Alaska Department of Fish and Game
Division of Game
Federal Aid in Wildlife Restoration
Research Progress Report

LOWER SUSITNA VALLEY MOOSE POPULATION IDENTITY AND MOVEMENT STUDY

by
Ronald D. Modafferi
Project W-22-5 and W-22-6
Job 1.38
June 1988

STATE OF ALASKA
Steve Cowper, Governor

DEPARTMENT OF FISH AND GAME
Don W. Collinsworth, Commissioner

DIVISION OF GAME
W. Lewis Pamplin, Jr., Director
Steven R. Peterson, Research Chief

Additional copies of this report, or reports on other species covered in this series may be obtained from:

Publications Technician
ADF&G, Game Division
P.O. Box 3-2000
Juneau, AK 99802
(907) 465-4190

PROGRESS REPORT (RESEARCH)

State: Alaska

Project No.: W-22-5 W-22-6 Project Title: Big Game Investigations

Job No.: IB-1.38 (2nd year) Job Title: Lower Susitna Valley Moose Population Identity and Movement Study

Period Covered: 1 July 1985 - 30 June 1987

SUMMARY

This report includes aerial-survey, marking, and radio-relocating data collected from moose (*Alces alces gigas* Miller) observed and/or captured between October 1985 and May 1987 in alpine areas of the western foothills of the Talkeetna Mountains and lowland forests of the lower Susitna River Valley in Southcentral Alaska. This report also contains pertinent survey and radio-relocation data gathered between April 1980 and May 1986 during previous moose studies in lowland riparian areas of the Susitna River Valley.

Periodic aerial surveys conducted from October through April 1985-86 and from November through March 1986-87 documented increase, peak, and decrease phases in moose utilization of 7 subareas of alpine habitat in the western foothills of the Talkeetna Mountains. Maxima of 919 and 1,405 moose were observed in alpine habitats on 18 November 1985 and 26 November 1986, respectively. Moose numbers decreased earlier and more dramatically in 1986-87. During both winters, moose numbers in the Sunshine area continued to increase after the areawide peak. Differences in peak numbers (53%) and dynamics were attributed to variation in population size and/or climatic conditions. Antlerless, calf, and antlered moose accounted for 68%, 28%, and 4% of the increase, respectively. Relative to antlerless moose, antlered moose decreased by 30% (40:100 to 28:100) and calf moose increased by 44% (18:100 to 26:100) from 1985-86 to 1986-87. Changes within subpopulations on Bald Mountain and Willow Mountain, respectively, were primarily responsible for a decrease in antlered and an increase in calf moose.

After moose numbers declined in alpine habitats, about 150 moose were observed in lowland mature forests west of Willow Mountain. About one-half of the moose observed occurred in less than 23% of the area surveyed. Moose densities were

greatest between Little Willow Creek and the Kashwitna River. Commercial timber harvest is proposed for this area. Timber harvest will alter plant communities and may impact moose.

Herd size, composition, and mortality of moose were assessed for 3 lowland riparian areas (Alexander, Moose, and Kroto Creeks) during 3 winters. Alexander and Moose Creeks functioned as typical moose winter ranges; as expected, these winter ranges supported relatively large numbers of moose though March and April, respectively. Moose use of Kroto Creek, however, was different; it more closely paralleled moose use of alpine postrut areas. Moose numbers on Kroto Creek decreased greatly between February and March; herd composition and winter mortality there also differed from other areas, and more male and fewer calf moose were observed. Significant winter-kill was also observed during all winters on Kroto Creek. Hypotheses based on nutritive condition of dams were posed to explain area differences in production (calf numbers), herd composition, and winter-kill. Data on fetus sex ratios skewed towards males (2.4:1) were used to implicate postrut range quality as an ultimate factor affecting dam nutritive condition.

Moose mortality and movements were assessed from remains of moose found dead and relocations of 44, 7, and 15 moose radio-marked in alpine areas of the Talkeetna Mountains in 1985-86, in adjacent lowland forests in 1987, and along the Susitna River floodplain in 1980-85, respectively.

Hunters killed 48% of the 25 marked moose that died. Death of the remaining 13 moose was allocated between winter-kill (16%), predation (12%), poaching (12%), injury/wounds (8%), and collisions with trains (4%).

Mortality rate for some factors appeared to be sex dependent. Forty-one percent of 22 marked males were killed by hunters. Only 7% of 42 marked females were killed by hunters. Hunting regulations favor the killing of male moose.

Death of 3 females and 1 male was attributed to winter-kill. It was hypothesized that winters are more likely to weaken and kill females (vs. males) because most are diverting part of their energy and nutrient resources to grow feti.

Three females (and no males) were presumed killed by bears. It was hypothesized that female moose (vs. males) are more susceptible to bear predation because of their association with neonates.

Data from radio-marked moose indicated that a major portion of moose subpopulations that occur in alpine areas of Bald, Moss, and Willow Mountains during the postrut period moved south to lowland disclimax habitats near human settlements in winter 1986-87. In winter 1985-86, most marked moose remained at higher elevations. Differences in movement patterns were related to temperature and snowpack depth. Browse is abundant in disclimax plant communities among human settlements.

During both winters, small numbers of moose moved west among human settlements along railroad and highway rights-of-way and near the Susitna River floodplain. Westerly, rather than southerly, movements to winter range appeared more characteristic for moose subpopulations north of Little Willow Creek. Winter range near Pittmann and Wasilla, which was commonly utilized by more southern subpopulations, may be too distant.

Marked female moose throughout the Talkeetna Mountains occurred west of the Susitna River during parturition. This movement was more prevalent for moose north of Little Willow Creek. It was hypothesized that lack of preferred calving habitat and higher predator levels in the Talkeetna Mountains foothills were responsible for this seasonal movement.

Most moose marked in the Talkeetna Mountains began aggregating near timberline in June and July. Some moose moved higher into alpine habitats in August. By early September, most moose moved back into forested habitats at lower elevations. The latter movement was associated with rutting activities. However, influx of hunters into alpine habitat at about this same time may also have prompted this movement. Marked moose remained in midelevation forested habitat until late October when movements into alpine postrut areas near initial capture sites commenced. While in postrut areas, males commonly occurred in sex-segregated groups at slightly higher elevations than females.

Potential impacts on moose of land development, timber harvest, and other alternative land uses proposed for the lower Susitna River Valley were discussed. Concern was expressed about potential impact of access that would be created incidentally by the development.

Growth characteristics of browse in alpine and lowland habitats were related to moose fall-winter movements and foraging strategies. Hypotheses proposed suggested that (1) moose should not be discouraged from overbrowsing lowland riparian forage and (2) moose should not be encouraged to overbrowse alpine forage.

Contemporary hypotheses on plant antiherbivory evolutionary strategies suggest that fast, tall-growing plants on fertile lowland floodplain substrates probably provide more palatable moose forage than do slower, lower-growing plants that occur in less productive environments at higher elevations. These strategies may partly explain why large numbers of moose move to lowland floodplains in winter, rather than remain at higher elevations. Future research plans are outlined.

Key Words: Moose, *Alces alces gigas*, Susitna Valley, radiotelemetry, habitat, movements, aerial survey, population identity, Southcentral Alaska.

CONTENTS

BACKGROUND

Prior to statehood, the Susitna River Valley was ranked as the most productive moose (Alces alces gigas Miller) habitat in the territory (Chatelain 1951). Today, the innate potential of this area as habitat for moose is probably unsurpassed throughout the state.

Presently, the lower Susitna Valley is the focal point of more development than any other region in the state. Proposed and progressing projects involving grain and crop agriculture, dairy and grazing livestock, commercial forestry and logging, personal-use cutting of firewood, mineral and coal mining, land disposals, hydroelectric development, capitol site selections, wildlife ranges and refuges, human recreation, human settlement, urban expansion, further development of the highway system, and increased railroad traffic in the region may greatly detract from the potential of the area to support moose.

Though development and associated activities may tend to decrease overall moose abundance in the Susitna Valley, there is pressure from resource user groups to increase moose populations so that their demand for greater direct allocations to commercial, consumptive, and nonconsumptive uses can be satisfied.

The development activities and conflicting demands of resource users have created a tremendous need for timely and accurate general and site-specific knowledge about moose populations in the lower Susitna River Valley (Game Management Units [GMU] 14A, 14B, 16A, 16B, and 13E). The demand for this information originates from an array of local, state, and federal land and resource management agencies, and it will likely intensify in the future in response to (1) increased pressures to develop additional lands, (2) increased numbers of users and types of resource use, and (3) a more complex system for allocating the resource to potential users.

Game Division presently lacks appropriate and/or sufficient information about moose populations in the lower Susitna Valley to accurately, consistently, and satisfactorily assess ultimate impacts of contemporary demands on the moose resource. The Division is therefore unable to knowledgeably dispute or condone specific demands or provide recommendations that would effectively regulate and minimize negative impacts on moose populations or habitat. Additionally, the Division must be knowledgeable about moose subpopulation behavior in order to propose, design, and implement mitigation plans to offset unavoidable negative impacts to moose subpopulations or habitat.

Since major decisions on land use and resource allocation in the lower Susitna River Valley are presently being made and will continue to be made in the future, it is imperative that the Game Division (1) proceed to review, unify, and summarize the present state of knowledge on lower Susitna Valley moose populations; and (2) proceed with new studies to augment this data base so that future actions having an impact on moose populations or their habitat may be promptly recognized, evaluated, and minimized and/or mitigated. The lower Susitna Valley is extensive in size and its habitats and environmental conditions vary greatly. Because many resource use conflicts require site-specific knowledge, numerous interrelated sub-studies will be required to adequately understand movement patterns and identities of major moose subpopulations. Initial substudies should be conducted in areas where immediate problems or conflicts in moose management exist.

When I evaluated conflicts in resource use for the entire lower Susitna Valley, it was apparent that initial research efforts should begin in the western foothills of the Talkeetna Mountains (GMU's 14A and 14B) for the following reasons: (1) this area possesses the largest, densest postrutting aggregation of moose in the region and, perhaps, the state; (2) it is the nucleus of development activities and resource use; (3) it provides recreation and resources accessible to over half of Alaska's human population; and (4) it has unique problems involving railroad and highway systems. Also, recent information obtained from Susitna River hydroelectric environmental studies and a habitat suitability assessment project has pointed out a lack of basic knowledge about moose in the area.

Historical information available on moose populations in the Susitna Valley is limited to (1) harvest statistics (ADF&G files), (2) annual but inconsistently conducted sex-age composition surveys (ADF&G files), (3) inconsistently collected data for train- and vehicle-killed moose (ADF&G files), (4) an outdated population movement study based on resightings of "visually collared" moose (ADF&G files), (5) studies on railroad mortality and productivity of the railbelt subpopulation (Rausch 1958, 1959), (6) a sporadically monitored radio-telemetry population identity study in the Dutch and Peters Hills (Didrickson and Taylor 1978), (7) a past, uncompleted study of moose-snowfall relationships in the Susitna Valley, and (8) a study of extensive moose mortality in a severe winter (1970-71) for which there is no final report.

Recent studies designed to assess the impact of a proposed hydroelectric project on moose have provided substantial amounts of contemporary data on populations in areas adjacent to the Susitna River and downstream from Devil Canyon

(Arneson 1981; Modafferi 1982, 1983, 1984). These data have not been summarized to provide general or specific information about those moose subpopulations when they are occupying areas removed from the Susitna River floodplain. Circumstantial evidence and cursory examination of these data suggest that traditional sex-age composition counts conducted in widely spaced alpine areas of GMU's 14A and 14B give biased results and do not include samples from large segments of hunted moose subpopulations. These data also suggest that moose killed during late-winter hunting seasons in Subunit 14B originate in Subunit 16A and that moose killed during hunting seasons in Subunit 16A are included in composition surveys for Subunits 14A and 14B. I believe that moose subpopulations in most of Subunit 16A (subpopulations that remain largely unsurveyed because they occur in forested habitats) could be surveyed during winter when they occur in riparian habitats common to both Subunits 14B and 16A. The aforementioned data and the fact that traditional composition surveys have remained relatively insensitive to large annual changes in moose mortality rates indicate that contemporary assumptions about movements and identities of moose subpopulations in the western foothills of the Talkeetna Mountains (Subunits 14A and 14B) are incorrect or, at least, too simplistic.

A recent joint study conducted by Divisions of Game and Habitat (Modafferi and Albert, unpubl. data) and designed to evaluate methods for assessing moose population status and habitat suitability has begun to identify important moose wintering areas and to document moose-snowfall relationships in a large portion of the lower Susitna River Valley (GMU's 14A 14B, 16A, 16B, and 13E).

OBJECTIVES

Primary

To identify and delineate major moose subpopulations in the lower Susitna River Valley.

To more precisely delineate annual movement patterns and location, timing, and duration of seasonal habitat use.

To identify habitats and land areas that are important for maintaining the integrity of moose subpopulations in the lower Susitna River Valley.

Peripheral

To identify location of winter range and calving areas used by lower Susitna River Valley moose subpopulations.

To determine natality rate and timing of calf and adult mortality.

To assess effects of seasonal timing on results of sex-age composition surveys on results obtained.

To identify moose subpopulations that sustain "accidental" mortality on highway and railroad rights-of-way and mortality from open hunting seasons.

STUDY AREA

The overall study area encompasses the lower Susitna River Valley in Southcentral Alaska. This area includes all watersheds of the Susitna River south of Talkeetna (Fig. 1) and all or portions of Subunits 14A, 14B, 16A, and 16B (Fig. 2). Initial field studies were centered in alpine habitats along the western foothills of the Talkeetna Mountains between the Little Susitna River and the Talkeetna River (Subunits 14A and 14B). Moose were marked (Fig. 3) and aerial surveys (Fig. 4) were conducted in these areas.

In late winter 1987, parallel field studies were initiated in 2 lowland moose wintering areas (see Figs. 3 and 4): (1) forested habitats between the Kashwitna River and Willow Creek (GMU 14B) where the Alaska Division of Forestry has proposed to let leases for timber harvest and hunter access has greatly increased and (2) riparian habitats along Alexander Creek (GMU 16B) where human settlement has escalated and late-winter subsistence moose hunting seasons occur.

In subsequent years, similar field studies involving radio-marked moose will be initiated to study subpopulations in other geographical areas within the lower Susitna River Valley. Data on moose herd composition were gathered on aerial surveys of lowland riparian wintering areas in the lower Susitna River Valley (Fig. 3).

METHODS

To identify and delineate moose subpopulations, to determine annual movement patterns and timing, duration, and magnitude of use of seasonal habitats, and to identify lands (habitats) that are important to specific moose subpopulations, it was necessary to periodically locate individually identifiable moose. To provide individually identifiable moose that could be periodically relocated, individuals were captured and marked with ear tags as well as visual and radio-transmitting neck collars. Each ear tag featured a discrete numeral, and each neck collar featured a discrete, highly visible numeral and radio-transmitted frequency.

For marking and capturing purposes, moose were located in (1) an alpine substudy area along the western foothills of the Talkeetna Mountains between the Little Susitna River and the South Fork of Montana Creek (GMU 14A and B) during winter 1985-86, (2) a lowland forested substudy area between Willow Creek and the Kashwitna River during late winter 1986-87, and (3) a lowland riparian substudy area along Alexander Creek during early spring 1987.

Moose were typically immobilized with 4-6 mg carfentanil (Wildlife Laboratories, Ft. Collins, Co.), dissolved in 2-3 cc H_2O and administered with Palmer Cap-Chur equipment by personnel aboard a hovering Bell-206B or Hughes-500D helicopter. While immobilized, moose were marked with ear tags and neck collars and aged by visual inspection of wear on incisor teeth. Antler conformation was considered when assessing ages of males. Though specific birth years were assigned to captured moose, age categories of calf, yearling, 2-5, 6-12, and 12+ years are more realistic because of imprecision in the aging technique. Sex of marked moose and their association with young of the year were noted. Immobilized moose were revived with an intramuscular injection of 90 mg naloxone hydrochloride (Wildlife Laboratories, Ft. Collins, Co.) per mg of carfentanil administered.

Forty-four moose were captured and marked between 23 December 1986 and 4 February 1987 in the alpine substudy area (Appendix A). Marking procedures were initiated after 18 November 1985, when peak numbers of moose were observed on prior aerial surveys (Modafferi 1987). Distribution of sampling effort between subareas within the alpine area roughly paralleled moose distribution observed on aerial surveys. Proportion of male moose marked was higher than that observed on sex composition surveys, because male moose usually dominate the open-hunting season harvest and more complete information about their behavior (vs. females) was desired.

Seven moose were captured and marked on 28 January 1987 in the Kashwitna Forest substudy area. Sampling effort roughly paralleled moose distribution observed in the area proposed for timber harvest.

Fourteen and 6 moose were captured and marked in the Alexander Creek area on 10 and 27 March 1987, respectively. Sampling procedures roughly paralleled moose distribution previously observed along the creekbed. Further details of research activities in this substudy will be reported under a separate job number.

Fifteen moose captured and radio-marked during previous studies (Arneson 1980; Modafferi 1982, 1983, 1984) in the lower Susitna River valley typically and frequently ranged throughout GMU's 14A and 14B. Information gathered from these individuals supplemented that obtained from moose that had been specifically radio-marked for this study.

