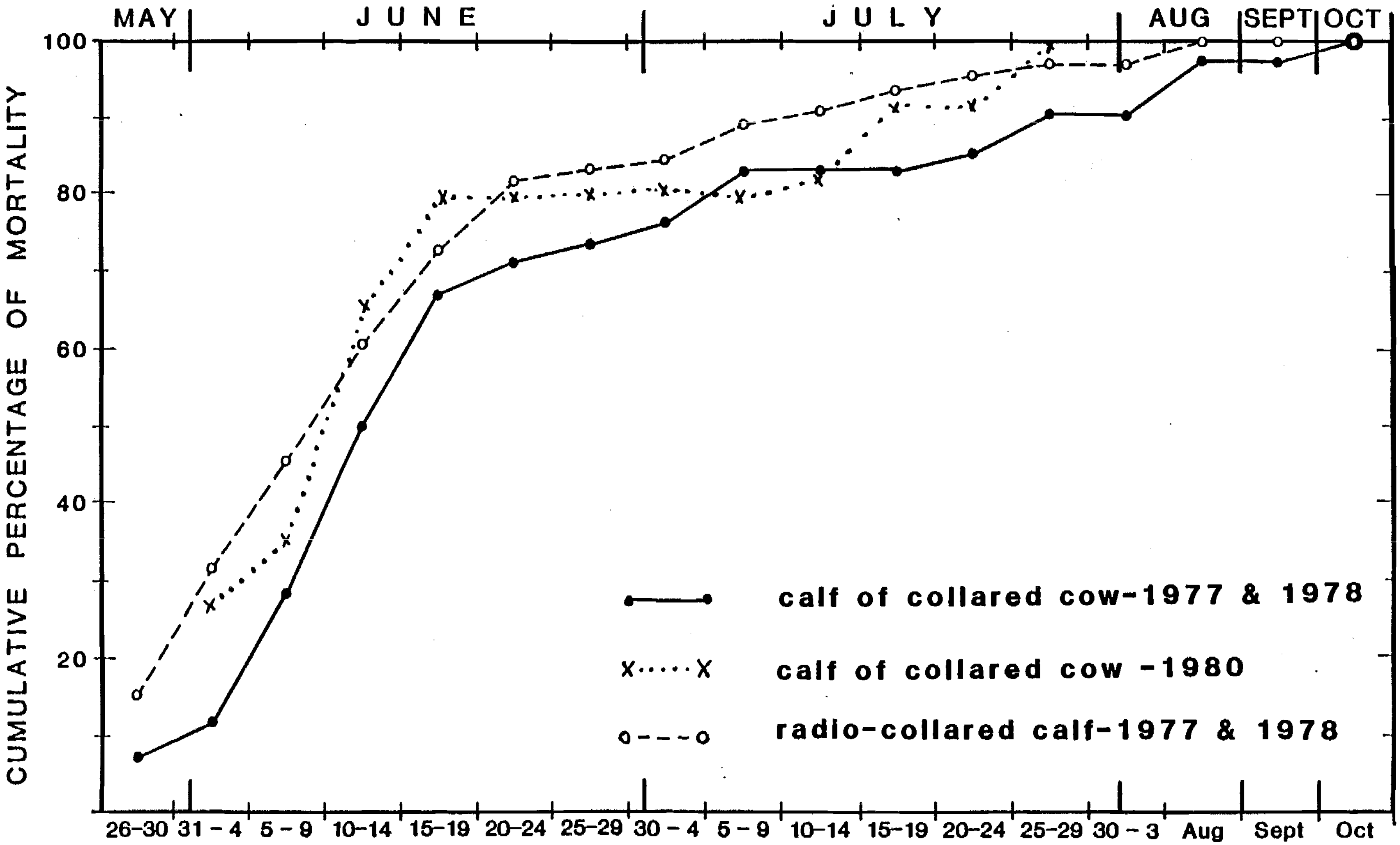

Fig. 12. Dates of mortalities of collared and uncollared moose calves within GMU 13, 1977-1980 (modified from Ballard et al. 1981).

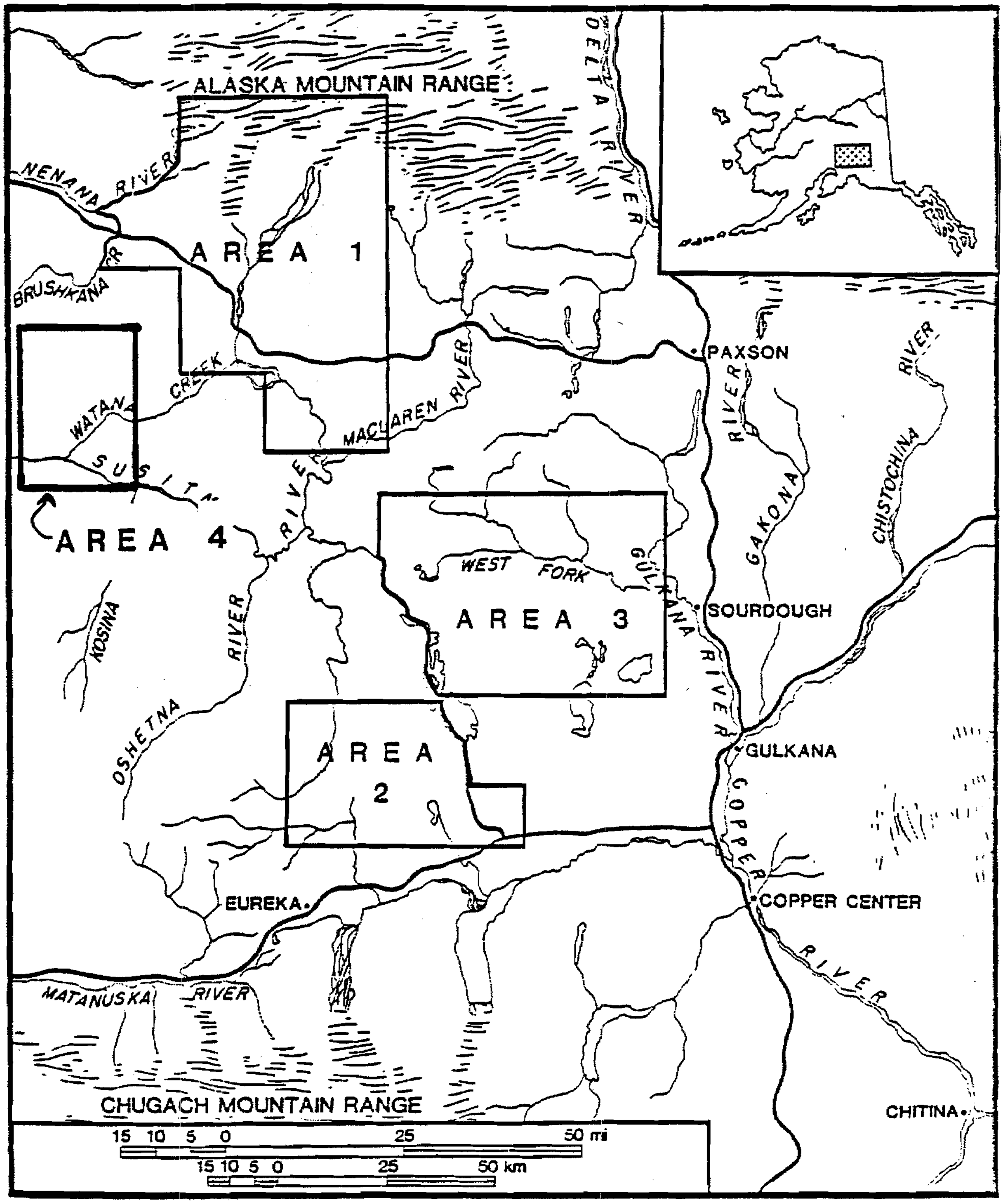

Fig. 13. Location of 4 study areas within GMU 13 where causes of moose calf mortality were determined, 1977-1984.

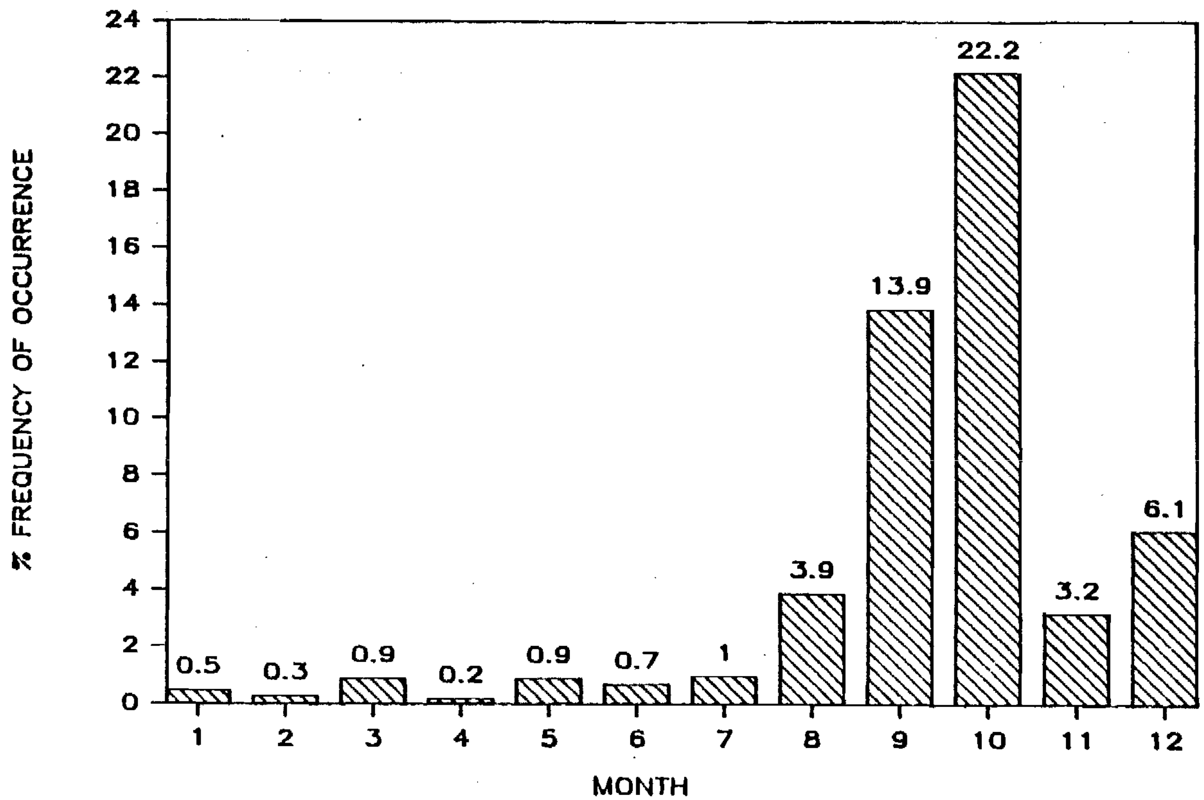

Fig. 14. Frequency of large (> 9) group sizes of radio-collared moose in GMU 13 of southcentral Alaska, 1977-1985.

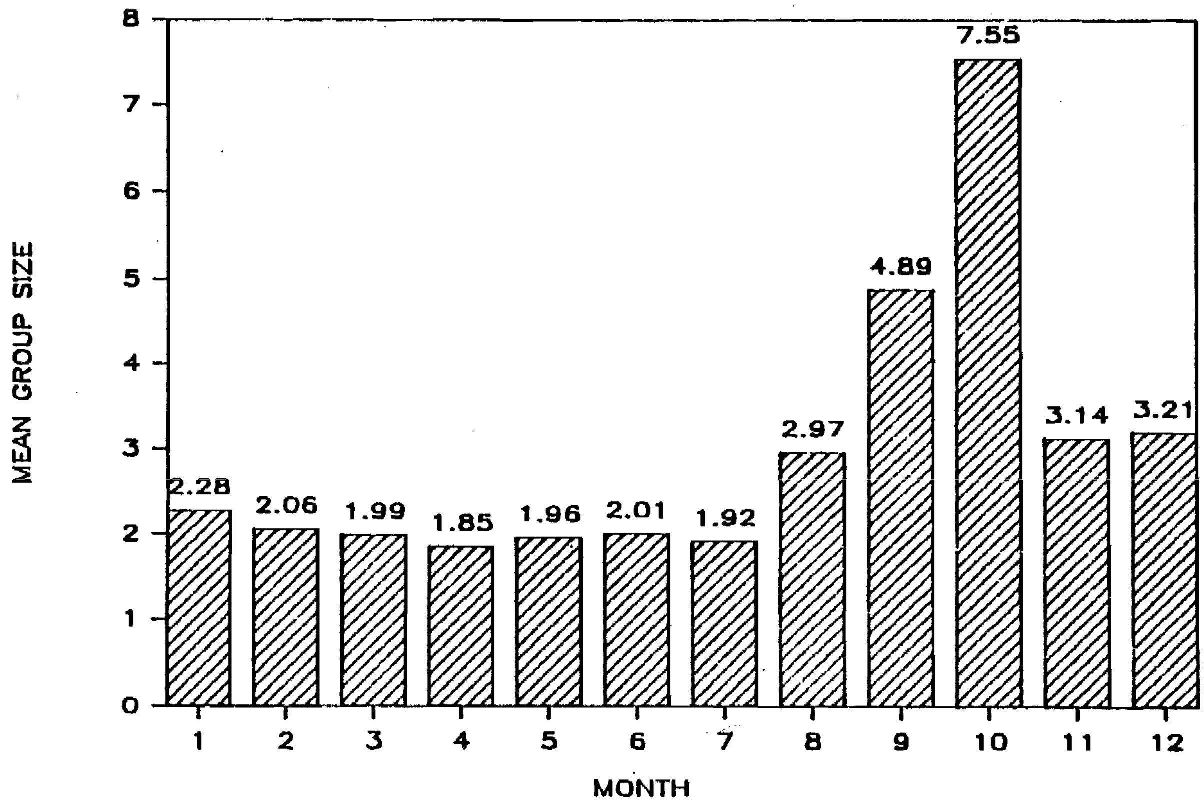

Fig. 15. Average group size of radio-collared moose by month of observation in GMU 13 of southcentral Alaska, 1977-1985.

