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MOOSE RESEARCH CENTER REPORT

by
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and
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JOB PROGRESS REPORT (RESEARCH)

State: Alaska

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Project No.: W-17-9 Project Title: Big Game Investigation

Job No.: 1.14R Job Title: Evaluation and Testing Techniques for Moose Management

Period Covered: July 1, 1976 through June 30, 1977

SUMMARY

A combination immobilizing drug (etorphine + xylazine hydrochloride) was first used on free-ranging moose with satisfactory results. The mixture of 7 mg etorphine and 300 mg xylazine hydrochloride provided the best proportions for moose immobilization. The mean induction time was 16 minutes. Hyaluronidase (250 units) was added to this immobilizing mixture on a later trial and mean induction time was 7.3 minutes. The reduced induction time may not be completely attributed to the addition of hyaluronidase because the moose were in extremely poor condition and were stressed by recent calving and initiation of lactation.

Pellet-group plots in Pen 1 were cleared in September 1976 and counted and cleared in May 1977. From stratified total winter pellet groups (27,592) and 1976-77 total moose days in Pen 1, 16.0 pellet groups/moose/day were calculated. From the unstratified total winter pellet groups (28,113), 16.3 pellet groups/moose/day were calculated. These calculations were comparable to actual mean deposition rate of 17.6 pellet groups/moose/day.

A study plan was designed for establishing fertilizer plots in the rehabilitated area of Pen 1 to investigate the potential for the use of nitrogen fertilizer to improve the quantity of moose forage. Fertilization blocks were layed out and ammonium sulfate fertilizer was applied during April 1977 at two rates of application and with one control block.

Biotelemetry trials on two moose with implanted heart rate and temperature transducers proved workable; however, the transmission range was limited and not usable for metabolic assessment. In addition, difficulty was experienced with recording and decoding the temperature data. The variability in voltages (battery) affected the decoder readings and we considered the temperature readings suspect. To accomplish our objectives the temperature and heart rate transmissions must have greater range (retransmitted from a receiver-transmitter on the moose's collar), the transmitter frequencies should not be FM, and the decoder must be improved or eliminated.

Part 2 of the Kenai Peninsula Predator Prey study (moose calf mortality) was initiated during this report period to assess the use of the mortality transmitters (which switch to fast mode after 4 hr. immobility), the capture techniques (immobilizing cows and capturing calves versus capturing calves alone), the automated monitoring system (30 m tower, programable receiver, and alarm system at the Kenai Moose Research Center [MRC]), the physiologic characteristics of both cows and calves during this critical period, and the causes of calf mortality. Fifteen radio-collared, post-capture bonded calves were monitored. Through June 30 black bear predation accounted for 26.7 percent mortality (4 calves), wolf 6.7 percent (1 calf), brown bear 6.7 percent (1 calf), and unknown predation 6.7 percent (1 calf). Total predation accounted for 46.7 percent of the moose calf mortality. There was no other mortality to the bonded calves.

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BACKGROUND

The Kenai Moose Research Center (MRC), with known numbers of confined animals, provides unique conditions for developing and testing techniques applicable to moose (*Alces alces*) management. Completion of programmed studies under this job was not always possible because developments in related fields providing drugs, equipment, and procedures potentially applicable to moose management determined the thrust of our activity. A final report covering activities under this project from July 1969 through June 1974 was completed (Franzmann et al. 1974). The 1976 progress report (Franzmann and Arneson 1976) covering this job was primarily devoted to pellet count census evaluations at the MRC from 1970 through 1974, the use of combinations of immobilizing drugs, and initial attempts at biotelemetry monitoring of temperature and heart rate. Drug testing and biotelemetry studies were continued. The pellet count census in Pen 1 was modified and accomplished by clearing plots in the fall.

Since winter 1974-75, the Kenai National Moose Range has mechanically rehabilitated 2266 ha (5600 acres) of moose browse in the 1947 Kenai burn using LeTourneau tree crushers (method described in Hakala et al. 1971). During fall 1976, 72.8 ha (180 acres) were rehabilitated in the southern one-third of Pen 1 at the MRC. Through observation and comparison with the established pellet group plots in Pen 1, relative use of the rehabilitated area versus the non-rehabilitated areas was assessed (Franzmann et al. 1976b).

Carpenter and Williams (1972) reviewed the role of mineral fertilizers in big game range improvement and concluded that much information exists on the effects of fertilization on forb and grass production. They also concluded, however, that effects upon browse yields are not as well documented. Most reports listed showed some favorable shrub response to nitrogen application (Schultz et al. 1958, Gibbens and Pieper 1962, Cosper et al. 1967, and Freyman and Van Ryswyk 1969). Merriam (1971) reported an increase in both vigor and quality of the Sitka black-tailed deer (*Odocoileus hemionus sitkensis*) browse species *Vaccinium ovalifolium* after application of biourea on winter range near Petersburg, Alaska. The possibility of using nitrogen fertilization to improve the quantity of moose forage has not been investigated in Alaska, and the mechanically rehabilitated portion of Pen 1 at the MRC provided an ideal area in which to make this determination.

On July 22, 1976, a supplement to the cooperative agreement between the U.S. Fish and Wildlife Service, Alaska Area, and the State of Alaska Department of Fish and Game became effective. Appendix I of this report contains the cooperative agreement and associated Kenai Peninsula Predator-Prey Study. Part 2 of the study as outlined was not funded for fiscal year 1977 by the Alaska Department of Fish and Game; however, Department approval was obtained to test procedures associated with the plan under this job.

A prototype moose mortality collar (AVM Instrument Co. Inc., Champaign, IL) was tested at the Kenai Moose Research Center (MRC) enclosures, and it proved acceptable for field application, testing and assessment. The U.S. Fish and Wildlife Service agreed to assist the Alaska Department of Fish and Game with the additional funding needed to complete the field testing and assessment. The U.S. Fish and Wildlife Service also funded the development, installation, and testing of the automated monitoring system at the MRC.

It was essential that Part 2 (Moose Calf Mortality) of this study not be delayed another year because Part 1 (Wolf Study) has been funded and initiated on the effective date of the cooperative agreement. Before the trial moose calf mortality study was initiated, four packs of wolves (*Canis lupus*) on the northern Kenai Peninsula were being monitored by radiotelemetry. The largest of these packs (18 wolves) was utilizing the study area for the proposed moose calf mortality study.

OBJECTIVES

To test and evaluate techniques that are potentially useful for determining population status, movements, and other factors necessary for management of moose.

PROCEDURES

Immobilizing, Reversing and Adjunct Drugs

No new drugs were tested during this report period; however, some new combinations of drugs were used. The combination of etorphine (M-99, D-M Pharmaceuticals, Inc., Rockville, Maryland) and xylazine hydrochloride (Rompun, Haver-Lockhart Laboratories, Shawnee, Kansas) was first used in the Interior on a routine immobilizing, sampling, marking and radio-collaring project (Gasaway et al. 1977). Moose were darted from a helicopter with 7 and 10cc projectile syringes fired from Cap-Chur guns (Palmer Chemical and Equipment Co., Douglasville, Georgia). Diprenorphine (M50-50, D-M Pharmaceuticals, Inc. Rockville, Maryland) was administered intravenously as the antagonist. Hyaluronidase (Wydase) was later added to the immobilizing combination to speed induction time.

Extended immobilization of moose was required for surgical procedures associated with implanting temperature and heart rate transmitters (Franzmann and Arneson 1976). The etorphine (M-99) and xylazine hydrochloride mixture was used for initial immobilization. The depth and time of immobilization were then altered by additional intravenous injections of xylazine hydrochloride.

Pellet Group Plots

Pellet group plots in Pen 1 (160 plots - 17.8m^2) that were used for census evaluation from 1970-74 (Franzmann et al. 1976b) were cleared of pellet groups from September 21-23, 1976. From May 24-26, 1977 these plots were counted and cleared and moose days were calculated for this 246-day period. We considered the moose estimates for Pen 1 the most accurate since we initiated these studies.

Effects of Nitrogen Fertilization Upon Production of Moose Forage

Wayne Regelin designed the following planned procedures for this study. Six blocks of land were selected for treatment with nitrogen (N) fertilizer. Two forms of fertilizer, two rates of application, and two seasons of application will be evaluated. Ammonium sulfate was applied to four blocks in April. These blocks will be given a fall application in October 1977. The remaining two blocks will also be given a fall application of urea. The blocks were divided into three treatment plots, each 30 x 30 m. Within each block, one plot received 67 kg/ha of actual N, one plot 134 kg/haN, and a third plot will serve as a control area. The fertilizer was spread with a "whirlybird" backpack spreader.

Five sampling plots, each 1 x 5 m in size, will be premanently established within each treatment plot. The number of hardwood shrubs (*Betula papyrefera, Populus tremuloides,* and *Salix* spp) and spruce trees (*Picea glauca* and *P. mariana*) rooted within each plot will be counted to provide density estimates. Within each plot all hardwood shrubs will be permanently tagged for intensive measurements, unless more than 10 shrubs of one species occur within the plot. In that case the 10 tallest shrubs of each species will be tagged. The following measurements will be made on each plant: (1) total height to nearest cm; (2) number of current annual growth (CAG) leaders; (3) length of each CAG leader measured from the nearest bud scale scar to the end of the terminal bud and recorded to the nearest cm; and (4) diameter of each CAG leader measured at the terminal end of the bud scale scar and recorded to nearest mm. The height of the four spruce trees closest to each plot will be measured and recorded to the nearest cm.

Estimates of plant biomass will be obtained by clipping all live vegetation (up to 2 m height) on 20 plots (30 x 60 cm) within each treatment plot. The clip plots will be located on four transect lines with five plots per line. The clip plots will not be located within any of the 1 x 5 m density plots. Birch, aspen, willow, and spruce species will be sacked individually; all other species will be sacked together. The clipped material will be dried for 24 hours at 100°C and weighed to the nearest 0.1 gram. All vegetation measurements will be made in late August.

The mean length and diameter of CAG twigs of each species will be calculated for each 1 x 5 m plot. Data will be analyzed by a random block analysis of variance to compare differences between the three rates (0, 67, 134 kg N/ha) of fertilizer. Separate analysis of variance will be evaluated by a T test. Analysis of plant height and biomass production data will be handled by similar methods but with more observations per treatment.

Schedule of study will be: (1) layout of blocks - April 1977; (2) spring application of fertilizer - April 12, 1977; (3) fall application of fertilizer - October 3, 1977; (4) vegetation measurements - August 1977, 1978, 1979.

Biotelemetry

Temperature transducers (Wildlife Materials Inc., Carbondale, IL), sealed in a glass cylinder (12 cm long x 6 cm diameter) and powered by one "D" size lithium battery, were placed in two moose, "Mike" on November 9, 1976, and "Olivia" on November 11, 1976. A laparotomy (Frank 1964) was performed and the apparatus was placed in the abominal cavity.

The FM frequency signals were recorded on a FM receiver with a cassette tape recorder. A 10 m tower was erected and a FM antenna with directional capabilities was installed. The recorded signal was decoded (Wildlife Material Inc.) to provide a millivolt reading which was then converted to an internal abdominal temperature reading. Prior to placement of transducers in the moose the millivolt correlations with temperature were obtained by means of controlled temperature water baths.

The heart rate transmitters tested in winter 1976 (Franzmann and Arneson 1976) were replaced with redesigned rectangular shaped (3 cm x 4 cm x 6 cm) transmitters and implanted in Mike and Olivia at the same time the temperature transmitters were placed in the abdominal cavity. The heart rate transmitters were implanted in the subcutaneous area anterior to the head of the humerus in the fossa formed by the cutaneous colli, brachiocephalicus, and anterior superficial pectoral muscles. The looseness of the overlying skin negated the pressure necrosis experienced during winter 1976 (Franzmann and Arneson 1976).

The temperature and heart rate signals were monitored on the FM receiver and recorded on tape. For close range a hand-held FM antenna was used and for longer range the tower antenna was employed.

Moose Calf Mortality Study

The study area was in the northcentral Kenai Peninsula lowlands in the vicinity of the 1947 Kenai burn (see Oldemeyer et al. 1977 for a description of the area). The area is bounded on the north by Moose Lake, on the east by the Chickaloon River, on the south by Bear Lake and the Moose River Flats, and on the west by the MRC (Fig. 1).

On May 29, 1977, eleven moose calves were processed and radio-collared following capture by means of a Bell Jet Ranger II helicopter (Kenai Air Service). The 10 associated cows (1 cow had twins) were also immobilized, visual-collared, and processed. On May 31, 1977, eight more moose calves were radio-collared. Three of the calves' dams (2 cows with twins) were immobilized, visual-collared, and processed; the remainder of the calves (4) were radio-collared and processed without immobilizing the associated cows. On June 7, 1977, another six calves were radio-collared and processed without immobilizing the associated cows.

Processing the cows and calves included blood-sampling the cows from the jugular vein (Franzmann et al. 1976c); blood-sampling the calves from the radial vein using a 21 gauge needle on a 10 cc syringe; plucking and collecting at least 1 gram of hair from the hump (Franzmann et al. 1975); measuring total length, chest girth, and hind foot length (Franzmann et al. 1977b); weighing the calves; extracting the first incisor from the cow for aging (Sergeant and Pimlott 1959); and assessing condition class of the cow (Franzmann et al. 1976c). Roto-tags (Nasco Inc., Modesto, CA) were placed in each calf's ear and cows were visual-collared, ear-tagged and flagged (Franzmann et al. 1974). A small burlap bag was placed over each calf's head and all four legs were tied together to assist handling.

The cows were immobilized using a combination of 7 mg etorphine (M-99, D-M Pharmaceuticals Inc., Rockville, MD), 300 mg xylazine hydrochloride (Rompun, Chemagro, Kansas City, MO), and 250 units hyaluronidase (Wydase, Wyeth Laboratories, Inc., Philadelphis, PA) (See Immobilizing, Reversing, and Adjunct Drugs section this report). Upon completion of processing both cow and calf or calves, the antagonist diprenorphine (M 50-50, D-M Pharmaceuticals, Inc., Rockville, MD) was injected into the cow's jugular vein. The cow was generally up in 2 to 4 minutes following injection.

The cow and calf or calves were together when the cow was given the antagonist, except for twin calves 39-171 and 39-173, which were 200 m from their cow when processed. We left the calves on a bog island when the cow left them during immobilization. We classified the remaining capture events as follows: (1) the calf was caught or caught and processed and placed in the helicopter; the cow was immobilized; and the calf was kept with the cow during processing (5 calves); (2) the cow was immobilized; the calf was caught and carried to the downed cow; and the cow and calf were processed together (4 calves); and (3) the cow was immobilized; the calf or calves stayed with the cow; and the cow and calf or calves were processed together (5 calves, including 2 sets of twins). Location of calves captured was recorded (Fig 1).

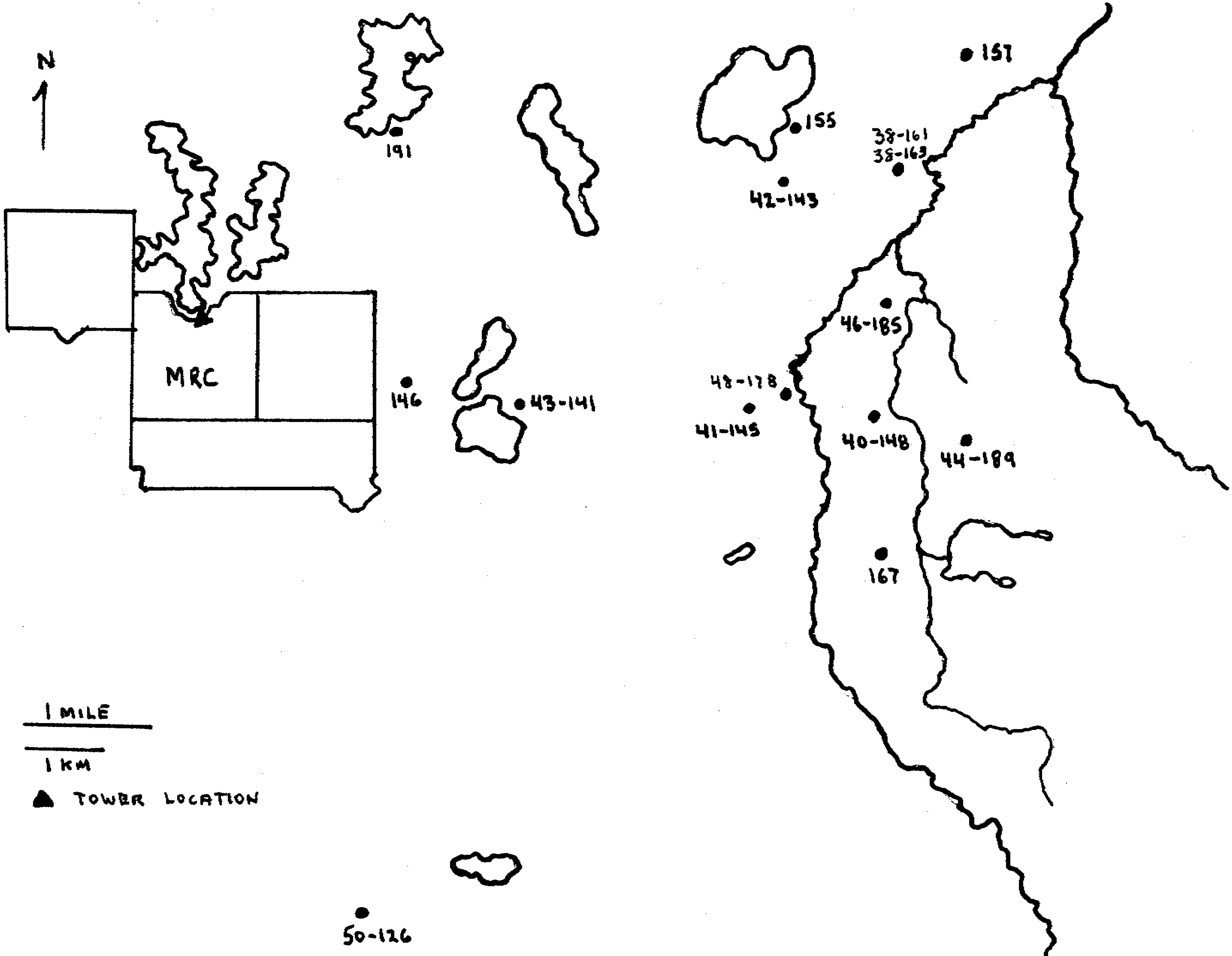


FIGURE 1. STUDY AREA AND CAPTURE LOCATIONS

The radio transmitters (AVM Instrument Co., Champaign, IL) placed on the calves ranged in frequency from 164.025 to 164.919 and while in motion pulsed at approximately 60 beats/minute. When movement ceased for approximately four hours the pulse tripled (188 to 217 beats/min). The radio-collar was designed to expand with calf growth to 66 cm circumference and then fall off. The beginning circumference was 33 cm (13 in). The collar was fashioned after the design for expanding goose neck bands and was constructed of vinyl plastic (4 cm wide x 2 mm thick). The transmitter was encased in acrylic and fastened to the collar by vinyl plastic rings through which the collar could freely expand. A 25 cm insulated wire antenna protruded from the encased transmitter and extended along the side of the collar.

From May 30 to June 15, 1977, the calves were monitored and located by daily flights (at 0700 hrs) in a Super Cub equipped with two yagi antennas clamped to each wing strut. Locations and movements were plotted using Kenai National Moose Range (KNMR) aerial photographs. During this period daily flights in a Super Cub (1900 hrs) were made by circling up over Kenai airport to an altitude necessary (300 m) to obtain a signal from each calf.

By June 15, 1977, a 30-m tower equipped with two yagi antennas had been erected at the MRC. A Falcon Five receiver (Wildlife Materials Inc., Carbondale, IL) and a memory unit (W. W. Cochran design) were used to monitor the calves. The original intent was to utilize the system which would activate a signal to the KNMR repeater station when the fast mode was detected and broadcast it through the KNMR communications system. The signal consisted of a siren burst, followed by the pulse beat and then by binary coded tones which indicated which transmitter had been activated. The system was operational for fast mode signals at close range; however, it could not always detect the fast mode signal from the study area (up to 9.7 km from tower) when the collar was on the ground. Standing calves were easily monitored on slow mode. These circumstances provided another option to monitor the calves, that of regularly (every hour or two) monitoring the calves with the receiver at the MRC. If a calf's signal was not heard for several hours, we would be alerted to monitor more intensively, and if no signal was heard for 4 to 6 hours we would check the calf by Super Cub. When a fast signal was monitored we would similarly respond. If a calf's fate could not be determined from the Super Cub, a helicopter or Super Cub on floats was employed to go to the area and proceed to the calf on ground. A thorough investigation of the calf and area was made at that time. If predation was suspected, a form designed by Mike Schlegel, Idaho Fish and Game Department, was used to record area, carcass, and predator data. A necropsy was performed on calves which were sufficiently intact. Appropriate samples were collected. A photograph was taken of each calf prior to handling or movement.

FINDINGS

Immobilizing, Reversing, and Adjunct Drugs

Results of the immobilizing drug mixture of etorphine and xylazine hydrochloride used on free-ranging moose were reported (Gasaway et al.

1977). The mixture of 7 mg etorphine and 300 mg xylazine hydrochloride provided the best proportions of these drugs for moose immobilized during August and October 1976 on the Tanana Flats and during April 1977 near Mother Goose Lake on the Alaska Peninsula ($\bar{x}$ induction time = 16 min.).

Hyaluronidase (250 units) was added to each immobilizing dose for adult female moose immobilized for the moose-calf mortality study (see Moose Calf Mortality section this report). The mean induction time was reduced to a mean of 7.3 minutes (range 3-15 min, n = 13). One cow required an additional 3 mg etorphine for immobilization since the initial dart did not completely inject its contents.

The reduced induction time with the addition of hyaluronidase (an enzyme which breaks down connective tissue permitting more rapid assimilation) may be misleading. The moose immobilized for the calf mortality study were in extremely poor condition and had been stressed by recent calving and initiation of lactation. These factors may have been more responsible for reduced induction time than was the addition of hyaluronidase. Future immobilization procedures with etorphine and xylazine hydrochloride should include hyaluronidase. Better assessment of the value of hyaluronidase can be made with seasonally comparable moose immobilizations.

The best antagonist results were obtained using 20 mg diprenorphine intravenously for moose immobilized with etorphine and xylazine hydrochloride with or without the addition of hyaluronidase.

Pellet Group Plots

A Poisson distribution was tested with the pellet group data from each vegetation type. In all cases the Poisson distribution fit the observed distribution (Table 1), indicating a random placement of pellet groups.

From stratified total winter pellet groups (27,592) and 1976-77 total moose days in Pen 1 (1,722), a deposition rate of 16.0 pellet groups/moose/day was calculated. From unstratified total winter pellet groups (28,113), 16.3 pellet groups/moose/day were calculated. These calculations were comparable to the actual mean deposition rate of 17.6 pellet groups/moose/day (Franzmann et al. 1976a).

