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FACTORS LIMITING MOOSE POPULATION GROWTH IN GAME MANAGEMENT UNIT 20E

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Progress Report
Federal Aid in Wildlife Restoration
Project W-22-3, W-22-4, Job 1.37R

(Printed October 1985)

PROGRESS REPORT (RESEARCH)

State: Alaska

Cooperators: None

Project No.: W-22-3, W-22-4 Project Title: Big Game Investigations

Job No.: 1.37R Job Title: Factors Limiting Moose Population Growth in Game Management Unit 20E

Period Covered: 1 July 1983-1 September 1984

SUMMARY

Preliminary data are presented to test 2 hypotheses: (1) predation limits moose (Alces alces) population growth in Game Management Unit (GMU) 20E, and (2) food is limiting moose population growth. Data suggest rejection of the food-limiting hypothesis. The predation-limiting hypothesis could not be conclusively tested, but preliminary data indicate predation is the likely limiting factor.

Fall moose/wolf (Canis lupus) ratios in the experimental area were only 16/1 and 14/1 during 1982 and 1983, respectively, following wolf removal, compared to the minimum ratio of about 40/1 needed to more clearly evaluate the effects of wolf predation on moose and to minimize the effects of wolf predation while investigating the effects of bear predation. Moose/grizzly bear (Ursus arctos) ratios (about 4/1) and moose/grizzly and black bear (Ursus americanus) ratios (about 3/1) are lower in GMU 20E than in other studies where bear predation alone was an important limiting factor on moose. The combined effects of predation by grizzly bears, black bears, and wolves on this low-density moose population (about 2 moose/1 predator) strongly suggest that predators may be limiting moose population growth in GMU 20E.

Numbers of wolves preying on moose in the experimental area ranged from 125 prior to wolf removal (fall 1981) to 52 in spring 1982, 77 in fall 1982, 46 in spring 1983, 87 in fall 1983, and 62 in spring 1984. Overall, moose were the primary winter prey of wolves. Caribou (Rangifer tarandus) were preyed on to some extent by all wolf packs and a few packs consumed mostly caribou, presumably in direct proportion to the availability of caribou. Radio-collared wolves were not observed to abandon their home ranges to maintain contact with migrating caribou.

Moose calf mortality during the 1st 8 weeks after birth was 75%: 63% due to predators and 12% due to accidents. Grizzly bears killed 17 (52%) of the radio-collared calves, wolves killed 3 (9%), black bears killed 1 (3%), and 4 (12%) drowned.

Rejection of the hypothesis that food was limiting moose in GMU 20E was based on: (1) high browse availability and low overall use (<5%) of browse, (2) high pregnancy rates (100%) in 27 adult female moose examined, (3) relatively large morphometric measurements and high body condition indices of adult moose, (4) high marrow fat content of predator-killed adult moose, and (5) high twinning rates (45-50%).

Key words: Alaska, black bears, browse evaluation, calf mortality, grizzly bears, moose, nutritional condition, predator-prey relationships, reproduction, wolves.

CONTENTS

BACKGROUND

Moose (*Alces alces*) populations continue to decline or remain at low densities throughout much of Interior Alaska. Many past management actions, such as shortening or eliminating hunting seasons, have not been effective in increasing moose numbers. To manage moose more effectively, limiting factors of selected moose populations must be studied in detail so appropriate management actions can be taken. Knowledge gained from these detailed studies will allow more accurate predictions of the likely limiting factors in similar areas where information is less definitive.

Federal predator poisoning in Game Management Unit (GMU) 20E during 1947-59 (Davis et al. 1978*a*) allowed moose to attain densities of approximately 2.6 moose/km² (1 moose/mi²) during the early 1960's. Following the termination of predator poisoning, a 70-90% decline in numbers of moose occurred between the mid-1960's and the early 1980's. This decline corresponded to a period of high wolf (*Canis lupus*) populations (Davis et al. 1978*a*), although wolf numbers declined during the 1970's (D. Grangaard, pers. observ.). Alaska Department of Fish and Game (ADF&G) wolf removal was initiated in GMU 20E in November 1981 to increase moose and caribou (*Rangifer tarandus*) numbers to levels approaching those of the 1950's and 1960's.

Moose-predator relationships in GMU 20E contrast sharply with moose-predator studies elsewhere in Alaska, particularly in regard to the relatively low moose densities and moose/predator ratios in GMU 20E. Using current population estimation techniques, we estimated that 630 ± 140 moose occupied 7,500 km² (2,900 mi²) of moose habitat in the southwest quarter of GMU 20E in fall 1981. The mean moose density was 0.5 moose/km² (0.2 moose/mi²), which is by far the lowest density recorded in Alaska using current techniques. This low density and continued poor recruitment stimulated the Alaska Board of Game to initiate wolf removal in November 1981. In other areas where predators were removed to increase moose numbers (GMU 13 and 20A), moose densities were initially relatively high (3-10 times greater than in GMU 20E), but recruitment was similarly poor.

Man's harvest of moose has not been a major factor limiting moose population growth in GMU 20E. Harvest of moose has been relatively low since the 1960's and good hunting access has been limited to the Taylor Highway. If hunting was once a limiting factor, its effects would have been localized along the highway. Antlerless moose seasons were discontinued after 1974 and the hunting seasons closed from 1977 through 1981. Yet, the moose population continued to decline. Harvests from

1970 through 1976 ranged only from about 70 to 100 moose (1 to 2% of the population), and bull harvests since 1981 (10-day seasons) were 29 in 1982 and 46 in 1983 (less than 3% of the population).

Several winters of deep snowfall have adversely affected moose in interior Alaska (Gasaway et al. 1983). Unusually deep snowfall occurred in the experimental area in 1965-66, 1966-67, 1970-71, and 1978-79. However, the moose population continued to decline during years of low snowfall.

We propose to test hypotheses about factors currently limiting moose population growth in GMU 20E through actions that will lead directly to their acceptance or rejection. Predator removal (Bergerud 1971, Ballard et al. 1980, Gasaway et al. 1983) has allowed a more rapid and accurate assessment of factors limiting ungulates than strictly using the "collar-and-watch" approach; therefore, we will rely heavily on predator removal to provide definitive tests of the following 2 hypotheses:

H_1: PREDATION LIMITS MOOSE POPULATION GROWTH.

Actions to be taken and tests of the hypothesis:

1. Continue to reduce wolves in the experimental area in 1985-88. Control areas (without wolf removal) are in the nearby Ladue River, Sixtymile River, and Washington Creek drainages.

a. Accept H_1 if calf survival and numbers of moose increase in response to wolf removal by fall 1988.

b. Rejection of H_1 not possible if no positive population response. Assess bear predation.

2. Radio-collar 30 calf moose in experimental area in 1984 to assess bear predation and remaining wolf predation.

a. Supports acceptance of H_1 if predation is a large mortality source.

b. Supports rejection of H_1 if little predation occurs.

3. Radio-collar 15 grizzly bears (Ursus arctos) to determine predation rates on adult moose in 1985-86.

a. Supports acceptance of H_1 if bears regularly kill adult moose.

b. Supports rejection of H_1 if bears kill few moose.

4. If grizzly bears are implicated, reduce bears in experimental area in 1986-89 while maintaining wolves at low density.

a. Accept H_1 if moose survival increases and population grows.

b. Reject H_1 if no change in numbers of moose and if black bears (Ursus americanus) are not implicated as major predators on calves.

5. If black bears are a major predator on calves and there is little response by moose to wolf and grizzly reductions, reduce black bear abundance.

a. Accept H_1 if moose survival increases and population grows.

b. Reject H_1 if no change in moose survival occurs.

H_2: WINTER FOOD LIMITS MOOSE POPULATION GROWTH.

Actions to be taken and tests of the hypothesis:

1. Estimate browse availability and utilization in experimental and control areas.

a. Accept H_2 if there is very high browse utilization.

b. Reject H_2 if there is adequate browse and low rates of use.

2. Measure moose population trend and calf survival in experimental and control areas after predator removal.

a. Supports acceptance of H_2 if no positive moose population response.

b. Reject H_2 if population increases in experimental area with no improvement to vegetation.

3. Assess condition of live cow moose by blood chemistry, physical status, and morphometric measurement.

a. Accept H_2 if moose are in poor condition during a winter of normal weather.

b. Reject H_2 if moose are in good condition as determined by standards set by Franzmann and Schwartz (1983) and Franzmann and LeResche (1978).

4. Determine pregnancy and twinning rates in 1984.

a. Supports acceptance of H_2 if rates are low (<80% pregnancy rate for females >2 years old and <20% twinning rate).

b. Supports rejection of H_2 if rates are average or above average.

5. Determine marrow fat content of adult moose killed by predators.

a. Supports acceptance of H_2 if fat content is consistently low (<15%) for adult moose.

b. Supports rejection of H_2 if average fat content is >50%.

These actions were proposed in 1981 and will be refined as the study progresses.

OBJECTIVES

To determine if either predation or food limits the low-density moose population in GMU 20E; if predation is limiting, determine how much control managers need to exert over wolf and bear populations to allow a low-density moose population to rapidly grow; to correlate moose/predator ratios and moose population dynamics; and to apply findings to the management of other populations in Interior Alaska as appropriate.

STUDY AREA

The study area (Fig. 1) consists of an experimental area where research, management, and wolf removal are focused and 3 control areas (upper North Fork of the Ladue River, upper Sixtymile River, and Washington Creek) where wolf numbers have not been reduced. Moose population composition in control areas was compared with composition in the experimental area to assess results of the wolf removal program. Each control area had 1 trend count area (119-161 km², 46-62 mi²) for assessing moose population composition. The experimental area includes 1 trend count area (108 km^2, 42 mi^2) north of Mount Fairplay and extensive contour count areas throughout much of the area.

The experimental area (9,800 km^2, 3,800 mi^2), located in east-central Alaska north of Tok (Fig. 1), consists of rolling hills of mature black spruce (Picea mariana) interspersed with subalpine and alpine areas, poorly drained river flats, burned spruce, and drainages bordered by willow (Salix spp.), dwarf birch (Betula spp.), and alder (Alnus spp.). Subalpine vegetation consists primarily of dwarf birch and willow, interspersed with willow-lined drainages, and is used extensively by moose in September, October, and early November. Most of the upper Sixtymile River count area and a portion of the North Fork Ladue count area are in subalpine habitat. Poorly drained river flats occur most notably in the Mosquito Fork drainage (Mosquito Flats) and upper Middle Fork and are dominated by dwarf birch, willows, and sedge (Carex spp.) meadows. All 30 adult moose were radio-collared in the northeast portion of the Mosquito Flats, an important wintering area, in March. Extensive burns occurred during the mid-to-late 1960's in the experimental area north and northeast of Mount Fairplay, and in the North Fork Ladue and Washington Creek control areas. All 3 areas are now prime moose habitat with willows and birch dominating regrowth.

Elevations in most of the experimental area range from 600 m (2,000 ft) in valley bottoms to 1,000 m (3,300 ft) at treeline. Elevations of 6 mountain peaks in the experimental area range from 1,500 to 1,750 m (5,000-5,800 ft). The upper Sixtymile and North Fork Ladue control areas have elevations ranging from 600-1,650 m (2,000-5,400 ft), and the Washington Creek control area ranges in elevation from 300-650 m (1,000-2,100 ft) with nearby mountain peaks of 1,600-1,700 m (5,200-5,600 ft).

The climate in the experimental and control areas is typically more continental (colder in winter and drier year-round) than the remainder of Interior Alaska. Temperatures frequently reach 20 to 25 C in summer and -20 to -45 C in winter (Oct-Apr). Snow depths are generally below 55 cm (22 inches), and snow usually remains loosely packed except where windblown at high altitudes. Historical average snow depth on Mount Fairplay, in the experimental area, is 46 cm (18 inches) (U.S. Bureau of Land Management files, Tok, Alaska).