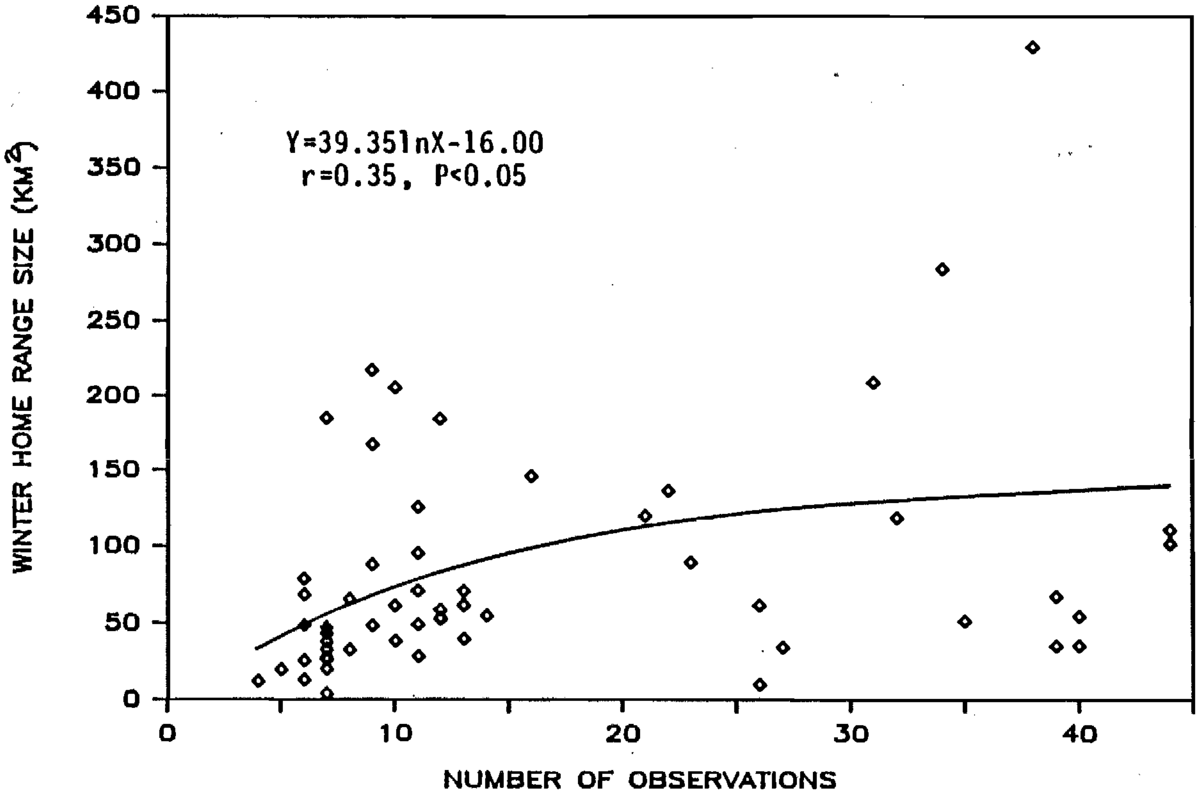

Fig. 16. Relationship between numbers of relocations and size of winter home ranges for resident adult female radio-collared moose in GMU 13, 1976-1985.

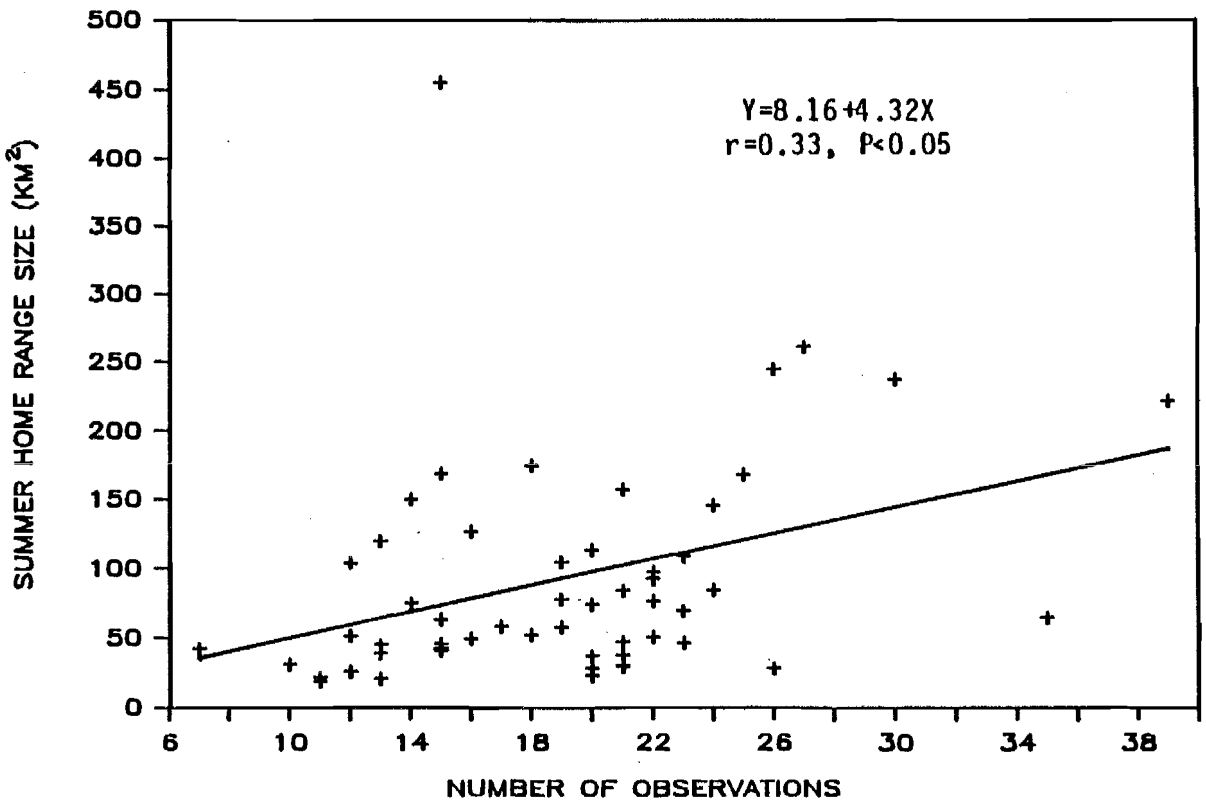

Fig. 17. Relationship between numbers of relocations and size of summer home ranges for resident adult female radio-collared moose in GMU 13, 1976-1985.

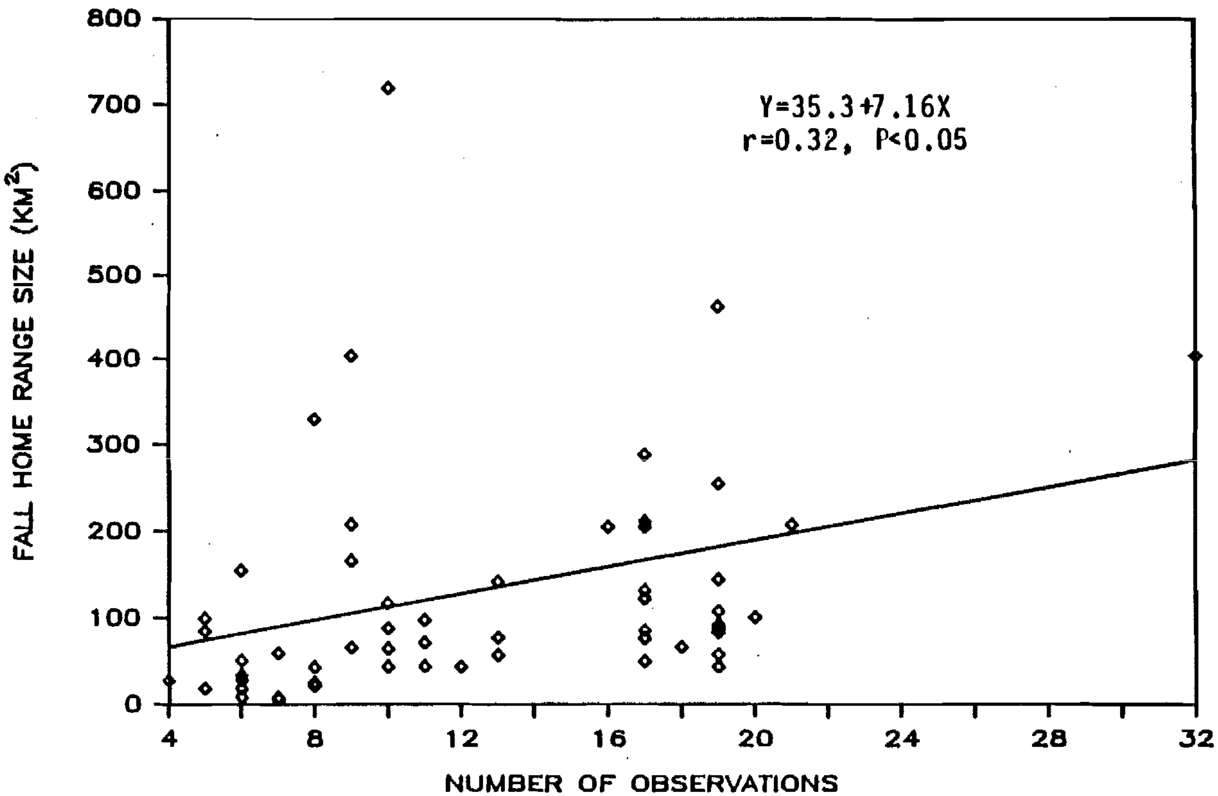

Fig. 18. Relationship between numbers of relocations and size of fall home ranges of resident adult female radio-collared moose in GMU 13, 1976-1985.

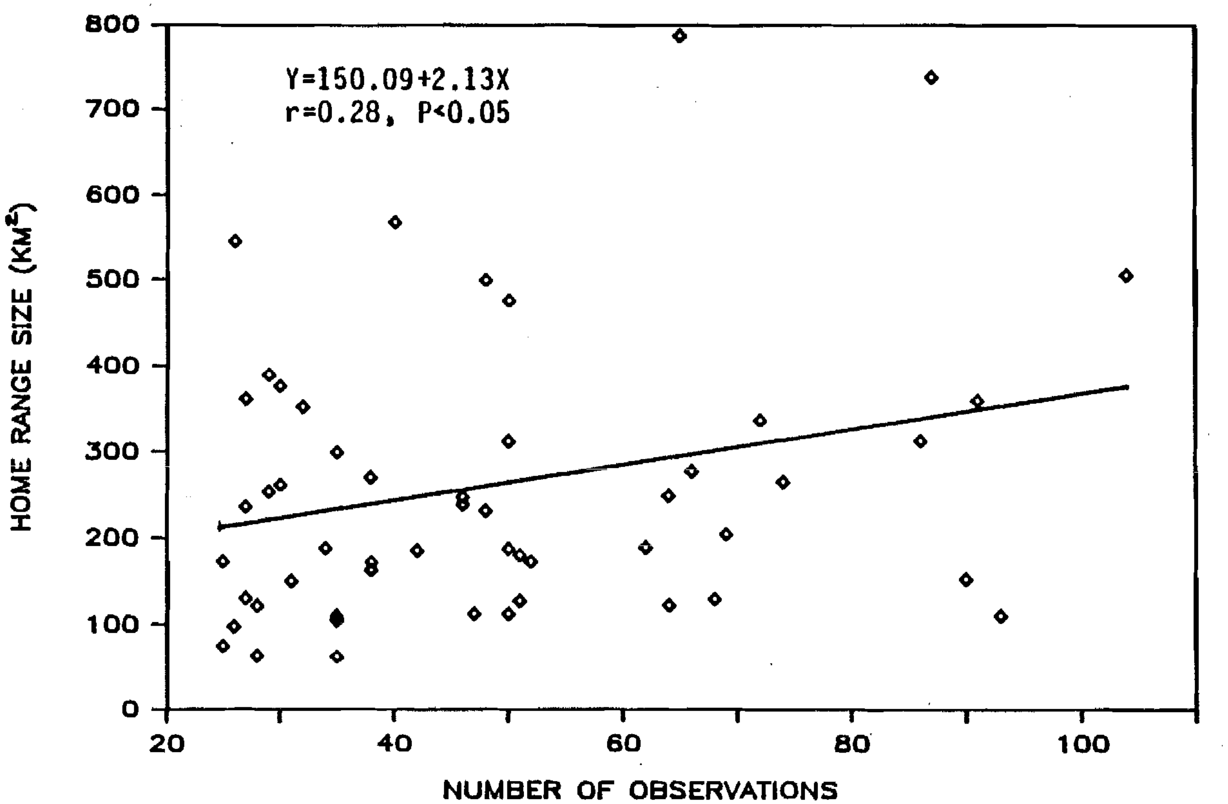

Fig. 19. Relationship between numbers of relocations and total home range sizes of resident adult female radio-collared moose in GMU 13, 1976-1985.

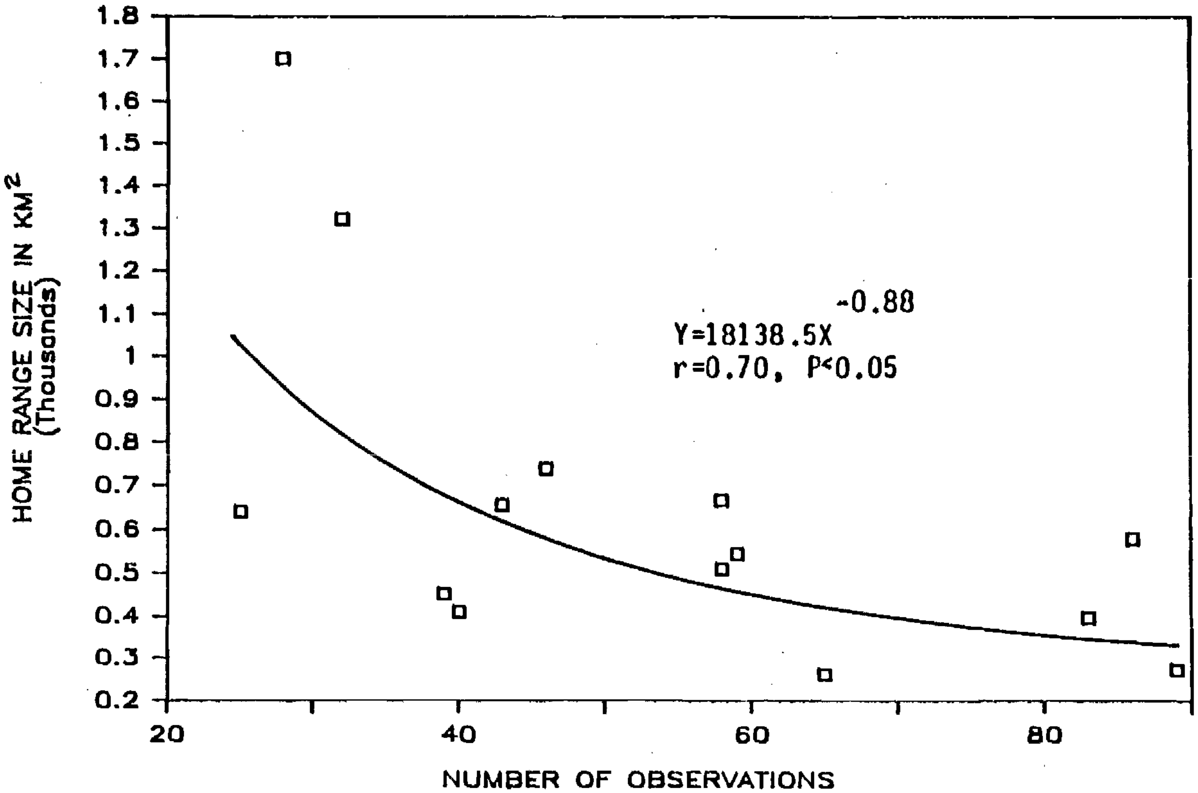

Fig. 20. Relationship between numbers of relocations and total home range sizes of migratory adult female radio-collared moose in GMU 13, 1975-1985.