Calculated pellet groups deposited/moose/day from 1970 through 1974 were much higher than the actual deposition rate and calculations from this study (range 20.0 - 28.7 pellet groups/moose/day) (Franzmann et al. 1976b). The improved calculated estimate was attributed to clearing the pellet group plots in September and not using estimated time of pellet formation by moose. We plan to clear the plots again during September 1977 and determine if the calculated estimates remain realistic for the 1977-78 winter survey.

Effects of Nitrogen Fertilization upon Moose Forage

Fertilization blocks were layed out and ammonium sulfate fertilizer was applied on April 12, 1977 as per study design.

Table 1. Pellet group survey and analysis, 1977

Vegetative Type	Acres	Hectares	Pellet Groups Per Plot	S^2	Pellet Groups Per Acre	Pellet Groups Per Hectare	Pellet Groups Per Type	X^{2*}
Dense Mature Hardwood	52	21.0	0.111	0.102	25.2	10.2	1309	0.01
Thin Mature Hardwood	39	15.8	0.56	0.529	127.0	51.4	4953	0.06
Spruce Regrowth	39	15.8	0.14	0.143	31.8	12.9	1238	0.00
Spruce-Birch Regrowth	22	8.9	0.25	0.212	56.7	22.9	1247	0.03
Thin Birch-Spruce Regrowth	37	14.9	0.235	0.191	53.3	21.6	1972	0.06
Med. Birch-Spruce Regrowth	60	24.3	0.125	0.116	23.4	9.5	1701	0.01
Dense Birch-Spruce Regrowth	98	39.7	0.35	0.618	79.4	32.1	7779	0.28
Rehabilitated Area	159	64.3	0.205	0.260	46.5	18.8	7392	0.22
Total	506	204.8	0.245	0.285	55.6	22.5	28113	0.92

* X^2 analysis to determine if observed distribution of pellet groups within a type fit a Poisson distribution.

Biotelemetry

On November 9, 1976, a temperature transmitter (FM freq. 92) and a heart rate transmitter (FM freq. 101) were placed in "Mike," a male 1976 twin calf of Raquel. A location and activity transmitter (VHF) freq. 151.220 mhz) was also placed on the moose for ease of location. On November 11, 1976, a temperature transmitter (FM freq. 104) and a heart rate transmitter (FM freq. 96) were placed in "Olivia," a female 1975 yearling of Raquel. The location and activity radio-collar placed on Olivia had a VHF frequency of 150.970 mhz. On November 18, 1976, "Mike" was immobilized and the activity transmitter was replaced with a 30.06 mhz transmitter because of suspected overide of the signal on the heart rate transmitter. The overide also occurred with the 30 mhz transmitter. Further complications developed when a new FM station in Kenai went on the air on November 18. The station frequency was 100.6, which made it impossible to monitor the 101 frequency heart rate transmitter.

Following implantation the heart rate transmitter in Olivia was transmitting her heart beat; however, we had to stand within 3 m of her to monitor it. With that limited range, application of heart rate data was not feasible.

The only option remaining was to monitor temperature. We received temperature transmission up to 75 m using the 30 m tower and antenna. We monitored and recorded internal temperatures on Mike and Olivia from November 9 and 11, 1976, to March 8, 1977. Temperatures tapes recorded after December 14 were not converted because of a malfunction of the decoder. Even prior to the malfunction, it was noted that voltage output variability at recording and playback into the decoder significantly influenced millivolt readings. Both variables were influenced by ambient temperature, length of time batteries were used at each recording or playback, and period of disuse prior to recording or playback.

We attempted the following procedures to minimize this influence: (1) insured that batteries had at least a 6-volt output at recording by checking daily; (2) kept recorder as warm as possible; (3) utilized an AC converter for playback and decoding; and (4) used the same power source. Several unanswered questions remained as to: (1) what influence or differences in millivolt readings were occurring when battery output exceeded 6 volts; (2) how much variability remained in the system using battery source to record; (3) what long term influences occurred with drop in voltage of battery on transmitter; and (4) what influence moving the decoder had on its consistency in recording. We had noted variability in readings when the decoder was moved or bumped.

With all of these unknowns we were somewhat relieved when the decoder finally malfunctioned completely. It was of no value to have it repaired, since our basic problems still remained.

Taking all the precautions possible, we found the internal temperature range of Mike varied from 37.0 C (98.6 F) on November 19 to 40.0 C (104.1 F) on December 2. Olivia's temperature ranged from 37.2 C (98.9 F) on November 17 to 38.3 C (100.9 F) on several dates. The extremes were not associated with any major ambient temperature changes. Winter 1976-77 provided no prolonged severe weather; the lowest temperature recorded while monitoring the moose temperatures was on December 8, when the temperature was -13 F at 0815 hrs.

The data obtained are suspect, to say the least. Many changes must be made to make the monitoring system work, including: (1) finding an alternative to FM frequencies; (2) retransmitting the signal from the transducer via a receiver-transmitter carried on the moose's collar or placing retrievable receiving and recording devices on the collar; (3) developing a dependable decoder if required; and (4) establishing a close working relationship with the designer and developer of the equipment.

Moose Calf Mortality Study

Capture Method

The mean induction time for adult female moose was 7.3 minutes (range 3-15 min.). Gasaway et al. (1977) reported mean induction times of 16 minutes (range 5-50 min.) for adult moose immobilized in August and April. The addition of 250 units of hyaluronidase may have been responsible for the decrease in induction time; however, moose immobilized in this study were in very poor condition (most were class 5 or 6 - see Franzmann et al. 1976c). The poorer condition, in addition to the stresses of recent calving and lactation, may have been primarily responsible for decreased induction time. The post-immobilization tranquilizing effects of xylazine hydrochloride may have partially influenced cow-calf separation. No data suggest this, but separation occurred in some instances and anything which may have been a contributing factor should be investigated. The partially tranquil cow may not respond to stimuli that maintain or reinstate the cow-calf bond. Conversely, the partially tranquil cow may not be affected by post-capture activity (helicopter in area) and may rebond more readily. To assess cow response future immobilization attempts should be made with reduced dosages of xylazine hydrochloride.

We immobilized the cow of each calf or calves for the first 14 cows (17 calves). Subsequent monitoring of these individuals indicated potential cow-calf separation. Additionally, one cow died from unknown causes at capture prior to receiving the antagonist and female #47 bogged down after capture. In spite of slinging her to high ground with the helicopter, she continued to weaken and was sacrificed. She was in extremely poor condition at capture (she fell down on initial pursuit). Her incisors were worn to the gums, yet she had twin calves. Aging data were not available in time for this report. Her packed cell volume (PCV) was 31 percent and hemoglobin was 10.5 gm/100ml. These were the lowest recorded for an adult female moose (Franzmann et al. 1976c).

The remainder of the calves radio-collared were processed without immobilizing the cow (Table 2).

Cow/calf separation

Three of five cows immobilized by method A (Table 2) (the calf was caught or caught and processed and placed in the helicopter; the cow was immobilized and cow and calf were kept together during processing) experienced

Table 2. Capture, mortality, and survival of moose calves on Moose River Flats area, Kenai Peninsula, Alaska.*

Calf	Date Captured		Capture Weight and Age[1]	Capture[2] Event	Separation[3] or Bond	Separation Result	Predation Date and Age	Other Mortality	Method of Detection	Age At Death (Days)
50-126	5/29/77	M	21.1 kg 5 day	B	Bond		6/12/77 19 day Black Bear		Observed (Super Cub)	19
49-176	5/29/77	M	14.1 kg 1 day	A	Separation	Starvation 5/31/77			Mortality Signal	3
48-178	5/29/77	M	16.4 kg 3 day	B	Bond		6/13/77 14 day Black Bear		Observed 6/12/77 Mortality Signal 6/13/77	18
47-181 Twins ↕	5/29/77	M	13.4 kg 1 day	C	Bond Cow Bogged down Slung to high ground 5/30/77 Sacrificed			Kicked by down cow	Mortality Signal	2
47-183	5/29/77	F	13.4 kg 1 day	C	cow 5/31/77			Sacrificed with cow	Observed	2
46-185	5/29/77	M	-- 3 day	A	Bond					
45-187	5/29/77	M	22.0 kg 6 day	A	Separation	Black Bear Predation 5/31/77			Observed	7
44-189	5/29/77	F	20.2 kg 4 day	B	Bond		6/21/77 28 day Black Bear		Monitored from MRC Mortality Signal 6/23/77	28
43-141	5/29/77	M	24.3 kg 8 day	B	Bond		6/2/77 12 day Wolf		Observed	12

Table 2. (cont.) Capture, mortality, and survival of moose calves on Moose River Flats area, Kenai Peninsula, Alaska.*

Calf	Date Captured	Sex	Capture Weight and Age[1]	Capture[2] Event	Separation[3] or Bond	Separation Result	Predation Date and Age	Other Mortality	Method of Detection	Age At Death (Days)
42-143	5/29/77	M	25.2 kg 8 day	A	Bond		6/3/77 13 day Black Bear		Observed 6/3/77 Mortality Signal 6/5/77	12
41-145	5/29/77	M	14.3 kg 2 day	A	Bond		6/2/77 6 day Unknown (Black Bear Suspect)		Mortality Signal	6
40-148	5/31/77	M	14.5 kg 2 day	C	Separation	Adopted by unmarked cow 6/1/77				
39-171 ↑ Twins ↓	5/31/77	M	19.5 kg 4 day	Modified C Did not process together Calves processed on island, Cow processed 200 M from calves	Separation	Starvation 6/6/77			Mortality Signal	6
39-173	5/31/77	M	14.5 kg 4 day		Separation	Starvation 6/6/77			Mortality Signal	6
38-161 ↑ Twins ↓	5/31/77	M	25.9 kg 8 day	C	Bond				Mortality Signal (lost collar) 6/8/77	
38-163	5/31/77	M	22.3 kg 8 day	C	Bond					
37-165	5/31/77	F	20.9 kg 5 day	Cow died Calf sacrificed Collar Removed						5
167	5/31/77	M	15.9 kg 3 day	Calf only	Bond					
169	5/31/77	F	18.6 kg 4 day	Calf only	Separation	Starvation 6/6/77			Mortality Signal	10

Table 2. (cont.) Capture, mortality, and survival of moose calves on Moose River Flats area, Kenai Peninsula, Alaska.

Calf	Date Captured	Sex	Capture Weight and Age[1]	Capture Event[2]	Separation or Bond[3]	Separation Result	Predation Date and Age	Other Mortality	Method of Detection	Age At Death (Days)
157 ↑ Twins	5/31/77	M	15.4 kg 3 day	Calf Only	Bond		6/15/77 18 day Brown Bear		Monitored from MRC	18
↓ 159	5/31/77	M	15.4 kg	No Radio	Bond		--		--	
153	6/7/77	M	28.2 kg 10 day	Calf Only	Separation	Wolf Predation	6/8/77 11 day		Observed 6/8/77 Mortality Signal 6/9/77	11
151	6/7/77	M	36.3 kg+ 16 day	Calf Only (in water)	Unknown (Died day of capture)		Pneumonia	Foreign body Signal (Aspirated Water)	Mortality	17
155	6/7/77	M	35.0 kg 15 day	Calf Only	Bond					
191	6/7/77	M	30.4 kg 12 day	Calf Only	Bond					
193	6/7/77	F	29.1 kg 11 day	Calf Only	Bond				Mortality Signal (lost collar) 6/9/77	
146	6/7/77	M	26.4 kg 9 day	Calf Only	Bond					

1. Age was based upon weight (Birth weight $\bar{x}$ of 30# + 3#/day gain)
2. A = the calf caught, or caught and processed, placed in helicopter, the cow was immobilized, & cow & calf kept togethe during processing.
   B = the dow was immobilized, the calf caught and carried to cow, and processed together.
   C = the cow was immobilized, the calf stayed with the cow, and processed together.
3. Calf with cow for minimum of 48 hrs post capture.

* Data until June 30, 1977.

permanent separation. By method B (the cow was immobilized, the calf caught and carried to cow, and the calf and cow were processed together) no permant separation was experienced (n=4). Using method C (the cow was immobilized, the calf or calves stayed with the cow, and the cow and calf or calves were processed together) one of three experienced permanent separation; however, that calf was apparently adopted by another unmarked cow and they bonded permanently and were together at the time of this report. When one cow (#39) was processed separately from her calves, absolute separation occurred. When calves alone were captured, 2 of 8 cow-calf groups were permanently separated, and one outcome was unknown (Table 2).

It is apparent that permanent cow-calf separation may occur during this type of study. Methods which lessen such a possibility should be adopted whenever feasible. If the study objectives include obtaining data from the cow, it seems beneficial to immobilize the cow prior to handling the calf. It may be necessary to refrain from immobilizing the cow if upon initial pursuit the cow/calf bond appears weak, with separation occuring at the first sign of the cow's disinterest in her calf. If study objectives do not include obtaining data from the cow, immobilizing the calf alone would be proper. Separation occurred with this method also; however, each case involved processing the calf for physiologic and morphometric data. If such data are not part of the objectives and simply radio-collaring the calf will suffice, separation would likely be lessened by capturing the calf, installing the radio-collar, and leaving as soon as possible. It should be noted that calves alone were captured later during this study and thus were older (Table 1), a factor which may have increased their ability to maintain a post-capture bond.

The lack of physiologic and morphometric data from the cows and calves or from calves collared alone may be a substantial loss in terms of interpreting events taking place at this critical period in the life history of moose.

We found that considerable time was saved during observational monitoring of cows and calves when the cow wore a visual collar. The visual collar was a definite aid in obtaining data about cow-calf separation and recording post-predation movement of the cow. The adoption of calf #40-148 by an unmarked cow would not have been detected had this calf's mother also been unmarked. In addition, radio-collaring at least some of the cows for purposes of monitoring predator-prey activities during calving is warranted by the presence of three major predator species in the area.

The helicopter costs of radio-collaring and processing a calf alone were $197.00; capturing and processing a cow cost an additional $201.00. Drug cost per calf processed was $54.50. Costs for doing calves alone were somewhat biased in that these calves were larger and harder to find. Unfortunately, we do not have same-day cost comparisons, but the costs/unit do not appear to be a limiting factor.

Physiologic and Morphometic Measurements

Preliminary blood data from adult female moose reflected poor condition (Franzmann et al. 1976c). No packed cell volumes (PCV) exceeded

45 percent ($\bar{x}$ = 39%) and hemoglobin (Hb) values did not exceed 16.5 gm/100ml ($\bar{x}$ = 14.0 gm/100 ml). Calf PCV values did not exceed 39 percent ($\bar{x}$ = 29.9%) and Hb values did not exceed 13.5 gm/100 ml). Other blood chemistries have not yet been analyzed but should provide more information regarding physiologic status of cows and calves (Franzmann et al. 1976c). Likewise, hair element analyses have not been received nor have the cows been aged (cementum anuli). All cows but one had extensively worn incisors and appeared to be older individuals. Comparative physiologic data from cows with calves experiencing predation and/or separation may provide clues as to the possibility of a physiologic basis for vulnerability to predation or bond breakdown. These possibilities will be investigated when analyses are complete.

Calf weights at time of capture were used in estimating age (Table 1). A male calf born at the MRC weighed 14.5 kg (32 pounds) at birth and at age one week weighed 23.6 kg (52 pounds), a gain of 1.3 kg (2.9 pounds) per day (Franzmann and Arneson 1973). The range in moose weights was 14.4 kg (30 pounds) to 36.3 kg (80 pounds) for calves age 1-16 days.

Morphometric measurements also reflected calf age. For calves age 1-16 days, total length measurements ranged from 88 to 115 cm; heart girth ranged from 55 to 75.5 cm; hind foot ranged from 31 to 41 cm (length to dewclaw was approximately 10 cm less on all age classes); and neck circumference ranged from 27 to 36 cm. Reported total length/weight correlation was 0.94; chest girth/weight correlation was 0.90; and hind foot/weight correlation was 0.87 (Franzmann et al. 1977b). Measurement/weight relationships from calves age 1-16 days corresponded to these correlations. Neck circumference measurements were not available for newborn calves prior to radio-collaring, and an estimated collar circumference of 33 cm (13 inches) was obtained and confirmed by data extrapolation from older moose.

Bonded Calf Mortality

Only calves that had retained the cow/calf bond after capture were monitored to establish natural mortality. Fifteen calves remained bonded with their cows for 48 hours or more after capture (Table 3). An additional unradioed twin calf (#159, brother of calf #157) was available for observation until June 15, 1977, when two brown bears (*Ursus arctos*) killed #157. The fate of calf #159 was unknown. Total predation of bonded calves was 46.7 percent. Black bear (*Ursus americanus*) predation was 26.7 percent; wolf predation was 6.7 percent; brown bear predation was 6.7 percent; and unknown predation was 6.7 percent. No other type of mortality was recorded (Table 3). These figures are inclusive to June 30, 1977 (this report date).

Calf #41-145 was monitored on fast mode at 1600 hrs on June 2, 1977, and we arrived at the site at 1900 hrs. No predators were seen in the area. The cow was sighted 100 m from carcass (#41 collar). The birch (*Betula papyrifera*)-spruce (*Picea mariana*) canopy cover was approximately 10 percent. The uncovered carcass was 90 percent consumed, with only parts of skull, mandible and teeth, broken femurs, other bone pieces and the partially inverted hide remaining. No predator sign was located (scats, hair, or prints). The hide was ripped

Table 3. Mortality of moose calves with good post-capture cow/calf bond until June 30, 1977

Calf Number	Predator and Predation Date				Other Mortality and Date
	Black Bear	Brown Bear	Wolf	Unknown	
38-161					
38-163					
40-128					
41-145				6/2/77	
42-143	6/3/77				
43-141			6/2/77		
44-189	6/21/77				
46-185					
48-178	6/12/77				
50-126	6/12/77				
146					
155					
157		6/15/77			
167					
191					
Percent	26.7%	6.7%	6.7%	6.7%	Total 46.8

in several areas. The cause of mortality was recorded as unknown predator but was likely a black or brown bear.

Calf #43-141 was located by Super-Cub on June 2, 1977, with a black wolf near the slow mode signal site at 0800. At 1930 we went to the area by helicopter. The black wolf was again sighted in the area, and the signal was still on slow mode. The calf's carcass was found buried in the duff layer at the base of a hill in a mature birch stand with 50 percent canopy cover. The calf was approximately 40 percent consumed (hind legs, entrails), with the hind legs lying 47 m from the remainder of the buried carcass (hide still intact). The radio-collar was on the carcass. The cow was not seen in the area. The cause of mortality was determined as wolf predation.

On June 3, 1977, a black bear was sighted at 0745 near the slow mode signal origin of calf #42-143, but neither cow nor calf was observed. On subsequent morning flights (June 4 and 5) neither cow nor calf was sighted, though the signal origin location remained the same. At 1900 on June 5 a fast mode signal was detected at 1900 m over Kenai Airport. On June 7 we went to the site via helicopter and found the calf carcass 84 percent consumed (by weight). All that remained were bone fragments and the partially inverted hide, which had 30-40 cm tears. The radio was 20 m from the feeding site. Four bear scats were located within a 30 m radius of the feeding site. The cause of mortality was determined as black bear predation.

On June 11, 1977, cow #48 and calf #48-148 had moved 17.6 km up Thurman Creek into the mountains. The signal location was identified but the calf was not seen in the heavy spruce. Two black bears were sighted in the area. On June 12 at 0830 the slow mode signal was located farther up Thurman Creek but neither cow nor calf was sighted. A black bear was sighted 1 km from the signal. On the morning of June 13 the signal was on fast mode. We went to the area via helicopter and located the uncovered calf carcass on a hillside near Thurman Creek in a 20 percent spruce canopy cover. The partially inverted hide and partially eaten head (ears, tongue, and nose) were at a site 12 m from the broken radio-collar, parts of broken femur, and scapula. No predator sign was found in the area. The cause of mortality was determined as black bear predation.

On June 12, 1977, at 0930 the carcass of calf #50-126 was sighted by Super-Cub in a clump of spruce. A large black bear was feeding on a winter-kill calf 60 m from the calf carcass. Cow #50 was not in the area. The radio signal was on slow mode. On June 13 we went to the site via helicopter. The signal was still on slow mode and the cow was still not in sight. The uncovered carcass was 80 percent consumed (all flesh except one thigh) and was located in a spruce bog area with 30 percent canopy cover. The leg bones were not cracked and the head was eaten. The hide was partially inverted and torn. The cause of mortality was determined as black bear predation.

From 0300 on June 14, 1977, to 1400 on June 15, we were not able to monitor any signal from calf #157 using the tower and receiver at the MRC. A Super-Cub was flown to the area and two large brown bears were seen feeding on the carcass of calf #157. This calf was a twin to unradioed calf #159 and its fate was unknown. No flights were made to land at the site because the predator had been positively identified. The remains at the site were negligible. The cause of mortality was determined as brown bear predation.

The signal from #44-189 was sporadic or not heard at MRC on June 21 and 22, 1977. The fast mode signal was received via Super-Cub on June 23 at 0930 and the carcass was sighted. At 1500 we arrived at the site via Super-Cub on floats. The calf carcass was 300 m south of Buteo Lake in spruce-birch regrowth with 10 percent canopy cover. The carcass was 95 percent utilized with only mandibles and teeth, hooves, hide and bone fragments remaining. The broken radio-collar was at the feeding area. Black bear sign was evident (4 scats, and tracks). The carcass was not covered, but there were two dug areas (1 m^2) within 10 m of the carcass. The cow was not in the area. The cause of mortality was determined as black bear predation.

The question arises as to whether or not the calves classified as predation mortalities may have died of other causes prior to predation. Separation and starvation of four calves (one set of twins) and capture-related deaths of two cows (one cow at capture, one sacrificed after unsuccessful attempts to sling her from a bog) occurred during this study. We were not able to check back on all the capture-related deaths, but those which we checked were virtually unutilized for days. Cow #47 was sacrificed on May 31, 1977, and no sign of disturbance was noted till June 12, 1977. Calf #39-171 died on June 6, 1977, and had not been disturbed as of June 14, 1977. Calf #169 was dead 36 hours prior to radio recovery, and it was undisturbed at that time. Calf #151 died June 8, 1977, was necropsied that same day, and, when visited on June 18, had not been utilized. Warren Ballard witnessed similar predator-scavenger non-use of dead moose calves in his study conducted in Unit 13 (pers. comm.). Using calf carcasses for baiting wolf traps during early June, Rolf Petersen (pers. comm.) observed similar predator-scavenger non-use of dead calves.

During the flights over the study area, 13 adult or subadult black bears were seen in addition to a sow and three cubs, which were observed several times. Two subadult brown bears were seen on two occasions and two adult brown bears were seen on three occasions. A single grey and a single black wolf were also seen. With three major potential predators (black bear, brown bear and wolf) in the area, it may be difficult to identify a predator without witnessing it at the kill site when sign (scats, tracks, etc.) at the site is absent.