Large carnivores inhabiting the study area include wolves, black bears, and grizzly bears. Their prey include moose, caribou, beavers (Castor canadensis), and snowshoe hares (Lepus americanus). Dall sheep (Ovis dalli) (about 100-150) are restricted to the northwest border of the experimental area. Some Fortymile Herd caribou (numbering about 13,000 animals) spend a portion of most years (usually winter) in the experimental and control areas (Davis et al. 1978b). Seasonal distribution of caribou fluctuates greatly between years, but in most years caribou spend more time in the experimental area than in control areas. Snowshoe hares have not been abundant in the study area since the early 1970's.

PROCEDURES

Wolf Population Status

Estimating Wolf Abundance:

The primary technique used to determine distribution and abundance of wolves was to count tracks in snow from the air during mid-to-late winter (Stephenson 1978, Gasaway et al. 1983). During each winter (1980-81 through 1983-84), 1 to 3 wolves in several packs were captured in leghold traps or locking snares, immobilized with 12.5 mg Sernylan, and radio-collared (Telonics, Mesa, Ariz.) to assist in estimating wolf abundance and distribution. Spring population size was the sum of observed wolves and wolf tracks thought to represent different individuals in packs plus 10% for single wolves not associated with packs (Mech 1973). Fall population size, which was used to calculate prey/wolf ratios and population trend, was equal to the spring population plus the number of wolves harvested prior to surveys. Estimates of fall populations are probably underestimates because wolves dying from natural causes during winter could not be included.

Aerial wolf surveys in the experimental area were conducted during winters 1981-84 and used to estimate wolf abundance in the preceding falls. During winters 1981-84, approximately 80, 70, and 170 flight hours, respectively, were spent on wolf surveys, radio-collaring, and radio-tracking. Total flight hours during which wolf population and movement data were gathered numbered 2-4 times the above figures, when including flight hours for wolf removal, wolf recovery, and moose surveys. Information was also solicited from local trappers and pilots in each of these years.

Removal of Wolves:

During winters 1980-83 and early winter 1983-84, ADF&G removed wolves from the study area primarily by shooting them from a helicopter or fixed-wing aircraft. ADF&G wolf removal, restricted in winter 1980-81 to GMU 20D, involved removing wolves from 2 packs (Mansfield Creek and Divide packs) with territories that extended into the experimental area. Some wolves were also taken by ADF&G with leghold traps and snares. A statewide mandatory reporting program for wolf harvest began in 1972 and provided reliable information on the number, sex, and location of wolves harvested by hunters and trappers in the study area.

Food Habits and Predation Rates:

Knowledge of wolf food habits and predation rates in the experimental area is based on observations of the carcasses of large prey during monitoring of both radio-marked and unmarked packs and on the stomach and intestinal contents and radiocesium (C^{137}) levels (Holleman and Stephenson 1981) of 42 wolf carcasses. Radiocesium levels in wolves indicate the relative importance of caribou and moose during winter and reflect food habits during the 30 days prior to death. These data were collected primarily during winters 1980-82; only 5 wolf carcasses were examined during winter 1982-83.

Age Structure, Reproductive Status, and Nutritional Condition:

Examination of 42 wolves killed in the experimental area during winters 1980-83 provided data on wolf nutritional condition, age, sex, and reproduction. Wolves less than 1 year old were identified by tooth development and wear and by the degree of epiphyseal closure at the distal end of the radius-ulna (Rausch 1967). Age of wolves greater than 1 year old was estimated from tooth development and wear. Uteri of females were examined for placental scars and fetuses. Ovaries were examined grossly for signs of reproductive activity, and, after sectioning, corpora lutea and corpora albicantia were counted. Nutritional condition is reflected by body weight, kidney fat (average weight of fat around each kidney), xiphoid fat (weight of the xiphoid fat deposit), and subcutaneous fat (total depth of fat layer over sternum, flank, and rump).

Moose Population Status

Estimating Parameters of Adult Moose:

Thirty adult female moose were immobilized and radio-collared (Telonics, Mesa, Ariz.) in the Mosquito Flats during 19-21 March 1984 to provide data on physical status, population age structure, pregnancy rates, birth rates, frequency of twinning, movements, and adult mortality. Pulse rate on radio collars doubled (150 beats/min) when movement ceased for 4 hours. Immobilization followed procedures described by Gasaway et al. (1978a) using 8 mg M99 (etorphine hydrochloride, Lemmon Company, Sellersville, Pa.), 200 mg Rompun (xylazine hydrochloride, Haver-Lockhart, Shawnee, Kans.), and

600 NF units lyophilized Wydase (hyaluronidase, Wyeth Laboratories, Philadelphia, Pa.) per dart. Data obtained from immobilized moose included: body condition (Franzmann et al. 1976), blood chemistry (Franzmann and LeResche 1978), morphometric measurements (Franzmann and Schwartz 1983), age from cementum annuli in 1st incisors (Sergeant and Pimlott 1959, Gasaway et al. 1978b), and pregnancy rate through rectal palpation (Arthur 1964). Amount of femur marrow fat in moose that were found dead was used as an index to their nutritional condition (Neiland 1970). All radio-collared cows were visually located daily from 15 to 24 May and at 3- to 7-day intervals thereafter until 15 June to estimate birth rate and frequency of twinning. A fixed-wing aircraft (Bellanca Scout or Piper Super Cub) equipped with telemetry gear (Telonics, Mesa, Ariz.) was used to locate moose. Cows with radio-collared calves were visually located daily (except 3 days) from date of collaring to 4 July and on a monthly basis with all radio-collared cows beginning 20 July. These locations provided data on movements and adult mortality rates (Gasaway et al. 1983). Audible mortality signals were monitored several times in June to more closely estimate adult mortality rate.

Estimating Timing, Rate, and Cause of Natural Mortality of Calf Moose:

Thirty-five calves were radio-collared to provide data on natural mortality; 2 were killed by their dams and classified as capture-related mortalities. Further discussion will pertain only to the 33 successfully radio-collared calves.

Description of calf radio collars deserves special mention. We attached mortality-mode radio transmitters (model SZB5, Telonics, Mesa, Ariz.) which pulsed at about 75 beats/min (normal mode). Pulse rate doubled when movement ceased for 1-2 hr (mortality mode). We sewed transmitters into an 8 cm x 10 cm pocket made in 4 layers of a 183 cm x 10 cm Ace brand bandage (Schwartz et al. 1983). The remaining bandage material served as the collar (2 layers of material), which was about 35 cm in circumference. Single layer zig-zag stitches with cotton thread were used exclusively, and antennas protruded from opposite ends of the collar. We wrote collar numbers on each collar and handled collars only with sterilized gloves. Transmitters were rinsed in alcohol to remove scent; collars were washed and well rinsed. Each collar was stored in a plastic bag.

Methods used to collar calves included searching for calves daily from 16 through 24 May from a fixed-wing aircraft (Bellanca Scout and Piper Super Cub) and a helicopter (Hughes 500). The helicopter hovered over the calf to help force the cow away while we caught and radio-collared the calf or calves. Gunshots were also used in a few instances to discourage the cow from interfering with calf capture. We wore sterilized latex gloves and held calves away from our torsos (Ballard et al. 1979). Disturbance to the cow and calf commonly lasted only 2 to 3 min in an effort to minimize cow-calf separation (Ballard et al. 1979). Four calves were collared on 16 May, 2 on 17 May, 7 on 18 May, 4 on 20 May, 10 on 21 May, 6 on 22 May, and 2 on 24 May.

To monitor timing and rate of calf mortality, we visually located radio-collared calves daily (except 3 days) from date of collaring to 4 July using fixed-wing aircraft. After 4 July, we located calves on 11 July, 20 July, and 14 August (the end of this reporting period).

All death sites were reached by helicopter. To assess cause of calf mortality, we examined and usually photographed all carcasses or remains of carcasses on the ground and recorded descriptions of carcass remains, death sites, and signs of predators (Ballard et al. 1979). We necropsied calves that were sufficiently intact.

Estimating Moose Population Composition:

Two types of surveys were flown to determine composition of the moose population, trend counts and contour counts. The 2 counts differ in that trend counts have specific boundaries and a prescribed search intensity (4-6 min/mi^2 of moose habitat). Contour counts are flown in roughly similar areas from year to year and at less intensive search patterns; efforts are made to fly the same pattern and intensity each year.

Trend counts were flown in 4 areas beginning in 1982; 3 were in control areas (the 1969 Washington Creek burn, the upper Sixtymile River, and the 1969 North Ladue River burn) and 1 in the experimental area immediately north of Mount Fairplay (the 1966 Chicken burn) (Fig. 1). Only the Washington Creek trend count area was flown in 1983 due to a scarcity of snow in other areas.

Contour counts have been flown annually since 1966 in the experimental area. Primary contour count areas have included Mount Veta, Mosquito Flats, Sixtymile Butte, and Mount Fairplay. Some areas were flown for several years and then abandoned (e.g., Taylor Mountain 1969-76) or expanded (e.g., Mount Fairplay) due to a scarcity of moose. New survey areas (e.g., upper Mosquito Fork) were also developed in recent years in attempts to obtain meaningful sample sizes and to compare calf survival between areas.

Estimating Browse Availability

The moose browse evaluation form and instructions for use are included as Appendix A. During 5 May-24 June 1982 and 16-26 May 1984, 5 and 24 transects were completed, respectively. Twenty transects were located in the Mosquito Fork drainage and 9 in the West Fork Dennison-Mount Fairplay area (Fig. 1).

RESULTS AND DISCUSSION

Testing the Predator-Limiting Hypothesis

Wolf Population Status:

Population Size and Pack Territories: The number of wolves with territories in or partially in the experimental area ranged from 46 to 125 during 1980-84. Known pack territories encompassed a total area of about 15,500 km² (6,000 mi²) (Table 1, Fig. 2-4). Densities ranged from 3 to 8 wolves/1,000 km² (9-21 wolves/1,000 mi²). Percentages of wolves removed by all causes during winters 1981-84 were 58%, 40%, and 29%, respectively (Table 1). Corresponding natural increases in wolf numbers during summers 1982 and 1983 were 48% and 89%, respectively, compared to 30-40% on the Kenai Peninsula (Peterson et al. 1984), Nelchina Basin (Ballard et al. 1981a), Tanana Flats and adjacent foothills (Gasaway et al. 1983), and in several other studies (Keith 1983). The high rates of increase from spring to fall in GMU 20E are due to both production and immigration. These rates exemplify the need for proportionately large wolf removal areas in relation to the areas where increased moose numbers are desired, particularly when wolves are harvested at low rates in surrounding areas. Examples of wolves likely to have immigrated into the experimental area include the new Mansfield Creek and West Fork packs in summer 1982 and new Billy Creek, Slate Creek, and Mosquito Flats packs in summer 1983 (Table 1).

Vacant areas between the minimum pack territories (Fig. 2-4) are to a large extent a result of limited data, rather than the existence of voids between wolf territories. Average pack territory size in GMU 20E pre-wolf removal likely exceeded 1,000 km² (390 mi²). Subsequent reports will investigate the relationships between average territory size, prey density, and predator densities.

The large amount of overlap in the home ranges of various packs in GMU 20E (Fig. 2-4) could reflect the generally low abundance of resident prey. Low prey densities have been reported to cause wolf packs to trespass on territories of neighboring packs (Mech 1977). Yet, despite the increasing scarcity of moose, none of the radio-collared packs abandoned their home ranges to maintain contact with migrating caribou, as has been observed in areas where migratory caribou are the only large prey available to wolves (Parker 1973, Stephenson and James 1982).