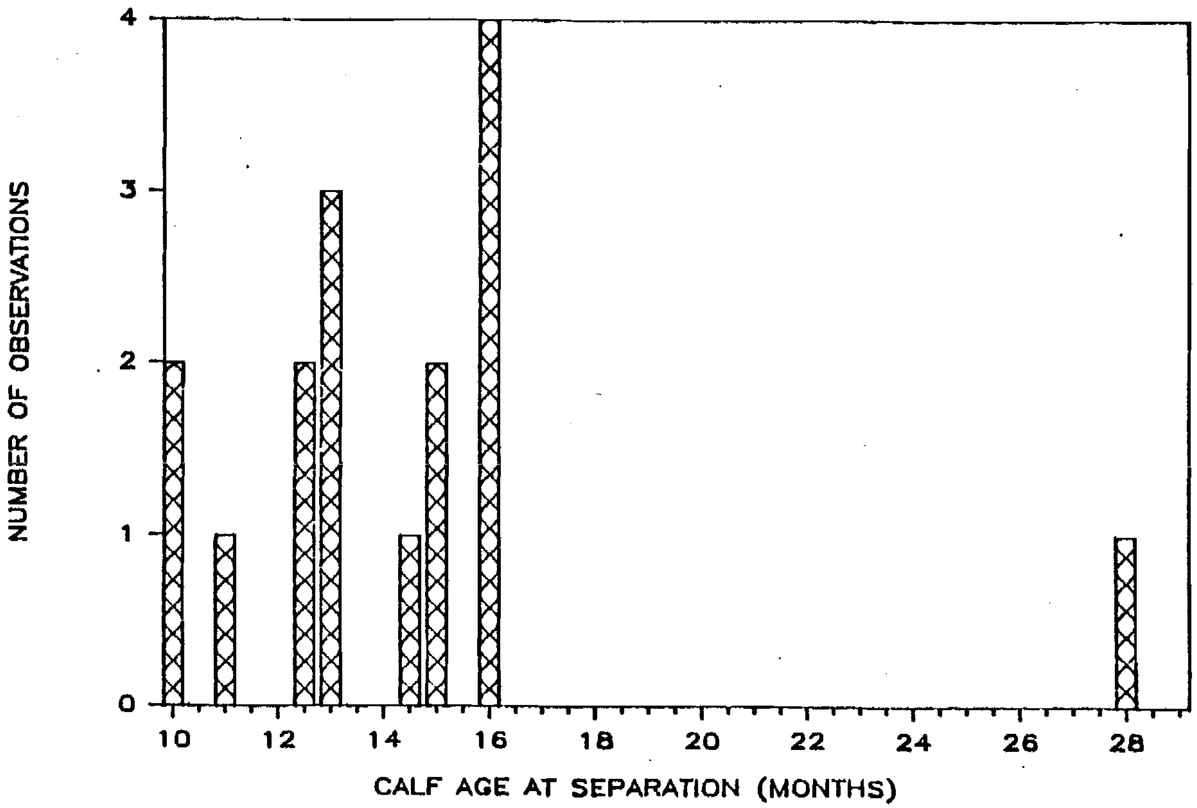

Fig. 21. Ages at which moose offspring separated from adults in GMU 13 of southcentral Alaska, 1981-1984.

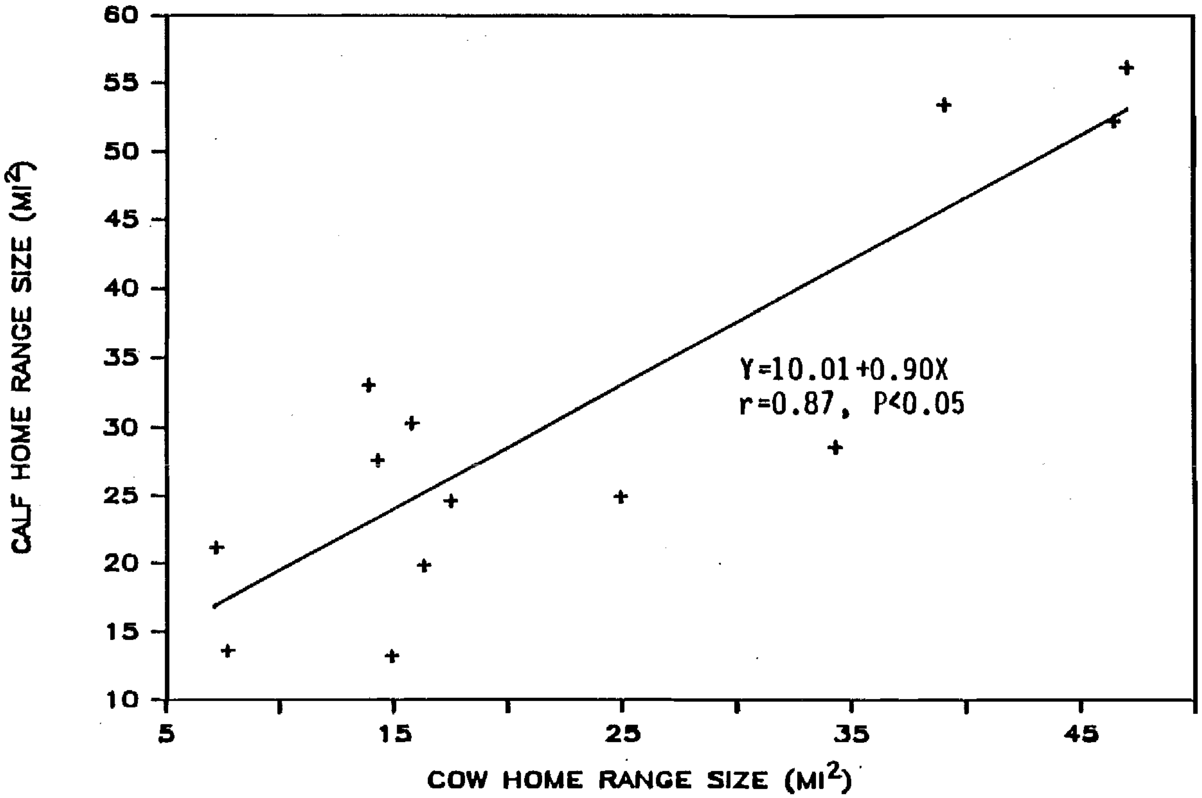

Fig. 22. Relationship between parents' and offsprings' total home range sizes following separation of offspring from adult moose in GMU 13, southcentral Alaska, 1977-1985.

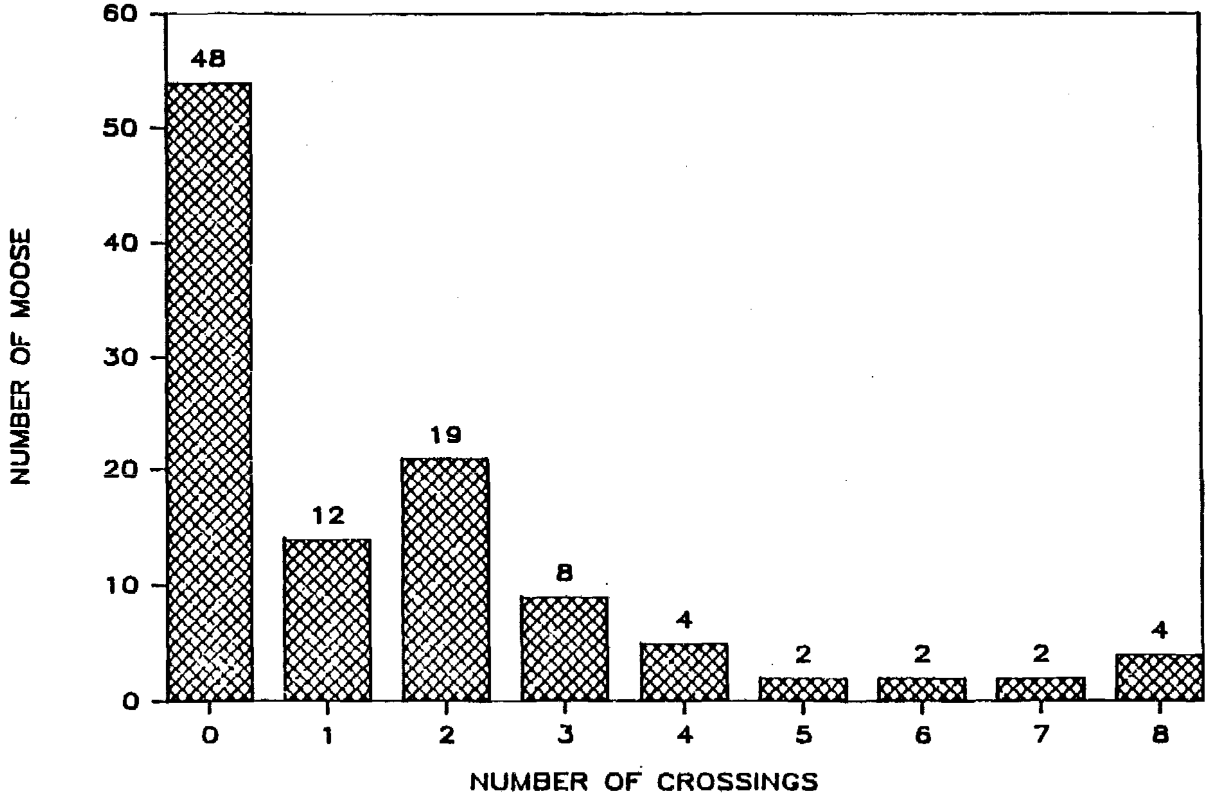

Fig. 23. Numbers of occasions radio-collared moose crossed the Susitna River in the vicinity of the proposed impoundments in GMU 13, southcentral Alaska, 1976-1984 (percentages listed above bars).

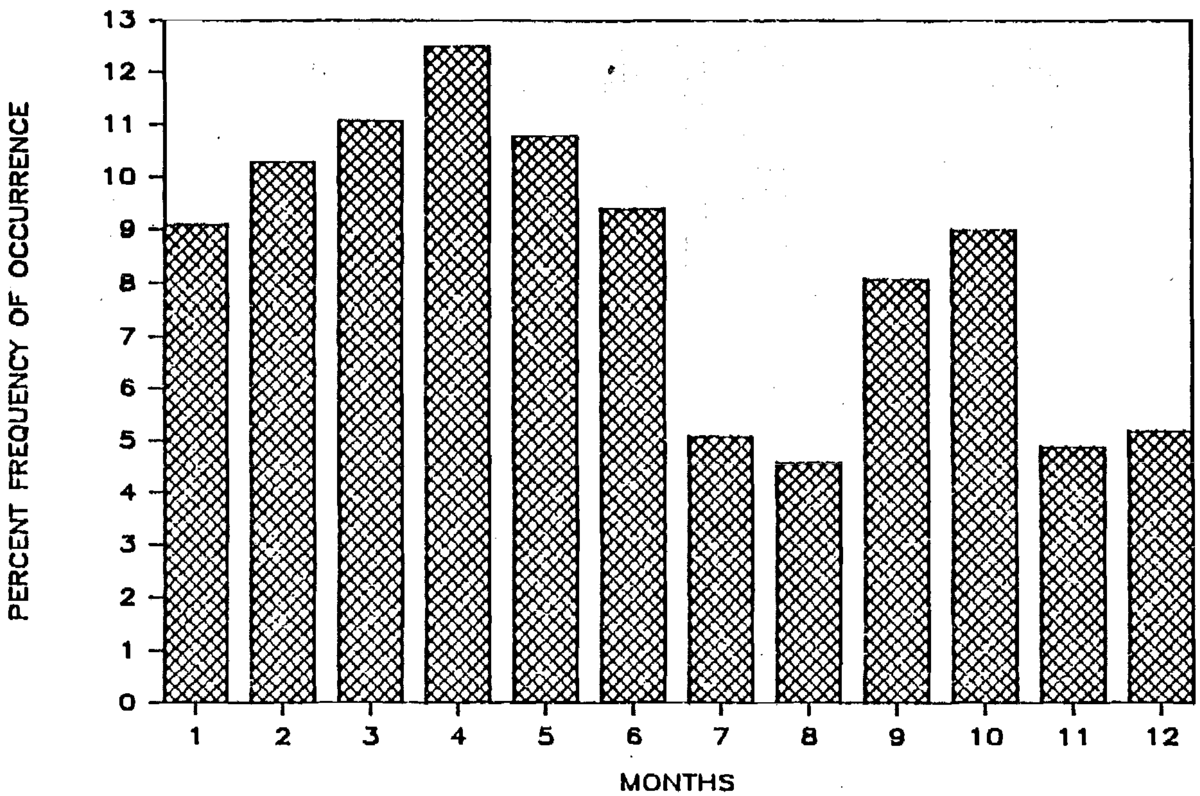

Fig. 24. Frequency of occurrence, by month, of river crossings by radio-collared moose in the vicinity of the 2 proposed impoundments along the Susitna River in southcentral Alaska, 1976-1984.

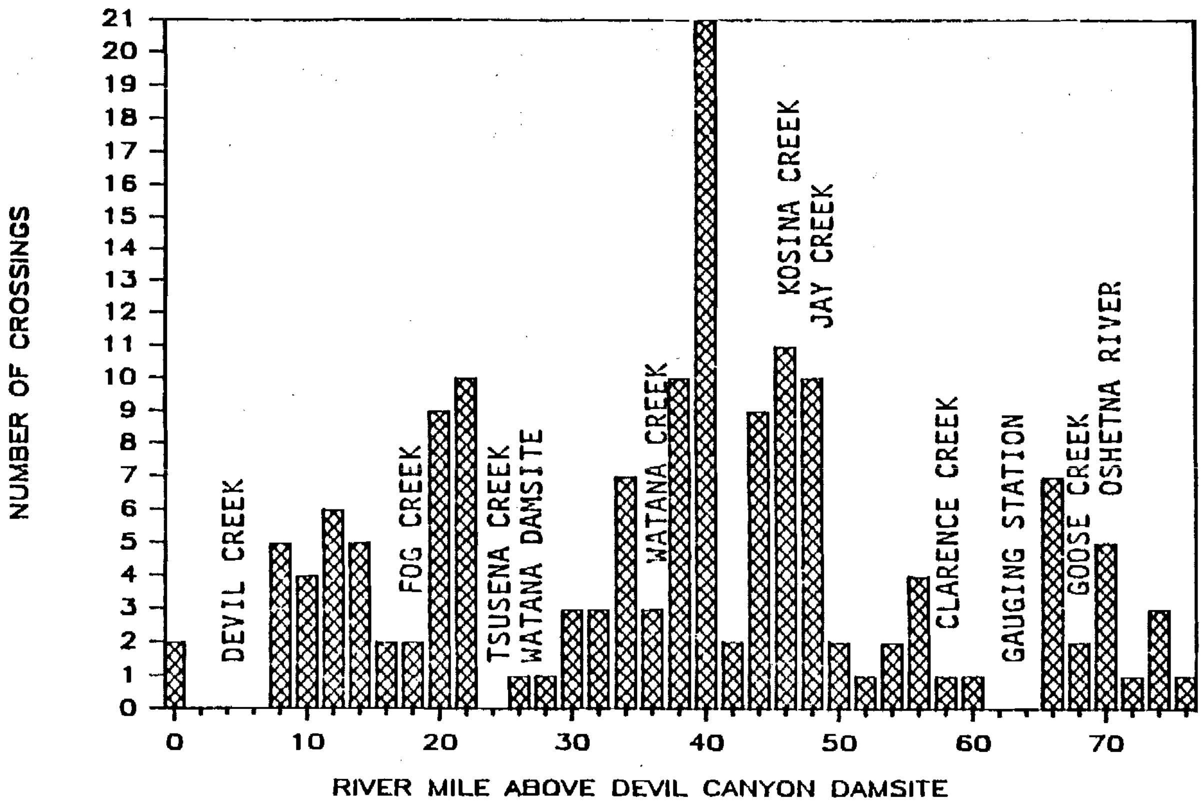

Fig. 25. Number of river crossings at specific locations for radio-collared moose in the vicinity of the 2 proposed impoundments along the Susitna River in southcentral Alaska, 1976-1985.