Survey flights in Cessna 180 or 185 and Piper PA-18 aircraft equipped with a 2-element yagi antenna (Telonics, Mesa, Az.) fixed on each wing were conducted periodically to relocate marked moose. Moose relocations (audio-visual or audio) were noted on USGS topographic maps (1/63,360 scale) during aerial surveys. Relocation points were later transferred to translucent overlays of those maps in preparation for computer digitization and geoprocessing. Relocation surveys were conducted at about 2-3 weeks intervals and provided about 22, 7, and 165 relocations through 27 May 1987 for moose marked in the Talkeetna Mountains, Kashwitna Forest, and Susitna River areas, respectively.

To determine moose distribution, abundance, and herd composition and to help delineate timing, magnitude, and duration of use of habitats during winter, periodic surveys were conducted in areas where moose were marked. Four, 2, and 2 aerial moose surveys were conducted in the Talkeetna Mountains, Kashwitna Forest, and Alexander Creek areas, respectively. Results of these surveys were, in part, employed to determine when to initiate moose marking procedures and how to distribute sampling effort between subareas.

Information on moose herd composition and mortality were collected during previous studies of lowland riparian wintering ranges in the lower Susitna River Valley (Modafferi, unpubl. data). Data gathered on surveys of Moose Creek, Kroto Creek, Kroto Creek Islands, Yentna River, and Alexander Creek are presented and analyzed to provide supplemental information for assessing moose use of lowland riparian winter ranges. Information gathered on occurrence and sex composition of multiparous litters of moose killed during late-winter hunting seasons (ADF&G files) was analyzed to help explain observed differences in moose herd composition. Data on fate of marked moose were analyzed to describe sources of mortality for moose subpopulations in the lower Susitna River Valley.

For ease of reference and to denote hypothetical moose subpopulations, 7 subareas were identified within the Talkeetna Mountains alpine substudy area: Bald Mountain Ridge, Moss Mountain, Willow Mountain, Witna Mountain, Brownie Mountain, Wolverine Mountain, and Sunshine Mountain (Fig. 3). Subarea names are those associated with Vertical Datum Bench Mark (VDBM) notations on USGS topographic maps (1:250,000 scale).

RESULTS AND DISCUSSION

This report presents field data collected from April 1980 through May 1987. Data collected prior to October 1985 were accumulated during previous moose studies in the Susitna River Valley. Data collected from October 1985 through May 1987 were gathered specifically for this study.

Dynamics of Moose Distribution, Abundance, and Herd Composition in Alpine Habitats

Eight and 4 surveys were conducted to document distribution, abundance, and herd composition changes of moose in 7 alpine subareas in the western foothills of the Talkeetna Mountains during the winters of 1985-86 and 1986-87, respectively (Table 1). During both winters, numbers of moose observed in alpine areas fluctuated greatly and appeared to peak toward the latter part of November. Peak number of moose observed in the winter of 1986-87 was considerably greater than that observeed in the previous winter. After the mid- to late-November peak, the number of moose observed declined. Moose numbers decreased more abruptly in the winter of 1986-87 than in the winter of 1985-86. In both winters, numbers of moose observed in the Sunshine Mountain subarea continued to increase past the areawide late-November peak and significant decreases were not recorded until until March.

In the winter of 1985-86, numbers of moose observed in alpine areas peaked at 919 on 18 November and decreased to 202 by April. In the winter of 1986-87, a peak of 1,405 and a low of 133 moose were observed on 26 November and 2 March, respectively. The peak number of moose observed in the winter of 1986-87 was 53% greater than that recorded in the previous winter. Moose numbers declined more abruptly in the winter of 1986-87, compared with that in the winter of 1985-86. In 1986-87, moose numbers declined by 77% from late November to mid-January, compared with a 24% decrease from mid-November to late February in 1985-86.

Temperature (Edwards and Ritcey 1956) and snow (Coady 1974) may affect moose movements and behavior. Dynamics in numbers of moose observed on aerial surveys in alpine habitats may be related to climatic conditions. Moose numbers in alpine areas may be negatively related to ambient temperatures and snowpack depth.

October and November air temperatures were normal in 1985-86 (Clagett 1986:19) and above normal in 1986-87 (Clagett 1987:22). Relatively cold ambient temperatures in the winter of 1985-86 were associated with relatively low numbers of moose in alpine habitats, whereas above normal air temperatures in the winter of 1986-87 were associated with relatively large numbers of moose in alpine habitats. Ambient temperatures could have directly affected moose behavior, or more likely, ambient temperatures may have affected forage quality that, in turn, influenced moose movement patterns.

Snowpack depth for February through April was below the 22-yr recorded minimum in 1986 (Clagett 1986:29) and above the historical average in 1987 (Clagett 1987:22). Shallow snowpack in the winter of 1985-86 probably did not discourage moose from remaining in alpine habitats, whereas above-average snowpack early in the winter of 1986-87 probably encouraged moose to vacate those areas after November.

Another possibility is that moose behavior did not vary between years, but that the size of moose populations in the study area was larger in the winter of 1986-87 and, therefore, led to observations of more moose. However, this contention seems unlikely because of the relatively low proportion of calves (potential recruits) observed in the population in November 1985 (11 calves:100 moose or 18 calves:100 antlerless [female] moose) (Table 2). If the increase in moose numbers was attributable to recruitment, I would expect to observe a similar significant increase in moose numbers in November 1987 (vs. 1986).

Antlerless moose accounted for 68% of the increase in moose observed in November 1986 (Table 3). One hundred and thirty percent (i.e., 135) more calves were observed. Nine percent of the increase was attributable to antlered moose. The proportion of antlered:100 antlerless moose observed decreased (i.e., 40 vs. 28) between 1985 and 1986, whereas the proportion of calves:100 antlerless moose increased (i.e., 18 vs. 26). Occurrence of antlerless adult moose and, to a lesser extent, calves largely accounted for the increased numbers of moose observed in November 1986; these herd characteristics could have resulted from increased production and/or survival of moose calves during 1986 or from drastic annual differences in moose distribution.

Except for the Sunshine Mountain subarea, relationships of moose numbers between areas remained relatively constant during both winters. Contrary to this general data pattern, during both winters the number of moose observed in the Sunshine Mountain subarea continued to increase through November and did not exhibit a significant decrease until March. Moose use of this subarea differed from that of other subareas.

When I combined data for subareas, the percentage of antlerless moose observed differed little between years (63%

vs. 65%), whereas the percentage of antlerless and calf moose decreased (25% vs. 18%) and increased (11% vs. 17%), respectively, during 1985 and 1986 (Tables 2 and 3). Relative to the antlerless moose observed, males decreased from 40:100 to 28:100 and calves increased from 18:100 to 26:100. The greatest decrease in antlered moose (29%) occurred in the Bald Mountain subarea. Large contributions to the overall increase in antlerless moose occurred in Bald, Willow, Witna, and Brownie Mountain subareas.

The most dramatic increase in the percentage of calf moose occurred in the Willow Mountain subarea; in spite of a 66% increase in number of antlerless moose, there was a 4-fold increase in the proportion of calves:antlerless moose. Nearly 7 times as many calf moose were observed on Willow Mountain in November 1986 than in November 1985. Causes of a parallel 70% annual increase in calf moose observed on Bald Mountain may be different because, in contrast, the calf:100 antlerless moose ratio there changed only slightly between years (25:100 vs. 28:100).

The relative decrease in males and increase in calves are most easily explained by an increase in the proportion of females with calves in alpine habitats in November 1986. It is generally assumed that in fall and early winter females with calves more commonly occur in forested rather than alpine habitats (ADF&G files). Possibly, annual variation in climatic conditions (as previously described) was responsible for the altering distribution of females with calves from forested to alpine habitats in November 1986.

The 29% decrease in antlered moose (51% for the ratio of antlered:100 antlerless moose) observed on Bald Mountain may be attributed to the harvest during open hunting season. The recent tremendous increase in ownership and use of ATV's by hunters and the relative ease of access to Bald Mountain by hunters lead me to believe that hunting contributed to the decrease in antlered moose observed in November 1986.

Moose Distribution and Herd Composition in Kashwitna Forest

Because the Division of Forestry was planning to promote timber harvests in the mixed forests adjacent to Willow Mountain, I initiated a study to more fully understand how moose utilize these habitats. As moose numbers observed in alpine habitats on Willow Mountain decreased, substantial numbers of moose were observed in adjacent midelevation forested habitats. Aerial surveys conducted on 7 January and 6 February 1987 provided baseline information on distribution and relative abundance of moose in this area (Table 4). Because these surveys were primarily designed to ascertain moose distribution, numerical totals are merely indices of absolute numbers of moose. They are not meant to represent the absolute number of moose present. I estimate that 30% of the moose present were actually observed. This approximation is realistic because about 500 moose were observed above timberline on Willow Mountain in November and in January; these observations occurred after moose numbers in this habitat had decreased significantly and 151 moose (roughly 30%) had been observed on surveys in the adjacent forest habitats.

By 6 February the number of moose observed in forested habitats had decreased to 98. Results from this survey may not be directly comparable to results from the 7 January survey because of different observers and because snowcover had deteriorated and proportionately fewer moose could be observed. Regardless of possible shortcomings with surveys, I suspect moose numbers in these forested habitats had decreased. Other data also suggest that when snowpacks become deep (e.g., in February), moose from the western foothills of the Talkeetna Mountains move farther west (out of forested habitats), presumably to forage near human settlements and along the Susitna River floodplain (ADF&G files).

Data from two of 7 moose radio-marked in the Kashwitna Forest area on 28 January 1987 indicated movements to other areas and habitats by 24 February. One individual moved west to lower elevations near the railroad right-of-way, and the other one moved east to higher elevations. Both moose moved to locations where snowpack depth was less.

Substantial numbers of moose utilized the mixed-forest habitats west of Willow Mountain and between Willow Creek and the Kashwitna River. Timing and magnitude of moose use of the area may be closely related to snowpack depth in surrounding areas. Moose were not evenly distributed within the lowland mixed-forested areas surveyed (Table 4); subsection f (Fig. 4) encompassed roughly 23% of the survey area but contained 49% and 50% of the moose observed on 7 January and 6 February 1987, respectively. The ecological basis for nonrandom moose distribution within forested habitats remains unknown. If moose movement out of alpine areas is primarily westerly (i.e., little north-south movement), observed differences in density may reflect local differences in subpopulation size. More moose may move from areas nearer Little Willow Creek and the Kashwitna River than from areas near Willow Creek and Peters Creek. Local differences in moose subpopulation size may result from differential hunter harvests. Southern portions of Willow Mountain are more accessible to hunters and have been more heavily hunted.

These data raise important questions regarding timber harvest and moose management in mixed-forest habitats of the Kashwitna forest. Moose in this area prefer to occupy either forest, or the more typical shrub-dominated habitats during the winter. If the former preference is correct, it would be wise moose management to minimize timber harvests, at least, in subsection f of the Kashwitna Forest. If the latter preference is correct, it would be wise moose management to encourage timber harvests throughout all of the Kashwitna forest. Continued studies will provide additional information so that the best moose-related forest management practice can be determined.

The percentage of calves observed on 7 January 1987 in lowland forest habitats adjacent to Willow Mountain was sightly less than that observed on 26 November 1986 in alpine habitat on Willow Mountain (20% vs. 17%, respectively) and similar to the total observed for all subareas. Previous data (ADF&G files) suggested that the percentage of calves in lowland forest habitats would be greater than that in alpine habitats; however, either the proportion of calf moose present in forested habitats was not greater than that in alpine habitats or a disproportionate calf mortality between areas or an influx of adult moose occurred prior to 7 January. Data from radio-marked individuals along with documented decreases in numbers of moose observed in alpine habitats suggest that there was a movement of adult moose into lowland forested habitats. The continued decrease in the percentage of calves observed in lowland forest habitats between the 7 January and 6 February surveys may be attributable to either calf mortality or differential movement patterns between other sex or age classes. Based on the aforementioned data, I suspect calf ratios observed in forested habitats will continue to be diluted with the influx of adult moose from alpine habitats.

<u>Herd Size, Composition, and Mortality in Lower Susitna Valley Riparian Wintering Areas</u>

Status of moose populations is typically evaluated by aerial composition surveys. Herd composition surveys are commonly conducted in late November and early December when moose are in postrut aggregations in alpine habitats.

Evaluating status of lowland moose subpopulations is difficult because they typically occur in timbered habitats during the postrut period when herd composition surveys are normally conducted. Snow cover is frequently inadequate in lowland areas, and mature mixed-forest canopies obstruct observability of moose. However, later in winter, moose from lowland subpopulations commonly depart forest habitat and gather in relatively open-shrub habitats on riparian floodplains where the status of these lowland herds can be more determined. To evaluate this possibility, one must understand the factors affecting dynamics of moose herd composition on riparian floodplains.

Moose population growth is largely determined by recruitment that is assessed by enumerating calf and, to a lesser extent, yearling proportions in the postrut aggregations (November or December). Unfortunately, these assessments are conducted before the winter period when calf and yearling moose cohorts sustain considerable mortality. Late-winter herd composition surveys would more accurately assess recruitment. Likewise, winter mortality assessments should weigh heavily when formulating management strategies for subsequent fall hunting seasons.

Population simulation models help biologists understand the population dynamics of moose. Year-round information on moose mortality and herd composition provide the necessary data to formulate realistic population simulation models. Information on moose herd composition and mortality in winter is lacking for the lower Susitna River Valley.

I collected data on dynamics, herd composition, and mortality of moose on lower Susitna River valley riparian ranges in winter 1983-83, 1984-85 (Modafferi, unpubl. data). Parallel demographic data were gathered for the same areas in winter 1986-87 (Table 5).

Dynamics in Use of Ranges:

Data obtained from winter moose herd composition surveys indicate that different riparian areas may serve different ecological functions. Moose use (i.e., moose numbers) of the Kroto Creek floodplain peaked in early December and appeared to decline thereafter. Timing for this sequence of events was similar to that observed for alpine areas in the western foothills of the Talkeetna Mountains.

In contrast, moose use of the Moose and Alexander Creek floodplains appeared to peak during January and February, respectively. Moose use of the former areas remained high until late March. Timing of moose use of these riparian floodplains closely paralleled that observed for the Susitna River floodplain (Modafferi 1984).

Moose and Alexander Creeks functioned as typical moose winter ranges. Moose use of Kroto Creek more closely paralleled that of the alpine postrut range.

Experimental studies indicate that while in alpine postrut range moose consume large quantities of high-quality forage, maintain a positive energy balance, and improve nutritive condition (Schwartz et al. 1984); whereas, while on lowland winter range moose consume substantially less forage, experience a negative energy balance, and lose nutritive condition (Schwartz et al. 1984). The basic underlying difference in moose ecology is that the energy balance is positive on the early winter, postrut range and negative on the winter range.

Snowpack depth could be responsible for area differences in moose use of lowland riparian winter ranges. The early occurrence of deep snowpacks may have encouraged moose to leave the Kroto Creek floodplain before moose had vacated other floodplain winter ranges. Excessive snowpack depths in midwinter may have prevented moose from leaving the Moose and Alexander Creek floodplains for more desirable winter ranges. Presently, I cannot explain the observed differences in moose use of "apparent" lowland riparian winter ranges.

Herd Composition:

Composition of moose herd counts varied over winter and between lowland riparian winter areas (Table 5). Variation in moose herd composition may be attributed to antler drop in males and age or sex differences in movement or mortality.

Male moose with "half-racks" (antlers on one-side only) have been observed in early November. "Half-racks" were observed on less than 2% of 281 males in mid-November. Most moose have shed antlers by mid-January. Ratios of male and calf moose:adult females were calculated from the 12 December 1985 survey (Table 6.).

Male moose were observed in all areas. Percentage of male composition varied between areas. Kroto Creek exhibited the highest percentage of males (22%) as well as the highest ratio of males:100 adult females (37). The disparate sex ratios may have resulted from differential movement patterns or production and/or the greater survival of males using the Kroto Creek drainage.

Fetus samples from pregnant moose killed by hunters in late winter along the Parks Highway in the early 1980's indicate that in utero sex ratios are skewed towards males (ADF&G files). Nine of 13 (69%), 10 of 15 (67%), and 8 of 12 (67%) feti examined in 1981, 1982, and 1983, respectively, were males (Table 7). Seventy-two percent of the feti in 12 multiparous litters were males. Previous studies indicated that in most years moose from the Kroto Creek area (GMU 16A) move to areas along the Parks Highway by January and are available to hunters during late winter. It is likely that females sampled during late-winter hunts represented moose from the Kroto Creek area. In contrast, samples from dams killed by collisions with trains and vehicles in the "Railbelt" of GMU 14B (between Matanuska and Curry) indicated that fetal sex ratios were about equal in the mid 1950's (Tables 7 and 8).

Differences in fetal sex ratios between time periods may be accounted for by differences in subpopulation behavior, nutritive condition, or stage of population growth. Possibly, behavior of subpopulations has changed between the mid-1950's and early 1980's. Moose sampled in the same areas during different time periods may have represented different subpopulations with contrasting fetal sex ratios.

Fetal sex ratios for a given subpopulation can vary with nutritive condition of dams that, in turn, may be related to population status. During the earlier time period (mid-1950's), moose populations in the Matanuska Valley were at high levels, range conditions probably were of high quality, and moose were generally well nourished. By the 1980's, moose population levels had declined, range quality had deteriorated, and moose were not as well nourished.