Food Habits and Predation Rates: Examination of 153 predator kills or suspected kills in the experimental area during winters 1980-84 revealed 90 (59%) moose and 63 (41%) caribou kills. Forty of these moose were classified by sex and/or age (13 adult bulls, 14 adult cows, 3 yearlings, and 10 calves). Calves composed 25% of the kills even though the moose population had only 7-9% calves. No selection of adults by sex was noted.

Wolf stomach contents and radiocesium levels (Table 2) indicated that 5 of 10 packs studied relied much more heavily on moose than caribou during winters 1980-82. These 5 packs included the Mansfield Creek, Billy Creek, Mitchels Ranch, Middle Fork, and Divide packs (Fig. 2). The Middle Fork (1983 only), Ketchumstuk, and Dennison Fork wolves consumed about equal proportions of moose and caribou during winter, as indicated by stomach contents, radiocesium levels, and observations of kills. These indicators also revealed that caribou were the primary winter prey of the West Fork pack and, particularly, the Portage Creek pack. High radiocesium levels in 1 member of the Joseph Creek pack also indicated a greater winter consumption of caribou than moose.

Caribou distribution in the experimental area varies annually and seasonally and is unpredictable. However, limited knowledge of caribou distribution since 1980, the results of wolf necropsies, and sightings of wolf kills suggest most of the 16 wolf packs in the experimental area (Table 1) rely more heavily on moose than caribou on an annual basis. Caribou provide a portion of the annual diet of all 16 wolf packs (Table 1), presumably in direct proportion to the relative availability of caribou.

Keith (1983) reviewed predation rates from 5 North American studies of wolves and moose. The rate of predation ranged from 3.1 to 5.5 days/kill/pack and averaged 4.1 days. However, the abundance of moose in these study areas was roughly 3 to 10 times the density of 0.5 moose/km^2 estimated in GMU 20E in 1981, and no reliable data exist for documenting predation rates at very low moose densities. It is likely that predation rates for packs relying on moose in GMU 20E are about 5.5 days/kill (Keith 1983).

Preliminary data on wolf food habits and predation rates indicate wolf predation is a major mortality source for this low-density moose population and may limit moose population growth.

Age Structure, Reproductive Status, and Nutritional Condition: Data on age structure, reproductive status, and condition of 42 necropsied wolves (Table 2) suggest that, despite the low availability of prey in most areas, the wolf population remained productive and in good condition. Pups composed 36% of the sample of 42 wolves, and 8 of 10 female wolves 2 years old and older showed signs of reproductive activity (follicles, corpora lutea, fetuses, or placental scars) during the current or previous year. Fat condition and body weights indicated good nutritional status in mid- to late winter. However, the relatively small size (29 kg) of 2 pups in the Portage Creek pack and 1 in the West Fork pack (Table 2) suggests a relative scarcity of prey in summer or fall. These small body sizes are probably related to the scarcity of caribou in the West Fork and Portage Creek drainages in summer and the year-round scarcity of moose. Mid- to late-winter pup sizes smaller than about 32 kg indicate a scarcity of prey in summer and fall.

Grizzly and Black Bear Population Status:

Preliminary data on bear numbers are from 34 incidental sightings of lone grizzlies and family groups and 5 sightings of lone black bears and family groups during daily flights from 16 May to 4 July to locate collared moose. Most bears observed were on calf or adult moose carcasses, and all observations of bears were in the approximately 1,100 km^2 (420 mi^2) area where radio-collared moose cows and calves were intensively monitored (Fig. 5). We distinguished 14 different grizzlies and 8 different black bears during this period and calculated minimum densities of 1 grizzly bear/78 km^2 (1/30 mi^2) and 1 black bear/130 km^2 (1/50 mi^2). The 14 individually distinguishable grizzlies consisted of 7 lone bears and 3 family groups (2 sows with 1 2-year-old each and 1 sow with 2 yearlings). The 8 individually distinguishable black bears consisted of 2 lone bears and 2 family groups (1 sow with 3 newborn cubs and 1 sow with 1 yearling).

Because observers in a Super Cub cannot individually distinguish most grizzlies, and because it is likely only a small proportion of the grizzlies in the area were observed, grizzly densities in the experimental area west of the Taylor Highway likely approach densities observed on the north slope of the Alaska Range (Reynolds and Hechtel 1984a), in the western Brooks Range (Reynolds and Hechtel 1984b), and in GMU 13 (Miller and Ballard 1984); i.e., 1 bear/35-45 km^2 (1 bear/14-17 mi^2). We will assume densities are about 1 grizzly bear/52 km^2 (1 grizzly bear/20 mi^2) west of the Taylor Highway and 1 grizzly bear/104 km² east of the Taylor Highway until further data are collected. Observations by hunters, trappers, and ADF&G personnel suggest that grizzly densities are significantly lower east of the Taylor Highway. Actual black bear densities are probably in the range of 1 black bear per 90-115 km² (1/35-45 mi²).

Harvest of grizzly bears has increased significantly since 1980. Prior to 1981, annual grizzly harvests in GMU 20E varied from 0 to 6 bears. Less restrictive harvest regulations beginning in 1981 resulted in harvests of 10 grizzlies in 1981, 24 in 1982, and 22 in 1983. If we assume a density of 1 grizzly bear/52 km² (1 grizzly bear/20 mi²) in the 8,000 km² (3,100 mi²) portion of the experimental area west of the Taylor Highway, approximately 155 grizzly bears are in this area. The calculated harvest rate of approximately 15% from this area during the past 2 years indicates the grizzly bear population may not be increasing. Rather, this population is likely declining slowly.

Preliminary data indicate grizzly density is high relative to moose densities. Moose/bear ratios are much lower in GMU 20E (about 4 moose/1 grizzly bear and about 3 moose/1 bear [grizzly and black bear]) than found elsewhere in Interior and Southcentral Alaska (10-20 moose/1 grizzly bear in GMU 13 in 1980, and 14 moose/1 grizzly bear in the foothills portion of GMU 20A in 1984). Grizzly bears limited moose in GMU 13 (Ballard et al. 1980) when the ratio was about 10-20 moose/1 grizzly bear and wolves were scarce. On the Kenai Peninsula, Schwartz et al. (1983) demonstrated that black bear predation was an important mortality source on calf moose when ratios were about 3-6 moose/1 black bear. In GMU 20E, the combined effect of grizzly bears, black bears, and wolves on moose (about 2 moose/1 predator) strongly suggests that predation limits the moose population.

Grizzly bears are important both as predators and scavengers. As scavengers, grizzly bears elevated wolf kill rates by consuming wolf-killed moose carcasses, e.g., grizzly bears were found feeding on all summer wolf-killed moose older than 1 year old ($\underline{n}$ = 3) within 2-5 days of the moose's death.

<u>Adult Moose Mortality</u>:

An 8% annual natural mortality rate was calculated (Gasaway et al. 1983) for the 30 radio-collared cow moose for the 1st 5 months of collar life. One of the 30 radio-collared cows died due to grizzly bear predation on 21 May 1984. In addition, we found 6 carcasses of moose older than 1 year old during flights in spring and summer 1984: 4 wolf kills, 1 drowning in late winter, and 1 probable grizzly bear kill that had prior wounds from wolves.

Information gathered to date on adult moose mortality rates is insufficient to support acceptance or rejection of the predation-limiting hypothesis. Collared moose will be radio-tracked monthly through winter 1985-86 to obtain more data on natural mortality rates.

Calf Mortality:

Natural Mortality: Twenty-five of the 33 newborn calves (76%) died within 8 weeks of birth. Four (12%) drowned and 21 (64%) were killed by predators. Grizzly bears killed 17 (52%) of the calves, wolves killed 3 (9%), and a black bear killed 1 (3%). These data support acceptance of the hypothesis that predation limits moose population growth in GMU 20E.

It is significant to note in evaluating these data that wolf density in the calf mortality study area (Fig. 5) was approximately 50% of the density prior to wolf removal and that grizzly harvest had increased in the 3 previous years. A maximum of 30 wolves older than 1 year used portions of the calf study area (Fig. 5) during the calf mortality study, whereas about 65 wolves lived in the study area prior to wolf removal in fall 1981.

Qualification of above data on calf mortality rates is required, because each calf mortality was treated independently. In reality, mortality of twin calves could not be treated independently during the 1st 4-5 weeks due to the efficiency of grizzly bear and wolf predation on twins. In all 6 cases between 17 May and 24 June, when twin calves were encountered by grizzly bears or wolves, both twins were killed within 24 hr. These mortalities account for 12 (57%) of the 21 calves killed by predators. One could argue, therefore, that mortality of a set of twins should be treated as a single mortality during the 1st 5 to 6 weeks of life when measuring predation rates by grizzly bears and wolves. This scheme does not apply, however, in regard to drownings or black bear predation (Franzmann et al. 1984). The single instance of black bear predation in this study occurred 8 or 9 days after the calf's birth, and only 1 calf in a set of twins was killed.

The high proportion of twins in this population provided an opportunity to determine differences in mortality rates of single and twin calves. Twins composed 73% of the collared calves. Grizzly bears killed 17 calves and 12 were from sets of twins (71%). Kills by all predators totaled 21, with 16 twins (76%); of the total 25 calf mortalities, 20 were twins (80%) (Table 3). It appears twin calves had equal or slightly greater chances of dying compared to single calves, because the percentage of twins found dead (80%) was slightly greater than the percentage sampled (73%). Franzmann et al. (1984) found a similar pattern on the Kenai Peninsula, where black bears are the major predator on calves.

The cause of calf mortality was determined in all 25 deaths. The predator was observed near the carcass in 15 (71%) of the 21 mortalities caused by predators. If the predator was observed on or near the kill, we usually postponed carcass examination until the following day to avoid disturbing the predator and possibly increasing the predation rate. We relied primarily on daily flights and results of other studies (Ballard et al. 1981b, Franzmann et al. 1980) to conclude that predators were killing healthy calves rather than finding and scavenging recently dead calves. This conclusion was supported by an instance where we left a dead calf (capture-related mortality) in the study area for 3 days before retrieval; the carcass was undisturbed by predators or scavengers.

We examined 14 (56%) of the 25 death sites within 24 hr of the time when mortality was first observed or suspected; i.e., within 36 hr of death. In 7 additional cases (28% of 25 sites), we examined remains of carcasses within 48 hr of the time mortality was suspected or within 60 hr of death. Of the remaining 4 cases, we investigated 2 carcasses approximately 3 days after death, one between 1 and 6 days after death, and one (where grizzlies also killed the adult cow) 6 days after death.

We found predator hair, scats, and/or tracks at nearly all sites, which facilitated distinguishing wolf, black bear, and grizzly bear predation. Inverted and/or intact hides and longitudinally cracked long bones helped distinguish bear from wolf predation (Ballard et al. 1979).

Chronology of Calf Mortality: Birth dates of collared calves were from approximately 13 to 24 May. Most calf mortality (84%) occurred from 17 May through 6 June (21 days) with additional mortality on 18 June (single of twins), 24 June (twins), and between 4 and 11 July (single of twins) (Table 3, Fig. 6). Eight of the 33 calves were alive on 15 August.

Moose Population Composition in Experimental and Control Areas:

Calves per 100 cows and percentages of calves were lower in the experimental area (Table 4) than in the control areas (Table 5) during 1982 and 1983, despite increased harvest of grizzly bears and a 60% reduction of wolves in and around the experimental area in winter 1981-82 (Table 1). Also, calf survival and yearling recruitment in the experimental area did not increase after wolf removal (Table 4).