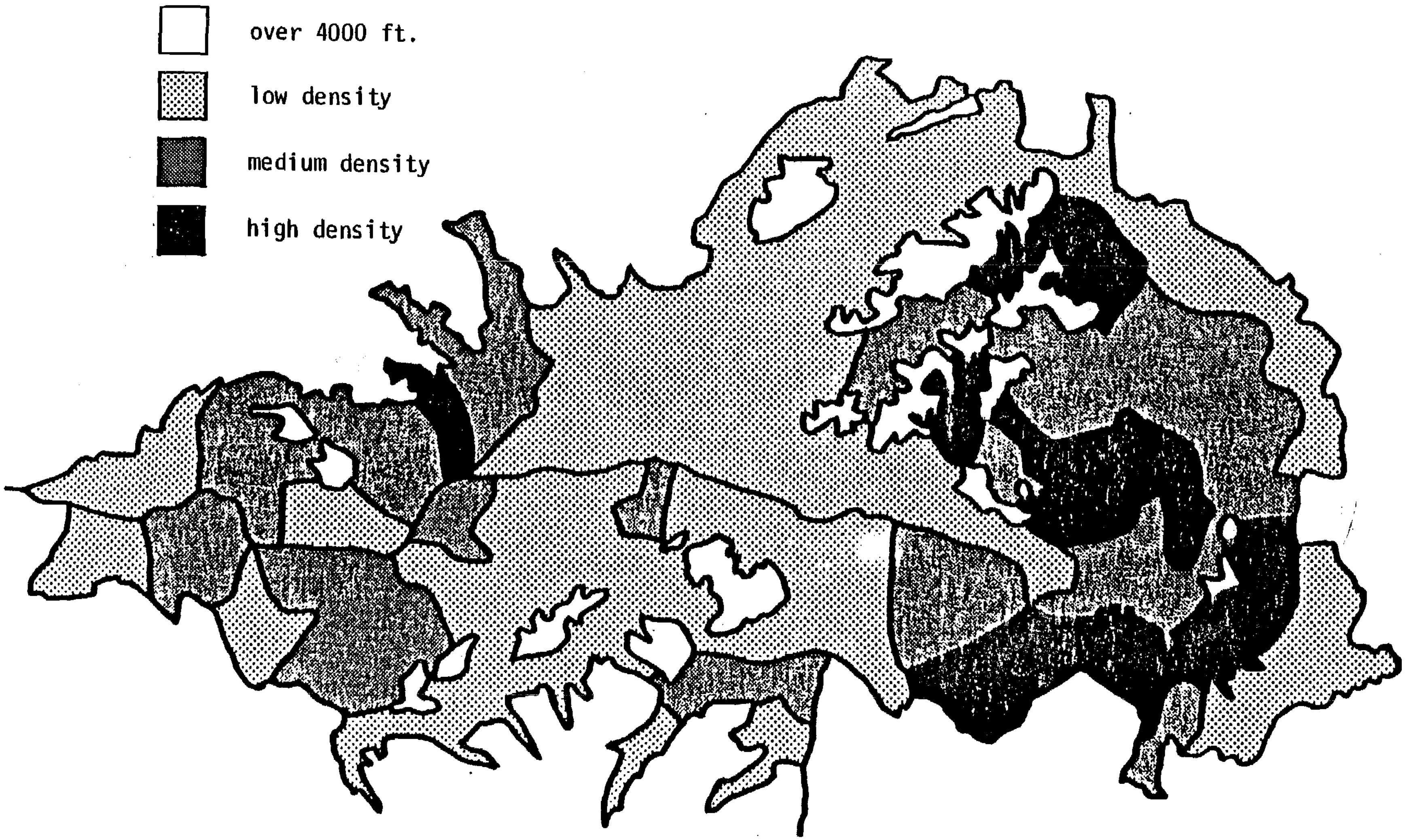

Fig. 26. Relative densities of moose within the primary moose impact zone along the Susitna River of GMU 13, as determined from stratification and census flights, November 1980.

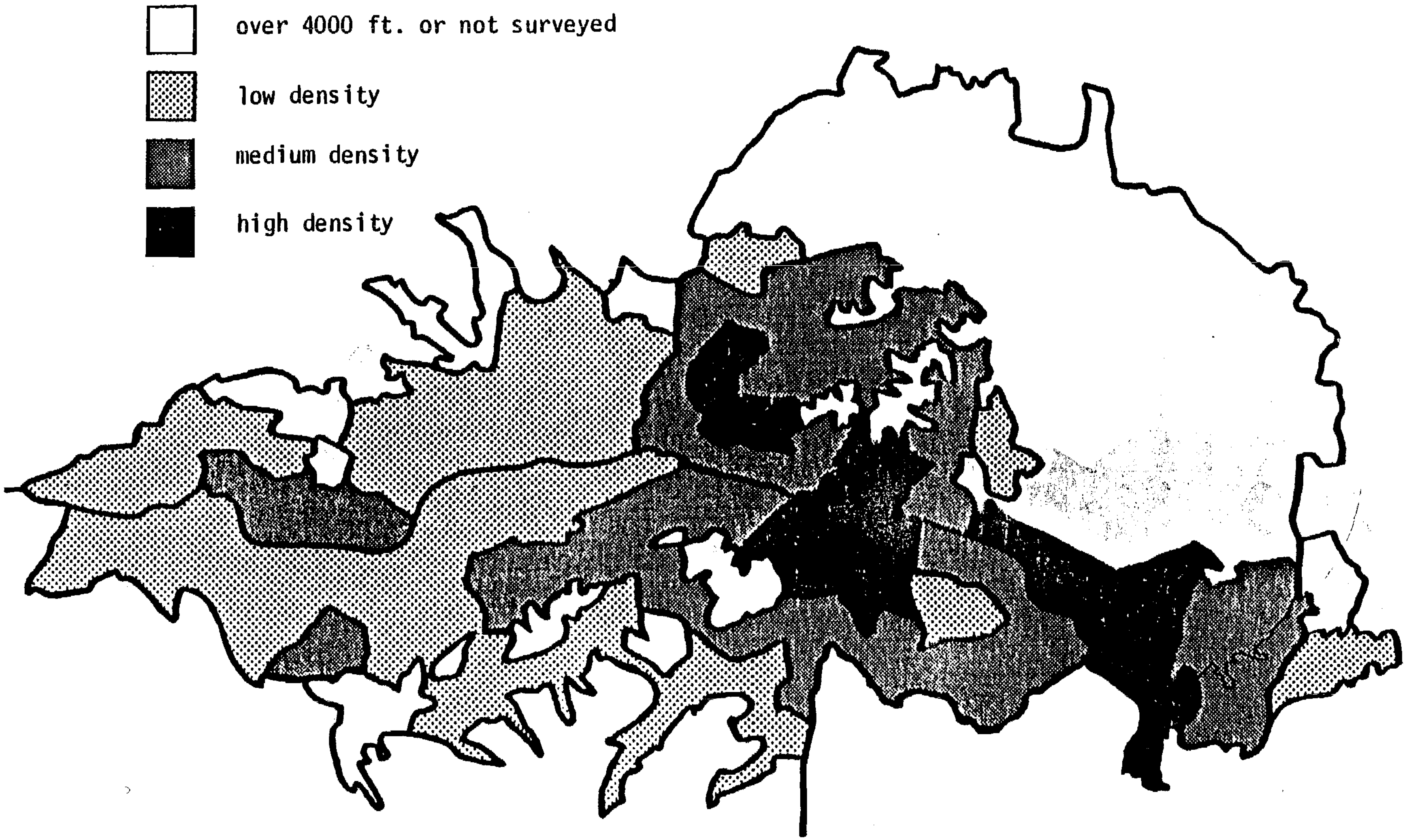

Fig. 27. Relative densities of moose within the primary moose impact zone along the Susitna River in GMU 13, as determined from stratification and census flights, November 1980.

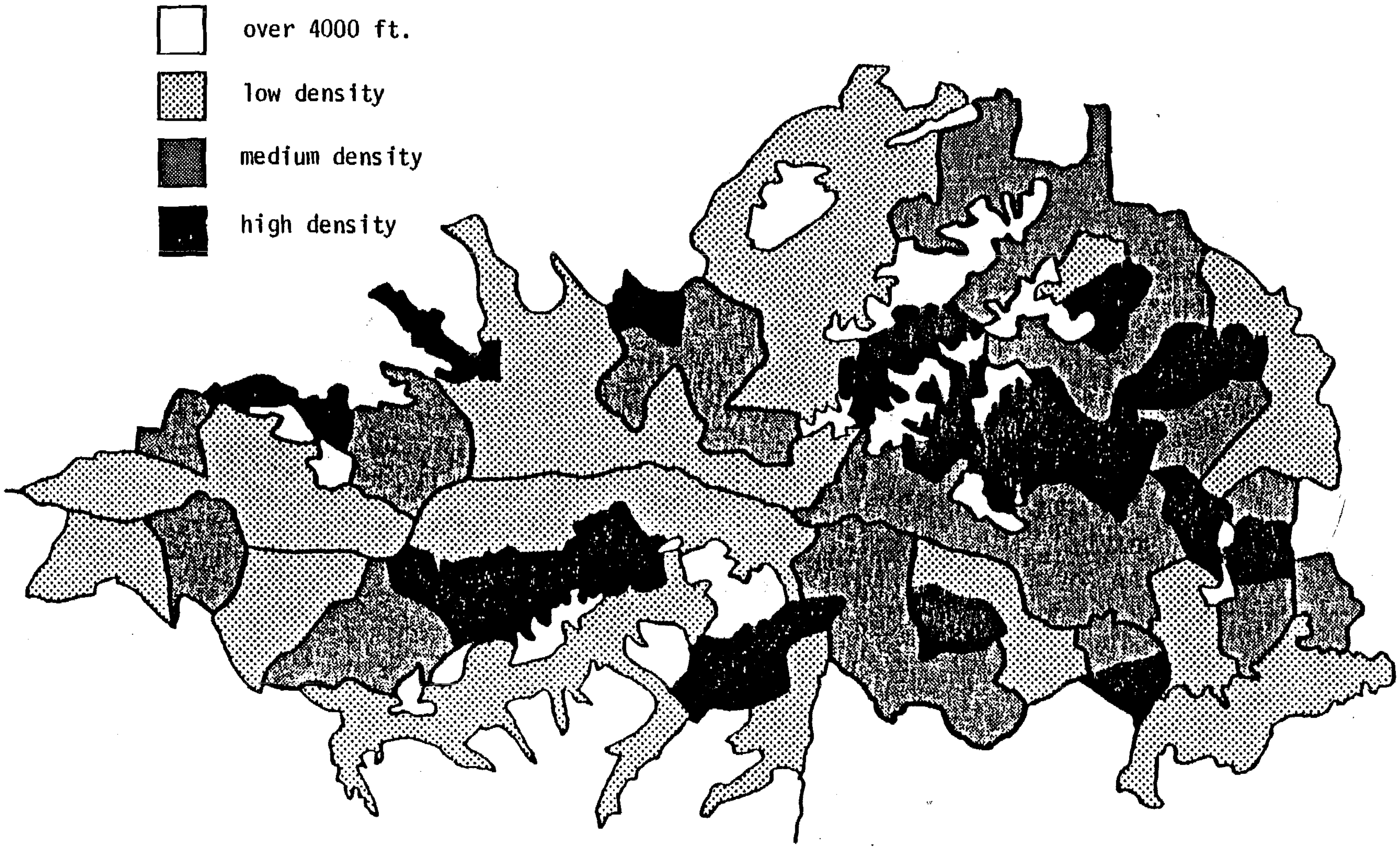

Fig. 28. Relative densities of moose within the primary moose impact zone along the Susitna River in GMU 13, as determined from stratification and census flights, November 1983.

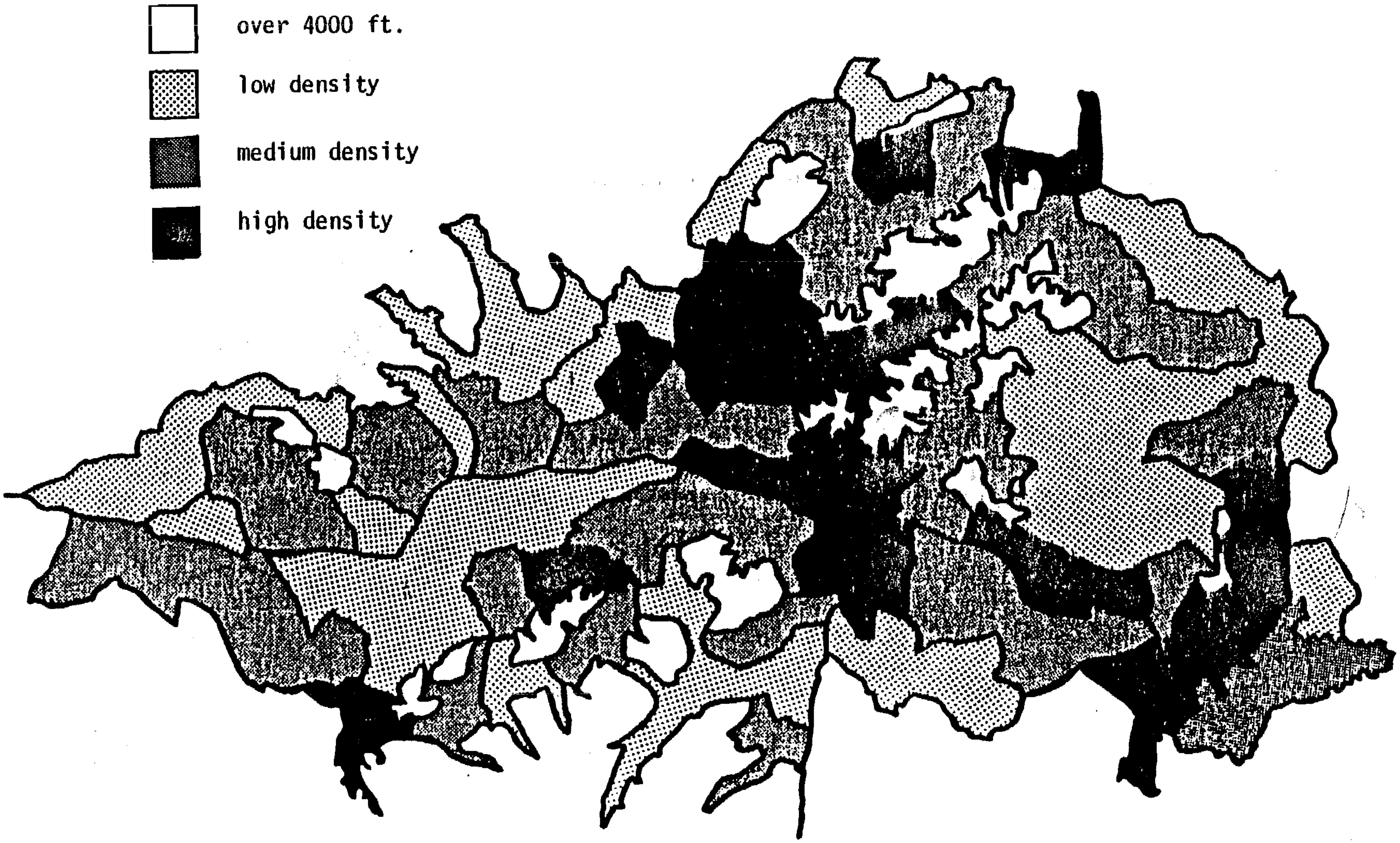

Fig. 29. Relative densities of moose within the primary moose impact zone along the Susitna River in GMU 13, as determined from stratification flights, March 1985.