The two wolf-killed calves (one bonded, one separated), both of which predations had been witnessed, were buried in the duff layer, their remains almost invisible. Neither had been completely eaten. No victims of black or brown bear predation were buried. On the basis of this observation calf #41-145 may be transferred from the "unknown" classification to the "unknown bear" classification. The hides of bear-killed calves appear to be torn or ripped more than those of wolf-killed calves. Bears seem to invert the hide regularly; only one wolf did so and then only slightly. Wolves refrained from eating the head; however, the carcases were not completely consumed, as in the cases of bear predation, though wolves may have returned to the kills at a later date to resume feeding. Teeth in the mandible, hide, hooves, and bone fragments were all that remained of most bear-killed calves.

Movements (Bonded Calves)

From capture dates (May 29 and 31 and June 7, 1977) movement of the cow and calf or calves was plotted by daily Super-Cub flights until June 15, 1977, when monitoring from the MRC was begun. Thereafter, moose calves were located on a schedule compatible with radioed wolf tracking and flights to assess calf mortality.

No specific movement activities were evident from this small sample; however, certain movement observations may be associated with predation or predation attempts. In general, all bonded calves tended to remain within 1.6 km (1 mile) of the capture site (usually within 100 m). Movements of 1.6 km or more (up to 14.4 km) were recorded for what seemed, at the time, no apparent reason (Fig. 2). When movements were compared with predation a pattern seemed to develop. The moose calves killed by black bears had traveled 3.2, 4.8, and 14.4 km one or two days prior to predation. Calves killed by the wolf and by brown bears and the unknown kill were within 1.6 km of capture site. Calves not killed by June 15 had on occasion made sporadic moves, but only one exceeded 3.2 km. Calf #44-189 moved 4.8 km 7 days after capture. It was later killed by a black bear on June 21, but no pre-kill movement data were available).

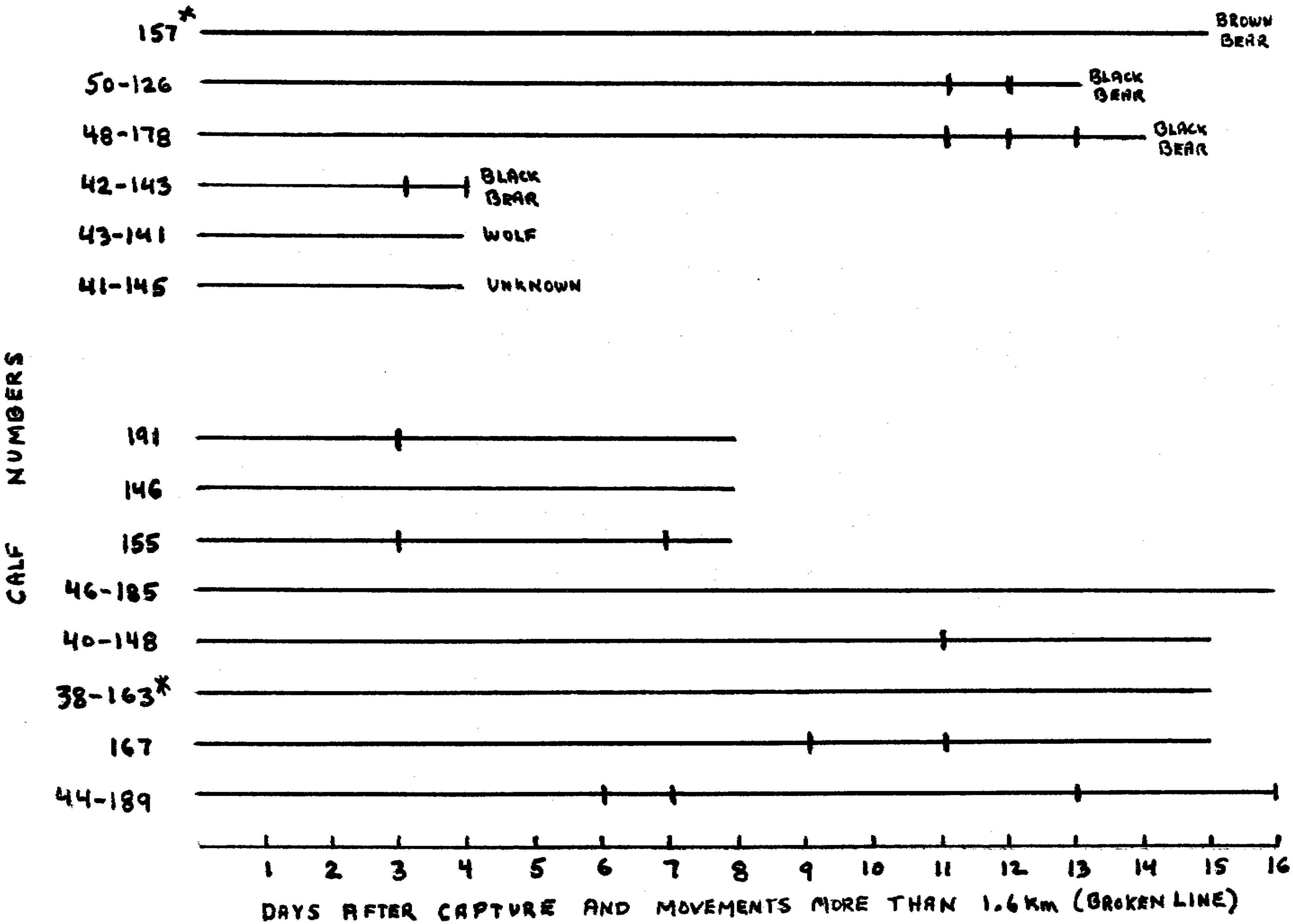
During the study a black bear was observed stalking a cow and calf. The bear made no direct moves toward the pair but continually moved in their general direction, forcing the nervous cow to move in bursts. She would stop, observe the bear, and then proceed at a rapid gait, gradually slowing and then stopping. She would then repeat the process. The calf stayed with her. The bear continued to stalk the pair until it sighted the observer (A. Franzmann) and bolted in the opposite direction. The cow and calf came right by the observer without concern.

Moose calf movements associated with black bear kills may be interpreted from this observation to be the result of tactics used by black bears in stalking and killing moose calves. The cow and calf may be forced into unfamiliar surroundings, thus increasing the predator's chances for success. The lack of movement of calves killed by the wolf and brown bears may be the result of a different predator strategy. Other major movements not actually followed by black bear predation may have occurred because of attempted predation.

Obviously, more observations and data are required, but these preliminary findings indicate that there are opportunities to obtain such data and that there is need for a more intensive approach to the study.

Monitoring movements via the system installed at the MRC was discussed with W. W. Cochran, and he indicated that for approximately $600.00 an activity mode could be placed in the MRC receiver system and integrated into Rustrak recording devices. A Rustrak recorder

FIGURE 2. MAJOR MOVEMENTS OF MOOSE CALVES



* REPRESENT TWINS

would be required for every four moose monitored. This would serve as a backup system for the 1-or-2-hour mortality mode transmitters (the 4 hour time in this trial was too long) and provide additional diurnal activity data for cows and calves. The transmitters should also be more finely tuned and the antennas extended to 41 cm (16 inches). Circuitry for transmitters is being developed which would provide substantially improved transmitting capabilities, and it should be available for the next calving season. Monitoring from the MRC saves considerable time and expense by decreasing the need for monitoring flights.

RECOMMENDATIONS

1. Hyaluronidase (250 units) should be added to the immobilizing drug combination of etorphine and xylazine hydrochloride to allow further comparisons of reductions in induction time.

2. Pellet group plots in Pen 1 should be used to continue monitoring habitat (particularly rehabilitated habitat) use by moose and to reaffirm calculated pellet groups/moose/day.

3. Biotelemetry transducers with greater range must be utilized to assess the metabolic stress of moose associated with various treatments during critical winter months. FM frequency transmitters should be avoided.

4. The moose calf mortality study should be initiated at full scale for the next calving season.

5. Mortality transmitters should be set at one or two hours and a back-up activity receiver and recorder should be utilized for monitoring at the MRC.

6. Several cows (6) should be radio-collared to assist interpretation of bond disruption, movement associated with predation, and post-predation activity.

7. The additional information obtained from processing both cow and calf warrants continuation of this procedure for a portion of the sample, depending upon the initial cow/calf response to helicopter immobilization.

8. The nature and extent of the predation observed in this study indicate that Part 3 of the Kenai Peninsula Predator-Prey Study (Bear Study) should be initiated as soon as possible.

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Appendix I

SUPPLEMENT TO

COOPERATIVE AGREEMENT

between the

UNITED STATES FISH AND WILDLIFE SERVICE, ALASKA AREA

and the

STATE OF ALASKA DEPARTMENT OF FISH AND GAME

Relating to the moose-range relationship studies to be undertaken on the Kenai National Moose Range under penned conditions.

Under this Supplemental Cooperative Agreement effective this 22 day of July, 1976.

The Service agrees:

(a) To cooperate fully with the Department in investigational studies of moose calf mortality and bears as outlined under the Kenai Peninsula Predator - Prey Study.

(b) To have primary responsibility for conducting the wolf part of the Kenai Peninsula Predator - Prey Study.

(c) To assist and have secondary responsibility for carrying out moose calf mortality and bear portions of the Kenai Peninsula Predator - Prey Study.

The Department agrees:

(a) To cooperate fully with the Service in investigational wolf studies as outlined under the Kenai Peninsula Predator - Prey Study.

(b) To have the primary responsibility for conducting the moose calf mortality and bear portions of the Kenai Peninsula Predator - Prey Study.

(c) To assist and have secondary responsibility for carrying out the vegetative studies within the pen.

The Department and the Service mutually agree:

(a) To meet periodically (at least annually) to form a united approach in reviewing studies in progress and discuss and plan future investigations.

(b) To cooperate jointly in preparing investigation results for publication. Each agency shall have an opportunity to review all proposed publications resulting from this joint study before the publications are submitted to a journal. Manuscripts will be authored by those individuals responsible for carrying out the investigations irrespective of the primary responsibility assignments. Press releases to the various news media designed to acquaint the public with the objectives and progress of the study are included in the foregoing provision. In addition, both agencies should be credited in all releases.

(c) That if either agency having the primary responsibility for conducting any phase of these investigations is unable to complete their project due to lack of funds or personnel, the other agency may undertake its completion.

(d) That for the purpose of coordinating research the Refuge Manager of the Kenai National Moose Range and the Regional Research Coordinator of the Department will have the authority to speak for both agencies in carrying out day to day activities of this program.

(e) Study data will be mutually available to either agency at any time.

(f) An annual progress report due on April 30 will be prepared for each part of the Kenai Peninsula Predator - Prey Study (wolf, moose calf mortality and bear).

BUREAU OF SPORT FISHERIES AND WILDLIFE

By ______________________________
Regional Director

Date ______________________________

ALASKA DEPARTMENT OF FISH AND GAME

By ______________________________
Commissioner

Date ______________________________

Project Title: KENAI PENINSULA PREDATOR-PREY STUDY

Project Coordinators: James B. Monnie, Kenai National Moose Range; Karl B. Schneider, Alaska Department of Fish and Game

Principal Investigators: Albert W. Franzmann, Alaska Department of Fish and Game; Rolf O. Peterson, U. S. Fish and Wildlife Service

Project Objective: To determine the nature and extent of wolf and bear predation on prey species and the characteristics of both predator and prey that influence their interaction.

Location: Project will encompass the Kenai Peninsula as delineated by Game Management Unit (GMU) 7 and Game Management Subunits 15A, 15B and 16C.

Cooperative Aspects: Project is cooperative venture of Alaska Department of Fish and Game and the U.S. Fish and Wildlife Service through the Kenai National Moose Range as per Supplement to Cooperative Agreement now in force.

Job Title: Kenai Peninsula Predator Prey Study: Part 1 - Wolf Study

General Objective: To determine population size, population structure, population trends, and territories of wolves on the Kenai Peninsula and assess their prey utilization, food habits, and general physical and physiological parameters.

Sepcific Objectives:

1. To determine number and sizes of wolf packs.

2. To determine sex, age structure and physical and physiological condition of wolf packs.

3. To determine stability, dispersal, and territories of the wolf packs.

4. To refine estimates of wolves and wolf population trends on the Kenai peninsula.

5. To determine seasonal food habits of wolves.

6. To determine sex, age and condition of wolf prey in respect to general characteristics of prey population.

7. To assess the impact of wolves on their primary prey, the moose.

8. To integrate concurrent moose calf mortality and bear studies in a physical and informational manner.

Justification: Management decisions regarding Kenai Peninsula wolves will be better substantiated with information on pack size, pack numbers, wolf population distribution and trends, which this study will provide. An informed assessment of wolf predation impact on moose, the primary prey on wolves on the Kenai, would provide additional information for formulating moose management decisions.

Status: Moose distribution, habitat, fluctionaions, movement and migrations on the Kenai Peninsula were reviewed by LeResche et al. (1974), Bishop and Rausch (1974) and LeResche (1974). Moose management and management pland for Alaska were reviewed by Rausch et al. (1974). The Kenai Moose Population Identity Study is an active project (Franzmann and Arneson 1974) designed to additionally refine Kenai moose population information. In general, Kenai moose population characteristics are well documented.

Moose populations on the Kenai Peninsula have experienced a steady decline in recent years based upon population estimates from random stratified counts (Evans et al. 1966) on the Kenai National Moose Range (14.9 percent decrease from 1973 to 1974, 31 percent decrease from 1974 to 1975). Heavy calf mortality at the Kenai Moose Research Center (Franzamnn and Arneson 1973, 1974, 1975) and on the Kenai Peninsula (LeRoux 1975a) was a major factor in this decline. Contributing factors were long-term range deterioration of moose habitat (Oldemeyer et al. 1976), increase of local human utilization of habitat, hunting, poaching, and highway mortality, with each factor additively impacting on the resident moose population. Adjustments in hunting aessons were made in light of these events (LeRoux 1975a).

Concurrent with the moose population decline, wolf numbers have increased from near extinction in the 1960's to present conservative estimates of up to 90 individuals (LeRoux 1975b). Recent information indicates a continued increase in wolf numbers (LeRoux, personal communication). Assessment of wolf predation impact on the moose population at this time is speculative due to simultaneous action of other surveilance and recovery of moose carcasses is evident. In addition, bone marrow fat analysis of moose femurs (Neiland 1970) on the Kenai Peninsula indicated no specific wolf predatory preference toward starving moose (Franzmann and Arneson 1976). Wolf predation in winters with high moose mortality may be additional to starvation mortality.

Caribou were reestablished on the Kenai Peninsula (Burris and McKnight 1973) resulting in a relatively stable lowland population and an expanding mountain population. Effects of predation on their populations are unknown. Dall sheep and mountain goat are major game species on the Kenai Peninsula which are potential prey species. A Dall sheep study and a mountain goat study were recently initiated. Information from these studies will be utilized and integrated when applicable, particularly in relation to predation.

Specific Procedures (by objective number):

1. Radio transmitter collars will be placed on up to 2 wolves per pack. Present estimates indicate a minimum of 12 packs of wolves for a total of 24 transmitters. Wolves will be captured and immobilized by live-trapping, live snaring, and/or darting from helicopters. Data from aerial radio tracking will be used to determine number and sizes of wolf packs, movement, territories, total population estimates and population trends. Wolf movements will be plotted on appropriate maps.

2. Sex and age determinations will be made of captured wolves and a physical assessment will be made of each individual based on a 1 to 10 scale modified for wolves from Robinson (1966). Wolves captured will be weighed. Blood serum and whole blood samples will be collected for blood chemistry, hematology and serology values. Hair samples will be plucked for mineral analysis. From these data an assessment of physical and physiological condition can be made. Post-mortem examination will be performed on all wolf mortalities and efforts will be made to obtain carcasses of trapped and shot wolves during the regular seasons.

3. Pack stability, pack dispersal and territories of wolves will be determined by radio tracking packs and/or individual wolves and plotting these movements through time and seasons.

4. Consolidation of aerial observations and surveys with radio tracking data will provide refined estimates of the total Kenai Peninsula wolf population, and continued effort over time will provide trend data. Wolf mortalities from all causes will be recorded.

5. Seasonal food habit information will be obtained by observation during aerial surveys, examination and plotting of kills, and fecal examination.

6. All suspected and known wolf kills of major ungulates will be examined if possible and sex and age determined. Bone marrow fat will be analyzed to evaluate condition. A subjective (1 to 10 score) prey condition evaluation will be made (Franzmann and Arneson 1973). Seasonal comparison of moose prey condition and sex and age structure will be made with the general moose population from collections and sampling at the Kenai Moose Research Center. Composition counts of Kenai moose populations will provide comparable sex and age structure data for comparison. Dall sheep and mountain goat study population information will be integrated as it pertains to predation.

7. The impact of wolves on prey will be estimated by synthesizing estimates of wolf numbers, food consumption, sex and age compostion of prey, and utilization of incidental and seasonal food sources. Moose population structure, relative abundance, and movement information obtained by ongoing and continuing programs will provide the basic population information on moose. Sheep, mountain goat and caribou population estimates from studies and survey and inventory activities will provide population information on these potential prey species. Assessment of changes in number, relative abundance, and sex and age composition of prey will be made in light of information on the major predator.

8. Concurrent moose calf mortality and bear studies will be integrated by utilizing manpower and equipment in combination with other studies when feasible. Information from each study supports and strengthens the others and information from each will be coordinated in the final assessments and reports of each study.

Schedule:

Fiscal Year	Procedure	Cost	Man-Days
1976	Purchase Equipment & Supplies		
	Transmitters (24)	3,000.00	
	Receivers (2)	1,600.00	
	Two-Way radio (2)	1.200.00	
	Traps and Snares	1,000.00	
	Drugs, Darts, Collecting Equip.	800.00	
	Total	7,600.00	8
1977	Trap, Capture, Sample Wolves		
	Helicopter (40 hrs.)	12,000.00	20
	Travel Mileage (Trapping)	1,200.00	50
	Aerial Survey & Tracking		
	Fixed Wing (300 hrs.)	16,500.00	100
	Laboratory Analysis	1,200.00	10
	Travel & Per Diem for Mech	1,500.00	
	Plotting & Assembling Data		100
	Miscellaneous	3,000.00	
	Total	35,400.00	280
1978	Trap, Capture, Sample Wolves		
	Helicopter (30 hrs.)	9,000.00	15
	Travel Mileage (Trapping)	1,000.00	100
	Aerial Survey - Tracking		
	Fixed Wing (400 hrs.)	22,000.00	120
	Laboratory Analysis	700.00	5
	Travel & Per Diem for Mech	1,500.00	
	Plotting & Assembly Data		100
	Miscellaneous	2,000.00	
	Total	36,200.00	335
1979	Aerial Survey-Tracking		
	Fixed Wing (400 hrs.)	22,000.00	120
	Helicopter (5 hrs.)	1,500.00	2
	Travel & Per Diem for Mech	750.00	
	Plotting & Assembly Data		100
	Miscellaneous	1,000.00	
	Total	25,250.00	222
1980	Preparation of Final Reports & Publications		150
	Publication Costs	1,000.00	
	Data Analysis	1,000.00	
	Mileage & Per Diem	2,000.00	
	Total	4,000.00	150

Job Title: Kenai Peninsula Predator-Prey Study: Part 2 - Moose Calf Mortality

General Objective: To identify cause and evaluate moose calf summer mortality in relation to general condition of calves and to assess impact of this mortality on population trends.

Specific Objectives:

1. To determine cause and extent of neonatal and summer moose calf mortality.

2. To assess condition and pathology of dead moose calves.

3. To assess the impact of summer calf mortality on moose population trends.

4. To integrate concurrent wolf and bear studies in a physical and informational manner.

Justification: A continual reoccurring gap of knowledge in moose populaiton dynamics relates to neonatal and summer calf mortality. An insight into the cause, extent and impact of calf mortality will provide additional information to better formulate management plans and decisions.

Status: LeResche (1968) reported a drop in calves/100 cows from 84.3 to 36.2. (50 percent +) from May to October near Palmer, Alaska. LeRoux (personal communication) recognizes a significant drop in spring to fall cow/calf ratios annually on the Kenai Peninsula. Spring to fall mortality of calves at the Kenai Moose Research Center enclosures has been extremely low (Franzmann and Arneson 1973, 1974, 1975). Mech (KNMR Proposal) indicated this strongly implicates wolf and bear predation as a major mortality factor outside the enclosures. LeResche (1968) indicated brown bear predation was an important mortality factor in his study.

Other studies have reported significant predation by wolves on young ungulates (Mech 1966, Mech and Frenzel 1971, Kuyt 1972, Rausch and Bratlie 1965, VanBallenberghe et al. 1975). We have reason to suspect heavy predation on moose calves, but the extent and potential impact are presently unknown.

As outlined in Status Section Part 1 (Wolf Study) of the proposal, the population characteristics of the Kenai moose are well documented. This provides a good base from which to proceed in identifying the summer calf mortality gap in our accumulating information on population dynamics of the Kenai Peninsula moose.

Procedures (by objective number):

1 & 2. At calving time, or soon thereafter, up to 50 calves/year will be captured using a helicopter and on each will be placed a mortality transmitter which will activate at death. Each calf will be examined and an assessment of general health and condition will be made. The calf will be weighed and blood and hair samples will be taken.

An automatic monitoring system composed of automatic repeaters placed on high ground around the Moose River Flats will be utilized to detect the signal acitvated by a dead calf. A mercury switch on the calf's collar will activate a signal when no movement has occurred for six hours. Automatic repeater placement will be tested by placing a transmitter in various locations over and around the Moose River Flats and monitoring reception. Up to eight automatic repeaters may be required. In operation, the signal from the dead calf will be received by an automatic repeater which will transmit on another channel detectable by receivers in aircraft or in the field. The automatic repeater signal will also be relayed to and through the Kenai National Moose Range communications system permitting personnel to monitor the system from nearly any location on the Kenai Peninsula. A search for the calf utilizing aerial tracking will be done and personnel will proceed to site by whatever means is deemed best (from ground tracking to use of helicopter). An onsite assessment of cause of death will be made and remains of calf will be examined by standard necropsy procedure. Appropriate samples will be collected for histological, pathological and toxicological examination (Siegmund 1973).

Transmitter collars for calves are available which will exapnd with growth and the feasibility of an automated monitoring system has been cooroborated (William Cochran, personal communication).

3. The impact of summer calf mortality will be assessed by indexing from collared calves and recovered calves into the population. Summer survival rates in relation to winter survival will provide an estimate of importance of summer mortality to annual recruitment into the population.

4. Concurrent wolf and bear studies will be integrated by utilizing manpower and equipment in combination with these other studies when feasible. Information from each study supports and strengthens the others and information from each will be coordinated in the final assessments and reports of each aspect of this overall predator-prey study.