These data suggest 2 possible options for a predator-limiting hypothesis. Firstly, during the pre-wolf removal period, wolves may have killed small proportions of calves during summer, and grizzly bears may have been the major predator on young calves, as was found during calf mortality studies after wolf removal (Fig. 6). If this were true, removing wolves would not significantly increase calf survival during summer. Also, harvest of grizzly bears has been too low to expect increased calf survival. Secondly, increased grizzly bear predation on calves may have compensated for the lower wolf predation post-wolf removal. This option indicates the possible need for simultaneous removal of wolves and grizzly bears to increase calf survival. Further study will be required to understand the complex relationships between calf survival and predation by bears and wolves. These studies will include manipulation of predator populations.

Moose-Wolf Relationships:

In assessing the response of moose populations to wolf removal in GMU 20E, 3 factors are important: (1) fall moose/wolf ratios pre- and post-wolf removal, (2) effects of compensatory and noncompensatory grizzly bear predation on moose, and (3) the availability of caribou as alternate prey for wolves. Where moose are the wolf's primary prey and fall moose/wolf ratios are less than 20/1, wolf predation can cause declines in moose abundance or prevent moose from increasing as a result of low survival of calves and adults, even in areas with few grizzly bears (Gasaway et al. 1983). In the moose-caribou-wolf-grizzly bear system of GMU 20E, ideally a fall moose/wolf ratio of >40 moose/1 wolf is needed to clearly evaluate the effects of wolf predation on moose population dynamics, and to minimize the effects of wolf predation while investigating the effects of bear predation. Due to the extremely low moose density in GMU 20E, it is largely impractical to attain and, particularly, to sustain fall moose/wolf ratios >40/1. A ratio of 30/1 is close to the practical limit of a wolf control program in GMU 20E. The effect of caribou on moose population growth is not known, i.e., the availability of caribou as alternate prey is beneficial to wolves and grizzly bears, but the caribou's availability may either beneficially affect moose population growth by providing wolves an alternate prey species or adversely affect moose population growth by sustaining higher numbers of wolves.

Wolf removal efforts in GMU 20E (Table 1) resulted in fall 1982 and 1983 ratios of 16 and 14 moose/1 wolf, respectively (Table 6). High spring ratios were 23 moose/1 wolf in 1982 and 26 in 1983, but, in the absence of summer wolf removal, wolf numbers increased dramatically by fall. Moose/wolf ratios calculated post-wolf removal are maximum values, because the moose population was assumed to be stable (Table 6). It is more likely that the moose population decline continued, but at a slower rate following wolf removal.

Given that fall moose/wolf ratios never exceeded 16/1 (Table 6), we expected little improvement in calf survival or recruitment as a result of wolf removal alone. In fact, no improvement in calf survival or yearling recruitment was noted in the Mount Veta-Mosquito Flats contour count area, the most suitable test area, after wolf removal (Table 7).

Testing the Food-limiting Hypothesis

Browse Availability:

Salix pulchra (50% occurrence), *Betula glandulosa* (34%), and *Salix arbusculoides* (6%) were the major browse species among the 2,820 browse plants examined on 29 transects in the experimental area. Minor proportions (<3%) of *Salix scouleriana*, *Salix bebbiana*, *Salix glauca*, *Salix alaxensis*, *Salix* spp., and *Populus tremuloides* were found.

Overall use of annual browse production was less than 5%. Of 2,820 browse plants examined, 86% had not been browsed during the previous winter, 9% had low use (1-25% of current annual growth), 3% had moderate use (26-75%), and 2% had high use (76-100%). Of 1,399 *Salix pulchra* (a highly preferred moose browse species) plants examined, 12% were in the low use class, 4% in the medium class, and 2% in the high class. Even *Salix pulchra* on transects in the wintering area with the highest moose density (Mosquito Flats) had less than 10% overall use of annual browse production.

These data support rejection of the food-limiting hypothesis. High availability and low use of preferred *Salix* spp. is evidence that moose are below nutritional carrying capacity.

Condition of Radio-collared Cow Moose:

Pregnancy rates, morphometric measurements, and body condition values (Table 8) of moose radio-collared during 19-21 March 1984 in GMU 20E indicated moose were in excellent late-winter nutritional condition, despite the high proportion of old-age moose. Ages were obtained from 27 moose and 43% were 10 years old or older (Table 8). Twenty-seven moose were tested for pregnancy and 100% were pregnant. Average body size is a well-known index to overall nutritional regime in ungulate populations. We used total body length and hind foot length as indices of body size. Average total length of radio-collared moose in GMU 20E (302.0 cm) exceeded values for almost all other Alaska moose populations (Table 9). Average hind foot length of moose in GMU 20E (90.5 cm) was the highest reported in Alaska (Table 9). Body condition values (Franzmann and Schwartz 1983) for the 30 radio-collared moose ranged from 5 to 9 and averaged 7.0, which is slightly above normal for adult females in late winter. Nearly identical late-winter averages were reported by Faro and Franzmann (1978) for the Alaska Peninsula, Smith and Franzmann (1979) for the Yakutat Forelands, and Ballard and Gardner (1980) for the Nelchina Basin. Grauvogel (1982) and Boertje and Young (1982) reported lower yet normal late-winter values for the Seward Peninsula (6.1) and the Stikine River (5.9), respectively.

Condition-related blood parameters analyzed to date (Table 10), hemoglobin (Hb) and packed cell volume (PCV), do not indicate a low nutritional status. Uses of these parameters, however, are limited to detecting extremes in nutritional status. They cannot be used to rank populations when median values are exhibited (Franzmann and Schwartz 1983). Blood samples underwent 21 additional analyses. Complete blood chemistry data will be presented in the next progress report.

All condition indices collected to date support rejection of the food-limiting hypothesis.

Twinning Rate as an Index of Condition:

During daily flights to capture calves (16-24 May), we documented 13 single births and 14 sets of twins for a calculated twinning rate of 52%. However, the actual twinning rate was probably between 45 and 50%. The calculated twinning rate was based on data collected during the 1st 9 days of calving and may overestimate the actual twinning rate. Shorter gestation for twin calves has been recognized in the literature for domestic cattle for many years (Craig 1912), although little evidence exists to support this relationship in wild ungulates. These relatively moderate twinning rates (Blood 1974, Franzmann and Schwartz 1984) suggest a good nutritional regime and support rejection of the food-limiting hypothesis.

Our observations of uncollared calves of collared cows at weekly intervals during 25 May-15 June (as compared to daily observation prior to 25 May) suggest the twinning rate declined during the latter portion of the calving period. Two sets of twins and 8 singles were observed during this period which would suggest an overall twinning rate of 43% (16 sets of twins and 21 singles). Possible explanations for the higher frequency of single calves during this latter period are that drowning or predators were more likely to kill one of the twins, leaving a higher proportion of single calves, or that total mortality rates were disproportionately higher on sets of twins than singles during calving. However, calf mortality data (Table 3) do not support either of these possibilities, suggesting that the twinning rate actually did decline during the calving period.

Marrow Fat and Ages of Predator-killed Moose Older than 1 Year Old:

Marrow fat content of 10 adult moose killed by wolves in the experimental area revealed low marrow fat in 2 moose (Table 11). Both were old bulls and their poor condition may have been associated with old age and season of the year rather than inadequate forage. The 100% occurrence of old-age moose ($\geq$11 years old) in the sample is probably due in part to: (1) the very low recruitment during the last decade (Table 4) and (2) selection by wolves for old-age moose, as described by Peterson et al. (1984) on the Kenai Peninsula. Age distribution of collared moose suggested only 32% of adult cow moose were $\geq$11 years old (Table 8). Results of marrow fat analyses and age determinations are not yet available for adult moose killed during summer 1984.

Preliminary data on marrow fat content support rejection of the food-limiting hypothesis. Predators are apparently killing moose that are largely in good nutritional condition. Similar results were reported by Franzmann and Arneson (1976) and Gasaway et al. (1983).

CONCLUSIONS

We reject the hypothesis that food limits moose population growth in GMU 20E, based on: (1) measurements of browse availability and use, and (2) moose reproductive and nutritional status.

To date, we have no unequivocal test of the predation-limiting hypothesis because insufficient numbers of predators were removed. To evaluate the effects of wolf predation on moose population dynamics and to minimize the effects of wolf predation while investigating the effects of bear predation, wolves should have been reduced to a level that produced moose/wolf ratios of at least 40/1. However, this strategy became largely impractical because wolves could not be reduced to a sufficiently low density given the very low moose density in GMU 20E. A more practical approach for investigating the predation-limiting hypothesis in GMU 20E is to simultaneously reduce numbers of wolves and grizzlies.

Preliminary data, however, strongly support acceptance of the predator-limiting hypothesis. Numbers of moose/wolf and moose/grizzly bear are lower in the experimental area than in other study areas where predation was a limiting factor on moose. This suggests that either wolves or grizzlies alone could limit moose population growth in GMU 20E. We found a high rate of grizzly bear predation on young calves in GMU 20E. Therefore, if predation is limiting, a reduction in numbers of bears, in addition to wolves, will be required for rapid growth of the moose population.

Despite the scarcity of the wolf's primary prey in the experimental area, evidence indicated wolves had high reproductive rates and good nutritional status. Also, rates of increase in wolf numbers (including immigration) were high in the experimental area between spring and fall in 1982 and 1983.

RECOMMENDATIONS

1. Estimate the predation rate by grizzlies on adult moose to evaluate the overall predation rate on moose.

2. Reduce numbers of wolves and grizzly bears to give an unequivocal test of the predation-limiting hypothesis.

3. Increase grizzly and wolf harvest by working with the public and the Board of Game.

ACKNOWLEDGMENTS

We thank Jeff Shryer of the Bureau of Land Management for providing a portion of the browse-use data and pilot Ron Warbelow for excellent helicopter and fixed-wing support throughout the study.