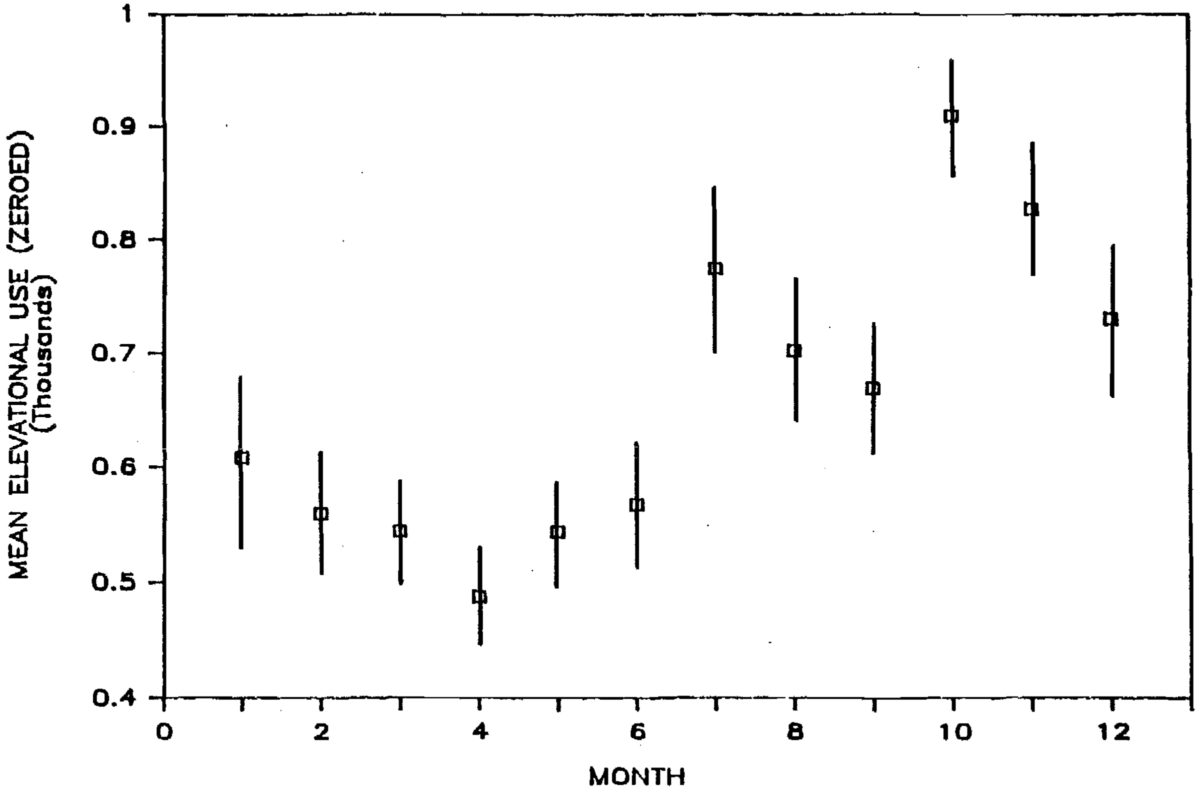

Fig. 30. Average monthly relative elevation occupied by radio-collared moose in GMU 13 of southcentral Alaska, 1976-1984 (standard deviation denoted by solid line). Lowest elevation occupied by each radio-collared moose was considered zero elevation.

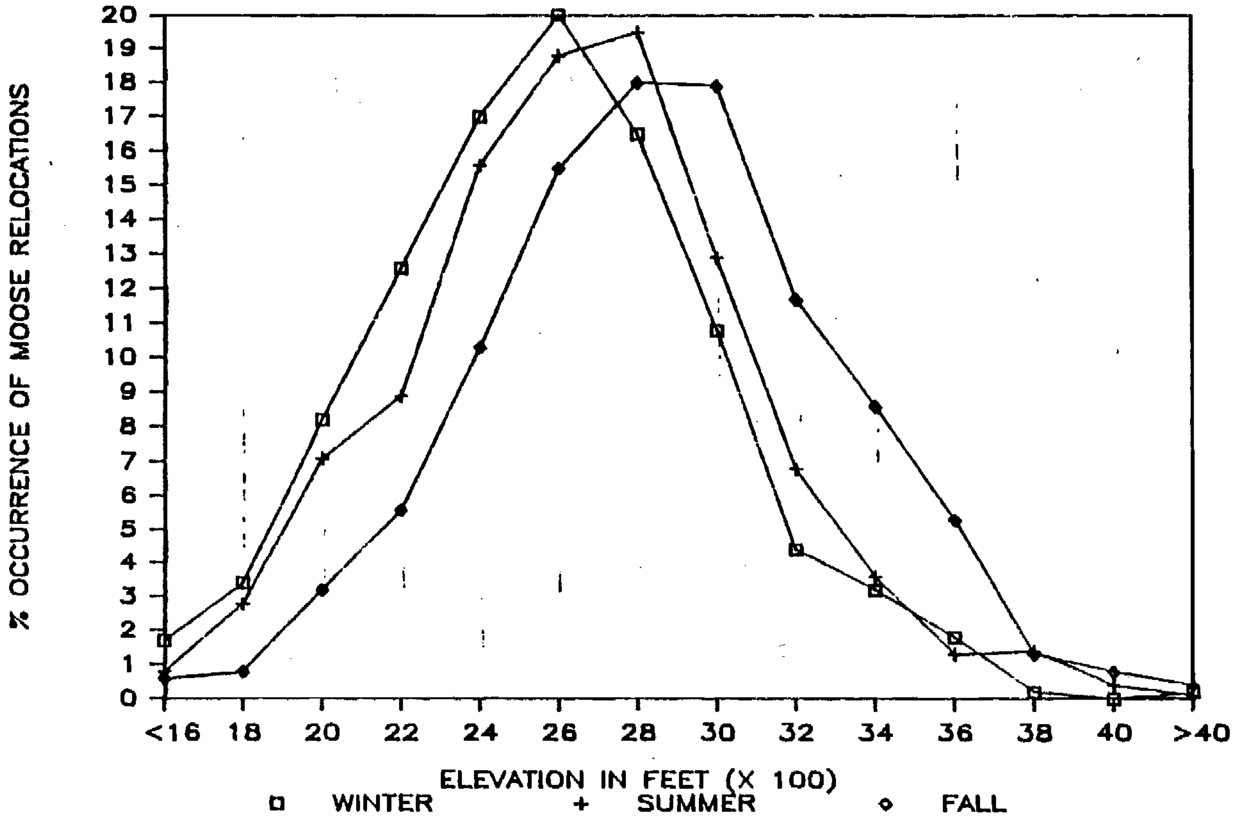

Fig. 31. Frequency occurrence of radio-collared moose relocations by elevation and season within GMU 13 of southcentral Alaska, 1976-1984.

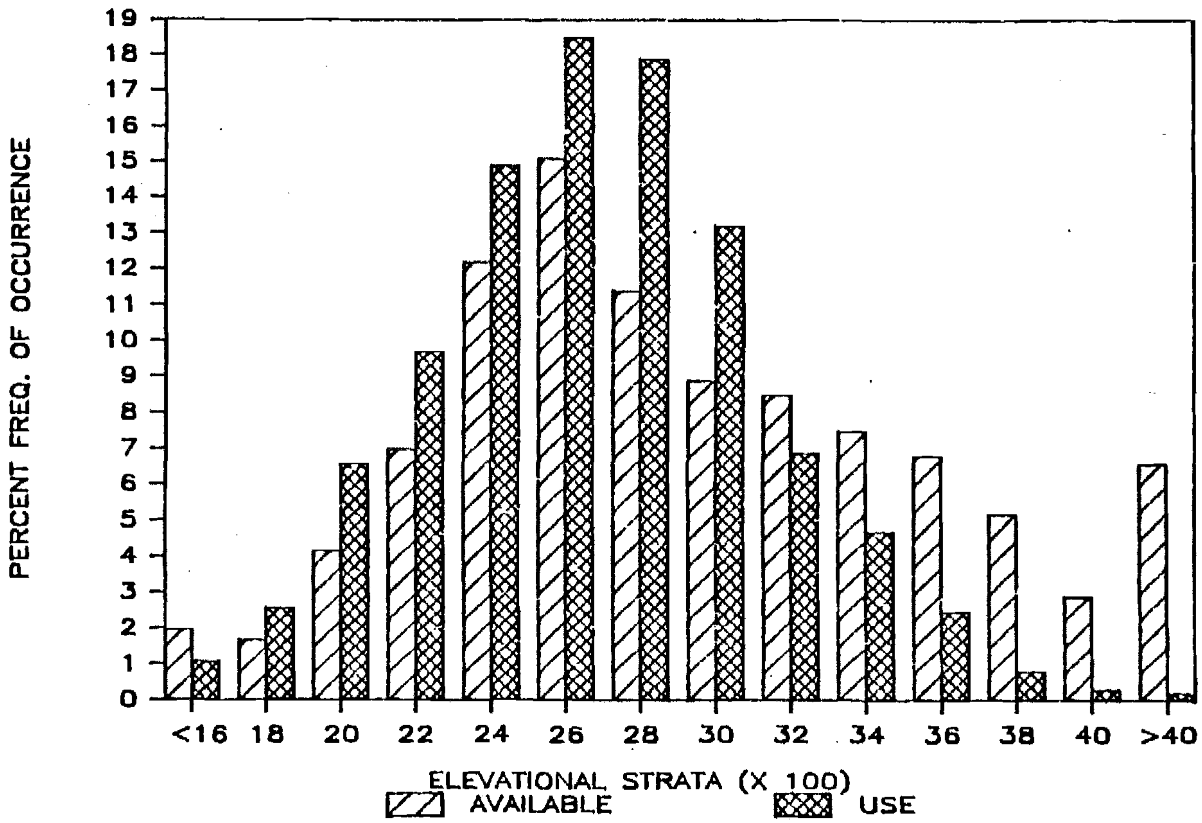

Fig. 32. Comparison of year-round use of various elevations by radio-collared moose in relation to availability of elevations within the moose study area along the Susitna River of southcentral Alaska, 1976-1984.

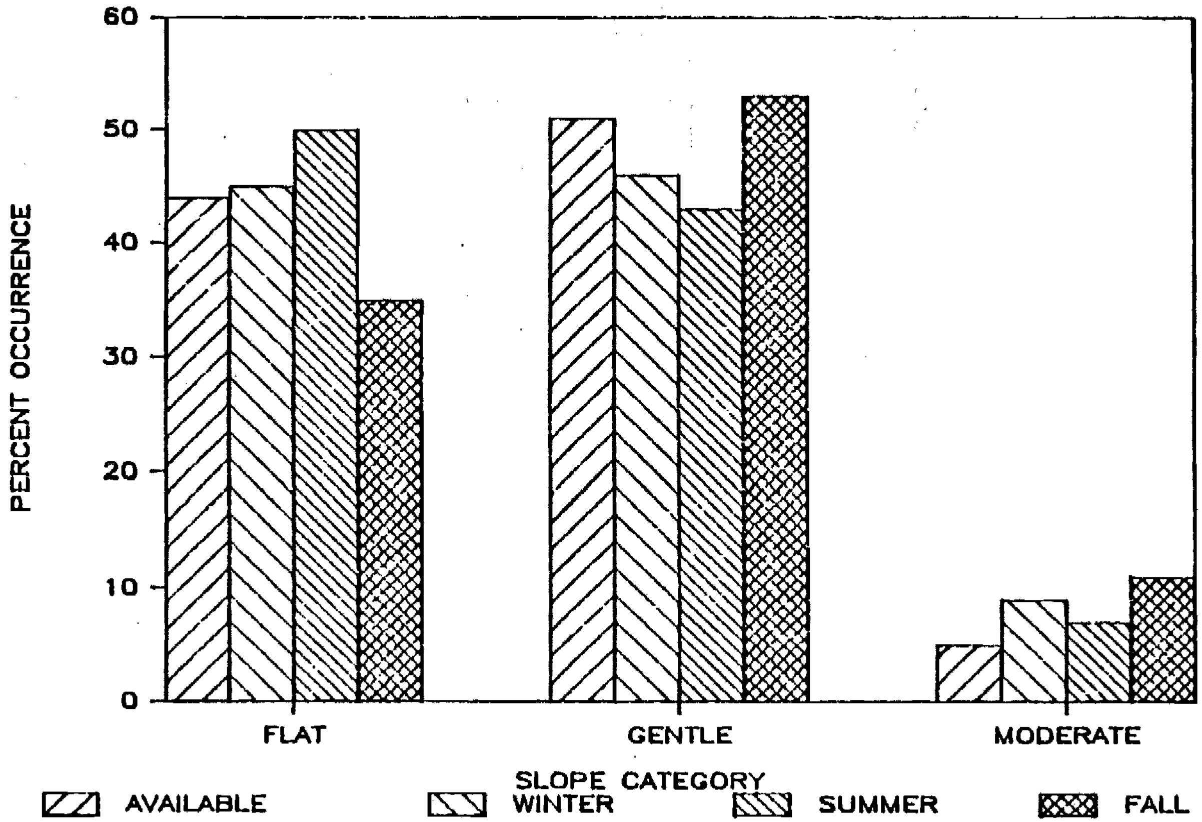

Fig. 33. Use of slopes by radio-collared moose in comparison to slope availability along the Susitna River of southcentral Alaska, 1976-1984.