Schedule:

Fiscal Year	Procedure	Cost	Man-Days
1976	Purchase Telementry equipment		
	Radio Transmitters	12,500.00	2
	Total	12,500.00	2
1977	Radio collar calves		
	Helicopters (50 hrs.)	15,000.00	25
	Fixed Wing (20 hrs.)	1,100.00	9
	Monitoring station	6,000.00	10
	Laboratory analysis	1,200.00	
	Recover & locate dead calves		
	Helicopter (25 hrs.)	7,500.00	12
	Fixed Wing (50 hrs.)	2,750.00	20
	Data analysis		20
	Miscellaneous	3,000.00	
	Total	36,550.00	96
1978	Radio collar calves		
	Helicopter (50 hrs.)	15,000.00	25
	Fixed wing (20 hrs.)	1,100.00	9
	Laboratory analysis	1,200.00	
	Recover & locate dead calves		
	Helicopter (25 hrs.)	7,500.00	12
	Fixed wing (50 hrs.)	2,750.00	20
	Data analysis		20
	Miscellaneous	2,000.00	
	Total	29,550.00	86
1979	Repeat of 1978		
	Total	29,550.00	86
1980	Preparation of final reports & publications		150
	Publications Costs	1,000.00	
	Data Analysis	1,000.00	
	Mileage & Per Diem	2,000.00	
	Total	4,000.00	150

Job Title: Kenai Peninsula Predator-Prey Study: Part 3 - Bear Study

General Objective: To assess the impact of black and brown bear predation on moose calves in the Moose River Flats calving area and to ascertain density, movements, home range, and food habits of black and brown bears in and near the moose calving area.

Specific Objectives:

1. To determine the impact of black and brown bear predation on moose calves.

2. To determine density and movement of bears into and around the moose calving area and assess the temporal, seasonal, and spatial aspects of bear movements.

3. To determine food habits of black and brown bears, particularly at calving time.

4. To integrate the bear study with concurrent wolf and moose calf mortality studies in a physical and informational manner.

5. To obtain movement and home range data on bears in addition to that related to calving activity on the Moose River Flats.

Justification: An assessment of bear predation on moose calves will provide information to better formulate management plans and decisions. Combining data from other parts of this overall predator-prey study with bear predation and movements will additively background the management decision process.

Status: Bear predation (black and brown) has been observed on moose calves on a sporadic basis over time on the Kenai Peninsula. No effort to study bear predation has been done on the Kenai. LeResche (1968) indicated brown bear predation was an important mortality factor in his study near Palmer.

As outlined in Status Section of Part 2 (Moose Calf Mortality), there appears to be a significant loss of calves from spring to fall. Bear activity on the Moose River Flats is high during calving and significant predation may occur. Since no comprehensive study of black, brown or grizzly bear predation has been reported in the literature, we can only rely on bits and pieces of evidence regarding bear predation.

Procedures (by objective number):

1. Immobilize and equip with radio-transmitter collars up to 20 bears/year on calving grounds by helicopter and/or live-trapping. Black and brown bears will be immobilized in approximate proportion to their relative abundance. In addition, black bears denning at MRC can be immobilized and collared at den sites during winter. Weekly monitoring flights will be made and when indicated, increased monitoring activity can be initiated. Ingress, activity and egress of bears in the calving area will be related to temporal and seasonal moose movement and vegetative changes.

   Each captured bear will be measured (skull measurements first priority), tooth extracted for aging, blood collected for chemistry and hematology analysis, hair sampled for mineral analysis, ear-tagged, and tatooed.

2. Food habit information will be obtained by observation during monitoring and scat analysis. Particular attention will be given during the calving period (15 May through 30 June) on the Moose River Flats to assess food habits of both black and brown bear.

3. & 4. The impact of brown and black bear predation will be assessed separately and combined utilizing observation and kill data from bear monitoring combined with population estimates of moose calves in the Moose River Flats. This population information will be obtained partly from monitoring aspects of this study, but primarily from the moose calf mortality part of the overall study. The importance of the combined efforts of the parts of the study to additively support one another are evident.

5. Black and brown bear movement and home range information, in addition to that associated with calving activities, will be provided with concurrent monitoring of wolves and moose. This side benefit will provide additional information on bear ecology to enhance management decisions.

Schedule:

Fiscal Year	Procedure	Cost	Man-Days
1976	Purchase radio transmitters (30)	4,500.00	2
	Total	4,500.00	
1977	Radio collar bears		
	Helicoptet (30 hrs.)	9,000.00	10
	Laboratory analysis	800.00	
	Monitor bears activity		
	Fixed wing (150 hrs.)	8,250.00	70
	Miscellaneous	2,000.00	
	Data computation		10
	Total	20,050.00	90
1978	Same as 1977	20,050.00	90
1979	Same as 1977	20,050.00	90
1980	Preparation of final reports & publications		100
	Publications costs	1,000.00	
	Mileage & Per Diem	2,000.00	
	Total	3,000.00	100

Summary of Cost and Man-days by Fiscal Year For all Parts of Study:

Fiscal Yera	Cost	Man-Days
1976	$ 24,600.00	12
1977	92,000.00	466
1978	84,800.00	511
1979	74,850.00	398
1980	13,000.00	300

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JOB PROGRESS REPORT

State: Alaska

Cooperators: Albert W. Franzmann and Theodore N. Bailey

Project No.: W-17-9 Project Title: Big Game Investigations

Job No.: 1.21R Job Title: Moose Productivity and Physiology

Period Covered: July 1, 1976 through June 30, 1977

SUMMARY

Updated findings on reported studies concerning hair element metabolism, blood chemistry and hematology, morphometric measurements, productivity and mortality of Kenai Moose Research Center (MRC) moose, and browse production, utilization and quality are summarized. Reported studies prepared during this report period are contained in appendices to maintain continuity in progress reports.

TABLE OF CONTENTS

BACKGROUND

A final P-R report, "Moose Productivity and Physiology", was completed (Franzmann et al. 1976). The study was renewed to complete various phases of ongoing investigations and to accomodate expansion of physiologic data collection and interpretation from other Alaskan moose (*Alces alces*) populations. Background for these continuing studies was outlined in that report.

During this report period several manuscripts were prepared or published under this job outline (Bailey and Franzmann 1977, Flynn and Franzmann 1977, Franzmann 1977, Franzmann and Bailey 1977, Franzmann and Flynn 1977, Franzmann et al 1977a, Franzmann et al 1977b, and Oldemeyer et al. 1977).

Those reports not already published constitute Appendices I-IV.

OBJECTIVES

To establish baselines by sex, age, season, reproductive status, area, drug used, excitability and condition for blood, hair, and milk parameters in moose, and to evaluate their usefulness as indicators of nutritional and general condition status of moose.

To apply the above criteria to various moose populations over the state.

To estimate browse production and utilization and to quantitatively and qualitatively estimate consumption of all plant materials by moose at the Kenai Moose Research Center (MRC).

To determine nutritional values and digestibilities of the more common moose forage species and to relate hair element monitoring to moose mineral metabolism.

To measure natality, mortality and general condition of moose at the MRC.

The overall objective is to obtain a more thorough and specific knowledge of how moose affect vegetation and how vegetation affects moose. The applications of the indicator species concept to moose by gaining knowledge specific to moose physiology was an integral part of this objective.

PROCEDURES

Hair (Metabolism)

Specific procedures for collecting, handling, and analyzing moose hair samples have been reported (Franzmann et al. 1975 and Franzmann et al. 1976). During this report period hair samples were collected from the moose populations listed in the Blood Chemistry and Hematology Procedures section of this report. Regional hair element value differences from Alaskan moose for 10 elements (Ca, Mg, K, Na, Cu, Fe, Mn, Zn, Cd, and Pb) through mid-1975 were reported (Franzmann et al. 1977a). This report updates those findings by addition of eight elements (Co, Cr, Mo, Ni, Se, Al, As, and Hg) and reporting results from recent collections. The potential of volcanic ash remineralization on the Kenai Peninsula was reported (Franzmann and Flynn 1977).

Hair (Forensic)

See Appendix II.

Blood Chemistry and Hematology

Specific procedures for collecting, handling and analyzing blood were outlined (Franzmann et al 1976). During this report period blood samples were collected October 22-28, 1976, from the upper Susitna area in Game Management Unit (GMU) 13; March 18-23, 1977, from the same area; April 5-7, 1977, near Mother Goose Lake on the Alaska Peninsula in GMU 9; and May 29-June 7, 1977, on the Moose River Flats area in GMU 15A. Samples were also obtained from moose trapped at the MRC.

Condition

See Appendix III.

Morphometric Measurements and Body Weight

See Appendix IV.

Productivity and Mortality of MRC Moose

Mortality and natality within the MRC enclosures were assessed by ground observations, periodical aerial observations, trapping, and radiotelemetry.

Browse Production, Utilization, and Quality

Procedures were published (Oldemeyer et al. 1977).

FINDINGS

Hair (Metabolism)

Hair element values for 18 elements (Ca, Mg, K, Na, Au, Fe, Mn, Zn, Cd, Pb, Co, Cr, Mo, Ni, Se, Al, As, and Hg) from various Alaskan moose populations are listed in Tables 1, 1a, 2, 2a, 3, 3a, 4, 4a, 5, 5a, 6, 6a, 7, 7a, 8, 8a, 9, 9a, 10, 10a, 11, 11a, 12, and 12a. These values update those reported in Franzmann et al. (1977a).

Hair (Forensic)

Preliminary results from application of hair element values were reported (Flynn and Franzmann 1977, Appendix II). Accumulation of additional seasonal baseline data from various Alaskan moose populations will strengthen the potential of this tool for Alaskan moose forensic science. Analyses of samples collected from various body parts of moose to establish variability of these collections have not yet been completed. The stability of element levels in moose hair samples stored at room temperature for five years will be assessed by re-analyzing these samples. These data are also required to improve the reliability of utilizing moose hair for forensic applications.

Blood Chemistry and Hematology

Complete analyses from populations sampled during this report period were not completed and/or analyzed by report due date. Condition-related blood parameters were available for some populations sampled during March, April and May, 1977 and are listed in Table 13. Susitna, Alaska Peninsula, and Moose River Flats results are additions to Table 15 in Franzmann et al. (1976). The relationships of blood and measurement data to moose conditions were outlined (Franzmann 1977, Appendix III) and measurement data were included in Table 13.

Interpretation of data from these populations will be completed when all the data are available. Using hemoglobin (Hb) and packed cell volume (PCV) for preliminary comparisons, the Alaska Peninsula and Moose River Flats values were similar to the MRC baseline values and reflect poor moose condition. The moose calf values are extremely low but are not necessarily comparable. We have not had substantial samples from calves less than one week old and these values may be normal. The March 1977 Susitna moose Hb and PCV values reflect good condition and were comparable to samples collected in GMU 13 during April 1973.

Measurements from Alaska Peninsula moose were similar to those for the Copper River Delta population. Moose River Flats cows were small by total length and chest girth measurement comparisons and were more similar to cows at the MRC than to those from other populations.

Condition

The application of morphometric and physiologic parameters to assess general condition of moose was reported (Franzmann 1977, Appendix III).

Table 1. Alaskan moose mean hair element levels during January (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1973 n=21	196.0 ±38.1	55.4 ±10.7	326.9 ±66.1	1174.9 ±384.3	2.6 ±1.2	59.0 ±23.6	1.6 ±2 0	66.7 ±6.0	0.02 ±0.07	4.0 ±2.7
Moose Research Center 1974 n=17	203.4 ±50.6	32.0 ±16.0	497.1 ±163.2	1250.9 ±441.2	1.4 ±0.3	48.8 ±21.1	1.7 ±1.3	95.9 ±3.5	0.59 ±0.23	0.0 ±0.6
Moose Research Center 1975 n=10	234.9 ±78.8	67.4 ±15.4	502.6 ±126.6	1131.7 322.3	2.4 ±0.9	50.9 ±8.1	2.2 ±1.2	59.0 ±11.4	0.12 ±0.14	5.6 ±3.0
Fort Richardson 1973 n=44	280.4 ±100.3	76.8 ±22.0	406.2 ±239.0	1189.5 ±503.1	7.1 ±2.5	55.8 ±14.4	1.6 ±2.1	65.2 ±9.2	0.47 ±0.34	5.1 ±7.1
Nome 1975 n=26	167.6 ±55.7	44.9 ±14.4	643.8 ±144.5	705.8 ±106.1	9.2 ±1.6	44.4 ±9.8	0.5 ±0.3	71.7 ±11.4	0.32 ±0.29	0.5 ±0.7
Elmendorf 1976 n=21	695.4 ±297.3	177.9 ±82.2	1348.8 ±583.2	394.4 ±76.1	10.4 ±1.9	34.6 ±6.4	0.79 ±0.14	97.2 ±14.5	1.21 ±0.14	12.9 ±4.6

Table 1a. Alaskan moose mean hair element levels during January (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=19	0.2 ±0.1	0.08 ±0.06	< 0.1	0.4 ±0.1	0.7 ±0.3	0.3 ±0.3	N.D.	0.03 ±0.05
Moose Research Center 1975 n=10	0.2 ±0.1	0.14 ±0.05	< 0.1	0.2 ±0.1	0.8 ±0.3	0.2 ±0.1		0.08 ±0.02
Nome 1975 n=26	0.7 ±0.4	0.38 ±0.07	0.5 ±0.2	0.2 ±0.2	0.9 ±0.3	0.7 ±0.3	< 0.05	0.03 ±0.04
Elmendorf 1976 n=21	0.3 ±0.1	0.42 ±0.51	0.6 ±0.3	< 0.1	1.9 ±0.7	2.4 ±0.8	< 0.05	< 0.05

Table 2. Alaskan moose mean hair element levels during February (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1973 n=23	295.6 ±68.0	51.1 ±12.7	379.4 ±134.6	870.0 ±185.3	4.8 ±3.6	55.5 ±19.5	0.7 ±1.2	81.0 ±13.2	0.88 ±1.89	5.5 ±2.5
Moose Research Center 1974 n=18	280.2 ±45.7	31.4 ±5.7	473.0 ±90.2	914.8 ±391.8	1.3 ±0.3	48.2 ±15.9	2.3 ±1 3	96.3 ±11.3	0.64 ±0.14	0.1 ±0.2
Moose Research Center 1975 n=12	208.7 ±27.5	50.6 ±9.0	454.6 ±124.4	738.6 ±109.1	2.7 ±1.2	52.2 ±7.7	0.2 ±0.2	54.6 ±12.0	0.62 ±0.26	5.7 ±2.0
Fort Richardson 1974 n=50	289.9 ±58.5	75.2 ±17.1	445.9 ±144.9	1257.3 ±452.0	7.5 ±2.6	53.1 ±16.8	1.2 ±1.5	61.6 ±9.1	0.42 ±0.36	5.2 ±3.8
Elmendorf 1975 n=20	337.7 ±84.2	77.6 ±12.6	471.8 ±90.0	939.1 ±221.5	8.5 ±2.1	46.9 ±10.6	1.9 ±1 3	61.7 ±6.5	0.38 ±0.24	3.9 ±1.9
Elmendorf 1976 n=17	667.5 ±259.6	152.5 ±86.8	1153.4 ±302.6	369.1 ±58.8	10.1 ±2.3	41.0 ±5.3	0 77 ±0.09	93.9 ±15.0	1.28 ±0.10	13.3 ±4.9

Table 2a. Alaskan moose mean hair element levels during February (ppm).

Area and Year Sampled	Elements Sampled Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=18	0.3 ±0.1	0.17 ±0.06	< 0.1	0.4 ±0.1	0.6 ±0.4	0.4 ±0.3	ND	< 0.1
Moose Research Center 1975 n=12	0.2 ±0.1	0.14 ±0.05	< 0.1	0.2 ±0.1	< 0.1	0.7 ±0.1	< 0.05	< 0.05
Fort Richardson 1974 n=50	1.3 ±0.4	ND		ND				
Fort Richardson 1975 n=20	0.8 ±0.2	0.07 ±0.08	0.3 ±0.3	< 0.05	0.6 ±0.4	1.0 ±0.5	< 0.05	< 0.05
Elmendorf 1976 n=17	0.2 ±0.1	0.23 ±0.32	0.8 ±0.4	< 0.1	1.6 ±0.4	2.2 ±0.5	< 0.05	< 0.05

Table 3. Alaskan moose mean hair element levels during March (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1973 n=23	241.8 ±42.2	49.1 ±18.8	429.4 ±124.0	787.2 ±149.8	7.5 ±3.8	64.1 ±18.2	1.8 ±1.2	74.3 ±24.1	0.18 ±0.26	5.4 ±2.7
Copper River Delta 1974 n=50	132.1 ±63.2	64.0 ±3.6	501.2 ±172.5	894.7 ±182.2	10.0 ±2.8	28.4 ±9.8	0.6 ±0.3	102.0 ±16.1	0.48 ±0.20	4.3 ±3.3
Glennallen 1975 n=64	321.7 ±51.3	68.4 ±9.4	633.8 ±77.5	816.1 ±71.2	7.8 ±2.5	52.8 ±5.9	2.0 ±0 8	109.7 ±19.0	0.58 ±0.23	7.4 ±2.1
Fairbanks 1975 n=5	159.2 ±16.3	62.1 ±8.2	743.6 ±107.7	489.8 ±137.7	6.0 ±1.4	63.6 ±10.7	0.6 ±0.2	65.5 ±1 8	0.84 ±0.30	3.8 ±0.4

Table 3a. Alaskan moose mean hair element levels during March (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Copper River Delta 1974 n=50	0.5 ±0.1	0.53 ±0.15	<0.1	0.3 ±0.1	1.6 ±0.5	0.5 ±0.2	N.D.	0.11 ±0.05
Fairbanks 1975 n=5 n=5	0.5 ±0.1	0.38 ±0.08	0.6 ±0.2	0.4 ±0.2	0.8 ±0.2	0.6 ±0.2	<0.05	0.08 ±0.03
Glennallen 1975 n=64	0.6 ±0.2	0.40 ±0.09	0.4 ±0.2	0.4 ±0.2	1.5 ±0.3	0.8 ±0.4	<0.05	0.07 ±0.04

Table 4. Alaskan moose mean hair element levels during April (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center n=29	249.3 ±46.1	45.5 ±12.4	435.0 ±112.7	644.7 ±146.0	7.8 ±4.0	67.7 ±20.7	1.7 ±1.6	74.0 ±21.2	0.15 ±0.32	5.6 ±3.3
Glennallen 1975 n=10	591.9 ±127.7	72.6 ±8.0	552.5 ±41.1	702.8 ±78.4	4.6 ±1.1	50.1 ±5.7	1.2 ±0.3	57.7 ±10.0	0.79 ±0.31	
Homer 1975 n=31	192.0 ±41.1	67.0 ±10.8	558.3 ±71.8	703.1 ±100.3	7.0 ±2.1	51.2 ±12.9	1.3 ±0.5	74.6 ±8.2	0.56 ±0.16	

Table 4a. Alaskan moose hair element levels during April (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Glennallen 1975 n=10	0.2 ±0.1	0.16 ±0.11	< 0.05	0.3 ±0.1	0.2 ±0.2	0.2 ±0.2	< 0.05	< 0.05
Homer 1975 n=31	0.2 ±0.1	0.10 ±0.04	< 0.05	0.4 ±0.2	0.2 ±0.4	0.3 ±0.2	< 0.05	< 0.05

Table 5. Alaskan moose mean hair element levels during May (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=11	335.0 ±67.7	38.3 ±6.0	257.5 ±71.0	633.5 ±113.3	3.4 ±1.4	33.4 ±12.1	3.6 ±1.8	65.5 ±9.6	0.28 ±0.23	5.6 ±1.8
Moose Research Center 1974 n=10	226.7 ±74.3	33.8 ±6.2	697.1 ±373.4	687.6 ±170.3	2.0 ±0.7	65.8 ±16.4	1.5 ±1.0	95.5 ±8.8	0.65 ±0.22	1.4 ±0.5
Fairbanks 1975	245.3 ±151.6	110.2 ±68.7	230.2 ±150.6	1356.1 75.3	9.6 ±1.8	53.8 ±10.7	1.5 ±0.3	92.6 ±8.8	1.47 ±0.14	9.3 ±4.4

Table 5a. Alaskan moose hair element levels during May (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=10	0.3 ±0.1	0.13 ±0.04	0.3 ±0.1	0.4 ±0.1	1.8 ±0.8	0.9 ±0.4	N.D.	0.15 ±0.09
Fairbanks 1975 n=41	0.2 ±0.1	$<$0.1	0.4 ±0.2	N.D.	0.8 ±0.2	0.7 ±0.2	N.D.	0.05 ±0.03

Table 6. Alaskan moose mean hair element levels during June (ppm).

Area and Year Sampled	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=19	284.7 ±108.1	29.4 ±12.8	756.1 ±485.8	460.4 ±141.7	3.4 ±1.3	52.9 ±19.4	0.8 ±1.4	49.6 ±8.7	0.32 ±0.31	5.1 ±2.5
Moose Research Center 1973 n=22	216.2 ±262.5	36.4 ±30.0	1001.1 ±535.7	670.1 ±308.4	7.0 ±3.7	32.9 ±33.8	0.1 ±0.4	82.8 ±21.5	0.35 ±1.42	5.5 ±5.0
Moose Research Center 1974 n=19	258.5 ±87.3	41.6 ±23.2	898.1 ±407.2	771.6 ±250.0	2.1 ±0.7	68.1 ±29.0	2.4 ±0.8	79.8 ±20.3	0.81 ±0.29	3.9 ±2.4

Table 6a. Alaskan moose hair element levels during June (ppm).