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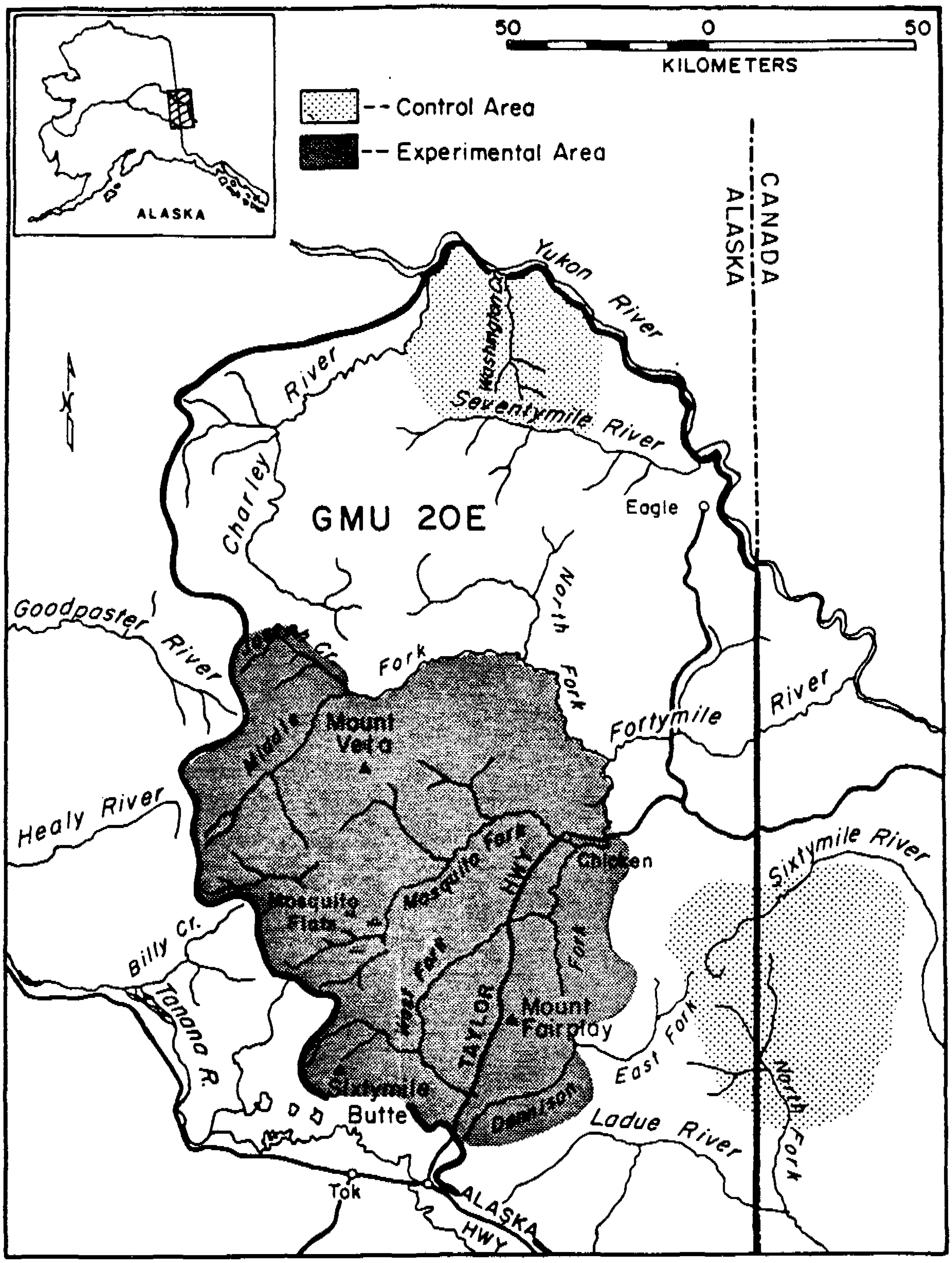

Fig. 1. Experimental area (with wolf removal) and control areas (without wolf removal) in Game Management Unit (GMU) 20E, Alaska, and adjacent Yukon Territory, Canada.

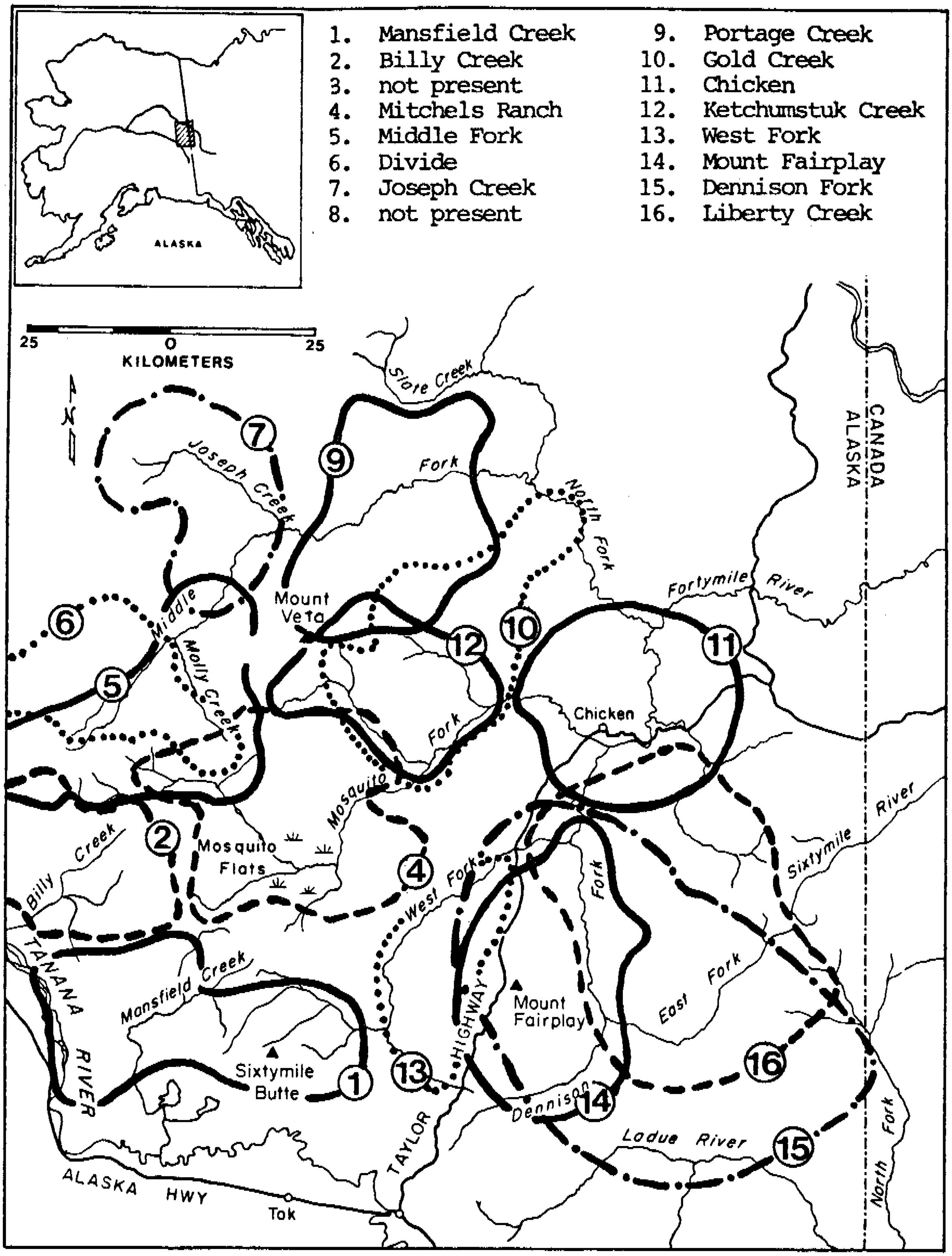

Fig. 2. Location and minimum size of wolf pack territories in and overlapping into the experimental area of Game Management Unit 20, Alaska, 1980-82.

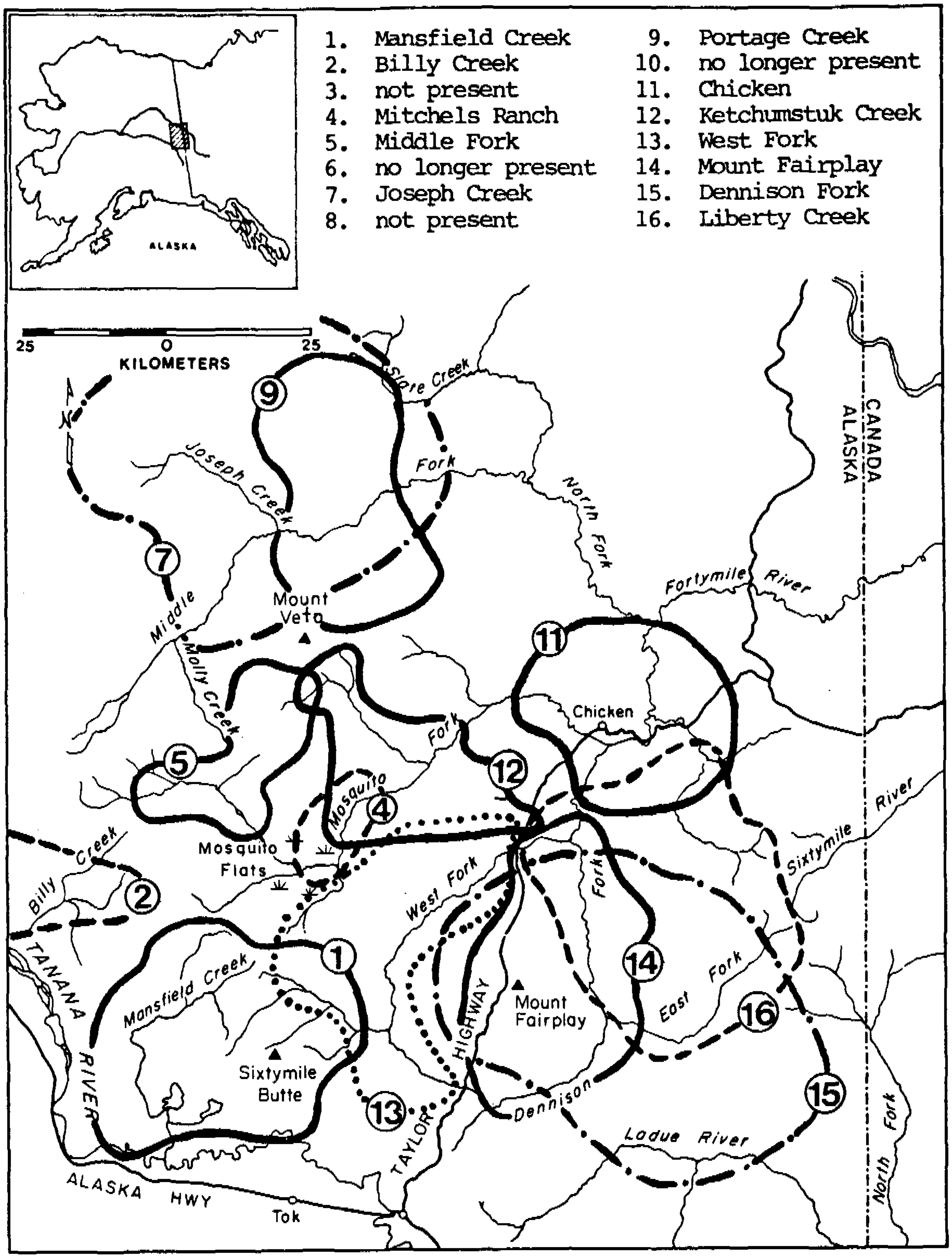

Fig. 3. Location and minimum size of wolf pack territories in and overlapping into the experimental area of Game Management Unit 20E, Alaska, 1982-83.