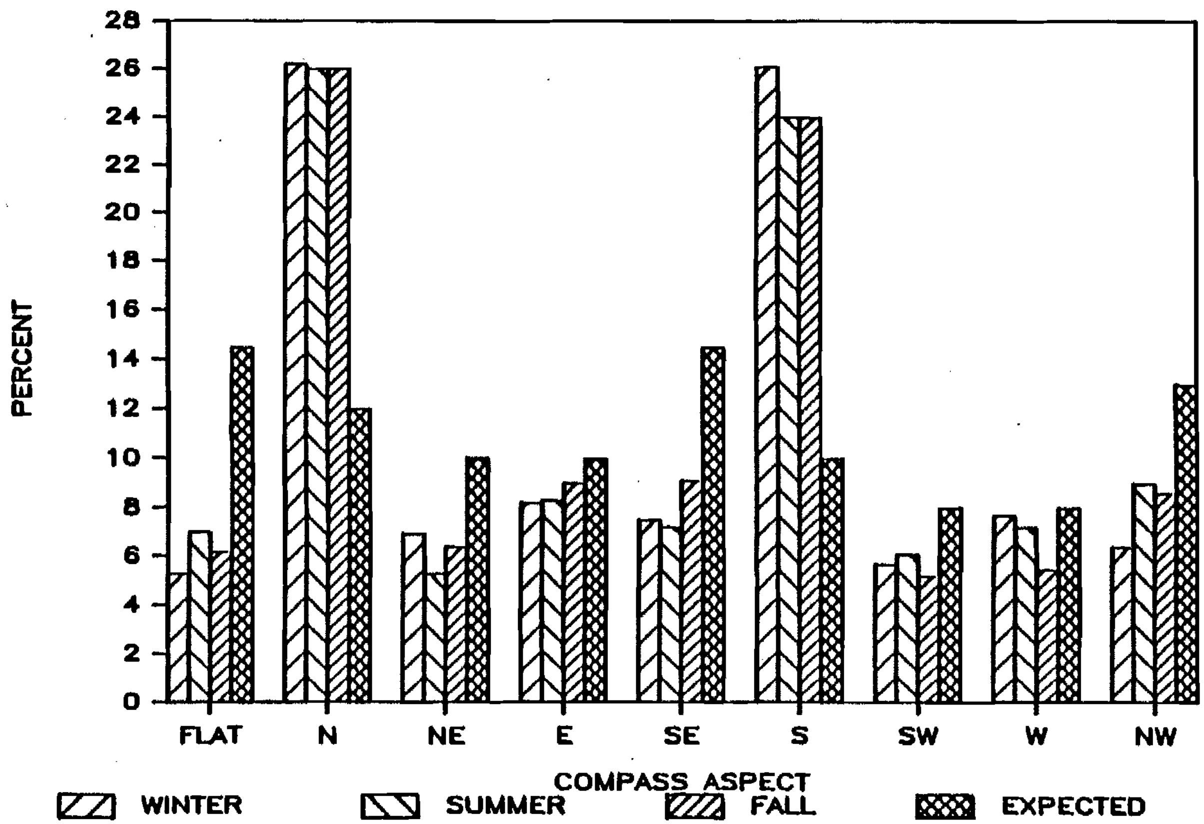

Fig. 34. Annual use of compass aspects by radio-collared moose in relation to aspect availability along the Susitna River in GMU 13, 1976-1984.

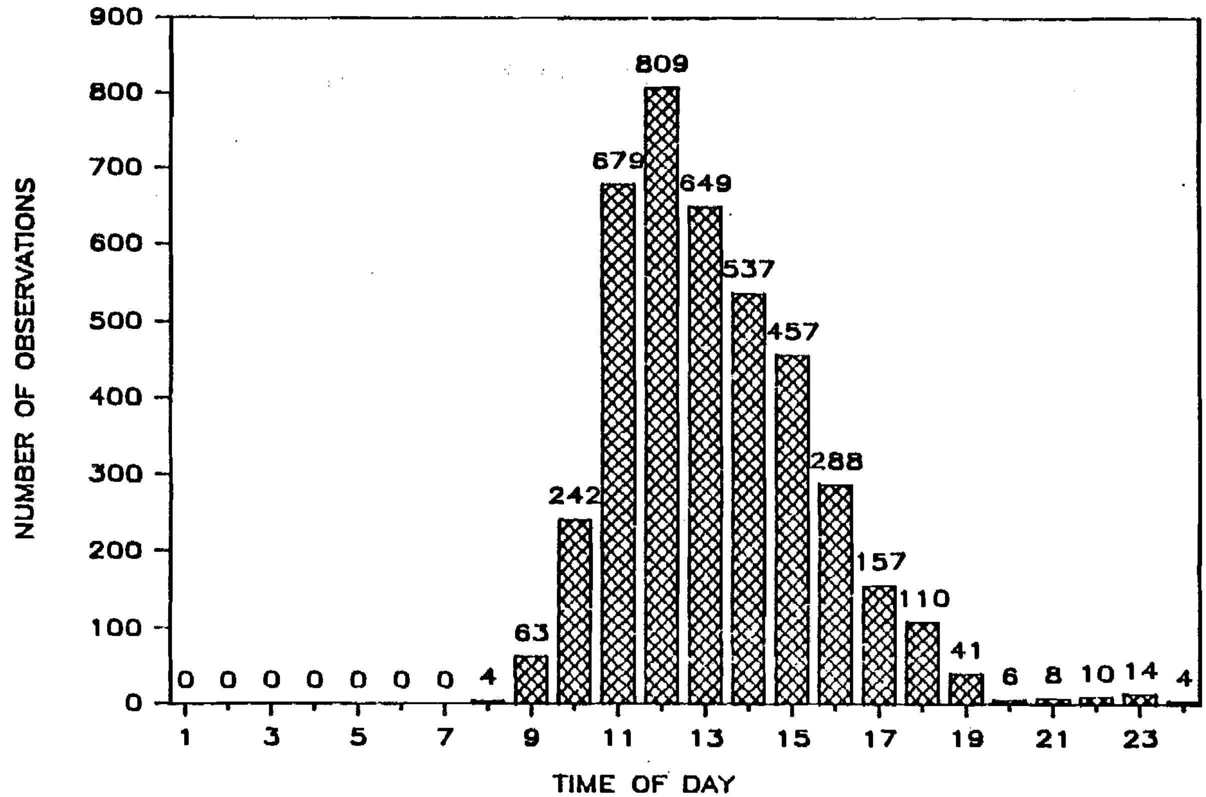

Fig. 35. Distribution of radio-collared moose relocations by time of day in GMU 13 of southcentral Alaska, 1976-1985.

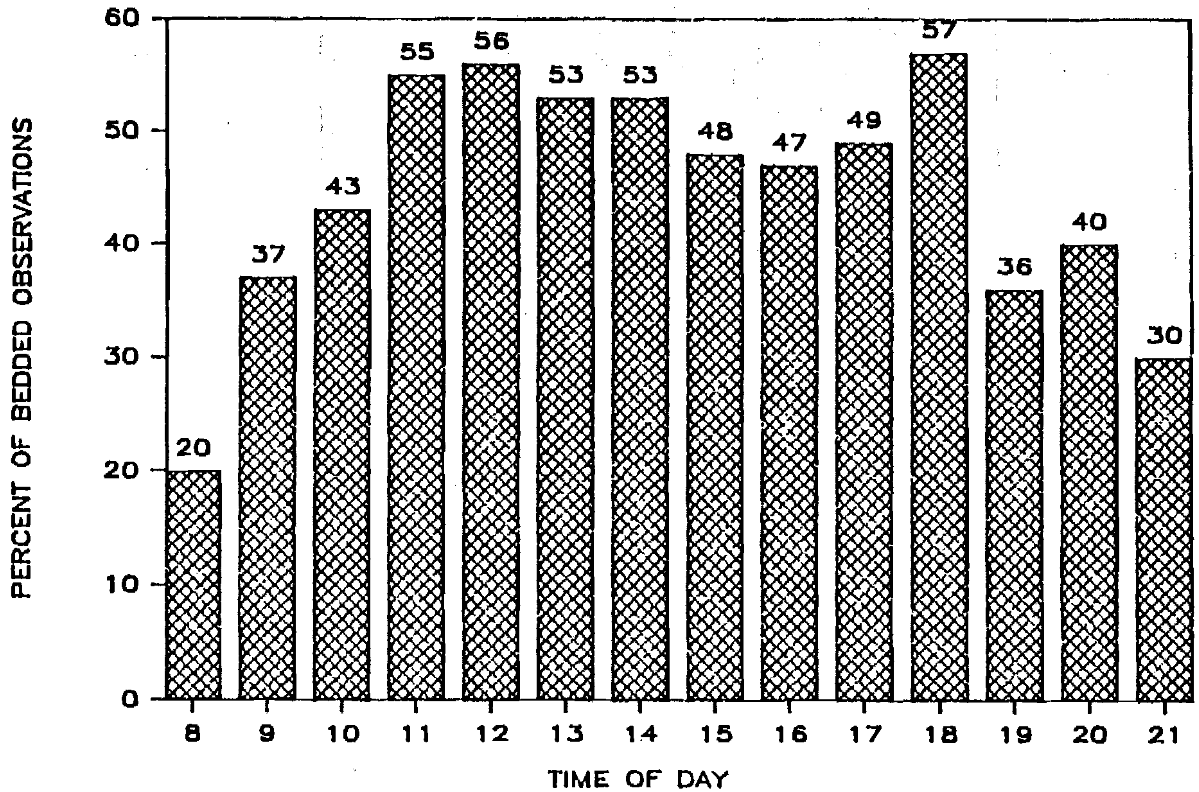

Fig. 36. Percent of observations, by time of day radio-collared moose were observed bedded, in GMU 13 of southcentral Alaska, 1976-1985.

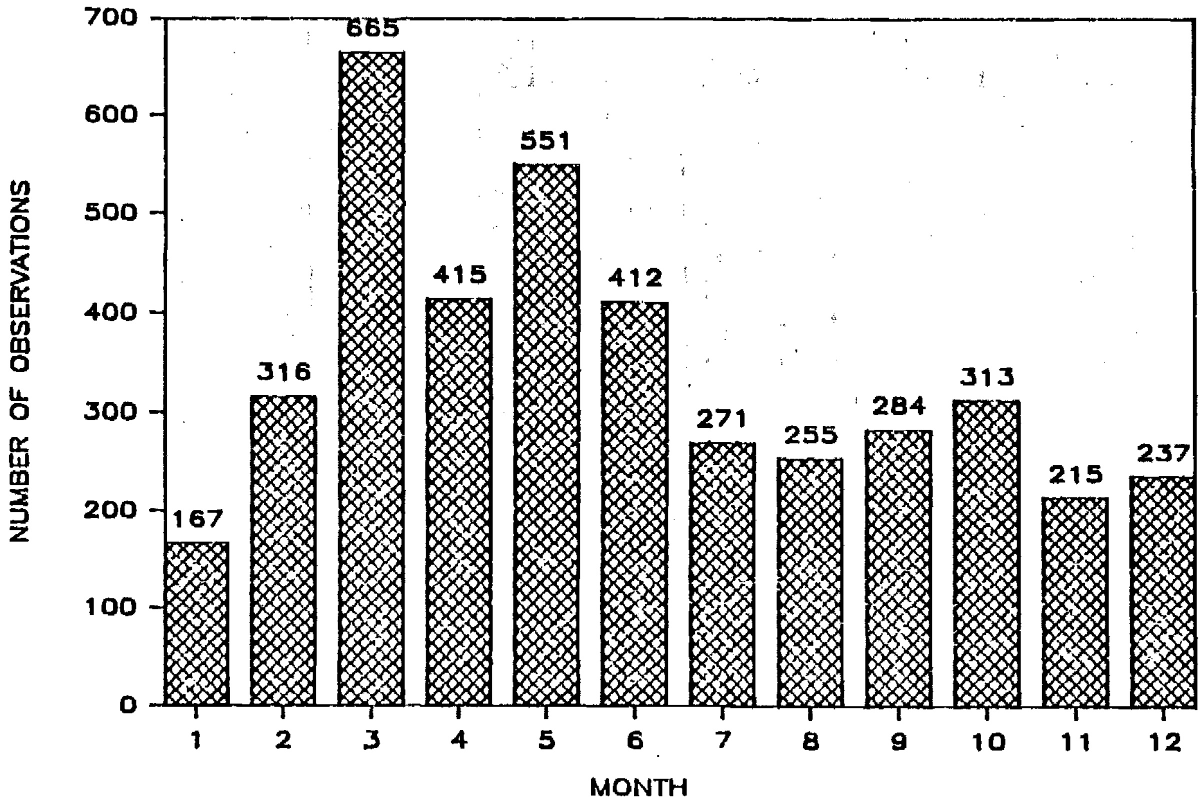

Fig. 37. Number of monthly observations of radio-collared moose in GMU 13 of southcentral Alaska, 1976-1985.

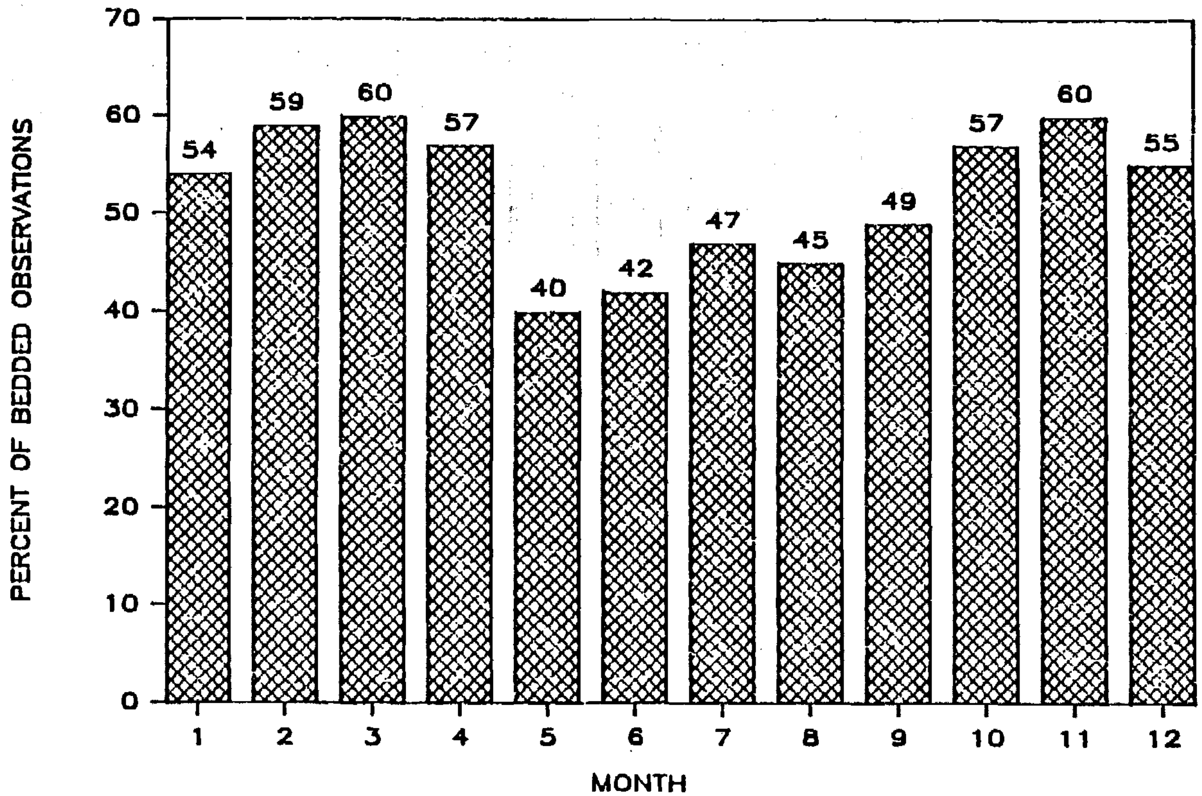

Fig. 38. Percent of total observations per month that radio-collared moose were observed bedded in GMU 13 of southcentral Alaska, 1976-1985.