Proportions of calves observed on moose herd composition counts were lower on Kroto Creek (19%) than on Moose (25%) and Alexander (23%) Creeks; even after accounting for the relatively high proportion of males in the sample, the discrepancy was still apparent. Disparate proportions of calves may have been caused by (1) differential movement patterns or (2) lower calf production and/or survival in the Kroto Creek drainage. Calf composition on all 3 riparian floodplains decreased through winter.

<u>Winter Mortality</u>:

The numbers of moose carcasses observed on floodplain areas increased throughout the winter (Table 5). These losses, primarily calves, became apparent in February and were attributed to "winter kill." Although "winter kill" may result from many causes, the ultimate common factors are low body fat reserves and inadequate nutrition; it is also more likely to occur when snowpacks are deep. The snowpack in the winter of 1984-85 was rated as the deepest in 10 years (Clagett et al. 1985), and the "winter kill" was common to all areas during that period.

For all areas, proportions of calves observed on surveys generally decreased from approximately 20% in early December to less than 10% in March. Moose carcasses were first observed in February as calf composition approached 10%. Carcasses were observed on Kroto Creek during the winters of

1984-85, 1985-86, and 1986-87. No carcasses were observed on Moose Creek in March 1984 or on Alexander Creek in 1987. Nineteen of 24 carcasses examined in these areas in the winter of 1984-85 were calves (Modafferi unpubl. data).

Observations of moose carcasses imply that range quality on all riparian areas was inadequate, relative to moose population size and winter weather conditions in two of 3 years. Based on observations of moose carcasses, range quality on Kroto Creek was probably inadequate in all years. Alternatively, lowland winter ranges were of adequate quality, but the postrut ranges, where most moose improve nutritive condition prior to winter (Schwartz et al. 1984), were of inadequate quality, relative to moose population size.

The simplest explanation for the herd composition and winter mortality data is a lightly hunted moose subpopulation. Light hunting mortality levels led to excessive subpopulation levels that caused overutilization and degradation of range quality that, in turn, affected moose nutrition and resulted in high winter mortality (Table 5) and low productivity (Table 6).

A less direct, alternative explanation that considers bull ratios, winter mortality, and productivity but does not require low male mortality is based on the nutritive condition of dams. Studies of moose (Reuterwall 1981) and White-tailed deer (Verme 1965, 1969; Verme and Ozoga 1981) provide evidence that occurrence of unequal sex ratios in mammals is not uncommon. These studies indicate that differential mortality can lead to skewed adult sex ratios. Their data also indicate that poor nutrition in dams, delayed mating, or delayed fertilization may lead to male-dominated sex ratios at conception.

Even if a winter range is determined to be of high quality, nutritional stress cannot be ruled out as the ultimate factor causing "winter kill." "Winter kill" and high-quality winter range are not mutually exclusive. Julander et al. (1961) provided evidence that nutritional stress may originate long before animals arrive on winter range. They linked low productivity in mule deer to poor quality in the summer range.

Boisonnas (1935, _in_ Verme 1981) provided circumstantial evidence that delayed mating in red deer (_Cervus elaphus_) resulted in hinds carrying a preponderance of male fetuses. Delayed mating resulted either from (1) hunter harassment of rutting animals and interference with rutting activities or (2) relatively low proportions of breeding males to estrous females. In the former case, moose were constantly moving to avoid hunters instead of rutting, and in the latter case, too few males were present to service all females during their first estrus.

Accessible parts of the Kroto Creek area (along river and lake shores) are heavily hunted; however, because large portions of the area are relatively inaccessible, overall hunting activity there has been light. Hunter harassment of moose and interference of rutting activities may occur locally but are probably not prevalent throughout the area.

Relatively high proportions of antlered moose in the Kroto Creek area during the winter suggest that males were lightly hunted. Observations of "winter kill" indicate that moose wintering on Kroto Creek were nutritionally stressed. The fetal sex ratios (i.e., skewed towards males) and the low proportions of calves are additional factors supporting the nutritional stress hypothesis; these factors also indicate that nutritional stress may occur before moose are on lowland winter range. The high proportions of adult males observed on Kroto Creek may have resulted from nutritional stress of dams on the postrut range.

Previous studies in the area have provided data supporting the correlation between fetal sex ratios, population status, and range quality (Rausch 1959). In the early 1950's, when moose populations in the area were increasing and range conditions were likely better, fetal sex ratios were essentially equal.

<u>Fate of Radio-marked Moose</u>

<u>Moose Marked In This Study</u>:

Forty-four moose were radio-marked between 23 December 1985 and 28 January 1987 in the western foothills of the Talkeetna Mountains. Seven additional moose were radio-marked on 28 January 1987 in the Kashwitna Forest area (Appendix).

Thirty-two radio-marked individuals were under surveillance on 27 May 1987. Seven of 19 males (37%) and one of 30 females (3%) were killed during open hunting seasons. Two other females (7%) whose transmitting collars have not been recovered were suspected killed by hunters (perhaps illegally). Three females were suspected killed by brown bears. Death of 1 male and 1 female was attributed to "winter kill." One male that died shortly after hunting season was suspected to have died from a bullet wound.

One female (visual collar No. 481) died shortly after she had been captured and handled. Although this mortality was classed as captured related, the individual (estimated to be 18 years old) was extremely emaciated at capture. I suspect capture trauma only precipitated an inevitable "winter kill" mortality.

I killed 1 male that had been incapacitated by an infection in the femur-tibia joint. Bone fragments in the infected area indicated the infection had resulted from an injury. The injury was probably the result of fighting during the rut, a bullet wound, or a fall.

Moose Marked in Other Studies:

Fifteen moose that had been radio-marked between April 1980 and January 1984 for other studies in the lower Susitna River Valley (Modafferi, unpubl. data) were found to utilize habitats in the present study area (Appendix). Data obtained from these individuals were included in the present study. Seven of these moose were under surveillance through 27 May 1987. Two of 3 males and one of 12 females were known to have been killed by hunters during open hunting season. Another female whose remains had been consumed by brown bears was suspected to have been legally killed by hunters during open hunting season. Death of 2 moose was attributed to "winter kill." One female was killed by a collision with a train and 1 male whose collar was found in the Talkeetna landfill shortly after being after being located along the highway right-of-way was suspected to have been killed illegally.

Mortality Factors for Radio-marked Moose

Twenty-five (39%) of the 64 radio-marked moose (Table 10) that provided data for this study are dead. Mortality of radio-marked moose was attributed to 6 factors (Table 9). Twelve (48%) of the deaths were attributed to hunting, four (16%) to "winter kill," three (12%) to predation, three (12%) to poaching, two (8%) to injury or bullet wounds, and one (4%) to a collision with a train.

Mortality rates for some factors varied between sex categories. Nine of 22 (41%) and three of (7%) 42 radio-marked moose, respectively, were killed by hunters (Table 10). Deaths of 3 (7%) females and 1 (5%) male was attributed to "winter kill." Mortality of 3 (7%) radio-marked female moose was attributed to bear predation.

One male and 2 female moose, representing 5% of the marked moose, were thought to have been illegally killed (poached) by hunters. Both female moose were poached during an open hunting season (male only). The male was poached after the season had closed. Mortality of 2 male and 1 female radio-marked moose was attributed to injuries from wounds and a collision with a train, respectively.

Hunting was a major source of mortality for male moose in the study area (Table 10). Restrictive hunting regulations regarding female moose concentrates the harvest on antlered males. Regulations specifying harvest for only bull moose essentially preclude harvest of calf moose. Subarea specific data indicate that harvest of male moose was greatest in subpopulations south of Willow Mountain (Bald and Moss Mountain) and north of Brownie Mountain (Wolverine and Sunshine Mountain) where easy access is afforded by all-terrain vehicles (ATV's). Only one of 10 radio-marked moose on Willow Mountain was killed by hunters. Hunter harvest rates in these areas appear largely dependent on hunter access. I expect the moose harvest in these areas to increase in relation to the increasing ease of access caused by the use of ATV's. The road proposed by Alaska Division of Forestry for timber harvest will also provide easy access into forested portions of Willow and Witna Mountain areas, and ATV's will provide hunters with additional access to move freely throughout most of the areas. Under present regulations, the increased access will increase the moose harvest from these subpopulations.

"Winter kill" was the next most important mortality factor, and its significance was greatly underestimated because it primarily affects calf and yearling moose, age categories that were not represented in the radio-marked samples. Additionally, "winter kill" is not an important mortality factor when average winter conditions prevail. The significance and impact of "winter kill" can only be evaluated during severe winter conditions (e.g., winters of 1970-71 and 1984-85). Entire cohorts of calves can be lost during a severe winter (ADF&G files). I suspect that "winter kill" would rate significantly higher as a mortality factor if I were to collect data during a severe winter. However, I doubt that "winter kill" rates for Talkeetna Mountain moose subpopulations would approach those for lowland moose subpopulations west of the Susitna River where deeper snowpacks more typically occur (Modafferi, unpubl. data).

Data available from other studies indicate that brown (Ballard et al. 1980) and black bears (Ursus americanus) (Franzmann et al. 1980) can be significant predators on moose calves. Circumstantial data (Modaferri, unpubl. data) suggest that bear predation on adult moose is both common and sex dependent; bears may prey on females more commonly because of their association with calves. These predators actively pursue calf moose. Dams may have been killed while trying to protect their calves; e.g., the death of 2 females attributed to bears occurred during July, a time when neonates are vulnerable.

I have obtained no evidence of predation on male moose. Though brown bears on the Alaska Peninsula have been known to attack and kill large bull moose during the rut (ADF&G files) when they are probably less wary, I suspect the larger size of male moose affords added protection from bears. Because male moose are not accompanied calves they may be able to escape pursuing bears. Data collected also imply that predation rates on adult moose may be less in lowland than in alpine habitats where brown bear occur more commonly.

Documentation of "injury-induced" moose mortality during the winter period (ADF&G files) prompts me to speculate that those mortalities occurring shortly after hunting season (and before midwinter) may ultimately be attributed to infections from injuries sustained from fighting during the rut, bullet wounds, or falls, rather than "winter kill."

Moose poaching in the study area should not be regarded lightly. Depressed economies, increases in rural inhabitants, timing and duration of moose movements into settled areas, and deep snowpacks that may affect moose temperament and daily movements can affect rate of moose poaching; however, the greatest factor influencing poaching rate is the tremendous increase in human settlements in remote areas. Human settlements typically occur in lowlands along watercourses, and floodplains are typical wintering areas for moose.

Loss of moose to collisions with trains (and highway vehicles) can be a significant mortality factor to specific subpopulations (Modafferi unpubl. data). Rights-of-way for railroads and highways are typically constructed in lowland areas along major drainages. Common use of lowland areas creates a high potential for train- and vehicle-induced mortality. Moose mortality from this source increases with numbers of moose on winter ranges (population size and movement patterns) and length of time they utilize these areas. Mortality is greatest when deep snowpacks persist for extended periods and moose occupation of winter ranges is lengthened.

Moose Movements

Summaries of moose movements by subarea of capture (Figs. 5-12) illustrate annual ranges for moose subpopulations observed during typical ADF&G sex-age composition counts in Subunits 14A and 14B.

Bald Mountain:

Movements for the Bald Mountain moose subpopulation were basically bounded on the north by Willow Creek (Fig. 5). Movements south occurred during midwinter (December) and terminated near Pittman and Wasilla; by February 1987, all radio-marked moose in this subarea had also moved south. These data imply that roughly all 400 moose observed on Bald Mountain (see Table 1) made similar movements to the wintering areas near Pittman and Wasilla. Shallow snowpacks and availability of preferred browse apparently attracted moose to this area. One 2-year-old male moved west over 100 km from its capture site and was killed by a hunter near Hiline Lake in September.

Moss Mountain:

In 1986-87 the only remaining radio-marked moose from the Moss Mountain subarea moved south about 25 km to winter near Wasilla (Fig. 3). This movement paralleled that for moose from Bald Mountain. This behavior pattern probably characterized movements for other moose in the Moss Mountain subpopulation. The other radio-marked moose in this subarea was killed by a hunter near Houston in September 1986.

Willow Mountain:

Five of 10 radio-marked moose on Willow Mountain that were relocated during winter 1986-87 moved south about 35 km to winter near Houston and Wasilla. These findings imply that approximately 250 of the 500 moose composing the Willow Mountain subpopulation made similar movements to this winter range. At parturition time, two of 6 radio-marked females were located west of the Susitna River near Kroto Creek. These data imply that about 30% of the females observed on Willow Mountain moved to lowlands west of the Susitna River for parturition. One radio-marked male moved west to winter along highway and railroad rights-of-way near the Susitna River at Montana. The later data suggest that only a small percentage (10%) of the moose observed on Willow Mountain in November moved west to winter along railroad and highway rights-of-way near the Susitna River.

Witna Mountain:

The only radio-marked moose in this area wintered near highway and railroad rights-of-way. This individual moved west of the Susitna River during parturition. In August it returned to alpine habitats of the Talkeetna Mountains. These data suggest that females from this subarea winter near the Susitna River and calve west of the Susitna River.

Brownie Mountain:

Radio-marked moose in this subarea generally remained near higher elevations not far from their alpine capture sites.

For a short period of time after marking, several individuals moved south across the Kashwitna River into the Witna subarea. The following November, 1 female moved north into the Wolverine subarea. One female ranged from the upper Kashwitna River in late winter to the Susitna floodplain during parturition, a linear distance of 60 km. Another radio-marked female ranged south into the Willow Mountain subarea.

Wolverine Mountain:

Two males accounted for major movements recorded for moose marked in this subarea. One individual ranged from upper Sheep Creek, Sheep River, and the North Fork of Kashwitna River in summer to the Susitna River floodplain in winter. Another male ranged from Sheep River in spring and summer to near Caswell Lakes during the rut. During parturition, one radio-marked female moved far up Sheep Creek in summer and fall and another moved west of the Susitna River near the Sunshine Bridge.

Sunshine Mountain:

Three radio-marked females that provided data for this area moved across the Susitna River during parturition. One individual traveled southwest about 70 km to a calving area. These data suggest that preferred calving environments (i.e., those that may have fewer predators) are of limited availability to this subpopulation. Predators such as brown and black bears and wolves (Canis lupas) become increasingly more common in northern portions of the Talkeetna Mountains study area. Moose from this subpopulation commonly moved west to lowland wintering areas near human settlements along highway and railroad rights-of-way.

Kashwitna Forest:

Shortly after capture, 2 marked females moved about 20 km easterly to higher elevations in the Purches and Sheep Creek drainages; they remained there until spring. Another female moved west to winter in lowland areas along the highway and railroad rights-of-way. In April a female moved west about 45 km across the Susitna River. The latter movement was presumably for parturition.

Study Area Summary:

Large numbers of moose from Little Willow Creek winter in lowland areas between Houston and Wasilla. Prevailing winds in these areas keep snowpacks shallow, and human disturbance to lands has resulted in revegetation by preferred moose browse. Significant numbers of these moose are killed by collisions with highway vehicles. Smaller numbers of moose from this area move west to winter among human settlements and along railroad and highway rights-of-way where human disturbance to lands has resulted in revegetation by preferred moose browse. Moose from subpopulations near Kroto Creek and the Susitna River also utilize this same winter range (Modafferi 1984). Moose begin to leave lowland wintering areas in March or April and return to forested habitats near timberline in the Talkeetna Mountain foothills. Females are in calving areas by late May. Some travel to wet muskeg habitats across the Susitna River, others remain in forested habitats slightly below timberline. By late June or early July, many moose are in timberline and alpine habitats. Moose remain there until late August when they begin to move into more timbered habitats for rutting activities. Moose begin gathering in alpine areas in November after the rut. Moose numbers in postrut alpine areas peak by about the last week of November and decline thereafter as moose begin moving to lowland wintering areas. Snowpack depth can influence timing of this movement.

In some aspects, moose behavior in subareas between Little Willow Creek and the South Fork of Montana Creek differs from that in more southern subareas. In inclement winters, migratory moose from these subareas move west to lowland areas near human settlements along railroad and highway rights-of-way and the Susitna River floodplain. Significant mortality can result from collisions with vehicles and trains. Greater proportions of these more northern subpopulations appear to remain in alpine areas and near timberline through winter. Some moose from these same subpopulations winter in birch forest habitats between timberline and the lowlands. In inclement and/or long winters, many of the later moose probably continue moving westward to destinations in lowland areas. A greater proportion of female moose from these more northern subareas calve in muskeg habitats west of the Susitna River. This may be because of lack of preferred calving habitat and/or high predator levels.

Habitat Considerations

Changing patterns of land use threaten to alter moose habitat in the lower Susitna River Valley. Habitat alterations associated with a ski resort in the Hatcher Pass area, land management of the Willow Capitol site, agricultural and homesite land disposals, development of industries based on timber harvest, development of a coal mine and subsequent plant succession, and development of lands previously cleared for homesteads can impact local moose populations.

Timber harvest may not always be beneficial to moose; however, it can have positive effects on moose when it causes regrowth of preferred moose browse. Alternatively, timber harvest may eliminate mature forest habitat components preferred by moose for other reasons or during other seasonal periods. In these instances and when winter range is not limiting, timber harvest can be detrimental to maintenance and growth of moose populations.