Area and Year Sampled	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=20	0.4 ±0.1	0.24 ±0.09	0.4 ±0.1	0.5 ±0.1	1.8 ±0.7	0.9 ±0.5	N.D.	0.18 ±0.05

Table 7. Alaskan moose mean hair element levels during July (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=19	313.3 ±107.0	31.9 ±16.8	1056.4 ±409.0	618.0 ±185.8	3.5 ±1.9	50.5 ±16.7	0.1 ±0.2	45.3 ±14.5	0.26 ±0.20	8.8 ±3.7
Moose Research Center 1973 n=22	297.6 ±206.7	57.9 ±52.4	964.8 ±511.4	791.9 ±161.4	8.0 ±3.2	55.4 ±75.4	0.4 ±0.6	75.4 ±15.4	0.32 ±0.31	12.2 ±7.2
Moose Research Center 1974 n=22	514.3 ±398.2	82.6 ±56.3	1215.1 ±532.5	606.9 ±181.1	6.0 ±3.0	39.3 ±9.0	1.4 ±0.7	93.8 ±21.0	2.27 ±0.64	4.0 ±1.7

Table 7a. Alaskan moose hair element levels during July (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974	0.7 ±0.2	0.24 0.05	0.5 ±0.1	0.4 ±0.2	2.0 ±0.6	1.3 ±0.4	<0.1	0.22 ±0.07

Table 8. Alaskan moose mean hair element levels during August (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=13	699.7 ±208.8	107.5 ±40.5	916.8 ±498.4	448.2 ±148.2	4.8 ±1.8	35.1 ±9.9	0.2 ±0.4	54.9 ±13.5	0.50 ±0.61	7.2 ±3.2
Moose Research Center 1973 n=16	361.1 ±158.1	191.8 ±65.2	1669.9 ±611.8	1037.2 ±170.9	11.2 ±2.4	51.2 ±15.9	1.3 ±0.4	67.1 ±7.1	0.88 ±0.35	17.6 ±1.1
Moose Research Center 1974 n=14	382.9 ±255.3	94.0 ±62.0	1161.0 ±593.0	556.8 183.8	5.2 ±2.9	35.2 ±6.6	1.2 ±0.6	94.6 ±19.3	2.34 ±0.73	5.2 ±2.4
Copper River Delta 1974 n=12	712.5 ±71.1	122.4 ±20.1	784.5 ±250.4	600.9 ±123.8	17.7 ±3.8	48.9 ±13.6	3.6 ±1 3	135.6 ±10.5	1.73 ±0.63	12.8 ±5.4
Nome 1974 n=5	347.9 ±152.6	114.3 ±58.9	1285.7 ±326.1	652.6 ±260.1	14.5 ±10.1	51.9 ±14.4	1.3 ±0.2	99.8 ±6.0	1.88 ±1.01	7.6 ±3.8
Fairbanks 1976 n=49	704.0 ±214.6	159.9 ±69.5	2482.7 ±1880.0	6154.7 ±133.7	2.7 ±1.7	18.2 ±7.6	0.3 ±0.1	122.1 ±22.6	0.97 ±0.17	16.0 ±8.6
Nome 1976 n=19	1177.4 ±361.2	241.5 ±95.6	3145.2 ±1429.0	5075.0 ±801.5	2.3 ±1.3	28.8 ±10.2	0.50 ±0.26	118.0 ±17.7	0.77 ±0.39	10.4 ±5.9

Table 8a. Alaskan moose hair element levels during August (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=14	0.8 ±0.1	0.25 ±0.07	0.6 ±0.1	0.4 ±0.2	2.1 ±0.8	1.7 ±0.5	<0.1	0.24 ±0.07
Nome 1974 n=5	0.6 ±0.1	0.21 ±0.03	0.6 ±0.3	0.3 ±0.1	2.5 ±0.3	1.4 ±0.4	<0.1	0.18 ±0.05
Copper River Delta 1974 n=12	1.4 ±0.2	0.72 ±0.17	0.6 ±0.2	0.6 ±0.1	1.1 ±0.4	0.7 ±0.2	<0.05	0.09 ±0.03
Fairbanks 1976 n=49	0.1 ±0.05	0.25 ±0.20						
Nome 1976 n=19	0.2 ±0.07	0.6 ±0.2	1.0 ±0.6		1.7 ±0.6	2.7 ±1.0		0.09 ±0.02

Table 9. Alaskan moose mean hair element levels during September (ppm).

Area and Year Sampled	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=12	515.5 ±125.5	149.5 ±61.6	1579.1 ±947.2	714.2 ±140.7	13.3 ±3.3	41.9 ±14.9	2.2 ±1 4	78.4 ±12.9	1.35 ±1.30	9.1 ±3.9
Moose Research Center 1973 n=20	283.0 ±126.1	166.2 ±45.8	1653.1 ±343.4	1025.4 ±230.7	12.3 ±3.7	62.7 ±3.4	0.9 ±0.4	68.1 ±5.9	1.42 ±1.80	15.7 ±7.7
Moose Research Center 1974 n=26	207.8 ±119.2	102.6 ±33.5	1046.0 ±607.2	674.7 ±191.1	10.4 ±2.3	51.3 ±18.1	3.7 ±1.2	97.8 ±12.2	2.30 ±0.81	4.1 ±1.4
Southeast Alaska 1973 n=13	602.2 ±205.9	72.0 ±24.6	1367.1 ±953.9	1438.1 ±328.2	10.2 ±1.9	69.1 ±34.7	0.9 ±0.4	112.9 ±14.6	0.52 ±0.21	3.7 ±2.1
Copper River Delta 1974 n=27	569.6 ±108.1	132.3 ±17.9	906.6 ±266.9	859.2 ±137.8	24.2 ±4.2	51.7 ±6.5	4.2 ±0 8	133.9 ±11.6	4.17 ±1.81	13.5 ±5.3
Nome 1974 n=37	293.4 ±209.3	72.1 ±47.7	1185.9 ±592.3	897.9 ±267.7	12.5 ±6.3	49.4 ±12.4	1.2 ±0.9	106.7 ±16.0	1.93 ±1.27	2.6 ±2.7
Haines 1974 n=10	795.7 ±305.3	93.6 ±17.6	1517.2 ±874.5	2823.0 ±411.0	8.3 ±3.9	42.2 ±6.6	0.7 ±0.2	86.6 ±14.2	1.76 ±0.10	8.0 ±3.7
Nome 1975 n=19	940.7 ±399.4	110.2 53.5	2582.3 ±1688.8	3624.1 ±1098.0	18.6 ±2.5	57.6 ±44.9	<0.1	110.1 ±10.5	1.84 0.99	10.9 ±17.3
Haines 1975 n=21	644.5 ±239.2	99.8 ±38.6	2508.9 ±1002.9	1700.5 ±919.4	8.2 ±3.2	66.8 ±64.7	0.8 ±0.3	89.8 ±10.6	0.89 ±0.15	8.6 ±3.9
Copper River 1975 n=34	661.1 ±322.2	88.5 ±48.6	1799.2 ±651.6	1770.3 ±473.7	19.8 ±4.6	121.0 ±137.4	0.83 ±0.39	120.5 ±33.6	1.23 ±0.23	12.3 ±4.0
Nome 1976 n=84	1135.6 ±649.5	707.6 ±131.5	2348.7 ±1345.6	5230.5 ±644.9	3.9 ±4.4	36.3 ±18.2	0.72 ±0.36	119.4 ±26.0	1.31 ±0.23	10.3 ±0.81

Table 9a. Alaskan moose hair element levels during September (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Southeast 1973 n=13	0.4 ±0.1	0.60 ±0.15	<0.1	0.5 ±0.3	1.8 ±0.6	0.4 ±0.1	<0.05	<0.1
Moose Research Center 1974 n=26	1.4 ±0.5	0.35 ±0.10	0.7 ±0.2	0.5 ±0.1	2.6 ±0.6	1.7 ±0.3	<0.1	0.26 ±0.07
Nome 1974 n=17	0.8 ±0.2	0.26 ±0.05	0.7 ±0.3	0.3 ±0.1	2.3 ±0.6	1.6 ±0.6	<0.1	0.23 ±0.06
Copper River Delta 1974 n=27	1.8 ±0.5	0.76 ±0.15	0.7 ±0.2	0.6 ±0.2	1.5 ±0.3	1.0 ±0.4	<0.05	0.01 ±0.04
Haines 1974 n=10	0.3 ±0.02	0.24 ±0.09	<0.1	<0.1	0.7 ±0.2	0.6 ±0.2	<0.1	0.08 ±0.02
Haines 1975 n=21	0.2 ±0.03	0.43 ±0.13	0.6 ±0.3	<0.1	2.0 ±0.7	2.2 ±0.7	<0.1	0.07 ±0.02
Nome 1975 n=19	0.2 ±0.05	0.40 ±0.19	0.5 ±0.2	N.D.	0.8 ±0.5	1.4 ±0.9	N.D.	0.04 ±0.03
Copper River Delta 1975	0.2 ±0.1	0.5 ±0.2	0.7 ±0.2	N.D.	1.6 ±0.5	1.8 ±0.8	N.D.	<0.05
Nome 1976 n=84	0.3 ±0.1	0.4 ±0.2	1.4 ±0.4		1.9 ±0.6	3.0 ±1.1		0.09 ±0.03

Table 10. Alaskan moose mean hair element levels during October (ppm).

Area and Year Sampled	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
	Elements Sampled									
Moose Research Center 1972 n=10	227.8 ±66.4	92.0 ±17.8	1943.6 ±693.3	1073.2 ±279.2	14.0 ±2.8	47.9 ±17.4	5.1 ±3.0	86.3 ±32.4	1.71 ±1.61	12.3 ±6.3
Moose Research Center 1973 n=21	134.8 ±48.4	152.4 ±32.1	1125.2 ±144.7	1125.2 ±144.7	10.6 ±3.6	67.0 ±4.6	3.9 ±3.6	63.0 ±6.4	1.38 ±0.46	11.5 ±3.4
Moose Research Center 1974 n=26	93.9 ±48.8	45.6 ±14.3	1800.2 ±1066.7	1181.3 ±253.1	8.7 ±1.3	59.5 ±10.8	1.6 ±0.6	92.7 ±6.6	1.93 ±1.13	2.5 ±2.3
Kenai Benchland 1972 n=58	225.2 ±71.3	120.5 ±45.1	2090.4 ±781.4	1235.4 ±328.5	14.7 ±5.0	51.4 ±14.6	11.6 ±8.4	89.1 ±26.5	1.50 ±1.46	12.3 ±5.9
Alaska Range n=21	129.6 ±37.6	102.5 ±34.3	854.9 ±324.0	1374.6 ±381.4	13.0 ±3.5	68.0 ±7.0	10.3 ±4.3	60.1 ±6.6	1.20 ±0.80	14.8 ±5.8
Caribou Hills 1973 n=67	238.8 ±42.0	122.6 ±39.3	1972.1 ±443.2	1258.1 ±296.9	11.5 ±3.1	55.9 ±13.6	11.0 ±8.6	69.5 ±15.2	1.16 ±1.22	10.2 ±5.0
Nome 1974 n=21	241.0 ±164.1	56.5 ±42.5	1101.9 ±631.0	902.1 ±360.7	11.7 ±4.0	49.0 ±8.0	1.2 ±0.8	104.9 ±24.6	1.71 ±0.87	1.5 ±6.4
Glennallen 1974 n=68	167.6 ±107.0	93.9 ±25.7	868.2 ±554.5	601.9 ±201.8	11.7 ±2.4	74.2 ±41.5	2.7 ±1.1	105.5 ±13.5	1.93 ±0.82	4.1 ±2.7
Nome 1975 n=13	985.4 ±414.9	138.5 ±76.4	1858.7 ±1610.8	2833.4 ±486.2	19.2 ±2.5	47.6 ±26.8	0.1	131.7 ±29.7	1.38 ±0.50	6.4 ±9.9
Glennallen 1975 n=45	498.7 ±224.3	103.1 ±50.0	1742.9 ±1264.7	2583.8 ±460.6	10.7 ±2.4	43.6 ±4.7	0.71 ±0.21	125.2 ±29.7	0.93 ±0.14	11.5 ±6.2
Nome 1976 n=41	1020.9 ±474.0	170.6 ±98.2	1700.8 ±1266.0	5073.4 ±117.4	5.9 ±5.4	34.5 ±12.3	0.61 ±0.25	115.7 ±29.5	1.13 ±0.22	8.9 ±9.7

Table 10a. Alaskan moose hair element levels during October (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1974 n=26	0.8 ±0.3	0.37 ±0.09	0.7 ±0.2	2.0 ±1.9	1.6 ±0.5	0.7 ±0.2	<0.05	N.D.
Nome 1974 n=20	1.0 ±0.6	0.39 ±0.10	0.9 ±0.4	0.8 ±1.3	1.7 ±0.5	0.9 ±0.3	<0.05	0.04 ±0.04
Glennallen 1974 n=68	1.8 ±0.7	0.31 ±0.09	0.7 ±0.2	0.5 ±0.1	2.3 ±0.6	2.0 ±0.7	<0.1	0.26 ±0.06
Nome 1975 n=13	0.2 ±0.05	<0.1	0.3 ±0.2	N.D.	0.9 ±0.4	1.1 ±0.5	N.D.	0.02 ±0.03
Glennallen 1975 n=45	0.2 ±0.02	0.4 ±0.2	0.4 ±0.2	N.D.	0.7 ±0.4	0.9 ±0.3	N.D.	<0.05
Nome 1976 n=41	0.3 ±0.1	0.2 ±0.2	1.5 ±0.5		2.2 ±0.5	3.6 ±1.5		0.09 ±0.02

Table 11. Alaskan moose mean hair element levels during November (ppm).

Area and Year Sampled	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=16	196.4 ±38.0	80.8 ±19.8	1032.2 ±569.4	1191.6 ±292.7	12.2 ±6.6	42.1 ±12.3	5.2 ±3.4	71.6 ±8.0	0.75 ±1.09	13.8 ±9.9
Moose Research Center 1973 n=10	194.2 ±85.8	50.0 ±21.5	1479.6 ±579.9	1964.3 ±569.5	1.7 ±0.6	31.4 ±8.4	2.8 ±1.3	103.3 ±27.0	0.39 ±0.26	0.4 ±0.9
Moose Research Center 1974 n=11	195.2 ±38.1	72.1 ±10.3	950.9 ±233.6	1250.1 ±176.4	11.8 ±2.6	48.9 ±8.6	4.6 ±1.9	68.2 ±9.4	0.82 ±0.28	10.4 ±3.3
Nome 1974 n=20	75.1 ±37.9	35.1 ±20.5	571.1 ±246.3	758.4 ±238.2	9.0 ±1.6	62.8 ±11.8	0.9 ±0.7	95.2 ±15.2	2.24 ±0.86	1.3 ±1.3
Homer 1974 n=60	84.7 ±60.7	38.6 ±26.4	1034.8 ±602.9	935.3 ±331.3	9.2 ±1.6	50.1 ±9.4	0.8 ±0.4	91.1 ±8.6	1.51 ±1.07	1.7 ±1.3
Paxson Lake 1974 n=20	75.1 ±37.9	35.1 ±20.5	571.1 ±246.3	758.4 ±238.2	9.0 ±1.6	62.8 ±11.8	0.9 ±0.7	95.2 ±15.2	2.24 ±0.86	1.3 ±1.3
16A 1975 n=53	513.6 ±220.7	102.0 ±43.4	1519.3 ±730.4	1395.3 ±328.9	19.6 ±2.3	44.7 ±8.2	0.7 ±0.3	99.2 ±9.6	1.26 ±0.19	6.1 ±3.9

Table 11a. Alaskan moose hair element levels during November (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1973 n=10	0.3 ±0.1	0.28 ±0.10	< 0.1	0.3 ±0.1	1.2 ±0.3	0.6 ±0.1	N.D.	0.11 ±0.06
Moose Research Center 1974	0.3 ±0.1	0.20 ±0.07	<0.1	0.3 ±0.1	1.2 ±0.3	0.8 ±0.2	<0.05	0.11 ±0.02
Paxson Lake 1974 n=20	0.7 ±0.3	0.27 ±0.09	0.6 ±0.2	1.3 ±1.4	1.1 ±0.4	0.8 ±0.02	<0.05	0.08 ±0.05
Homer 1974 n=60	0.7 ±0.3	0.33 ±0.12	0.6 ±0.2	2.0 ±1.5	1.2 ±0.4	0.7 ±0.2	<0.05	<0.01
GMU 16A n=53	0.2 ±0.1	0.56 ±0.18	0.6 ±0.2	N.D.	1.6 ±0.4	1.7 ±1.0	N.D.	<0.05

Table 12. Alaskan moose mean hair element levels during December (ppm).

Area and Year Sampled	Elements Sampled									
	Ca	Mg	K	Na	Cu	Fe	Mn	Zn	Cd	Pb
Moose Research Center 1972 n=17	220.9 ±31.8	64.2 ±12.2	467.8 ±203.2	1277.1 ±285.0	1.5 ±1.0	51.9 ±18.8	6.5 ±4.8	63.1 ±4.9	0.34 ±0.31	10.7 ±5.3
Moose Research Center 1973 n=15	225.1 71.0	40.9 ±16.4	863.3 ±444.4	1088.6 ±233.5	1.5 ±0.4	36.9 ±7.2	2.8 ±1.1	102.6 ±16.9	0.96 ±0.26	0.9 ±2.1
Moose Research Center 1974 n=17	222.2 ±67.2	65.8 ±15.2	537.7 ±148.7	1206.1 ±189.8	3.7 ±2.2	52.0 ±10.0	4.8 ±1.7	57.1 ±7.7	0.23 ±0.30	10.0 ±2.2

Table 12a. Alaskan moose hair element levels during December (ppm).

Area and Year Sampled	Elements Sampled							
	Co	Cr	Mo	Ni	Se	Al	As	Hg
Moose Research Center 1973 n=15	0.2 ±0.1	0.17 ±0.04	$<$ 0.1	0.3 ±0.1	0.8 ±0.2	0.5 ±0.3	N.D.	0.09 ±0.04
Moose Research Center 1974 n=17	0.2 ±0.1	0.18 ±0.07	$<$ 0.1	0.2 ±0.2	1.2 ±0.3	0.3 ±0.2	$<$ 0.05	0.10 ±0.02

Table 13. Condition related blood parameters and measurements from moose population sampled during late winter and spring (sampled size in parenthesis).

Blood Values		Copper River Delta (March 1974)		MRC (Feb.,Mar.,Apr.) 1972-1975		GMU 13 (April 1973)		GMU 15C (April 1975)	
Calcium	mg/100ml	10.38	0.74(44)	9.81	0.64(39)	10.91	0.86(58)	9.61	0.98(29)
Phosphorus	mg/100ml	5.50	0.69(44)	3.90	1.09(39)	5.63	0.99(59)	4.72	1.08(29)
Glucose	mg/100ml	147.0	37.5(44)	116.2	26.1(39)	127.8	20.2(59)	91.3	16.2(29)
Total protein	g/100ml[45]	7.07	0.57(45)	6.60	0.44(39)	7.43	0.40(61)	6.70	0.83(30)
Albumin	g/100ml	3.82	0.39(45)	3.76	0.46(39)	5.21	0.39(61)	4.21	0.51(30)
Beta globulin	g/100ml	0.72	0.09(45)	0.58	0.10(39)	0.60	0.11(61)	0.55	0.12(30)
Hemoglobin	g/100ml	19.8	0.5(46)	15.9	2.2(39)	19.7	0.7(60)	18.7	1.5(29)
PCV	%	53.2	4.2(46)	39.9	4.6(39)	49.2	3.7(60)	45.9	3.9(29)
Total Length	cm	301.5	8.1(23)	282.6	9.1(254)	295.6	10.9(115)	288.9	14.2(210)
Chest Girth	cm	201.3	13.8(25)	179.5	11.1(252)	191.3	14.3(105)	182.2	16.3(194)
Hind Foot	cm	81.5	1.8(16)	79.3	1.9(246)	80.0	2.9(79)	79.9	3.8(203)
Shoulder Height	cm			75.9	8.1(86)	185.5	11.1(7)	174.9	14.1(65)

Table 13. Condition related blood parameters and measurements from moose population sampled during late winter and spring (sample size in parenthesis).

Blood Values		GMU 14C (Feb. 1976)		Susitna (March 1977)		Alaska Peninsula (April 1977)		Moose River Flats (May-June 1977)	
Calcium	mg/100ml	10.33	0.81(18)			10.80	0.43(57)		
Phosphorus	mg/100ml	4.74	1.51(18)			4.35	0.86(57)		
Glucose	mg/100ml	109.9	16.3(18)			158.1	22.2(57)		
Total protein	g/100ml[45]	7.20	0.54(18)			7.79	0.43(57)		
Albumin	g/100ml	4.80	0.41(18)			5.05	0.28(57)		
Beta globulin	g/100ml	0.60	0.07(18)			0.74	0.11(57)		
Hemoglobin	g/100ml	15.4	1.2(17)	18.7	1.4(24)	16.4	1.3(54)	*14.0(14)	**10.8(26)
PCV	%	43.4	2.8(19)	50.2	3.5(51)	39.0	5.4(56)	*37.8(14)	**28.7(26)
Total Length	cm					302.1	6.8(54)	*279.5(14)	
Chest Girth	cm					201.1	12.2(53)	185.9(14)	
Hind Foot	cm					80.8	1.8(12)	79.0(6)	
Shoulder Height	cm					--	--	--	

* Cows
** Calves

Morphometric Measurements and Body Weight

Measurement and weight data from Alaskan moose are being reported (Franzmann et al. 1977b, Appendix IV).

Productivity and Mortality of MRC Moose

Annual progress reports have listed histories of individual moose and have listed moose mortalities at the MRC. Tables 14, 15, 16, 17, and 18 update these accounts to June 30, 1977.

The winter of 1976-1977 was characterized as mild. Temperatures did not drop below -25°C (-13°F), and this low lasted only for a few days at the MRC. Snow accumulation did not exceed 28 cm (11 inches) at the MRC, the maximum level occurring on March 30, 1977, in a thin birch-spruce regrowth vegetative type snow plot. Icing conditions occurred during several periods but were not persistent and were not aggrevated by significant snow accumulation.

The weather conditions during winter 1976-77 were likely responsible for winter calf survival of 7 of 10 (70 percent) calves at the MRC. The survival rate may have been better (up to 100 percent), but surveys to this report date have not accounted for 3 of these calves (2 in Pen 3, and 1 in Pen 4).

Calf productivity assessments for spring 1977 are not yet complete, but it is known that to report date three mature cows did not produce calves.

Moose within the enclosures up to the 1977 calving season consisted of: Pen 1 - three adult males, three adult females, and one calf; Pen 2 - two adult males, four adult females, two female yearlings, and four calves (including Raquel, Olivia, Mike and Ike); Pen 3 - one adult male, five adult females, and one calf (possibly two others); Pen 4 - two adult males, six adult females, one male yearling and one calf (possibly two others). The total MRC moose population consisted of 8 adult males, 18 adult females, 3 yearlings, and 7 to 10 calves for a total of 36 to 39 moose.

A manuscript was prepared comparing mortality of resident versus introduced moose at the MRC (Bailey and Franzmann 1977, Appendix I).

Browse Production, Utilization and Quality

Browse production, utilization and quality studies as outlined in Franzmann and Arneson (1974) continued at the MRC. They are conducted by John L. Oldemeyer (U.S. Fish and Wildlife Service) and his new assistant, Wayne Regelin. Browse quality and its influence on the Kenai moose population were reported (Oldemeyer et al. 1977), as were some vegetative responses to mechanical rehabilitation of moose browse (Oldemeyer 1977).

Table 14. Histories of Pen 1 individual moose at Kenai Moose Research Center, July 1, 1976 through June 30, 1977.

			Significant Observations				
Moose No.	Sex	Age (Years)	Date	Event	Circumstances	No. times Observed	No. times Captured
35	M	9	June 23, 1977	Last Seen	Observed	9	2
43	M	10	Oct. 5, 1977	Limping badly on left rear leg	Observed	13	1
			June 23, 1977	Last Seen	Observed		
58	M	7	June 17, 1977	Last Seen	Observed	8	2
R70-8	F	9	June 11, 1976	Without Calf	Observed	8	1
			Nov. 10, 1976	Radiocollared, 30.18	Trapped		
69	F	8	June 14, 1976	Without Calf	Helicopter Survey	1	0
125	F	11	Nov. 10, 1976	With Calf	Observed	14	0
			June 16, 1977	With yearling F	Observed		
UC	F	1	June 20, 1977	Last Seen (1976 Calf of 125)	Observed	10	0

Table 15. Histories of Pen 2 individual moose at Kenai Moose Research Center, July 1, 1976 through June 30, 1977.