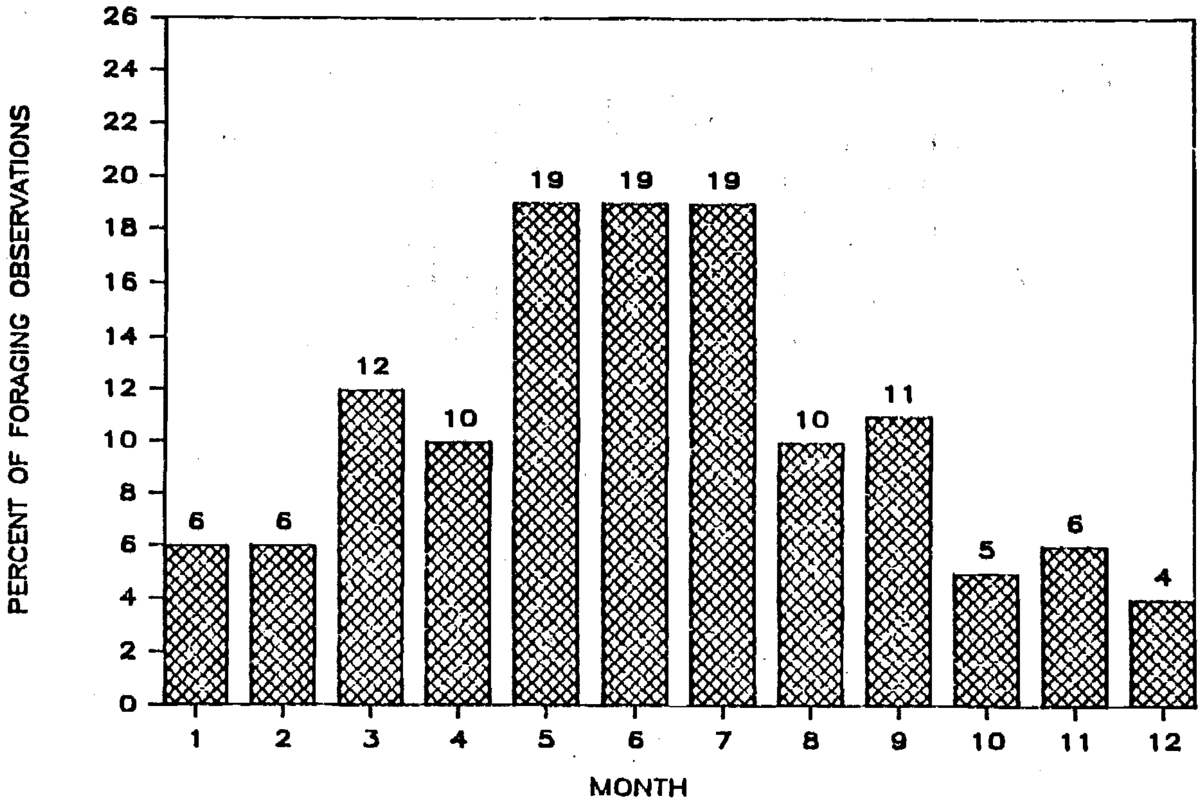

Fig. 39. Percent of total observations that radio-collared moose were observed feeding in GMU 13 of southcentral Alaska, 1976-1985.

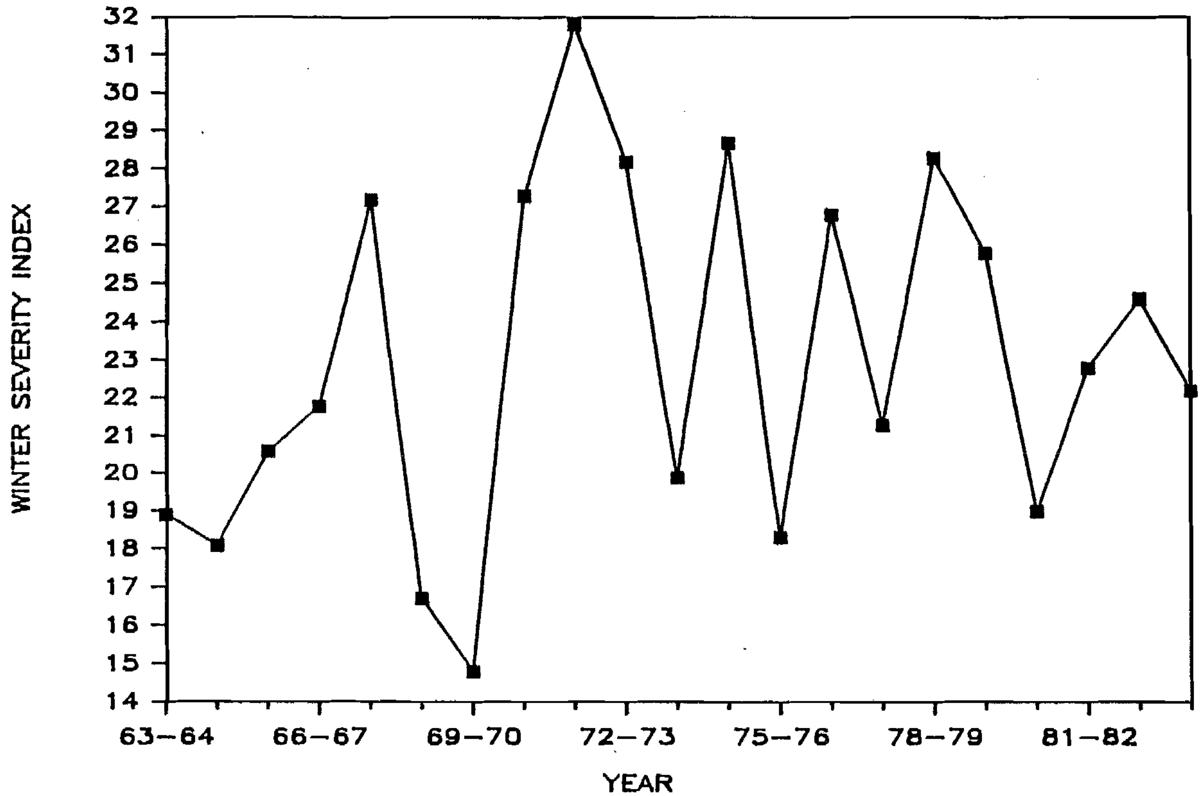

Fig. 40. Comparison of annual winter severity indices in the middle Susitna River Basin of southcentral Alaska, 1964-1985. Larger indices correspond to winters of increasing severity.

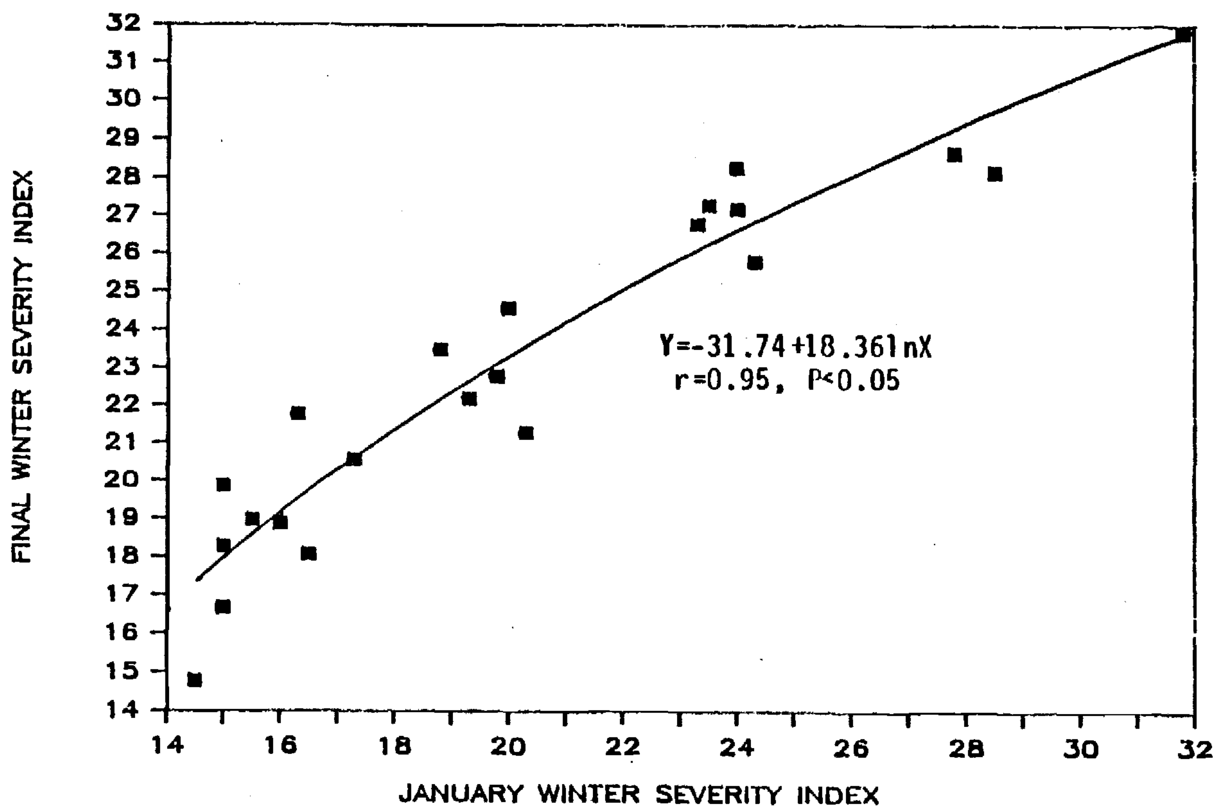

Fig. 41. Relationsip between annual and January winter severity indices each year within the middle Susitna River Basin of southcentral Alaska, 1974-1985.

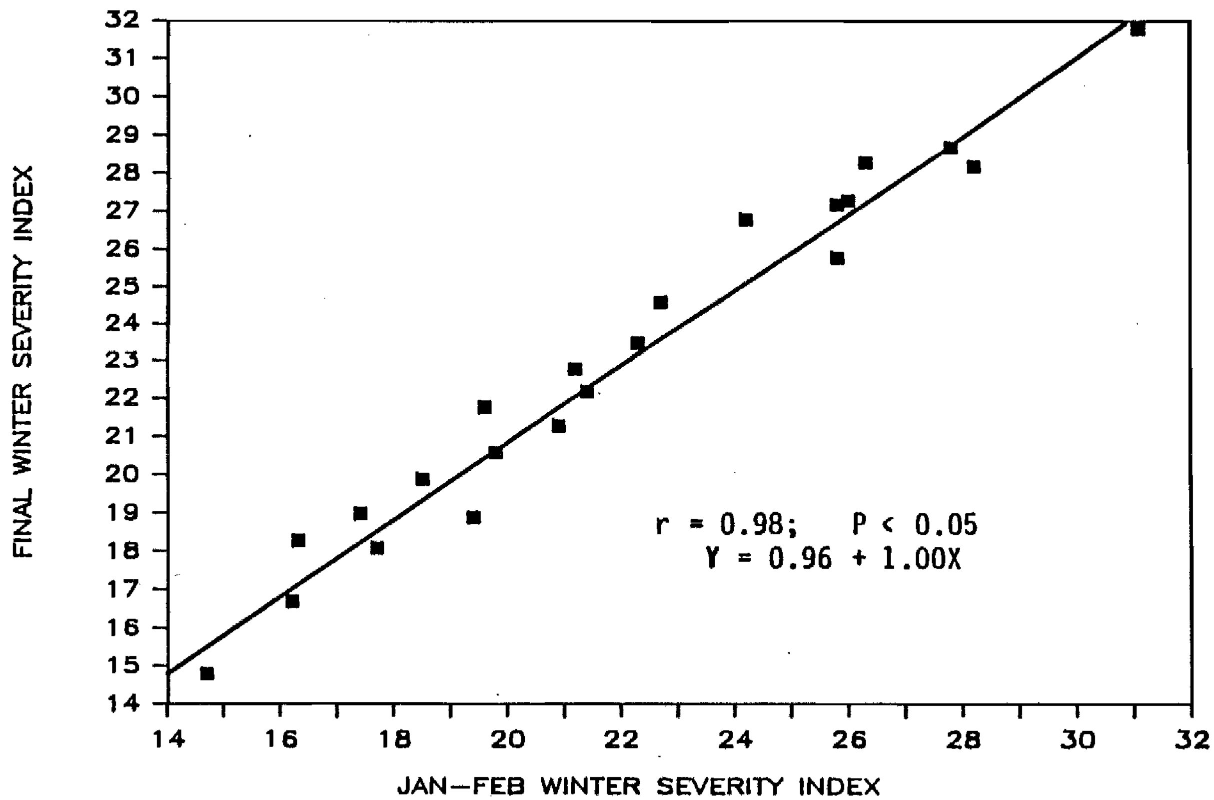

Fig. 42. Relationship between annual and January-February winter severity indices each year within the middle Susitna River Basin of southcentral Alaska, 1964-1985.