In many instances, mitigation for loss of moose or habitat is appropriate. However, in cases where conflicts in land use pertain to lands utilized by large numbers of moose or where new or additional winter range will be of little benefit to impacted subpopulations, alternative land uses should be strongly opposed. Habitats important to large numbers of moose (critical habitats) should be preserved.

Large portions of moose subpopulations in the lower Susitna River Valley utilize wintering areas in disclimax habitats among human settlements. Alternate uses of these private lands would reduce available winter range and significantly impact those subpopulations.

Impact of Access on Moose Subpopulations

Access Related to Hunting:

Use of ATV's increases the efficiency and success of hunters over large land areas and will likely lead to shortened hunting seasons. In areas where hunters utilize ATV's, success of hunters without ATV's (foot-hunters) is probably reduced. To maintain or increase length of hunting seasons and more equally allocate the moose harvest among all hunters, I suggest that some subareas be closed to the use of ATV's in the taking of game.

The use of ATV's negatively impacts landscape. Presently, the proportion of habitat destroyed by ATV's is relatively small; however, small areas of affected habitats can negatively impact the aesthetics of large landscapes. Because ATV's are primarily used in remote areas by hunters in pursuit of game, hunting regulations indirectly affect the area and timing of that use. Wildlife managers must become concerned with impact of ATV's on habitat quality as well as on moose population levels.

Access Not Related to Hunting:

Human disturbance of moose during the postrut (when moose are preparing for winter by regaining nutritive condition lost during rut activities) and winter periods (when moose are attempting to conserve energy) may negatively affect moose energy bugets. Easy access into the postrut and winter ranges of moose may encourage human use of these areas. Disturbances from human activities (e.g., recreational snowmachining, skiing, and photography, etc.) may alter normal activity patterns of moose or displace them from their preferred ranges. This unnecessary harassment during critical periods may ultimately affect the survival of moose. Newly created access into the Willow Mountain subarea, a popular snowmachining area, may lead to human disturbance of that moose subpopulation.

Winter Forage and Foraging Strategies in Alpine and Lowland Habitats:

The winter forage of moose in lowland areas of the lower Susitna River Valley primarily includes willows, birches, and poplars in riparian or disclimax seral plant communities. These plant species typically exhibit rapid growth rates that in 5-10 years place the most palatable components out of reach to moose. At this time, the plant may remain productive, but moose are unable to utilize them. Regardless of the influence of moose, these plant species can only be considered as temporarily available food sources. Intensive browsing pressure by moose may protract the period of availability of plants browsed. Unbrowsed plants will continue to grow rapidly. Degeneration (senescence) of browse plants resulting from "overbrowsing" would be of little consequence in the long term. In this situation, the strategy of moose would be to utilize available browse heavily because it would only be available for a short period of time.

Moose winter forage in alpine areas of the lower Susitna River Valley consists primarily of willows, birches, and nonbrowse species in climax communities. Growth rates of plants at these higher elevations are probably slower than those at lower elevations, and mature plants would be seldom out of reach to moose. Plants in alpine communities are always available to browsing by moose (i.e., they never grow out of reach to moose and are not a temporary food source if not covered by snow). Overbrowsing of plants in alpine communities could result in decreased long-term production and encourage premature degenerative senescence. An evolutionary strategy for moose exploiting browse in alpine plant communities would be to not heavily browse or "overbrowse" available plants. Overutilization of food sources available in alpine communities would result in premature senescence or degeneration of plants and lead to deterioration and permanent loss of the range in the long term. It appears that overbrowsing on alpine ranges may have more profound and longer-lasting impacts.

In terms of evolutionary strategies, moose may be encouraged to heavily utilize available forage on lowland riparian winter range and be discouraged from overutilizing available forage on alpine postrut and winter range. It appears that over-browsing on alpine range may have more profound long-term affects on quantity of available browse.

Perhaps, frequent and periodic weather-related winter moose die-offs and range overutilization observed on lowland ranges function as a control of a subpopulation's size that, in turn, deter overutilization of the more vulnerable alpine postrut and winter range. Likewise, movements of the majority of moose out of alpine postrut and winter ranges to lowland winter ranges may be an evolutionary adaptation to guard against overutilization of browse in alpine plant communities.

In contrast, plants have apparently evolved counter mechanisms to discourage overutilization by herbivores. Recent studies suggest that plant life form (MacLean and Jensen 1984), plant growth rate and leaf life time (Coley 1988), and secondary chemical compounds that inhibit forage digestion (Bryant and Kuropat (1980) or intake (Robbins et al. 1987) are important components of the antiherbivory defense mechanisms of plants. Concepts basic to these hypotheses, may be summarized in the following manner: The preferred evolutionary strategy of a plant is to grow rapidly enough to escape browsing. This antiherbivory strategy is probably common for plants growing in fertile substrates (probably more so in lowland floodplains than at higher alpine elevations). In less fertile substrates where plants may grow more slowly and are accessible to browsers for relatively longer periods, they have evolved chemical or physical mechanisms (e.g., thorns) to discourage herbivory. Recent hypotheses suggest that chemical components that act by discouraging intake are more appropriate than those compounds that inhibit digestion because the latter substances may only encourage consumers to increase forage intake (browse more!) to obtain required amounts of minerals and nutrients.

Obviously, plants that never grow out of reach of herbivores (i.e., shrubs, low growing subspecies, etc.) and/or remain excessively attractive in winter (i.e., evergreen conifers and ericaceous shrubs) have to rely on chemical and physical mechanisms to discourage herbivory. Considering the antiherbivory strategies of plants, I would hypothesize that low, slow-growing forage plants (which rely primarily on chemical and physical deterrents to discourage herbivory) available to moose at higher elevations in relatively unfertile substrates in alpine habitats are not as "palatable" as the faster growing, early successional forage plants (which rely primarily on rapid grow rates to avoid herbivory) available in relatively fertile lowland substrates along river floodplains. This may explain why large numbers of moose seek winter range in lowland floodplain areas along the Susitna and other rivers.

However, these same scenarios lead one to raise the following question: if plants in alpine habitats employ antiherbivory "tactics" to discourage moose browsing, why do they attract such large numbers of moose during the important foraging period succeeding the rut and preceding winter? It may be that plants only synthesize and/or translocate antiherbivory chemical compounds into "browseable" shoots immediately preceding winter senescence or, at least, after leaf abscission. If defensive chemicals were incorporated into "browseable" plant parts prior to leaf abscission or "down" translocation of other substances into storage depots, plants would have to synthesize much larger amounts of the compounds to maintain relatively high (and functional) concentrations of deterrents in "browseable" plant parts. Because production of additional deterrent compounds would be "energetically" more costly to plants, it is avoided by waiting until "browseable" plant biomass is minimal.

Management Implications:

Traditional sex-age composition trend surveys are conducted in early winter in alpine habitats where moose aggregate during the postrut period. Data (Modaferri, unpubl. data) from surveys in alpine habitats during the postrut period indicate that (1) weather and timing of surveys can drastically affect numbers and composition of moose observed, (2) annual variation in number of moose observed may be attributed to weather conditions, rather than changes in subpopulation size, and (3) annual variation (changes) in subpopulation demography may be "masked" when data from several subpopulations are combined.

Decreased numbers and percent of antlered moose on Bald Mountain, an accessible and popular hunting area, most likely resulted from loss of males killed during open hunting seasons. Twenty-seven percent of the radio-marked adult male moose in the Talkeetna Mountains were killed by hunters after 2 open hunting seasons. Three of 5 radio-marked adult males on Bald Mountain were killed during the same time interval. These data indicate relatively high hunter harvest rates for males in GMU's 14A and 14B. Impact of these harvest rates on moose management goals should be evaluated.

Higher moose calf ratios were observed on Willow Mountain in winter 1986-87 than in winter 1985-86. Calf ratios on Bald Mountain remained relatively unchanged between those years.

These data could be the result of open antlerless moose hunting seasons in GMU 14B or annual differences in environmental conditions. Elevated calf ratios could occur if (1) hunters selected and killed lone antlerless moose rather than antlerless moose accompanied by calves, (2) hunters did not select for lone antlerless moose, and (3) orphaned calf moose were not misclassified as adults during composition surveys. An open antlerless hunting season occurred on Willow Mountain (GMU 14B), whereas a limited number of permits were issued for antlerless moose for Bald Mountain (GMU 14A).

Annual and subpopulation differences in calf ratios observed on Willow and Bald Mountains may also be attributed to effects of the relatively severe 1984-85 winter (excessive snow pack) on nutritive condition of pregnant females, resulting in lowered calf production and survival. While winter environmental conditions could have depressed calf ratios in the Willow Mountain subpopulation, they may not have adversely affected calf ratios in subpopulations on Bald Mountain. The Willow Mountain subpopulation primarily winters between Kashwitna River and Willow Creek, and most of the Bald Mountain subpopulation winters between Pittman and Palmer; excessive snowpack depth seldom occurs there. If this scenario is accurate and the productivity of the moose subpopulation on Willow Mountain was depressed by winter conditions in 1984-85, then improving winter range quality (carrying capacity) for the Willow Mountain subpopulation would likely increase the size of that subpopulation.

Annual differences in environmental conditions from fall through winter could have altered distribution of calves in the Willow Mountain moose subpopulation. If this was the case, then the elevated calf composition observed in November 1986 (vs. 1985) was an artifact of nonrepresentative sampling.

In January 1987 substantial numbers of moose were observed in forested habitats west of Willow Mountain. The Division of Forestry is proposing timber harvests in this area. Previous studies have indicated that moose also use nearby forested habitats during spring and summer. In order to knowledgeably comment on proposed timber harvests, the Game Division must gather additional information to identify the reasons moose occur in forested habitats.

Bull:cow ratios are frequently utilized to assess the impact of hunter harvests on moose populations. Data from several different sources indicated that elevated bull:cow ratios observed in GMU 16A riparian wintering areas may be attributed to effects of poor quality range on dams or skewed sex ratios. Dams that have mated late or ones that have been in poor nutritive condition during mating tend to produce more males than females. In the absence of population estimates, ratios should never be solely used to assess status of moose populations.

Because proportions of yearling males in fall moose populations are utilized to estimate the annual increment of breeding females, it is extremely important to know fetus sex ratios. If fetus sex ratios are skewed 2:1 toward males, then observations of 6% yearling males would perhaps suggest an equal number of yearling females rather than a higher number. In male-only hunting areas, it is typically assumed that survival rates for yearling females is considerably higher than for males. Current data on fetus sex ratios should be obtained where hunting of females occurs.

Moose mortality on lowland riparian winter ranges in GMU 16A must be quantified annually; this factor must be considered when calculating allowable hunting harvest. Additional studies should be conducted to determine cause of mortality in lowland riparian wintering areas.

Movements of radio-marked moose indicate that postrut aggregations in GMU 14B represent numerous, relatively discrete subpopulations. Losses (mortality) and gains (productivity) to a specific moose subpopulation only affect that subpopulation. These findings indicate that moose in GMU 14B should be managed at the subpopulation level.

Moose from several subpopulations may utilize the same winter range. Areas among human settlements south of the Little Susitna River and north of the Parks Highway between Houston and Palmer are an important moose winter range. Negative impacts to this winter range through development or advances in plant succession will affect large numbers of moose from numerous subpopulations. I estimate that about 1,000 moose presently utilize this winter range. Loss of moose winter range in this area should be avoided. If range loss is unavoidable, alternative winter ranges should be established.

In winter, moose frequently become a nuisance to humans when they occur among human settlements and interfere with human activities. Additionally, because highway and railroad rights-of-way occur within moose winter ranges, large numbers of moose are killed by collisions with trains and highway vehicles. Information on movement patterns of moose in the lower Susitna River Valley may be utilized to designate areas where moose winter range could be established to help preclude mortality and conflicts with human activities.

Use of ATV's and snowmachines have become popular recreational endeavors in unsettled areas of the lower Susitna River

Valley. Snowmachine and ATV use may alter habitats, displace moose from seasonal ranges, and/or cause them to alter usual behavior patterns. Disturbances from human recreational activities may directly or indirectly result in mortality of moose. Disturbance of moose by snowmachines in winter on winter range and by ATV's on fall range (during rut) are areas of concern. Wildlife managers must become cognizant of the potential impact of these human activities on moose.

Use of ATV's by hunters in GMU 14B has increased substantially in the last several years. In many areas, ATV trails are obvious features of the landscape. ATV use in wet marshy areas alters those habitats. Wildlife managers must recognize that hunting regulations may indirectly affect habitat quality.

Data on fate of radio-marked moose in the lower Susitna River Valley indicate that the following component categories should be considered when calculating annual mortality (losses) for a moose subpopulation: (1) hunter harvest, (2) crippling kill, (3) illegal harvest, (4) predator kill, (5) collisions with trains, (6) collisions with highway vehicles, (7) winter kill (range carrying capacity, population size, and winter severity all relevant factors), (8) old age, (9) injuries from fighting in rut (males), (10) injuries from accidents (falling or slipping on ice), (11) drowning (after falling through ice or open water leads in rivers, while crossing rivers, or getting caught in ice jams during breakup).

Population demography and movements of radio-marked moose indicate that a distinct subpopulation occurs on Bald Mountain. This subpopulation sustains substantial mortality from collisions with vehicles and trains and poaching while on winter range in lowland areas between Houston and Palmer. Mortality from these sources is less common to other GMU 14A moose subpopulations east of Government Peak and more similar to GMU 14B subpopulations north of Bald Mountain. The Bald Mountain moose subpopulation exhibits levels of productivity higher than subpopulations on Willow Mountain, presumably because of higher quality winter range. These data indicate that the Bald Mountain moose subpopulation may require more site-specific management than presently exists under the GMU 14A classification.

FUTURE RESEARCH PLANS

1. Periodically Continue radio-relocating marked moose.
2. Conduct herd distribution, abundance, and composition surveys as snow cover permits through the 1987-88 winter.

3. Conduct surveys in alpine areas of Talkeetna Mountains, on Alexander Creek, and on the Yentna River near the new proposed Skwentna and McDougall study areas.

   Skwentna and McDougall, on the Yentna River, were selected as component areas for extension of moose research in the lower Susitna River Valley. These riparian habitats are commonly known to be important moose wintering areas. Extensive use of these habitats by moose was documented during previous winter surveys (Modafferi, unpubl. data). Late winter subsistence hunting seasons occur in these areas. Similar to the Alexander Creek substudy area, this area represents a wintering habitat (lowland riparian) grossly different from alpine areas in the western foothills of the Talkeetna Mountains.

4. Conduct field excursions into Kashwitna forest subarea to assess moose winter use of that habitat.

5. Initiate a cooperative study with U. S. Fish and Wildlife Service involving marking moose with satellite-tracking collars.

   Satellite-tracking collars provide information on activity and movement of marked moose. Potentially discernible activities include feeding, running, and bedding. These data may provide baseline information to quantitatively evaluate the influence of human disturbances on moose winter behavior. Satellite-tracking collars provide daily movement data regardless of weather conditions. Satellite-tracking collars have a 1-year useful life expectancy. Because satellite collars must be attached "snugly" to obtain activity data, they are only installed on females. Two females in the Willow Mountain subarea will be marked with satellite-tracked collars.

6. Radio-mark additional moose in the Willow Mountain subarea near where timber harvests are proposed.

   Additional moose may also be radio-marked in the Bald Mountain subarea because of the reduced sample size in that area and to provide additional information on moose use of the Willow Capitol Site Land Management Area.

ACKNOWLEDGEMENTS

I am especially grateful to Dennis C. McAllister, Alaska Dept. Fish and Game, who made useful suggestions, pertinent criticisms, and willfully provided his assistance throughout this study. Dennis always managed to be available when needed; sometimes at the expense of his own time. Dennis was invaluable in field aspects of this study. I am thankful to Dennis for his able assistance is all facets of this study.

I am grateful to my immediate supervisor Karl Schneider, Alaska Dept. Fish and Game, who has always diligently supported and lobbied for the study of moose in the lower Susitna Valley. Karl's sincere interest in the study has been a welcomed stimulus to my efforts. Karl has also labored to keep my administrative duties to a minimum so I might concentrate on the biological problems. I greatfully appreciate all his efforts.

The following persons also deserve special thanks:

C. Soloy, Soloy Heli-Ops, Wasilla, for expertly piloting helicopters during moose capture procedures; B. Wiederkehr, Wiederkehr Air Inc. Palmer, for piloting Piper Super Cub aircraft during herd distribution, abundance and composition surveys, and aerial surveys to locate radio-marked moose; and Larry Rogers, Southcentral Air, Kenai, for piloting Cessna 180/185 on moose radio-relocation surveys. These individuals are commended for piloting aircraft safely and efficiently during low-level flight operations. B. Taylor and J. Didrickson are recognized for assistance in field aspects of this study. J. Didrickson and N. Steen, area game management biologists responsible for GMU's 14A and 14B (the study area), are acknowledged for freely providing local knowledge, logistic assistance, a congenial working atmosphere, and "area support" from conception through the present stage of this study. L. Pank, U. S. Fish and Wildlife Service, is acknowledged for stimulating my interest in the application of satellite telemetry on moose and willingly cooperating in a joint-agency study.

LITERATURE CITED

Arneson, P. 1981. Big game studies. Vol. II. Moose. Ann. Prog. Rep. Susitna Hydroelectric Proj. Alaska Dept. Fish and Game. Juneau. 64pp.