			Significant Observations				
Moose No.	Sex	Age (Years)	Date	Event	Circumstances	No.times Observed	No.times Captured
36	M	10	June 20, 1977	Last Seen	Observed	6	0
73	M	8	June 23, 1977	Last Seen	Observed	5	0
1	F		July 9, 1976	With Calf and Yearling	Observed	8	0
			Nov. 5, 1976	With Calf, Last Seen	Helicopter Survey		
670	F	7	June 1, 1976	With Calf	Observed	3	0
			Nov. 5, 1976	Without Calf	Helicopter Survey		
			June 23, 1977	Without Calf	Observed		
120	F	6	Dec. 13, 1976	With Calf, Last Seen	Observed	2	0
Raquel	F	8	Apr. 12, 1977	Last Seen	Observed	Numerous	0
Olivia	F	2	June 18, 1977	Last Seen	Observed	Numerous	1
Mike	M	1	June 24, 1977	Last Seen	Observed	Numerous	2
Ike	M	1	June 24, 1977	Last Seen	Observed	Numerous	2
UC	F	2	June 18, 1977	Last Seen (1975 Calf of #1)	Observed	4	0
UC	F	1	June 24, 1977	Last Seen (1976 calf of 1)	Observed	5	0
UC	M	1	June 21, 1977	Last Seen (1976 Calf of 120)	Observed	3	0

Table 16. Histories of Pen 3 individual moose at Kenai Moose Research Center, July 1, 1976 through June 30, 1977.

			Significant Observations				
Moose No.	Sex	Age (Years)	Date	Event	Circumstances	No.times Observed	No.times Captured
80	M	8	Nov. 5, 1976	Last Seen	Helicopter Survey	2	0
27	F	10	Jan. 14, 1976	Last Seen	Helicopter Survey	1	0
2870	F	7	July 2, 1976	Without Calf	Helicopter Survey	1	0
72	F	7	Nov. 5, 1976	With Calf	Helicopter Survey	2	0
75	F	8	Nov. 5, 1976 June 24, 1977	With Calf Without Calf or yrlg.	Helicopter Survey Observed	4	0
98	F	--	Aug. 19, 1976	With Calf and Yearling	Helicopter Survey	1	0
UC		1	Aug. 19, 1976	Last Seen (Yrlg. of 98)	Observed	2	0

Table 17. Histories of Pen 4 individual moose at Kenai Moose Research Center, July 1, 1976 through June 30, 1977.

Moose No.	Sex	Age (Years)	Significant Observations: Date	Event	Circumstances	No. times Observed	No. times Captured
7	M	8	June 23, 1977	Last Seen	Observed	4	0
100	M	8	June 16, 1977	Last Seen	Observed	1	0
37	F	8	Nov. 5, 1976	With Calf	Helicopter Survey	3	0
			June 21, 1977	With Yearling, No Calf	Observed		
57	F	7	Nov. 5, 1976	With Calf	Helicopter Survey	2	0
71	F	8	Nov. 5, 1976	Without Calf	Helicopter Survey	2	0
81	F	8	Nov. 5, 1976	With Yearling	Helicopter Survey	2	0
103	F	7	Nov. 5, 1976	Without Calf	Helicopter Survey	2	0
124	F	8	July 5, 1976	Without Calf	Helicopter Survey	2	0
UC	-	1	June 21, 1977	Last Seen (1976 Calf of 37)	Observed	2	0
UC	M	2	June 23, 1977	Last Seen (1975 Calf of 81)	Observed	2	0
UC	F	Adult	June 23, 1977	Could be 57 or 71	Observed	1	0

Table 18. Mortalities within Kenai Moose Research Center enclosures July 1, 1976 through June 30, 1977.

Pen No.	Moose No.	Sex	Age	Date	Cause
1	Uncollared	M	1+yr.	Sept.22, 1976	Regurgitation and inhalation of rumen contents following immobilization with M99-Rompun. Moose was ataxic on release and fell with legs up. Found following day.
1	Uncollared	F	1+yr.	Never found	Assumed dead
2	Uncollared	--	Calf	Calf of 670 Observed June 1, 1976. Never found after.	Assumed dead

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APPENDIX I

MORTALITY OF RESIDENT VERSUS INTRODUCED MOOSE IN A CONFINED POPULATION[1]

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Abstract: Mortality and productivity were compared among 129 individually identifiable moose (*Alces alces*) initially, born, or experimentally introduced into four 2.6 km^2 enclosures on the Kenai Peninsula, Alaska, from 1968 to 1976. Initial residents and moose born in the enclosures survived significantly longer than introduced moose. Fewer introduced males survived than introduced females, but those surviving were as old as surviving females. Most moose apparently died of nutrition-related causes, and most introduced moose died within 6 months, usually during winters. Mortality rate of introduced moose was directly related to density of moose within each enclosure. Introduced moose that died may have entered a state of negative energy balance while unsuccessfully attempting during winters to return to their former and presumed familiar seasonal ranges. Resident females produced more calves than introduced females and older, initially enclosed females raised more calves to yearlings than females born and introduced in the enclosures. Because of home range familiarity and perhaps aggressiveness, resident moose appeared to have a distinct advantage in terms of survival over introduced moose.

Among many terrestrial mammals, established residents are believed to survive longer and generally live more secure lives than transients. Higher mortality among transients is assumed to be related to their increased vulnerability in unfamiliar terrain and to competition and aggression from residents.

The causes of differential mortality among residents and transients vary with the species and environmental conditions. Transients of small prey species may be subject to greater predation than residents because they are in unfamiliar terrain and unaware of locations of escape cover (Metzgar 1967, Errington 1943). Stress resulting from competition and aggression from residents either before or after dispersal may also predispose transients to a greater variety of decimating factors, such as disease, parasites, malnutrition and predation (Christian 1970, Bailey 1969, Wynne-Edwards 1962). Residency and familiarity with a particular area are therefore considered to be of great survival value to many terrestrial mammals (Ewer 1968).

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Moose are essentially solitary and have one or several seasonally distinct ranges to which they are strongly attached (LeResche 1974, Houston 1968, Geist 1963). Female moose, especially those with calves, appear most solitary and are most aggressive toward other moose, particularly during winters (Houston 1974). The relative small size of home ranges of moose (Berg 1971, Van Ballenberghe and Peek 1971, Houston 1968, LeResche 1966, Knowlton 1960) and the moose's winter food requirements (Heptner et al. 1961 cited in Geist 1971) imply intensive use of winter food resources. Migrating moose returning to winter home ranges presumably do so because such ranges provide resources and an environment for winter survival. Although female moose with calves may be an exception (Altmann 1958, LeResche 1966), moose are not considered territorial (Geist 1963).

Most reported mortality information on moose has been related to hunter harvest and natural predation, primarily during the winter months. Mortality information has not been available in terms of resident and transient moose because of the difficulty in locating identifiable individuals, dead or alive, over an extended period. Since moose are often tagged at random, their home ranges may have no relation to the tagging area. It is therefore difficult to discern which moose are residents, migrants, or actual transients in a particular area without identifying all moose in the area and following their subsequent movements for at least 1 year. Furthermore, one must distinguish natural from man-caused mortality, as the latter may not be selective in terms of residents and transients (Storm et al. 1976).

This paper reports on survival and productivity of individually identifiable moose within four 2.6 km^2 enclosures at the Kenai Moose Research Center (MRC), Alaska, from 1967 to 1976. It compares mortality of moose initially living in the area after it was enclosed by fences, moose later born within the enclosures and moose accidentally or experimentally introduced into the enclosures. Because of their past and subsequent histories, initially enclosed moose and moose later born in the enclosures were considered residents. Introduced moose were from immediate adjacent areas but considered equivalent of transients since they were not familiar with the area in the enclosures and were forced to live with the residents. Purpose of the enclosures was to provide information on moose physiology and productivity, behavior and habitat and to develop study techniques for moose.

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STUDY AREA

Four 2.6 km^2 enclosures known as the Moose Research Center are located in the northern lowlands of the Kenai Peninsula in southcentral

Alaska. Vegetation on the Kenai Peninsula and within the Moose Research Center enclosures has been described by LeResche et al. (1974). The climate is intermediate between the dry continental climate of Interior Alaska and the wet but mild climate of the Gulf of Alaska coast. At Kenai the average mean temperature is 12.4°C in July and -11.8°C in January. Winter low temperatures sometimes drop to -44.8°C. Snow usually falls in September, covers the ground by November and persists until April. Maximum snow depths vary from 25 to 64 cm. Meteorlogical information was obtained from the Kenai Federal Aviation Administration.

The MRC lies within the Kenai National Moose Range, a 7,000 km^2 area set aside in 1941 to protect the habitat of the Kenai moose. Construction of the enclosures began in 1966 and was completed in 1969. Numbers of moose naturally occurring within the enclosed areas were then estimated to range from 12 to 24 per enclosure, or about 10.9 moose per square kilometer (LeResche and Davis 1971, P-R Job Prog. Rep., Proj. W-17-3, Alaska Dept. Fish and Game, Juneau). Each enclosure has been maintained at different population levels for specific reasons. Initially, moose in enclosures 1 and 2 were to be left unmolested, allowing the populations to increase, decrease or remain constant. Enclosure 3 was to be retained at its original population level and sex composition as representative of moose populations outside the enclosures. Enclosure 4 was to be stocked with four or five times its "normal" density (LeResche 1970, P-R Job Prog. Rep., Proj. W-17-2, Alaska Dept. Fish and Game, Juneau).

METHODS AND MATERIALS

Twenty-one fenceline traps were used to capture, identify and introduce moose into the enclosures (LeResche and Lynch 1973). Captured moose were immobilized and identified with a combination of ear-tags and flags and numbered neck-collars (Franzmann et al. 1974). Except for short periods (<1 year), all adult moose within the enclosure have been marked. Besides regular trapping and ground observations, moose survival and productivity were assessed twice annually (January and June) by complete aerial coverage with fixed-wing aircraft and/or helicopter.

The fates of 129 tagged moose of known origin are included in this report (Table 1). Moose of unknown origin were omitted, as was a tame but free-roaming female and her offspring which were artificially fed. Twenty-nine moose for which deaths were known or suspected to be handling-related were also excluded. Ages of nearly all adults were determined by the tooth cementum technique (Sergeant and Pimlott 1959) and recorded to the nearest whole year. Periods of survival were recorded to the nearest month and time of death estimated from date individuals were last seen alive and/or their carcasses recovered.

RESULTS

Survival

Initial residents and moose born within the enclosures survived significantly longer, on the average, than moose introduced into the enclosures (Table 2). There was no significant difference between average periods of survival for initial residents and moose born within the enclosures. However, initial residents generally survived twice as

Table 1. Sex and status of moose at Moose Research Center, 1968-1976.

Status	Sex		Total
	Males	Females	
Initial resident			
Dead	3	22	25
Alive	3	2	5
Born in enclosures			
Dead	11	16	27
Alive	4	14	18
Introduced into enclosures			
Dead	11	34	45
Alive	2	7	9
Total	34	95	129

Table 2. Number of months moose survived in enclosures excluding living moose, January 1967 to July 1976.

	Females		Males	
	Number	Mean $\pm$ SD	Number	Mean $\pm$ SD
Initial Residents	22	41.0 $\pm$23.5	3	23.7 $\pm$7.5
Born Residents	15	20.3 $\pm$27.0	11	11.6 $\pm$5.9
Introduced	35	5.6 $\pm$7.3	11	4.0 $\pm$3.0

"t"-Tests: Initial resident females vs. introduced females $t=8.34, df=55, P<0.01$

Born resident females vs. introduced females $t=3.07, df=48, P<0.01$

Initial resident males vs. introduced males $t=7.90, df=12, P<0.01$

Born resident males vs. introduced males $t=3.95, df=20, P<0.01$

long as moose born within the enclosures and over five times longer than moose introduced into the enclosures. Introduced female moose survived only slightly longer periods, on the average, than introduced males.

Average age of initial resident moose at time of enclosure and of moose later introduced into the enclosures were not significantly different (Table 3), supporting earlier observations that ages of moose inside and outside the enclosures were similar (LeResche 1970, P-R Job Prog. Rep., Proj. W-17-2, Alaska Dept. Fish and Game, Juneau). Although the average age of female moose introduced into the enclosures was less than the average age of females at time of enclosure, the difference was not significant. Among males, average age of initial residents and introduced moose was nearly equal. As expected, average age at death of initial resident females was significantly greater than that of introduced females (Table 4). Average age of surviving adult moose revealed that only initial resident females were significantly older than moose born or introduced into the enclosures (Table 5).

Most moose introduced into the enclosures died within 6 months and moose less than 1 year old died most rapidly (Table 6). Introduced female moose 1 to 5 years old appeared to survive longer than younger or older introduced females. Small sample size prevented a similar comparison among introduced male moose. Based on the average age of surviving introduced moose, young female moose appeared more handicapped by the introductions than similar-aged males.

Period of introduction appeared to influence an introduced moose's chances of survival. Using the four seasonal periods that Franzmann et al. (1976) found significant in assessing the physiological condition of moose and ranking survival time of introduced moose by sex, it appeared that female moose survived longer if their introduction occurred in the summer-fall period (Table 7). Male moose survived longer when introduced into the enclosures in late winter-early spring. These average survival times were probably related to seasonal fluctuations in physiological condition of moose and the severity of winters. Moose in good condition at time of introduction would be expected to survive longer than moose introduced in poor condition. Because of the rut, males generally are in poorer condition at the beginning of winters than are females.

Most moose in the enclosures apparently died of starvation during the winters. Death from starvation was most prevalent among moose less than 1 year old (Franzmann and Arneson, 1973, P-R Prog. Rep., Proj. W-17-5, Alaska Dept. Fish and Game, Juneau).

Of 97 natural deaths of moose at least 76 occurred during winters. Ninety-two percent of the males died during winters compared to 74 percent of the females. Since enclosures 2 and 4 had the highest average moose densities and highest mortality rates for introduced moose (Table 8), it appears mortality was related to moose density. Black bears (*Ursus americanus*) and, more rarely, brown bears (*U. arctos*) were occasionally seen in the enclosures but were hibernating when most moose died. Although

Table 3. Age in years of moose at time of enclosure and introduction, January 1967 to July 1976.

	Females		Males	
	Number	Mean $\pm$ SD	Number	Mean $\pm$ SD
Initial Residents	28	7.4 $\pm$3.6	6	1.2 $\pm$0.4
Introduced	41	5.1 $\pm$4.4	21	1.5 $\pm$1.3

Table 4. Age in years of moose dying in enclosures, January 1967 to July 1976.

	Females		Males	
	Number	Mean $\pm$ SD	Number	Mean $\pm$ SD
Initial Residents	21	11.0 $\pm$3.4	2	2.0 $\pm$1.4
Born Residents	15	1.9 $\pm$2.1	11	1.1 $\pm$0.3
Introduced	33	5.7 $\pm$4.9	10	1.3 $\pm$0.7

"t"-Tests: Initial resident females vs. introduced females $t=4.38, df=22, P< 0.01$

Table 5. Age in years of adult moose surviving in enclosures, excluding 1976 calves and 1975 yearlings, January 1967 to July 1976.

	Females		Males	
	Number	Mean ± SD	Number	Mean ± SD
Initial Residents	2	10.5 ±2.1	3	7.0 ±0
Born Residents	9	6.7 ±0.7	4	7.5 ±1.3
Introduced	6	7.5 ±2.1	2	8.4 ±1.4

Table 6. Percent of introduced moose dying or surviving according to age at introduction, January 1967 to July 1976.

Sex	Numbers	Age of Moose (years)	Survival Time in Months				
			6	6-12	13-24	25+	Still Alive
Female	14	1	86	14	--	--	--
	8	1-5	38	--	13	13	38
	12	6-10	58	17	8	--	17
	4	11+	50	50	--	--	--
Male	10	1	80	10	--	--	10
	2	1-5	50	--	--	--	50
	0	6-10	--	--	--	--	--
	0	11+	--	--	--	--	--

Table 7. Survival time in months of introduced moose according to season, January 1967 to July 1976.

	Survival Time			
	Females		Males	
Season	Number	Mean ± SD	Number	Mean ± SD
Summer-Fall (June-Sept.)	7	6.9 ±5.0	2	5.0 ±0
Rut (October)	9	4.8 ±5.1	3	2.7 ±0.6
Early Winter (Nov.-Jan.)	15	6.5 ±10.0	3	2.3 ±2.3
Late Winter (Feb.-May)	4	1.8 ±1.0	2	7.5 ±6.4

Table 8. Moose densities and death rates of moose according to enclosures, January 1967 to January 1976.

Enclosure number	Average number of moose[1]	Number of moose introduced[2]	Percent dying
1	10.5[3]	4	50
2	14.8[3]	8	88
3	9.4[4]	2	50
4	17.4[4]	41	88

1) Total number of moose days for all moose divided by 365 days.

2) Excludes thirteen moose dying from handling-related deaths.

3) Average per year from January 1967 to January 1976.

4) Average per year from January 1970 to January 1976.

a lone wolf (*Canis lupus*) may have once killed a calf in enclosure 4, predators had little impact on moose numbers in the enclosures.

Winter mortality of moose varied with severity of winters. Most moose died during the winter of 1971-72, when snow depths reached 67 cm and depths of 50 cm or more were present for 3 consecutive months in five or eight snow plots in the enclosures (LeResche, Franzmann and Arneson 1973, P-R Job Prog. Rep., Proj. W-17-4, Alaska Dept. Fish and Game, Juneau). Seventeen of 18 moose (6 adults, 11 calves) introduced into the enclosures just prior to this period died during the winter. Mortality rates among resident moose also varied with severity of winters but, among adult moose, moose born in the enclosures had the lowest average winter mortality rate and introduced individuals the highest (Table 9).

CALF PRODUCTION AND SURVIVAL

Female moose initially within the enclosures produced more calves and raised more to yearlings than females born within or introduced into the enclosures. Although the differences between means of calf productivity and survival were not statistically significant among different status females (Table 10), the information suggested older females familiar with the enclosures were more successful reproductively than younger females born within or similar-aged females introduced into the enclosures. Assuming females born in the enclosures later became as familiar with their environment as their mothers, their lower reproductive success may have been age-related. Yearling moose have lower fertility rates than older females (Peterson 1974), and females probably do not reach maximum fecundity until 5 or 6 years of age (Markgren 1969). Females at 18 years of age are probably reproductively senile (Houston 1968).

Since older resident females initially enclosed raised more of their calves to yearlings than younger females of the same status, age and perhaps familiarity with the enclosures may have influenced their reproductive success (Table 11). That similar-age females introduced into the enclosures produced and raised to yearlings fewer calves suggested age was not the factor limiting their reproductive success.

DISCUSSION

Our data indicated resident moose survived longer and were reproductively more successful than moose introduced into the enclosures. Since most moose died during winters, residents appeared to have a distinct advantage over introduced moose during this critical period. Residents, because of their familiarity with the enclosures, presumably expended less energy to find food and conserved more energy at other times than introduced moose. Residents may also have been able to find more better quality food. This and their presumed superior nutritional status would contribute to their higher reproductive success.

Because of plant succession and browse utilization, range conditions probably deteriorated with time within and outside the enclosures. Initial residents may therefore have been reared under better range conditions than moose later born in the vicinity. However, mineral uptake of moose as measured by hair analysis (Franzmann and Arneson 1975, P-R Job Prog. Rep.,

Table 9. Winter mortality of adult moose.

Winter	Severity[2]	Status of moose					
		Initial residents		Born in enclosures		Introduced into enclosures	
		Number dying	Percent[2] dying	Number dying	Percent dying	Number dying	Percent dying
1968-69	10	1	6	0	0	0	0
1969-70	5	4	16	0	0	0	0
1970-71	20	0	0	0	0	0	0
1971-72	110	8	40	2	10	6	40
1972-73	50	1	9	0	0	8	50
1973-74	60	0	0	0	0	3	19
1974-75	100	4	44	1	7	3	38
1975-76	30	0	0	0	0	0	0
Annual mean	-	2.2	14.4	0.4	2.8	2.5	18.4

1 Number of days snow depths exceeded 31 cm (1 point) or 62 cm (2 points). Total to nearest 5 points. Snow depths recorded at Kenai FAA station, Kenai.

2 Based on numbers of adults alive before each winter.

Table 10. Productivity and survival of moose calves born in enclosures, 1968 to 1976.

Status of Female	Number	Number per female per year: Calves Mean ± SD	Number per female per year: Yearlings Mean ± SD
Initial Resident	24[1]	0.50 ±0.47	0.16 ±0.25
Born Resident	12[1]	0.34 ±0.26	0.04 ±0.07
Introduced	10[1]	0.29 ±0.32	0.02 ±0.06

1) Excludes yearlings that died before reaching sexual maturity.

Table 11. Productivity and survival of moose and age of mother.

Age of female at enclosure or Introduction (years)	Initial-resident: Number	Initial-resident: Calves Mean ± SD		Initial-resident: Yearlings Mean ± SD		Introduced: Number	Introduced: Calves Mean ± SD	Introduced: Yearlings Mean ± SD	
1-5	10	0.53	±0.26	0.09	±0.10	6	0.34 ±0.38	0.03	±0.08
6-10	8	0.47	±0.44	0.21	±0.26	3	0.28 ±0.25	0	0
11-15	4	0.75	±0.88	0.33	±0.47	0	--	--	
15+	1	0	0	0	0	0	--	--	

Proj. W-17-7, Alaska Dept. Fish and Game, Juneau) suggested similar to slightly poorer browse quality inside the enclosures compared to outside. Yet, as adults, moose born in the enclosures had a lower mortality rate within the enclosures than moose introduced from outside the enclosures.

Circumstantial evidence suggests that during their first winter in the enclosures introduced moose expended more energy than they gained trying to return to their former, and presumed familiar, home ranges. Whether this behavior was reinforced by competition or aggression from residents was unknown, although overt aggression was not regularly observed between resident and introduced moose. Often, introduced moose either sensed the direction or recognized their familiar ranges and attempted to return. Attempts of moose to return to their familiar areas were strong and persistent, taking the form of frequent pacing along the fenceline nearest their familiar range for periods up to 6 months after introduction (Franzmann and Arneson 1973, P-R Job Prog. Rep., Proj. W-17-5, Alaska Dept. Fish and Game, Juneau).

Introduced female moose appeared more handicapped by their introduction into unfamiliar environments than males. Introduced males survived longer than similar-age females, but introduced females over 5 years of age died more rapidly than females 1 to 5 years of age. More resident females have survived than males, but surviving males born in the enclosures are just as old as the surviving females also born in the enclosures. This suggests that males may adapt more readily to unfamiliar environments than females and that home range familiartiy is more important in terms of survival to females than males.

Aggressiveness of established female moose may also have enhanced their chances of survival. Adult females are more aggressive toward other moose than are adult males (Houston 1974), and females with calves may even dominate adult males (Geist 1963). If established resident females monopolized the best habitat in the enclosures, other adults may have been forced to utilize poorer habitat. Natural winter mortality among males may be greater than among females, especially if the males are in poorer condition because of the rut. For example, Pitcher (cited in Bishop and Rausch 1974) reported that 65 percent of winter-killed adults in the Susitna River Valley, Alaska, were males, although males comprised only 24 percent of the adult moose observed in fall surveys.