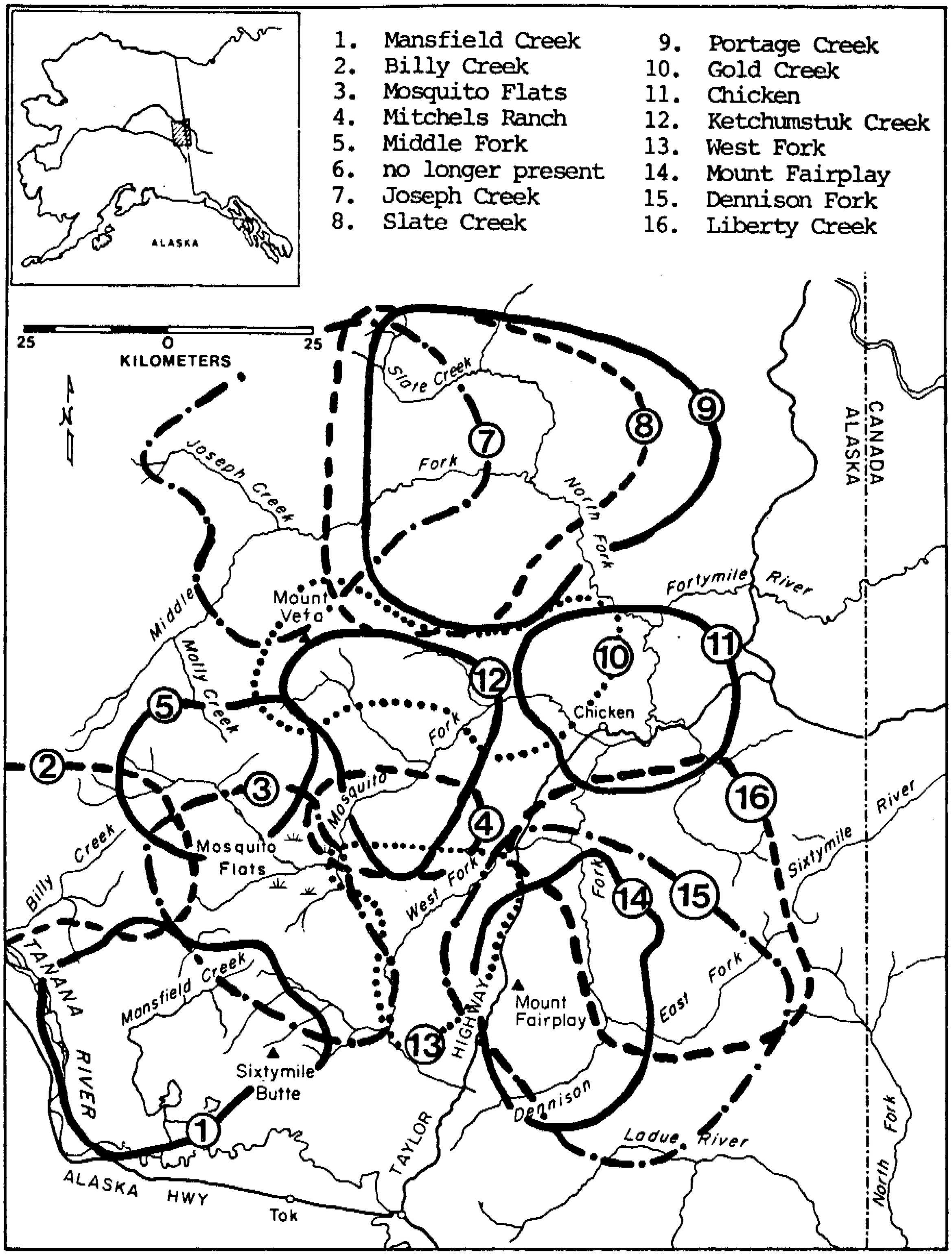

Fig. 4. Location and minimum size of wolf pack territories in and overlapping into the experimental area of Game Management Unit 20E, Alaska, 1983-84.

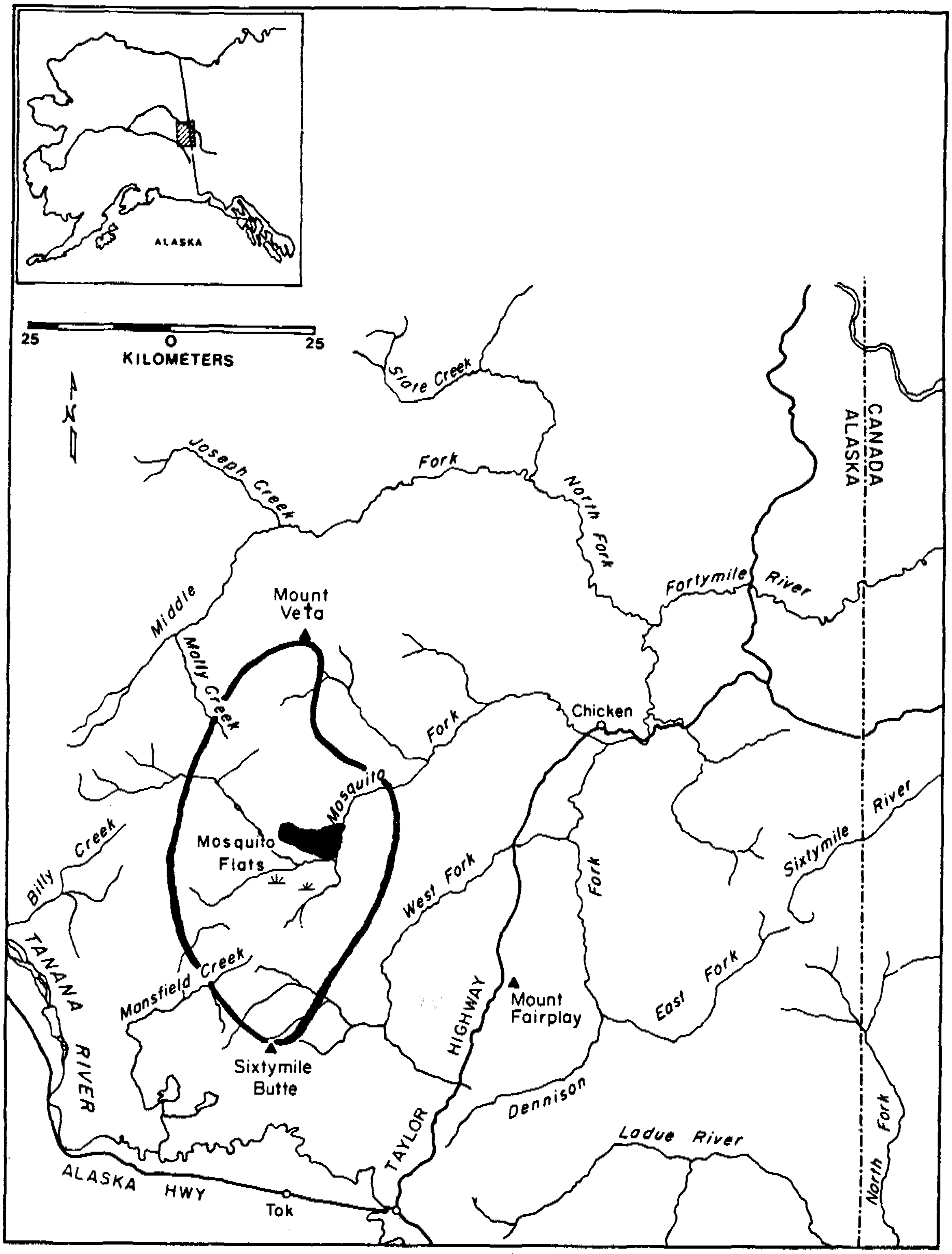

Fig. 5. Range of radio-collared moose cows and calves (solid line), March-August 1984. All cows were collared in the darkened portion of the Mosquito Flats, Alaska, 19-21 March 1984.

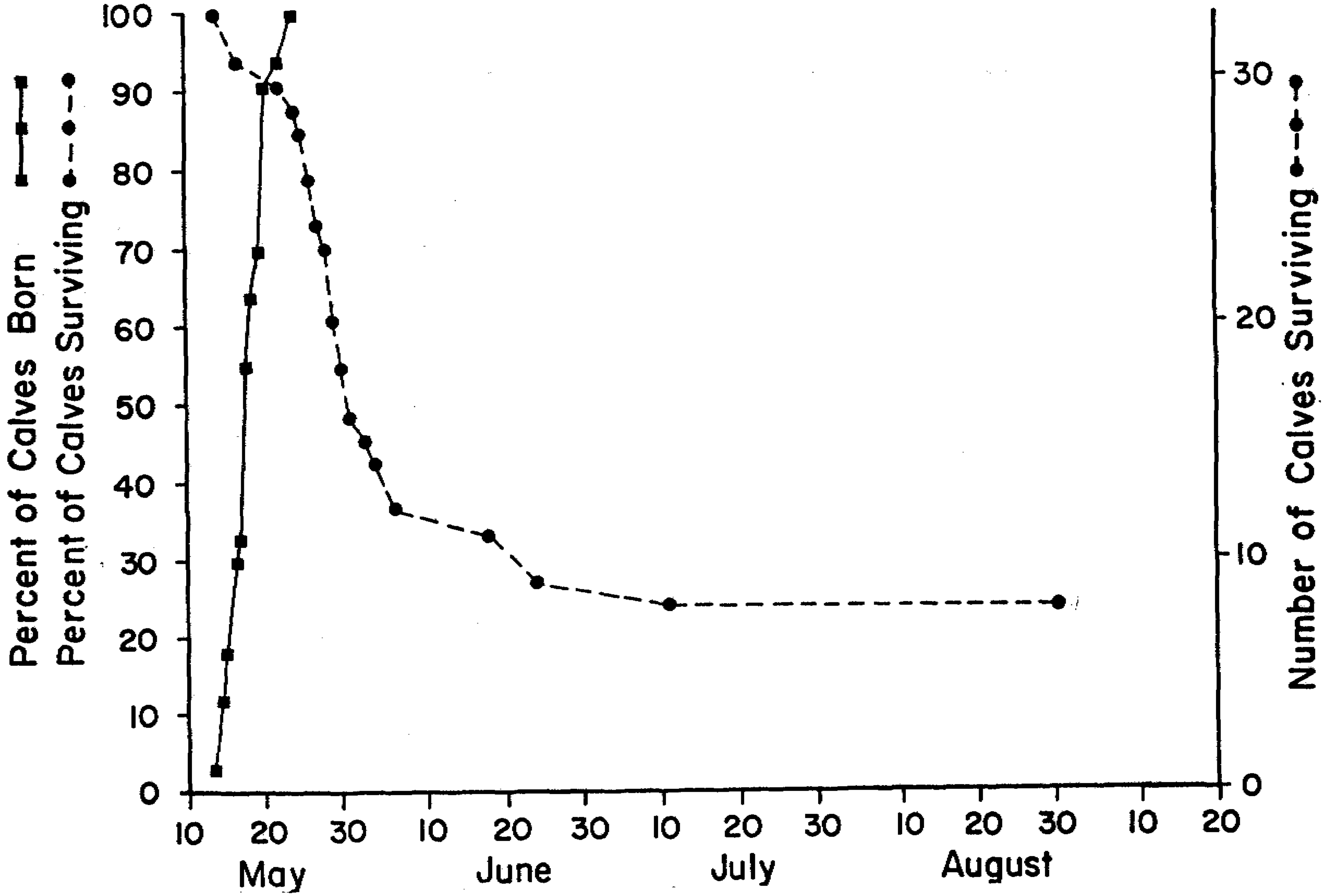

Fig. 6. Timing of birth and death of 33 moose calves radio-collared during May 1984 in and near the Mosquito Flats, Alaska.

Table 1. Estimated total numbers of wolves in packs located in the experimental area of Game Management Unit 20, Alaska, fall 1981-spring 1984. Numbers added to pack sizes are wolves observed in the pack's territory but not associated with the pack.

Pack no.	Pack name	Before wolf removal	After wolf removal[a]				
		fall 1981	spring 1982	fall 1982	spring 1983	fall 1983	spring 1984
1	Mansfield Creek	7[b] + 2	0 + 2	8 + 2[c]	1	5	3
2	Billy Creek	8[d] + 1[c]	2[c]	2[c]	1	8	8[d]
3	Mosquito Flats	0	0	0	0	8	4
4	Mitchels Ranch	15[d]	2	2	2	4	2[c]
5	Middle Fork	11[e]	2	3	3	5[c]	2
6	Divide	8[f]	0	0	0	0	0
7	Joseph Creek	6	2	2	2	6	3[c]
8	Slate Creek	0	0	0	0	6	6
9	Portage Creek	12[c]	4[c]	4[c]	0	9	8[c]
10	Gold Creek	5[c]	0	0	0	3	3
11	Chicken	7	3	5	4	8	4
12	Ketchumstuk	3	3	5[c]	2	1 + 1	1[c] + 1[c]
13	West Fork	7 + 3	2	10 + 2 + 2	10 + 2	3 + 1	2 + 1
14	Mount Fairplay	2	2	2 + 1	2	2	2
15	Dennison Fork	9	9	9 + 1 + 1	1	1 + 1	1
16	Liberty Creek	8	8	8	8	10	6[c]
	Unidentifed lone wolves	11	11	8	8	5	5
Total wolf numbers		125	52	77	46	87	62
Percentage change			-58%	+48%	-40%	+89%	-29%
Density (wolves/1,000 km^2)		8	3	5	3	6	4
(wolves/1,000 mi^2)		21	9	13	8	14	10

Table 1. Continued.