Ballard, W. B., T. H. Spraker, and K. P. Taylor. 1980. Causes of neonatal moose calf mortality in southcentral Alaska. J. Wildl. Manage. 45:335-342.

Boisonnas, J. 1935. In Verme L. J. and J. J. Ozaga. 1981. L'appel des cerfs. Review de Paris. 21:130-147.

Bryant, J. P. and P. J. Kuropat. 1980. Selection of winter forage by subarctic browsing vertebrates: the role of plant chemistry. Ann. Rev. Ecol. and Systemat. 11:261-285.

Chatelain, E. F. 1951. Winter range problems of moose in the moose in the Susitna Valley. Proc. Alaska Sci. Conf. 2:343-347.

Clagett, G. P. 1986. Alaska snow surveys. U.S. Dept. of Agriculture, Soil Conservation Service. Anchorage. 30pp.

Clagett, G. P. 1987. Alaska snow surveys. U.S. Dept. of Agriculture, Soil Conservation Service. Anchorage. 31pp.

Clagett, G. P., R. McClure, and T. Robles. 1985. Snow surveys and water supply outlook for Alaska. U.S. Dept. of Agriculture, Soil Conservation Service. Anchorage.

Coady, J. W. 1974. Influence of snow on behavior of moose. Naturaliste can. 417-436.

Coley, P. D. 1988. Effects of plant growth rate and leaf lifetime on the amount and type of antiherbivore defense. Oecol. 74:531-536.

Des Meules, P. 1964. The influence of snow on the behavior of moose. Trans. NE. Wildl. Conf., 21. 11 Figs., 17pp.

Didrickson, J. C. and K. P. Taylor. 1978. Lower Susitna Valley moose population identity study. Alaska Dept. of Fish and Game. Fed. Aid Wildl. Rest. Proj. Final Rept., W-17-8 and 9. Jobl.16R. Juneau. 20pp.

Edwards, R. Y. and R. W. Ritcey. 1956. The migrations of a moose herd. J. Mammal. 37:486-494.

Franzmann, A. W., C. C. Schwartz, and R. O. Peterson. 1980. Moose calf mortality in summer on the Kenai Peninsula, Alaska. J. Wildl. Manage. 44:764-768.

Julander, O., W. L. Robinette, and D. A. Jones. 1961. Relation of summer range condition to mule deer herd productivity. J. Wildl. Manage. 25:54-60.

MacLean, S. F. and T. S. Jensen. 1985. Food plant selection by insects in Alaska arctic tundra the role of plant life form. Oikos 44:211-221.

Modafferi, R. D. 1982. Big game studies. Vol II. Moose-Downstream. Final Phase I Rep. Susitna Hydroelectric Proj. Alaska Dep. Fish and Game. Juneau. 114pp.

__________. 1983. Big game studies. Vol. II. Moose-Downstream. Prog. Rep. Phase II. Susitna Hydroelectric Proj. Alaska Dep. Fish and Game. Juneau. 114pp.

__________. 1984. Big game studies. Vol. II. Moose-Downstream. Prog. Rep. Phase II. Susitna Hydroelectric Proj. Alaska Dep. Fish and Game. 116pp.

__________. 1987. Lower Susitna Valley moose population identity and movement study. Alaska Dept. Fish and Game. Fed. Aid Wildl. Rest. Final Rep. Proj. W-22-5. Job 1.38R. Juneau. 17pp.

Rausch, R. A. 1958. The problem of railroad-moose conflicts in the Susitna Valley. Alaska Dept. of Fish and Game. Fed. Aid Wildl. Rest. Final Rep. Proj. W-3-R. Job 1-4. Juneau. 116pp.

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

Robbins, C. T.. 1959. Some aspects of population dynamics of the railbelt moose populations, Alaska. M.S. Thesis. Univ. Alaska, Fairbanks. 81pp.

__________, T. A. Hanley, A. E. Hagerman, O. Hjeljord, D. L. Baker, C. C. Schwartz, and W. W. Mautz. 1987. Role of tannins in defending plants against ruminants: reduction in protein availability.

Reuterwall, C. 1981. Temporal and spatial variability of the calf sex ratio in Scandinavian moose Alces alces. Oikos 37:39-45.

Schwartz, C. C., W. L. Regelin, and A. W. Franzmann. 1984. Seasonal dynamics of food intake in moose. Alces 20:223-242.

Verme, L. J. 1965. Reproduction studies on penned white-tailed deer. J. Wildl. Manage. 29:74-79.

__________. 1969. Reproductive patterns of white-tailed deer related to nutritional plane. J. Wildl. Manage. 33:881-887.

__________ and J. J. Ozaga. 1981. Sex ratio of white-tailed deer and the estrous cycle. J. Wildl. Manage. 45:710-715.

PREPARED BY:

Ronald D. Modaferri
Game Biologist III

APPROVED BY:

W. Lewis Pamplin, Jr., Director

Steven R. Peterson
Chief of Research

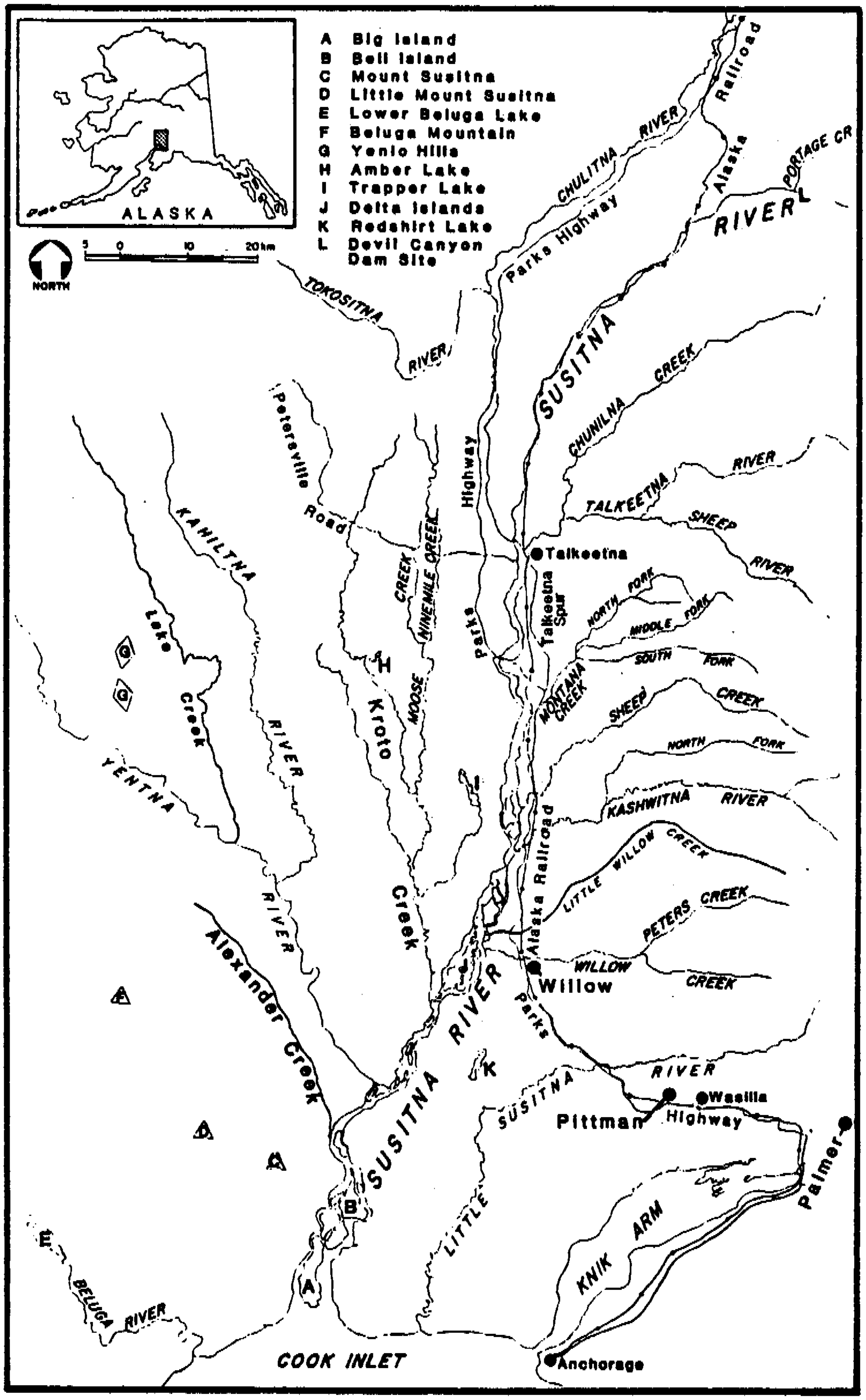

Figure 1. Map showing location of the study area in Alaska with names listed for rivers, lakes and other prominent landscape features.

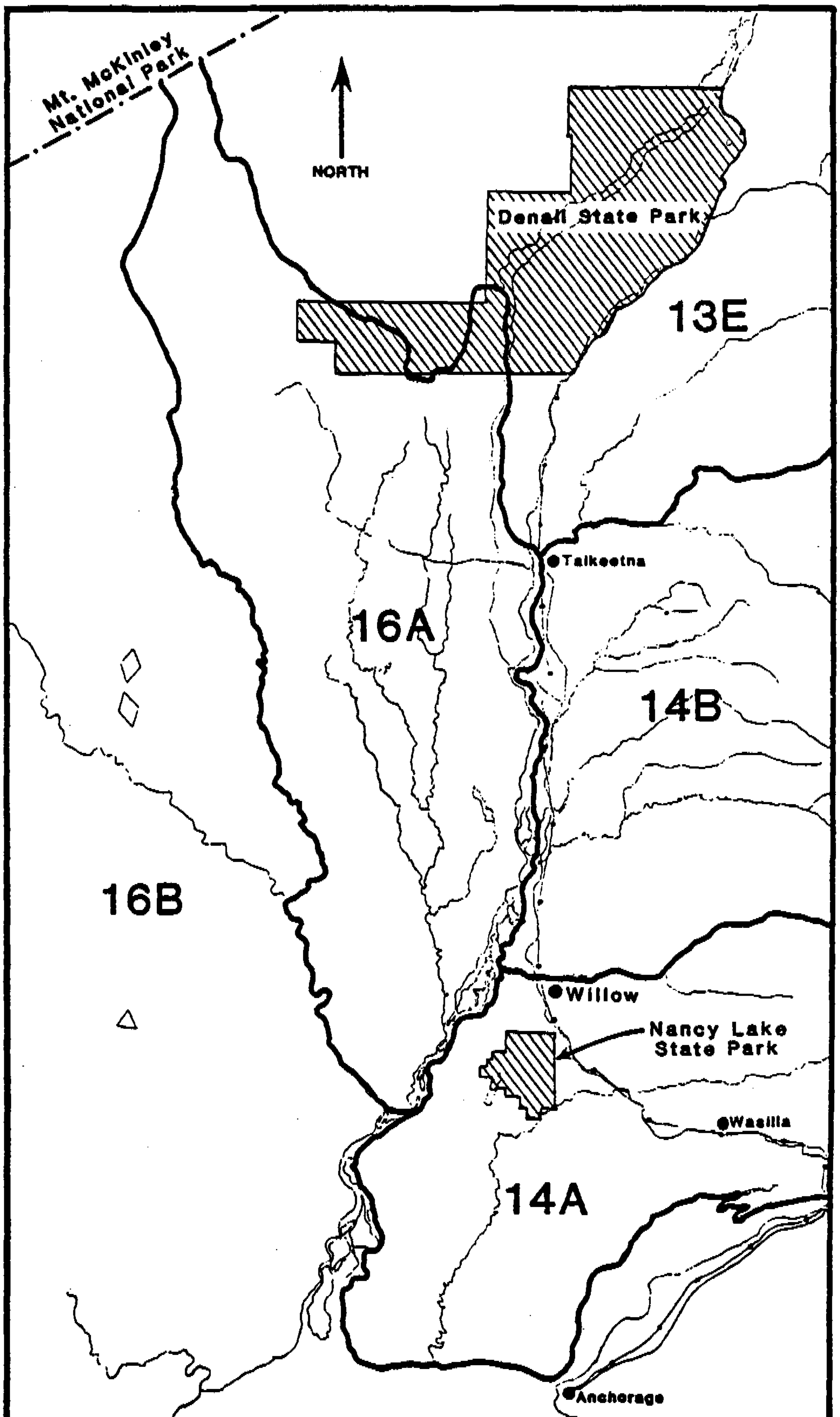

Fig. 2. Location of Game Management Subunits (13E, 14A, 14B, 16A and 16B) and state and national parks in the study area.

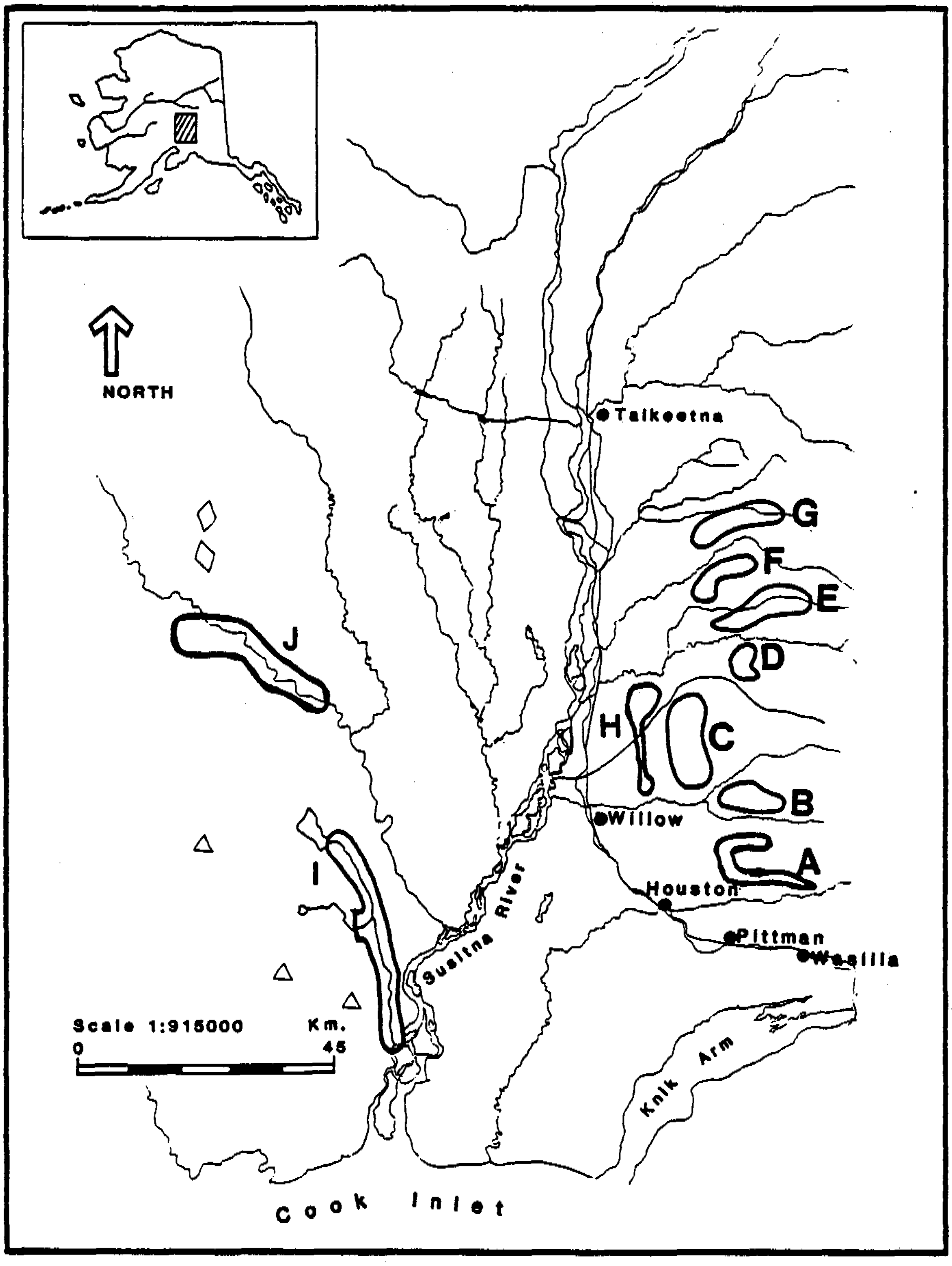

Fig. 3. Location of Talkeetna Mountains subareas (A–G), Kashwitna Forest (H) and Alexander Creek (I) where moose were radio-marked in Winter 1985–86, January 1987 and March 1988, respectively and the Yentna River (J) where moose will be radio-marked in March 1988.