Survival of moose calves was probably related to the female's care during the calf's first year of life. Unfortunately, since all calves introduced as orphans died during the severe winter of 1971-72 and no other calves were introduced as orphans, no comparisons could be made with orphan calf survival in other years. However, most calves introduced with their mothers also died during their first winters. Their survival appeared dependent on their mother's survival. Since predation on calves in the enclosures was insignificant, starvation during winters appeared their principal cause of death. This information suggests the age of the mother or possibly her social rank and her presumed familiarity with a home range increased her calves' chances of survival. Older females initially within the enclosures brought more of their calves through winters than younger females born within or older females introduced into the enclosures. Home range familiarity and aggression or dominance by older or established females would be of survival value to their calves if such females controlled or were able to utilize the best available habitat.

In terms of management, this information suggests that moose prevented from utilizing their familiar calving or wintering ranges may experience greater mortality and poorer productivity during their first seasons in unfamiliar terrain. Wintering areas appear especially critical, and even if sufficient forage is available in previously unused areas, older moose, particularly females, may not readily utilize them. Similarly, spring-summer areas may be depleted of resident moose through overhunting (Goddard 1970, LeResche 1974) because adults from neighboring regions may be reluctant to leave their traditional and familiar areas even if forage conditions in nearby overhunted areas are more favorable. Reestablishment of moose populations in areas formerly populated by moose, as well as true dispersal into new habitats, may therefore be dependent on productivity of nearby populations, since younger moose appear to be the colonizers of new habitat (DeVos 1956, Geist 1963, Houston 1968, LeResche 1974). This might also account for the relative slow dispersal rate of moose into new habitat despite the ability of older moose to travel great distances between seasonal but familiar home ranges.

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APPENDIX II

FORENSIC MINERAL ELEMENT ANALYSIS IN MOOSE MANAGEMENT

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ABSTRACT

Control of illegal harvesting of moose is costly and difficult, even when the probable individuals can be identified. Generally, the evidence collected is circumstantial in nature and provides little objective proof in a court of law. We have examined mineral element analysis of mammal hair as an objective link between kill site remains and carcasses found in the possession of suspects.

Hair samples of only 100 mg are needed for analysis by atomic absorption spectroscopy for eight elements: Ca, Cu, Fe, K, Mg, Na, Pb, and Zn. Pearson $\underline{r}$ coefficient of correlations were calculated comparing hair samples and critical values of $\underline{r}$ determined to describe the probability of such correlations. These elemental patterns in the hair "finger print" the samples and allow for good statistical comparison. Four cases involving illegally taken moose from the State of Alaska will be discussed to demonstrate the utilization of the results as objective evidence. Mineral element analyses may have even greater potential than just comparative analysis, for such determinations can also pinpoint geographical site and month of harvest.

Introduction

Over the past five years we have demonstrated that hair acts as a recording filament of nutritional changes in intake of mineral elements in the Alaskan moose. The series of studies completed have demonstrated the great breadth of application of hair mineral analysis. It was first noted that hair analysis was able to indicate seasonal changes in elemental intake in the moose that relates to browse quality (1). Variations in mineral content of hair in relation to geographical sites has delineated subpopulations of moose within the State of Alaska (2). One of the subpopulations, on the Kenai Peninsula, was likewise noted to manifest a copper deficiency with faulty hoof keratinization, initially defined by hair analysis (3).

The relationship of mineral nutrition to moose management techniques has been discussed at these meetings (4). Land use planning was a major area dealt with but may not be the only area of impact. Other areas of management concern demonstrate attempts to limit uncontrolled population influences (5,6). Karnes et al (7) reported that in non-hunting losses of moose, vehicular accidents and poaching were by far the top two causes related to man. Methods that would allow for closer control or limit these two areas would be a worthy management tool.

Direct application of hair analysis to moose management may be noted in several areas, one being forensic analysis. Control of illegal harvesting of moose would be greatly enhanced if more objective proof could be provided in a court of law.

Human forensic science has utilized hair mineral comparison and demonstrated the range of content among different persons to be considerable, thus allowing individualization. Jervis in 1956 initially showed that the pattern of three elements, arsenic, copper and sodium, could clearly distinguish individuals (8). Large scale surveys have since delineated the strength of hair mineral comparisons in determining individuality (9). Factors thought to influence hair comparison were noted: geographical location, occupational exposure, age, family groups, identical twins and mothers with newborn infants, and none appeared to be a major factor clouding individuality (10). Subsequently, hair mineral analysis comparisons have been successfully used in courts of law in the United States and Canada (11). Application of the mineral analysis of hair to forensic comparisons in wildlife management was examined based on the human studies.

A series of cases that utilize hair mineral element assays to determine if samples found at a poaching site and in the possession of a hunter had come from the same animal provided an opportunity to test hair analysis as a tool in wildlife forensic work.

Methods and Materials

Properly identified hair samples were sent to the laboratory in Cleveland, Ohio, by registered mail. The samples were then entered into a log and prepared for analysis of eight mineral elements.

The cleansing and digestion of the moose hair have been described elsewhere (12). The procedure involves washing the hair twice with an organic solvent, diethyl ether, to remove surface particulate matter without leaching minerals from the hair structure. The hair is dried for 24 hours at 55°C and weighed. One hundred milligrams of hair were then digested in 10.0 ml of 24% methanolic tetramethyl ammonium hydroxide for two hours at 55°C (13). The clear amber digestants were then diluted and analyzed for eight mineral elements (calcium, copper, iron, lead, magnesium, potassium, sodium and zinc) by flame atomic absorption spectroscopy. Recoveries from this digestion technique were determined by means of standard additions and found to be greater than 90% for every element. The determinations were conducted on a semi-automated Perkin-Elmer Model 503 spectrometer adapted for automated diultions with a Hamilton Precision Dispenser. Standard methods for flame atomic absorption analysis were used throughout this study (14).

A statistical comparison of the results from the two samples provided per case was made calculating Pearson *r* coefficients of correlation.

The significance of the coefficients for the eight elements was determined by computing the critical values of *r* (15).

Results

Case 1

The mineral element analyses of the two hair samples are noted below. Sample 1 came from the kill site of the illegally harvested moose and sample 2 from pieces of moose found in the possession of the alleged poacher. The request received by the laboratory from the state was: are the two samples from the same animal?

Mineral Analysis of Hair (PPM)

	Ca	Cu	Fe	Pb	Mg	K	Na	Zn
Sample 1	132	25	24	14	30	438	206	133
Sample 2	144	18	8	11	23	410	202	115

The Pearson $\underline{r}$ coefficient of correlation on these results was: $\underline{r} = +0.923$; $\overline{P} < 0.01$).

The strong positive correlation indicates that the two samples came from the same animal. The outcome of the case was an admission of guilt on the part of the alleged poacher.

Case 2

The mineral element analyses of the two hair samples are noted below. Sample 1 came from pieces of moose found in the possession of an alleged poacher and sample 2 came from other pieces of moose in the possession of the same individual. The alleged poacher stated they came from the same animal; the state contends they are from two animals.

Mineral Analysis of Hair (PPM)

	Ca	Cu	Fe	Pb	Mg	K	Na	Zn
Sample 1	72	25	42	16	17	308	230	157
Sample 2	118	18	16	11	14	368	162	112

The Pearson $\underline{r}$ coefficient of correlation on these results was: $\underline{r} = +0.364$. This coefficient does not show significant correlation.

The results suggest that the two samples came from different animals. The outcome was also an admission of guilt on the part of the alleged poacher.

Case 3

The mineral element analyses of the two hair samples are noted below. Sample 1 came from the drag path of the illegally harvest moose and sample 2 came from pieces of moose found in the possession of the alleged poacher at his home. The request from the state was to match by chemical analyses the two samples and determine seasonal differences.

Mineral Analysis of Hair (PPM)

	Ca	Cu	Fe	Pb	Mg	K	Na	Zn
Sample 1	98	5	6	8	20	88	560	40
Sample 2	33	5	7	10	12	62	560	21

The Pearson $\underline{r}$ coefficient of correlation on these results was: $\underline{r} = +0.909$; $\overline{P} < 0.05$.

The strong positive correlation indicates that the two samples came from the same animal. The outcome of this case is still pending.

The question of seasonal difference was determined since the alleged poacher stated the hair from his home came from an animal kill three months earlier. The results compared with the data base in hand do not agree with the month the alleged poacher indicated.

Case 4

The mineral element analyses of the two hair samples are noted below. Sample 1 came from the kill site of the illegally harvested moose and sample 2 from the box of the alleged poacher's pick-up truck. The request received by the laboratory was to determine if samples 1 and 2 were from the same animal.

Mineral Analysis of Hair (PPM)

	Ca	Cu	Fe	Pb	Mg	K	Na	Zn
Sample 1	83	22	35	0.1	24	54	530	38
Sample 2	85	36	46	0.1	26	126	581	25

The Pearson *r* coefficient of correlation on these results was: $r = +0.902$; $P < 0.05$.

The strong positive correlation indicates that the two samples came from the same animal. The outcome of this case has been delayed.

A general comparison of randomly selected hair samples from the over 3,000 hair samples analyzed to date was made for 50 pairs of samples and the Pearson *r* coefficient of correlation of $r = +0.550$. This coefficient of correlation is not significant, but indicates the species similarity.

Discussion

The availability of hair from mammals makes its use in forensic analysis very opportune. With the establishment of a data base (a significant body of information covering, in addition to numbers, seasonal variations) strong evidence can be generated from hair mineral analysis. The strength of this type of information comes in addition in the use of this type data in human forencis analysis (9,10). The widespread use of comparative hair analysis in rape and murder cases establishes the precedent in a court of law (9).

Several important strengths and weaknesses are to be noted in the use of such information. The strength of the analysis lies in comparing two samples as coming from the same animal. Very positive correlations can be noted. Although not discussed in the results, a number of samples received showed no strong correlation and were determined as not coming from the same animals. The ability to contrast samples, however, is not as strong a point. Since samples are from moose a certain amount of similarity will always be noted. The general survey of random analysis of known different samples was $r = +0.550$. This positive but not significant coefficient of correlation does not lend itself to strong conclusions as to the origin of the hair samples.

Several factors must also be considered in the variability of results from hair analysis. An attempt was made to analyze only the non-pigmented section of the hair shaft adjacent to the follicle, since variations in pigmentation have been reported to influence mineral element levels (16). Slight variations in mineral element values are also noted with differences in the body site of sampling. Such body site variations may be the major source of difference in hair sample comparisons. Other influences such as age and sex have also been considered, but our results have not shown these to significantly vary the hair mineral element results (1).

The utilization of hair mineral element analysis to demonstrate other features of the animal's history can also be contemplated. One cannot over-emphasize that a good data base allows for many additional conclusions to be drawn. Season variations have been determined via hair mineral analysis and related to primarily dietary changes (1,16). Establishing the season of a kill may be a vital comparative point in a court of law. Also, geographical differences have been noted which relate to different subpopulation restrictions (2). All of this information can directly relate to the strength of such evidence in a court of law.

Hair mineral element analysis may provide, therefore, another moose management tool to allow the control of another variable of the population growth. The strength of the tool will come, however, with use and publicity of this technqiue.

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APPENDIX III

CONDITION ASSESSMENT OF ALASKAN MOOSE

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Abstract: The ultimate measure of a population's condition is its reproductive success; however, in some instances this information may not be available or easily obtained. Other methods to assess population condition may then be useful to game managers as sole or supplemental data. Condition assessments were made of Alaskan moose (*Alces alces gigas*) populations using morphometric measurements (total length, chest girth, hind foot, and shoulder height); weight; antler growth; condition grading based on form and composition; and physiological parameters (blood and hair). Blood parameters which best reflected condition in Alaskan moose were calcium, phosphorus, total protein, hemoglobin, and packed cell volume. Hair mineral element determinations did not directly reflect condition of populations, but they were useful in identifying potential trace element deficiencies which may influence reproductive success. Application of these various condition assessments to different Alaskan moose populations resulted in similar population condition ranking.

Introduction

Game managers have long sought methods to make general condition assessments of animals under their jurisdiction. Condition for this application may be defined as the physical composition, form, or stage of existence that an animal exemplifies at a certain time. The trained and experienced eye was a valid approach to condition assessment; however, today's need for more sophisticated management requires quantitative evidence in some form.

Many approaches have been used to assess condition of animals representing a population, and perhaps the best methods available are those measuring a population's reproductive success. This is the ultimate measure of a population's condition or well being. Bishop and Rausch (1974) reviewed procedures for obtaining moose population composition and reproductive information. Timmermann (1974) reviewed moose censusing techniques, and Simkin (1974) reviewed reproduction and productivity of moose.

This paper is concerned with condition assessment techniques of moose populations other than those associated with censusing, reproduction, and productivity and those associated with carcass data (VFA, fat deposition, etc.). In many instances supplemental information relative to moose population condition are needed, and in some instances no reproductive or productivity data are available. The animal living in an environment functions as an indicator of the state of the environment and we use this concept to assist in making comparative environmental assessments.

Physical Status (Measurements and Weights)

Several methods are available to assess condition via physical status of moose. Morphometric measurements (total length, chest girth, hind foot, and shoulder height) comparisons were made between adult moose from several Alaskan populations (Franzmann et. al. 1977). Significant differences ($P < 0.05$) were detected between populations. The Kenai Moose Research Center (MRC) population consistently had the smallest measurements, while the Copper River Delta population had the largest (Table 1). Outside MRC, Kenai Peninsula, and Glennallen area populations ranked between the MRC and Copper River populations. Measurements of interior Alaska moose by Cody (1973) in general ranked near the Copper River sample.

Weight was another physical attribute used to compare condition of two Alaskan moose populations (MRC and Kenai Peninsula). One-hundred-seventy live weights were obtained using a winch tripod device (Arneson and Franzmann 1975). Weight differences were compared on a monthly basis and Kenai Peninsula adult females were significantly heavier from June to December, but through winter differences were not detectable (Franzmann, et. al. 1977). Male moose comparisons were similar; however, smaller distribution and size of sample permitted only limited comparisons. Weights of interior Alaska moose reported by Coady (1973) during October and June were higher than either MRC or Kenai Peninsula moose during same months. High ranges and standard deviations were experienced with moose weight data, and large samples would be necessary for meaningful comparisons. Live weights are difficult to obtain, and dressed weight data introduces other sources of variation. Additionally, comparisons would have to be on a same month-same year basis.

Physical Status (Condition Classes)

A condition evaluation for moose handled at the MRC was routinely made. Condition classes were established based upon the premise that animal form and composition are largely dictated by the interaction of the complexes of climate and nutrition (Ledger 1968). Condition classes were graded from 1 to 10 on the basis of the following criteria (adapted from Robinson 1960).

Class 10. A prime, fat moose with thick, firm rump fat by sight. Well fleshed over back and loin. Shoulders are round and full.

Class 9. A choice, fat moose with evidence of rump fat by feel. Fleshed over back and loin. Shoulders are round and full.

Class 8. A good, fat moose with slight evidence of rump fat by feel. Bony structures of back and loin not prominent. Shoulders well fleshed.

Class 7. An "average" moose with no evidence of rump fat, but well fleshed. Bony structures of back and loin evident by feel. Shoulders with some angularity.

Table 1. Rank of moose population condition based upon blood, morphometric, antler, and condition class parameters[a].

Condition Related Parameters	Rank 1[b]	2	3	4	5
Ca	Glennallen	Copper R.	Southcentral	Kenai Pen. (Homer)	MRC
P	Glennallen	Copper R.	Southcentral	Kenai Pen. (Homer)	MRC
TP	Glennallen	Southcentral	Copper R.	Kenai Pen. (Homer)	MRC
Hb	Copper R.	Glennallen	Kenai Pen. (Homer)	Southcentral	MRC
PCV	Copper R.	Glennallen	Kenai Pen. (Homer)	Southcentral	MRC
Total Length	Copper R.	Glennallen	Kenai Pen.	MRC	
Chest Girth	Copper R.	Glennallen	Kenai Pen.	MRC	
Hind Foot	Copper R.	Glennallen	Kenai Pen.	MRC	
Shoulder Height	Copper R.	Glennallen	Kenai Pen.	MRC	
Antler	Copper R.	Alaska Pen.	Seward Pen.	Interior	Kenai Pen
Weight	Interior	Kenai Pen.	MRC		
Condition Class	Copper R.	Glennallen	Kenai Pen.	MRC	

a. Blood values from late winter/early spring (February, March and April).

b. Highest values.

Class 6. A moderately fleshed moose beginning to demonstrate one of the following conditions: (A) definition of neck from shoulders; (B) upper fore leg (humerus and musculature) distinct from chest; or (C) rib cage is prominent.

Class 5. A condition in which two of the characteristics listed in Class 6 are evident.

Class 4. A condition in which all three of the characteristics listed in Class 6 are evident.

Class 3. A condition in which the hide fits loosely about neck and shoulders. Head is carried at a lower profile. Walking and running postures appear normal.

Class 2. Signs of malnutrition are obvious. The outline of the scapula is evident. Head and neck low and extended. The moose walks normally but trots and paces with difficulty, and cannot canter.

Class 1. A point of no return. A generalized appearance of weakness. The moose walks with difficulty and can no longer trot, pace or canter.

Class 0. A dead moose, from malnutrition and/or accompanying circumstances.

The grading evaluation was particularly useful when done by the same individual or individuals over a long period of time. This grading system was used at the MRC to assist in determining which physiological parameters reflected animal condition.

Antler Growth

Antler growth may be used as a comparative condition index of moose. Gasaway (1975) compared antler growth and spread from several areas of Alaska and concluded that moose from the lower Copper River drainage and Alaska Peninsula grew the biggest antlers on the youngest moose. Moose from the Kenai Peninsula, interior Alaska, southcentral Alaska and the Seward Peninsula generally had smaller antlers at the same ages. Kenai Peninsula moose had the smallest and slowest growing antlers.

Hair Element Analysis

Comparisons of hair element analysis were made on a monthly basis from various regions in Alaska (Franzmann et. al. 1977) and significant differences ($P < 0.01$) were detected. The relationship of these values to condition of the animals is not well understood; however, the values were used to compare with condition ranking of populations (Table 2).

Blood Chemistry and Hematology

Franzmann et. al. (1976) reported that blood calcium (Ca), phosphorus (P), total protein (TP), hemoglobin (Hb), and packed cell volume (PCV) reflected condition status in moose. Albumin, beta globulin, and glucose also reflected condition status, but were influenced by excitability

Table 2. Rank of moose populations based on hair mineral element parameters sampled late winter/early spring (February, March, and April).

Hair Elements	Rank 1[a]	2	3	4	5	6
Ca	Glennallen	Southcentral	MRC	Homer	Interior	Copper R.
Mg	Southcentral	Glennallen	Homer	Copper R.	Interior	MRC
K	Interior	Glennallen	Homer	Copper R.	Southcentral	MRC
Na	Southcentral	Copper R.	Glennallen	Homer	MRC	Interior
Cu	Copper R.	Southcentral	Glennallen	Homer	Interior	MRC
Fe	MRC	Interior	Southcentral	Homer	Glennallen	Copper R.
Mn	Glennallen	Southcentral	MRC	Homer	Interior	Copper R.
Zn	Glennallen	Copper R.	Homer	MRC	Interior	Southcentral
Cd	Interior	Glennallen	Homer	Copper R.	Southcentral	MRC
Pb	Glennallen	MRC	Southcentral	Copper R.	Homer	MRC

a. Highest values.

and were of lesser value for application. These values must be used as comparisons between populations during the same month and preferably the same year. Late winter (March and April) comparisons between Alaskan moose populations indicated significant differences between populations and a condition ranking was made (Table 1).

Application of Combined Condition Criteria

Testing of these combined criteria on different populations was made using two populations which have been well studied and documented as the potential low and high extremes based on productivity data. The MRC population represented the low and the Copper River population represented the high. Table 1 ranks these populations with other populations sampled (Glennallen, Southcentral, Kenai Peninsula) during late winter/early spring (February, March and April) using blood, morphometric, antler and condition class criteria. Table 2 ranks the MRC and Copper River populations with other populations sampled (Glennallen, Southcentral, Homer, Interior) also during late winter/early spring. The blood, morphometric, antler, and condition class ranking has a definite pattern; however, the hair element ranking lacks a clear pattern.

Discussion

Applying the various condition-related criteria to Alaskan moose populations provided a means to evaluate these criteria, particularly as they related to the low productivity of the MRC and high productivity of the Copper River populations. The Copper River population ranked highest for all morphometric, antler, and condition class criteria. Highest ranking of blood values from the Copper River population were shared with the Glennallen population. The MRC population ranked lowest for all criteria.

Certain of these parameters have greater value in assessing moose population's condition than others. Franzmann et. al. (1976) considered PCV the most useful blood parameters for assessing condition, since it reflected differences between nearly all condition class comparisons. Total protein rated next, followed in order by P, Ca, and Hb. Moose measurements which had the highest correlation with body weight were considered the mose useful parameters; however, all four measurements ranked populations the same. Total length/weight correlation coefficient (r) was 0.94, chest girth r was 0.90, shoulder height r was 0.87, and hind foot r was 0.81 (Franzmann et. al. 1977). Using the best blood parameter (PCV) and the best measurement parameters (total length and chest girth), moose population condition ranked the same (Table 1) (Southcentral measurements were not available).

Ranking of moose populations using hair mineral element values provided no pattern relative to condition assessments as detected with other parameters (Table 2). Excess minerals may be stored or excreted and relative stored abundance would not necessarily relate to condition. Deficiencies in mineral levels, as reflected by hair analysis, could, however, influence condition. With an identified Cu deficiency syndrome on the Kenai Peninsula (Flynn and Franzmann 1974), the population ranking based on Cu levels proved interesting. The MRC populations ranked lowest and the Copper River population ranked highest. This demonstrates the potential value in making population comparisons using hair element analysis. We may identify in certain populations ranking low in certain values a priority for investigating certain mineral elements. We cannot, however, relate hair element values to condition status at this time.

Quantitative condition assessment of moose populations provides a means for game managers to determine priorities for more intensive investigation. In Alaska, moose are widely distributed and in many instances little is known regarding the status of certain populations. Other populations, however, have been intensively studied and are regularly monitored. Obtaining condition-related data from these populations provides a comparative standard to which comparisons with populations of unknown quality may be made. We will use the MRC and Copper River populations in Alaska as the low and high standards when assessing other populations. The parameters we will use in order of preference are the blood profile (PCV, TP, D, Ca, and Hb), total length and chest girth measurements, condition class grading, antler growth, and weight. This ranking may vary with individuals in other areas as conditions dictate. Carcass information should be used when possible; however, this outlined procedure relates to obtaining data from live, immobilized moose.