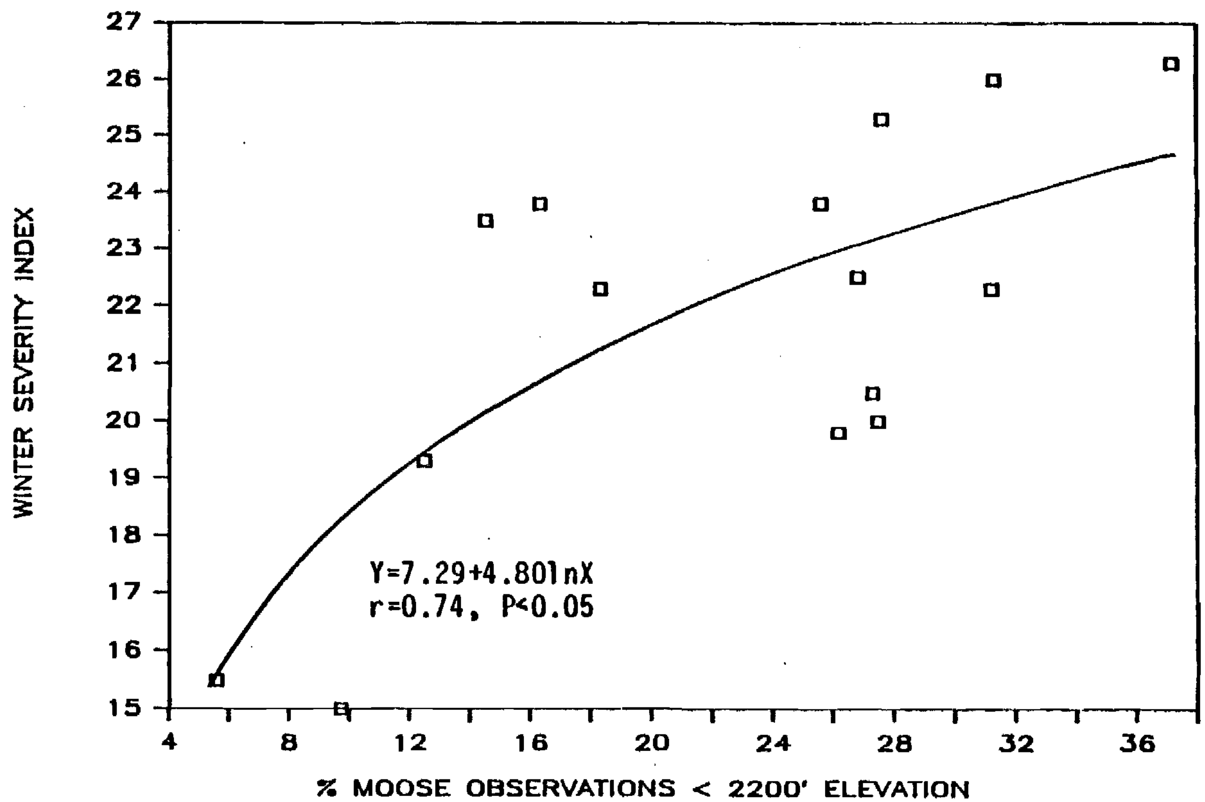

Fig. 43. Relationship between monthly winter severity indices and percent of moose relocations per month at elevations less than 2,200 ft during 1981-84.

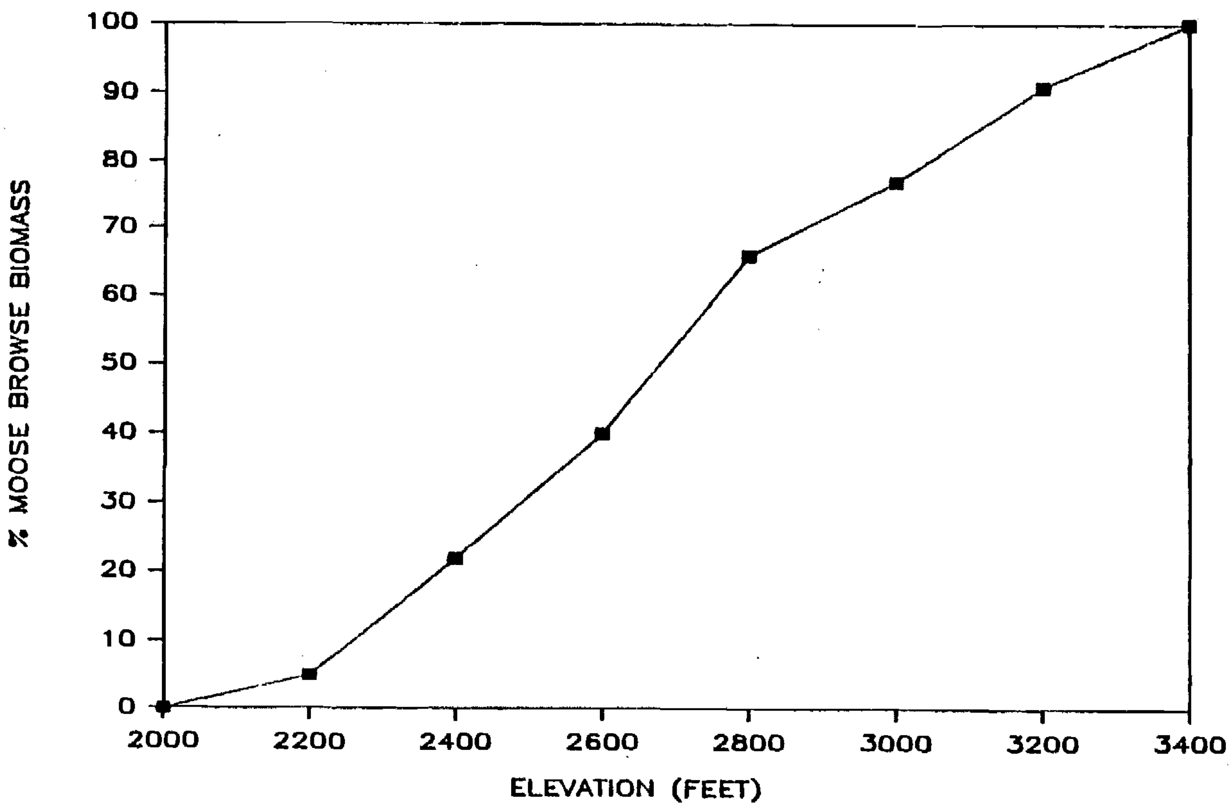

Fig. 44. Cumulative percent of moose browse biomass by elevation along the middle Susitna River Basin of GMU 13 in 1984 and 1985.

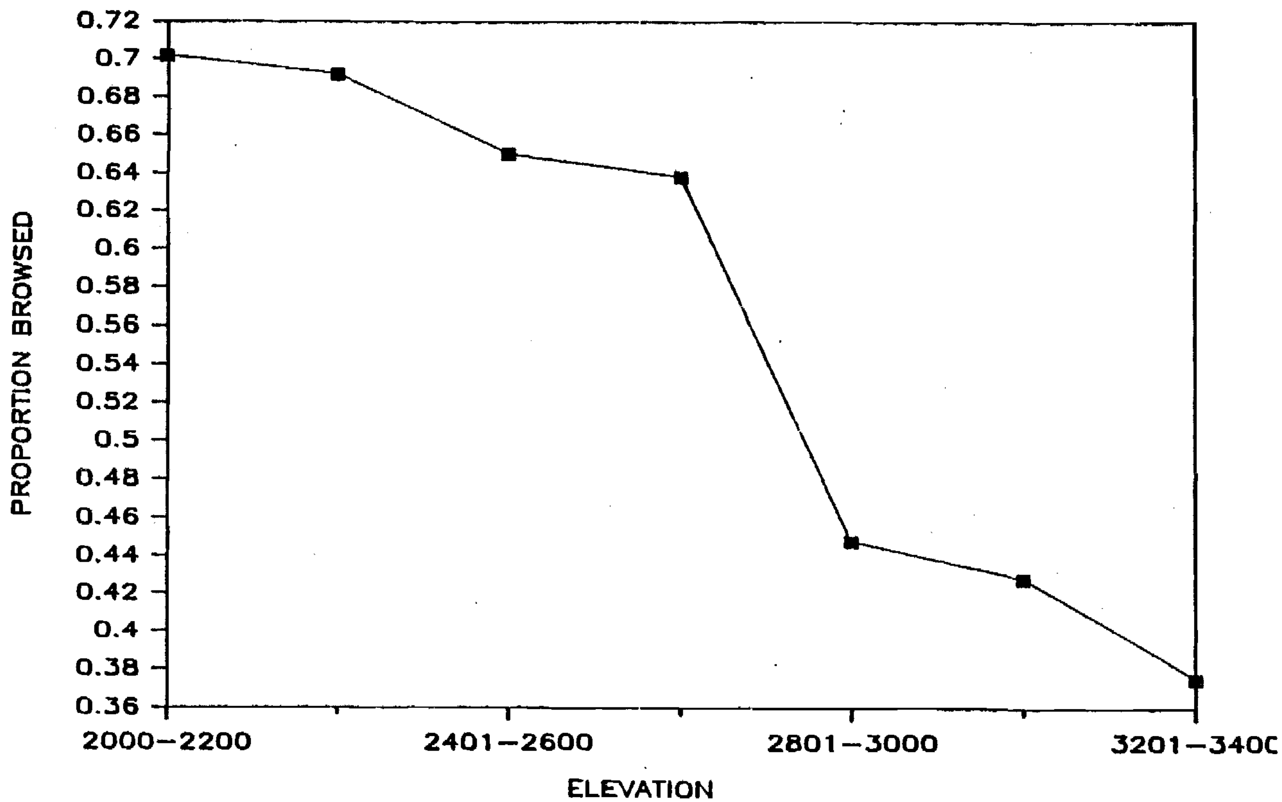

Fig. 45. Proportion of browse used by moose at different elevations along the middle Susitna River in GMU 13 in 1985.

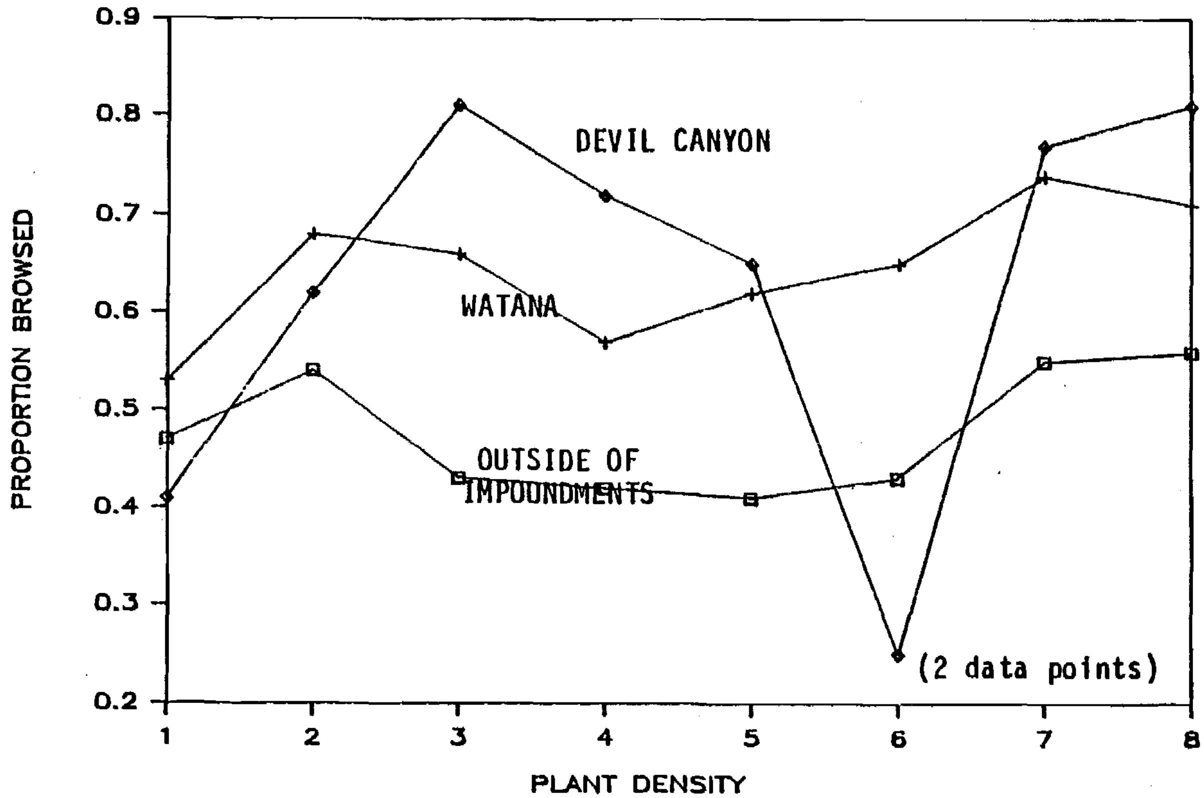

Fig. 46. Comparison of browse used with plant density by area for the middle Susitna River Basin of GMU 13 in 1985.

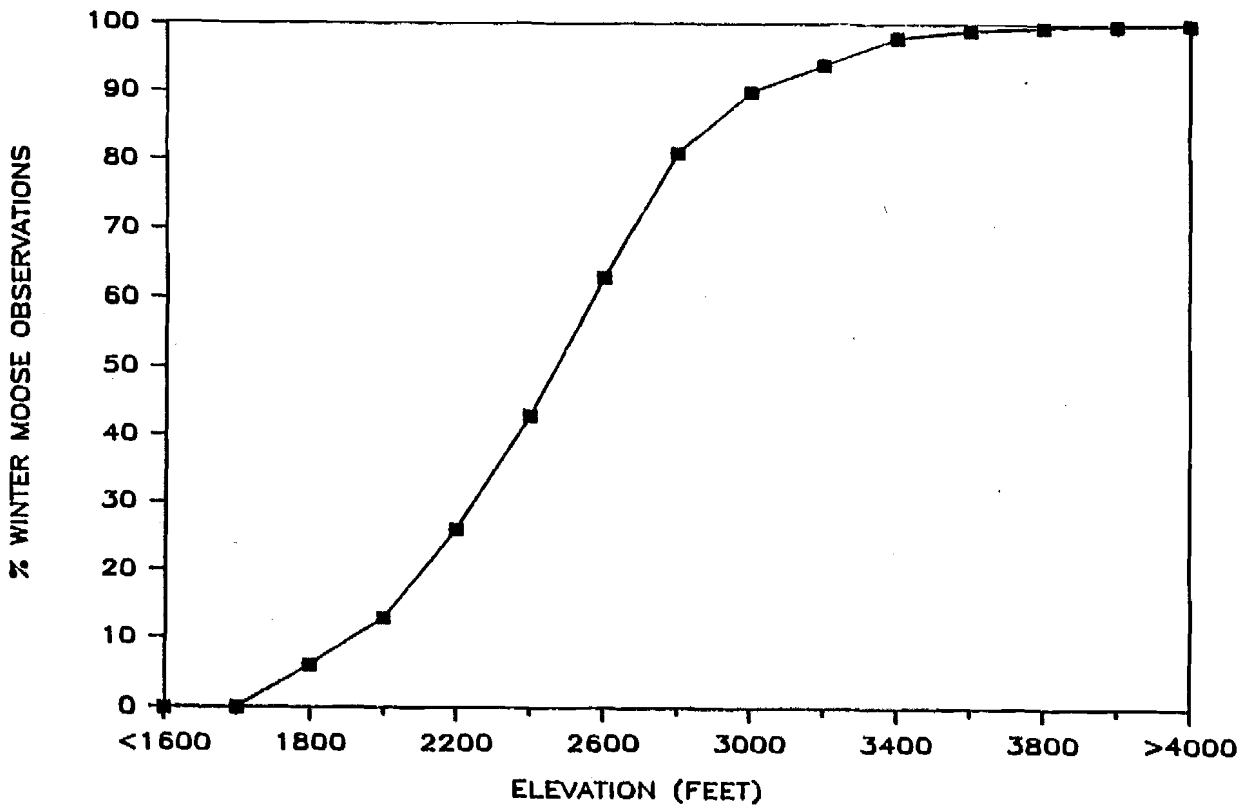

Fig. 47. Percent of moose relocations by elevation for radio-collared moose along the middle Susitna River of southcentral Alaska, 1976-1985.