[a] Department wolf take was 9 during winter 1980-81, 56 during 1981-82, 15 during 1982-83, and 7 during 1983-84. The remaining wolf take was by private trappers and hunters (ground shooting only).

[b] The Mansfield Creek pack was removed from GMU 20D in winter 1980-81.

[c] One wolf had a functioning radio collar.

[d] Two wolves had functioning radio collars.

[e] Three wolves had functioning radio collars.

[f] Two wolves in this pack were removed from GMU 20D in winter 1980-81; the remainder were removed from GMU 20E in winter 1981-82.

Table 2. Necropsy data from 42 wolves killed in the experimental area of Game Management Unit 20, Alaska, during winters 1980-83.

Pack name	Date	Age (yr)	Sex	Weight (kg)	Kidney fat(g)	Subcu. fat(mm)	Stomach contents	Radio-cesium[a]	Female reproductive status and comments
Mansfield Creek	3/16/81	3	F	40	87	16	Moose, hare, microtine	639	First pregnancy, 5 fetuses about 30 days development.
Mansfield Creek	3/16/81	3	M	43	112	33	Moose	546	
Billy Creek	2/10/81	Pup	M	39	81	31	Moose	5,201	
Billy Creek	3/25/81	Pup	F	34	75	30	Hare	7,475	Inactive repro.
Billy Creek	2/28/82	7	F	36	46	6	Caribou	1,691	In estrus, had ovulated, 3 corpora lutea, 7 placental scars from 1980 or 1981.
Mitchels Ranch	3/24/81	Pup	F		83	33	Empty	3,203	Inactive repro.
Mitchels Ranch	3/3/82	Pup	M	39	55	43	Caribou	362	
Mitchels Ranch	3/28/82	Pup	M	44	69	23	Moose	462	
Mitchels Ranch	3/28/82	3-4	F	40	104	18	Moose	661	In estrus, had ovulated, at least 3 corpora lutea and 1 follicle. Possibly very faint placental scars visible, but may be first breeder.

Table 2. Continued.

Pack name	Date	Age (yr)	Sex	Weight (kg)	Kidney fat (g)	Subcu. fat (mm)	Stomach contents	Radio-cesium[a]	Female reproductive status and comments
Mitchels Ranch	3/28/82	3	F	43	82	26	Moose	718	Small reproductive tract, not in estrus. Possible second non-breeding year as adult.
Mitchels Ranch	3/29/82	2	F	32	88	33	Moose, hare		In estrus, may have ovulated.
Mitchels Ranch	3/29/82	3	M	50	91	42	Moose	571	
Middle Fork	4/22/81	Pup	F	36	50	12	Moose calf[b]	1,984	Inactive repro.
Middle Fork	4/22/81	2	M	42	79	24	Moose calf[b]	2,139	
Middle Fork	12/15/81	Pup	M	48	69	48	Hare		
Middle Fork	10/30/83	3	F	48		15	Caribou	13,410	
Middle Fork	10/26/83	3	M	45		37	Caribou	9,885	
Divide	12/3/81	4-5	M	50	132	58	Empty		
Divide	12/81	Pup		34				1,591	Carcass scavenged. Considerable subcutaneous fat present.
Joseph Creek	2/28/82	3	M	52		27		7,136	Carcass scavenged.

Table 2. Continued.

Pack name	Date	Age (yr)	Sex	Weight (kg)	Kidney fat(g)	Subcu. fat(mm)	Stomach contents	Radio-cesium[a]	Female reproductive status and comments
Joseph Creek	2/19/82	Ad	M	52	73	39	Caribou		
Portage Creek	1/4/82	4	F	36	110	27	Caribou	11,246	Presently inactive repro., 5 new and 3 old placental scars visible.
Portage Creek	3/5/82	3	M	39	43	18	Caribou	10,364	
Portage Creek	3/5/82	8	F	36	102	29	Empty	20,338	Early estrus, no follicles or corpora lutea visible. 4 new, 4 old placental scars visible. Many physical infirmities noted.
Portage Creek	3/7/82	3	M	50	108	27	Caribou	15,718	
Portage Creek	3/9/82	2		34	118	28	Empty	15,532	Carcass scavenged.
Portage Creek	3/11/82	Pup	F	34	48	21	Moose	12,377	Inactive repro.
Portage Creek	3/12/82	Pup	M	29	37	18	Empty	17,380	
Portage Creek	3/20/82	Pup	F	29	53	21	Moose	13,356	Inactive repro.
Ketchumstuk	3/7/81	5	F	43	80	12	Moose	5,080	No sign of present or previous reproductive activity.

Table 2. Continued.

Pack name	Date	Age (yr)	Sex	Weight (kg)	Kidney fat (g)	Subcu. fat (mm)	Stomach contents	Radio-cesium[a]	Female reproductive status and comments
Ketchumstuk	3/31/82	5	F	45	140	23	Moose	5,256	In estrus, had ovulated, probably early pregnancy. 4 corpora lutea. 6 placental scars from 1981.
Ketchumstuk	3/31/82	4	M	50	99	26	Moose	4,672	
Ketchumstuk	4/1/82	Pup	M	29	0	0	Caribou	13,092	Radio-collared male. Antler wound anterior to sternum, emaciated. Femur marrow 9%. Weighed 36 kg when collared in November.
Ketchumstuk	4/1/82	Pup	M	37	139	25	Moose	5,339	
West Fork	2/7/82	Pup	F	39		21	Caribou		Viscera scavenged. Canines very short (17mm).
West Fork	2/7/82	Pup	F	29	35	13	Caribou	4,996	
West Fork	3/31/82	6-10	M	38	49	5	Empty	17,248	
West Fork	4/9/82	4	M	41	62	22	Caribou	10,047	Jaw broken, healed.
West Fork	4/9/82	2-3	F	37	54	10	Empty	15,588	Pregnant, 4 fetuses. No placental scars visible.

Table 2. Continued.

Pack name	Date	Age (yr)	Sex	Weight (kg)	Kidney fat(g)	Subcu. fat(mm)	Stomach contents	Radio-cesium[a]	Female reproductive status and comments
West Fork	11/5/83	4	M	48	ND	40	Caribou	6,804	Rib broken, healed.
Dennison Fork	11/83	5	M	48	ND	10	Caribou	10,665	4 ribs broken, healed.
Dennison Fork	11/83	5	M	50	ND	12	Caribou	8,502	

[a] Cs-137 concentration in pCi/kg wet muscle.

[b] The wolves were taken while feeding on a moose calf.

Table 3. Mortality data from 35 moose calves captured in the Mosquito Flats and adjacent areas of Game Management Unit 20E, Alaska, 1984.

Calf No.	Single or twin calf	Date collared	Cow collared	Comments
1	Single	5/16	No	Grizzly bear predation 6 Jul
2	Single	5/16	Yes	Grizzly bear predation 22 May
3	Twin of #4	5/16	Yes	Grizzly bear predation 17 May
4	Twin of #3	5/16	Yes	Grizzly bear predation 17 May
5	Twin of #6	5/17	No	Grizzly bear predation 30 May
6	Twin of #5	5/17	No	Abandoned by cow on 18 May
			Yes	Adopted by cow of calf #3 and #4 on 19 May
				Grizzly bear predation 29 May
7	Single	5/21	No	Killed by cow after collaring
8	Twin of #9	5/18	No	Alive 14 Aug
9	Twin of #8	5/18	No	Drowned 24 May
10	Twin of #11	5/20	No	Drowned 6 Jun
11	Twin of #10	5/20	No	Grizzly bear predation 18 Jun
12	Single	5/24	No	Alive 14 Aug
13	Single	5/18	Yes	Grizzly bear predation 27 May
14	Twin of #15	5/18	Yes	Alive 14 Aug
15	Twin of #14	5/18	Yes	Alive 14 Aug
16	Twin of #17	5/18	Yes	Grizzly bear predation 11 Jul
17	Twin of #16	5/18	Yes	Alive 15 Aug
18	Single	5/21	Yes	Dropped transmitter between 18 Jul and 15 Aug
				Alive with cow 15 Aug
19	Single	5/20	No	Alive 14 Aug
20	Single	5/20	Yes	Alive 14 Aug
21	Twin of #22	5/21	No	Wolf predation 24 Jun
22	Twin of #21	5/21	No	Grizzly bear predation 24 Jun
23	Twin of #24	5/21	No	Grizzly bear predation 31 May
24	Twin of #23	5/21	No	Grizzly bear predation 31 May
25	Single	5/21	No	Grizzly bear predation 26 May
26	Twin of #27	5/21	Yes	Grizzly bear predation 27 May
27	Twin of #26	5/21	Yes	Grizzly bear predation 27 May
28	Twin of noncollared calf	5/21	Yes	Killed by cow during collaring
29	Twin of #30	5/22	Yes	Black bear predation 30 May
30	Twin of #29	5/22	Yes	Grizzly bear predation 2 Jun
31	Twin of #32	5/22	Yes	Drowned 27 May
32	Twin of #31	5/22	Yes	Drowned 26 May
33	Single	5/22	No	Grizzly bear predation 3 Jun
34	Twin of #35	5/24	Yes	Wolf predation 25 May
35	Twin of #34	5/24	Yes	Wolf predation 26 May

Table 4. Moose sex and age ratios in the experimental area of Game Management Unit 20E, Alaska, October-November 1966-83.

Date	Total bulls/ 100 cows	Yrlg bulls/ 100 cows	Yrlg bull % in herd	Calves/ 100 cows	Calves/ 100 cows >2 yr old	Incidence of twins/ 100 cows with calf	Calf % in herd	Moose/ hour of survey	Total moose surveyed
Before wolf removal:									
1966[a]	59	14	8	21	24	0	12	68	509
1967[a]	47	12	8	7	8	0	5	59	498
1968	64	4	2	13	13	0	7	38	389
1969	55	11	6	25	28	11	14	48	365
1970	46	9	5	24	26	0	14	53	368
1971[a]	39	7	4	18	20	0	10	53	251
1972	37	4	2	16	17	0	11	32	363
1973	40	7	5	8	8	0	5	47	269
1974	39	3	2	8	8	11	6	40	361
1975	42	2	1	8	8	0	5	39	168
1976	40	3	2	2	2	0	2	19	124
1977	51	11	7	8	9	0	5	22	235
1978	56	13	7	13	14	10	7	17	175
1979[a]	21	4	3	19	23	25	14	24	73
1980	92	12	6	20	22	13	9	13	108
1981	88	14	7	20	24	10	10	10	184
After wolf removal:									
1982	82	15	7	17	20	0	8	30	201
1983[b]	--	--	--	--	--	0	7	20	215

[a] Severe winters were 1965-66, 1966-67, 1970-71, and 1978-79.

[b] Surveys delayed until January 1984, after initiation of antler drop, due to shallow snow.

Table 5. Moose sex and age ratios in trend count areas in the control areas of Game Management Unit 20E, Alaska, and adjacent Yukon Territory, 1982-83.

Date	Total bulls/ 100 cows	Yrlg bulls/ 100 cows	Yrlg bull % in herd	Calves/ 100 cows	Calves/ 100 cows >2.0 yr old	Incidence of twins/ 100 cows w/calf	Calf % in herd	Moose/ hour of survey	Total moose surveyed
1982	71	14	7	33	39	0	16	4	43
1983[a]	65	13	7	17	20	0	10	14	42

[a] Only 1 of 3 control areas were flown in 1983 due to shallow snow.