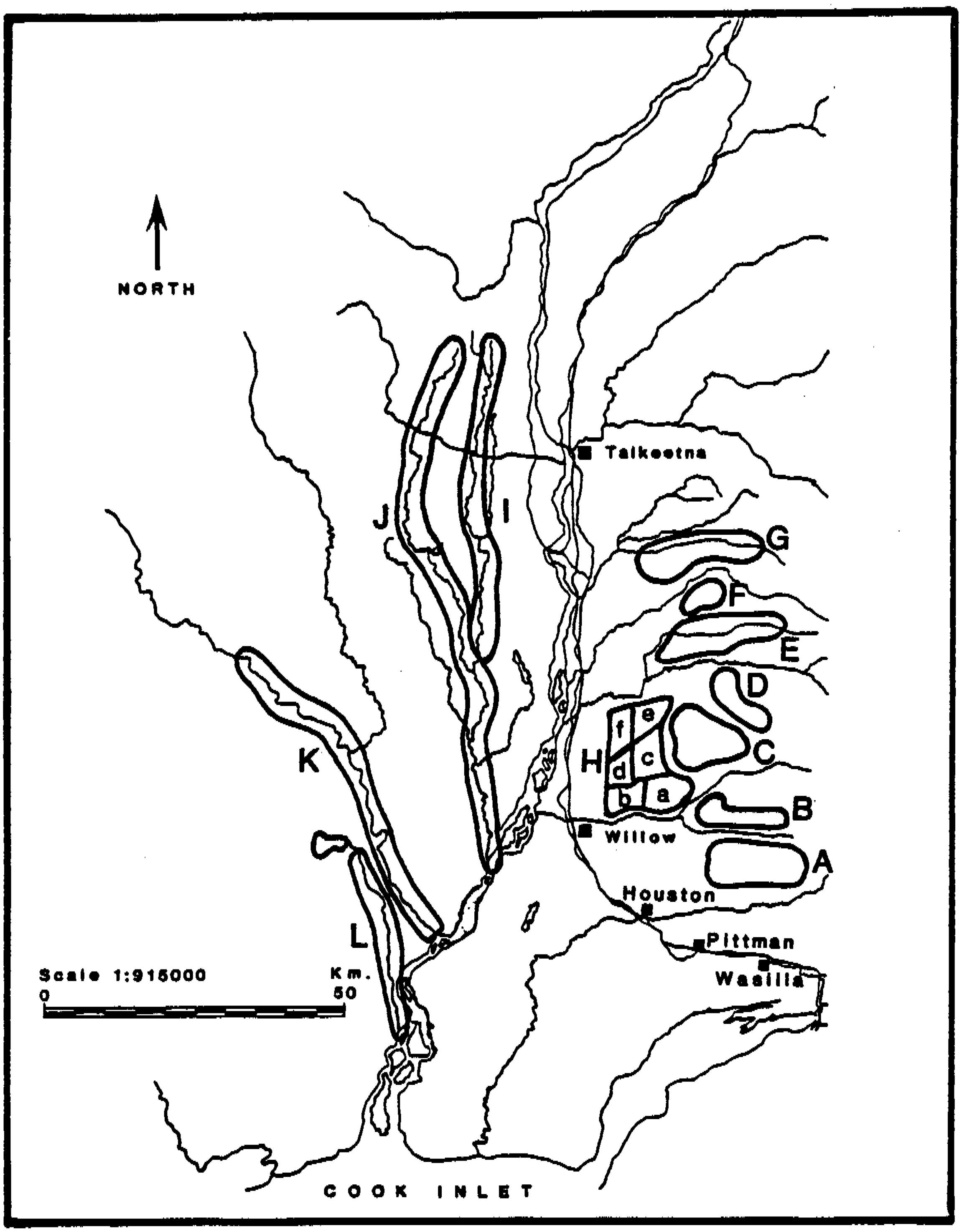

Fig. 4. Locations for Talkeetna Mountains subareas (A-G), Kashwitna Forest (H) subareas (a-b), Moose Creek (I), Kroto Creek (J), Yentna River (K) and Alexander Creek (L) where moose surveys were conducted (A=Bald Mtn., B=Moss Mtn., C=Willow Mtn., D=Witna Mtn., E=Brownie Mtn., F=Wolverine Mtn., and G=Sunshine Mtn.).

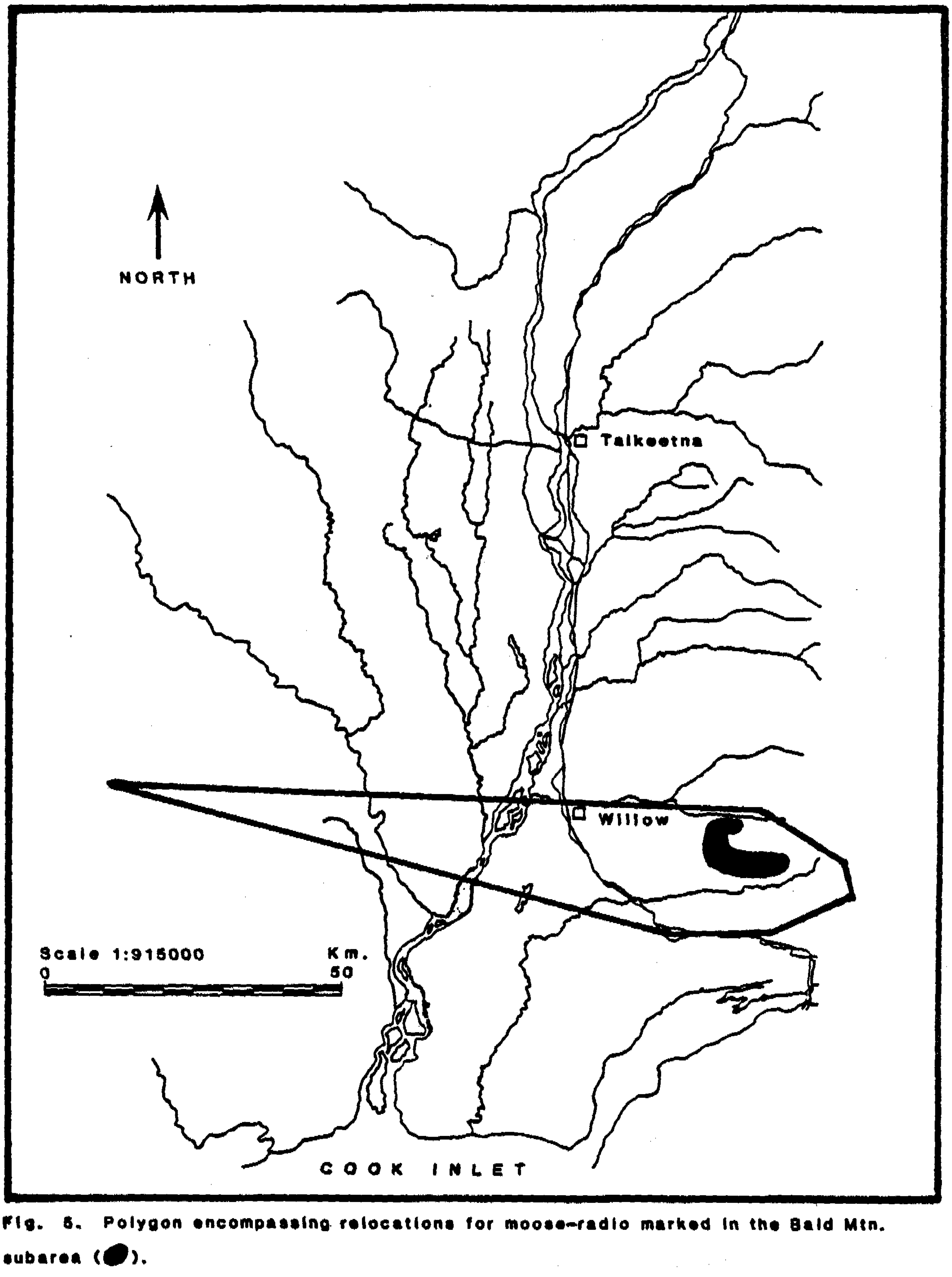

Fig. 5. Polygon encompassing relocations for moose-radio marked in the Bald Mtn. subarea (●).

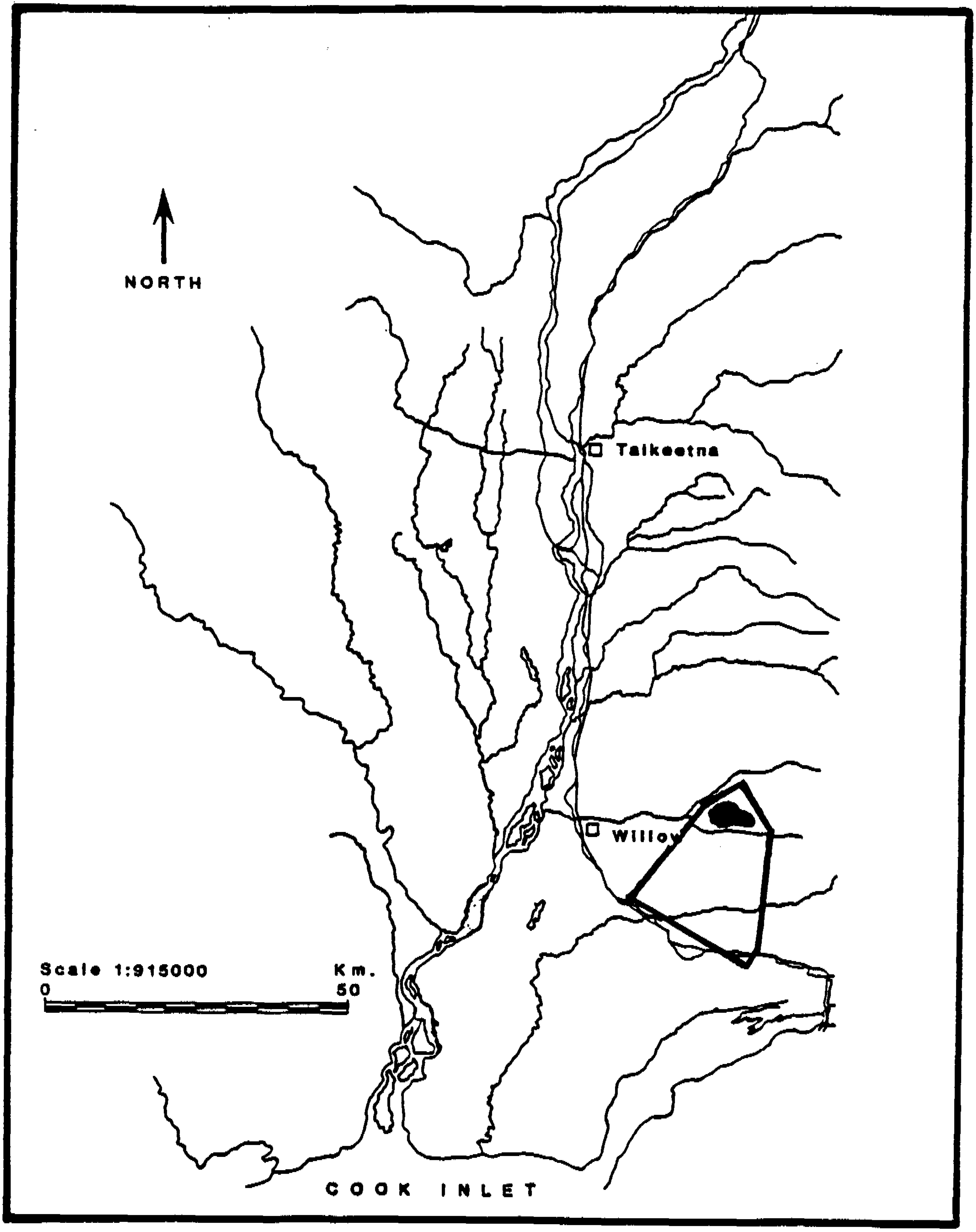

Fig. 6. Polygon encompassing relocations for moose radio-marked in the Moss Mtn. subarea (●).

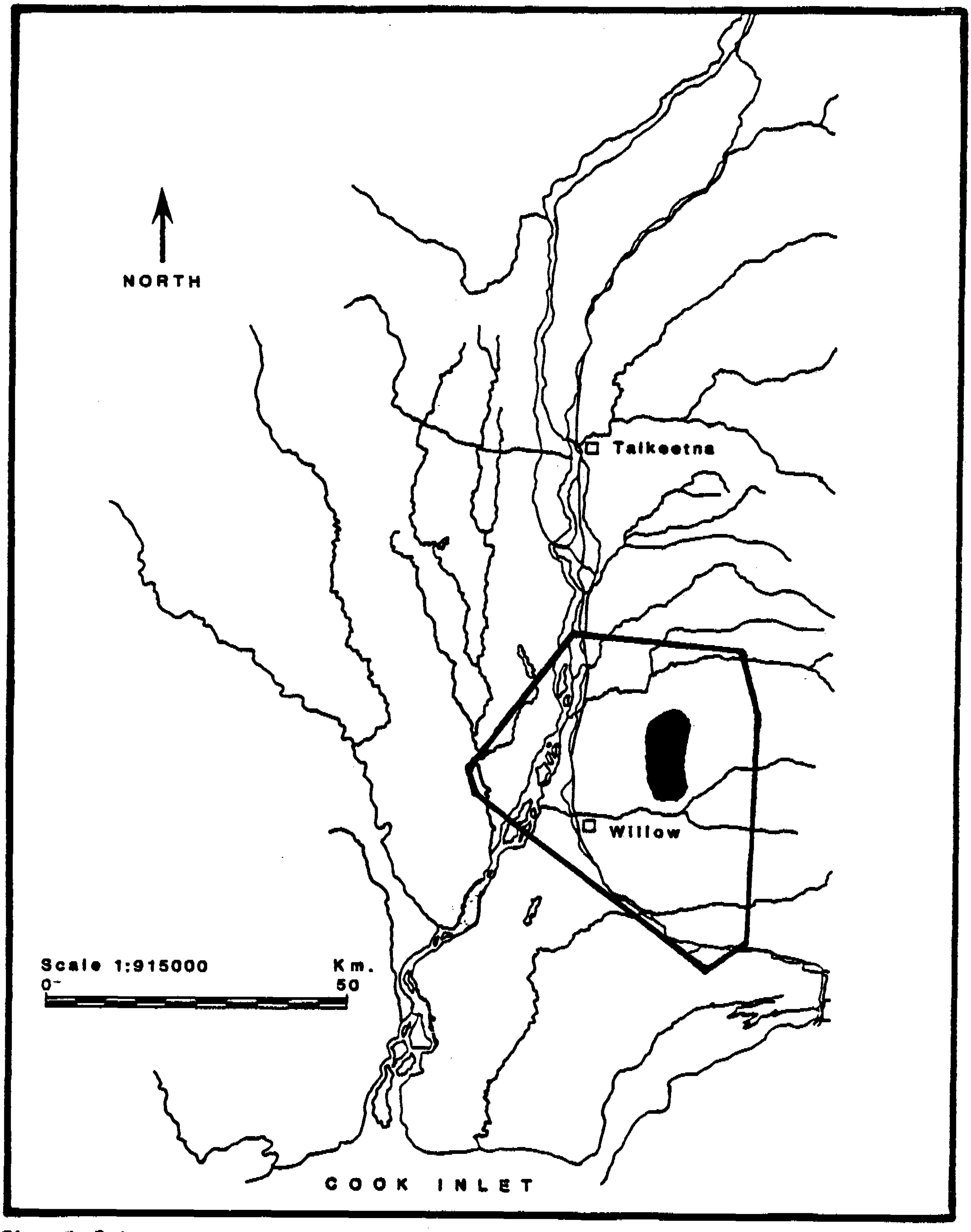

Fig. 7. Polygon encompassing relocations for moose radio-marked in the Willow Mtn. subarea (●).

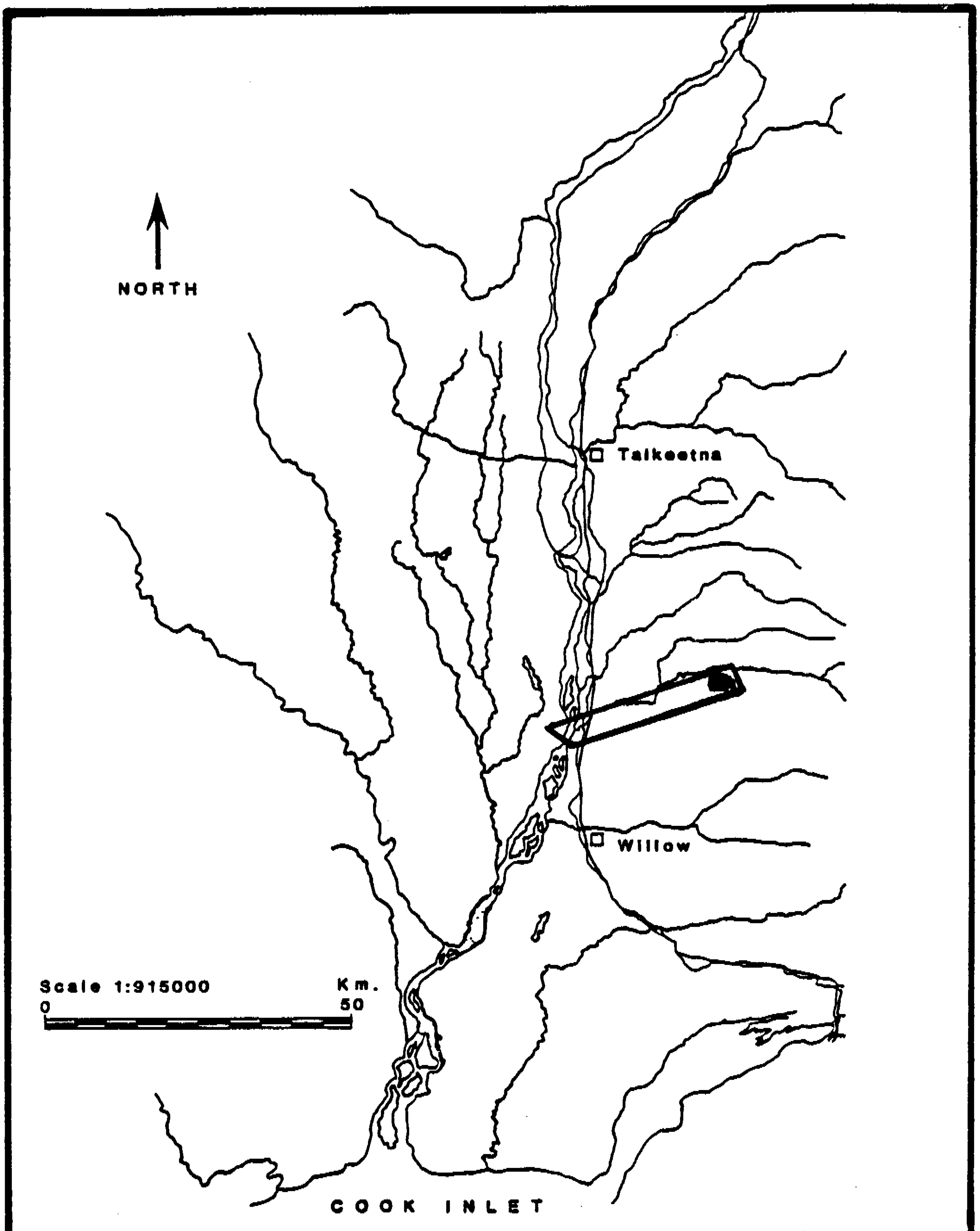

Fig. 8. Polygon encompassing relocations or moose radio-marked in the Witna Mtn. subarea (⬤).