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APPENDIX IV

ALASKAN MOOSE MEASUREMENTS AND WEIGHTS AND MEASUREMENT-WEIGHT RELATIONSHIPS

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Abstract: A total of 1329 Alaskan moose (*Alces alces gigas*) were measured for total length, 1340 for chest girth, 1317 for hind foot, 618 for shoulder height, and 1219 for ear length. Five hundred and four moose were weighed. These data were classified by sex, age, month sampled, and location. Growth rates were plotted and discussed. No morphometric differences were detected by sex and location classifications up to age 36 months. Location differences were detected which corresponded to general condition, productivity, and condition-related blood parameters of the populations. Seasonal weight patterns demonstrated increases from 21 to 55 percent from spring to late fall. Measurements, particularly total lengths, were better indicators of growth rate than were weights. All body measurements were significantly correlated with weight: total length $r = 0.94$, chest girth $r = 0.90$, shoulder height $r = 0.87$, and hind foot $r = 0.81$. Combined sex regression equations were derived because the slight differences between the male and female regression lines were unimportant in field application. These regression equations were: wt(kg) = -239.7 + 2.07 (total length) and wt(kg) = -245.3 + 3.14 (chest girth).

INTRODUCTION

Peterson (1974) reviewed moose (*Alces alces*) weight and measurement data and concluded that accurate live weights of older moose of any race were based upon extremely small samples. He stressed that moose weights are affected by seasons and by individual condition and that conversion from dressed to live weights includes additional factors which make critical analysis of most available weight data suspect, if not meaningless. He also indicated that body measurements have not accumulated sufficiently in recent years to provide adequate data for critical analysis in relation to age, sex, or geographic variation. Serial weights of moose have not been reported.

Measurement - weight relationships are lacking for moose but have been utilized for domestic animals (Fourie 1959 and Mullick 1950), Columbian black-tailed deer (*Odocoileus hemionus columbianus*) (Bandy et al. 1956), barren-ground caribou (*Rangifer arcticus*) (McEwan and Wood 1966), white-tailed deer (*Odocoileus virginianus*) (Smart et al. 1973), and some African ungulates (Talbot and McCulloch 1965).

The objective of this study was to provide substantial weight and measurement data from Alaskan moose for comparative purposes with consideration given to sex, age, and seasonal differences within a moose population and between populations. Generating predictive equations for measurement-weight relationships was anticipated in experimental design.

METHODS

Moose were measured with a flexible steel tape for up to six parameters (hind foot, chest girth, total length, shoulder height, ear length, and tail length). Definitions followed were those of Anderson (1948) and Peterson (1974). Measurement data were collected from January 1957 to August 1975 in conjunction with studies and projects involving handling moose, primarily on the Kenai Peninsula, Alaska. However, data were also obtained from other areas of the state (Cordova, Glennallen, Fairbanks, and the Matanuska Valley). Age was determined from tooth section cementum layers (Sergeant and Pimlott 1959).

Whole live weights were obtained from trapped (LeResche and Lynch 1973) and immobilized (Franzmann and Arneson 1974) moose at the Kenai Moose Research Center (MRC) from 1969 through 1975 using a winch-tripod device (Arneson and Franzmann 1975). Whole carcass weights were obtained from the Fairbanks area, the Matanuska Valley, and the Kenai Peninsula prior to 1969. These data were primarily from moose under two years of age.

Weight and measurement data were recorded and sent to Computer Services Division of the Alaska Department of Administration, Anchorage, for storage and later analyses based upon sex, age, month sampled, and location. These data provided input for t-test, regression analysis, and analysis of variance programs. All hypotheses were tested at $P = 0.01$ level. Analysis of variance was used to test for differences among areas sampled and Scheffe's S test was utilized to determine where differences occurred among areas sampled with significant ANOVA.

RESULTS

Measurements

A total of 1329 moose were measured for total length, 1340 for chest girth, 1317 for hind foot, 618 for shoulder height, and 1219 for ear length. Tail length measurements were discontinued early in the study due to variability in establishing proximal beginning point.

Ear length measurements were separated from other morphometric data since no significant differences were detected for sex, season, and location. Substantial ear growth occurred from age 1 - 36 months (Fig. 1), but no significant differences were detected between age classes over 36 months (n=749). Mean adult moose (over age 36 months) ear length ($\pm$ 95% confidence interval) was 25.2 ± 0.53 cm (n=749).

Measurements of combined sexes from all locations were compiled by month to age 12 months and were combined by season (June through October, November through January, and February through May) from age 13 - 36 months (Table 1). Sex and location data were combined, since no significant differences were detected with these classifications up to age 36 months.

Table 2 lists measurements of adult moose (over age 36 months) from all locations by age class. Sample sizes were not adequate when location was separated by age class to make meaningful comparisons; however, by combining all adult females (Table 3) and adult males (Table 4) we were able to statistically compare measurements among locations. The areas from which adequate samples were available for comparison were the MRC, outside MRC, Kenai Peninsula (other than MRC or outside MRC), Game Management Unit 13 (Glennallen area), and Game Management Unit 6 (Cordova area). Kenai Peninsula moose, especially those from MRC, were significantly smaller than moose from Units 13 and 6. Cows from inside MRC were smaller than those outside MRC and elsewhere on the Kenai Peninsula. Comparisons by location for adult males were difficult to assess because of inadequate sample sizes for outside MRC, Glennallen area, and Cordova area samples. However, the information available seems to indicate that a trend in measurements similar to that which occurred with females would also be evident in adequate male samples.

Figure 2, which combines sex and location, depicts Alaskan moose growth rate to age 36 months using total length measurements and has a similar growth pattern to ear length measurements (Fig.1).

Weight

A total of 504 moose weights were obtained, of which 54 percent (270) were live weights from the MRC. The remaining 234 weights represented whole carcass body weights from other areas of the state. Two hundred twelve of the 234 weights were from moose under age 36 months.

Weights of adult male MRC, adult female MRC and female non-MRC moose were compared. It was established that female MRC moose (339.2 kg, n=81) weighed less than adult male MRC moose (402.3 kg, n=21), which weighed about the same as female non-MRC moose (400.5 kg, n=66). Five adult non-MRC males weighed an average of 454.6 kg. Figures 3 and 4 depict weight increases by age. Figure 3 represents moose up to age 36 months; sex and location are combined since there were no significant differences between sexes or among locations. Figure 4 compares MRC adult moose with non-MRC adult moose by sex. No significant differences in weight were observed between age classes or between outside MRC moose and other Alaskan moose when non-MRC males and females were combined.

Seasonal weight patterns were striking. In June MRC females averaged 278 kg, approximately their minimum annual weight (1 female in May weighed 254 kg). In December MRC females averaged 393.5 kg, approximately their maximum annual weight and an increase of 42 percent over the June average (increase of 55 percent over May weight). MRC males exhibited a similar pattern; average weight of the males increased 47 percent from 318.7 kg in June to 469.5 kg in September (Fig. 4).

Serial weight data obtained from several MRC moose in 1974 exemplify seasonal weight variation. Male moose #35 weighed 347 kg in May, 481 kg in August and 434 kg in October. He experienced a 28 percent weight gain up to rut and 10 percent weight loss into rut. No post-rut weight was available. Male moose #58 and #73 also reflected the same general pre-rut and into rut weight loss (418 kg to 386 kg for #58 and 391 kg to 384 kg for #73). Male moose #43 weighed 526 kg in August, 549 kg in September and 484 kg in October. The weight in early September likely reflects the peak seasonal weight for this animal. He also suffered weight loss as he went into rut.

Female moose #3 weighed 309 kg in June, 370 kg in August, 373 kg in September, and 382 kg in November. Female moose #36 weighed 288 kg in July, 398 kg in September and 402 kg in December. Number 84 weighed 325 kg in July, 380 kg in September and 370 kg in December. She had a slight post-rut weight loss; however, she had a calf and moose #3 and #36 had none.

Measurement-Weight Relationships

Sexes and ages were combined to correlate body measurements with weight and to obtain appropriate regression equations. All body measurements correlated significantly with weight: total length $r=0.94$, chest girth $r=0.90$, shoulder height $r=0.87$, and hind foot $r=0.81$. We calculated the multiple correlation of total length and chest girth with weight and obtained $r=0.94$, which was the same as that of total length. The lack of improvement with multiple correlation was undoubtedly the result of the high correlation ($r=0.90$) between total length and chest girth.

We then separated the sexes and calculated the correlation of total length and weight, of chest girth and weight, and of total length and chest girth. For males and females, respectively, the correlation coeffecients of total length with weight were 0.93 and 0.95; those of chest girth with weight were 0.88 and 0.91; and those of total length with chest girth were 0.90 and 0.89.

DISCUSSION

Between-year comparisons of either measurements or weights could not be made because of the small samples. The between-year variabilities were an innate part of these data, particularly with respect to weight data; however, morphometric data would be inherently less susceptible to between-year variabilities.

Measurements

Despite the large number of moose measured (over 1300), when the sample was classified to sex, age, season, and location, we were working with smaller sample sizes than desired. Some trends were noted in the classified data, but when statistical differences were not detected, the data were combined. Discussion of data will concentrate on differences and trends that were statistically significant, but the possible implications of other differences will also be mentioned.

Peterson (1974), using eviscerated moose carcass weight data, describes a steep growth period extending from birth to about age 18 months with no significant differences between males and females. Our morphometric measurements indicate that moose of both sexes experience a rapid growth rate from birth to age 12 months and that a period of rapid growth follows to age 18 months (Fig. 1, and 2). The stable growth period corresponds to the winter season (October to May).

Peterson (1974) described a second growth rate period from age 18 months to wear class V (6 years) as a period of less accelerated growth in both sexes, but with females increasing at a slower rate. We detected no difference by sex in growth rate from birth to age 36 months, but females appeared to grow at a slower rate after age 36 months (Table 2).

From wear class V (6 years) to wear class VIII (12 years) Peterson (1974) characterized growth rate tendency toward stability with the probability that the observed variations in both sexes result from responses to both individual (internal) and environmental (external) factors. Our data generally concur, although with some variations. Using total length, chest girth, and hind foot measurements of adult female moose from several locations we detected an upward growth trend to 10 years age (to 11 years with hind foot measurements) followed by a decline (Table 2). Peterson (1974) described this decline as beginning at wear class VIII (age 12).

We believe that morphometric data, particularly total length, were a better indicator of growth rate than weight data. Adult moose weights varied seasonally from 21 to 55 percent (Fig. 4). Weight data has the inherent variability associated with stomach content variability related to season and state of feeding.

Differences in growth between the four Alaskan moose adult female populations based on morphometric measurements were evident (Tables 3 and 4). Blood samples were taken simultaneously from these populations and blood parameters correlated with moose condition reflected similar differences among the four populations (Franzmann et al. 1976). The MRC population was in relatively poorer condition, while the Glennallen population was in better condition. We did not graph the Cordova population due to lack of data for certain age classes; however, when data for adult moose were combined (Tables 3 and 4) the Cordova population exhibited the largest morphometric measurements. Blood parameters also rated the Cordova population in best condition. The Cordova moose population was an expanding, productive population (McKnight 1975, P-R Job Prog. Rep., Proj. W-17-6, Alaska Dept. Fish and Game, Juneau) and the MRC population was a high density, confined, low productive population (Franzmann and Arneson, 1975, P-R Job Prog. Rep., Proj. W-17-7, Alaska Dept. Fish and Game, Juneau). These populations represent the low and high productive populations sampled and correspondingly, the low and high condition of individuals in the population based upon blood parameters (Franzmann et. al 1976). Condition of individuals in a population would generally be reflected by morphometric measurements. These data support the use of selected blood parameters, as well as morphometric measurements, for population condition evaluation.

Blood et al. (1967) measured 6 adult female moose (*A. a. andersoni*) and mean measurements were: hindfoot - 68.2 cm, chest girth - 165.9, total length - 210.1 cm, shoulder height - 160.2 cm, and ear length - 21.8 cm. Measurements of 3 adult males (Blood et al. 1967) were: hind foot - 71.5 cm, chest girth - 170.1 cm, total length - 224.0 cm, shoulder height - 171.6 cm, and ear length - 23.3 cm. These measurements were all considerably smaller than respective adult Alaskan moose measurements from all locations (Tables 3 and 4). Dennison (1956) and Peek (1962) provided measurements of *A. a. shirasi* up to age 91 days; our measurements were greater for comparable ages (Table 1). Unfortunately, a deficiency of published measurement data prevents meaningful range or subspecies comparisons.

Weight

We detected no significant weight differences in moose to age 36 months attributed to sex or location. This fact was particularly relevant in considering animals up to age 12 months because of their greater over-all representation. Weights of moose from ages 12 to 36 months were combined by season because monthly samples during this period were small. Peterson (1974) graphed eviscerated carcass weight data and detected no sex weight differences to age 18 months.

Moose calf growth cessation and occasional slight decline during the October-May period was detected by weight data (Fig. 6) and by graphed morphometric measurements (Figs. 1 and 2). Table 1 shows growth cessation as indicated by chest girth, hind foot, and shoulder height data.

We detected no significant weight differences between age classes of adult moose by location or when combined due to extreme seasonal variation in moose weights (Fig. 7). Therefore, adult moose weights were combined and plotted according to month sampled (Fig. 7). Seasonal weight differences varied from 21 to 55 percent with the greatest differences occurring at the MRC. The MRC moose were semi-confined and lacked the flexibility of habitat selection available to free-moving and/or migrating moose. MRC moose also received the lowest condition evaluation rating based on selected blood parameters (Franzmann et al. 1976). Both weight data and morphometric data corresponded to the low condition evaluation rating.

Mean whole weights of 6 adult female and 3 adult male Alberta moose (*A. a. andersoni*) were 418 and 414 kg, respectively (Blood et al. 1967). The mean weight of non MRC adult female Alaskan moose was 400.5 kg (n=66) and the adult male mean was 454.6 (n=5). No whole weight data were available for comparison other than those converted from dressed weights. Comparing whole weights of moose from different populations or areas has the seasonal bias which would require comparisons on a same year/same month basis. Attempting to compare whole weights when derived from dressed weights adds another bias which may, as Peterson (1974) indicated, make weight data suspect, if not meaningless.

Some evidence for validity of carcass conversion to whole weight was provided by Peterson (1974:Table 2). He compared converted yearling total weights from *A. a. andersoni* (Blood et al. 1967), *A. a. americana* (Heyland 1964 and 1966:unpublished data), and *A. a. alces* (Markgren 1964) and detected a remarkable similarity of mean weights. For both male and female yearlings (age 16-18 months) the range of means was 267.5 kg to 283.4 kg. Whole weights of Alaskan moose yearlings (age 16-18 months) averaged 278.3 kg (n=7).

Measurement-Weight Relationships

Total length measurements were highly correlated to moose weights. Chest girth measurements were next best and have been used as the most representative measurements in other measurement-weight studies (Bandy et al. 1956, Talbot and McCullough 1965, and Smart et al. 1973). Since total length and chest girth are highly correlated both to one another and to weight, either measurement can be used to estimate weight; in certain instances, however, one measurement may prove more applicable than the other. Our remaining morphometric measurements correlated less well with weight and were therefore not used to derive weight-predictive equations.

The hypothesis that there is no difference in the total length-weight regression line between males and females was tested and rejected. A slight difference between males and females was in fact noted. Combining data by sex seems nonetheless the most practical approach to estimating moose weights because the minimal differences between the two regression lines were insignificant in field application. The regression equations calculated from the combined male-female data are:

$$Wt(kg) = -239.7 + 2.07\ (\text{total length}) \text{ and}$$
$$Wt(kg) = -245.3 + 3.14\ (\text{chest girth}).$$

These lines and their narrow 95 percent confidence limits are of practical value in estimating live weights of moose from field measurements.

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Table 1. Combined sex and location measurements of Alaskan moose to 36 mo age.

Age (mo)	Measurements (cm)											
	Total Length			Chest Girth			Hind Foot			Shoulder Height		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
1	108.9	10.7	30	69.4	11.6	19	46.4	2.2	37	87.7	10.3	19
2	158.4	13.5	10	104.0	16.2	11	56.0	3.3	14	112.6	11.7	13
3	185.2	11.8	18	128.7	21.2	19	64.3	2.1	19	124.5	8.2	10
4	205.8	9.4	17	143.7	12.4	16	66.2	2.0	19	135.8	7.3	10
5	215.9	14.8	7	146.0	10.8	11	67.8	1.3	5	145.2	6.7	5
6	208.8	9.8	19	142.7	4.1	19	68.7	2.1	22	145.8	9.9	12
7	202.0	11.9	23	137.1	11.3	21	68.3	1.4	21	142.0	10.0	15
8	201.0	16.7	25	145.7	13.6	58	69.8	4.3	56	144.6	11.2	48
9	199.4	18.9	56	148.8	12.6	50	69.0	3.6	76	142.8	7.8	59
10	202.1	12.2	47	138.2	13.1	57	69.8	4.2	61	143.6	9.6	58
11	198.8	18.3	20	143.0	14.2	21	69.6	2.4	29	145.1	11.9	27
12	203.6	8.5	5	136.7	14.9	6	70.6	3.8	7	138.4	16.8	6
13–17	247.3	23.6	33	156.5	18.8	37	73.9	4.6	34	150.6	12.7	17
18–20	267.4	11.3	16	169.5	21.3	16	77.3	2.0	16	165.3	2.8	3
21–24	261.0	9.1	37	166.6	15.7	39	78.3	1.5	35	164.3	10.9	13
25–29	275.9	16.1	47	171.4	20.4	47	78.3	3.2	45	170.3	11.8	27
30–32	272.3	21.8	8	183.9	18.8	8	78.7	3.7	7	179.0	9.0	2
33–36	274.1	12.2	56	177.9	14.7	53	78.4	3.6	40	167.5	21.2	17

Table 2. Adult (36 mo. +) Alaskan moose measurements by year class.

Age (mo)	Sex	Total Length $\bar{x}$	Total Length SD	Total Length n	Chest Girth $\bar{x}$	Chest Girth SD	Chest Girth n	Hind Foot $\bar{x}$	Hind Foot SD	Hind Foot n	Shoulder Height $\bar{x}$	Shoulder Height SD	Shoulder Height n
37-48	F	276.8	14.7	43	176.8	13.5	43	78.4	2.3	41	167.8	17.3	11
	M	279.5	10.1	14	180.6	10.6	15	80.8	1.8	12	180.3	5.7	6
49-60	F	277.6	14.7	46	178.0	13.8	46	78.8	2.1	45	174.9	8.0	18
	M	286.4	13.3	29	187.4	11.2	26	80.0	2.1	27	181.1	7.4	8
61-72	F	279.2	8.6	35	172.9	12.9	35	78.8	1.9	36	175.4	5.8	13
	M	288.3	12.1	20	186.6	14.2	18	79.9	1.7	19	186.3	3.3	4
73-84	F	283.1	8.4	15	182.4	6.6	18	78.3	1.7	17	179.5	8.0	6
	M	290.4	7.0	7	203.1	7.4	7	79.3	0.8	7	188.8	3.8	4
85-86	F	278.5	10.5	18	180.5	14.4	15	79.1	1.8	18	177.8	2.3	8
	M	317.8	7.3	5	204.8	1.8	5	81.2	1.6	5	190.0		1
97-108	F	289.6	11.3	17	179.1	9.5	17	80.4	2.8	15	173.1	9.5	9
109-120	F	288.9	8.3	16	185.6	10.4	16	80.3	2.3	16	182.8	5.7	4
	M	298.0	0.0	2	188.0	8.6	2	79.0	1.2	2			
121-132	F	288.3	8.4	25	184.3	10.6	24	80.0	1.2	22	181.3	5.9	10
133-144	F	292.1	9.5	23	183.9	8.9	23	80.5	1.5	23	180.2	3.3	5
Over 144	F	287.5	13.3	16	182.2	8.4	15	80.2	1.2	13	176.5	12.0	2

Table 3. Adult female (36 mo. +) Alaskan moose measurement comparisons by locations.

Location and Years Collected	Total Length $\bar{x}$	Total Length SD	Total Length n	Chest Girth $\bar{x}$	Chest Girth SD	Chest Girth n	Hind Foot $\bar{x}$	Hind Foot SD	Hind Foot n	Shoulder Height $\bar{x}$	Shoulder Height SD	Shoulder Height n
Kenai Moose Research Center 1968 to 1976	282.6 a*	9.1	254	179.5 a	11.1	252	79.3 a	1.9	246	175.9 a	8.1	86
Outside Kenai Moose Research Center 1968 to 1976	289.8 b	10.2	116	189.0 b	13.6	122	79.6 ab	2.1	121	179.6 ab	12.8	44
Kenai Peninsula 1969 to 1975	288.9 b	14.2	210	182.2 c	16.3	194	79.9 acd	3.8	203	174.9 ac	14.1	65
Game Management Unit 13 (Glennallen area) 1973-74	295.6 c	10.9	115	191.3 b	14.3	105	80.0 bd	2.9	79	185.5 bc	11.1	7
Game Management Unit 6 (Cordova area) 1974	301.5 d	8.1	23	201.3 d	13.8	25	81.5 c	1.8	16			

* Any means followed by a common letter are not significantly different ($P > 0.05$) for a given measurement.

Table 4. Adult male (36 mo. +) Alaskan moose measurement comparisons by locations.

Location and Years Collected	Measurements (cm)											
	Total Length			Chest Girth			Hind Foot			Shoulder Height		
	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n	$\bar{x}$	SD	n
Kenai Moose Research Center* 1968 to 1976	288.3 a	13.2	77	188.5 a	14.7	73	80.1 a	1.6	72	183.5 a	7.1	23
Outside Kenai Moose Research Center 1968 to 1976	300.4 b	10.9	5	195.7 a	18.9	6	81.5 ab	1.8	4	183.8 a	12.9	5
Kenai Peninsula 1969 to 1975	297.9 b	12.6	50	191.0 a	26.7	48	81.5 b	2.8	33	178.5 a	16.8	27
Game Management Unit 13 (Glennallen area) 1973-74	298.5 ab	8.8	2	199.0 a	11.7	2						
Game Management Unit 6 (Cordova area) 1974	305.5 b	1.5	3	204.1 a	8.7	5						

* Any means followed by a common letter are not significantly different ($P > 0.05$) for a given measurement.

Table 5. Weight data suggesting the nutritional "cost" of calving and rearing young.

Moose	Age	Date	Circumstances	Weight (kg)
6	12+	12 Aug	With no calf	414
6	13+	23 Jul	With one calf	373
6	13+	22 Sep	With one calf	395
(Calf rearing "cost" ca: 33/414 kg or 8% of total body weight in mid-August)				
R70-7	6+	29 Jul	With one calf	323
R70-7	7+	23 Jul	With no calf	393
(Calf rearing "cost" 70/393 kg or 18% of total body weight in late July)				
22	5+	17 Jul	With no calf) +19%	300
22	5+	1 Sep	With no calf)	357
28	8+	17 Jul	With one calf) 0%	346
28	8+	15 Sep	With one calf)	348
6	13+	23 Jul	With one calf) +6%	373
6	13+	22 Sep	With one calf)	395
(22 gained 57/300 kg = 19% of mid-Jul weight by Sep, 28 gained 2/346 kg + 0% of mid-Jul weight by Sep, 6 gained 22/373 kg = 6% of Jul weight by Sept)				