Table 6. Moose and wolf densities in the experimental area of Game Management Unit 20E, Alaska, fall 1981-spring 1984.

	Minimum number of wolves	Approximate moose density[a] moose/1,000 km^2	Wolf density[b] wolves/1,000 km^2	Number of moose/1 wolf
Before wolf removal:				
Fall 1981	125	77	8.0	10/1
After wolf removal:				
Spring 1982	52	77	3.4	23/1
Fall 1982	77	77	4.9	16/1
Spring 1983	46	77	3.0	26/1
Fall 1983	87	77	5.6	14/1
Spring 1984	62	77	4.0	19/1

[a] Moose density was determined in the experimental area west of the Taylor Highway in fall 1981 and assumed stable, although moose populations may have declined slightly.

[b] Wolf density was calculated for the total area (15,500 km^2) (6,000 mi^2) occupied by wolf packs in Fig. 2.

Table 7. Composition of moose in the Mount Veta-Mosquito Flats contour count area in Game Management Unit 20E, Alaska, before and after wolf removal, 1978-84 cohorts.

Cohort	Number of cows ≥2 yr old	Calves/ 100 cows ≥2 yr old	% Calves	Yearlings/ 100 cows ≥2 yr old	Total moose observed
Before wolf removal:					
1978	58	14	7	9	112
1979	46	17	12	33	67
1980	24	21	8	33[a]	59
1981[a]	72	26	12	18	
After wolf removal:					
1982	55	16	8		119
1983[b]			9	20	70
1984	61	13	7		119

[a] Data from 1981 census in experimental area west of the Dennison Fork (Fig. 1).

[b] Survey flown in January 1984 after initiation of antler drop.

Table 8. Characteristics of 30 radio-collared adult female moose, 19-21 March 1984, Mosquito Flats, Alaska.

Moose No.	Age (yr)	With calf	Pregnant	Body condition[a]	Blood parameters PCV (%)	Blood parameters HB (g/dl)	Body measurements (cm) Total length	Body measurements (cm) Hind foot length
1	11	-	+	6	38.0	19.5	323	93
2	7-9[b]	-	+	7	36.5	13.0	321	90
3	7	-	+	7	38.5	14.0	307	93
4	16	-	+	6	36.5	13.5	301	91
5	4	-	+	8	43.0	15.5	293	89
6	8	-	+	9	46.0	17.5	313	91
7	9	-	+	8	39.5	14.5	309	91
8	12	-	+	8	35.0	14.0	317	92
9	10	-	+	8	47.0	17.0	304	86
10	11	-	+	7	47.0	17.0	312	88
11	13	-	+	5	37.5	15.5	315	95
12	8	-	+	8	42.0	16.5	294	91
13	10	-	+	7	40.0	14.5	315	93
14		-	+	8	37.5	14.5	273	89
15	3	-	+	6	37.0	15.0	270	86
16	4	+	+	6	35.0	13.0	278	90
17	3	-	+	7	35.0	13.5	287	91
18	11	+	+	6	36.0	14.5	304	89
19		-		8			302	92
20	4-5[b]	+		7			309	91
21	11	-	+	7	36.0	14.5	315	90
22	13	-	+	7	36.0	14.0	316	92
23		+		8			280	87
24	7	+	+	6	43.0	15.5	297	92
25	10	-	+	8	47.0	17.7	304	91
26	4	-	+	5	39.0	14.3	286	91
27	3	-	+	7	43.0	16.7	297	93
28	6	-	+	7	35.0	13.3	306	89
29	11	+	+	6	35.5	13.9	304	91
30	9	-	+	8	38.0	14.3	309	89
Mean				7.0	39.2	15.1	302.0	90.5
± SD				1.0	4.0	1.6	14.1	2.1

[a] As per Franzmann et al. (1976).

[b] Age estimated by wear.

Table 9. Morphometric measurements from adult female Alaskan moose populations[a] during late winter/early spring season, 1969-84.

Population	Total length (cm)			Hind foot length (cm)		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Moose Research Center (inside)	283	21	40	79.3	3.3	39
Moose Research Center (outside)	286	11	51	79.4	2.6	50
GMU 1, 1978	276	14	4	79.4	2.7	7
GMU 5, 1978	288	11	32	81.3	2.8	31
GMU 6, 1974	302	9	25	82.5	2.2	20
GMU 9, 1977	302	7	54	80.8	1.8	12
GMU 13, 1975	296	10	53	79.2	2.9	32
GMU 13, 1977	292	16	25			
GMU 13, 1979	290	13	12	85.7	4.1	11
GMU 13, 1980	315	16	26	80.3	4.1	24
GMU 13, 1981	289	15	8	80.0	8.3	7
GMU 15, 1970	285	20	55	79.1	6.6	46
GMU 15, 1971	292	13	45	79.0	4.6	39
GMU 15, 1975	286	11	23	80.0	2.6	17
GMU 15, 1977	272	26	13			
GMU 20, 1971	276	15	8			
GMU 20E, 1984	302	14	30	90.0	2.1	30
GMU 22, 1981	290	19	27	88.2	3.5	24
Combined	290	11	531	81.6	3.5	389

[a] All population parameters are from Franzmann and Schwartz (1983), except GMU 20E, 1984 (this study).

Table 10. Condition-related blood parameters for Alaskan moose populations[a] during late winter/early spring season, 1969-84.

Population[a]	PCV % $\bar{x}$	PCV % SD	PCV % n	Hb (g/dl) $\bar{x}$	Hb (g/dl) SD	Hb (g/dl) n
Moose Research Center (inside)	41.0	5.0	37	16.8	2.1	38
Moose Research Center (outside)	41.8	5.2	38	16.5	1.9	39
GMU 1, 1978	36.6	6.1	14	14.2	2.3	14
GMU 1, 1982	40.8	5.9	16	14.7	1.7	16
GMU 5, 1978	40.4	3.4	36	16.6	1.4	36
GMU 6, 1974	53.5	3.8	32	19.9	0.3	32
GMU 9, 1977	39.0	5.4	56	16.4	1.3	54
GMU 13, 1975	49.2	3.8	55	19.7	0.7	55
GMU 13, 1979	40.9	3.6	10	16.8	1.6	10
GMU 13, 1980	43.0	5.2	23	17.8	1.2	23
GMU 13, 1981	43.8	4.3	9	17.8	1.7	9
GMU 14, 1974	35.8	10.2	21	13.5	3.0	20
GMU 15, 1975	46.4	3.0	25	18.9	1.3	25
GMU 15, 1977	36.5	4.4	12	13.2	2.3	12
GMU 20E, 1984	39.2	4.0	27	15.1	1.6	27
GMU 22, 1981	42.6	4.0	25	17.3	1.1	25
All populations combined	41.9	4.7	436	16.6	2.0	436

[a] All population parameters are from Franzmann and Schwartz (1983), except GMU 1, 1982 (Boertje and Young 1982) and GMU 20E, 1984 (this study).

Table 11. Sex, age, and percentage marrow fat of 10 moose killed by wolves in Game Management Unit 20E, Alaska, 1981.

Date killed	Location	Sex	Cementum age	% Marrow fat
19 Feb 81	Mansfield Creek	M	12	7
20 Feb 81	Fortymile River	M	13[a]	16
Mar 81	Billy Creek	M	14	35
8 Mar 81	Mosquito Flats	F	12	86
10 Mar 81	Mosquito Flats	M	14	93
13 Mar 81	Mosquito Flats	F	17	90
16 Feb 83	Mosquito Flats		15	87
16 Feb 83	Mosquito Flats	F	17	82
10 Mar 83	Billy Creek	F	14	85
24 Mar 83	Billy Creek	F	11	93

[a] Age estimated by tooth wear.

Appendix A

Instructions and Field Form for Browse Evaluation

INSTRUCTIONS FOR COMPLETION OF
MOOSE HABITAT EVALUATION SHEET

A. Background Information

1. Ref. No. Each 500 step transect should be numbered and cross-coded with a map.

2. Observers. Self explanatory

3. Date. Self explanatory

4. GMU. Self explanatory

5. Elevation. Estimate from location on topo map.

6. Slope Aspect. Estimate from location on topo map.

7. Main Drainage. Self explanatory.

8. Specific Location/Description. Note the location as closely as possible and describe the habitat through which the transect will be run, i.e., south side of ridge between Bear and Waterman Creeks; 15-year-old burn dominated by mixed hardwood saplings.

B. The Transect

Data will be collected at 100 points along a 500-step transect (every 5 steps). The transect can be U-shaped so that the starting and ending points are close, or the transect may be run along a compass bearing in a straight line. The transect type should be noted in the comments section. If possible, transects should be run in only one habitat type at a time.

1. Species. At each point on the transect, note the species of the nearest known moose browse species to that point. Do not note spruce trees or browse species unavailable to moose.

2. Use. None (0), Low (L), Moderate (M), High (H). Estimate the percentage of current year leaders on the shrub that has been browsed. Check "0" if none, "L" if less than 25%, "M" for 25 to 75%, and "H" if 75 to 100% of the leaders have been browsed.

3. Height (h). Estimate and record the height, in feet, of the plant.

4. Distance (d). This is the distance, in feet or inches, from the sample plant nearest your point to the next closest plant of the same species. This measurement can be used to gain knowledge of the density of plants of various species in the stand through which the transect is run.

C. Transect Summary

1. Species encountered. List all species encountered on the transect at the 100 points.

2. % occurrence in sample. Record the number of each species encountered. The number and the % will be the same with a total sample size of 100 plants.

3. Mean distance to neighbor. Calculate a mean distance for each species from nearest neighbors.

4. Mean height. Calculate the mean height for each species.

5. Use. For each species encountered, the % of use is calculated by dividing the number of plants in each use category by the total number of that species.

6. Comments. Note type of transect and additional observations. For example, a high percentage of <u>Salix alaxensis</u> plants along a transect may be too tall for moose (10 ft +) and not be represented in the sampling; note this situation.

BGDIF Part II c.6.a. Habitat, moose, browse evaluation form. Ref. No. ______________

Observer(s) ______________________________ Date ______________ GMU
Elevation (ft) __________ Aspect __________ Main drainage ______________
Location: ______ 1. Flats/valley bottom, ______ 2. hillside/upland, ______ 3. alpine
Community: ______ 1. shrub, ______ 2. deciduous forest, ______ 3. white spruce forest,
______ 4. black spruce forest, ______ 5. mixed (describe) ______________
Seral stage: ______ 1. young (1-30 yrs. post-fire or other disturbance)
______ 2. middle age (full size trees but not decadent)
______ 3. old growth (100 yrs.+, deciduous trees decadent)

Transect location/description (specific enough to permit replication, i.e., starting point, compass heading, paces between points: ______________

Remarks:

Transect Summary (to be calc. from data on reverse side):

Species Encountered	Occurrence in sample (%)	Mean distance to neighbor	Mean height	% with no use	% with low use	% with moderate use	% with high use
1)							
2)							
3)							
4)							
5)							
6)							
7)							
8)							
9)							
10)							

Key to data:

h = Estimated height (ft) of selected plant.
d = Estimated distance (ft) between selected plant and nearest neighbor of same species.
0 = No evidence of browsing on current annual growth.
L = Low use of annual growth (0-25% browsed).
M = Moderate use of annual growth (25-75% browsed).
H = High use of annual growth (75-100% browsed).

Browse Utilization Data Sheet (Key on flip side):

Plant Species	h	d	Use (✓)				Remarks	Plant Species	h	d	Use (✓)				Remarks
			O	L	M	H					O	L	M	H	