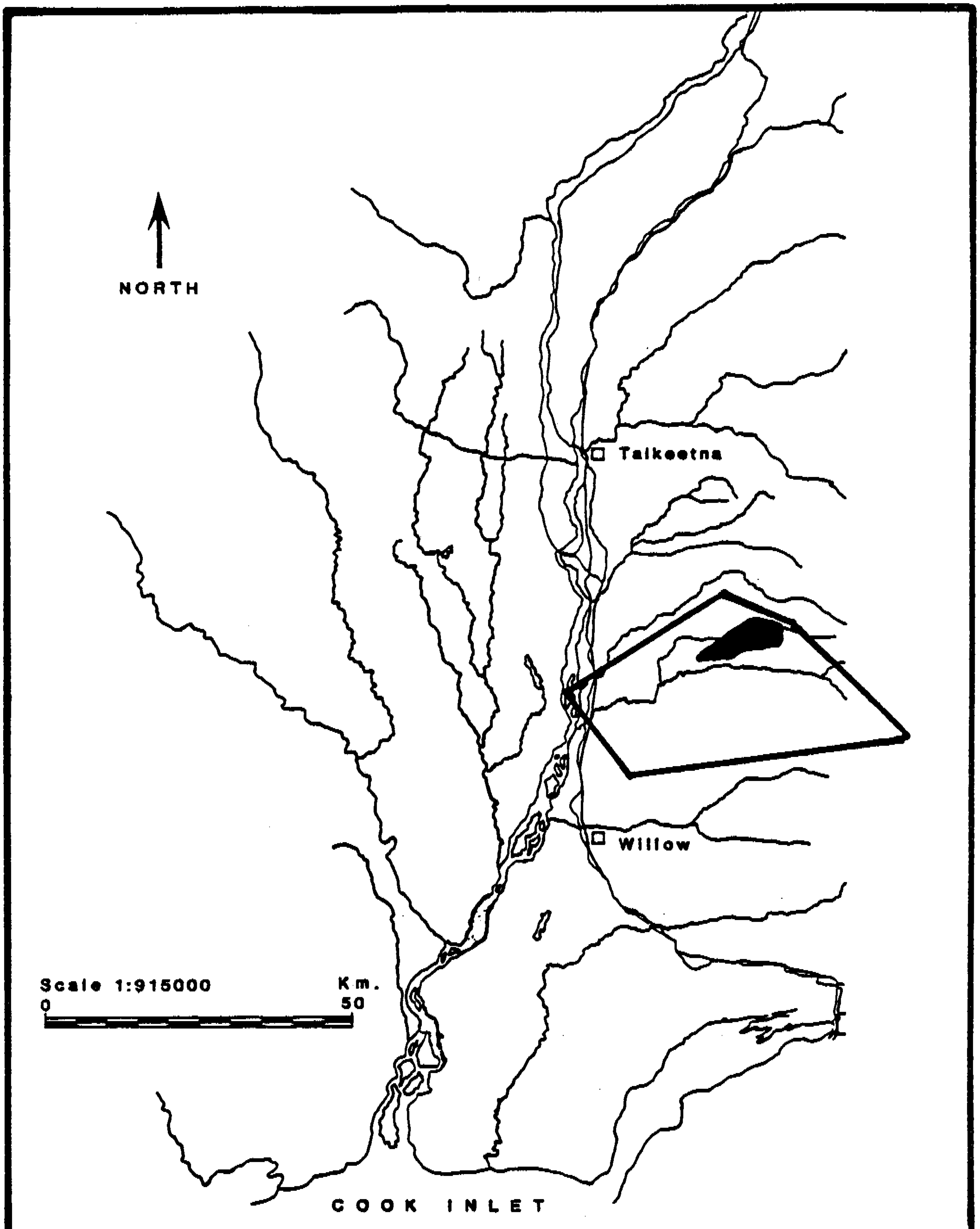

Fig. 9. Polygon encompassing relocations for moose radio-marked in the Brownie Mtn. subarea (●).

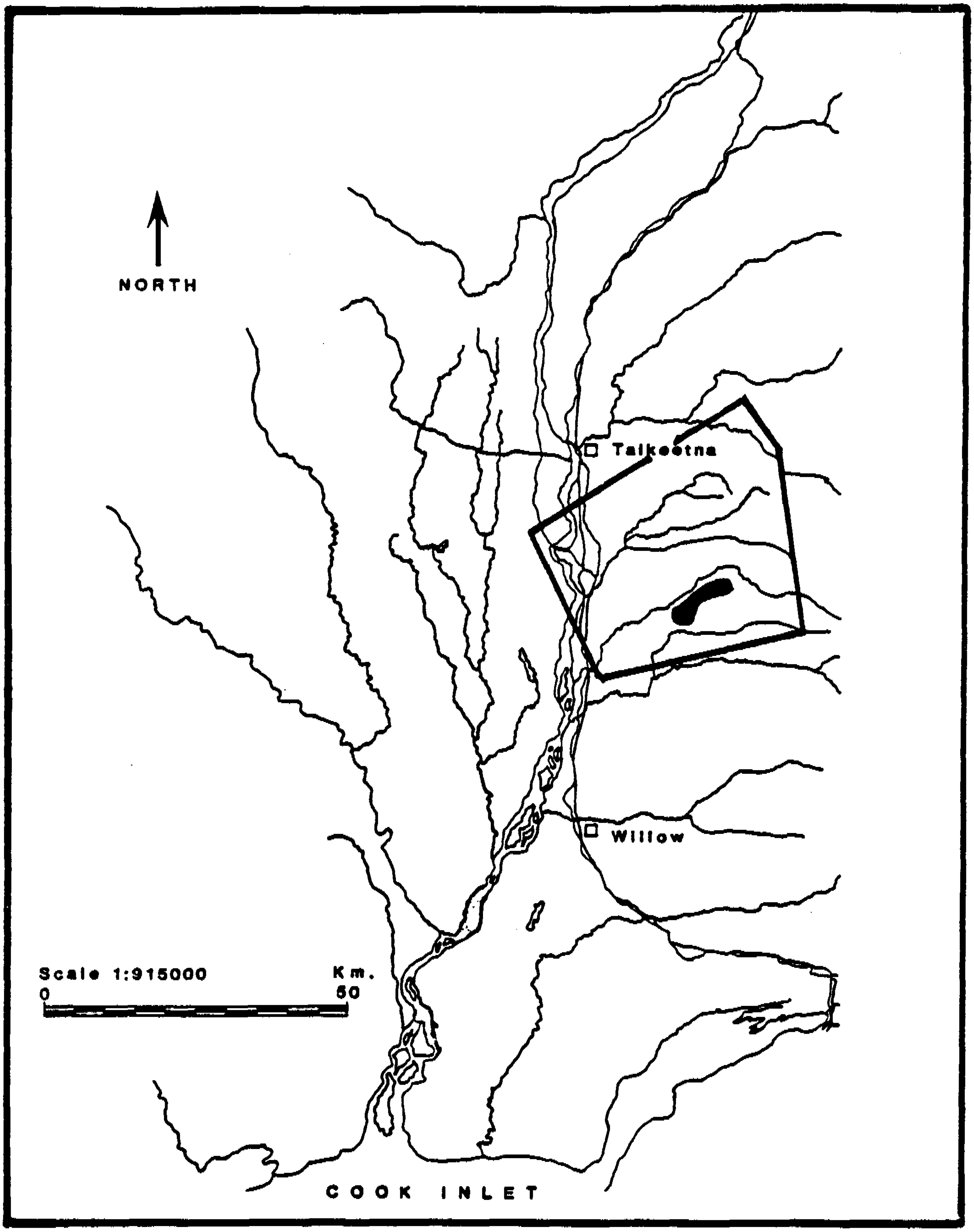

Fig. 10. Polygon encompassing relocations for moose radio-marked in the Wolverine Mtn. subarea (●).

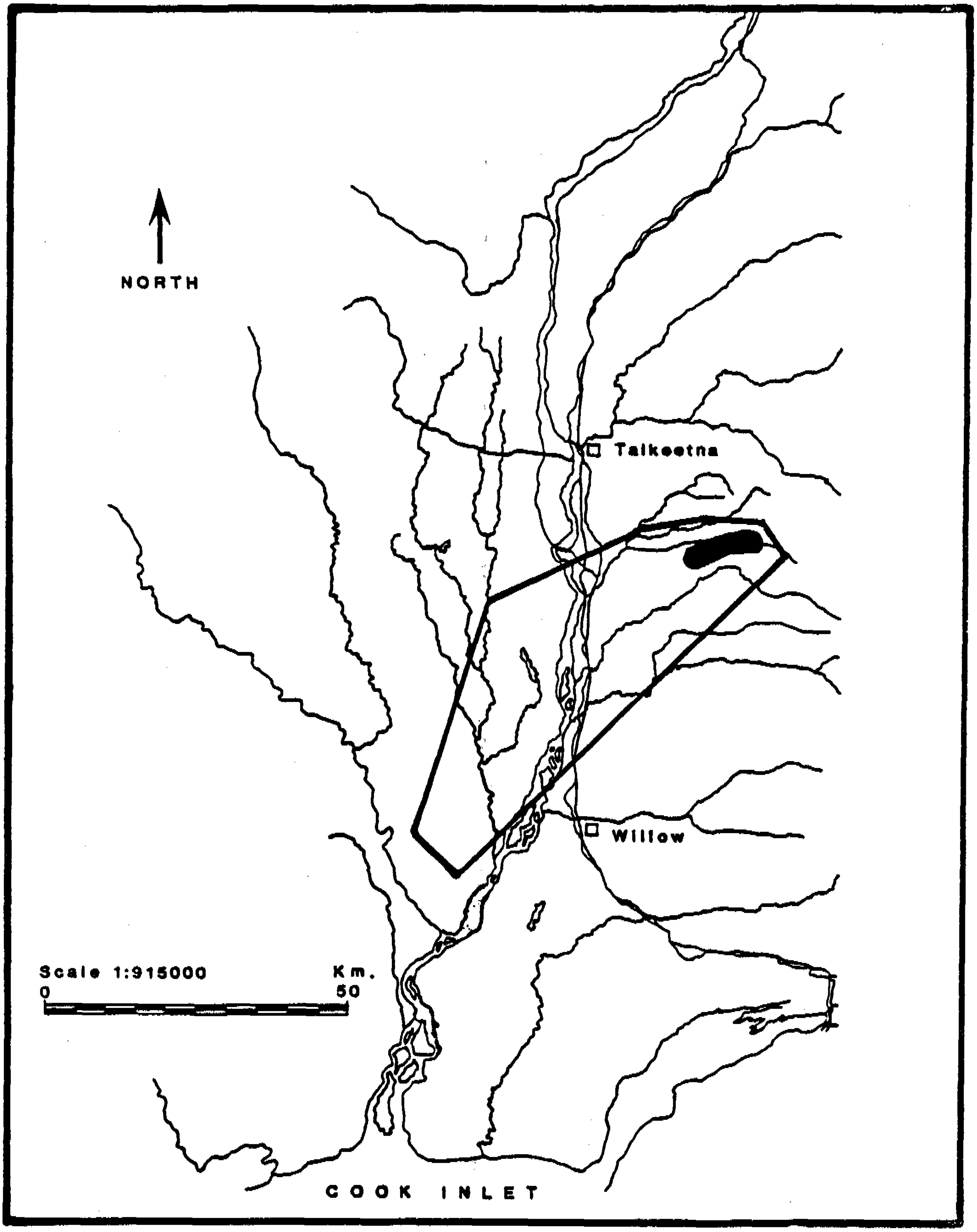

Fig. 11. Polygon encompassing relocations for moose radio-marked in the Sunshine Mtns. subarea (●).

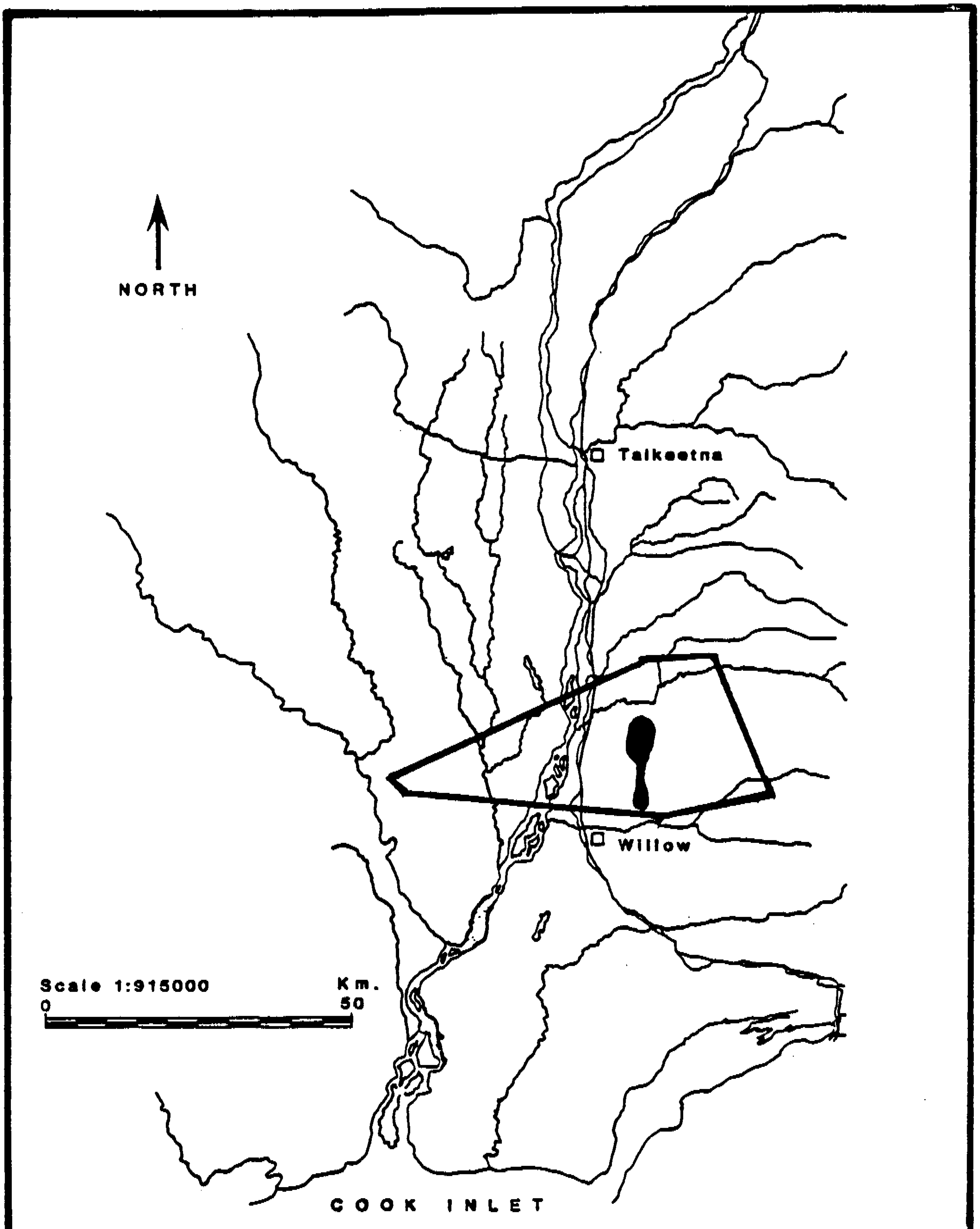

Fig. 12. Polygon encompassing relocations for moose radio-marked in the Kashwitna Forest subarea (●).

Table 1. Number of moose observed on periodic surveys in alpine areas of the Talkeetna Mountains foothills in southcentral Alaska during 2 winters, 1985-87.

	Winter											
	1985-86					1986-87						
Area[a]	4 Oct	17 Oct	8 Nov	18 Nov	3 Dec	23 Feb	31 Mar	17 Apr	26 Nov	24 Dec	15 Jan	2 Mar
A	37	109	264	302	260	275	191	40	408	120	47	20
B	0	19	37	50	54	33	26	15	38	45	11	9
C	5	148	262	268	313	164	121	59	492	43	15	15
D	0	9	24	19	20	42	13	11	101	6	9	26
E	0	25	110	125	112	104	96	49	197	61	41	30
F	0	41	54	129	93	32	22	14	148	18	8	14
G	0	2	21	26	39	50	21	14	21	56	51	19
Total	42	353	775	919	890	703	487	202	1,405	349	181	133

[a] Areas A, B, C, D, E, F, and G = Bald Mountain, Moss Mountain, Willow Mountain, Witna Mountain, Brownie Mountain, Wolverine Mountain, and Sunshine Mountain, respectively.

Table 2. Herd composition for moose observed in alpine subareas of the Talkeetna Mountains foothills in southcentral Alaska, 18 November 1985.

Subarea	Moose		At[a]		Al		C		At:	C:
	No.	%	No.	%	No.	%	No.	%	100 Al	100 Al
Bald Mountain	302	33	66	22	189	63	47	16	35	25
Moss Mountain	50	5	7	14	35	70	8	16	20	23
Willow Mountain	268	29	81	30	173	65	14	5	47	8
Witna Mountain	19	2	6	32	8	42	5	26	75	63
Brownie Mountain	125	14	41	33	71	57	13	10	58	18
Wolverine Mountain	129	14	23	18	90	70	16	12	26	18
Sunshine Mountain	26	3	8	31	17	65	1	4	47	6
Total or Avg.	919	100	232	25	583	63	104	11	40	18

[a] At = antlered moose, Al = antlerless adult moose and C = calf moose.

Table 3. Herd composition for moose observed in alpine subareas of the Talkeetna Mountains foothills in southcentral Alaska, 26 November 1986.

Subarea	Moose		At[a]		Al		C		At:	C:
	No.	%	No.	%	No.	%	No.	%	100 Al	100 Al
Bald Mountain	408	29	47	12	281	69	80	20	17	28
Moss Mountain	38	3	10	26	25	66	3	8	40	12
Willow Mountain	492	35	108	22	287	58	97	20	38	34
Witna Mountain	101	7	25	25	63	62	13	13	40	21
Brownie Mountain	197	14	40	20	138	70	19	10	29	14
Wolverine Mountain	148	11	22	15	104	70	22	15	21	21
Sunshine Mountain	21	1	2	10	14	67	5	24	14	36
Total or Avg.	1,405	100	254	18	912	65	239	17	28	26

[a] At = antlered moose, Al = antlerless adult moose and C = calf moose.

Table 4. Herd composition for moose observed in subsections of the Kashwitna forest survey area in southcentral Alaska, 7 January and 6 February 1987.

Survey date	Subsection[a]	Number of Moose[b]				
		At	Al	C	Total	%C
7 Jan	a	0	8	0	8	0
	b	0	18	4	22	18
	c	1	15	4	20	20
	d	0	16	4	20	20
	e	0	6	1	7	14
	f	6	55	13	74	18
	Total	7	118	26	151	17
6 Feb	a	0	7	4	11	36
	b	0	5	0	5	0
	c	0	14	1	15	7
	d	0	8	0	8	0
	e	0	8	2	10	20
	f	0	44	5	49	10
	Total	0	86	12	98	12

[a] Subsections a, b, c, d, e, and f were estimated to encompass 10, 13, 10, 10, 11, and 16 mi^2, respectively.

[b] At = antlered moose, Al = antlerless adult moose and C = calf moose.

Table 5. Moose herd composition (At = antlered adults, Al = antlerless adults, Cf = calves, and carcasses = Cs) observed on aerial surveys of Moose Creek, Kroto Creek, Kroto Creek Islands, and Yentna River areas, 1984-1987.

		Moose						
		At		Al		Cf		Cs
Location	Date	No.	%	No.	%	No.	%	No.
Moose	5 Mar 84	0	0	58	87	9	13	0
	29 Nov 84	5	16	18	56	9	28	0
	12 Dec 84	11	14	50	62	20	25	0
	28 Dec 84	13	11	70	61	32	28	0
	11 Jan 85	8	6	114	83	16	12	0
	7 Feb 85	0	0	123	84	24	16	0
	20 Feb 85	0	0	162	90	19	10	1
	5 Mar 85	0	0	155	92	14	8	0
	9 Mar 85	0	0	143	91	15	9	2
	20 Mar 85	0	0	106	91	11	9	3
	28 Mar 85	0	0	69	99	1	1	13
	4 Apr 85	0	0	62	93	5	7	10
	16 Apr 85	0	0	41	93	3	7	18
	18 Mar 87	0	0	47	89	6	11	12
Kroto Ck.	5 Mar 84	0	0	37	93	3	7	13
	29 Nov 84	46	32	71	50	25	18	0
	12 Dec 84	56	22	150	59	48	19	0
	27 Dec 84	21	12	124	70	32	18	0
	11 Jan 85	5	3	141	80	30	17	0
	7 Feb 85	0	0	127	88	17	12	0
	20 Feb 85	0	0	134	89	17	11	4
	5 Mar 85	1	1	81	90	8	9	4
	9 Mar 85	0	0	61	95	3	5	2
	20 Mar 85	0	0	36	97	1	3	1
	28 Mar 85	0	0	29	100	0	0	2
	4 Apr 85	0	0	18	95	1	5	9
	16 Apr 85	0	0	11	92	1	8	6
	18 Mar 87	0	0	34	89	4	11	9
Kroto Is.	20 Mar 85	0	0	39	89	5	11	0
	28 Mar 85	0	0	29	94	2	6	3
	4 Apr 85	0	0	27	87	4	13	1
Yentna	22 Feb 85	0	0	133	92	11	8	9

Table 5. (cont'd)

		Moose						
		At		Al		Cf		Cs
Location	Date	No.	%	No.	%	No.	%	No.
Alexander	29 Nov 84	12	23	27	51	14	26	0
	12 Dec 84	17	15	68	62	25	23	0
	27 Dec 84	11	9	94	79	14	12	0
	11 Jan 85	3	1	191	78	52	21	0
	7 Feb 85	0	0	172	86	28	14	2
	20 Feb 85	0	0	149	90	16	10	3
	5 Mar 85	0	0	186	88	26	12	0
	9 Mar 85	0	0	170	90	18	10	1
	20 Mar 85	1	1	142	91	13	8	3
	28 Mar 85	0	0	134	94	8	6	7
	4 Apr 85	0	0	151	94	9	6	6
	16 Apr 85	0	0	124	92	11	8	6
	18 Feb 87	0	0	125	85	22	15	0
	12 Mar 87	0	0	85	85	15	15	0

Table 6. Herd composition (At = antlered, Al = antlerless adults, and C = calves) for moose observed on aerial surveys of Moose, Kroto, and Alexander Creeks, 12 December 1985.

Subarea	Moose No.	Moose %	At[a] No.	At[a] %	Al No.	Al %	C No.	C %	At: 100 Al	C: 100 Al
Moose	81	11	14	50	62	20	25	22		40
Kroto	254	56	22	150	59	48	19	37		32
Alexander	110	17	15	68	62	25	23	25		37

[a] At = Antlered moose, Al = antlerless adult moose and C = calf moose.

Table 7. Sex ratio of feti from dams killed by hunters and by collisions with trains or vehicles in Game Management Subunit 14B during the winters of 1955-58 and 1980-83.

Sex[a]	Collision kill[b]				Hunter kill[c]			
	1955 -56	1956 -57	1957 -58	Total or Average	1980 -81	1981 -82	1982 -83	Total or Average
M	6	20	4	30	9	10	12	31
F	7	19	3	29	4	5	4	13
M:1 F	0.9	1.1	1.3	1.0	2.3	2.0	3.0	2.4

[a] M = males and F = females.
[b] Data from Rausch 1959, Table 5 p.20-22.
[c] Data from ADF&G files.

Table 8. Sex of feti in multiparous litters of moose killed by collisions with trains and vehicles and hunters in Game Management Subunit 14B in the winters 1956-58 and 1980-83.

Sex[a]	Collision kill[b] 1955 -56	1956 -57	1957 -58	Total or Average	Hunter kill[c] 1980 -81	1981 -82	1982 -83	Total or Average
FF	0	3	0	3	0	0	1	1
FM	1	1	1	3	2	1	1	4
MM	0	2	0	2	2	2	2	6
MMF	0	0	0	0	0	1	0	1
TM	1	5	1	7	6	7	5	18
TF	1	7	1	9	2	2	3	7
M:1 F	1.0	0.7	1.0	0.8	3.0	3.5	1.7	2.6

[a] FF = 2 females, FM = 1 female and 1 male, MM = 2 males, MMF - 2 males and 1 female, TM - total males, TF = total females, and M:1F = males per 1 female.

[b] Data from Rausch 1959, Table 5 p.20-22.

[c] Data from ADF&G files.

Table 9. Mortality factors for radio-marked moose in the Talkeetna Mountains (N=49) and along the Susitna River floodplain (N=15).

Mortality Factors	Study Talkeetna No.	%	to Susitna River No.	%	Total No.	%
Hunter kill	8	47	4	50	12	48
Winter kill	2	12	2	25	4	16
Predation	3	18	0	0	3	12
Injury/wounding	2	12	0	0	2	8
Poaching	2	12	1	13	3	12
Collision with train	0	0	1	13	1	4
Total	17	101	8	101	25	100

[a] In cases where actual cause of death was uncertain, individuals were assigned to the most probable cause after considering circumstances.

Table 10. Capture location, sex composition, and fate of radio-marked moose in subareas of the lower Susitna River Valley in southcentral Alaska, 1980-87.

Subarea	Males[a]			Females			Total			
	Mk	Hk	OK	Mk	Hk	OK	MK	Hk	Off	OK
Bald Mountain	5	3	2	5(1)	0	3	10	3	5	5
Moss Mountain	1	1	0	1	0	0	2	1	2	0
Willow Mountain	6	1	4	8	0	6	14	1	4	10
Witna Mountain	0	0	0	1	0	1	1	0	0	1
Brownie Mountain	3	0	2	4	0	4	7	0	1	6
Wolverine Mountain	2	1	0	3(1)	1	2	5	2	3	2
Sunshine Mountain	2	1	1	1	0	1	3	1	1	2
Kashwitna Forest	0	0	0	7	0	6	7	0	1	6
All subareas	19	7	9	30(2)	1	23	49	8	17	32
Susitna River[b]	3	2	0	12	2	7	15	4	8	7
Total	22	9	9	42(2)	3	30	64	12	25	39

[a] Mk, Hk, Ok, and Off = No. moose marked, killed by hunters, presently under surveillance, and no longer under surveillance, respectively. Numbers in parentheses indicate moose that were captured and marked but subsequently died as a result of capture procedures. These moose are excluded from other totals.

[b] Radio-marked moose in parallel studies and which provided supplemental information for this study.

APPENDIX

Table A. Fate and capture data for radio-marked moose in subareas of the lower Susitna River Valley in southcentral Alaska, 1980-87.

Capture date	Capture location	Sex	Age[a]	Number: Left ear tag	Right ear tag	Visual collar	Transmitter	Status[b]
12/23/85	Bald Mt.	M	3	2354	1546	31	18135	HK
12/23/85	Bald Mt.	F	8	2360	1506	262	18136	CM
12/23/85	Bald Mt.	F	8	2389	2388	33	18130	OK
12/23/85	Bald Mt.	F	5	2400	2395	27	10591	OK
12/23/85	Bald Mt.	F	5	1510	2485	29	10598	OK
12/23/85	Bald Mt.	F	2	2392	2399	371	6359	WK
12/23/85	Bald Mt.	M	1	2397	2396	35	18131	HK
12/23/85	Willow Mt.	F	10	1551	1524	34	18137	OK
12/23/85	Willow Mt.	F	6	1575	1570	36	18138	OK
12/23/85	Willow Mt.	F	4	2482	2440	3	6397	PK
12/23/85	Willow Mt.	F	4	2433	2368	9	6396	PK
12/23/85	Willow Mt.	M	8	1568	1569	8	6383	WM
12/23/85	Willow Mt.	M	4	2394	2391	32	18134	OK
12/23/85	Willow Mt.	M	5	2398	2393	5	6374	OK
12/26/85	Willow Mt.	M	6	1571	2497	28	6425	OK
12/26/85	Bald Mt.	F	3	2357	1512	2	12807	IK
12/26/85	Bald Mt.	M	12	1573	1574	1	10498	OK
12/26/85	Bald Mt.	M	9	1501	1554	4	6372	OK
12/26/85	Bald Mt.	M	4	1504	2390	7	6356	HK
12/26/85	Moss Mt.	F	15	1538	1513	38	10498	IK
12/26/85	Moss Mt.	M	4	1517	1532	25	6438	HK
01/02/86	Brownie Mt.	F	7	2387	2382	49	6460	OK
01/02/86	Brownie Mt.	F	4	2380	2386	50	6495	OK
01/02/86	Brownie Mt.	M	3	2378	2385	54	6499	OK
01/02/86	Brownie Mt.	M	4	2381	2383	52	6454	WK
01/02/86	Brownie Mt.	M	3	2379	2384	53	6504	OK
01/02/86	Witna Mt.	F	5	1508	1503	55	6402	OK
01/02/86	Wolverine Mt.	F	9	2376	2377	51	6496	OK
01/07/86	Brownie Mt.	F	3	1562	2414	43	10496	OK
01/07/86	Brownie Mt.	M	8	1528	2409	30	6411	OK
01/07/86	Sunshine Mt.	F	3	1511	1555	11	6410	OK
01/07/86	Sunshine Mt.	M	5	1560	1561	47	6500	OK
01/07/86	Sunshine Mt.	M	3	2411	2479	10	6494	HK
01/07/86	Wolverine Mt.	F	18	1586	2436	481	6501	CM
01/07/86	Wolverine Mt.	F	12	2423	2370	46	18133	HK
01/07/86	Wolverine Mt.	M	5	1505	1509	441	10594	HK
02/04/86	Wolverine Mt.	M	7	1698	2158	48	6501	IM
02/04/86	Wolverine Mt.	F	13	2073	2150	581	23933	OK
02/04/86	Willow Mt.	F	8	2071	2106	721	6458	OK
02/04/86	Willow Mt.	F	4	2161	2116	60	6457	OK

Table A. Cont.

Capture date	Capture location	Sex	Age[a]	Number: Left ear tag	Right ear tag	Visual collar	Transmitter	Status[b]
02/04/86	Willow Mt.	M	7	2162	2190	16	6365	HK
02/04/86	Willow Mt.	M	11	2200	2059	17	6380	OK
02/04/86	Willow Mt.	F	3	2156	1652	61	6517	OK
02/04/86	Willow Mt.	F	3	2101	2142	261	18136	OK
01/28/87	Kashwitna For.	F	8	42	50	21	26100	PK
01/28/87	Kashwitna For.	F	3	39	43	731	26101	OK
01/28/87	Kashwitna For.	F	1	62	44	24	26104	OK
01/28/87	Kashwitna For.	F	6	69	67	25	26106	OK
01/28/87	Kashwitna For.	F	18	80	45	15	26107	OK
01/28/87	Kashwitna For.	F	7	--	--	23	26109	OK
01/28/87	Kashwitna For.	F	4	66	38	14	26110	OK
04/17/80	Susitna River	F	2	15753	15752	26	10603	OK
04/17/80	Susitna River	F	5	15754	15755	22	10592	OK
04/17/80	Susitna River	F	2	15737	15378	23	10594	RK
04/17/80	Susitna River	M	2	15371	15370	27	6388	HK
03/10/81	Susitna River	F	11	8442	--	79	6502	HK
03/10/81	Susitna River	M	5	--	8453	84	6460	HK
02/24/82	Susitna River	F	6	16984	--	94	10597	OK
01/31/84	Susitna River	F	4	16	--	812	6424	OK
02/24/82	Susitna River	F	3	16704	--	100	10602	OK
02/24/82	Susitna River	F	2	16998	--	41	6494	HK
01/03/85	Susitna River	F	9	2149	2076	2	13128	OK
02/24/82	Susitna River	F	7	--	16937	87	10593	WK
03/10/81	Susitna River	M	10	8477	--	65	6413	IK
01/31/84	Susitna River	F	7	6	17	61	6459	OK
02/26/82	Susitna River	F	11	--	--	39	10596	WK

[a] Age determined from incisor wear; assigned age probably encompassed within intervals of: 1, 2-3, 4-6, 7-12, and 12+ years.

[b] OK = alive and functional; HK = hunter kill; WK = winter kill; CM = capture/drug related mortality; PK = predator kill, these are not documented but presumed to be most likely cause of death; IK = illegal kill; WM = hunting/wound mortality and IM = mortality from injury/wounding. Date for all OK = 05/27/87.